

Reinforced concrete pile, pile assembly, method of joining the piles' heat transfer pipes to each other, and method of fabricating a reinforced concrete pile

Object of the invention

- 5 The invention relates to a reinforced concrete pile according to the preamble of claim 1. The invention further relates to a pile assembly comprising at least two reinforced concrete piles, to a method of joining the reinforced concrete piles' heat transfer pipes to each other, as well as to a method of fabricating a reinforced concrete pile.

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Background of the invention

- Deep foundations are often needed when building on poor quality soil. The use of driven piles is a common way of making deep foundations. In pile driving, prefabricated piles are hammered into the ground by using a pile driving machine. Piles can be fabricated for example from wood, steel, or reinforced concrete. The length of piles depends on soil qualities and the required load-bearing capacity of foundations. If the distance is short between soil surface and bedrock, piles can be driven to such a depth that the piles' bottom ends settle against the bedrock. In some cases, the friction between piles and surrounding soil can be high enough for attaining a sufficient load-bearing capacity, whereby the piles need not be driven all the way to the bedrock.

- Longer piles, if such are needed, are often assembled from shorter segments for facilitating transport and handling of the piles and enabling the piling also under bridges and in other locations with limited headspace above the ground.
- 25 The pile segments can be otherwise identical to each other, except that the pile segment to be driven deepest into the ground is generally provided with a tip designed and strengthened to enable its easy penetration into the soil and to withstand the pile-driving stress. Often used in relation to reinforced concrete piles are pile shoes attachable to the lowermost piles. It is for the purpose of driving piles all the way to bedrock that special rock shoes are employed.

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Piles can also be equipped with heat transfer pipes capable of circulating a heat transfer fluid. The heat transfer pipes can be used for collecting heat from

soil or storing heat in soil. It is by providing piles for example with a heat collection piping of the geothermal heating system that the construction of a separate heat collection pipe system is avoided in projects that would require the use of piling anyway.

- 5 The tightness of heat transfer pipes is important from the standpoint of both a functional heat collection or storage system and environmental protection. A challenge in pile driving is posed by the tightness of joints between the piles. Pile driving involves the use of major forces which may easily damage the joints with resulting pipe leaks.

10 Brief summary of the invention

- It is an objective of the invention to provide an improved reinforced concrete pile, which can be driven into the ground for supporting a building or the like structure, and by which problems of the prior art can be solved. The reinforced concrete pile comprises at least one heat transfer pipe for circulating a heat transfer fluid within the pile, at least one of the ends of the reinforced concrete pile constituting a splicing end, by which splicing end the pile is connectible to another identical or similar pile for constructing a longer pile assembly, and whereby, at said splicing end, said at least one heat transfer pipe is adapted to be connected to a respective heat transfer pipe of the pile connectible to the discussed splicing end. A pile of the invention is characterized by what has been presented the characterizing clause of claim 1.

- In a reinforced concrete pile of the invention, the pile has its splicing end fitted with a positioner sleeve which surrounds the heat transfer pipe's end in such a way that between the heat transfer pipe and the positioner sleeve develops an annular space for receiving a sealing sleeve, which is made at least partially from a plastically deformable material and which extends outward from the pile's splicing end, and the positioner sleeve has its end, which is further from said splicing end of the pile, designed to decrease in its inner diameter towards the discussed end in such a manner that, in the process of coupling two piles to each other, and when hammering the upper pile towards the lower pile, the sealing sleeve disposed in the annular space has its end within the positioner sleeve's decreasing inner diameter zone deforming plastically, thereby sealing against the heat transfer pipe's external surface.

It is by means of positioner and sealing sleeves that a tight and durable joint can be established between the heat transfer pipes of two piles.

According to one embodiment of the invention, the positioner sleeve is adapted to fix the position of the heat transfer pipe in the heat transfer pipe's radial
5 direction. The positioner sleeve is thereby capable of keeping the heat transfer pipe stationary during a pile casting process.

According to one embodiment of the invention, inside the heat transfer pipe, at the pile's splicing end, is disposed a support sleeve, which is adapted to pre-
10 vent the heat transfer pipe from collapsing as a result of the sealing sleeve being deformed as piles are being connected to each other. The support sleeve ensures the formation of a secure joint and enables a thinner wall thickness for the heat transfer pipe. However, the joint could also be constructed without a support sleeve.

15 According to one embodiment of the invention, the positioner sleeve comprises, at the end which is further away from the pile's splicing end, an attachment zone for securing the support sleeve immovably inside the heat transfer pipe by applying to the attachment zone a force for deforming the same plastically in such a way that the attachment zone presses the heat transfer pipe
20 against the support sleeve. It is by means of the attachment zone that the immovability of a support sleeve can be ensured as piles are being connected to each other.

According to one embodiment of the invention, the positioner sleeve is made of a metal or metal alloy. This enables the attachment of a positioner sleeve to
25 a pile's end plate or end enclosure by welding, a threaded joint, or a press joint. The positioner sleeve could nevertheless be also made from some other material.

According to one embodiment of the invention, the positioner sleeve is attached to an end plate present at the pile's splicing end. This ensures a precise
30 placement of the positioner sleeve during the fabrication of a pile.

According to one embodiment of the invention, the end plate forms part of an end enclosure surrounding the pile's splicing end.

According to one embodiment of the invention, the heat transfer pipe is dimensioned in such a way that between the ends of the interconnectible piles' heat transfer pipes can be disposed a sealing element. The sealing element is an annular component made of an elastic material, which compresses as piles
5 are being connected to each other and creates a tight joint between the piles' ends. The sealing element functions as a backup feature for the sealing provided by the sealing sleeve.

According to one embodiment of the invention, the annular space is provided with a sealing sleeve.

10 According to one embodiment of the invention, the pile is adapted to engage with another pile by means of at least one locking sleeve—dowel pair, whereby the pile's splicing end is provided with at least one dowel or locking sleeve, which is adapted to function with a locking sleeve or a dowel disposed at the
15 opposite pile's splicing end for securing the piles to each other, and the dowel and the locking sleeve are dimensioned in such a way that, in the process of joining the piles to each other, the dowel and the locking sleeve come into mutual contact before the sealing sleeve, disposed in said annular space, comes into contact with the opposite pile's respective annular space. Since the
20 dowel and the locking sleeve are adapted to withstand even major forces, it is by bringing those into mutual contact and by restricting a lateral movement between the piles that damage to the sealing sleeve and the heat transfer pipe's end is prevented as piles are being connected to each other.

