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

(11) **EP 1 964 981 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
03.09.2008 Bulletin 2008/36

(51) Int Cl.:
E02D 17/13 *(2006.01)*

(21) Application number: **08447013.7**

(22) Date of filing: **28.02.2008**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO SE SI SK TR
Designated Extension States:
AL BA MK RS

(30) Priority: **28.02.2007 EP 07004124**

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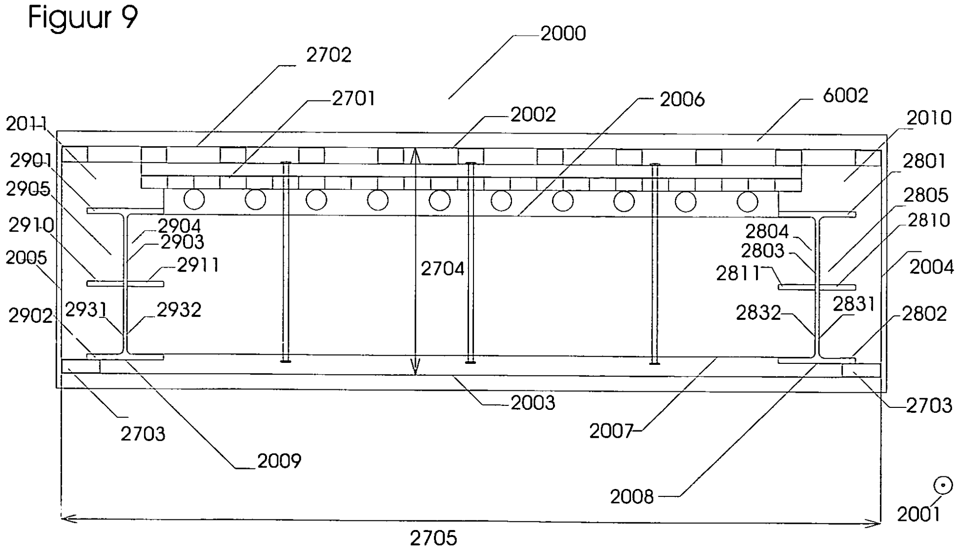
(54) **Reinforcement elements for in-situ cast walls and method to excavate in situ cast walls**

(57) An elongate reinforcement element for reinforcing an in-situ cast wall module has a substantially rectangular cross-section according to a plane perpendicular to an elongate direction. The cross-section has a first and second long side and a first and a second short side. The elongate reinforcement element comprises a first and a second reinforcement beam fixed to each other by means of a coupling means, the first reinforcement beam being provided at the first short side of the rectangular cross section, the second reinforcement beam being provided at the second short side of the rectangular cross section. Each of the first and second reinforcement beams has two outer flanges coupled by means of a web, the first and second reinforcement beams having their webs substantially parallel with the short side of the rectangular cross-section and the elongate direction. The flanges and the web of the first reinforcement beam create a channel-shaped profile at both sides of the web. Similarly, the flanges and the web of the second reinforcement beam create a channel-shaped profile at least at the side of the web oriented inwards the elongate reinforcement element. The channel-shaped profile oriented outwards the elongate reinforcement element of the first reinforcement beam is filled with sacrificial material. The first reinforcement beam further comprises a ridge being liquid-tightly coupled to the web along the web in elongate direction, the ridge being located at the side of the web of the first reinforcement beam, which side is oriented outwards the elongate reinforcement element.

Figuur 9



EP 1 964 981 A1

Description

Technical field of the invention

[0001] The present invention relates to an excavation means for excavating trenches in a ground surface and to methods for excavating trenches using such excavation means. The invention also relates to in situ cast sunken wall modules and modular walls comprising wall modules, the wall modules being provided by using such excavated trenches, and to methods for in situ casting such wall modules, as well as reinforcement to elements used in the methods to in situ cast wall modules and modular walls.

Background of the invention

[0002] It is known to excavate trenches, such as deep trenches, which trenches are provided with reinforcement elements and cast with casting material, such as concrete.

[0003] As an example, US4075852 discloses a method to cast steel reinforced underground walls. A number of mutually spaced trenches, hereafter called primary trenches, each having a substantially rectangular horizontal cross-section, are excavated by a clamshell excavator. A fluid substance such as bentonite, drillers mud or another thixotropic fluid is used to stabilise the walls of the trench during excavation. Once the trenches are excavated, a reaming tool is inserted in the trench to provide to the trench a precisely defined inner volume. In this volume, a reinforcing element is sunk, which has two H-or I-beams in vertical position at its two outer sides. The channel shaped profile of the beams oriented outwards the reinforcement element is filled with sacrificial material such as polystyrene foam. After casting the wall with concrete, a clamshell excavator is used to remove the soil between two cast wall modules in two consecutive excavation steps. The channel shaped profile of a beam of the first cast wall is used as a guide for the clamshell during a subsequent excavation step, during which a subsequent trench is excavated bridging about half the distance between two cast wall modules. In a consecutive step, the remaining distance is excavated by means of this clamshell excavator, this time using the channel shaped profile of a beam of the adjacent cast wall as a guiding means for the clamshell of the clamshell excavator.

[0004] This method, and as a consequence also modular walls cast using the method, has some disadvantages.

[0005] The primary trenches, each having a substantially rectangular horizontal cross-section, are excavated without any particular guiding of the clamshell excavator. Obstructions, like rocks and hard objects, positioned in the pathway of the clamshell excavator means, may deflect the clamshell excavator from its intended excavation direction. Hence the wall of the excavated trench may not be perfectly aligned, which requires the use of a reaming tool. However the reaming tool is not always fit to compensate for any obstruction which was encountered by the clamshell excavator. The excavating of the remaining soil between two primary trenches is done using a clamshell excavator which is guided at one side, still allowing deflection of the clamshell from its intended excavation direction. Further, the use of a reaming tool is time-consuming and creation of appropriate reaming tools causes additional costs to be incurred.

[0006] Immediately beyond ground level, the trench walls may be damaged due to sideways movement of the excavation means during entering in the trench part already excavated. Also when excavation is performed through unstable ground layers located beyond ground level, the walls of the excavation might collapse due to insufficient pressure in the trench when excavation is performed.

[0007] When using the disclosed reinforcement elements, the joint between the wall module cast in a primary trench and the wall module cast in the intermediate trench, may not be a liquid-tight seal.

Summary of the invention

[0008] It is an object of the present invention to provide reinforcement elements for in-situ cast walls, cast in excavated trenches, such as deep trenches, which allows precise dimensioning of the trenches being dug. It is an object of the present invention to provide an excavation means for excavating trenches, such as deep trenches, which allows precise dimensioning of the trenches being dug.

[0009] The above objective is accomplished by a method and device according to the present invention.

[0010] According to a first aspect of the present invention, an elongate reinforcement element for reinforcing an in-situ cast wall module is provided. The reinforcement element has a substantially rectangular cross-section according to a plane perpendicular to an elongate direction, the cross-section having a first and second long side and a first and a second short side. The elongate reinforcement element comprises a first and a second reinforcement beam fixed to each other by means of a coupling means, the first reinforcement beam being provided at the first short side of the rectangular cross section, the second reinforcement beam being provided at the second short side of the rectangular cross section. Each of the first and second reinforcement beams has two outer flanges coupled by means of a web, the first and second reinforcement beams having their webs substantially parallel with the short side of the rectangular cross-section and the elongate direction. The flanges and the web of the first reinforcement beam create a channel-shaped profile at both sides of the web. Similarly, the flanges and the web of the second reinforcement beam create a channel-shaped profile at least at the side of the web oriented inwards the elongate reinforcement element. The channel-shaped profile oriented outwards the elongate reinforcement element of the first reinforcement beam is filled with sacrificial material. The first reinforcement beam further comprises a ridge being liquid-tightly coupled to the web along the web in elongate direction, the ridge being located at the side of the web of the first reinforcement beam, which side is oriented outwards the elongate reinforcement element.

[0011] According to embodiments of the present invention, the flanges and the web of the second reinforcement beam may create a channel-shaped profile at both sides of the web, the channel-shaped profile oriented outwards the elongate reinforcement element of the second reinforcement beams being filled with sacrificial material. According to embodiments of the present invention, a third reinforcement beam may be provided having two outer flanges coupled by means of a web, the third reinforcement beam having its web substantially parallel with the long side of the rectangular cross-section and the elongate direction. One of the flanges of the third reinforcement beam may be coupled to and aligned with the second reinforcement beam. The flanges and the web of the third reinforcement beam create a channel-shaped profile at least one side of the web of the third reinforcement beam, the channel-shaped profile of the at least one side of the web of the third reinforcement beam being filled with sacrificial material.

[0012] According to embodiments of the present invention, the elongate reinforcement element may be provided with formwork providing the first surface of the reinforcement element, which first surface corresponds to the plane defined by the first long side of the cross-section and the elongate direction.

[0013] According to embodiments of the present invention, the formwork has a density or specific weight, which makes the formwork suitable to sink in a thixotropic fluid, which is used during excavation of the trenches in which the formwork, as part of the reinforcement element, is to be sunken. The formwork may have a specific weight of more than 1280 kg/m^3, such as for example more than more than 3500 kg/m^3.

[0014] The formwork may comprise a substantially flat plate, e.g. a steel plate, for providing the surface of the cast wall, which will be visible once the formwork is removed. The formwork may be provided as a box having two parallel outer faces provided by substantially flat plates, e.g. steel plates. The two faces are coupled to each other by means of intermediate beams, e.g. I- or H- profiled beams, e.g. I- or H- profiled steel beams. In the later case, and using steel plates to provide the faces, the steel beams may be welded to the steel plates. The beams may be provided in one or more directions parallel to the faces, e.g. in two mutually perpendicular directions, of which one may be parallel to the elongate direction of the reinforcement beams of the reinforcement element. The provision of such formwork may avoid bending of the formwork, in a direction perpendicular to the plane of the cast wall, when concrete is cast in the trench, in which the reinforcement element was sunken. The box may be filled with a ballast material, optionally with concrete, such as steel fiber reinforced concrete, e.g. reinforced using Dramix®-fibers. The formwork may be removably connected to the first and second reinforcement beam, e.g. suitable to be pulled from the cast wall after hardening of the concrete of the cast wall, e.g. by pulling the formwork upwards out of the trench after hardening of the concrete of the cast wall. A permanent mechanical fixation between the formwork and the reinforcement beams can be avoided.

[0015] According to embodiments of the present invention, the first reinforcement beam and the second reinforcement beam may have a first flange oriented towards the first long side. The sacrificial material is provided between the first flange of the first reinforcement beam and the formwork and sacrificial material is provided between the first flange of the second reinforcement beam and the formwork.

[0016] According to embodiments of the present invention, the first reinforcement beam and the second reinforcement beam may have a second flange oriented towards the second long side. The reinforcement element is provided with a spacer at the second flange of the first reinforcement beam and at the second side of the second reinforcement beam for accommodating the thickness of the reinforcement element with the dimensions of a trench in which the reinforcement element is to be used.

[0017] According to embodiments of the present invention, the second reinforcement beam further may comprise a ridge along the web in elongate direction, the ridge being liquid-tightly coupled to the web of the second reinforcement beam. The ridge is located at the side of the web of the second reinforcement beam, which side is oriented outwards the elongate reinforcement element.

[0018] According to embodiments of the present invention, the second reinforcement beam further may comprise a liquid blocking means provided along the ridge, at both sides of the coupling line between ridge and web.

[0019] According to embodiments of the present invention, one or more of the first or second reinforcement beams may comprise a further ridge along the web in elongate direction, liquid-tightly coupled to the web of the respective reinforcement beam, the further ridge being located at the side of the web of the respective reinforcement beam, which side is oriented inwards the elongate reinforcement element.

[0020] According to embodiments of the present invention, the first reinforcement beam further may comprise a liquid blocking means provided along the ridge, at both sides of the coupling line between ridge and web.

[0021] Further according to this first aspect of the present invention, an elongate insert reinforcement element is provided for being inserted between a first and a second elongate reinforcement element as set out above. The elongate insert reinforcement element comprises a formwork providing the first surface of the elongate insert reinforcement element. The formwork may be similar as or identical to the formwork of the first and second elongate reinforcement element as set out above.

[0022] The elongate insert reinforcement element further may comprise a reinforcement means comprising profiled reinforcing components having one side substantially parallel to the first surface, and, between the reinforcing components and the formwork, a slit adapted for contacting the flanges of the first and the second elongate reinforcement elements.

[0023] The slit is to match with the flanges, i.e. the flange is provided in the volume defined by the slit. When the insert reinforcement element is inserted between two elongate reinforcement elements having flanges at the outer sides, the contact between slit and flanges is to guide the elongate insert reinforcement element during insertion in the trench between the two elongate reinforcement elements, possibly, even preferably, being part of a cast wall module.

[0024] According to embodiments of the present invention, the elongate insert reinforcement element further may comprise formwork. The formwork may have a density or specific weight, making the formwork suitable to sink in a thixotropic fluid used during excavation of the trenches in which the formwork, as part o the reinforcement element, is to be sunken. The formwork may have a specific weight of more than 1280 kg/m^3, such as for example more than more than 3500 kg/m^3. A formwork similar or identical, and having the same or similar features as the formwork of the elongate reinforcement element as set out above, may be used.

[0025] According to the first aspect of the present invention, elongate reinforcement elements are provided which allow providing guidance for excavating tools once the wall of which the elongate reinforcement element is a part, is cast. The elongate reinforcement element provides the possibility to couple adjacent wall modules in a liquid-tight way. The ridge along the length of the first reinforcement beam, and oriented outwards from the wall module, which ridge is liquid-tightly coupled to the web of the first reinforcement beam, may become recessed in the cast material used to cast the adjacent wall module. As in the adjacent wall module, a possible reinforcement element will not be fixed to this first reinforcement beam prior to casting the adjacent wall module, the coupling of the first reinforcement beam and adjacent wall module will be made merely by the cast material of the adjacent wall module. Due to small displacements or vibrations or alike, once the cast material of the modular wall is cured, the cast material may loosen, be it very locally, from the web of the first reinforcement beam. The small rupture or crack thus generated may be sufficient to guide water or other fluids from one side of the wall module towards the other side. Because of the ridge present in liquid-tight coupling to the web of the beam, the cracks will only extend up to the ridge and not from one surface of the wall to the other. Thereby the water is prevented to ooze through the wall.

[0026] Once two such reinforcement elements are provided in two adjacent excavated trenches, and a wall is cast in these trenches by providing cast material in the trench and having the cast material cured, an intermediate trench can be excavated between the two cast walls. The intermediate trench excavated may have, at both sides, the elongate reinforcement elements provided, which were used as guidance for excavating tools excavating the intermediate trench. Once the wall of which the elongate reinforcement element is a part, is cast, the elongate reinforcement elements provided will cooperate with the elongate insert reinforcement element, as the latter has a slit which is provided by the formwork and the reinforcement components, which slit is adapted for matching with the flanges of the first and second elongate reinforcement element.

[0027] According to a second aspect of the present invention, an excavating device for excavating trenches in a ground surface in an excavation direction,
wherein the excavating device comprises

- a clamshell excavating means for excavating ground, the clamshell excavating means having an opened position for receiving ground to be excavated, the projection on a plane perpendicular to the excavation direction of the bite of the clamshell excavating means in opened position having a bite circumference,
- a guiding means being coupled to the clamshell excavating means in a locked position, the guiding means having a guiding surface extending in excavation direction over a guiding length Dg of more than 2 m, the guiding surface being adapted for contacting an inner wall of a hollow casing, the projection of the inner wall substantially coinciding with the bite circumference, the contact preventing the guiding means and the clamshell excavating means from deflecting from the excavation direction when moved in excavation direction.

[0028] The excavating device for excavating trenches in a ground surface in an excavation direction may comprise

- a clamshell excavating means for excavating ground, the clamshell excavating means having an opened position for receiving ground to be excavated, the projection on a plane perpendicular to the excavation direction of the bite of the clamshell excavating means having a bite circumference,
- a guiding means being coupled to the clamshell excavating means in a locked position, the guiding means having an outer guiding surface having a guiding length Dg being more than 2 m, the projection of the outer guiding surface in excavation direction substantially coinciding to the bite circumference,

the guiding surface being adapted for engaging an inner wall of a hollow casing of which the projection substantially coincides, more particular corresponds, to the bite circumference, the contact being adapted to prevent the guiding means and the clamshell excavating means from deflecting from the excavation direction when moved in excavation direction.

[0029] According to embodiments of the present invention, an excavating device for excavating trenches in a ground surface in an excavation direction, the excavating device may comprise

- a clamshell excavating means for excavating ground, the clamshell excavating means having an opened position for receiving ground to be excavated, the projection on a plane perpendicular to the excavation direction of the bite of the clamshell excavating means in opened position having a bite circumference;
- a guiding means being coupled to the clamshell excavating means in a locked position, the guiding means having a guiding surface extending in excavation direction, the guiding surface having a guiding length Dg in excavation direction;
- a hollow casing having an inner wall having a length Dc smaller than the guiding length Dg, the hollow casing being adapted to be pressed into the ground surface to a depth of less than or equal to Dc, the projection of the inner wall in excavation direction substantially coinciding to the bite circumference

wherein the guiding surface is adapted for contacting the inner wall of the hollow casing for preventing the guiding means and the clamshell excavating means from deflecting from the excavation direction during excavation.

[0030] The excavating device for excavating trenches in a ground surface in an excavation direction, the excavating device may comprise

- a clamshell excavating means for excavating ground, the clamshell excavating means having an opened position for receiving ground to be excavated, the projection on a plane perpendicular to the excavation direction of the bite of the clamshell excavating means having a bite circumference;
- a guiding means being coupled to the clamshell excavating means in a locked position, the guiding means having an outer guiding surface, the outer guiding surface having a guiding length Dg;
- a hollow casing having an inner wall having a length Dc smaller than the guiding length Dg, the hollow casing being adapted to be pressed into the ground surface to a depth of less than or equal to Dc, the projection of the inner wall in excavation direction substantially corresponding to the bite circumference; the hollow casing being adapted to allow passing the clamshell excavating means and the guiding means when the clamshell excavating means and the guiding means are moved in excavation direction;

wherein the guiding means has an outer guiding surface along its guiding length Dg for engaging the inner wall of the hollow casing for preventing the guiding means and the clamshell excavating means from deflecting from the excavation direction.

[0031] According to some embodiments, the distance between the outermost point of the clamshell excavating means in excavation direction in opened position and the outermost point of the guiding means may be less than the inner wall length Dc. According to embodiments of the present invention, the length Dc may be in the range of 0.5 m to 10 m, e.g. in the range of 4 m to 6 m, as an example 5 m.

[0032] When excavating in stable underground, a length Dc in the range of 0.5 m to 3 m may be suitable. The hollow casing may be pressed in the ground to a depth of less than or at most equal to the length Dc.

[0033] During excavation, the hollow casing is optionally kept filled with a thixotropic fluid. At the lower edge, a hydraulic pressure will be applied by the thixotropic fluid to the wall of the excavated trench. The magnitude of the hydraulic fluid at a given point of the excavated wall under the lower edge is dependent on the height of the column of fluid above the given point and the specific weight of the fluid.

[0034] When the underground is relatively unstable, and providing trench walls having the tendency to collapse, it might be advantageous to use a longer hollow casing, optionally maintaining the hollow casing partially above ground level, but kept filled with thixotropic fluid to a height above ground level. As such, at the lower edge of the casing, a hydraulic pressure provided by a height of thixotropic fluid, being larger than the depth of the casing over which the casing is inserted into the ground, is applied. Such high hydraulic pressures may prevent unstable ground layers present under ground level, to collapse.

[0035] In both cases, the hollow casing may be provided at its outer side with a flange for contacting a support beam, the flange being provided as suitable height from the lower edge of the hollow casing. Positioning the hollow casing such that the hollow casing is supported by the supporting beam when pressed in the ground surface may assist in maintaining the position of the hollow casing.

