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(54) **Method for repairing of buildings**

(57) Method for the temporary or permanent suspension of an existing building comprising the steps of:
a. building deep foundations (1) outside the perimeter of the existing building (E);
b. modular building, with reinforced adjacent ashlars (4), of a provisional foundation of the building (E) consisting of a grid of main beams (2) and of secondary beams (3) in correspondence of the load-bearing walls (M) of the building (E), wherein
i. said main beams (2) extend beyond the perimeter of the building (E) until resting on said deep foundations (1);
ii. said ashlars (4) are provided within with tubular elements arranged according to a preset design so as to form, all together, one or more continuous channels (T) which longitudinally cross said main beams (2) or secondary beams (3);
iii. said ashlars (4) are laterally shaped with mutually complementary shear keys (4a) apt to transmit the shearing stresses between adjacent ashlars (4);

c. post-tensioning on-site said main beams (2) through the insertion and subsequent tensioning of steel wires within said channels (T);
d. limited lifting of the building (E) by post-tensioning said main beams (2), wherein said channels (T) have a polygonal or curvilinear shape with upward concavity.

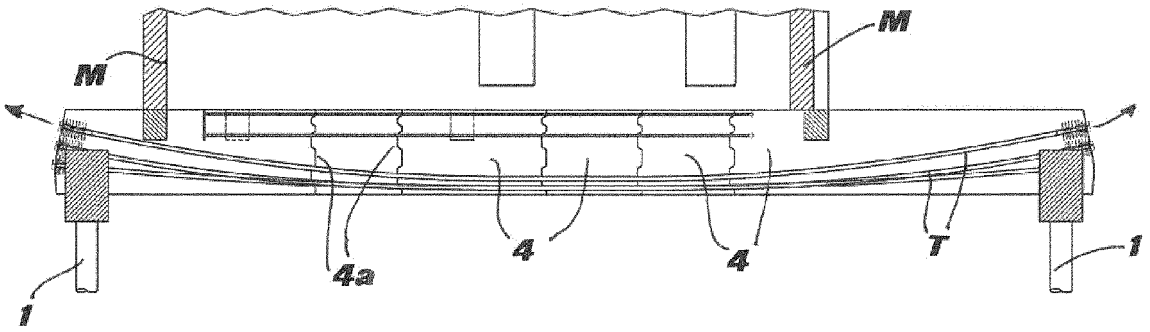

Fig. 2

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to a method for the temporary suspension of existing buildings, in particular residential buildings and monumental buildings. The invention specifically relates to a method of this type in which the existing building is entirely suspended, in safe conditions and regardless of the type of foundations thereof, so as to allow digging or new foundation operations in the area below the building in conditions of top safety, ease and execution speed.

BACKGROUND ART

[0002] In the building sector the technique of erecting new foundation under existing buildings is widely known, which is applied, for example, when it is necessary to restore or reinforce the foundations of a building for the most disparate reasons, such as deterioration of the foundations, absence or insufficient extent thereof, decline of the mechanical features of the ground, need to increase the size and the load capacity of the foundations due to an increase of the load resting on the same, for example following changes of use of or additional storeys to the building.

[0003] The need to build an under-foundation arises also in the cases in which the erection of a new basement storey of the building is required.

[0004] One of the under-foundation techniques widely used in the industry consists of digging, according to a programmed sequence, a series of limited digs under individual portions of the load-bearing walls of the building and then of erecting corresponding foundation portions in said digs, until completion of the entire new foundation. However, this method allows to obtain fairly good results only in the case of under-foundations of a limited height, since with the increase of the digging height, the risk of landslides, and of consequent possible localised subsiding of the above-standing building, becomes too large to guarantee both adequate safety conditions to the operators and the absence of structural damages to the existing building. Moreover, such method does not allow, or allows only in a limited manner, a mutual binding of the individual foundation portions built later and the overall mechanical performances of the new foundation are hence not comparable with those of a corresponding concrete foundation made as a single monolithic casting provided with continuous metal reinforcements.

[0005] In order to overcome these drawbacks, building methods have more recently been proposed which provide to harness the entire building with a new grid of beams arranged immediately above or immediately below the lower floor of the building. The beams are interconnected and are furthermore connected to the load-bearing floor and walls. The new beam grid is provided with a series of resting points on the ground with the interposition of a plurality of corresponding hydraulic jacks. The progressive and even actuation of the jacks hence allows to obtain the lifting of the building.

