US 20100200192A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2010/0200192 A1

(43) Pub. Date: Aug. 12, 2010

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(54) BURIED VERTICAL THREADED EXCHANGER FOR HEATING OR COOLING APPARATUS

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(21) Appl. No.: 12/666,752

(22) PCT Filed: Jun. 26, 2008

(86) PCT No.: PCT/FR2008/051168

§ 371 (c)(1),
(2), (4) Date: Dec. 24, 2009

(30) Foreign Application Priority Data

Jun. 26, 2007 (FR) 0704561

Publication Classification

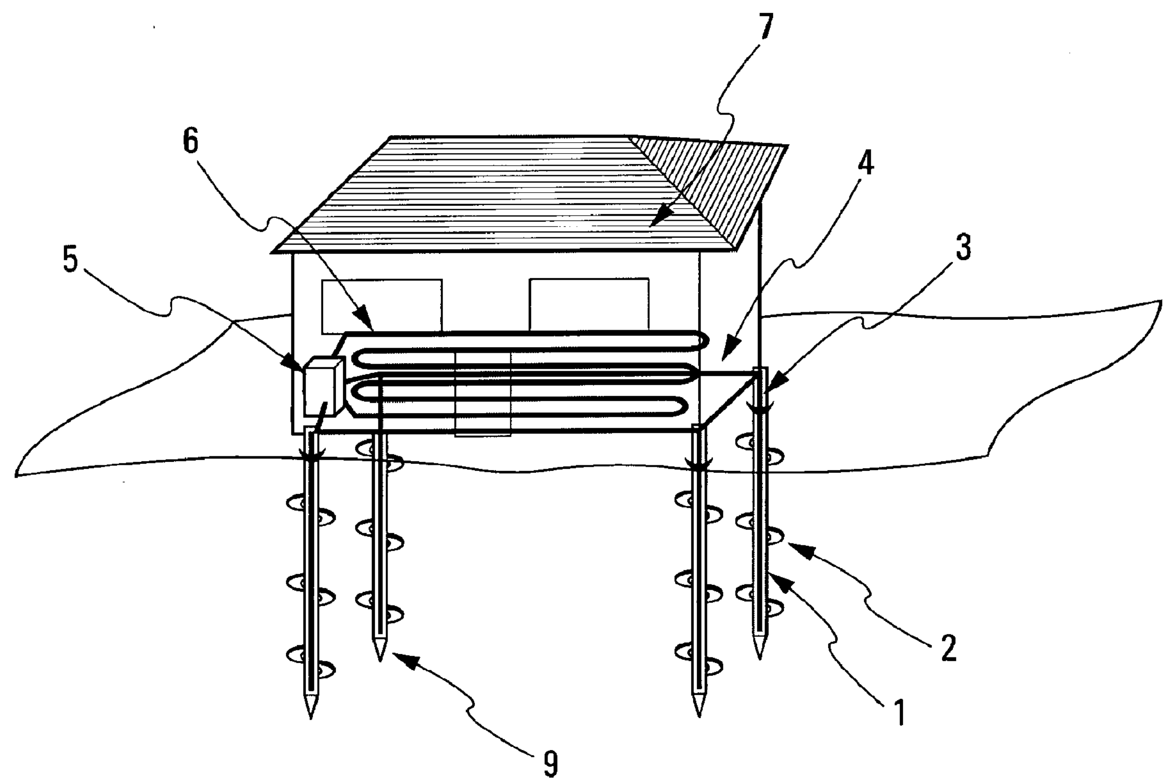
(51) Int. Cl.

F24J 3/08	(2006.01)
E02D 27/12	(2006.01)
E02D 27/46	(2006.01)

(52) U.S. Cl. **165/45**; 52/169.9; 52/169.11

(57) ABSTRACT

A hollow pile suitable for being sunk substantially vertically into the soil by screw-sinking, said hollow pile being characterized in that it has: at least one helical fin (**2**) having a flattened shape and a small pitch suitable for causing the pile to be sunk by a few centimeters per turn, when said pile is caused to move in rotation, the helical fin (**2**) finding itself united mechanically with and in thermal contact with the outside wall of the pile (**1**); and internal partitioning (**3**) defining an axial compartment (**11**) and an outer compartment (**12**) that communicate with each other at the bottom (**13**) of the pile; said hollow pile being characterized in that: the helical fin (**2**) is in direct thermal contact with the outer compartment (**12**) through the thickness of wall of the pile (**1**); and the outer compartment (**12**) has a flow section (S**2**) that is significantly smaller than the flow section (S**1**) of the axial compartment (**11**).