[0036] The hollow casing is adapted to allow passing the clamshell excavating means and the guiding means through the inner wall when the clamshell excavating means and the guiding means are moved in excavation direction the contact between inner wall and guiding surface is present along the whole length Dc of the inner wall of the casing.

[0037] According to embodiments of the present invention, the bite circumference may be rectangular-shaped, the bite circumference having four sides. The bite circumference may have a long side and a short side, the long side being in the range between 1 m and 5 m, the short side may have a length in the range of 200 mm to 1000 mm.

[0038] According to embodiments, for each of the four sides of the bite circumference, the projection of the guiding surface in excavation direction may have at least one point coinciding with the side. For each of the four sides, at each position along the guiding length Dg, the projection of the guiding surface at this position may have at least one point coinciding with the side.

[0039] According to embodiments of the present invention, the projection of the outer guiding surface in excavation direction may substantially correspond to the bite circumference.

[0040] According to embodiments of the present invention, the guiding means may have an outer guiding surface along its guiding length Dg for slidingly engaging the inner wall of the hollow casing.

[0041] According to embodiments of the present invention, the guiding length Dg of the guiding means may be in the range between 2 m and 100 m.

[0042] According to embodiments of the present invention, the dimensions of the guiding means may be adjustable.

[0043] According to embodiments of the present invention, the excavating device further may comprise a displacement means for displacing the clamshell excavating means and guiding means in excavation direction. The displacement means may be adapted to apply a force to the clamshell excavating means in excavation direction. The displacement means may be a hydraulic displacement means or a crane.

[0044] The excavation means according to the second aspect of the present invention has the advantage that precisely dimensioned excavations can be dug. There is no need to use reaming tools, being different from the clamshell excavator, in order to finish the excavation. The excavation has a volume which can be obtained more precisely because the clamshell excavating means is continuously guided during moving in and out of the excavated volume.

[0045] The use of the hollow casing in combination with the guiding means has the advantage that at the entrance of the excavation, a continuous protection of the sides of the excavation is obtained.

[0046] The guiding means, which may be a hollow structure, may be used as a channel for conducting e.g. hydraulic tubes to the clamshell excavating means, enabling the functioning of such clamshell excavating means.

[0047] During excavating, the guiding means and the clamshell excavating means are coupled to each other at a coupling zone. It is clear that both elements can preferably be unlocked and disconnected e.g. for maintenance purposes. The coupling of the clamshell excavating means and the guiding means ensures that the clamshell excavating means as a whole does not displace with regard to the guiding means. As an example, the clamshell excavating means comprises an axis of rotation, around which the buckets of the clamshell may rotate from open to closed position. This axis is coupled in a fixed position to the guiding means. Though the buckets of the clamshell excavating means may rotate relative to the guiding means about this axis, the clamshell excavating means remains in a fixed position to the guiding means, as the axis does not move in reference to the guiding means.

[0048] The outer guiding surface has one end oriented towards the clamshell excavating means. The bite of the clamshell excavation means in opened position is to be positioned beyond this one end of the guiding means in excavation direction. The other elements of the clamshell excavating means may be located or move within the guiding means, or, in alternative embodiments, may be located beyond the one end of the guiding means in excavation direction. Optionally the distance between the outer circumference of the bite of the clamshell excavating means in opened position and the one end of the guiding means oriented towards the bite in excavation direction, is less than the length of the hollow casing. This to always ensure a guiding contact between guiding means and hollow casing when the clamshell excavating means is excavating ground or material located beyond the outer end of the hollow casing.

[0049] Rigid supporting plates such as metal plates, e.g. steel plates, fixed to a support structure may provide the outer guiding surface of the guiding means. Alternatively the rigid supporting plates may have a number of perforations or openings, which is advantageous when the excavated hole is maintained at least partially filled with a thixotropic fluid during excavation. The fluid can move in and out of the guiding means more easily through the perforations or openings, which reduces the excavation time and/or reduces the spilling and loss of thixotropic fluid during excavation. In case of use of thixotropic fluid during excavation, the lower surface of the guiding means, delimited by the outer end of the guiding means is preferably open, i.e. fluid may pass to the inner side of the hollow structure of the guiding means. The guiding means may as well be a construction comprising rigid elements providing the guiding surface, of which the projection in excavation direction of this guiding surface has point coinciding with the bite circumference, hence with the projection in excavation direction of the hollow casing. These points enable the provision of a contact between inner hollow casing and guiding surface, which contact preventing the guiding means and the clamshell excavating means from deflecting from the excavation direction when moved in excavation direction

[0050] The guiding means is preferably a substantially cubic structure having its height in excavation direction. A cross-section according to a plane perpendicular to the excavation direction has a substantially rectangular shape of which the long side is referred to as width of the guiding means and the short side is referred to as depth. The guiding means may comprise means enabling to modify the dimensions thereof for accommodating the guiding means to hollow cases with different dimensions for providing trenches with different dimensions. The guiding means may comprise means for modifying its height, depth and/or width.

[0051] According to a third aspect of the present invention, a method for excavating trenches in a ground surface in an excavation direction is provided,
wherein the method comprises

- providing a clamshell excavating means for excavating ground, the clamshell excavating means having a bite in an opened position for receiving ground to be excavated, the projection on a plane perpendicular to the excavation direction of the bite of the clamshell excavating means in opened position having a bite circumference;
- pressing a hollow casing into the ground surface, the projection of an inner wall of the hollow casing in excavation direction substantially corresponding to the bite circumference, the hollow casing having a lower edge;
- removing the ground located in the hollow casing and providing a thixotropic fluid in the excavated volume, whereby the fluid level contacts the inner wall above the lower edge;
- excavating the trench using the clamshell excavating means until the trench with required depth is excavated, while maintaining the fluid level of the thixotropic fluid above the lower edge of the inner wall.

[0052] The hollow casing may have an inner wall having a length Dc smaller than the guiding length Dg, the pressing into the ground surface being to a depth of less than or equal to Dc. The depth of introducing the casing into the ground, and the length Dc may be selected to provide a sufficient hydraulic pressure at the lower edge of the hollow casing during excavation. The hydraulic pressure is provided by providing a thixotropic fluid in the hollow casing and maintaining the fluid level of the thixotropic fluid such that a sufficient hydraulic pressure is applied at the lower edge of the hollow casing.

[0053] According to embodiments of the present invention, the excavating the trench may be done by repetitively

o introducing the clamshell excavating means into the hollow casing;
o taking up ground to be excavated by changing the clamshell excavating means at least once from an open to closed position,
o retracting from within the hollow casing the clamshell excavating means and the ground taken up;
o discarding the taken ground from the clamshell excavating means.

[0054] According to embodiments of the present invention, the method further may comprise

- providing a guiding means being coupled to the clamshell excavating means in locked position, the guiding means having an outer guiding surface with a guiding length Dg;
- excavating the trench by repetitively

o introducing the clamshell excavating means and the guiding means into the hollow casing thereby establishing an contact between the outer guiding surface of the guiding means and the inner wall of the hollow casing for preventing deflection of the guiding means and the clamshell excavating means from the excavation direction;
o taking up ground to be excavated by changing the clamshell excavating means at least once from an open to closed position;
o retracting the clamshell excavating means, a part of the guiding means and the ground taken up, thereby interrupting the contact between the outer guiding surface of the guiding means and the inner wall of the hollow casing;
o discarding the taken ground from the clamshell excavating means; until the trench with required depth is excavated.

[0055] The hollow casing may have an inner wall having a length Dc smaller than the guiding length Dg, the pressing into the ground surface being to a depth of less than or equal to Dc.

[0056] According to embodiments of the present invention, the contact between the outer guiding surface of the guiding means and the inner wall of the hollow casing may be a sliding contact.

[0057] According to embodiments of the present invention, a trench having a depth more than 30 m may be provided.

[0058] According to embodiments of the present invention, the hollow casing may have a flange in angled orientation with regard to the inner wall, the method comprising, before pressing the hollow casing into the ground surface, providing a supporting beam and positioning the hollow casing such that the hollow casing is supported by the supporting beam when pressed in the ground surface.

[0059] According to this third aspect of the present invention, the method for excavating trenches enables the provision of trenches with precise inner dimensions within small tolerances.

[0060] The advantage of maintaining the fluid level of the thixotropic fluid above the lower edge of the inner wall is that the fluid level of the thixotropic fluid cannot be washed out by the changing fluid level, which would occur in case the fluid level of the thixotropic fluid is contacting the ground along the wall of the excavated trench.

Thus the dimensions and the volume of the trench dug out or excavated, is protected of changing due to washing out of ground. Simultaneously, in case a guiding means is used to contact the inner wall of the hollow casing for preventing the clamshell excavating means and the guiding means to deflect from the excavation direction, the trench is obtained within very narrow tolerances in excavation direction. Further, the opening of the trench, i.e. the most upper part of the trench, immediately under ground level, is protected from mechanical impacts of the clamshell excavating means when entering in the trench partially excavated. The hollow casing thus protects the upper part of the trench from damage due to clamshell excavating means hitting the wall and possibly removing ground at the upper part of the trench excavated. The thixotropic fluid further applies a hydraulic pressure to the wall of the excavated trench under the lower edge of the hollow casing, which may prevent the trench wall to collapse.

[0061] As the trenches may be used to in-situ cast walls, the walls obtained will meet limited tolerances as well, both in dimension and position. The method will result in a decrease of cast material used to cast the walls, as the trench volume will match more precisely the required volume of the wall to be cast. The use of superfluous cast material filling non-essential volumes of the trench occurring due to imprecise tolerances, may be reduced. As the inner walls of the trenches, obtained by using the method according to the second aspect of the present invention, are more precisely defined and positioned, such trenches allow the use of more precise reinforcement elements, snugly fitting within the trenches prior to casting the in-situ cast wall. The precisely defined, oriented and positioned walls of the trenches allow the reinforcement elements to have spacing elements for precisely locating the reinforcement elements within the trench prior to casting.

[0062] As the reinforcement elements may be positioned more precisely within the trench, and thus later on within the wall having more narrow tolerances, more precise positioning of adjacent wall modules of a modular wall made according to an aspect of the present invention my be obtained. This correct positioning of wall modules of modular walls may improve the water-tightness of the modular wall. As the seams of adjacent wall modules can be made more precise, the risk on even small dislocation of the modules, which may result in leakages of water or other fluids through the small cracks at the seam, is reduced.

[0063] The method further has the advantage that it can be used to excavate trenches near existing buildings with reduced danger of damaging the existing walls or foundations.

[0064] According to a fourth aspect of the present invention, a method to in-situ cast a wall module s provided, the method comprising

- providing a trench using one of the methods for excavating trenches according to the third aspect of the present invention;
- providing a reinforcement element in the trench;
- filling the trench with cast material; and
- curing the cast material.

[0065] It is understood these trenches may be excavated by using an excavating device according to the first aspect of the present invention.

[0066] According to embodiments of the present invention, the trench may have a cross-section according to a plane perpendicular to the excavation direction, the cross-section being a substantially rectangular cross-section. The reinforcement element may be provided with formwork at one of the long sides of the cross-section before providing it in the trench.

[0067] According to embodiments of the present invention, the reinforcement element is a reinforcement element according to the first aspect of the present invention.

[0068] According to a fifth aspect of the present invention, a method to in-situ cast an at least partially sunken modular wall is provided, the method comprising the steps of

- providing a first wall module using the method to in-situ cast a wall module according to the fourth aspect of the present invention;
- providing a second wall module using the method to in-situ cast a wall module according to the fourth aspect of the present invention, there being a predetermined distance between the first and second wall module;
- excavating in between the first and second wall module an intermediate trench of a width corresponding to the predetermined distance, by

    o providing an adapted clamshell excavating means having a set of buckets with bite profile adapted to remove the sacrificial material from the channel shaped profiles, and

    o excavating the intermediate trench between the first and second wall module by means of the adapted clamshell excavating means, whereby the channel-shaped profiles of the first and the second wall modules guide the adapted clamshell excavating means until the intermediate trench has a required depth;

- providing a reinforcement element in the intermediate trench;
- filling the intermediate trench with cast material;
- curing the cast material in the intermediate trench thereby providing the modular wall.

[0069] According to embodiments of the present invention, the reinforcement element in the intermediate trench may be an elongate insert reinforcement element according the first aspect of the present invention.

[0070] According to these fourth and fifth aspects of the present invention, wall modules and modular walls may be provided, being at least partially sunken walls. The walls may be provided with a visible surface, which has a surface condition matching the requirements of a finished wall suitable for use in cellars, basements, underground parking space garages and alike sunken or partially sunken rooms. The method also allows more precise positioning and dimensioning of wall modules and modular walls, which are at least partially sunken.

[0071] Particular and preferred aspects of the invention are set out in the accompanying independent and dependent claims. Features from the dependent claims may be combined with features of the independent claims and with features of other dependent claims as appropriate and not merely as explicitly set out in the claims.

[0072] Although there has been constant improvement, change and evolution of devices in this field, the present concepts are believed to represent substantial new and novel improvements, including departures from prior practices, resulting in the provision of more efficient, stable and reliable excavation means.

[0073] The above and other characteristics, features and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of the invention. This description is given for the sake of example only, without limiting the scope of the invention. The reference figures quoted below refer to the attached drawings.

Brief description of the drawings

[0074]

Fig. 1 is a schematic view of a clamshell excavating means according to a first embodiment of an aspect of the present invention.

Fig. 2 is a schematic view of a projection of the bite of the clamshell excavation means of Fig. 1, the outer guiding surface of a guiding means and the inner wall of a hollow casing.

Fig. 3 is a schematic view of an excavating means according to a second embodiment of the second aspect of the present invention.

Fig. 4a and 4b are schematic views of excavating means according to a third and a fourth embodiment of the second aspect of the present invention.

Fig. 5 is a schematic view of a part of an excavating means according to a fourth embodiment of the second aspect of the present invention, the excavating means comprising a displacement means.

Fig. 6a to 6f schematically illustrate different steps in the process of a method for excavating trenches in a ground surface in accordance with an embodiment of the present invention.

Fig. 7a is a cross-section and Fig. 7b a top view of a detail of a hollow casing pressed into ground surface, near an existing construction, in accordance with embodiments of the present invention. Fig. 7c shows a further alternative view of a detail of a hollow casing pressed into ground surface, but partially extending above ground level.

Fig. 8a to 8f schematically illustrate steps of a method to in-situ cast a wall module in accordance with embodiments of the present invention.

Fig. 9 schematically shows an elongate reinforcement element according to embodiments of the present invention.

Fig. 10a and Fig. 10b show alternative elongate reinforcement elements according to embodiments of the present invention.

Fig. 11 a to 11f schematically illustrate steps of a method to in situ cast an at least partially sunken modular wall, in accordance with embodiments of the present invention.

Fig. 12 schematically shows a suitable elongate reinforcement element for insertion in an intermediate trench, in accordance with embodiments of the present invention.

Fig. 13 schematically shows a modular wall having wall segments meeting in a corner, in accordance with embodiments of the present invention.

Fig. 14 shows a reinforcement element having apertures suitable for passing pipelines, utility lines, power lines and alike.

Fig. 15 shows schematically a front view and two cross-sections of a formwork suitable to be used as part of an elongate reinforcement element according to embodiments of the present invention.

Fig. 16 shows schematically a top view, a front view and a section of an elongate reinforcement element using the formwork as shown in Fig. 15.

[0075] In the different figures, the same reference signs refer to the same or analogous elements.

Description of illustrative embodiments

[0076] The present invention will be described with respect to particular embodiments and with reference to certain drawings but the invention is not limited thereto but only by the claims. The drawings described are only schematic and are non-limiting. In the drawings, the size of some of the elements may be exaggerated and not drawn on scale for illustrative purposes. The dimensions and the relative dimensions do not correspond to actual reductions to practice of the invention.

[0077] Furthermore, the terms first, second, third and the like in the description and in the claims, are used for distinguishing between similar elements and not necessarily for describing a sequence, either temporally, spatially, in ranking or in any other manner. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein.

[0078] Moreover, the terms top, bottom, over, under and the like in the description and the claims are used for descriptive purposes and not necessarily for describing relative positions. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other orientations than described or illustrated herein.

[0079] It is to be noticed that the term "comprising", used in the claims, should not be interpreted as being restricted to the means listed thereafter; it does not exclude other elements or steps. It is thus to be interpreted as specifying the presence of the stated features, integers, steps or components as referred to, but does not preclude the presence or addition of one or more other features, integers, steps or components, or groups thereof. Thus, the scope of the expression "a device comprising means A and B" should not be limited to devices consisting only of components A and B. It means that with respect to the present invention, the only relevant components of the device are A and B.

[0080] Similarly, it is to be noticed that the term "coupled", also used in the claims, should not be interpreted as being restricted to direct connections only. The terms "coupled" and "connected", along with their derivatives, may be used. It should be understood that these terms are not intended as synonyms for each other. Thus, the scope of the expression "a device A coupled to a device B" should not be limited to devices or systems wherein an output of device A is directly connected to an input of device B. It means that there exists a path between an output of A and an input of B which may be a path including other devices or means. "Coupled" may mean that two or more elements are either in direct physical or electrical contact, or that two or more elements are not in direct contact with each other but yet still co-operate or interact with each other.

[0081] Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment, but may. Furthermore, the particular features, structures or characteristics may be combined in any suitable manner, as would be apparent to one of ordinary skill in the art from this disclosure, in one or more embodiments.

[0082] Similarly it should be appreciated that in the description of exemplary embodiments of the invention, various features of the invention are sometimes grouped together in a single embodiment, figure, or description thereof for the purpose of streamlining the disclosure and aiding in the understanding of one or more of the various inventive aspects. This method of disclosure, however, is not to be interpreted as reflecting an intention that the claimed invention requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects lie in less than all features of a single foregoing disclosed embodiment. Thus, the claims following the detailed description are hereby expressly incorporated into this detailed description, with each claim standing on its own as a separate embodiment of this invention.

[0083] Furthermore, while some embodiments described herein include some but not other features included in other embodiments, combinations of features of different embodiments are meant to be within the scope of the invention, and form different embodiments, as would be understood by those in the art. For example, in the following claims, any of the claimed embodiments can be used in any combination.

[0084] In the description provided herein, numerous specific details are set forth. However, it is understood that embodiments of the invention may be practiced without these specific details. In other instances, well-known methods, structures and techniques have not been shown in detail in order not to obscure an understanding of this description.

[0085] The following terms are provided solely to aid in the understanding of the invention.

[0086] With respect to the present invention, the term "concrete" is used to refer to any appropriate type of concrete, and not only to refer to pure concrete. It also may be used to refer to an improved or optimized mixture of polymer-modified concrete, polymer impregnated concrete, whereby the concrete afterwards is impregnated with polymer, polymer concrete, or any other concrete having admixtures to enhance the properties of concrete. Thus other additional components, often added to improve the quality of the concrete may also be present. The term concrete thus should be interpreted broad as referring to concrete or possibly adjusted concrete. Concrete may also comprise fly ash or air-entraining agents.

[0087] With respect to the present invention, the terms "water blocking means", "water stop", "water resistance", "water tightness" and so on should be interpreted in a very broad way, i.e. no restriction should be given to the chemical components present in the water and to possible contamination present in the water. The terms should be interpreted broad and could be replaced by "liquid stop", "liquid resistance", "liquid tightness", liquid blocking means" and so on.

[0088] With respect to the present invention, the term "clamshell excavating means" is to be understood as any of various devices with at least two hinged jaws used for digging. The term "clamshell excavating means" also includes e.g. digging grabs or grapples.