[0006] The lifting extent may be extremely limited, i.e. what suffices to release the entire weight of the building on the plurality of jacks and to hence be able to freely remove the soil under it to erect the under-building, or it may arrive up to even a few meters, in order to obtain an actual lifting of the building, to allow the building of a new above-ground storey of the building or of a building support system on stilts, depending on the reasons which have led to the indication of lifting the building. Some specific application modes of this technique are disclosed for example in US-6 379 085, US 5 722 798 and WO 2009/087469.

[0007] However, the above-described building method implies a certain complexity, both concerning the installation and the procedure and it furthermore has - when used to erect an under-foundation or an under-building - serious drawbacks as far as the accessibility to the digging area is concerned.

[0008] As a matter of fact, the accessibility to the digging area is limited precisely by the same plurality of hydraulic jacks, which as a matter of fact must for obvious reasons be located evenly and sufficiently close across the entire building perimeter/area, so that it is not normally possible to accomplish a sufficiently large side entrance to the digging area to allow access to mechanic digging means. Moreover, the dig size and depth are seriously limited by the need not to impair, with the digging operations, the stability of the ground on which such jacks temporarily rest.

[0009] Again, moreover, the typical coupling mode of the above-described beams with the load-bearing walls, with structural connection elements arranged crosswise to the same walls, causes an important surface deterioration thereof which, in case of historical or monumental buildings, is often unacceptable due to the presence of coats of paintings or other types of surface decorations or finishes.

[0010] In any case, finally, the lifting or the suspension of a building on a network of hydraulic jacks for the extended period of time necessary for the building of an under-building, is rather problematic both from the point of view of the safety of the staff who operate under the building, and from the point of view of the possible differentiated subsidings which the ground resting systems of said jacks may undergo over time, mainly due to the same stresses induced by the digging operations necessary for the under-building.

PROBLEM AND SOLUTION

[0011] The problem at the basis of the present invention is hence that of proposing a new suspension method of existing buildings for the erection of under-foundations or under-buildings which is free from the above-cited drawbacks.

[0012] In particular it is a first object of the invention that such method provides a temporary suspension system of the building with high stability and safety, both with respect to the operators and with respect to the structural integrity of the building.

[0013] A second object of the invention is furthermore that such method does not limit the size of the dig in the area underlying the existing building, which dig can hence be sized at pleasure until reaching and possibly even exceed the size of the building, at least in the case of buildings which fall within non exceptional size classes.

[0014] A third object of the invention is then that such method allows the formation of wide lateral accesses to the area underlying the building, so that the digging operations may be performed, where desirable, with mechanical means having free access from the outside.

[0015] A fourth object of the invention is finally that of allowing an easy, effective and integral making safe of existing buildings with respect to seismic events.

[0016] This problem is solved and these objects are achieved through a suspension method of existing buildings having the features defined in claim 1. Other preferred features of the method are defined in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] Further features and advantages of the invention will be in any case more apparent from the following detailed description of preferred embodiments of the building suspension method of the invention, provided purely as a non-limiting example and illustrated in the attached drawings, wherein:

fig. 1 is a plan view of an existing building, which illustrates the schematic arrangement of a grid of main and secondary beams, for the suspension of the building using the method of the present invention;

fig. 2 is a section view in a vertical plane according to line A-A in fig. 1, which illustrates the structure of a main support beam;

fig. 3 is a view similar to fig. 2 which illustrates schematically some possible under-building works;

figs. 4A and 4B are section views similar to fig. 3 which illustrate two different modes of seismic insulation of the building of fig. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] The suspension method of existing buildings according to the present invention is articulated in different steps and precisely:

1. building of foundations, more or less deep depending on the mechanical features of the ground, erected in safe conditions outside the building perimeter;
2. defining a provisional foundation of the existing building consisting of a grid of main beams and of secondary beams;
3. modular building, with adjacent ashalrs, of the main and secondary beams of the grid;
4. alternative building of continuous secondary beams, possibly provided with tie-beams and counterthrust rafters;
5. making integral the ashlars of the modular beams through post-tensioning on-site;
6. digging in the area below the existing building;
7. building a new foundation of the under-building;
8. connecting the new foundation to the provisional foundation;
9. possible laying of the building on the new system of foundations and partial demolishing of the main beams;
10. forming of the seismic insulation;

which will be briefly illustrated in the following.