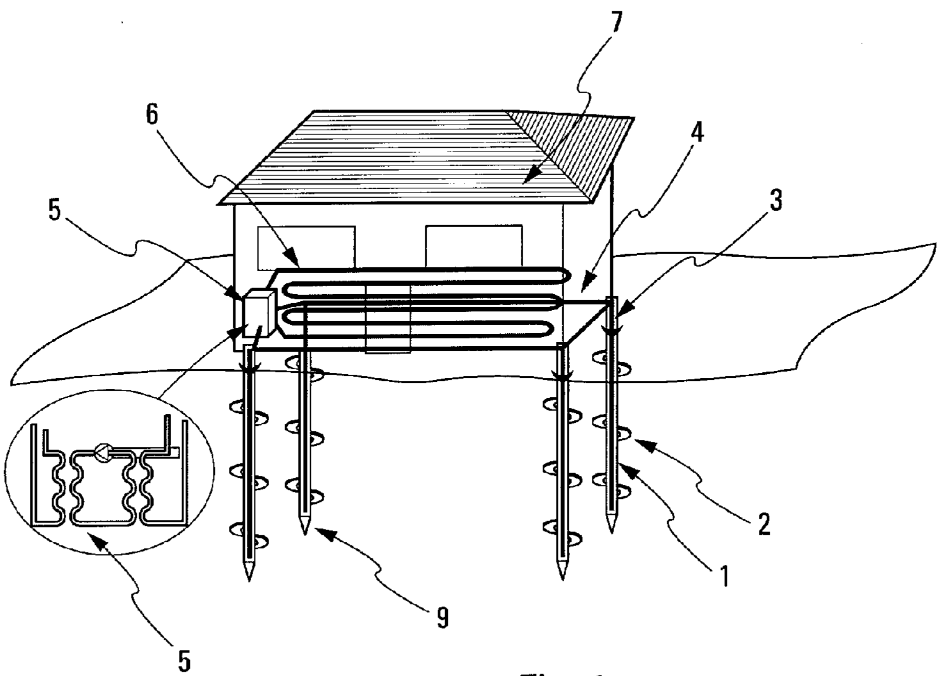


Fig. 2

Fig. 1

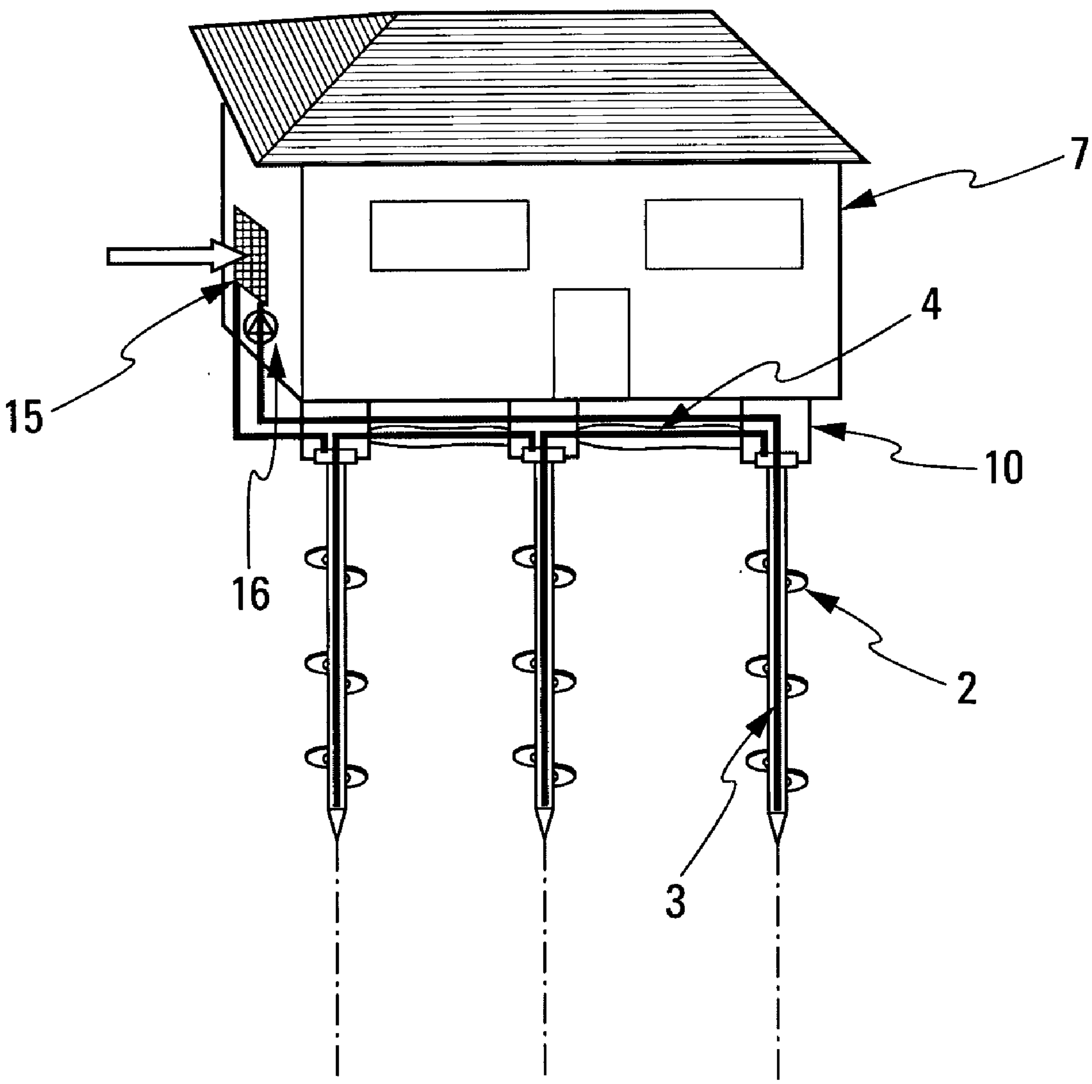


Fig. 3

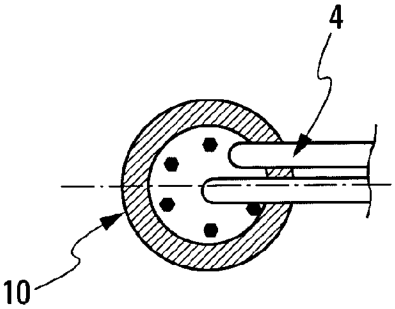


Fig. 5B

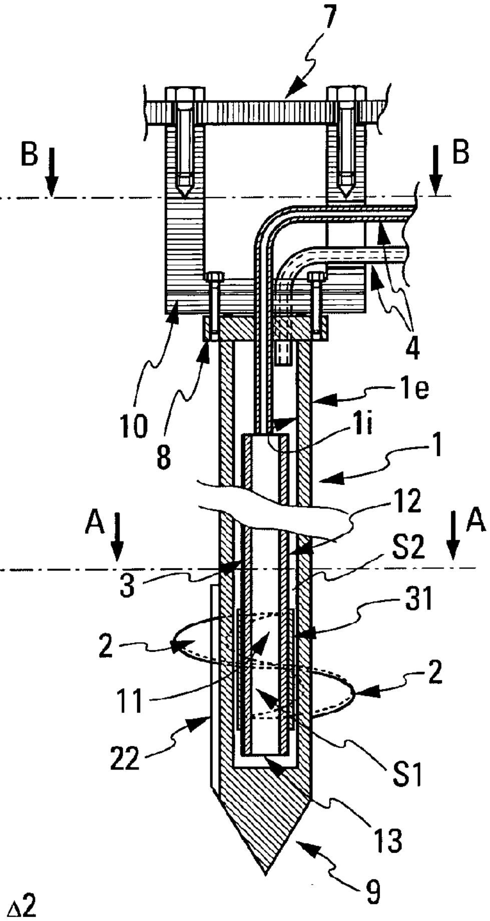


Fig. 4

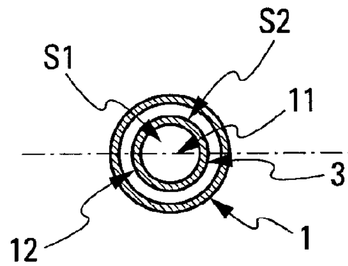


Fig. 5A

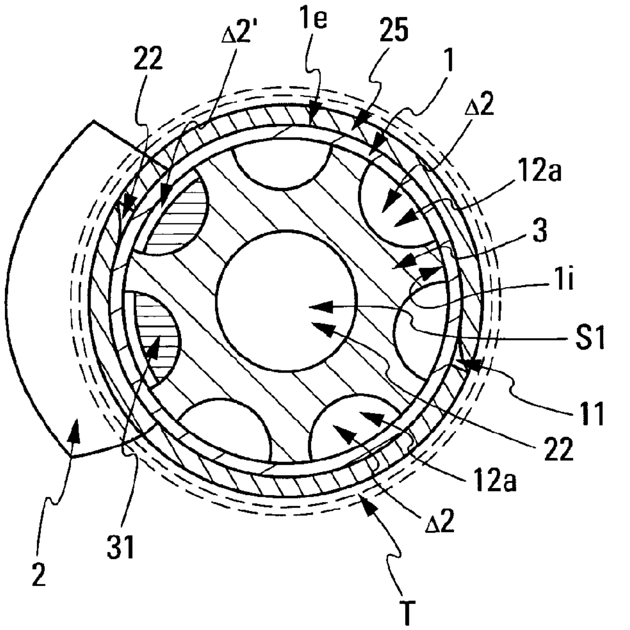


Fig. 6

BURIED VERTICAL THREADED EXCHANGER FOR HEATING OR COOLING APPARATUS

[0001] The field of the invention is shallow and medium-depth geothermal engineering. Consequently, the invention may also apply to laying foundations for buildings.

[0002] In the field of shallow and medium-depth geothermal engineering, air/soil or liquid/soil heat exchangers are known that are used in heating or air-conditioning installations and that are currently constituted either by sheets of tubes made of plastics materials or of metal and that are buried to depths of a few tens of centimeters, or else by vertical tubes, or indeed, in certain situations, by vertical pins.

[0003] Such heat exchangers pass a heat-transfer fluid. The heat-transfer fluid can be water, or water to which antifreeze and/or corrosion inhibitors has/have been added, or indeed a refrigerant of the category constituted by ammonia, by carbon dioxide, and by fluorine-containing compounds.

[0004] Devices known as "Canadian wells" or "Provencal wells" are also known, in which air is caused to pass through underground pipes placed at depths generally lying in the range 1 meter to 3 meters before the air, as moderated in temperature by passing through the soil, is fed into a building.

[0005] Implementing such prior art heat exchangers requires considerable earthworking means and is thus particularly costly. In addition, the performance of the heat exchangers depends directly on the surface areas of tubes in contact with the ground, that surface area being limited, by construction, to the surface area of the outside walls of the tubes, which walls are strictly cylindrical. Under all circumstances, such heat exchangers represent a pure extra cost, insofar as their sole function is to contribute to operation of the heating and/or air-treatment systems equipping any given building.