The pile assembly of the invention comprises a reinforced concrete pile as defined above disposed as a lower pile in such a way that the pile's top end is
25 a splicing end, and a reinforced concrete pile as defined above disposed as an upper pile in such a way that the pile's bottom end is a splicing end, and a sealing sleeve disposed in the lower pile's and the upper pile's annular spaces so as to seal a joint between the lower pile's heat transfer pipe and the upper pile's heat transfer pipe.

30 According to one embodiment of the invention, the sealing sleeve is made entirely from one or more metals or metal alloys. The sealing sleeve can be made completely from a single material. Optionally, the sealing sleeve may comprise two or more materials. The sealing sleeve may include for example a body

portion, which essentially retains its shape as piles are being connected to each other, and plastically deformable sealing zones provided at the ends of a sealing sleeve.

5 According to one embodiment of the invention, the sealing sleeve is at least partially made from copper or a copper-containing metal alloy. The sealing sleeve can be made entirely from copper or a copper-containing metal alloy. Optionally, the sealing sleeve may include a body portion of some other material and sealing zones of copper or a copper-containing metal alloy provided at the ends of a sealing sleeve.

10 According to one embodiment of the invention, between the ends of the lower pile's and the upper pile's heat transfer pipes is disposed a sealing element. The sealing element is an object made of a flexible material, which compresses as piles are being connected to each other and provides a tight joint between the ends of the piles. The sealing element functions as a safety backup for the
15 sealing provided by the sealing sleeve. The joint could also include two sealing elements. Hence, the end of each pile could be provided with a sealing element in such a way that, in the process of joining piles together, the sealing elements press against each other.

The method of the invention for joining to each other the heat transfer pipes of
20 a reinforced concrete pile as defined above comprises the steps of

- disposing one of the piles in the ground as a lower pile in such a way that the pile's top end is a splicing end,
- disposing, in the annular space of one of the piles, a sealing sleeve made of a plastically deformable material in such a way that the seal-
25 ing sleeve extends outward from the discussed pile's end,
- aligning the piles in such a way that the sealing sleeve is essentially concentric with a respective annular space of the other pile,
- lowering the-yet-to-be installed pile in such a way that the sealing sleeve penetrates into the annular space of the other of the piles,
- 30 - striking the upper pile in such a way that the piles' opposite ends come into mutual contact and the sealing sleeve deforms plastically in the annular spaces, producing a tight joint between the piles' heat transfer pipes.

According to one embodiment of the invention, prior to the lowering of a yet-to-be installed pile for installing a sealing sleeve, the end of at least the other pile's heat transfer pipe is fitted with a sealing element. The sealing element can be fitted as early as during pile fabrication of, alternatively, during pile driving.

The method of the invention for the fabrication of a reinforced concrete pile as defined above comprises the steps of

- providing at least one heat transfer pipe,
- disposing at least one end of said heat transfer pipe inside a positioner sleeve,
- casting concrete around said at least one heat transfer pipe in such a way that the positioner sleeve is left at least partially embedded in the cast concrete.

According to one embodiment of the invention, the method further comprises a step of disposing, inside the end of a heat transfer pipe, a support sleeve. The support sleeve can be disposed inside the end of a heat transfer pipe before or after the casting of concrete.

Description of the drawings

Embodiments of the invention will be described hereinafter in more detail with reference to the accompanying drawings, in which

Fig. 1 shows, in a simplified view, two interconnected reinforced concrete piles in cross-section,

Fig. 2 shows components of two interconnected reinforced concrete piles without actual concrete casting,

Fig. 3 shows the assembly of Fig. 2 in an overhead view,

Fig. 4 shows a cross-section of Fig. 3 along line A-A,

Fig. 5 shows, in an enlarged view, detail B of Fig. 4,

Fig. 6 shows a detail similar to Fig. 5 in another embodiment of the invention,

Fig. 7 shows a cross-section of Fig. 3 along line C–C,

Fig. 8 shows, in a flow chart, a method of the invention for joining the piles' heat transfer pipes to each other, and

Fig. 9 shows, in a flow chart, a method of the invention for the fabrication of
5 piles.

Detailed description of embodiments of the invention

Fig. 1 shows, in a cross-section view, two interconnected reinforced concrete piles 1, 1' according to certain embodiments of the invention. The reinforced concrete piles 1, 1' of the invention can be used in deep foundations to support
10 a building or the like structure. In addition to building foundations, the piles 1, 1' could be used for example under the roadway. The pile 1,1' is driven into the soil to such a depth that the pile's 1,1' tip makes contact with bedrock or that the friction between soil and pile is high enough to bear the required load. A wide variety of pile driving machines can be used for hammering the pile 1,
15 1' into the ground. Generally speaking, in pile driving, the end face of a pile is subjected to strikes by the force of which the pile 1, 1' is driven into the ground. The pile driving machines may utilize for example a heavy load, compressed air, or hydraulic pressure for applying a force to the end of the pile 1, 1'. A wide variety of pile driving machines and pile driving methods are known, not war-
20 ranting more detailed description at this time.

The length required of piles 1, 1' varies according to soil properties encountered in various project sites. Likewise, piles 1, 1' of varying lengths are often needed in a single construction site. Fabrication of piles in unequal lengths is not practical. Long piles 1, 1' are also inconvenient in terms of transport and
25 handling. Moreover, in certain construction sites, such as under bridges and other structures, the vacant headspace above a pile driving site may be limited. Therefore, piles are preferably manufactured in predetermined lengths and, should longer piles be needed, two or more piles will be connected together for obtaining a pile of appropriate length. In Fig. 1 there is depicted two piles
30 1, 1' connected to each other. The lower pile 1 of Fig. 1 can be used in foundations as a lowermost pile. The upper pile 1' of Fig. 1 can be attached to the lower pile 1 for obtaining a longer pile assembly. Several piles similar to the

upper pile 1' could be attached in succession to the pile assembly for obtaining a pile of required length.