[0089] The term "coinciding", when relating to the projection of the outer guiding surface in excavation direction and the bite circumference, is to be understood as having at least a part of the projection in common with the bite circumference. In this respect, "substantially" is to be understood as coinciding within acceptable tolerances, i.e. having a mutual distance of maximum 3 cm (but preferably less than 2 cm, such as less than 1,5 cm), where the projection of the guiding surface is to be within the bite circumference.

[0090] The term "corresponding", when relating to the projection of the inner wall of a hollow casing and the bite circumference, is to be understood as the projections matching along the length of the bite circumference. In this respect, "substantially" is to be understood as matching within acceptable tolerances, i.e. having a mutual distance of maximum 3 cm (but preferably less than 2 cm, such as less than 1,5 cm), where the bite circumference is to be within the projection of the inner wall of the hollow casing.

[0091] The clamshell excavating means in "opened position" is to be understood as the widest opened position of the clamshell, i.e. the position of the clamshells being such that the widest bite is made useful to grab, dig or excavate ground or material under the bite.

[0092] The invention will now be described by a detailed description of several embodiments of the invention. It is clear that other embodiments of the invention can be configured according to the knowledge of persons skilled in the art without departing from the true spirit or technical teaching of the invention, the invention being limited only by the terms of the appended claims.

[0093] An excavating device 100 according to an aspect of the present invention is shown in Figure 1. The excavating device 100 is adapted to excavate trenches 900 in a ground surface 901 in an excavation direction 902. The excavating device 100 comprises a clamshell excavating means 110 for excavating ground. The clamshell excavating means 110 has a closed position as shown in Figure 1, and has an opened position for receiving ground to be excavated as shown in Figure 2. The bottom circumference of the clamshell excavating means 110 in opened position is called the bite 111. The projection on a plane 200 perpendicular to the excavation direction 902 of the bite 111 provides a bite circumference 210, in the case illustrated a rectangular shaped bite having two small sides and two long sides. The shape and the dimensions of the bite are dependent on the shape and dimensions of the clamshell excavating means 110.

[0094] The excavating device 100 further comprises a guiding means 130 coupled to the clamshell excavating means 110 in a locked position, i.e. the clamshell excavating means 110 and the guiding means 130 are prevented to move one in respect to the other during excavation, e.g. using at least one fixed coupling point or coupling zone 131. Though it is clear that clamshell excavating means 110 and guiding means 130 may possibly be unlocked, the coupling zone 131 provides at least one fixed point. The guiding means 130 has an outer guiding surface 132 having a guiding length 133 (hereafter Dg) which may be more than 2m, even more than 3m, such as more than 10m, but can be 30m or more, such as 40m or more, even more than 50m, up to 100m or more. The projection in excavation direction 902 of the outer guiding surface 132 on the plane 200 substantially coincides with or, as shown in Figure 1 and 2, even corresponds to the bite circumference 210.

[0095] The outer guiding surface 132 is adapted for engaging an inner wall 142 of a hollow casing 140. The projection of the inner wall 142 also substantially coincides with the bite circumference 210. The contact between the outer guiding surface 132 and the inner wall 142 of the hollow casing 140 is adapted to avoid that the guiding means 130 and the clamshell excavating means 110 deflect from the excavation direction 902 when moving in the excavation direction 902. As shown in Figure 1, the contact of the inner wall 142 of the hollow casing 140 and the outer guiding surface 132 of the guiding means 130 is a sliding contact, wherein the outer guiding surface 132 slides within the inner void of the hollow casing 140.

[0096] The hollow casing 140 has an inner wall having a length 143 (hereafter Dc) being smaller than the guiding length Dg (133). The hollow casing 140 is adapted to be provided, e.g. pressed, into the ground surface 901 to a depth of less than or at most equal to length Dc (143). In this embodiment, the hollow casing 140 is provided from plate material, such as e.g. steel plate, having a thickness Tp in the range of 10 mm to 100 mm, more preferred in the range of more than 20 mm and less than 50 mm such as less than 35 mm, such as 30 mm. As an alternative, the hollow casing may be a concrete casing, or may be provided from polymer material, such as composite polymer material. The hollow casing 140 has a flange 145 in angled orientation with regard to the inner wall 142. During use, the flange 145 is to be in contact with the ground surface 901 is to be supported on a support structure applied into the ground surface 901. Preferably, the flange 145 of the hollow casing 140 is to be supported on a beam, e.g. a cast beam 150 or a steel or metal support beam, when pressed in the ground surface 901. The flange 145 is positioned under 90° with respect to the inner wall 142 (within typical tolerances), and in case the beam 150 is provided in horizontal position in or on the ground surface 901, the trench 900 will be substantially vertical, i.e. vertical with respect to the ground surface within tolerances. The transition between flange and inner wall may be angled or may be rounded. The flange may have a height of 50 mm to 200 mm, e.g. about 100 mm. The flange 145 may further be provided with a border 146, preferably an upright border, extending upwards from the flange 145, for thus creating a channel suitable for conducting fluids e.g. the thixotropic fluid, used during excavation for filling the excavated hole. The border preferably extends about 100 mm to 300 mm upwards, such as e.g. about 200 mm.

[0097] Figure 2 schematically shows the projections of the bite 111, outer guiding surface 132 of the guiding means 130 and inner wall 142 of the hollow casing 140 on a plane 200 perpendicular to the excavating direction

902. As shown in Figure 2, the projection of the inner wall 142 substantially corresponds to, or even coincides with the bite circumference 210. The hollow casing 140 is adapted to allow passage of the clamshell excavating means 110 and the guiding means 130 when the clamshell excavating means 110 and the guiding means 130 are moved in excavation direction 902 during excavation. The outer guiding surface 132 of the guiding means 130 is so designed that along its guiding length Dg (133), the inner wall 142 of the hollow casing 140 is engaged with the outer guiding surface, in such a way that a deflection from the excavation direction of the guiding means 130 and the clamshell excavating means 110 is avoided.

[0098] Possibly, the bite circumference may be oval or rectangular. The bite circumference as shown in Figure 1 and 2 has a substantially rectangular shape. The rectangular shape has two substantially parallel long sides, which are for example preferably more than 1000 mm long, even more than 1500 mm, but which are preferably less than 5000 mm, such as less than 4000 mm such as less than 3500 mm, e.g. about 2000 mm to 3000 mm. The short sides of the rectangular shape may for example be in the range of 200 mm to 1000 mm, such as more than 200 mm and less than 750 mm, e.g. in the range of 200 mm to 500 mm.

[0099] In the embodiment shown in Figure 1 and 2, the contact between the outer guiding surface 132 of the guiding means 130 and the inner wall 142 of the hollow casing 140 is a sliding contact. The guiding means 130 may be formed by rigid supporting plates such as metal plates, e.g. steel plates 135 which may be mounted on a supporting framework 136. An actual guiding wall is thus provided. The guiding means 130 may be a hollow structure and the interior of the guiding means 130 may be used for providing e.g. hydraulic lines 116 to the clamshell excavating means 110, for changing the buckets 112 and 113 of the clamshell excavating means 130 between opened and closed position.

[0100] The coupling of the clamshell excavating means 110 and the guiding means 130 ensures that the clamshell excavating means 110 as a whole does not displace with regard to the guiding means 130. As an example, the clamshell excavating means 110 may comprise an axis of rotation 114, around which the buckets 112 and 113 of the clamshell excavating means 110 may rotate from opened to closed position and vice versa. This axis 114 is coupled in a fixed position with respect to the guiding means 130. Though the buckets 112, 113 of the clamshell excavating means 110 may rotate about this axis 114 relative to the guiding means 130, the clamshell excavating means 110 remains in a fixed position with respect to the guiding means 130, as the axis 114 does not move in reference to the guiding means 130.

[0101] The outer guiding surface 132 has a bottom border 137 which is oriented towards the clamshell excavating means 110. In case thixotropic fluid is used during excavation to fill the produced hole for stability purposes, the lower side of the guiding means 130, of which the one bottom border 137 forms the boundary, is at least partially open, e.g. perforated, to allow the thixotropic liquid to flow through and into the guiding means 130. The bite 111 of the clamshell excavation means in opened position should be positioned beyond this bottom border 137 of the guiding means 130 in excavation direction 902. The other elements of the clamshell excavating means 110 may be located within the guiding means 130 as illustrated in the embodiment of Fig. 3, or may as well be located beyond the bottom border 137 of the guiding means 130 in excavation direction 902, as shown in Figure 1.

[0102] The distance 117 (hereafter De) between the outermost point of the clamshell excavating means 110 in excavation direction 902 when the clamshell excavating means 110 is in opened position, which is a point on the boundary of the bite 111, and the bottom border 137 of the guiding means 130, is less than the length Dc (143) of the hollow casing 140. This is to ensure a guiding contact between the guiding means 130 and the hollow casing 140 when the clamshell excavating means 110 is excavating ground or material located beyond (in excavation direction 902) the outer end of the hollow casing 140.

[0103] Rigid supporting plates, e.g. metal plates such as steel plates 135, fixed to a supporting framework 136 may provide the outer guiding surface 132 of the guiding means 130 as shown in Figure 1 and Figure 2, in which case the guiding surface is a guiding wall. In alternative embodiments, as shown in Figure 3, the rigid supporting plates, such as metal plates 3135, may have a number of perforations or openings 3101, which may be spread over the rigid supporting plates 3135 in regular or irregular patterns. The presence of such perforations or openings 3101 is advantageous when the excavation is performed under application of a thixotropic fluid to the excavated trench. The thixotropic fluid can move in and out of the guiding means 130 more easily through the perforations or openings 3101, which reduces the excavation time and /or reduces the spilling and loss of thixotropic fluid during excavation.

[0104] The guiding means may be oval in cross-section according to a plane perpendicular to the excavation direction, but preferably the guiding means 130 is a substantially cubic structure having its height in excavation direction 902.

[0105] In case the guiding means has a guiding wall, such as shown in Figure 1, Figure 2 or Figure 3, a cross-section according to a plane perpendicular to the excavation direction 902 has a rectangular shape of which the long side is referred to as width of the guiding means 130 and the short side is referred to as depth. As the bite circumference in these embodiments has a rectangular shape, the bite circumference has four sides. For each of the four sides of the bite circumference, the projection of the guiding surface in excavation direction, i.e. the projection of the guiding wall in excavation direction, has at least one point coinciding with the side of the rectangular shaped bite circumference. In this embodiment, the projection of the outer guiding surface 132 in excavation direction, in this particular case the guiding wall, substantially coincides with the bite circumference. As the plates provide a guiding wall along the whole of the guiding length of the guiding means, for each of the four sides of the bite circumference, at each position along the length Dg (133) of the guiding means, the projection of the guiding surface at this position has at least one point coinciding with the side of the bite circumference.

[0106] The guiding means 130 may comprise means enabling to modify its dimensions for accommodating the guiding means 130 to different hollow casings 140 for providing trenches with different dimensions. The means enabling to modify its dimensions may comprise means for adjusting, i.e. modifying, its height, depth and/or width. The dimensions of the guiding means 130 may be adjusted by e.g. adjusting its supporting framework 136. In that case, the supporting framework 136 may be provided as a modular framework, to which modules can be added or of which modules can be removed in length-, depth- or width direction, so as to adapt to the required or desired dimensions. The outer guiding wall 132 of the guiding means 130 may be provided by coupling rigid supporting plates 3135 such as steel plates to the supporting framework 136 once this is built in accordance with the required dimensions.

[0107] According to an alternative embodiment, as shown in Figure 4a, a plurality e.g. two rigid supporting plates 4101 and 4102 may be used to provide the outer guiding surface 132 of the guiding means 130 along each of the long sides of the rectangular cross section of the guiding means 130. Along the short sides of the cross-sections, the guiding surface may be provided by rigid supporting plates 4103 and 4104. The projection of the outer guiding surface 132 in excavation direction 902 onto a plane 200 perpendicular to the excavation direction 902 substantially coincides with the bite circumference 210 along discrete lengths, e.g. the lengths 4201, 4202, 4203, 4204, 4205 and 4206. These lengths are distributed along the bite circumference 210 so as to avoid deviation of the guiding means 130 and the clamshell excavating means 110 from the excavation direction 902 when moving in the excavation direction 902. Such deviation is avoided by having a contacting zone between the inner wall 142 of the hollow casing 140 and the outer guiding surface 132 of the guiding means 130, the outer guiding surface 132 being provided with a plurality of rigid supporting plates 4101, 4102, 4103, 4101 along each of the two long sides and along each of the two short sides of the cross-section of the guiding means 130.

[0108] According to another alternative embodiment, as shown in Figure 4b, a plurality e.g. four rigid elements 4121, 4122, 4123 and 4124 provide the outer guiding surface 132 of the guiding means 130 along each of the long sides and short sides of the rectangular cross section of the guiding means 130. Each of the rigid elements, such as metal bars, beams, tubes or rods, or set square profiles provides one surface along two adjacent sides of the rectangular cross section of the guiding means. Preferably steel set square profiled elements are used, having two sides of about 100 mm to 150 mm length and a thickness of 10 mm to 15 mm.

[0109] The projection of the outer guiding surface 132 in excavation direction 902 onto a plane 200 perpendicular to the excavation direction 902 substantially coincides with the bite circumference 210 along discrete lengths, e.g. the lengths 4221, 4222, 4223, 4224, 4225, 4226, 4227 and 4228. These lengths are distributed along the bite circumference 210 so as to avoid deviation of the guiding means 130 and the clamshell excavating means 110 from the excavation direction 902 when moving in the excavation direction 902. Such deviation is avoided by having a contacting zone between the inner wall 142 of the hollow casing 140 and the outer guiding surface 132 of the guiding means 130. Between the rigid elements 4121, 4122, 4123 and 4124, a plurality of coupling elements 4130 may preferably be connected to the rigid elements, thus providing rigidity to the guiding means. Some coupling elements 4130 may also provide an additional guiding surface to the guiding means. The coupling elements may be profiled coupling elements such as I-, H-, U- profiled elements, set square profiles, or tubes such as tubes with a circular, rectangular or even square cross-section. The distance between adjacent coupling elements in excavation direction (center-to-center distance) is preferably in the range of 0.5 m to 1 m. The coupling elements and the rigid elements are preferably steel elements having a wall thickens of about 10 mm to 15 mm.

[0110] For both embodiments of Fig. 4a and Fig. 4b, as the bite circumference is rectangular shaped, the bite circumference has four sides. For each of the four sides of the bite circumference, the projection of the guiding surface in excavation direction, i.e. the projection of the guiding wall in excavation direction, has at least one point coinciding with the four side of the rectangular shaped bite circumference. More particularly, along each of the four sides, there are discrete lengths of the projection in excavation direction of the guiding surface coinciding with the bite circumference. As the plates or rigid elements provide a guiding wall along the whole of the guiding length of the guiding means, for each of the four sides of the bite circumference, at each position along the length Dg (133) of the guiding means, the projection of the guiding surface at this position has at least one point coinciding with the side of the bite circumference.

[0111] As shown in the embodiments shown in Figure 1 and 2, the length Dc (143) of the inner wall 142 of the hollow casing 140 is in the range of 0.5 m to 6 m, in this embodiment in the range of 0.5 m to 3 m , e.g. more particularly in the range of 1 m to 2.5 m. The guiding length of the guiding means 130, i.e. the length of the guiding surface which can be brought into contact with the inner wall of the hollow casing, is more than the length Dc (143), such as more than 3 m, but can be even more than 30 m such as more than 40 m or more than 50 m, even more than 100 m.

[0112] In embodiments of the present invention, the excavating device 100 further comprises a displacement means for displacing the clamshell excavating means 110 and guiding means 130 in the excavation direction 902. The displacement means can be adapted to apply a force in excavation direction 902 to the clamshell excavating means 110, e.g. by means of an hydraulic system and/or by making use of a relatively stiff beam or tube to transfer hydraulic pressure to the coupled clamshell excavating means 110 and guiding means 130. The excavating device 100, comprising the clamshell excavating means 110 and guiding means 130 may be coupled to the hydraulically and/or mechanically powered coupling means 5001 of the mast of a Kelly drilling system 5002, e.g. an LRB 400 of the company Liebherr or a BG 40 of the company Bauer, as schematically shown in Figure 5. By moving the coupling means up and down in excavation direction 902, the clamshell excavating means 110 and guiding means 130 may be moved up and down in the hollow casing, thereby executing an excavating operation. The displacement means can be provided with one or more sensors such as pressure sensors and/or displacement sensors for measuring pressure applied to the bite 111 and/or the length and speed over which the guiding means 130 and clamshell excavating means 110 are displaced. Alternatively a crawler crane may be used.

[0113] According to another embodiment of the present invention, the displacement means can be a crane, wherein the guiding means 130 and the clamshell excavating means 110 are lifted using e.g. a set of cables, and wherein the guiding means 130 and the clamshell excavating means 110 moves downwards due to gravitational forces.

[0114] A method for excavating trenches in a ground surface 901 in an excavation direction according to embodiments of the present invention is shown in Figure 6. Prior to starting the excavation, the position 6000 of the trench to be excavated is defined, as shown in cross-section in step 601 illustrated in Fig. 6a. As shown in step 602, illustrated in Fig. 6b, a beam 6001, e.g. a concrete cast beam, is provided along at least a part of the border of the trench to be excavated, on or in the ground surface 901. In the embodiment illustrated, the beam 6001 is provided on the ground surface 901. The beam 6001 will be used to support the hollow casing 6002. The beam 6001 may alternatively be a steel profile. The beam 6001 is to be placed in line with the wall to be cast, and its upwards oriented surface is to be oriented horizontally.

[0115] Especially in case of trenches to be excavated having a rectangular cross-section, the beams 6001 may be provided along the long sides of the rectangular cross-section, as can be seen in the illustrated top view. In a consecutive step 603, illustrated in Fig. 6c, a hollow casing 6002 is pressed into the ground surface to a depth Dr of less than or equal to length Dc (143), Dc being the length of the inner wall 6006 of the hollow casing 6002. The hollow casing 6002 preferably is provided with a flange 6003, as set out above, which flange 6003 is brought into contact with the beam 6001 for providing support to the hollow casing 6002. A detail of the hollow casing 6002 pressed into ground surface, near an existing construction, e.g. an existing wall 6004 is shown in Figure 7a in vertical cross-section and in Figure 7b in top view. The lower end of the hollow casing 6002 may be provided with a cutting edge 6005 to facilitate easy insertion of the casing into the ground. The cutting edge may be provided as an outwards inclined edge as shown in Figure 7b. The outwards inclination has the advantage that, when the clamshell excavating means is filled with ground to be dug, and moves upwards, the hollow casing will have less risk to be pulled out of the trench in case the clamshell would accidentally hit the lower cutting edge 6005 of the hollow casing.

[0116] When the hollow casing is inserted into the ground, the casing may be mechanically locked relative to the beams 6001 in order to avoid that the casing 6002 displaces in a direction parallel to the beams 6001. This may be done by e.g. fixing blocking means such as bars to the beams, e.g. by bolting, which blocking means are provided along the free sides of the flanges of the hollow casing.

[0117] The provided hollow casing 6002 may have an inner wall 6006, whereby the projection of the inner wall 6006 in excavation direction 902 substantially corresponds to the bite circumference 210 of the clamshell excavating means 110 which will be used, and which corresponds to the cross-section of the trench to be dug, the cross-section being according to a plane perpendicular to the excavation direction 902. Once the hollow casing 6002 is inserted into the ground, the removal of the ground 6010 from within the hollow casing 6002 may take place as shown in step 604 illustrated in Fig. 6d. An excavating device 6100 according to an embodiment of the second aspect of the present invention is used. During removal of the ground 6010 from the volume within the hollow casing 6002, the inner wall 6006 of the hollow casing 6006 and the outer guiding surface 6101 of the guiding means 6104 may already engage but do not need to do so.