[0006] A main object of the invention is to improve the performance of fluid/soil heat-exchangers used in making heating or air-conditioning installations for buildings, regardless of whether said buildings are individual or collective residential buildings, service sector buildings, or industrial or agricultural buildings, or indeed lightweight buildings for residential leisure use.

[0007] A further object of the invention is to reduce the prices of fluid/soil heat exchangers while also increasing the life spans of such heat exchangers.

[0008] An additional object is to enable fluid/soil heat exchangers to be implemented rapidly without requiring the use of excessive earthworking means, and in particular to enable such heat exchangers to be installed in small plots of land or even directly under buildings that are already built, or indeed, in plots of ground areas that are fully occupied by buildings.

[0009] An additional object consists in facilitating building of lightweight constructions while also improving the thermal performance of such constructions.

[0010] In order to achieve these objects and others that appear on reading the description of embodiments and uses of the invention, the invention proposes to implement heat exchangers by means of screw-sunk metal piles, similar to those used for laying foundations for lightweight constructions. Such an embodiment, which is particularly inexpensive, makes it possible to increase the working heat-exchange area and thus the effectiveness of the heat exchangers. In a preferred embodiment, the screw-sunk metal piles have two functions in that they act both as building supports and also as heat exchangers for feeding the heating/air-conditioning systems of the buildings in question.

[0011] The invention is based on using hollow metal piles that have bottom ends of conical shape, and that are provided with mainly horizontal fins of helical shape, said fins having large surface areas and relatively small pitch (typically and in a manner lying within the prior art for laying foundations for lightweight constructions, pitch of a few centimeters per turn, so as to make it possible to put the piles into place by screw-sinking).

[0012] In the following description, it can be seen that the objects of reducing cost are achieved by using tried and tested installation and implementation methods that are designed for laying foundations and/or while combining the foundation function with the heat-exchanger function. It can be observed that the objects of improving efficiency are obtained by means of the action of helical fins that contribute to increasing the area of contact between each of the tubes and the soil, and therefore to increasing the quality and effectiveness of heat exchange, while also, when using the piles of the invention both as heat exchangers and as foundation elements, procuring a bed that is particularly resistant both to pushing-in forces and to pulling-out forces. It can also be observed that said helical fins offer not only the advantage of enabling the piles of the invention to be put into place rapidly and inexpensively since they can be put into place by means of a simple screw-sinking machine, but also the advantage of significantly increasing the area of contact between each of the tubes and the soil. In addition, it can be seen that the specific features recommended by the invention make it possible to increase the mass of materials involved in the heat exchange between the fluid and the soil, by putting materials into place, around the peripheries of the piles, which materials are adapted to facilitate such heat exchange, while also making it possible to strengthen the anchoring of the vertical piles in the soil.

[0013] In the invention, the mainly horizontal helical fins have three functions:

[0014] 1) they enable the piles to be sunk by screw-sinking whenever said piles are subjected to high rotary torque by means suitable machines or tooling;

[0015] 2) they constitute bearing surfaces suitable for improving the resistance of the piles to being pushed deeper and/or pulled out once said piles have been sunk into the soil; and

[0016] 3) they improve the area of heat exchange between the outside wall of the pile, with which wall they are in thermal contact, and the soil into which said pile has been sunk by means of the screw-sinking operations made possible by the presence of said fins.

[0017] Additionally, the piles of the invention are provided with mainly vertical fins that serve to push away the earth or the mineral matter making up the soil to a distance corresponding to the width of said mainly vertical fins relative to the outside walls of the piles. Once a pile has been put into place by screw-sinking, the resulting space generated as the piles are being sunk into the soil may be filled with a suitable material, e.g. lean cement, bentonite, or a substance that changes state. This suitable material offers the advantage of presenting conductivity that is greater than the conductivity of earth. Advantageously, it may also present high specific heat. In a variant offering particularly good performance, this material is constituted by a material chosen from paraffins, or from substances having the property of storing and of delivering large quantities of heat on going from their solid states to their liquid states, or from their liquid states to their solid states.