- Figure 2 depicts components for the piles 1, 1' of Fig. 1 without the actual concrete casting of the piles. The pile's 1, 1' body portion is made of concrete and provided with at least one reinforcement element 8. The reinforcement elements 8 extend almost through the entire concrete component in a longitudinal direction of the pile 1 and are made of steel. In the illustrated embodiments, each pile 1, 1' is provided with four reinforcement elements 8 of ribbed steel. The number of reinforcement elements 8 could also be something else. Thus, the number thereof could be more or fewer than four. The appropriate number of reinforcement elements 8 depends on the dimensions of a pile and the strength required thereof. The reinforcement elements 8 need not be straight as other types of reinforcement elements 8 could be used as well. The reinforcement elements 8 can be attached to each other with a binding wire.
- The pile 1, 1' comprises, in its lengthwise direction, a first end and a second end. When the pile 1, 1' is driven into the ground, the first end constitutes a bottom end of the pile 1, 1' and the second end constitutes a top end of the pile 1, 1'. The lower pile 1 of Fig. 1 is configured to be used as a first or lowermost pile, which is hammered into the ground. The pile 1 has its first end tapered to assist pile driving into the ground. In the example of Fig. 1, the tapered end comprises a pyramidal part 9 and a cylindrical part 10, the latter constituting a tip of the pile 1. The pile's 1 concrete component is protected by a pile point 7, which is manufactured in steel. The cylindrical portion 10 at the end of the pile 1 is disposed on the pile point 7. The pile point 7 further includes a collar element, which surrounds the end of the pile's 1 concrete casting and has an interior shape which matches an exterior shape of the concrete component. The pile point 7 can be provided with gripping devices by means of which it can be secured to the concrete component of the pile 1. The pile point 7 can be attached to the pile 1 during a pile casting process.
- Each pile 1, 1' is provided with at least one heat transfer pipe 2, 3. The heat transfer pipes 2, 3 can be used for circulating a heat transfer fluid for transferring heat from soil to heat transfer fluid or vice versa. The heat transfer fluid can be for example an ethanol- or glycol-based liquid, water, or water-based liquid. Hence, the pile 1, 1' can be used as part of a geothermal heating system

or for storing heat in the soil. It is by virtue of the heat transfer pipes 2, 3 that the drilling of separate heat collection or storage wells, or the burying of heat transfer pipes in the ground, can be avoided or at least the need thereof can be mitigated.

- 5 In the illustrated embodiments, each pile 1, 1' is provided with two heat transfer pipes 2, 3. One of the heat transfer pipes 2, 3 functions as a supply pipe by which the heat transfer fluid is delivered into the pile 1, 1' and the other of the heat transfer pipes 2, 3 functions as a return pipe along which the heat transfer fluid returns to the top end of the pile 1, 1'. In the lower pile 1 of Fig. 1, the heat transfer pipes 2, 3 are joined together at a first or bottom end of the pile. Thus, the pipes 2, 3 make up a U-shaped continuous pipe. The lower pile's 1 pipes 2, 3 can be constructed of a single bent pipe. Alternatively, the lower pile's 1 pipes 2, 3 can be connected to each other with a separate connecting piece 4. At a second or top end of the pile 1, the ends of the pipes 2, 3 are open. Instead of a U-shaped pipe, the pile's 1 heat transfer pipe could be in a different configuration, for example in a spiral shape. The spiral pipe would enable a longer pipe to be fitted in the pile 1, thereby increasing the pipe's heat transfer surface area. The pile 1 could also be provided with several heat transfer pipes. The heat transfer pipes 2, 3 may comprise for example plastic piping.
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- 20 The upper pile 1' includes two separate heat transfer pipes 2, 3. Both heat transfer pipes 2, 3 extend in a lengthwise direction of the pile 1' from a second end to a first end of the pile 1'. The first heat transfer pipe 2, functioning as a supply pipe, is provided at a second end of the pile 1' with an inlet and at a first end of the pile 1' with an outlet. Respectively, the second heat transfer pipe 3, functioning as a return pipe, is provided at a first end of the pile 1' with an inlet and at a second end of the pile 1' with an outlet. The heat transfer fluid may flow in the upper pile's 1' first heat transfer pipe 2 from the pile's 1' top end towards its bottom end and continue from there into the lower pile's 1 first heat transfer pipe 2. Respectively, the heat transfer fluid may flow from the lower pile's 1 second heat transfer pipe 3 into the upper pile's 1' second heat transfer pipe 3 and from there further towards the upper pile's 1' top end and to the second heat transfer pipe's 3 outlet. The supply pipe 2 and the return pipe 3 can be identical to each other. Hence, the inlet and the outlet may likewise be identical to each other and formed by open ends of the heat transfer pipe 2, 3.
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The lower pile 1 of Fig. 1 has its second end provided with an inlet for the heat transfer pipe 2, thereby enabling heat transfer fluid to be supplied via the outlet of the upper pile's 1' supply pipe 2 into the heat transfer pipe 2 functioning as a supply pipe for the lower pile 1. The heat transfer fluid flows in the heat transfer pipe 2 towards the pile's 1 first end. It is by way of a connecting pipe 4, disposed in the lower pile 1 of Fig. 1 in the proximity of the pile's 1 first end, that the heat transfer fluid is able to flow into the second heat transfer pipe 3 functioning as a return pipe, and to continue therealong towards the pile's 1 second end. The pile 1 has its second end provided with an outlet for the second heat transfer pipe 3. From there, the heat transfer fluid is able to flow into the upper pile's 1' heat transfer pipe 3 functioning as a return pipe. The lower pile's 1 heat transfer pipes 2, 3 and the connecting pipe 4 can be constructed as a continuous pipe.

Depending on a required total pile length, the pile assembly may comprise one lowermost pile 1 provided with a pile point 7, and one or several piles similar to the upper pile 1' attached on top of each other. The heat transfer pipes of what in the pile assembly is the uppermost pile 1' can be connected to an appropriate apparatus such as a heat pump.