[0118] Once at least some ground 6010 is removed from within the hollow casing 6002, and at least when all ground 6010 is removed from within the hollow casing 6002, the excavated volume is filled with thixotropic fluid 8001. During further excavation, the fluid surface is kept in contact with the inner wall of the hollow casing 6002. This level may fluctuate because of the movement of the clamshell excavating means and the guiding means. Optionally, also during excavating of the ground 6010 from within the hollow casing 6002, the hollow casing may already be filled with thixotropic fluid.

[0119] By providing the hollow casing 6002 and by keeping the fluid level in contact with the inner wall thereof, i.e. the fluid surface is present at least above the lower edge 6005 of the hollow casing, the ground immediately under the lower cutting edge 6005 is prevented to be washed away with the moving fluid surface. As such, collapsing of the upper part of the side walls of the excavated trench is prevented.

[0120] In figure 6a to 6f, the maximum hydraulic pressure at the lower edge 6005 caused by the height of thixotropic fluid is determined by the height of the casing Dc, which in the embodiment is substantially identical to the depth Dr over which the casing is inserted into the ground.

[0121] For increasing the hydraulic pressure applicable at the lower edge 6005, an alternative hollow casing 6002 as shown in Fig. 7c may be provided. The length Dc is here optionally in a range of 0.5 m to 6 m, e.g. about 4 m to 6 m. The hollow casing 6002 has also a flange 6003 for contacting the support beam 6001, but the height Dc of the inner wall 6006 is significantly larger than the depth Dr over which the hollow casing 6002 is inserted in the ground. As such, at the lower edge 6005, e.g. the cutting edge of the hollow casing, a hydraulic pressure corresponding to a thixotropic fluid column with height of maximum Dc may be provided, whereas the depth according to which the casing is introduced in the ground, i.e. Dr, is less than the height Dc of the inner wall 6006 of the casing 6002.

[0122] Further excavating of the trench 6500 may be done by

o introducing the clamshell excavating means 6103 and at least a part of the guiding means 6104 into the hollow casing 6002, thereby establishing a contact between the outer guiding surface 6101 of the guiding means 6104 and the inner wall 6006 of the hollow casing 6002 so as to avoid that the guiding means 6104 and the clamshell excavating means 6103 deviate from the predetermined excavation direction 6200;

o taking up ground 6010 to be excavated by changing the clamshell excavating means 6103 from an open to a closed position,

o retracting the clamshell excavating means 6103, a part of the guiding means 6104 and the ground taken up from the hollow casing, thereby interrupting the contact between the outer guiding surface 6101 of the guiding means 6104 and the inner wall 6006 of the hollow casing 6002; and

o discarding the ground taken up by the clamshell excavating means 6103.

[0123] These steps are repeated until the trench 6500 has a required depth 6501, as illustrated by step 605, illustrated in Fig. 6e.

[0124] It is to be understood that the excavating device 6100 may be removed after the excavation is finished as shown in step 606, illustrated in Fig. 6f. The hollow casing 6002 can be pulled back out of the trench and can be used during the excavation of a next trench. However, this step may not necessarily be taken prior to e.g. cast an in-situ cast wall in the trench, as will be set out further.

[0125] It is preferred to provide a sliding contact between the inner wall 6006 of the hollow casing 6002 and the outer guiding surface 6101 of the guiding means 6104.

[0126] During the step of excavation of the trench, the generated hole is maintained filled with a thixotropic fluid 8001. This has the advantage that caving in of the trench walls can be prevented. However it was found that the thixotropic fluid, such as bentonite, drillers mud, liquid cement and alike, also fulfils a lubrification function between the inner wall 6006 and the outer guiding surface 6101. In case liquid cement is used, the cement being brought in suspension in water or another suitable liquid, this liquid cement may be recuperated as base material for the concrete to be cast. Such recuperation may be done "in-situ" in case the concrete is mixed on the site where the trench is excavated.

[0127] Further it is preferred to apply a force other than the gravitation force in excavation direction 6200 to the clamshell excavating means 6103 during excavating. As an example a pressure providing machine, e.g. an LRB400 of Liebherr, may be used to provide hydraulic pressure to the bite when in contact with the ground 6010 to be excavated. As the movement of the clamshell excavating means 6103 is prevented from deflecting or deviating from the excavation direction 6200 by the contact of the inner wall 6006 and the outer guiding surface 6101, excavation speed and speed of lowering and lifting of the clamshell excavating means 6103 can be increased with regard to prior art methods, resulting in more efficient excavation.

[0128] It is understood by the skilled person that the depth 6501 of the trench 6500 may be chosen over a large range, but that the method according to embodiments of the present invention preferably is used to provide deep trenches, which depth may be approximately the length of the guiding means in excavation direction, such as up to 30 m, 40 m, 50 m, 60 m or even up to 100 m depth.

[0129] The trenches 6500 obtained by the method as described above, are very suitable to provide in-situ cast walls or wall modules of modular walls.

[0130] Different steps of a method according to embodiments of the present invention to in-situ cast a wall module are shown in Figures 8a to 8f. The method comprises the steps of lining out the position where the wall module is to be provided, as shown in step 801, illustrated in Figure 8a. After having lined out the position, a trench 6500 is provided as shown in step 802, illustrated in Figure 8b, using the method according to embodiments of the present invention as set out above. During excavation of the trench 6005, trench 6005 is kept filled with thixotropic fluid 8001, such as bentonite, drillers mud or alike. As the trench 6005 is very well dimensioned because of the use of the method as set out above, a precisely dimensioned elongate reinforcement element 8003 can be sunk in the trench as shown in step 803, illustrated in Fig.

8c. The reinforcement element 8003 may extend along the whole depth of the trench 6500. The elongate reinforcement element 8003 may be inserted into the trench 6005 through the hollow casing 6002, thus prior to removal of the hollow casing 6002. The hollow casing 6002 protects the trench entrance from being hit by the reinforcement element 8003, thus destroying at least part of the trench 6005, and again may function as a guiding means to guide the elongate reinforcement element 8003 downwards into the trench 6005, especially in case the perimeter of the reinforcement element 8003 is substantially equal to the inner perimeter of the trench 6005.

[0131] By introducing the reinforcement element 8003, some thixotropic fluid 8001 may flow out of the trench 6005. The hollow casing 6002 may be provided with a conduit 8011 to guide this fluid 8001 either to an adjacent location where a second trench is being excavated, or to a recuperating means where the fluid 8001 is recuperated either for recycling or discarding. In the next step as shown in 804, illustrated in Figure 8d, cast material 8007 such as e.g. concrete is cast in the trench 6500 provided with a reinforcement element 8003 and filled with fluid 8001. A casting tube 8004 for conducting cast material 8007 to the lower side of the trench 6500 is introduced into the trench, together with at least one, e.g. two vibrating units 8005 and 8006 in order to densify the cast material 8007 by vibration. By introducing the cast material 8007, some thixotropic fluid 8001 may flow out of the trench 6500, which can be either recuperated or discarded. During casting, the open end of the casting tube is preferably kept below the level of concrete already present in the trench. This to avoid mixing of the thixotropic fluid and the concrete cast. Once the trench 6500 is filed with cast material 8007 as shown in step 805, illustrated in Fig. 8e, the casting tube 8004 and the vibrating units 8005, 8006 are lifted out of the cast material 8007. Preferably the vibrating units 8005, 8006 continue to vibrate until they are completely lifted out of the cast material 8007. Alternatively the vibrating units may be removed after he casting of the concrete is completed. Once the casting is finished, as shown in step 806, illustrated in Fig. 8f, the hollow casing 6002 is removed from the trench 6500. Once the cast material 8007 is cured, e.g. hardened, for example in case of concrete, the wall module 8009 cast inside the trench 6500 is complete.

[0132] In Figure 9, a cross-section is shown of an embodiment of an elongate reinforcement element 2000, which is particularly suitable to be used in combination with trenches 6500 as a reinforcement element 8002 of an in-situ cast wall or wall module 8009, obtained according to a method in accordance with embodiments of the present invention as set out above.

[0133] An elongate reinforcement element 2000 has a substantially rectangular cross-section in a plane perpendicular to elongate direction 2001, i.e. in a substantially horizontal plane. This elongate direction 2001 will be substantially identical to the excavation direction of the trench 6500. The substantially rectangular cross-section has a first and second long side 2002 and 2003 and a first and a second short side 2004 and 2005, respectively. The elongate reinforcement element 2000 comprises a first and a second reinforcement beam 2008 and 2009 oriented in elongate direction 2001 of the reinforcement element 2000 and coupled in a fixed position to each other by means of coupling means 2006 and 2007, such as reinforcement bars, e.g. steel bars, grids or other known concrete reinforcement means.

[0134] The first reinforcement beam 2008 is provided at the first short side 2004 of the rectangular cross-section, the second reinforcement beam 2009 is provided at the second short side 2005 of the rectangular cross-section.

[0135] Each of the first and second reinforcement beams 2008, respectively 2009, has two outer flanges coupled by means of a web.

[0136] The first reinforcement beam 2008 has two outer flanges 2801 and 2802, coupled by a web 2803. The second reinforcement beam 2009 has two outer flanges 2901 and 2902, coupled by a web 2903. The webs 2803 and 2903 are substantially parallel with the short sides 2004, 2005 of the rectangular cross-section and the elongate direction 2001. The flanges 2801, 2802 and the web 2803 of the first reinforcement beam 2008 create a channel-shaped profile at both sides of the web 2803, more particularly a channel-shaped profile 2804 oriented inwards the elongate reinforcement element 2000 and a channel-shaped profile 2805 oriented outwards the elongate reinforcement element 2000.

[0137] The flanges 2901, 2902 and the web 2903 of the second reinforcement beam 2009 create a channel-shaped profile 2904 at least at the side of the web 2903 oriented inwards the elongate reinforcement element 2000. The flanges 2901, 2902 and the web 2903 of the second reinforcement beam 2009 also create a channel-shaped profile 2905 oriented outwards the elongate reinforcement element 2000.

[0138] The channel-shaped profile 2805 of the first reinforcement beam 2008, which channel-shaped profile 2805 is oriented outwards the elongate reinforcement element 2000 is filled with sacrificial material 2010, such as e.g. polystyrene foam.

[0139] The first reinforcement beam 2008 further comprises a ridge 2810 along the length of the first reinforcement beam 2008, i.e. along the web 2803 in elongate direction 2001. The ridge 2810 is liquid-tightly coupled to the web 2803 of the first elongate reinforcement beam 2008, the ridge 2810 being located at the side 2831 of the web 2803 of the first reinforcement beam 2008, which side 2831 is oriented outwards the elongate reinforcement element 2000. In case of steel beams and ridges, the ridge 2810 may be liquid-tightly welded to the beam 2008. Preferably the distance between ridge 2810 and first flange 2801 and the distance between ridge 2810 and second flange 2802 are substantially equal. Preferably the ridge 2810 is substantially parallel to the flanges 2801, 2802 and does not extend beyond the perimeter defined by the flanges 2801, 2802 and the web 2803. It is located within the channel shaped volume defined by the flanges and the web. Optionally, but not shown in Figure 9, the first reinforcement beam 2008 is provided with a liquid blocking means provided along the ridge 2810 in elongate direction 2001, at both sides of the coupling line between ridge 2810 and web 2803.

[0140] The first reinforcement beam 2008 preferably comprises a further ridge 2811 along the length of the first reinforcement beam, i.e. along the web 2803 in elongate direction 2001, which is also liquid-tightly coupled to the web 2803. This further ridge 2811 is located at the side 2832 of the web 2803 of the first reinforcement beam 2008, which side 2832 is oriented inwards the elongate reinforcement element 2000. Optionally, but not shown in Figure 9, the first reinforcement beam 2008 is provided with a liquid blocking means provided along the further ridge 2811 in elongate direction 2001, at both sides of the coupling line between ridge 2811 and web 2803.

[0141] Typical liquid blocking means that may be applied are hydrophilic water stops. Exposure to water induces expansion of the material to create a compression seal. These hydrophilic water stops are suitable for substantially non-moving joints only, which is the case in the present wall or wall module in which the elongate reinforcement element 2000 is to be used. Typical examples of hydrophilic water stops are Hydrotite, Swellstop and Duro-seal water stops as available from Greenstreak Inc. or Superstop as available from e.g. RPM/Belgium N.V. As an alternative, a tube of elastic material such as rubber can be used, which tube is filled with hardening material such as liquid cement, injected under pressure in the elastic tube.

[0142] The channel-shaped profile 2805 of the first reinforcement beam 2008, which channel-shaped profile 2805 is oriented outwards the elongate reinforcement element 2000 is filled with sacrificial material 2010.

[0143] In case the reinforcement beam 2008 is a steel beam such as an I- or H-profiled steel beam, the ridges 2810, 2811 may be steel plates or steel strips which are liquid-tightly welded to the web 2803 of the H- or I-profile. It is understood that the type of beam is chosen in function of the strength required and in function of the dimensions of the wall element to be cast.

[0144] Turning to the second reinforcement beam 2009 as shown in Figure 9, the flanges 2901 and 2902 and the web 2903 of the second reinforcement beam 2009 create a channel-shaped profile at both sides of the web 2903, in an identical or analogous way as for the first reinforcement beam 2008. The channel-shaped profile 2905 of the second reinforcement beam 2009, which channel-shaped profile 2905 is oriented outwards the elongate reinforcement element 2000 is filled with sacrificial material 2011.

[0145] The second reinforcement beam 2009 comprises a ridge 2910 along the length of the second reinforcement beam 2009, i.e. in elongate direction 2001 of the reinforcement element 2000, which ridge 2910 is liquid-tightly coupled to the web 2903 of the second reinforcement beam 2009. The ridge 2910 is located at the side 2931 of the web 2903 of the second reinforcement beam 2009, which side 2931 is oriented outwards the elongate reinforcement element 2000.

[0146] The second reinforcement beam 2009 comprises a further ridge 2911 along the length of the second reinforcement beam 2009, which ridge 2911 is liquid-tightly coupled to the web 2903 of the second reinforcement beam 2009. The further ridge 2911 is located at the side 2932 of the web 2903 of the second reinforcement beam 2009, which side 2932 is oriented inwards the elongate reinforcement element 2000.

[0147] Similar as for the first reinforcement beam 2008, a liquid blocking means may be provided along the ridges 2910 and/or 2911 1 in elongate direction 2001, at both sides of the coupling line between ridges 2910 and/or 2911 and web 2903.

[0148] The provision of ridges 2810, 2811 and 2910, 2911 to the reinforcement beams 2008 and 2009, which ridges 2810, 2811, 2910, 2911 will be integrated in cast material, have a water tightening effect. Along the join, i.e. the zones where cast material and the web 2803, 2903 of a reinforcement beam 2008, 2009 meet, and where no other mechanical coupling is present between the reinforcement beam 2008, 2009 and other parts of the reinforcing structure of the cast material, small ruptures or cracks may occur due to e.g. aging, vibrations or the "setting" of the construction comprising walls of which the reinforcement element 2000 is part. Such cracks may be sufficient to guide water from one side of the wall module towards the other side. Because of the ridge 2810, 2811, 2910, 2911 present in liquid-tight coupling to the web 2803, 2903 of the reinforcement beam 2008, 2009, the cracks will only extend up to the ridge and not from one surface of the formed wall to the other. Thereby, water is prevented from oozing through the formed wall.

[0149] Alternative elongate reinforcement elements 2100 and 2200 are shown in Figure 10a and Figure 10b. Identical references refer to analogous or identical features as in Figure 9.

[0150] The elongate reinforcement element 2100 comprises a third reinforcement beam 2101 having two outer flanges 2111 and 2112 coupled by means of a web 2113. The third reinforcement beam 2101 has its web 2113 substantially parallel with a plane defined by the long side 2003 of the rectangular cross-section and the elongate direction 2001. One of the flanges of the third reinforcement beam, here flange 2112, is coupled to and aligned with one of the first or second reinforcement beams, here the second reinforcement beam 2009.

[0151] In Figure 10a, the flange 2112 is coupled to and aligned with the second reinforcement beam 2009, by connecting the flange 2112 to the extremities of the flanges 2901 and 2902. The connection between the flange 2112 and the flanges 2901 and 2902 is a liquid-tight connection. In case of steel beams, this maybe performed by means of a liquid-tight weld.

[0152] In Figure 10b, the second reinforcement beam 2009 is a U-shaped beam, whereby the legs of the U-shape are formed by the flanges 2902 and 2901, which are oriented inwards the elongate reinforcement element 2200. The flange 2112 of the third reinforcement beam 2101 is coupled to and aligned with the second reinforcement beam 2009, by connecting the flange 2112 to the web 2903 of the beam 2009.

[0153] The flanges 2111 and 2112 and the web 2113 of the third reinforcement beam 2101 create a channel-shaped profile 2114 at least at one side of the web 2113 of the third reinforcement beam 2101, in the embodiments illustrated in Fig. 10a and 10b at both sides of the third reinforcement beam 2101. The channel-shaped profile 2114 of the at least one side of the web of the third reinforcement beam 2101 is filled with sacrificial material 2012.

[0154] In both the embodiments shown in Fig. 10a and Fig. 10b, the flanges 2111 and 2112 and the web 2113 of the third reinforcement beam create a channel-shaped profile 2114 at the side of the web of the third reinforcement beam 2101, which channel shaped profile is oriented towards one of the sides 2003 or 2002. Channel shaped profile 2114 is filled with sacrificial material 2117.

[0155] The third reinforcement beam 2101 further comprises a ridge 2119 along the length of the third reinforcement beam 2101, i.e. along the web 2113 in elongate direction 2001. The ridge 2119 is liquid-tightly coupled to the web 2113 of the first elongate reinforcement beam 2008, the ridge 2810 being located at the side 2118 of the web 2113 of the third reinforcement beam 2101, which side 2831 is oriented outwards the elongate reinforcement element 2000 to one of the sides 2002 or 2003. In case of steel beams and ridges, the ridges may be liquid-tightly welded to the beams. Preferably the distance between ridge and first flange and the distance between ridge and second flange are substantially equal. Preferably the ridge is substantially parallel to the flanges and does not extend beyond the perimeter defined by the flanges and the web. It is located within the channel shaped volume defined by the flanges and the web.

[0156] As shown in Figure 9, the elongate reinforcement element 2000 is provided with formwork 2701 providing the first surface 2702 of the reinforcement element 2000, which first surface corresponds to the plane defined by a first long side 2002 of the cross section and the elongate direction 2001. Such formwork 2701 is not illustrated in other embodiments of elongate reinforcement elements according to the present invention, but is present there as well.

[0157] The formwork shown in Fig. 9 may for example comprise a wooden structure and wooden plates, e.g. multiplex plates, to provide a smooth visible surface to the cast wall after concrete has hardened and the formwork is removed. The formwork 2701 may be removed after the wall is cast and the ground contacting the formwork 2701 is removed.

[0158] An alternative formwork 15000 is shown in Fig. 15. The formwork 15000 comprises a structure of metal beams, e.g. I- or H-profiled beams 15010 respectively 15020, coupled to each other in two, mutually substantially perpendicular directions 15011 respectively 15021, providing a grid-like structure. Steel plates 15030 and 15031 provide the outer surfaces 15001 and 15002 of the formwork 15000. The profiled beams 15010 and 15020 and the metal plates 15030 and 15031 may be coupled to each other e.g. by welding, as such providing a box. The volumes 15040 between the plates 15030 and 15031 and the beams 15001 and 15002 may be filled with concrete, e.g. metal fiber reinforced concrete, comprising e.g. Dramix®-fibers. This may be done by first coupling, e.g. by welding, one plate 15030 to the plurality of beams 15010 and 15020, filling the volumes between the beams, and closing the volumes by coupling the other metal plate 15031 to the beams 15010 and 15020, thereby enclosing the cast concrete. Optionally, means 15050 for lifting the formwork 15000 are provided, e.g. metal loops, which may allow the formwork to be lifted in a direction 15011.