[0018] Putting the piles into place by using a suitable machine that enables a first segment of tube provided with a tapering and pointed or conical bottom end to be subjected to thrust and rotation forces has the effect firstly of causing said segment to penetrate into the soil, under the effect of the mainly horizontal fin with which said segment is provided, and secondly of pushing away the earth at the periphery of said tube under the effect of the mainly vertical fins that compact the earth that has been broken up by the mainly horizontal fin and that form an empty cylindrical sheath between the outside wall of the pile and the cylinder of compacted earth. Once this first segment, which preferably has a length of about 3 meters, has been sunk into the ground, it is possible either to use it as it is by equipping it with internal partitioning and with a flange plate at its top, or to extend it with one or more additional segments, each of which may also have one or more mainly horizontal fins making it easier for them to penetrate into the soil and one or more mainly vertical fins pushing away and compacting the earth at the periphery of the tube. The additional segments are assembled to the bottom segment by crimping, by inter-fitting, by welding, or by screw-fastening. In any event, said segments are assembled together such that the resulting pile has the same shape as a single tube provided with a pointed end and with a plurality of mainly horizontal fins and, optionally, but particularly advantageously for the performance of the installation, with one or more mainly vertical fins. The resulting pile is sunk until its top end comes flush with the ground level, or indeed a little more deeply, in which case the soil is dug out down to a depth of about 50 cm. The pile is then equipped with internal partitioning, defining an axial compartment and an outer compartment, and with a flange plate at its top, through which flange plate the pipes pass that make it possible to feed fluid to the inner and outer compartments. In the particularly advantageous situation when the tubes forming the piles are equipped with mainly vertical fins, there exists a space having the shape of a hollow cylinder between the outside wall of the tube and the compacted earth that has been pushed away at the periphery of the tube by the action of said mainly vertical fins. The space is mainly occupied by the mainly vertical fin(s) and it can be understood that, in this condition said mainly vertical fins cannot effectively enable heat to be transmitted between the soil and the fluid flowing through the internal compartments of the piles. That is why the invention recommends completely filling the empty space generated by the mainly vertical fins moving in rotation. This filling is performed with a material that, at the time it is put in place by being cast, has viscosity sufficient to fill the entire void lying between the outside wall of the tube and the surface of the compacted earth. For example, the filling may be performed with:

- **[0019]** a lean mortar or cement;
- **[0020]** a resin preferably filled with conductive particles (e.g. with iron filings or carbon fibers);
- **[0021]** a material of the bentonite type or of some equivalent type; or
- **[0022]** a material having the property of changing state at positive temperatures, preferably close to 20° C., so that the quantities of heat stored and delivered are as large as possible. In order to avoid any risk of the material running away into the earth, it is advantageously contained in reservoirs of elongate cylindrical shape or of shape adapted to filling the empty space generated by the mainly vertical fins moving in rotation.

[0023] The invention can be understood more clearly with reference to the accompanying figures, in which:

[0024] FIG. **1** is a view showing a dwelling standing on four piles of the invention, which piles have two functions since they act both as supports for the dwelling and as heat exchangers for the primary circuit of a reversible heat pump used for heating and for cooling said dwelling;

[0025] FIG. **2** is an enlarged view of an element of FIG. **1**;

[0026] FIG. **3** is a view showing a dwelling standing on three piles of the invention, said piles feeding a liquid/air heat exchanger for moderating the temperature of replacement air for the dwelling;

[0027] FIG. **4** is a section view and shows implementation details of a pile of the invention;

[0028] FIGS. **5**A and **5**B are section views on section lines AA and BB of FIG. **4**; and

[0029] FIG. **6** is an enlarged section view of a pile of the invention in a preferred embodiment.

[0030] The figures show that the invention recommends using at least one hollow pile **1** as a heat exchanger for exchanging heat between the soil and a fluid, which pile is preferably made of metal and is sunk substantially vertically into the soil by screw-sinking. The pile has an inside wall (**1***i*), and outside wall (**1***e*) and a wall thickness that is substantially constant. The pile **1** can be made up of a plurality of segments connected together end-to-end in leaktight manner.

[0031] The pile **1** has:

- **[0032]** at least one helical and substantially horizontal fin **2** having a flattened shape and a small pitch, and being suitable for causing the pile to sink by a few centimeters per turn, when said pile is caused to move in rotation, said helical fin **2** finding itself united mechanically with and in thermal contact with the outside wall **1***e* of the pile;
- **[0033]** internal partitioning **3** defining two distinct compartments **11**, **12** that communicate with each other at the bottom **13** of the pile **1**, namely an axial compartment **11**, and an outer compartment **12**, the outer compartment **12** advantageously having a flow section S**2** that is significantly smaller than the flow section S**1** of the axial compartment **11**;
- **[0034]** a bottom portion **9** that is of conical shape; and
- **[0035]** a top flange plate **8** having through openings for pipes **4** communicating in leaktight manner with each of the two compartments defined by the internal partitioning **3**.

[0036] In a preferred embodiment that procures particularly good performance, in addition to being provided with the fin(s) **2**, the pile **1** is provided with at least one mainly vertical fin **22**. This mainly vertical fin **22** advantageously has a length such that it does not extend beyond the outer end of the mainly horizontal fin **2**, above which said mainly vertical fin is placed. Said mainly vertical fin is connected to the outside wall of the pile **1**, preferably by welding. The fin **22** has a rounded or beveled end so that, while it is moving in rotation, it pushes away the earth that has previously been broken up under the action of the mainly horizontal fin **2**. After all of the segments forming the fluid/soil heat exchanger have been put into place by screw-sinking, the void generated by the mainly vertical fin moving in rotation **22** is advantageously filled with a material that offers good performance as regards heat conduction and storage, or, for certain uses, as regards strength. Said material is lean mortar or cement, bentonite, or a substance having the property of changing stage at a temperature close to 20° C. and, in any event, greater than 10° C.

[0037] The fact that each of the piles of the invention has at least one vertical fin **22** of a width less than the diameter of the mainly horizontal fin **2** thus makes it possible to form an empty space that is coaxial with the pile. This space that is formed by the vertical fin **22** moving in rotation being filled with a material **25** having thermal inertia and conductivity greater than those of the earth in which said pile is sunk. And the material **25** can be chosen from among substances that have the feature of going from the solid state to the liquid state at a temperature greater than 10° C., e.g. from among the family of normal paraffins or of isoparaffins.