At least one end of each pile 1, 1' is provided with splicing means for connecting the pile 1, 1' rigidly to the next pile. The term "rigidly" indicates in this context that the splice between the piles 1, 1' is capable of resisting rotation of the upper pile 1' relative to such an axis which is co-directional with end faces of the piles 1, 1'. The rotation of a pile 1, 1' relative to a longitudinal axis of the piles 1, 1' is also prevented. Likewise, the rigid joint resists tension in a length-wise direction of the piles 1, 1'. Regarding the piles of Fig. 1, it is in the lower pile 1 that the pile 1 has just its second end provided with splicing means. In the upper pile 1', at least the first end is provided with splicing means for attaching it to the lower pile 1. If the number of piles installed on top of each other is three or more, the piles intended between two piles have both ends provided with splicing means.

In the illustrated embodiment, the lower pile 1 has its top end and the upper pile 1' has at least its bottom end provided with an end enclosure 13. The end enclosure 13 is made of a sheet material such as steel, and it comprises an end plate 13a disposed against the end of the pile's 1, 1' concrete component,

as well as a collar 13b which surrounds the pile's 1, 1' concrete component. The purpose of end enclosures 13 is to protect the ends of the piles 1, 1' during transport and handling thereof. However, the end enclosures 13 are not absolutely necessary as the piles 1, 1' could also be constructed without them. Instead of the end enclosures, the piles 1, 1' could also be equipped with a collar surrounding at least one end of the pile 1, 1' or with an end plate placed against an end face of the pile 1, 1'.

In order to connect the pile's 1, 1' heat transfer pipe 2, 3 to the next pile's 1, 1' respective heat transfer pipe 2, 3, the pile's 1, 1' splicing end is fitted with a positioner sleeve 14. The positioner sleeve 14 is co-directional with the pile's 1, 1' longitudinal axis. The positioner sleeve extends a distance from the pile's 1, 1' end. The positioner sleeve's 14 length can be for example 50–120 mm. The positioner sleeve 14 surrounds the heat transfer pipe's 2, 3 end in such a way that between the heat transfer pipe 2, 3 and the positioner sleeve 14 develops an annular space 6. The annular space's 6 length can be for example 25–100 mm. However, the annular space's 6 length is naturally less than that of the positioner sleeve 14. Thus, at the end of a pile 1, 1', the positioner sleeve's 14 inner diameter is larger than the heat transfer pipe's 2, 3 outer diameter. The annular space 6 is open at the pile's 1, 1' splicing end. The positioner sleeve 14 is essentially concentric with the heat transfer pipe 2, 3.

The annular space 6 is adapted to receive a sealing sleeve 11 made from a plastically deformable material. The positioner sleeve's 14 end, which is further from the splicing end, is designed in its inner diameter to be diminishing towards the discussed end in such a way that, in the process of joining two piles 1, 1' to each other and when hammering the upper pile 1' towards lower pile 1, the sealing sleeve 11, disposed in the annular space 6, has its end within the decreasing inner diameter zone deforming plastically, sealing against the heat transfer pipe's 2, 3 external surface. Other than the decreasing inner diameter zone, the positioner sleeve's 14 inner diameter can be of constant size. The zone of decreasing inner diameter can be obtained for example with a chamfer or rounding. Hence, the annular space's 6 end develops a wedge-shaped zone along which the distance between the positioner sleeve's 14 internal surface and the heat transfer pipe's 2, 3 internal surface is smaller than what it is closer to the pile's 1, 1' splicing end.

The heat transfer pipe 2, 3 may, at the splicing end of a pile 1, 1', extend to flushness with the pile's 1, 1' end, yet not beyond that. Since the heat transfer pipes 2, 3 of two piles 1, 1' are joined together by means of a sealing sleeve 11, the heat transfer pipe 2, 3 need not extend all the way to flushness with the pile's 1, 1' end but, instead, the pile assembly may be left with a small gap between the pile's 1, 1' heat transfer pipes 2, 3.

The sealing sleeve's 11 inner diameter matches essentially the heat transfer pipe's 2, 3 outer diameter. The sealing sleeve's 11 outer diameter matches essentially the positioner sleeve's 14 inner diameter. Accordingly, the sealing sleeve 11 can be pushed lightly into the annular space 6 so as to substantially fill the annular space 6 in radial direction. The sealing sleeve's 11 wall thickness can be for example 2–5 mm.

The sealing sleeve 11 can be manufactured from a metal or a metal alloy. As its material the sealing sleeve 11 may comprise for example a copper-containing metal alloy. Preferably, the sealing sleeve 11 is made from a material with a copper content of at least 30 percent by weight. The sealing sleeve 11 can be made entirely from a single material. Optionally, the sealing sleeve 11 may comprise two or more materials. The sealing sleeve 11 may have for example a body portion, which essentially retains its shape in the process of connecting piles 1, 1' to each other, and plastically deformable sealing zones arranged at the ends of a sealing sleeve 11. The body portion could be manufactured for example from a suitable plastic or composite material. The sealing zones at the ends could comprise metal rings or beads fastened to the body portion for example by casting.

The sealing sleeve's 11 length has been selected in such a way that, with two piles 1, 1' interconnected, the sealing sleeve 11 extends from the decreasing inner diameter zone of the lower pile's 1 positioner sleeve 14 to the decreasing inner diameter zone of the upper pile's 1' positioner sleeve 14. Thus, the sealing sleeve's 11 length depends on the dimensions of the annular space 6. The sealing sleeve's 11 length could be for example 50–100 mm. The sealing sleeve 11 can be installed in the annular space 6 just before the piles 1, 1' are connected to each other. Thereby is prevented damage to the piles 1, 1' during transport and handling.

The positioner sleeve 14 can be manufactured from a metal or a metal alloy. The positioner sleeve's 14 material can be for example steel. The positioner sleeve 14 could nevertheless be also made from some other material with sufficient strength properties, for example from a suitable composite material. The positioner sleeve 14 can be fastened to the end plate of a pile 1, 1' for example by means of threads or by welding.

In the illustrated embodiment, the positioner sleeve 14 is adapted to station a heat transfer pipe 2, 3 in a radial direction of the heat transfer pipe 2, 3. The positioner sleeve 14 has its end, which is further away from the splicing end, provided with a zone where the positioner sleeve's 14 inner diameter essentially matches the heat transfer pipe's 2, 3 outer diameter. Thus, the heat transfer pipe 2, 3 bears against the positioner sleeve's 14 internal surface. The end of a positioner sleeve 14 can be provided with a chamfer or rounding, facilitating attachment of the heat transfer pipe 2, 3 and the positioner sleeve 14 to each other. Likewise, the end of a heat transfer pipe 2, 3 may also be provided with a chamfer.