Step 1 - Forming of new deep, outside foundations

[0019] These are works which, depending on the overall building project, can alternatively have only a temporary function during the building suspension period (so-called provisional works), or be then integrated in a permanent manner in the new building body being erected. In both cases, such works are preferably erected outside the building perimeter and are planned and sized to bear the overall load of the existing building and of the grid of main and secondary beams meant to be a provisional foundation thereof.

[0020] Such deep foundations may be built with microposts, bored posts, sheet piles, etc., with or without top plinth, or, in the presence of ground water:

- on water-sealed slurry walls, with or without edge beams;
- on microposts berlinese, intersecting posts, jet-grouting, sheet piles or any other foundation work comprising the erection of watertight compartments.

[0021] In the absence of ground water the foundations may have the simple form of two parallel linear elements 1 (figs. 1 and 2), while in the presence of ground water they must necessarily have a continuous and closed shaped, normally rectangular or square (fig. 1), which in addition to elements 1 comprises crosswise elements 1a to allow the dig to be formed as a watertight compartment until work completion.

Step 2 - Definitioa of the provisional grid foundation

[0022] The building suspension method of the present invention provides the forming of a beam grid, along the same axis of the load-bearing walls M of the building, as schematically illustrated in fig. 1. A first series of beams 2, here also defined as main beams, extends outside the

perimeter of the building, until resting on the above-described deep foundations 1. A second series of beams 3, here also defined as secondary beams, rests instead on main beams 2 thus completing the above-said provisional foundation grid of the load-bearing walls M of the existing building.

Step 3 - Building of the main and secondary beams of the grid, in a modular configuration with adjacent ashlars

[0023] The building of the main and secondary beams of the grid is accomplished with a similar technique to the traditional one of under-foundations, i.e. forming a series of adjacent foundation portions 4, here defined as ashlars, through partial digging at the impost depth of the foundations of building E according to a preset sequence. The impost depth of ashlars 4 must preferably be above or equal to the intrados depth of the existing foundations of the building in order not to reduce the load-bearing capacity thereof. It is nevertheless possible to extend the depth of ashlars 4 also below the impost depth of the existing foundations.

[0024] As an example, in fig. 2 the building diagram of a main beam 2 consisting of six ashlars 4 is reported, which ashlars are built according to an ordinate sequence which has been overall designed for the entire grid of beams 2 and 3, also as a function of the length of the individual ashlars 4, in order not to impair in any way the integrity of load-bearing walls M under which it is being built. Each ashlar 4 is provided with a slack longitudinal reinforcement in a minimum extent, apt to comply with legal provisions, and with crosswise reinforcement (brackets) in the amount necessary to offer shear-resistance adequate to the transient and working stresses.

[0025] With respect to what occurs in traditional under-foundation works, ashlars 4 furthermore have two features which are peculiar of the method of the present invention.

[0026] Firstly, ashlars 4 are provided within with tubular elements made of metal or of other materials, for example knurled metal tubular sheaths, arranged according to a preset path in the longitudinal direction of the beams so as to form overall, once the building of ashlars 4 is completed, one or more continuous channels T which run across longitudinally the entire beam 2 or 3. Channels T are suited to house metal wires by which it is possible, once the building of the different ashlars 4 making up the beam has been completed, to impart a post-tensioning condition to the beam in the permanent configuration thereof.

[0027] Secondly, the individual ashlars are laterally shaped with mutually complementary shear keys 4a, sized in order to transmit, in part or wholly, the plan shearing stress between adjacent ashlars 4.

[0028] The completion of the building of ashlars 4 hence leads to the forming of a plurality of concrete beams 2, 3 which add to and/or replace the pre-existing foundations of the building, each beam consisting of a series of close ashlars 4, already in continuity due to the shear stresses for the presence of the shear keys, but still disjoined for bending stresses.

Step 4 - Building of part of the secondary beams of the grid, in a continuous configuration

[0029] Depending on the particular configuration of the building, at least part of secondary beams 3 of the grid may be built in the form of continuous concrete or steel beams, and such beams may be formed directly in the wall thickness or outside said thickness, preferably in a symmetrical way, i.e. on both sides of the wall. In both cases, the sizes of the opening and the loads resting on beams 3 may require the adoption of inclined tie-rods fastened in an intermediate position of beam 3 and apt to release on adjoining load-bearing walls M part of the load which rests on the beam. When said tie-rods are used, they are preferably fastened, at the upper end thereof, to a horizontal strut rather than directly to wall M. Said horizontal strut extends between the two opposite walls M to which it is suitably constrained and acts both as element neutralising the tie-rod-induced lateral thrusts, and as stabilising element of the highest part of the existing building.