[0038] Under these circumstances, it can be understood that the fluid that is colder in winter or hotter in summer relative to the soil exchanges heat firstly with the outside wall of the pile **1**, then with the horizontal fin(s) **2** and with the vertical fin(s) **22**, and, simultaneously, with the mass of filler material **25** that finds itself in thermal contact with the vertical fin(s) **22**. Finally, the filler material **25** exchanges heat with the compacted earth T that finds itself at its periphery, as shown in FIG. **6**, the heat finally diffusing to the rest of the soil that has not been affected by the operations of putting the piles into place by screw-sinking.

[0039] The piles of the invention are put into place in successive segments. The bottom segment has an end **9** of conical shape that is suitable for penetrating into the soil, and that makes it possible to close off the compartments in which the fluid flows. The segments are assembled together in leaktight manner by welding, by inter-fitting, or by screw-fastening, and each segment has one or more helical fins **2** in thermal contact with the outside wall **1** of said pile.

[0040] When the piles of the invention are used as foundations for a building, and more specially for a greenhouse or for a lightweight dwelling, each of them, at its top, is provided with a link piece **10** having fastening means suitable for being secured to the floor **17** or to the bottom structure of a building **7**, and with a side or top opening making it possible to pass feed and discharge pipes for the fluid. Thus, each of the vertical piles of the invention is provided with a top flange plate **8** that is secured to the floor **17** or to the bottom structure of a building **7** via a link piece provided with orifices for passing the pipes **4**.

[0041] The fluid that exchanges heat with the soil as it passes through the compartments of the heat exchanger constituted by one or more piles as described and connected together in series or in parallel via pipes **4** can be used to feed the primary circuit of a thermodynamic machine **5** of the heat pump type.

[0042] In order to enable heat exchange to take place between the fluid and the soil in which the piles of the invention are sunk, the outer compartment **12** is connected via pipes **4** to a liquid/air heat exchange unit **15**, said liquid/air heat exchange unit itself being connected via pipes **4** to the axial compartment **11**, which axial compartment **11** co-operates with the outer compartment **12**, with the pipes **4**, and with the liquid/air heat exchange unit **15** to form a leaktight and sealed circuit that also has at least one circulator **16**.

[0043] In order to enable the replacement air for a building to be pre-heated or to be cooled, the unit **15** passes the replacement air feeding the building, of which said pile forms part of the foundations.

[0044] In this way, the use of at least one pile of the invention makes it possible to implement heating or air-conditioning installations, or air treatment or air pre-treatment installations.

[0045] It is also possible, using at least one pile of the invention, to lay foundations for an industrial or agricultural building, an individual or collective residential building, or a leisure building, thereby enabling such buildings to benefit firstly from foundations that are inexpensive and that offer particularly good performance, and secondly from heating and/or cooling installations that have very low energy consumption.

[0046] In a simplified embodiment, each of the piles **1** is provided with a single fin **2** at its bottom, thereby enabling each pile to be implemented in a single segment. In a preferred embodiment, each of the piles **1** is provided with a plurality of fins **2**, each fin being situated at one end of a segment; the segments being assembled together by welding, by inter-fitting, by force-fitting, or by screw-fastening. Thus, the machine that exerts the screw-sinking torque and a vertical pressure on the successive pile segments can put each segment into place in succession, a leaktight mechanical connection being formed, e.g. by welding, at the outside walls of the piles. The operations of sinking the pile into the soil are facilitated by the presence of a conical piece **9** at the bottom of said pile. Advantageously, said conical piece **9** is fastened to the bottom end of a segment using the same means, e.g. screw-fastening, crimping, or welding, as those used for fastening one segment to the lower segment, so that the segments are identical to one another and each of them can then be connected equally well at its bottom to the conical end-piece or to another segment, and at its top either to a terminal flange plate or some other type of plate, or to another segment.

[0047] Under all circumstances, each of the piles **1** is equipped with means for causing a fluid to flow over all or almost all of its length. Such means can, for example, be internal partitioning **3** that opens out at its bottom **13** such that the fluid flows vertically along the length of the tube from top to bottom inside said internal partitioning **3**, at the bottom of which said fluid flows out and back up along the inside wall through an annular section lying between the outside wall of the axial tube and the inside wall of the pile **1**. Advantageously, the outside diameter of the internal partitioning **3** is close to the inside diameter of the tube constituting the pile **1**, in a manner such that the residual annular section S**2** lying between the two cylindrical surfaces defined by said walls is sufficiently small for the fluid to flow turbulently, even for relatively low flow rates. Also advantageously, and in accordance with an important characteristic of the invention, the internal partitioning **3** is provided with a section reducer that can be in the form of a projection or protuberance **31** that is placed at a height corresponding to the presence of a helical fin in thermal contact with the outside wall of the pile. This feature makes it possible to accelerate the fluid passing between the projection **31** and the outside wall of the tube forming the pile, so that the zone equipped with a helical fin constitutes a particularly effective heat exchange zone for heat exchange between the earth in which the pile is buried and the fluid flowing inside the pile. This original feature makes it possible to reduce the sinking depth and thus the cost of the fluid/soil heat exchangers relative to known geothermal probes for the same effectiveness. The combination firstly of the action of a metal fin having a large surface area in contact with the soil even at distances remote from the axis of the pile, and secondly of the turbulent flow of the fluid on either side of a metal wall makes it possible to obtain very high performance as regards heat exchange.