In the illustrated embodiment, inside the heat transfer pipe 2, 3, at the pile's 1, 1' splicing end, is arranged a support sleeve 5, which is adapted to prevent collapse of the heat transfer pipe 2, 3 as a result of the sealing sleeve's 11 deformation as piles 1, 1' are being connected together. The support sleeve 5 is manufactured from a material which provides the support sleeve 5 with a sufficient rigidity for upholding the heat transfer pipe 2, 3. The support sleeve 5 can be made for example from a metal or a metal alloy or from an appropriate plastic or composite material. The support sleeve 5 is adapted to extend to at least as far as the positioner sleeve's 14 decreasing inner diameter zone. In the illustrated embodiment, the support sleeve 5 is disposed in its entirety inside the heat transfer pipe 2, 3 of one pile 1, 1'. Thus, the support sleeve 5 does not extend outward from the pile's 1, 1' end, thus facilitating attachment of the piles 1, 1' to each other. The pile 1, 1' could nevertheless be also provided with such a support sleeve 5 which extends outward from the pile's 1, 1' end so as to enable its function as a support sleeve also for the heat transfer pipe 2, 3 of the other pile 1, 1' in the joint.

The support sleeve 5 is not absolutely necessary, since, when the heat transfer pipe 2, 3 is sufficiently rigid, the joint can be established reliably also without a

support sleeve 5. However, the support sleeve 5 makes possible a smaller wall thickness for the heat transfer pipe 2, 3.

The support sleeve 5 extends preferably to both ends of the positioner sleeve 14. Hence, the support sleeve 5 assists in ensuring a reliable attachment of the heat transfer pipe 2, 3 to the positioner sleeve 14. The joint between a support sleeve 5 and a heat transfer pipe 2, 3 can be implemented for example with a nut/bead joint or a press joint. The achievement of reliable immobilization between the positioner sleeve 14 and the heat transfer pipe 2, 3 both in lengthwise axis direction and in transverse direction contributes to the attainment of a reliable joint for the heat transfer pipes 2, 3, whereby for example the heat transfer pipe's 2, 3 thermomechanical changes do not induce a displacement of the end of the heat transfer pipe 2, 3.

In the illustrated embodiment, the positioner sleeve 14 comprises, at the end located further way from the pile's 1, 1' splicing end, an attachment zone 14a for securing the support sleeve 5 in a fixed position inside the heat transfer pipe 2, 3 by applying to the attachment zone 14a a force for its deformation plastically in such a way that the attachment zone 14a presses the heat transfer pipe 2, 3 against the support sleeve 5. In the attachment zone 14a, the positioner sleeve's 14 wall thickness may be smaller than within the annular space 6, whereby a lesser force is sufficient for deforming the attachment zone 14a. The attachment zone 14a can be deformed for example by compressing or by applying thereto a strike type force over a small area.

Instead of the positioner sleeve's 14 attachment zone, the support sleeve 5 could be immobilized in many other ways as well. For example, around the heat transfer pipe 2, 3 could be provided a separate tightening collar or the like for pressing the heat transfer pipe 2, 3 locally in order to secure the support sleeve 5. Alternatively, the support sleeve 5 could be secured for example by gluing to the heat transfer pipe's 2, 3 internal surface. The support sleeve 5 could also be equipped with a flange or protrusions for resting the same against the heat transfer pipe's 2, 3 end or some other component of the pile 1, 1'.

Fig. 6 depicts an embodiment of the invention, wherein the tightness of a joint between the heat transfer pipes 2, 3 is ensured with a sealing element 20.

Hence, the sealing element 20 works as a backup feature for a sealing provided by the sealing sleeve 11. In the embodiment of Fig. 6, the heat transfer pipes 2, 3 extend to just short of flushness with the pile's 1, 1' end. Accordingly, the pile's 1, 1' end develops a space in which can be fitted a sealing element 20 coming against the heat transfer pipe's 2, 3 end. The sealing element 20 is a ring-like object. The sealing element 20 is made at least partially from an elastic material. Before joining the piles 1, 1' to each other, the sealing element 20 extends in a lengthwise direction of the pile 1, 1' slightly beyond the pile's 1, 1' end. When the piles 1, 1' are being joined to each other, the sealing element 20 is compressed between the ends of heat transfer pipes 2, 3, producing thereby a tight joint. In some cases, the sealing sleeve 11 could even be replaced by a sealing element 20.

Between the ends of heat transfer pipes 2, 3 could also be two sealing elements 20. Thus, each pile 1, 1' could have its own sealing element 20, whereby the sealing elements 20 would be compressed against each other in the process of connecting the piles 1, 1' together.

The sealing element 20 may include an inflexible bracing member. The bracing member can be for example a sleeve made of metal or plastic. The sleeve can have its placement within the sealing material or along the sealing sleeve's 20 outer or inner periphery. The sleeve's length in its axial direction is less than the sealing element's 20 total length. The bracing member makes sure that the sealing element 20 does not buckle in the process of connecting the piles 1, 1' together.

The piles 1, 1' are coupled to each other with at least one locking sleeve-dowel pair in such a way that the pile's 1, 1' splicing end is provided with at least one dowel 16 or a locking sleeve 15, which is adapted to work with a locking sleeve 15 or a dowel 16 disposed on the opposite pile's 1, 1' splicing end for securing the piles 1, 1' to each other. The dowel 16 and the locking sleeve 15 are dimensioned in such a way that, when the piles 1, 1' are being connected to each other, the dowel and the locking sleeve 15 come into mutual contact before the sealing sleeve 11, disposed in said annular space 6, comes into contact with the opposite pile's 1, 1' respective annular space 6. Because the dowel 16 and the locking sleeve 15, intended for connecting the piles 1, 1', are adapted to bear even major forces, it is by bringing the same into mutual

contact before the sealing sleeve 11 comes into contact with the opposite pile 1, 1' that the sealing sleeve 11 is protected from being damaged during the making of a joint. In the illustrated embodiment, each pile 1, 1' connects to another pile 1, 1' with four locking sleeve-dowel pairs. Each splicing end of the pile features two locking sleeves 15 and two dowels 16. The number of locking sleeve-dowel pairs could also be something else. It is also possible that one end of the pile 1, 1' be provided with just locking sleeves 15 and the other end of the pile with just dowels 16. Details for the attachment arrangement according to one embodiment of the invention will be subsequently described more precisely.