Step 5 - Post-tensioning of the modular beams

[0030] When the beam grid meant to form the provisional foundation of the existing building is completed, the method of the invention provides the laying of harmonic-steel wires within the channels T formed inside ashlars 4, through manual or automatic insertion using so-called "strand-threading machines". In correspondence of the outer sides of the terminal ashlars 4 of beams 2, 3 metal stretching heads are rested, to which the wires are then connected according to the specific operation modes of the supplier of the post-tensioning system.

[0031] The post-tensioning degree and the wire stretching sequence of the individual beams 2, 3 are defined and sized in the structural project. The path of the wires within the beams may be rectilinear or curvilinear with upward concavity. The post-tensioning - normally adopted only for the main beams 2 resting on deep foundations 1 - accomplishes a contractive state which causes a limited suspension of the entire building, with resulting progressive transfer of the load of the same from the old to the new foundations. The passage of the loads occurs with the utmost gradualness and hence in highly safe conditions and furthermore having the possibility to check any displacements of the axis line of beams 2, 3, while the post-tensioning load is gradually increased. In this step it is hence possible to carry out a validation of the project hypotheses and of the previsional subsidings.

[0032] The post-tensioning system of the beams may be accomplished through any one of the methods known in the sector, for example:

- through harmonic-steel strands and subsequent injection of special cement grout to achieve the anti-corrosion protection of the wires (so-called "bonded" wires);
- through free strands covered by a sheath of Vipla®, known as "viplated strands" (so-called "unbonded" wires);
- through bars of the Dywidag® type, with or without grout injection.

Step 6 - Execution of the digging works underneath the existing building

[0033] Once completed, as described above, the suspension of the existing building on the grid-like foundation system formed by main beams 2 and secondary beams 3, which system in turn rests on deep foundations 1 outside the building perimeter, it is possible to proceed to digging in the area below the building. Such operations, as should be clear from the preceding description, can be performed in conditions of high safety and of full freedom of access to the area. The vertical elements on which the building now rests as a matter of fact consist of the sole deep foundations 1 outside the building and hence the digging may be carried out fully on the entire area occupied by the building, and possibly also on the entire area of greater extension limited precisely by said deep foundations 1.

[0034] It is hence evident that such digging operations may be carried out also through large mechanical means, and hence with a remarkable savings of working times, regardless of course from the above-standing structure of the existing building, which as a matter of fact is securely resting - moreover with no possible change of the stability in time and regardless from the digging progress conditions - on the grid of provisional foundations.

Step 7 - Forming of the new foundations system

[0035] Once the dig down to the depth of the planned dig bottom has been completed, it is possible to proceed to the building of new foundations 5, for example in the shape of a concrete bed or upturned beam, in a manner well-known per se.

[0036] Starting from this step of the construction, the building method of the present invention may develop in two different variants. According to a first variant, the provisional foundation consisting of the grid of beams 2 and 3 is maintained integrally as permanent foundation of the building; in this variant the new foundation built on the bottom of the dig will hence have to be sized only for supporting of the under-building erected under the ground floor of the building, which under-building will be structurally fully independent from the existing building. With the erection of the under-building the method of the invention, according to this first variant, is hence completed.

[0037] In a second variant, on the contrary, the new foundation 5 is meant to support at the end the entire building - normally due to the fact that the provisional foundation system must at least in part be dismantled for architectural or logistic requirements - and it must hence be sized accordingly to support the entire load of the building. In this second variant the method of the invention still comprises steps 8 and 9 briefly described in the following.

Step 8 - Connection of the new foundation to the existing building

[0038] As shown in fig. 3 with discontinuous lines, should beams 2 have to be later partially demolished and/or detached from deep foundations 1, limited to the portion thereof which does not cooperate to said new foundation system, in the space formed between the new foundation 5 and the impost depth of beams 2 (which space can of course be of such a height as to comprise within the same multiple below-ground storeys of the building) load-bearing pillars or walls 6 are built in such positions as to then be able to adequately release on the new foundations 5 the entire load of the existing building as well as of the provisional foundation portion 2 which will be left at the end of the reconstruction intervention.