[0159] The formwork 15000 may be provided in contact with the first and second beam 2008 and 2009 by having the formwork 15000 resting and supporting on feet 16000 fixed to the outer flange 2801 respectively 2901, which have a lip 16001 preventing the formwork 15000 to move in a direction away from the beams.

[0160] Once the reinforcement element is sunken in the excavated trench, the trench is filled with concrete, as will be set out further, and after the concrete is hardened, the formwork 15000 may be pulled up, i.e. pulled out of the trench. Since there is no permanent mechanical fixation between the formwork and the reinforcement beams, and since the formwork is made resistant to pulling forces due to the provision of e.g. the beams inside the box, the formwork may slide, in front of the beams, out of the trench, while providing to the cast wall a flush visible surface where the plate has contacted the cast material. As such a reusable formwork is provided and used.

[0161] Seen the high specific weight of the formwork, the formwork will have few or no tendency for buoying in the thixopropic fluid in the trench, e.g. in the bentonite or drilling mud used to fill the trench. Preferably the specific weight of the formwork is more than 1280 kg/m^3 such as for example more than more than 3500 kg/m^3.

[0162] The first reinforcement beam 2008 has its first flange 2801 oriented towards the first long side 2002 and the second reinforcement beam 2009 has its first flange 2901 oriented towards the first long side 2002. The sacrificial material 2010 respectively 2011 is provided between the first flange 2801 of the first reinforcement beam 2008 and the formwork 2701 and between the first flange 2901 of the second reinforcement beam 2009 and the formwork 2007.

[0163] As further shown in Figure 9, the first reinforcement beam 2008 has its second flange 2802 oriented towards the second long side 2003 of the rectangular cross-section of the elongate reinforcement element 2000. The second reinforcement beam 2009 has its second flange 2902 also oriented towards the second long side 2003. The elongate reinforcement element 2000 is provided with a spacer 2703 at the second flange 2802 of the first reinforcement beam 2008 and at the second flange 2902 of the second reinforcement beam 2009 for accommodating the thickness 2704 (hereafter Tre) of the elongate reinforcement element 2000 with the width of the trench in which the reinforcement element 2000 is to be used. As shown in Figure 9, the thickness Tre and the width 2705 (hereafter Wre) of the elongate reinforcement element accommodates the dimensions of the inner space of the hollow casing 6002. When the elongate reinforcement element 2000 is inserted into a trench 6500 through the hollow casing 6002, the inner wall 6006 of the hollow casing 6002 guides the elongate reinforcement element 2000 and prevents the movement of the elongate reinforcement element 2000 to deviate from its insertion direction.

[0164] Turning back to the method to in-situ cast wall module, elongate reinforcement elements 2000, 2100, 2200 according to embodiments of an aspect of the present invention, are suitable to cast wall modules of a modular wall of an at least partially sunken room.

[0165] The use of an elongate reinforcement element 2000, 2100, 2200 comprising formwork 2701 as set out above and as shown in Figure 9, has the advantage that, once the wall module or the wall of which the wall module is part, is cast, the ground present at the side of the wall being provided with formwork 2701 can be removed. This is usually the inner side of the at least partially sunken room to be provided. When the formwork 2701 is removed, the surface of the wall from which the formwork 2701 is removed, may be the visible surface of cellars, basements, underground parking space garages and alike sunken or partially sunken rooms which surface condition already match the requirements of a finished wall.

[0166] Method steps of an embodiment of a method to in situ cast an at least partially sunken modular wall according to an aspect of the present invention is shown in Figure 11a to 11e. A view of a cross-section according to a plane perpendicular to the excavation direction of steps 11100, 11200, 11300 and 11500 are shown for clarity in figure 11f. The method comprises the steps of:

- providing a first wall module 11001 and second wall module 11002, using one of the methods to in-situ cast a wall module according to embodiments of the present invention, wherein an elongate reinforcement element 2000, 2100, 2200 having two elongate reinforcement beams 2008, 2009 with channel-shaped profile 2805, 2905 filled with sacrificial material 2010, 2011, which channel-shaped profiles 2805, 2905 are oriented outwards the reinforcement element 2000, 2100, 2200 and provide the outer ends of the cast wall modules 11001, 11002, the distance between the first and second wall being D, as shown in step 11100, illustrated in Fig. 11 a both in vertical cross-section and in top view;
- excavating an intermediate trench 11004 of width D between the first and second wall modules 11001, 11002 as shown in step 11200, illustrated in Fig. 11b, by
    - o providing an adapted clamshell excavating means 11003 having a set of buckets 11030 with bite profile adapted to remove the sacrificial material from the channel shaped profiles 2805, 2905;
    - o excavating the intermediate trench 11004 between the first and second wall modules 11001, 11002 by means of the adapted clamshell excavating means 11003, whereby the channel shaped profiles 2805, 2905 guide the adapted clamshell excavating means 11003 until the intermediate trench 11004 has a required depth;
- providing a reinforcement element 11005 in accordance with embodiments of the present invention in the intermediate trench 11004 as shown in step 11300, illustrated in Fig. 11c in vertical cross-sectional view and in top view;
- filling the intermediate trench 11004 with cast material 11006 as shown in step 11400, illustrated in Fig. 11d, which may be done in a similar way as during casting of the wall modules 11001 and 11002; additionally an elongate insert reinforcement element 12000 may be inserted, as will be set out using Figure 12.
- curing the cast material 11006 in the intermediate trench 11004, whereby the modular wall is provided comprising the two wall modules 11001 and 11002, and an intermediate wall module 11007, as shown in step 11500, illustrated in Fig. 11e.

[0167] The clamshell excavating means 11003 may be adapted to remove the sacrificial material 2010, 2011 by providing additional teeth to the bite of the buckets 11030 of the clamshell excavation means 11003, which teeth match the inside of the channel-shaped profiles 2805, 2905. By having the clamshell excavation means 11003 adapted to remove the sacrificial material 2010, 2011, the clamshell excavation means 11003 is guided in excavation direction 902 by the reinforcement beams 2008, 2009 at both sides of the clamshell excavation means 11003. This prevents the clamshell excavation means 11003 from deflecting from the excavation direction 902. Optionally, a guiding means 11009 may be used, which snugly fits between the outer edges of the flanges of the profiles 2008 and 2009, i.e. make as sliding contact with the outer edges of the flanges of profiles 2008 and 2009.

[0168] Also during excavation of the intermediate trenches 11004, the already excavated hole may be maintained at least partially filled, an preferably full, with a thixotropic fluid, for stability reasons.

[0169] A suitable elongate insert reinforcement element 12000, for cooperating with an elongate reinforcement element 2000 of figure 9, and to be inserted in the intermediate trench 11004 is shown in Figure 12.

[0170] The elongate insert reinforcement element 12000 is provided with formwork 2601 providing the first surface 2602 of the reinforcement element 12000, which first surface 2602 corresponds to the plane defined by a first long side of the cross-section and the elongate direction 2001 of the elongate reinforcement element 12000.

[0171] Reinforcement means 2603 comprises profiled reinforcing components 2630, which have one side substantially parallel to the first surface 2602. Between reinforcing components 2630 and the formwork 2601, a slit 2640 is provided for matching, i.e. contacting, with the flanges 2801 and 2901 when the elongate reinforcement element 12000 is inserted in the trench dug out between two adjacent elongated reinforcement elements. The formwork and reinforcing components will match with the flanges such that, during insertion of the elongate insert reinforcement element 12000, this elongate insert reinforcement element is guided by the slit 2640. Optionally the reinforcing means 12000 comprises additional profiled reinforcing components 2631, which have one side substantially parallel to the first surface 2602, and which are positioned relative to the first profiled reinforcing components 2630 such that the additional reinforcing components are to match with the inner side of the flanges 2802 and 2902. A formwork similar to the formwork 15000 described above relative to figure 15 may be used. When sinking the insert reinforcing means in the trench between two cast walls, the formwork may slide along he beams until the formwork contacts the squares optionally present at the flanges of the beams. Again here, after casting and hardening the intermediate wall, the formwork may be pulled out of the trench.

[0172] A multitude of profiled reinforcing components 2630 and 2631 are provided in elongate direction, all being substantially parallel to each other and preferably all substantially perpendicular with the elongate direction. The distance of the profiled reinforcing components 2630 is about 0.5m to 1 m. The profiled reinforcing components may be set square profiles, I-, H-, U- profiles or may be tubes such as tubes with a circular , rectangular or even square cross section. The thickness and strength of the reinforcing components is chosen according to the required reinforcement to be provided. Reinforcement means 2603 and formwork 2601 are constructed to fit nicely with the flanges 2801, 2802, 2901, 2902 of the beams 2008 and 2009 of the elongated reinforcement element 2000 of the adjacent wall modules 11001 and 11002. As shown here in this embodiment, the beams 2008 and 2009 are provided with liquid blocking means 2610 provided along the ridges 2810, 2910 oriented outwards the beams 2008 and 2009 of the adjacent wall modules 11001 and 11002.

[0173] By alternately providing wall modules 11001, 11002 and intermediate wall modules 11004, a modular wall may be provided with any given length. By using appropriate elongate reinforcement elements having reinforcement beams with channel shaped profiles provided to webs of the beam, which webs are oriented parallel to the long side of a rectangular cross section, also modular walls having wall segments meeting in a corner may be provided, as shown in Figure 13. Figure 13 shows a cross-section 13000 of a sunken room having four wall segments 13001, 13002, 13003, and 13004 and four corners 13005, 13006, 13007 and 13008.

[0174] At each corner, as an example the corner 13005 of which a detail is shown, in Fig. 13 as well, one of the modules 13010 of the wall segment 13004 is provided with an elongate reinforcement element 2100 as shown in Fig. 10b, comprising a third reinforcement beam 2101 having two outer flanges 2111 and 2112 coupled by means of a web 2113, substantially parallel with the long side 2003 of the rectangular cross-section and the elongate direction of the elongate reinforcement element 2100. One of the flanges of the third reinforcement beam 2101, here flange 2112, is coupled to and aligned with the second reinforcement beam 2009.

[0175] The flanges 2111 and 2112 and the web 2113 of the third reinforcement beam create a channel-shaped profile 2114 at the side of the web of the third reinforcement beam 2101, which channel shaped profile is oriented towards the adjacent and meeting wall segment 13001 which whom a corner 13005 is formed. As such, two channel-like profiles, one provided by channel-shaped profile 2114 of the third reinforcement beam of module 13010, the other by the reinforcement beam 2008 of the wall module 13011, all filled with sacrificial material may be provided, which can be used to guide an adapted clamshell excavation means during excavation of an intermediate trench during the process of casting a wall module 13012.

[0176] When the ground at one side of the cast modular wall is at least partially removed, and in case the reinforcement elements were provided with formwork at one side, the formwork is removed, and the modular wall is suitable to be used as sunken or partially sunken modular wall. In case the modular wall encloses an enclosed volume, when the ground present in the enclosed volume is at least partially removed, and in case the reinforcement elements were provided with formwork at one side, the formwork is removed, and the modular wall is suitable to be used as sunken or partially sunken modular wall of a sunken or partially sunken room.

[0177] As shown in Figure 14, it is to be understood that the reinforcement elements 14001 may also be provided with armoring elements 14003 on which other construction elements such as floors, intermediate floors and alike, may be coupled. An example is a Stabox®. The reinforcement elements 14001, comprising a first and a second reinforcement beam 2008 and 2009 may also be provided with apertures 14002 suitable for passing pipelines, utility lines, power lines and alike. The first and a second reinforcement beam 2008 and 2009 are coupled in a fixed position to each other by means of coupling means 14004, such as reinforcement bars, e.g. steel bars, grids or other known concrete reinforcement means

[0178] It is to be understood that although preferred embodiments, specific constructions and configurations, as well as materials, have been discussed herein for devices according to the present invention, various changes or modifications in form and detail may be made without departing from the scope and spirit of this invention. Steps may be added to or removed from methods described while still staying within the scope of the present invention.

Claims

1. An elongate reinforcement element for reinforcing an in-situ cast wall module, the reinforcement element having a substantially rectangular cross-section according to a plane perpendicular to an elongate direction, the cross-section having a first and second long side and a first and a second short side, wherein the elongate reinforcement element comprises a first and a second reinforcement beam fixed to each other by means of a coupling means, the first reinforcement beam being provided at the first short side of the rectangular cross section, the second reinforcement beam being provided at the second short side of the rectangular cross section, each of the first and second reinforcement beam having two outer flanges coupled by means of a web, the first and second reinforcement beams having their webs substantially parallel with the short side of the rectangular cross-section and the elongate direction, the flanges and the web of the first reinforcement beam creating a channel-shaped profile at both sides of the web, the flanges and the web of the second reinforcement beam creating a channel-shaped profile at least at the side of the web oriented inwards the elongate reinforcement element, the channel-shaped profile oriented outwards the elongate reinforcement element of the first reinforcement beam being filled with sacrificial material, the first reinforcement beam further comprising a ridge being liquid-tightly coupled to the web along the web in elongate direction, the ridge being located at the side of the web of the first reinforcement beam, which side is oriented outwards the elongate reinforcement element.

2. An elongate reinforcement element according to claim 1, wherein the flanges and the web of the second reinforcement beam create a channel-shaped profile at both sides of the web, the channel-shaped profile oriented outwards the elongate reinforcement element of the second reinforcement beams being filled with sacrificial material.

3. An elongate reinforcement element according to claim 1, wherein a third reinforcement beam is provided having two outer flanges coupled by means of a web, the third reinforcement beam having its web substantially parallel with the long side of the rectangular cross-section and the elongate direction, one of the flanges of the third reinforcement beam being coupled to and aligned with the second reinforcement beam, the flanges and the web of the third reinforcement beam creating a channel-shaped profile at least one side of the web of the third reinforcement beam, the channel-shaped profile of said at least one side of the web of the third reinforcement beam being filled with sacrificial material.

4. An elongate reinforcement element according to any of claims 1 to 3, wherein the elongate reinforcement element is provided with formwork providing the first surface of the reinforcement element, which first surface corresponds to the plane defined by the first long side of the cross-section and the elongate direction.

5. An elongate reinforcement element according to claim 4, wherein the formwork has a specific weight of more than 1280 kg/m^3.

6. An elongate reinforcement element according to claim 4 or 5, the first reinforcement beam and the second reinforcement beam having a first flange oriented towards the first long side, wherein the sacrificial material is provided between the first flange of the first reinforcement beam and the formwork and wherein sacrificial material is provided between the first flange of the second reinforcement beam and the formwork.

7. An elongate reinforcement element according to any of claims 1 to 6, the first reinforcement beam and the second reinforcement beam having a second flange oriented towards the second long side, wherein the reinforcement element is provided with a spacer at the second flange of the first reinforcement beam and at the second side of the second reinforcement beam for accommodating the thickness of the reinforcement element with the dimensions of a trench in which the reinforcement element is to be used.

8. An elongate reinforcement element according to any of claims 1 to 7, wherein the second reinforcement beam further comprises a ridge along the web in elongate direction, the ridge being liquid-tightly coupled to the web of the second reinforcement beam, the ridge being located at the side of the web of the

second reinforcement beam, which side is oriented outwards the elongate reinforcement element.

9. An elongate reinforcement element according to claim 8, wherein the second reinforcement beam further comprises a liquid blocking means provided along the ridge, at both sides of the coupling line between ridge and web.

10. An elongate reinforcement element according to any of claims 1 to 9, wherein one or more of the first or second reinforcement beams comprises a further ridge along the web in elongate direction, liquid-tightly coupled to the web of the respective reinforcement beam, the further ridge being located at the side of the web of the respective reinforcement beam, which side is oriented inwards the elongate reinforcement element.

11. An elongate reinforcement element according to claim 10, wherein the first reinforcement beam further comprises a liquid blocking means provided along the ridge, at both sides of the coupling line between ridge and web.

12. An elongate insert reinforcement element for being inserted between a first and a second elongate reinforcement element according to any of claims 1 to 11, the elongate insert reinforcement element comprising a formwork providing the first surface of the elongate insert reinforcement element, the elongate insert reinforcement element further comprising a reinforcement means comprising profiled reinforcing components having one side substantially parallel to the first surface, and, between said reinforcing components and the formwork, a slit adapted for contacting the flanges of said first and said second elongate reinforcement elements.

13. An elongate insert reinforcement element according to claim 12, wherein the formwork has a specific weight of more than 1280 kg/m^3