Instead of or in addition to locking sleeves 15 and dowels 16, the piles 1, 1' could be equipped with guide means, for example guide pins and guide holes, for aligning the piles before the sealing sleeve 11 comes into contact with the other pile's annular space 6.

The joining to each other of the piles' 1, 1' heating pipes 2, 3 is described by referring particularly to Fig. 8, showing a method of the invention in a flowchart. In step 101 of the method, a pile 1, 1' of the invention is provided as a lower pile 1. Hence, the pile 1 is hammered into the ground with a pile driving machine. This can be carried out with some prior known method. The top end of a pile driven into the ground must be a splicing end.

In step 102 of the method, the sealing sleeve 11 is disposed in the annular space 6 of one of the joint's piles 1, 1'. This particular pile 1, 1' is preferably the lower pile 1, whereby the sealing sleeve 11 retains reliably its fixed position in the annular space 6. However, the sealing sleeve 11 could alternatively be also disposed in the annular space 6 of an upper pile 1'. If the sealing sleeve 11 is pushed with a sufficient force into said annular space 6, it shall be wedged within the zone of decreasing inner diameter, thus remaining immobilized also in a pile 1' in which the splicing end is at the pile's 1' bottom end. Step 102 need not follow step 101 but, instead, when disposed in an upper pile 1', the sealing sleeve 11 can be fitted in place even before hammering the lower pile 1 into the ground. While being fitted in place, the sealing sleeve 11 may extend somewhat into the annular space's 6 decreasing inner diameter zone, but not over its entire distance.

In step 103 of the method, the piles 1, 1' are aligned with each other, such that the sealing sleeve 1 is essentially concentric with the other pile's 1, 1' respective annular space 6.

5 In step 104 of the method, the yet-to-be installed or upper pile 1' is lowered in such a way that the sealing sleeve 11 is enabled to penetrate into the annular space 6 of the other of the piles 1, 1'. As presented above, the sealing sleeve 11 may therefore penetrate into either the upper 1' or lower pile's 1 annular space 6, depending on which one of the piles 1, 1' has the sealing sleeve 11 fitted therein.

10 In step 105 of the method, the upper pile 1' is struck, such that the piles' 1, 1' opposite ends come into mutual contact. At the same time, the sealing sleeve 11 penetrates in each pile's 1, 1' annular space 6 further into the decreasing inner diameter zone, as a result of which the sealing sleeve 11 deforms plastically in the annular spaces 6, bearing against the heat transfer pipe's 2, 3
15 external surface and forming a tight joint between the piles' 1, 1' heat transfer pipes 2, 3.

In the event that the joint between the heat transfer pipes 2, 3 is further tightened with a sealing element 20, the sealing element 20 is installed in place before the sealing sleeve 11 penetrates into the other pile 1, 1'. The sealing
20 element 20 can be installed as early as in the fabrication process of a pile 1, 1' or, alternatively, during piling.

In the illustrated embodiment, the pile's splicing means 12 comprise a locking sleeve 15, a dowel 16, at least two locking tabs 17, and an elastic element 18. The locking sleeve 15 is disposed at the end of one pile 1, 1' and the dowel 16
25 is disposed at the end of an opposite pile 1, 1'. In the illustrated embodiment, the locking sleeve 15 is fastened to the pile's 1, 1' reinforcement element 8. Respectively, the dowel 16 is fastened to the pile's 1, 1' reinforcement element 8. In the illustrated embodiment, the reinforcement elements' 8 ends are provided with an external thread, and the dowel 16 as well as the locking sleeve
30 15 are provided with a corresponding internal thread for fastening the dowel 16 or the locking sleeve 15 to the reinforcement element 8. Alternatively, the fastening of a dowel 16 and a locking element 15 to a reinforcement element 8 could be carried out by welding. In the illustrated embodiments, the dowel

16 is further provided with an external thread by means of which it can be fastened to an end enclosure 13 or to an end plate 13a. The dowel 16 and the locking sleeve 15 could alternatively only be fastened to the end enclosure 13 or to the end plate 13a.

- 5 The dowel 16 and the locking sleeve 15 are dimensioned in such a way that the dowel 16 fits and is able to penetrate inside the locking sleeve 15. The dowel 16 is provided with a locking groove 19 encircling its outer surface. In the illustrated embodiment, the splicing means comprise three locking tabs 17 per each dowel–locking sleeve pair. The locking tabs 17 are adapted to penetrate into the dowel's 16 locking groove 19 and to thereby prevent the dowel's
- 10 16 movement relative to the locking sleeve 15 in a lengthwise direction of the piles 1, 1'. The locking sleeve 15 comprises a locking sleeve body 15a and a locking sleeve cap 15b attached thereto. The locking sleeve body 15a is provided with an internal thread and the locking sleeve cap 15b with a matching
- 15 external thread for fastening the locking sleeve cap 15b to the locking sleeve body 15a. Between the locking sleeve body 15a and the locking sleeve cap 15b develops a groove 15c, in which the locking tabs 17 become seated in such a way that the movement thereof in a lengthwise direction of the piles 1, 1' is prevented.
- 20 The groove 15c, present between the locking sleeve body 15a and the locking sleeve cap 15b, is further provided with an elastic element 18. The elastic element 18 is adapted to subject the locking tabs 17 to a force which urges the locking tabs 17 into the dowel's 16 locking groove 19. The elastic element 18 is configured in such a way that the locking tabs 17 are able to penetrate into
- 25 the locking sleeve's 15 groove 15c in such a way that the locking tabs 17 are not seated in the dowel's 16 groove. This enables the dowel 16 to be pushed into the locking sleeve 15. The dowel's 16 end is designed to taper towards the end in such a way that, when the dowel 16 is pushed into the locking sleeve 15, the locking tabs 17 yield away into the locking sleeve's 15 groove 15c.
- 30 When the dowel 16 is pushed sufficiently far, the elastic element 18 will be able to push the locking tabs 17 into the dowel's 16 locking groove 19, whereby the dowel 16 and the locking sleeve 15 become locked to each other and connect the piles 1, 1' together.