Step 9 - Laying of the building (in the possible) amended embodiment

[0039] When the connection elements 6 are able to support the loads entrusted thereto, the post-tensioning degree of main beams 2 is gradually reduced, so as to obtain a gradual limited lowering of the building onto new foundations 5 and 6, which are thus loaded with the weight of the building, simultaneously releasing from the same weight the provisional grid-like foundation of beams 2 and 3 and deep foundation 1. Beams 2 and 3 may hence be partially removed according to the project indications and/or detached from deep foundations 1, for example in order to perform the restoration of the area outside the existing building in identical conditions to the original ones.

Step 10 - Seismic insulation

[0040] The method for the suspenson of buildings of the present invention is finally particularly well-suited to accomplish the seismic insulation of existing buildings, without having to carry out invasive works on the existing masonry, which works, in addition to being extremely expensive, do not reach an equal safety level against seismic events and are in any case very difficult to accomplish in buildings of great historical or artistic value subject to the protection by the Ministry of Cultural Heritage and Activities, which precisely for this reason provides a derogation from the otherwise compulsory seismic adaptation.

[0041] In the first variant of the method of the invention,

i.e. the one in which the existing building is permanently supported on the grid of beams 2 and 3 and on deep foundations 1, it is sufficient for this purpose to insert seismic insulators I, well-known per se, capable of insulating the building from the horizontal accelerations of the ground in the resting points of main beams 2 on deep foundations 1 (fig. 4A). In this case the new portion of under-building remains foreign to the seismic insulation and must hence be maintained disjoined, from a structural and plant-engineering point of view, from the above-standing building, to allow mutual oscillations of the two buildings during a seismic event.

[0042] In the second variant of the method, i.e. that in which the entire building is laid on the new foundations, being main beams 2 at least partly dismantled, it will instead be necessary to build a flooring slab 7 horizontally connected to pillars or load-bearing walls 6. The insulators are arranged- in a plan view depending on the static and dynamic requirements between the new foundation structures and the elevation pillars/walls. Flooring slab 7 is suspended on a layer of seismic insulators I which allows the free sliding thereof save for friction forces. Thereby the seismic insulation of the entire building E is obtained, including the part added as under-building, with respect to the foundation system consisting of deep foundations 1 and of new foundation 5.

[0043] From the preceding description it should be clear how the present invention has fully reached all the set objects in a particularly simple and effective way and without the need for special machinery or equipment which are not already commonly available at the building companies. In particular, the method of the invention allows the execution of under-buildings of existing buildings in conditions of high safety and, at the same time, of great rapidity, without altering in any way the structure and the finishes of the existing building and furthermore allowing, with the sole additional costs of seismic insulators I, the full anti-seismic making safe of the building.

[0044] However, it is understood that the invention must not be considered limited to the particular arrangements illustrated above, which represent only exemplifying embodiments thereof, but that different variants are possible, all within the reach of a person skilled in the field, without departing from the scope of protection of the invention, which is exclusively defined by the following claims.

Claims

1. Method for the temporary or permanent suspension of an existing building comprising the steps of:

   a. building deep foundations (1) outside the perimeter of the existing building (E);
   b. modular building, with reinforced adjacent ashlars (4), of a provisional foundation of the building (E) consisting of a grid of main beams (2) and of secondary beams (3) in correspondence of the load-bearing walls (M) of the building (E), wherein

      i. said main beams (2) extend beyond the perimeter of the building (E) until resting on said deep foundations (1);
      ii. said ashlars (4) are provided within with tubular elements arranged according to a preset design so as to form, all together, one or more continuous channels (T) which longitudinally cross said main beams (2) or secondary beams (3);
      iii. said ashlars (4) are laterally shaped with mutually complementary shear keys (4a) apt to transmit the shearing stresses between adjacent ashlars (4);

   c. post-tensioning on-site said main beams (2) through the insertion and subsequent tensioning of steel wires within said channels (T);
   d. limited lifting of the building (E) by post-tensioning said main beams (2), wherein said channels (T) have a polygonal or curvilinear shape with upward concavity.

2. Method for the suspension of buildings as claimed in claim 1, furthermore comprising the subsequent steps of:

   e. execution of a dig in the area underlying said grid-like provisional foundation;
   f. building of a new foundation (5) and/or under-building inside said dig.