[0048] In FIG. **4**, the flow section reducer or projection **31** is in the form a sleeve engaged around the internal partitioning **3** at the fin **2**.

[0049] FIG. **6** shows a preferred embodiment of the invention, particularly as regards the internal partitioning **3**. Similarly to the partitioning in the embodiment shown in FIG. **4**, this partitioning forms an axial central compartment or passage **11** having a cross-section S**1**. The outer compartment is subdivided by the partitioning **3** into a plurality of passages or cells **12***a* running along the inside wall **1***i* of the pile **1**. There are seven of these passages **12***a* in the embodiment shown in FIG. **6**. They are disposed in such a manner as to be distributed around the central axial compartment **11**. Each passage **12***a* has a substantially half-moon shape. It can be noted that the partitioning **3** has a wall thickness that is considerable given that it extends from the axial compartment **11** to the inside wall of the pile **1** between the passages **12***a*. The partitioning **3** thus occupies more than one half of the section of the pile **1**. It can be thought of as a solid bar whose axial core has been hollowed out to form the axial compartment **11**, and whose outside surface has been cut into to form the outer passages **12***a*. Since the internal partitioning **3** comes into contact with the inside wall of the pile **1**, it is centered automatically inside the pile **1**.

[0050] Each passage **12***a* has a cross section s**2**. The sum of the sections s**2** of all of the passages **12***a* corresponds to the total section S**2**. In the invention, the total section S**2** is less than the section S**1** of the axial compartment **11**. In addition, as shown in FIG. **6**, the two passages **12***a* situated at the helical fin **2** are partially filled with a filler element that forms a projection or protuberance **31** relative to the outside wall of the partitioning **3**. The projections **31** serve to reduce the sections of the passages **12***a* so that there remains only a reduced section s**2'** in each of them. The fluid is thus forced to flow at high speed along the inside wall of the pile **1** directly at the helical fin **2**. Said projections or protuberances **31** can be considered as flow section reducers.

[0051] In practice, the partitioning **3** can be made by extrusion so that it has a constant cross-section over its entire length. The partitioning **3** can be made of metal or of a plastics material. Preferably, the partitioning **3** is made of a plastics material so as to avoid heat exchange between the central compartment **11** and the outer compartment formed by seven passages **12***a*. The flow section reducers or projections **31** can be in the form of inserts mounted inside the passages **12***a*. In a variant, the flow section reducers or projections **31** can be formed directly by the partitioning or by the pile, e.g. in the form of internal extensions of the fins.

[0052] The fluid thus exchanges heat with the soil in which the piles **1** are sunk. This exchange is made more effective and faster by means of the action of the fins **2** that have a large surface area in contact with the soil and are in thermal contact with the metal tube constituting the pile. The fluid flowing in the piles **1** is then collected in pipes **4** that convey it to at least one system **5** for heating or cooling premises **7**, said premises **7** preferably, but not necessarily, being built on foundations formed by one or more piles of the invention.

[0053] In a particularly advantageous embodiment shown in FIGS. **1** and **2**, the heating or cooling system **5** is constituted by a water/water heat pump that is preferably reversible and whose primary circuit exchanges heat with one or more piles connected to the system **5** via a circuit **4**, and whose secondary circuit exchanges heat with a circuit **6**, e.g. a low-temperature under-floor heating circuit.

[0054] In a simplified embodiment shown in FIG. **3**, the circuit **4** collecting the fluid flowing through the pile(s) of the invention is connected to an air heat exchanger unit **15**, i.e. to an air/fluid heat exchanger, the replacement air for the premises going through said exchanger. Such a heating and cooling system, which is described, in particular, in Patent Application WO 2006/109003, makes it possible to procure all of the features of systems known as “Canadian wells” (or as “Provencal wells” or indeed as “Californian wells”) while requiring earthworks that are inexpensive, and a small footprint, and while facilitating maintenance operations.