The locking sleeve cap 15b is not an absolutely necessary component as, instead, the locking sleeve 15 could also be constructed as a single object, having the groove 15c provided therein. However, the separate locking sleeve cap 15b facilitates installation of the elastic element 18 and enables the use of a stiffer elastic element and thereby a more securely locking joint. In the illustrated embodiments, the locking sleeve cap 15b is provided with a thread by means of which it can be fastened to an end enclosure 13 or to an end plate.

The elastic element 18 is a ring-shaped object. The elastic element 18 can have a cellular structure. It is by virtue of a cellular structure that the elastic element 18 can be given appropriate elasticity. The elastic element 18 can be made for example from polyurethane. The elastic element 18 could also be made from some other suitable material such as metal, rubber, or plastic.

One side of the dowel's 16 locking groove 19 is inclined with respect to a transverse direction of the pile 1, 1'. The locking tab 17 has its respective side inclined in a corresponding manner. Hence, the dowel's locking groove 19 widens towards an outer periphery of the dowel 16 and the locking tab 17 tapers towards a center axis of the locking sleeve 15. In the figures, the side of the dowel's 16 locking groove 19, which is closer to the dowel's end, is inclined in such a way that the side's outer edge is closer to the end of the dowel 16 than the side's inner edge. The sides of the locking tabs 17, to be located closer to the dowel's end, are inclined to a matching angle. The angle of inclination from a transverse direction of the dowel 16 can be for example 3–15 degrees. Thus, the sides of a locking tab 17, to be located closer to the dowel's end, will be closer to the dowel's 16 end on the locking sleeve 15 side than on the dowel 16 side. It is by virtue of how the elastic element 18 and the locking groove 19 and the locking tabs 17 are designed that the joint between piles can be maintained without play.

In the illustrated embodiment, what in a lengthwise direction of the locking sleeve is the outer dowel-facing angle of the locking sleeve's 15 locking groove 15c is acute. If the piles 1, 1' are subjected to lengthwise forces, it is by virtue of the acute angle that movement of the locking tabs 17 is effectively prevented, thereby retaining the piles 1, 1' firmly locked to each other.

The piles 1, 1' can be equipped with a necessary number of splicing means 12. In the illustrated embodiment, each pair of piles connects to each other at four points. Thus, the joint comprises four locking-sleeve dowel pairs. Each pile 1, 1' is provided with two locking sleeves 15 and two dowels 16.

- 5 According to the prior art, the connecting of reinforced concrete piles to each other has been generally conducted by using connecting pins, which are fitted in each joint transversely relative to a lengthwise direction of the piles. A problem with connecting pins is a possible loosening thereof as a result of lateral pile movement or that installation of some connecting pins is completely neglected, either intentionally or by mistake. The installation of locking pins may also be hampered by deformations generated in the end plate as a result of fastening the splice locking elements by welding. The problem has often been solved by using connecting pins of reduced thickness, resulting in a compromised strength of the joint. The foregoing viewpoints may cause particular problems in piles equipped with heat transfer pipes, since the functionality of a pile joint has an impact on the functionality of a pipe joint as well. It is by using the above-described splicing means, based on dowels 16 and locking sleeves 15, for interconnecting piles 1, 1' provided with heat transfer pipes 2, 3, that the functionality of pipe joints is ensured. However, the piles 1, 1' could also be attached to each other with splicing means of some other type.

In the illustrated embodiment, the attachment of piles 1, 1' to each other with splicing means 12 takes place simultaneously with joining heat transfer pipes 2, 3 to each other. In piles fitted with some other type of splicing means, the attachment could take place after the joint between heat transfer pipes 2, 3 is established.

The method of the invention for manufacturing a reinforced concrete pile is described hereinafter with reference particularly to Fig. 9, which depicts a method of the invention in a flowchart.

- The piles 1, 1' are fabricated by casting. The casting is preceded by providing a mold. The mold used for casting is an elongated trough whose shape matches a desired shape of the piles 1, 1'. The mold has a bottom and side walls. The mold may also have one or two end walls. At least a part of the upper mold section is open for enabling the pouring of concrete into the mold.

In step 201 of the method, inside the mold are disposed at least one heat transfer pipe 2, 3, 4. Inside the mold are also disposed necessary reinforcement elements 8. The heat transfer pipes 2, 3, 4 and the reinforcement elements 8 are secured to appropriate locations for holding the same stationary relative to the mold during a casting process.

In step 202 of the method, the end of a heat transfer pipe 2, 3 is disposed inside a positioner sleeve 14. This may occur either before or after the placement of heat transfer pipes 2, 3 in the mold. The positioner sleeve 14 can be in attachment for example with an end enclosure 13, and the positioner sleeve 14 can be joined together with a heat transfer pipe 2, 3 while fastening the end enclosure 13 to the reinforcement elements 8.

After setting in place all components to be embedded in concrete casting, it is in step 203 of the method that concrete is cast in such a way that the positioner sleeve 14 is left at partially embedded within the cast concrete. Once the cast concrete has attained a required strength, the pile 1, 1' is removed from the mold.

In the event that inside the heat transfer pipe 2, 3 is installed a support sleeve 5, the installation may take place prior to casting the concrete. In case the support sleeve 5 is fastened to the heat transfer pipe 2, 3 by means of the positioner sleeve's 14 attachment zone 14a, the support sleeve 5 can be disposed inside the heat transfer pipe 2, 3 for example after the heat transfer pipe 2, 3 and the positioner sleeve 14 have been connected to each other. This is followed by modifying the positioner sleeve's 14 attachment zone 14a for securing the support sleeve 5 in place.

It is obvious for a person skilled in the art that the invention is not limited to the foregoing embodiments but may vary within the scope of the independent claims.