Fig. 1

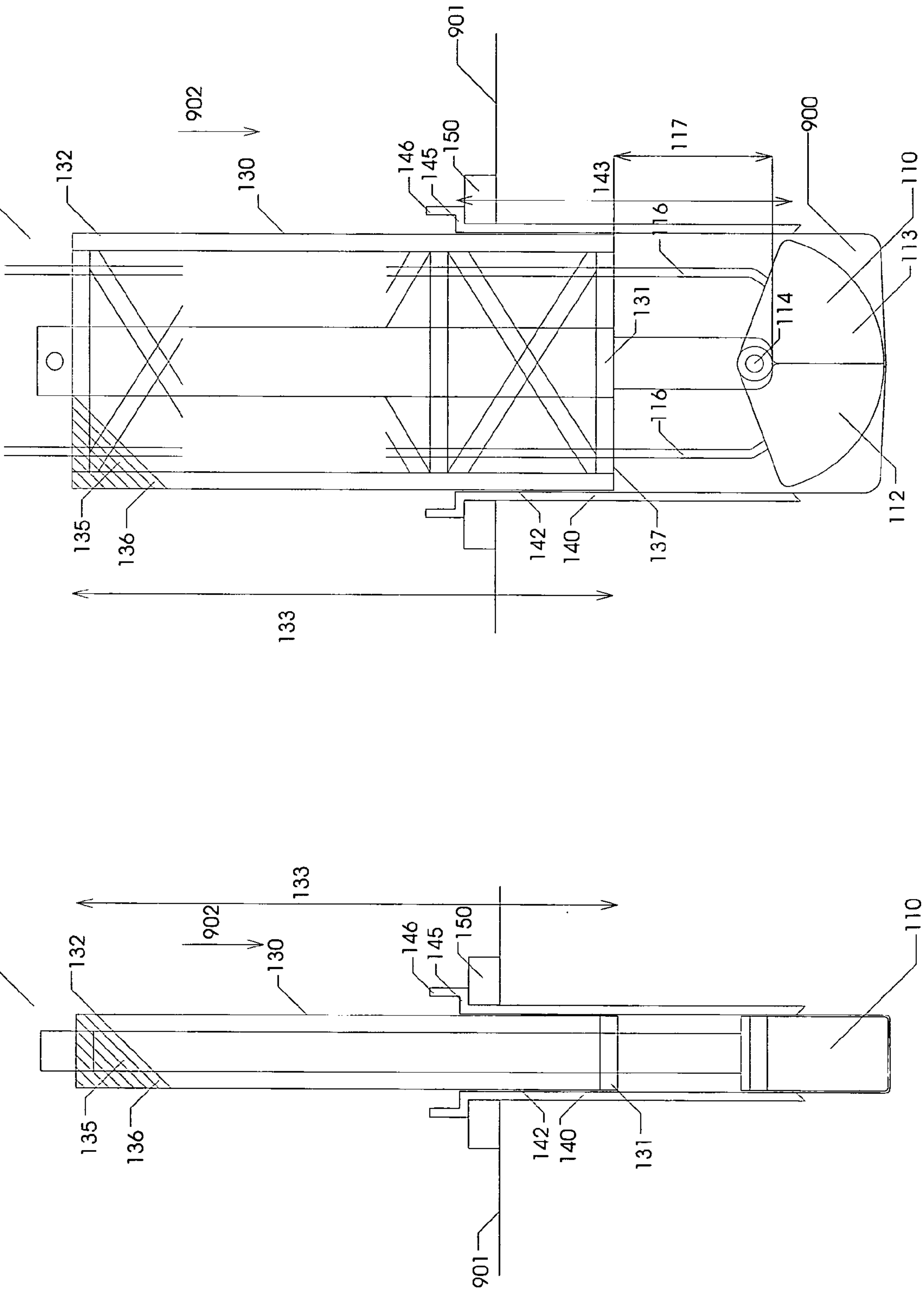

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Fig. 3

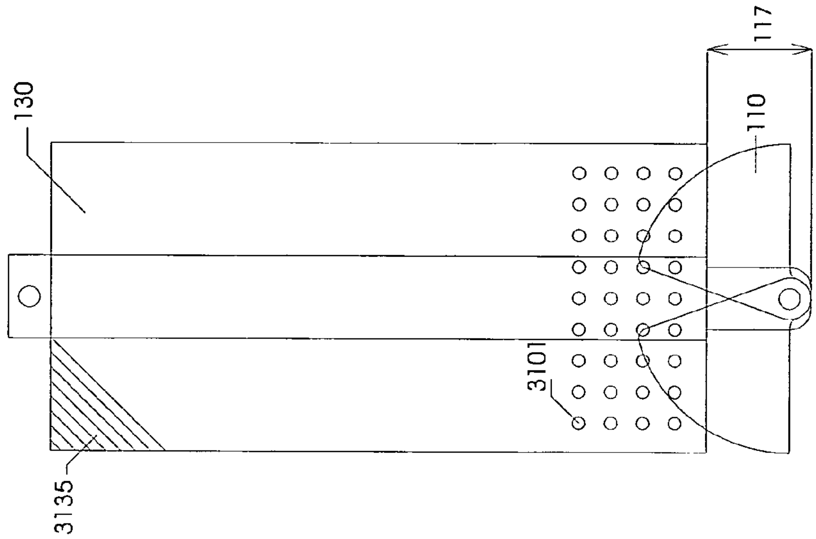

Fig. 2

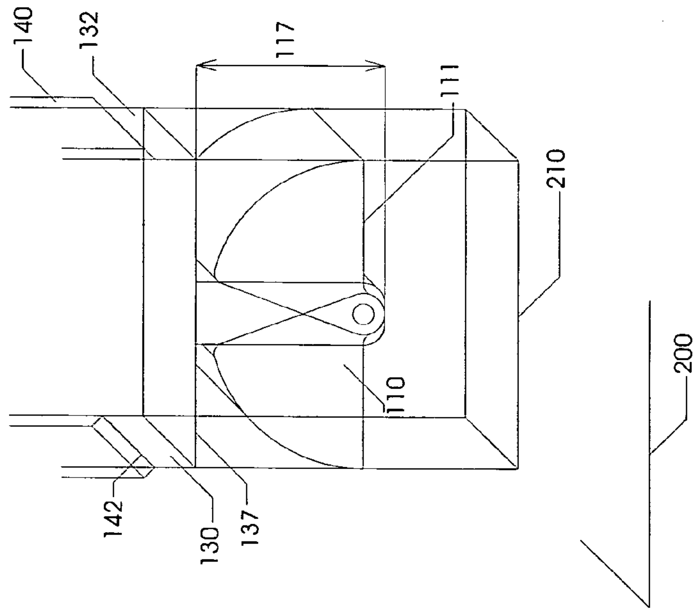

Fig. 4a

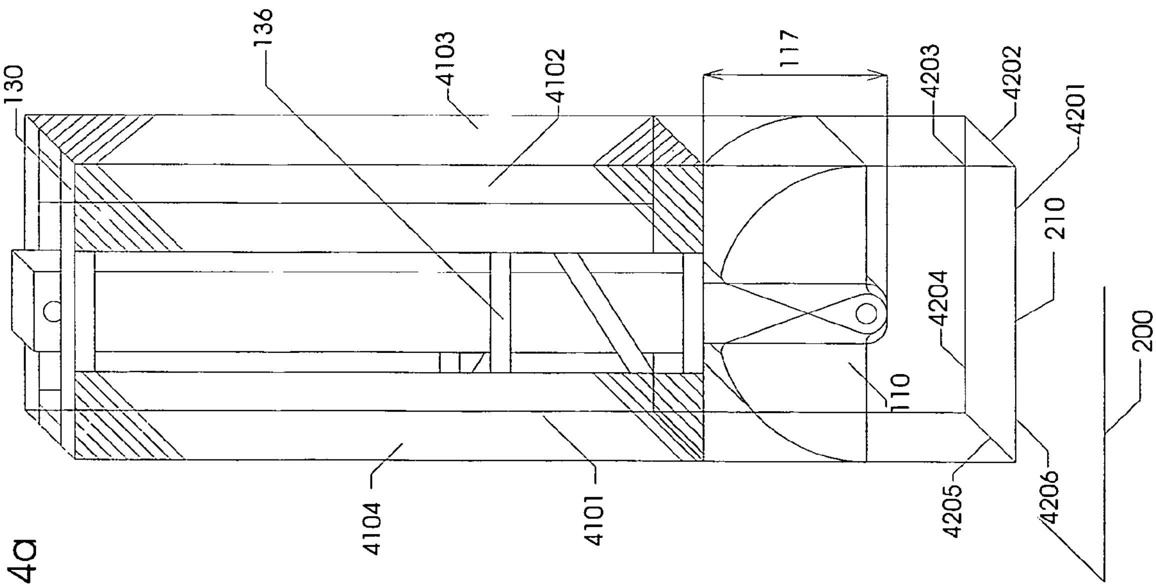
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Fig. 4b

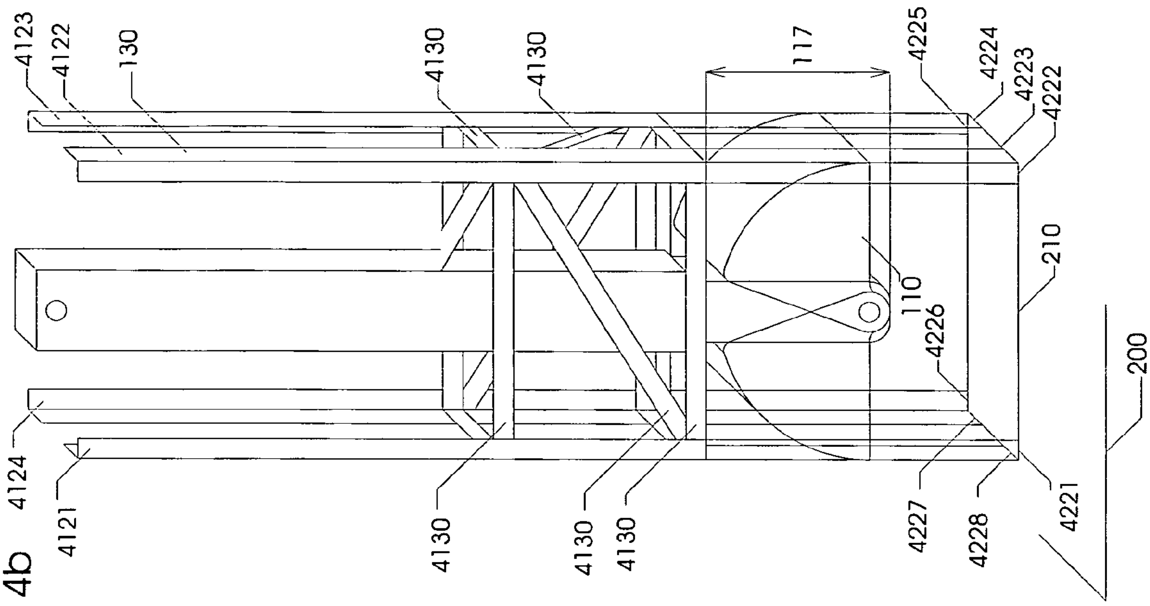
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Fig. 5

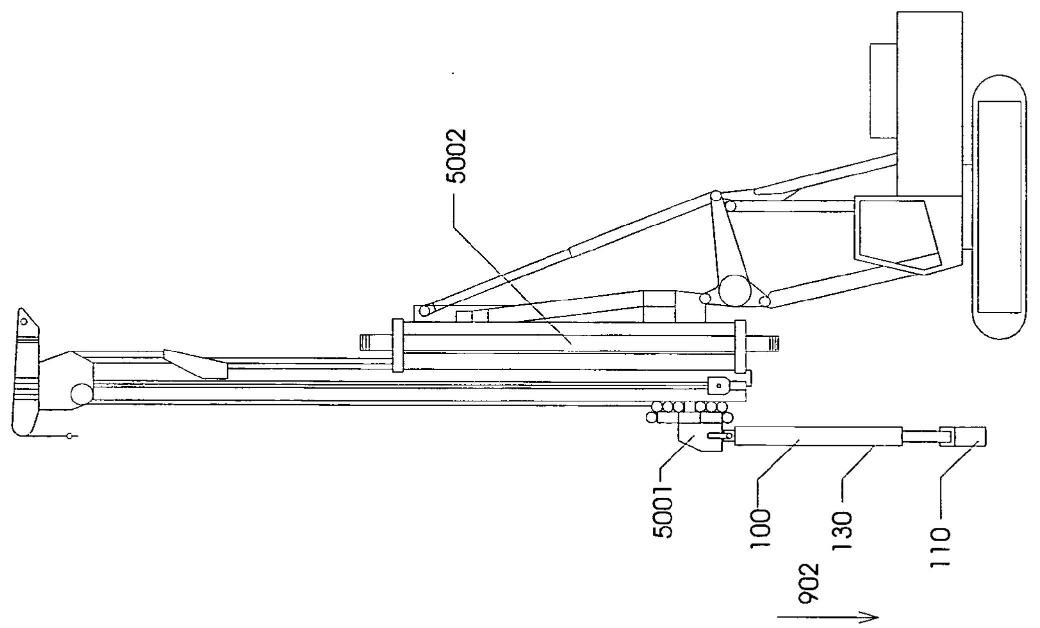


Fig. 6a

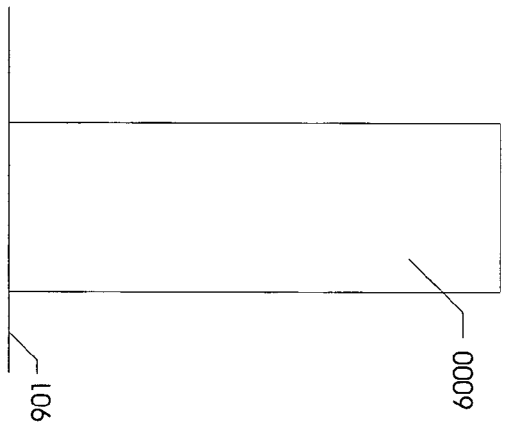
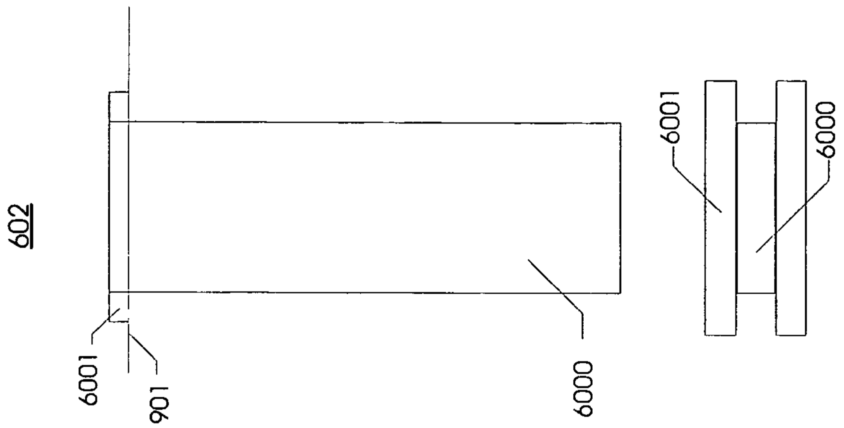


Fig. 6b



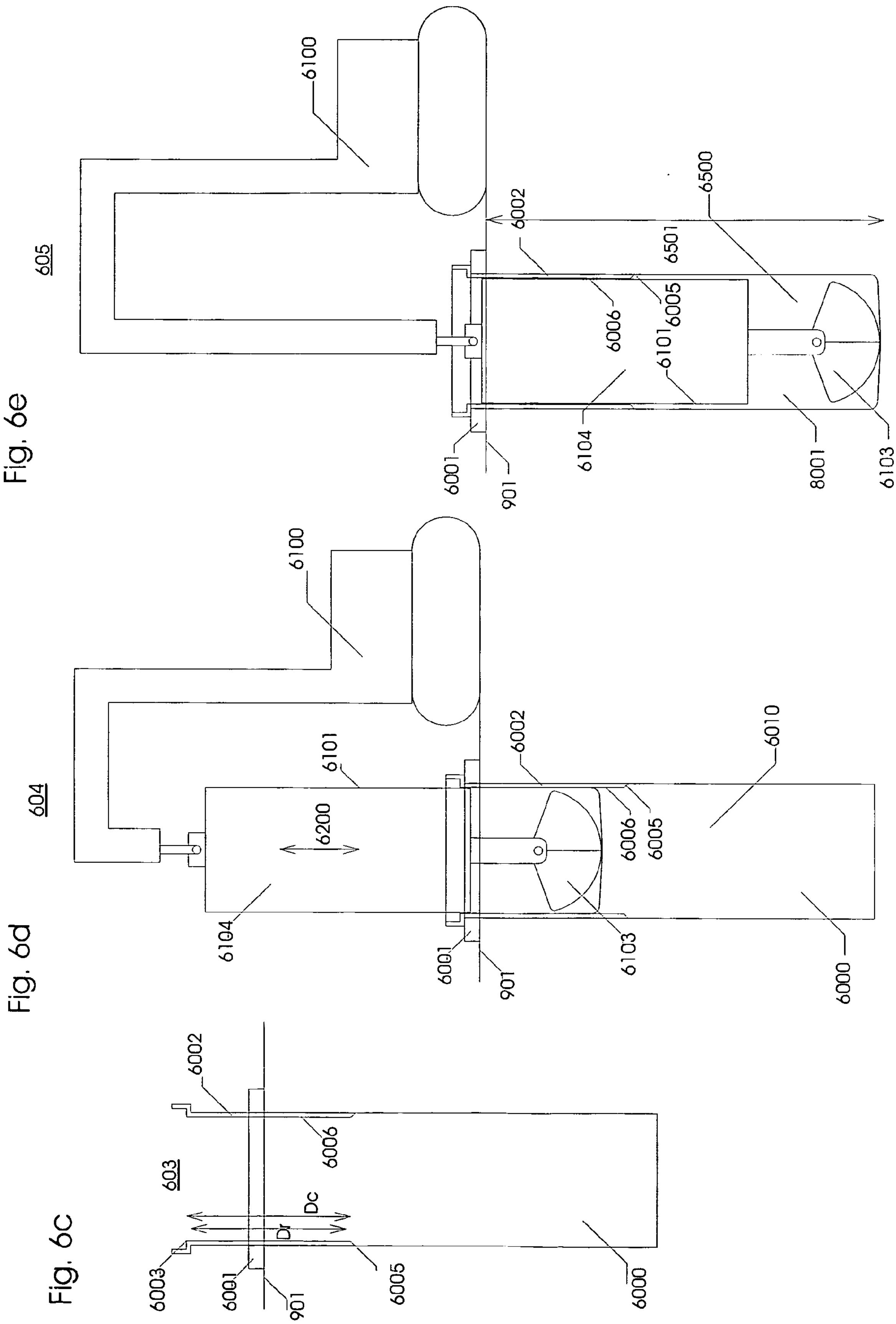


Fig. 6c
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Fig. 6d
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Fig. 6e
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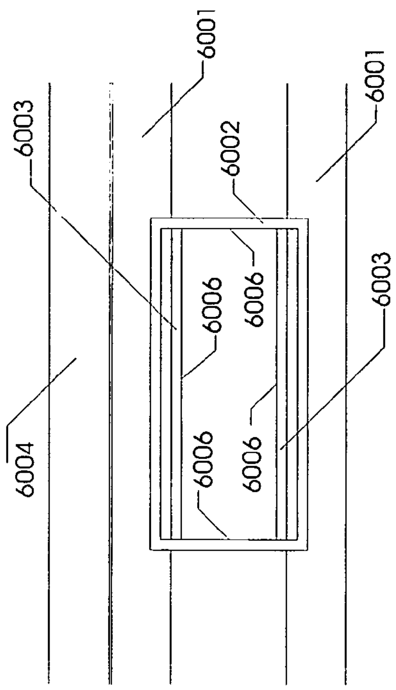