[0055] In the simple example shown by FIG. **3**, three piles **1** of the invention are used. Each of these piles has fins **2** and a conical bottom end **9** enabling it to be sunk by screw-sinking and facilitating heat exchange with the soil. The piles are provided with internal partitioning **3** inside which the fluid flows, the fluid in this example being water, optionally with anti-freeze added. This fluid is collected by a circuit **4** that is preferably buried at a depth of a few tens of centimeters below ground level. The fluid flows continuously by means of the action of a pump or circulator **16** so that, depending the current climate conditions, it exchanges heat with the new air fed into the premises under the action of a fan (not shown) that causes said new air to flow through an air heat exchanger unit **15** in which the fluid that benefits from the heat exchange with the soil flows, which heat exchange takes place due to said fluid flowing in the piles and is made particularly effective by means of the presence of the helical fins **2**. In order to improve heat-exchange capacities, and in order to make it possible to optimize operation in day/night cycles, all or some of the partitioning or of the zone at the periphery of the tube that is vacated by the compacting of the earth due to the mainly vertical fin **22** moving in rotation can be filled with a substance having the property of changing state at a temperature close to the looked-for comfort temperature, e.g. 20° C. and in all cases greater than 10° C. For example, this substance is chosen from among paraffins that offer the property of storing and delivering about 50 kilocalories per gram, when crossing their change-of-state thresholds. This particularly advantageous embodiment makes it possible to improve significantly the performance of liquid/soil heat exchangers of the invention, without significantly increasing their cost. In particular, this embodiment makes it possible, during summer seasons, to extract large quantities of heat during the day due the change of state from solid to liquid. This is made possible by previously freezing the paraffins during the night when the outdoor temperature is at a temperature lower than the melting point of the paraffins, such freezing resulting from the paraffins that are contained in the walls forming the partitioning **3** and/or filling the hollow cylinder going from the liquid state to the solid state.

[0056] At the top of each of the piles of the invention, a flange plate **8** is provided that serves as a cap and to which the internal portioning can be fastened, thereby defining an axial compartment and an outer compartment. The diameter of the tube forming the internal partitioning is chosen so that there remains only a flow space of small section between the partitioning and the outside wall of the pile, so that the fluid flows turbulently in this portion of the pile. Preferably, the partitioning wall has extra thickness or a protuberance at the external fin(s), such that heat exchange between the fluid and the wall of the pile is facilitated in this zone that has the advantage of high potential for thermal transmission to the surrounding environment constituted by the soil.

[0057] In general, it is possible to use any type of coupling with various systems for heating, air-conditioning, pre-heating or cooling residential premises or replacement air for residential premises, and in particular the couplings with air-to-air, air-to-water, water-to-water, water-to-air, refrigerant-to-water or refrigerant-to-air heat pumps, without thereby going beyond the ambit of the invention.

[0058] The invention is preferably used for building lightweight leisure dwellings that require shallow or medium-depth foundations and that need to be frost-protected by heat exchange with the soil, even while they are vacant. In this particular situation, the fluid can be caused to flow between the soil and at least one air heat exchanger unit by a pump powered by photovoltaic solar collectors. The invention is also particularly suitable for use in building agricultural or industrial structures such as greenhouses or sheds or warehouses, it being understood that these preferred uses are in no way limiting.

[0059] Insofar as the piles of the invention are used for both of their functions, i.e. both as heat exchangers and also as lightweight foundations, a link piece **10** is provided between firstly the top of each of the piles **1**, which top is equipped with a flange plate **8**, and secondly the floor **17** or a bearing piece of the bottom structure of the building **7**.

1. A hollow pile suitable for being sunk substantially vertically into the soil by screw-sinking, the pile comprising an inside wall, an outside wall and a thickness of wall, said pile further comprising:

at least one helical fin having a flattened shape and a small pitch suitable for causing the pile to be sunk by a few centimeters per turn, when said pile is caused to move in rotation, the helical fin finding itself united mechanically with and in thermal contact with the outside wall of the pile; and

internal partitioning defining an axial compartment and an outer compartment that communicate with each other at the bottom of the pile;

said hollow pile being characterized in that:

the helical fin is in direct thermal contact with the outer compartment through the thickness of outside wall of the pile; and

the outer compartment has a flow section that is significantly smaller than the flow section of the axial compartment.

2. A vertical pile according to claim **1**, wherein the outer compartment is provided with a flow section reducer at at least one helical fin.

3. A vertical pile according to claim **2**, wherein the flow section reducer is integral with the internal partitioning.

4. A vertical pile according to claim **1**, made up of a plurality of segments assembled together in leaktight manner by welding, by inter-fitting, or by screw-fastening, and wherein each segment is provided at its bottom with a helical fin in thermal contact with the outside wall of the pile.

5. A vertical pile according to claim **1**, further comprising a top flange plate having through orifices for passing pipes that communicate in leaktight manner with respective ones of the two compartments defined by the internal partitioning, the top flange plate being secured to a floor or to a bottom structure of a building via a link piece provided with through orifices for passing the pipes.

6. A vertical pile according to claim **1**, wherein the fluid circulating in the compartments inside the pile is used to feed the primary circuit of a thermodynamic machine of the heat pump type.

7. A vertical pile according to claim **1**, wherein the internal partition is partially filled with a substance having the property of changing state at a temperature close to 20° C., and preferably with a substance based on paraffin.

8. A vertical pile according to claim **1**, wherein the fluid extracted from the outer compartment is conveyed via pipes to a liquid/air heat exchange unit, said unit itself being connected via pipes to the axial compartment, the assembly that is made up of the outer compartment, of the pipes, of the unit, and of the axial compartment forming a leaktight and sealed circuit further comprising at least one circulator.

9. A vertical pile according to claim **8**, wherein the unit passes the replacement air feeding the building of which said pile constitutes part of the foundations.

10. An installation for heating, conditioning, treating or pre-treating air, said installation including at least one vertical pile according to claim **1**.

11. Foundations for an industrial, agricultural, individual or collective residential, or leisure building, said foundations including at least one vertical pile according to claim **1**.

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