Claims

1. A reinforced concrete pile (1, 1'), which is adapted to be driven into the ground for supporting a building or the like structure, the pile (1, 1') comprising at least one heat transfer pipe (2, 3) for circulating a heat transfer fluid within the pile (1, 1'), at least one of the ends of the reinforced concrete pile (1, 1') constituting a splicing end, by which splicing end said pile (1, 1') is connectible to another identical or similar pile (1, 1') for constructing a longer pile assembly, and whereby, at said splicing end, said at least one heat transfer pipe (2, 3) is adapted to be connected to a respective heat transfer pipe (2, 3) of the pile (1, 1') connectible to the discussed splicing end, **characterized** in that the pile (1, 1') has its splicing end fitted with a positioner sleeve (14) which surrounds the heat transfer pipe's (2, 3) end in such a way that between the heat transfer pipe (2, 3) and the positioner sleeve (14) develops an annular space (6) for receiving a sealing sleeve (11), which is made at least partially from a plastically deformable material and which extends outward from the pile's (1, 1') splicing end, and the positioner sleeve (14) has its end, which is further from said splicing end of the pile (1, 1'), designed to decrease in its inner diameter towards the discussed end in such a manner that, in the process of coupling two piles (1, 1') to each other, and when hammering the upper pile (1') towards the lower pile (1), the sealing sleeve (11) disposed in the annular space (6) has its end within the positioner sleeve's (14) decreasing inner diameter zone deforming plastically, thereby sealing against the heat transfer pipe's (2, 3) external surface.
2. A reinforced concrete pile (1, 1') according to claim 1, **characterized** in that the positioner sleeve (14) is adapted to fix the position of the heat transfer pipe (2, 3) in the heat transfer pipe's (2, 3) radial direction.
3. A reinforced concrete pile (1, 1') according to claim 1 or 2, **characterized** in that inside the heat transfer pipe (2, 3), at the pile's (1, 1') splicing end, is disposed a support sleeve (5), which is adapted to prevent the heat transfer pipe (2, 3) from collapsing as a result of the sealing sleeve (11) being deformed as piles (1, 1') are being connected to each other.

4. A reinforced concrete pile (1, 1') according to claim 3, **characterized** in that the positioner sleeve (14) comprises, at the end which is further away from the pile's (1, 1') splicing end, an attachment zone (14a) for securing the support sleeve (5) immovably inside the heat transfer pipe (2, 3) by applying to the attachment zone (14a) a force for deforming the same plastically in such a way that the attachment zone (14a) presses the heat transfer pipe (2, 3) against the support sleeve (5).
5. A reinforced concrete pile (1, 1') according to any of the preceding claims, **characterized** in that the positioner sleeve (14) is made of a metal or metal alloy.
6. A reinforced concrete pile (1, 1') according to any of the preceding claims, **characterized** in that the positioner sleeve (14) is attached to an end plate (13a), which is present at the pile's (1, 1') splicing end and forms part of an end enclosure (13) surrounding the pile's (1, 1') splicing end.
7. A reinforced concrete pile (1, 1') according to any of the preceding claims, **characterized** in that the heat transfer pipe (2, 3) is dimensioned in such a way that between the ends of the interconnectible piles' (1, 1') heat transfer pipes (2, 3) can be disposed a sealing element (20).
8. A reinforced concrete pile (1, 1') according to any of the preceding claims, **characterized** in that the annular space (6) is provided with a sealing sleeve (11).
9. A reinforced concrete pile (1, 1') according to any of the preceding claims, **characterized** in that the pile (1, 1') is adapted to engage with another pile (1, 1') by means of at least one locking sleeve–dowel pair, whereby the pile's (1, 1') splicing end is provided with at least one dowel (16) or a locking sleeve (15), which is adapted to function with a locking sleeve (15) or a dowel (16) disposed at the opposite pile's (1, 1') splicing end for securing the piles (1, 1') to each other, and the dowel (16) and the locking sleeve (15) are dimensioned in such a way that, in the process of joining the piles (1, 1') to each other, the dowel (16) and the locking sleeve (15) come into mutual contact before the sealing sleeve (11), disposed in said annular

space (6), comes into contact with the opposite pile's (1, 1') respective annular space (6).

10. A pile assembly, comprising a reinforced concrete pile (1, 1') according to any of the preceding claims disposed as a lower pile (1) in such a way that the pile's (1) top end is a splicing end, and a reinforced concrete pile (1, 1') according to any of the preceding claims disposed as an upper pile (1') in such a way that the pile's (1') bottom end is a splicing end, and a sealing sleeve (11) disposed in the lower pile's (1) and the upper pile's (1') annular spaces (6) so as to seal a joint between the lower pile's (1) heat transfer pipe (2, 3) and the upper pile's (1') heat transfer pipe (2, 3).
11. A pile assembly according to claim 10, **characterized** in that the sealing sleeve (11) is made partially or entirely from one or more metals or metal alloys, preferably from copper or a copper-containing metal alloy.
12. A pile assembly according to claim 10 or 11, **characterized** in that between the ends of the lower pile's (1) and the upper pile's (1') heat transfer pipes (2, 3) is disposed a sealing element (20).
13. A method of joining to each other the heat transfer pipes (2, 3) of a reinforced concrete pile (1, 1') according to any of claims 1–9, **characterized** in that

 - one of the piles (1, 1') is disposed in the ground as a lower pile (1) in such a way that the pile's (1) top end is a splicing end (101),
 - in one of the piles' (1, 1') annular space (6) is disposed a sealing sleeve (11) made of a plastically deformable material in such a way that the sealing sleeve (11) extends outward from the discussed pile's (1, 1') end (102),
 - the piles (1, 1') are aligned in such a way that the sealing sleeve (11) is essentially concentric with a respective annular space (6) of the other pile (1, 1') (103),
 - the-yet-to-be installed pile (1') is lowered in such a way that the sealing sleeve (11) penetrates into the annular space (6) of the other of the piles (1, 1') (104), and
 - the upper pile (1') is struck in such a way that the piles' (1, 1') opposite ends come into mutual contact and the sealing sleeve (11) deforms

plastically in the annular spaces (6), producing a tight joint between the piles' (1, 1') heat transfer pipes (2, 3) (105).

14. A method of fabricating a reinforced concrete pile (1, 1') according to any of claims 1–9, the method comprising the steps of
- 5 - providing at least one heat transfer pipe (2, 3) (201),
- disposing at least one end of said heat transfer pipe (2, 3) inside a positioner sleeve (14) (202),
- casting concrete around said at least one heat transfer pipe (2, 3) in such a way that the positioner sleeve (14) is left at least partially embedded in the cast concrete (203).
- 10
15. A method according to claim 14, **characterized** in that the method further comprises a step of disposing, inside the end of a heat transfer pipe (2, 3), a support sleeve (5).