Fig. 7a

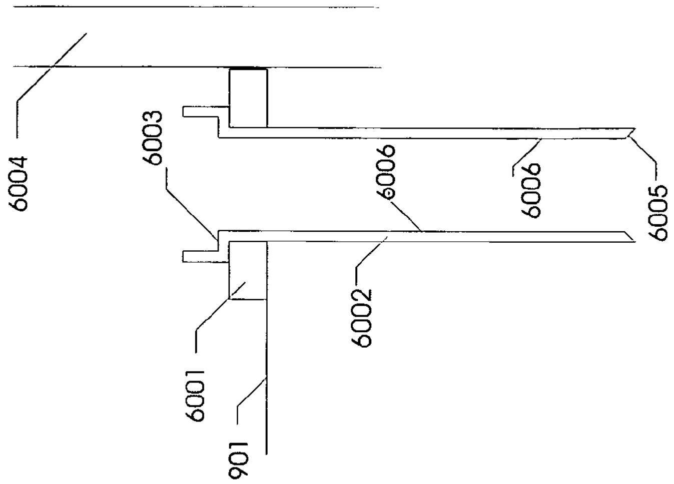


Fig. 7b

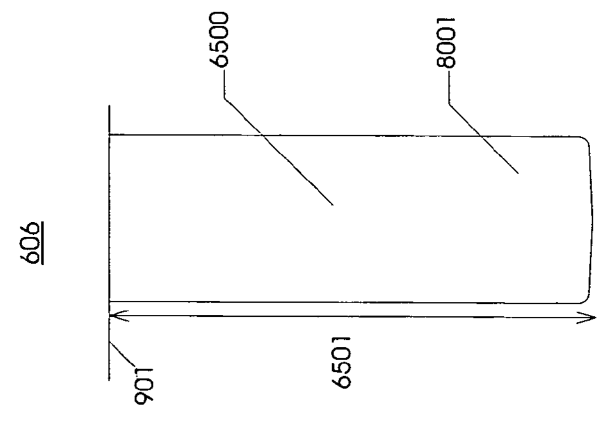


Fig. 6f

Fig. 7c

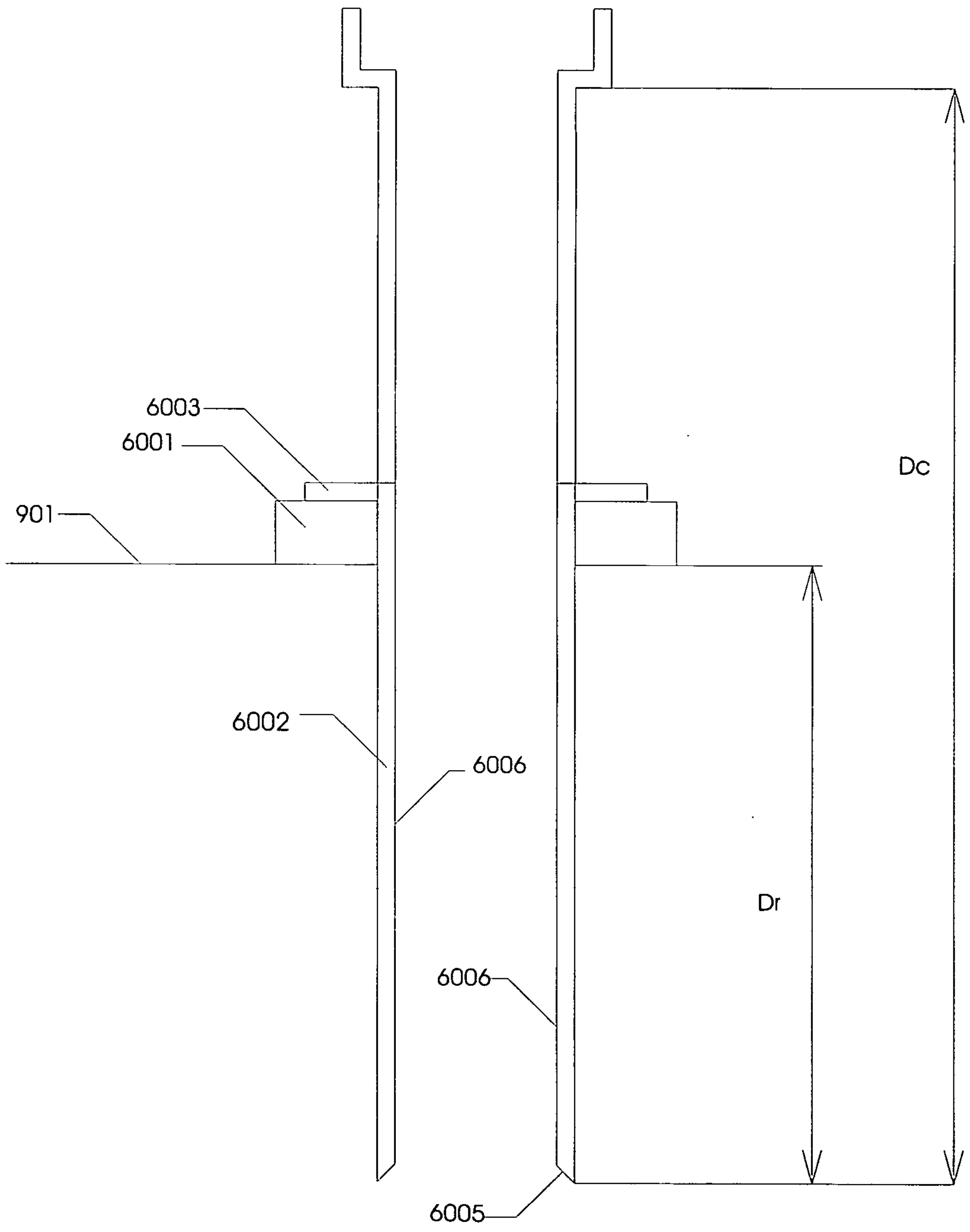


Fig. 8a

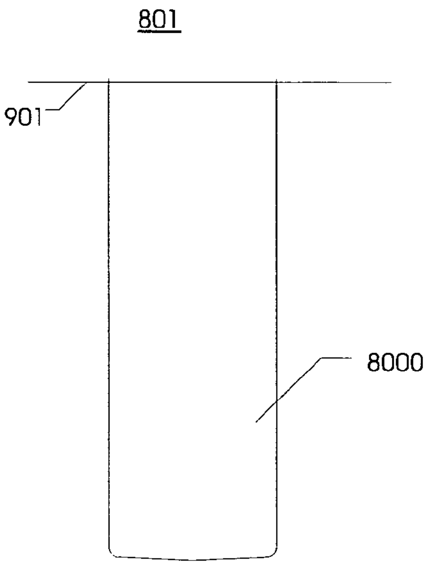


Fig. 8b

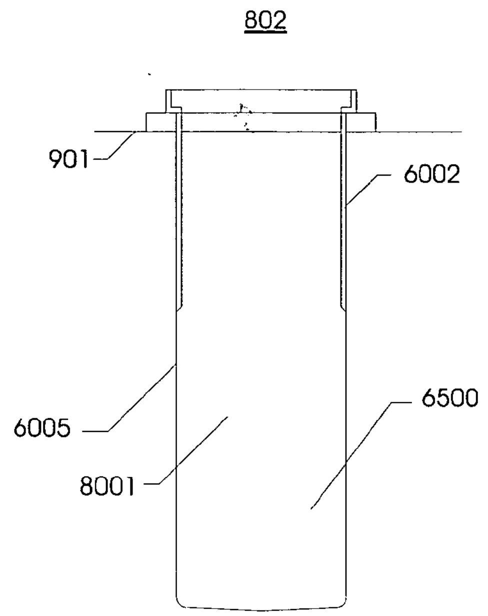


Fig. 8c

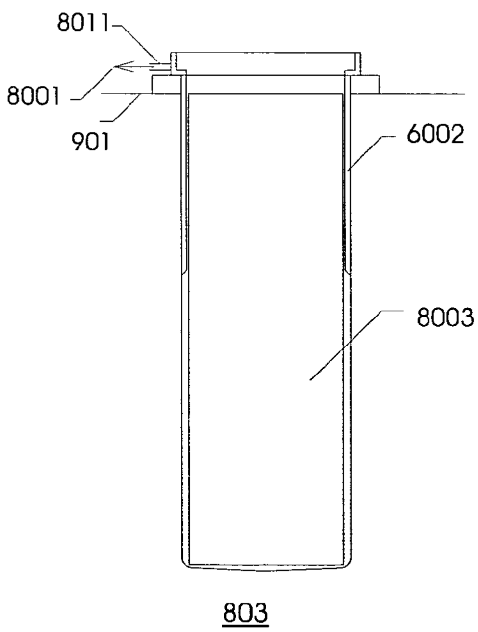


Fig. 8d

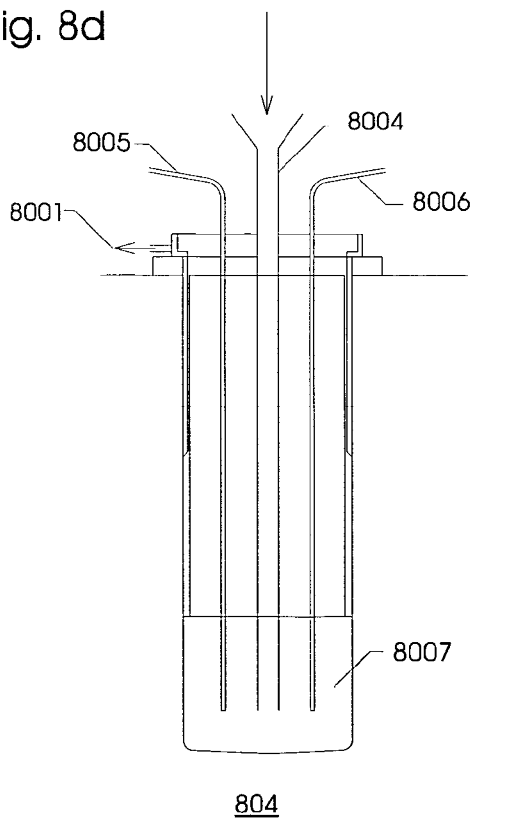


Fig. 8e

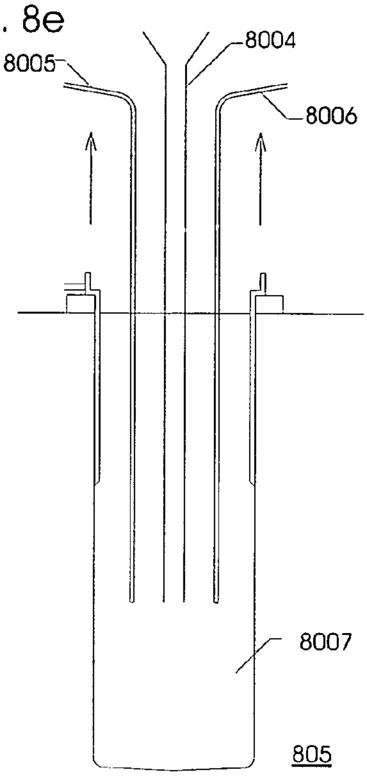
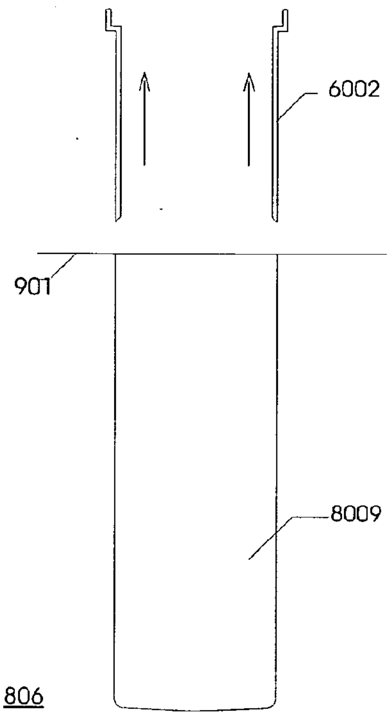