3. Method for the suspension of buildings as claimed in claim 2, furthermore comprising the further steps of:

   g. connecting the new foundation (5) to at least part of said provisional foundation (2, 3) through the building of pillars or load-bearing walls (6);
   h. laying of the building (E) on the foundation system comprising said new foundation (5), said connecting pillars and/or load-bearing walls (6) and at least part of said provisional foundation (2, 3), through the progressive release of the post-tensioning condition of said main beams (2).

4. Method for the suspension of buildings as claimed in claim 3, comprising the additional step of:

   i. possible partial demolition of said main beams (2) limited to the portion thereof which does not cooperate to said new foundation system.

5. Method for the suspension of buildings as claimed

in claim 2, furthermore comprising a plurality of seismic insulators (I) arranged in correspondence of the resting points of said main beams (2) on said deep foundations (1).

6. Method for the suspension of buildings as claimed in claim 3 or 4, furthermore comprising a flooring slab (7) connected to said pillars or load-bearing walls (6), free to slide on the new foundation (5), through the interposition of a plurality of seismic insulators (I) between said new foundation (5) and said slab (7).

7. Method for the suspension of buildings as claimed in any one of the preceding claims, wherein at least part of said secondary beams (3) are in the form of continuous concrete or steel beams.

8. Method for the suspension of buildings as claimed in claim 8, wherein said beams are provided with inclined tie-rods anchored at intermediate points of the beam and apt to release on the neighbouring load-bearing walls (M) part of the load which rests on said beams (3), said tie-rods being fastened at their upper end to horizontal struts for the neutralisation of the lateral thrusts induced thereby.

9. Method for the suspension of buildings as claimed in any one of the preceding claims, wherein the post-tensioning of said beams (2, 3) is alternatively obtained through the use, within said channels (T), of:

- strands of harmonic steel and injection of special cement grout;
- vipla covered strands;
- Dywidag®-type bars, with or without grout injection.

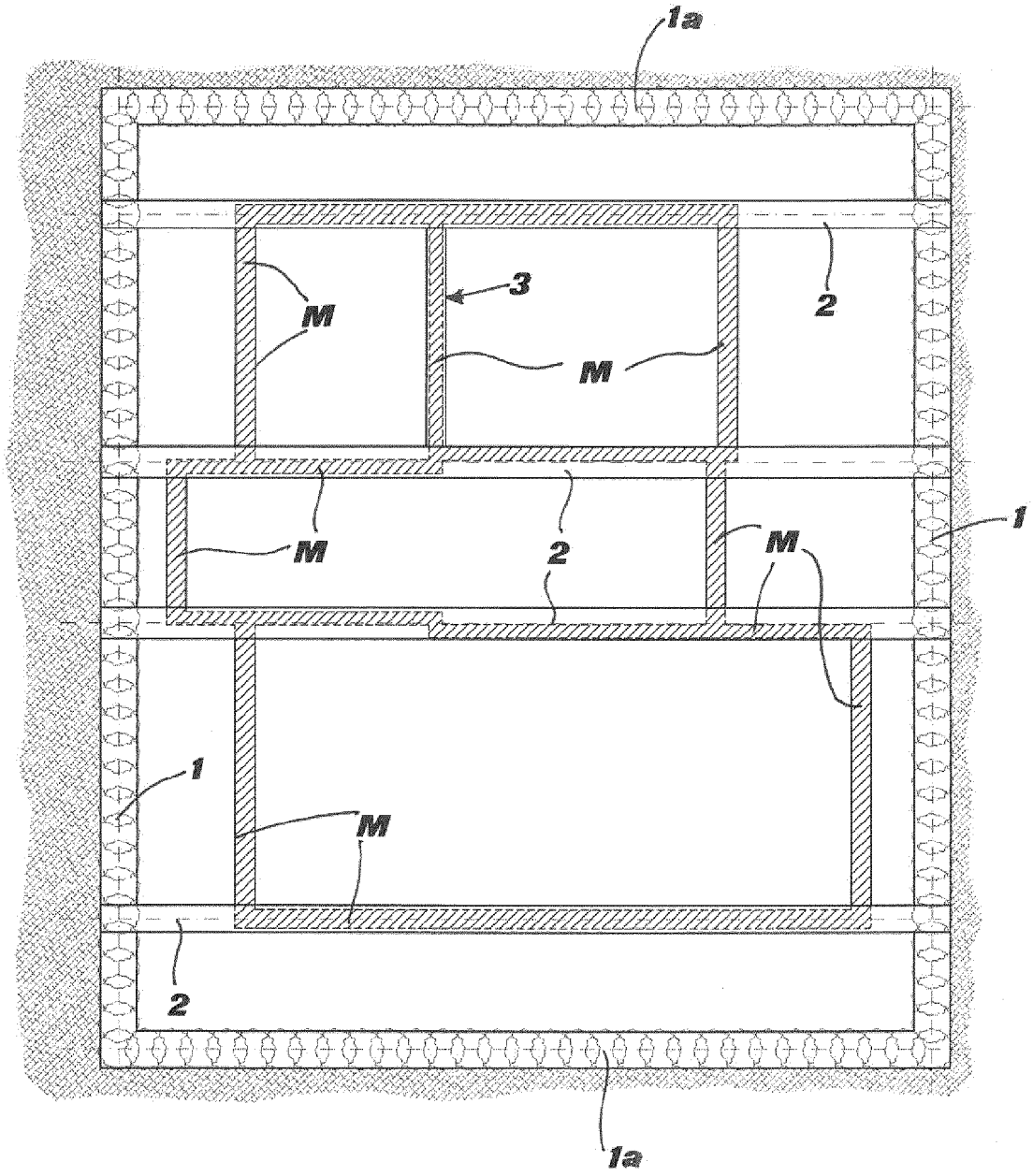

Fig. 1

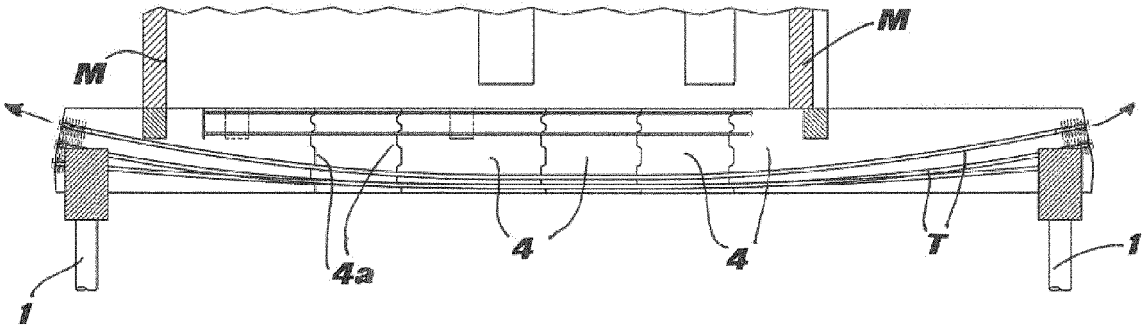

Fig. 2

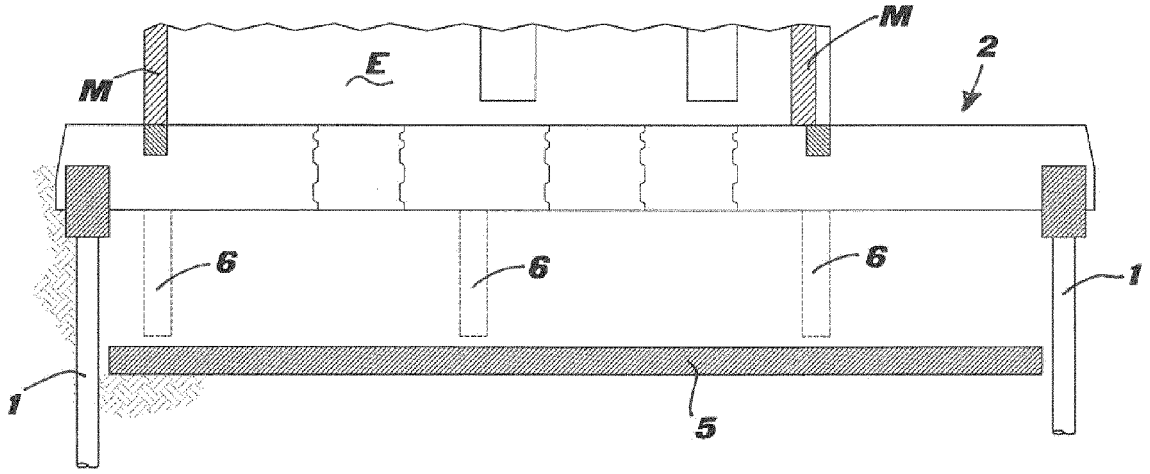

Fig. 3

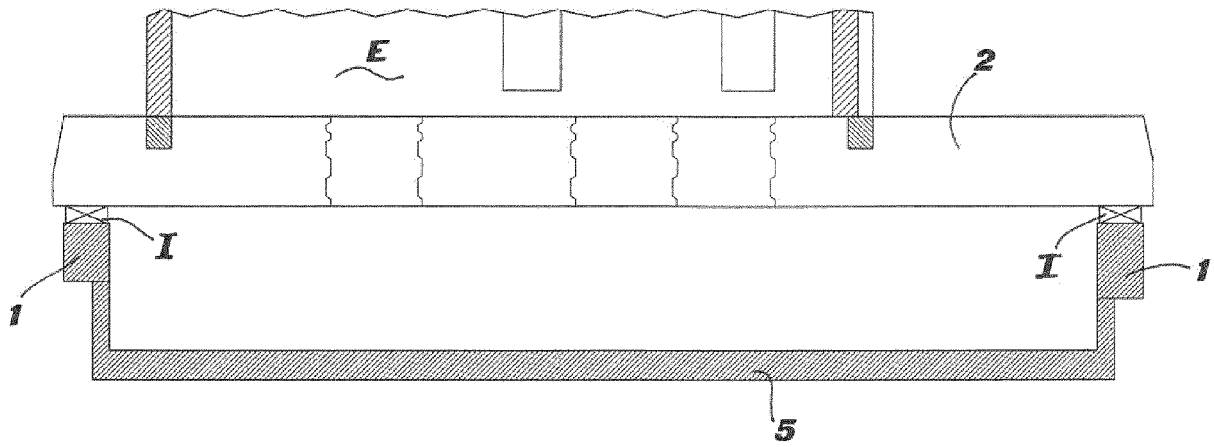

Fig. 4A

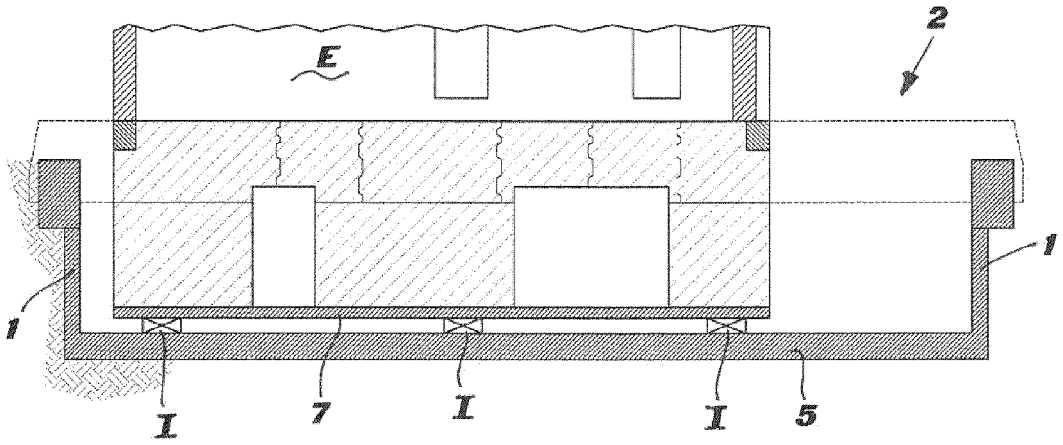

Fig. 4B

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EUROPEAN SEARCH REPORT

Application Number
EP 13 16 9397

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	WO 2009/087469 A2 (SO L E S SOCIETA LAVORI EDILI [IT]; MATTIOLI S P A [IT]; ZAGO ROBERTO) 16 July 2009 (2009-07-16) * the whole document * -----	1-9	INV. E02D35/00
A	EP 0 580 098 A1 (SUDBRACK BERNFRIED DR [DE]) 26 January 1994 (1994-01-26) * the whole document * -----	1-9	

TECHNICAL FIELDS SEARCHED (IPC)

E02D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	23 July 2013	Geiger, Harald

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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1

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 13 16 9397

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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23-07-2013

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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