Fig. 8f



Figuur 9

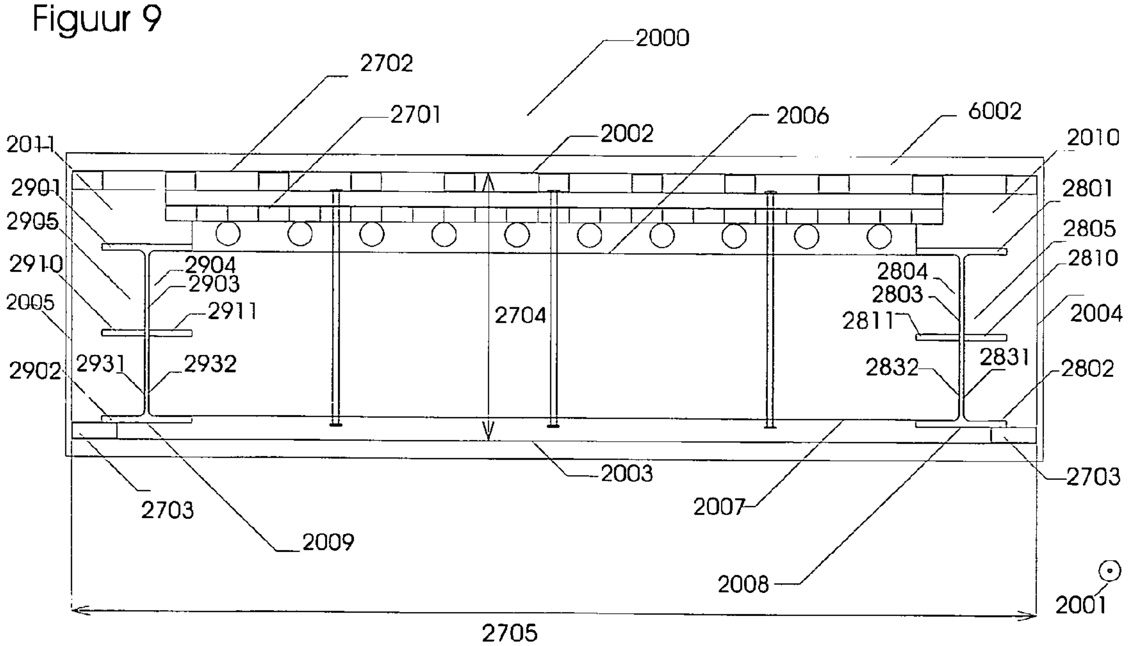


Fig. 10a

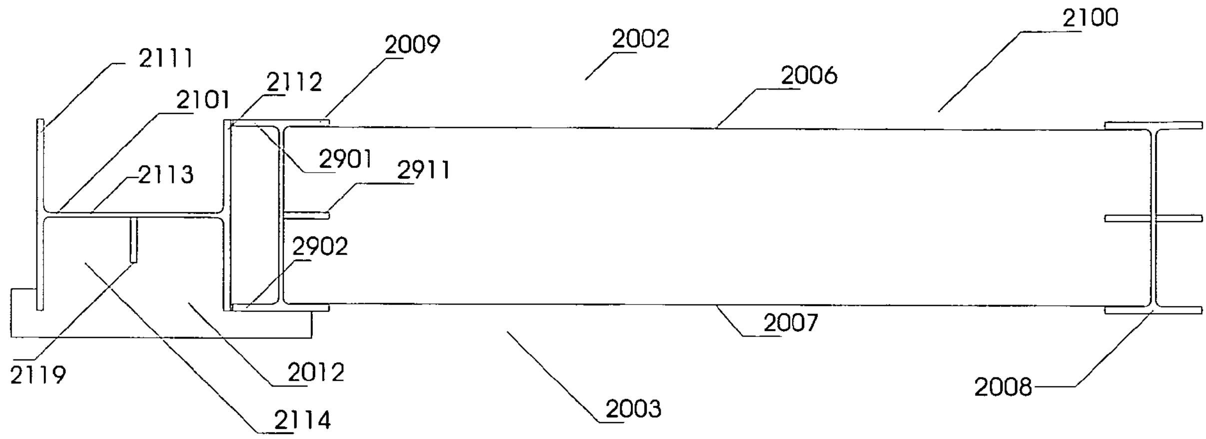


Fig. 10b

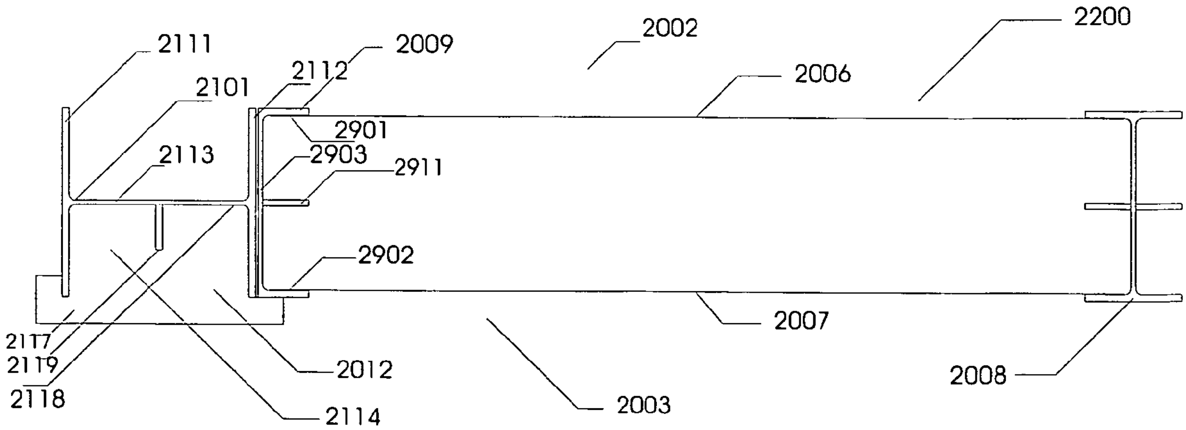


Fig. 11a

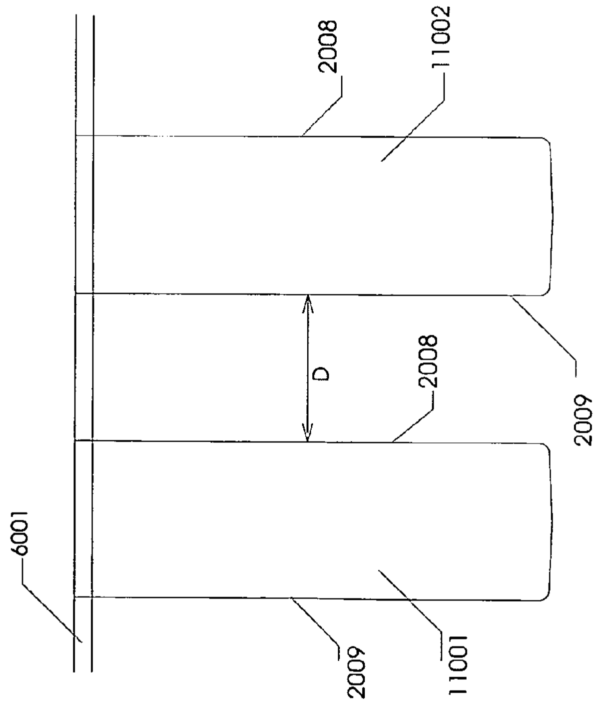


Fig. 11b

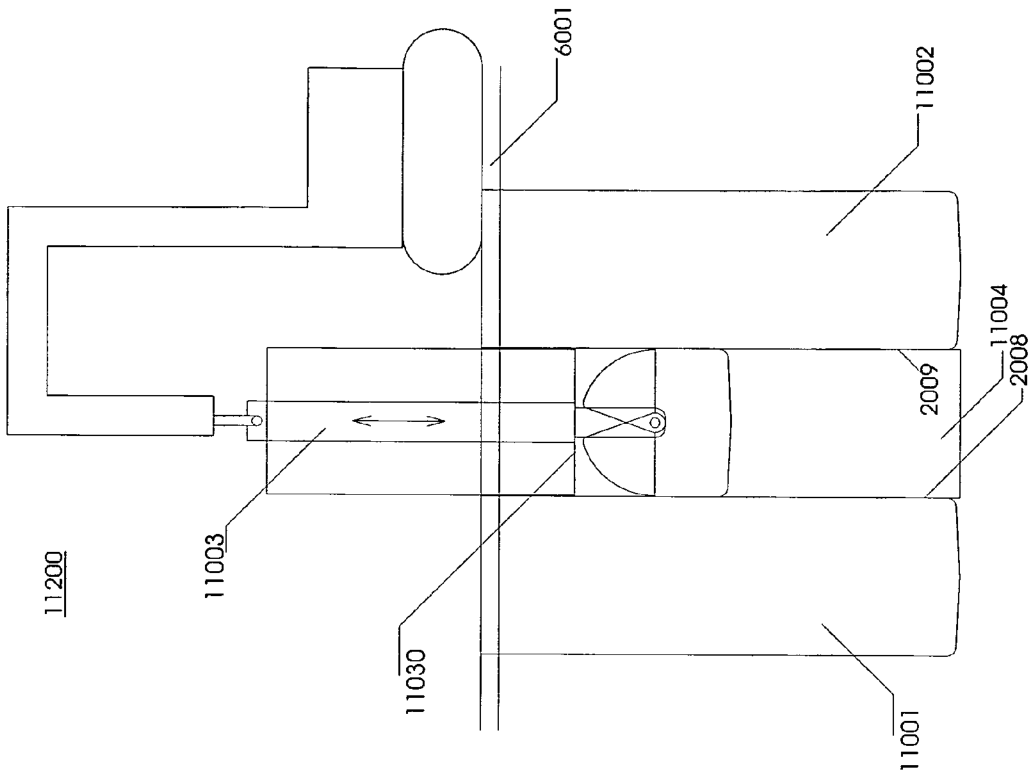


Fig. 11d

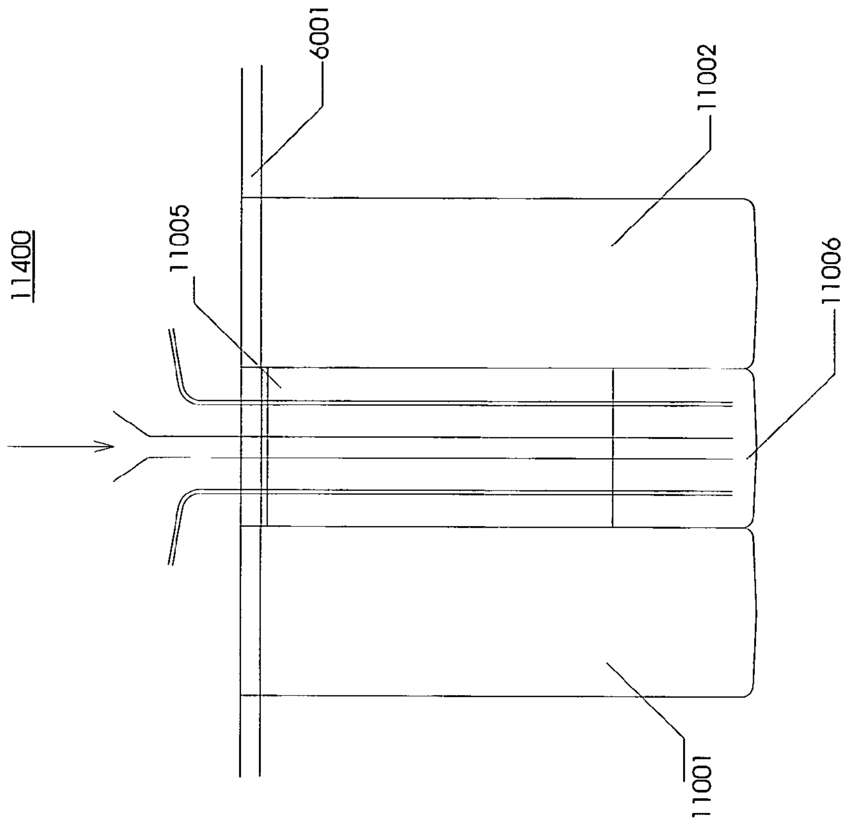


Fig. 11c

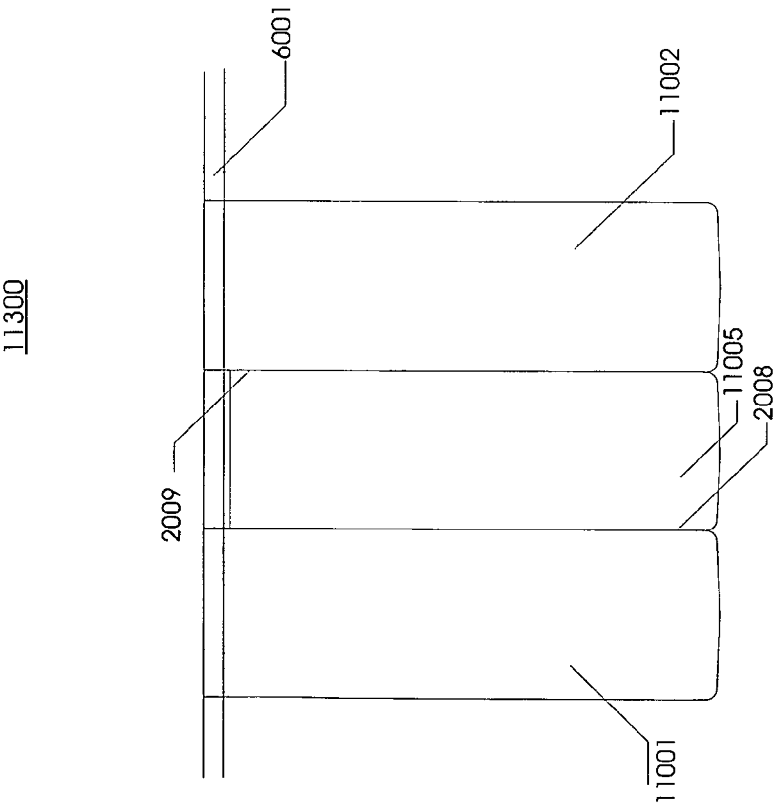


Fig 11f

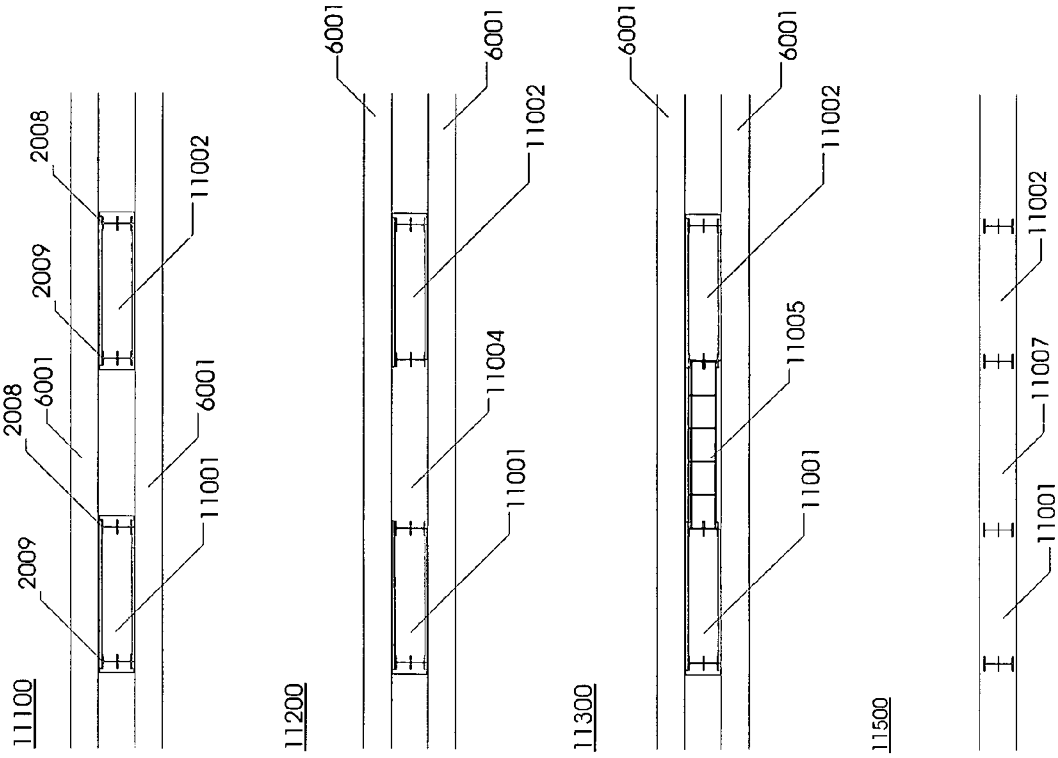


Fig. 11e

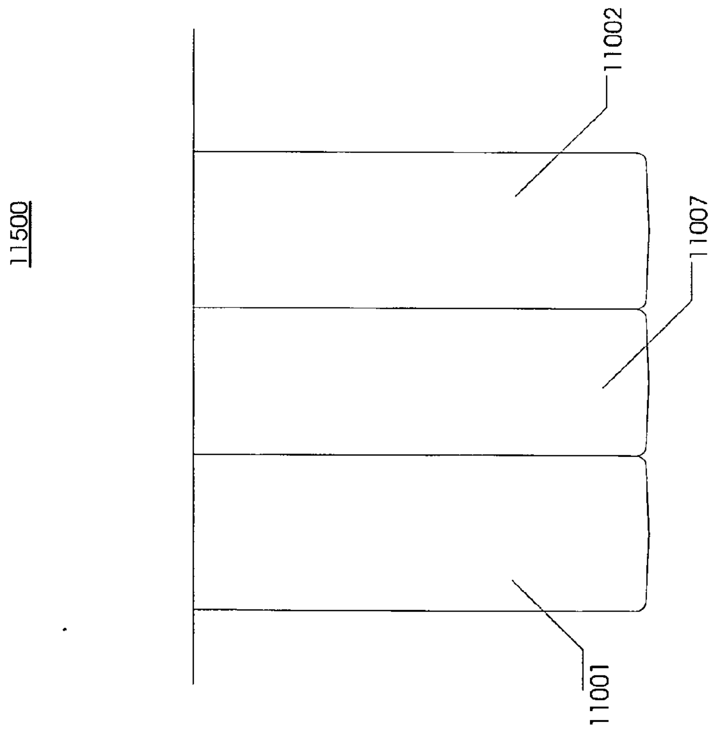


Fig. 12

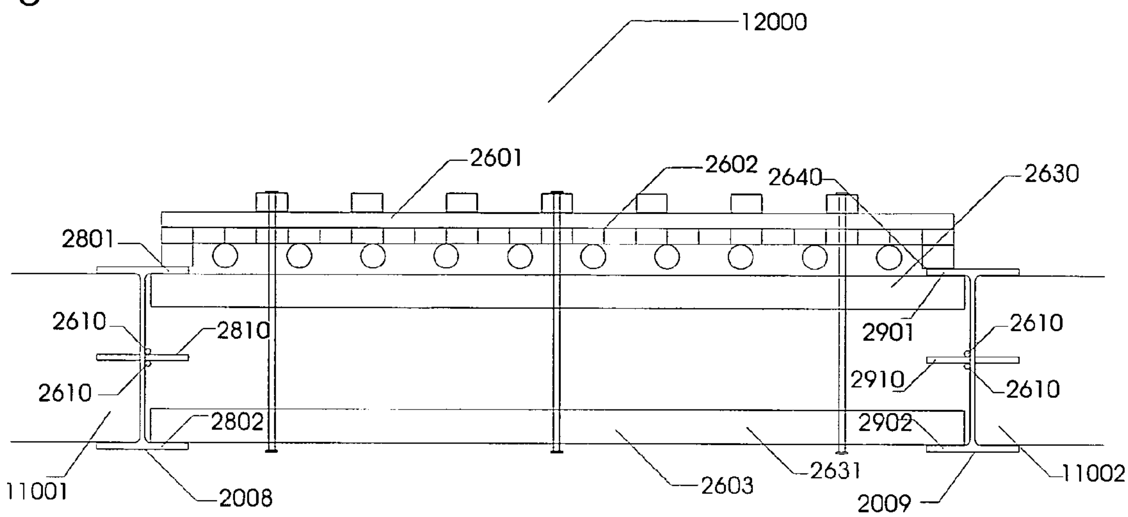

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Fig. 13

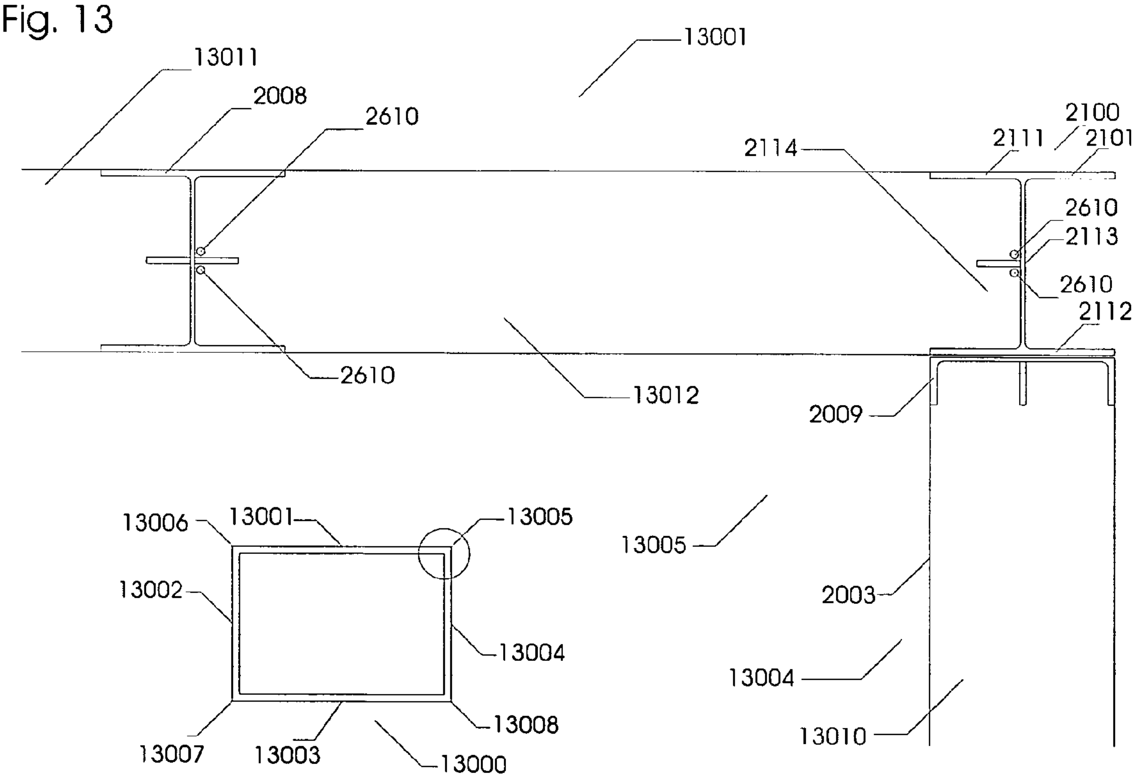
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Fig. 14

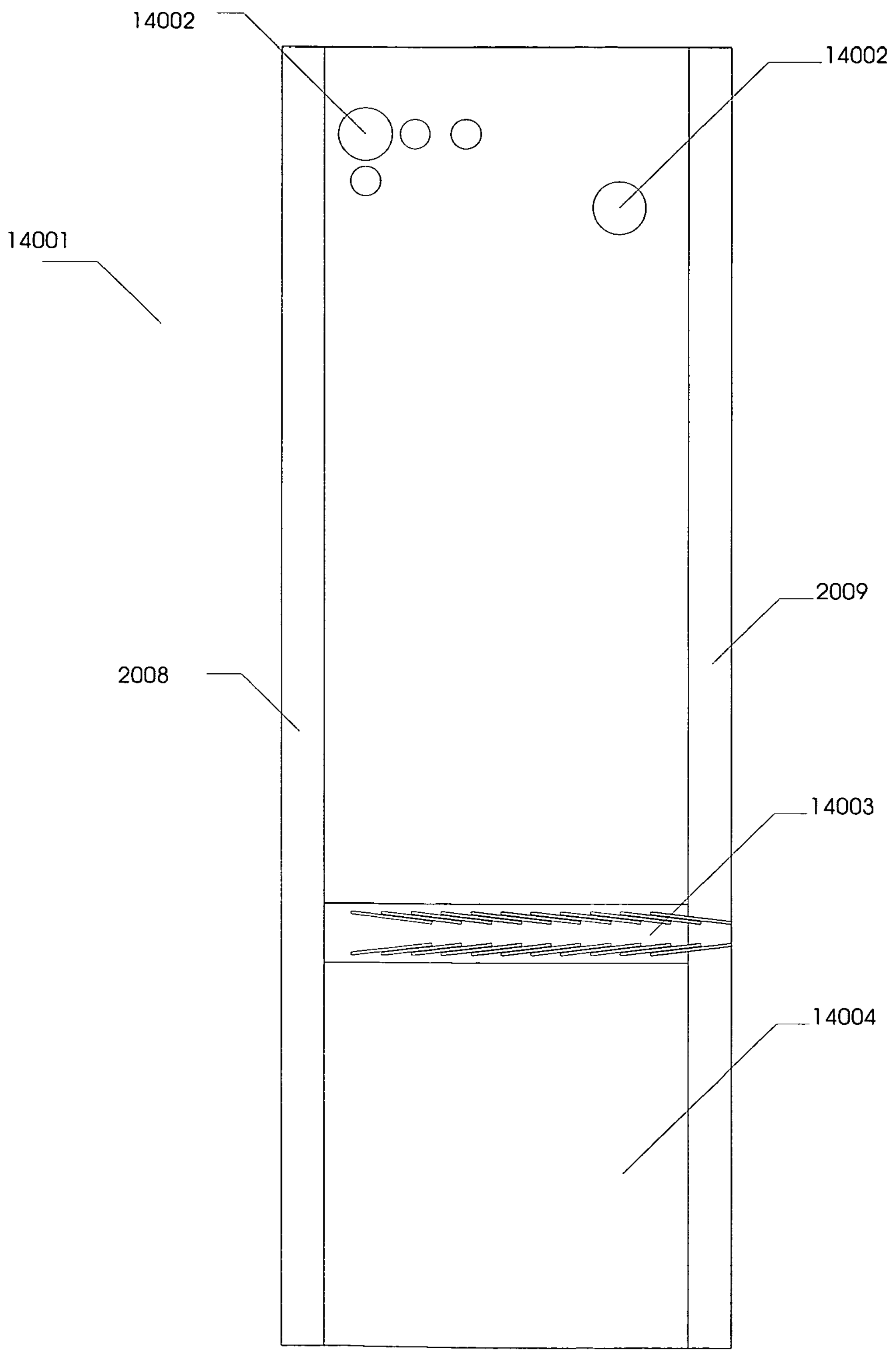

Fig. 15

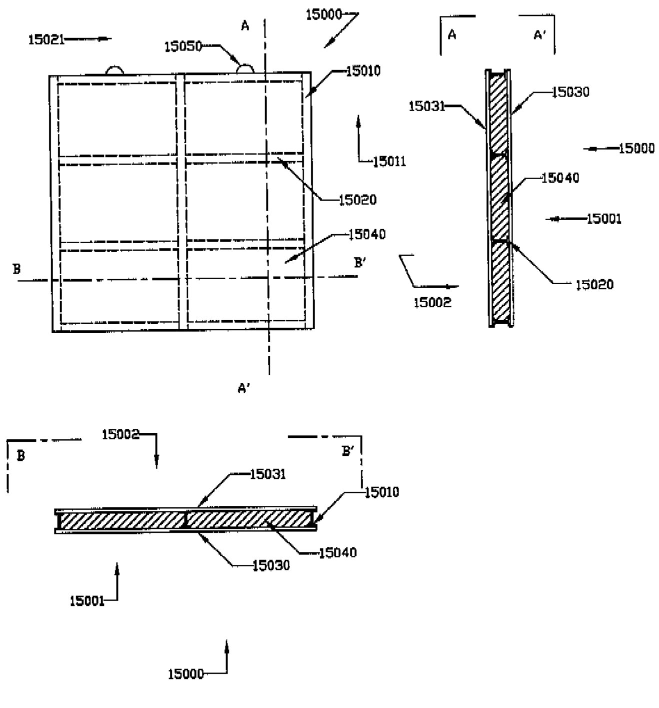
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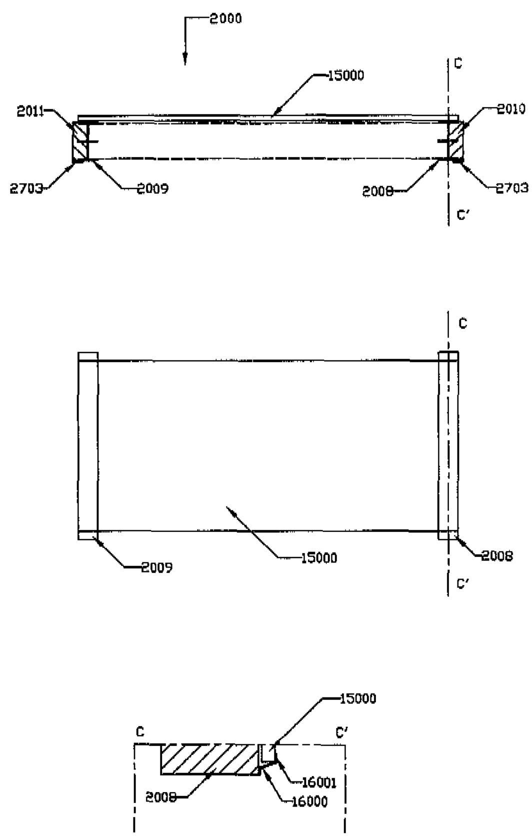
Fig. 16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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 08 44 7013

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	FR 2 789 095 A (BONIFACE DIDIER [FR]) 4 August 2000 (2000-08-04) * the whole document *	1-13	
P,A	EP 1 788 157 A (VELTHORST BEHEER B V [NL]) 23 May 2007 (2007-05-23) * paragraph [0013] - paragraph [0029]; figures 2,4,5 *	1-13	
A	EP 0 412 477 A (FROMME THEO [DE] BAUER SPEZIALTIEFBAU [DE]) 13 February 1991 (1991-02-13) * column 8, line 56 - column 9, line 36; figures 1,11 *	1-13	
A	US 6 240 700 B1 (SHEU CHYI [TW]) 5 June 2001 (2001-06-05) * column 3, line 25 - column 6, line 26; figures 4,7 *	1-13	TECHNICAL FIELDS SEARCHED (IPC): E02D E04C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	4 July 2008	Geiger, Harald

2

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