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(54) Method and system for manufacturing a composite slab, and composite slab

(57) The invention relates to a method and a system for manufacturing a composite slab and to a corresponding composite slab, which comprises a hollow-core slab (1) and a surface slab (3) placed upon it and separated from it by spacer elements (2) of elastic material. In the method, the hollow-core slab is cast upon a prestressing bed (4). The surface slab (3) is then cast directly onto the hollow-core slab (1) so that the upper surface of the hollow-core slab functions as a mould for the lower surface of the surface slab, thus giving the lower surface of the surface slab a surface relief that is complementary to the upper surface of the hollow-core slab. In the composite slab, the non-planar surface profile of the lower surface (6) of the surface slab (3) is, in the entire area of the lower surface, complementary to the surface profile of the non-planar upper surface (5) of the hollow-core slab (1), so that any distortions of the shape of the said surfaces, such as bulges and pits, are repeated in a mirror image fashion in the two opposite surfaces. The spacer elements (2) placed between the hollow-core slab (1) and the surface slab (3) are of equal thickness.

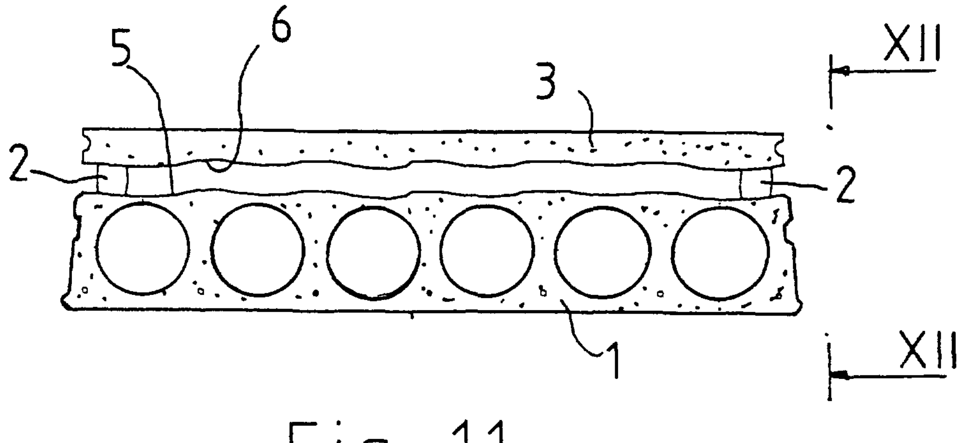

Fig 11

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Description

[0001] The present invention relates to a method as defined in the preamble of claim 1. Moreover, the invention relates to a system as defined in the preamble of claim 8. In addition, the invention relates to a composite slab as defined in the preamble of claim 16.

[0002] In particular, the invention relates to a hollow-core concrete slab structure with improved sound insulation properties, hereinafter called a composite slab, to its manufacture and to a system used for its manufacture. Such a composite slab usually comprises a hollow-core slab and a surface slab placed upon it and separated from it by spacer elements made of an elastic material. When the hollow-core slab is mounted in a building, it is fastened to the building frame, but the surface slab is not attached to the building frame structures; instead, it is supported by the hollow-core slab via a floating connection only formed by the elastic spacer elements. Composite slabs like this are known e.g. from Finnish patent specifications FI 89398, FI 48867, FI 44160.

[0003] The largest area of application of hollow-core slabs is the intermediate floors of residential multi-storied buildings. The worst problem associated with an intermediate floor made of hollow-core slabs has always been that of achieving at a reasonable cost a sufficient sound insulation level that satisfies the residents. Attempts have been made to improve the sound insulation properties of the hollow-core slab by increasing its height and weight or by casting at the building site a separate reinforced concrete surface slab upon sound insulating materials (so-called float floor). Increasing the weight has not brought sufficient relief (tread sound). Casting a separate surface slab at the building site is theoretically an excellent solution, but it is expensive and susceptible to numerous installation errors, the worst of which are, as shown by experience, the formation of "sound bridges" and moisture getting into the insulation layer during construction time and the consequent damage, above all molding. Significant additional disadvantages also result from the increased length of the construction period and disturbances of the normal working process during construction time as well as the difficulty of drying the structures in cases of water damage occurring during the service life of the building.

[0004] When the floor height of residential multi-storied buildings was increased from 280 cm to 300 cm a few years ago, the result was that the maximum intermediate floor structural height between the minimum room height of 250 cm and the floor height was to be 500 mm. This made it possible to provide even the highest hollow-core slab (h=400 mm) used in housing production with a separate reinforced concrete surface slab mounted at factory, supported by elastic spacers on top of the hollow-core slab.

[0005] Such prior-art composite slabs are manufactured by casting the hollow-core slab on one prestressing bed and the surface slab on another prestressing bed. In other words, a separate prestressing bed is needed for each slab. In practice, the slabs are cast at factory in lengths of 120 - 180 m, and after curing they are cut into fixed sizes. The use of two prestressing beds thus involves the problem that a considerable factory floor area is needed for the making of a single composite slab.

[0006] A further problem is that, since the slabs cannot be removed from their prestressing beds before they have hardened sufficiently, a single composite slab being made occupies two prestressing beds during its hardening time, which is relatively long, i.e. about 8 - 12 hours, during which the beds cannot be used for other production purposes, so the degree of utilization of the equipment remains low.

[0007] After each slab has hardened and been cut, the surface slab is moved onto the hollow-core slab, on which it is supported by spacer elements. This necessitates moving the surface slab inside the factory and requires appropriate conveyance equipment.

[0008] After the casting, the upper surface of the hollow-core slab is in practice not exactly even and planar; instead, it always comprises distortions of shape, such as bulges and pits. By contrast, the lower surface of the surface slab is even and planar as it has been formed on the even prestressing bed. This causes the further problem that, when a composite slab is to be produced which has a uniform thickness in all parts of it and in which the upper surface of the surface slab is exactly parallel to the lower surface of the hollow-core slab, the spacer elements have to be separately measured and cut one by one to fit them to each mounting position. For the measurement, special measuring equipment is needed, and cutting equipment is needed for the adjustment of the height of the spacer element.

[0009] However, if spacer elements of standard thickness were to be used between a hollow-core slab and a surface slab manufactured in the manner described above, this would involve the problem that each spacer element would receive a different load, resulting in an impairment of the sound insulation properties. In a narrow clearance where the opposite surfaces of the slabs would nearly touch each other, the spacer element would be completely compressed and it would carry too much of the weight of the surface slab, whereas in another area with a larger clearance, the spacer element might not receive any part of the load imposed by the surface slab.

[0010] The object of the invention is to eliminate the problems referred to above.

[0011] A specific object of the invention is to disclose a method and system that will make it possible to manufacture a composite slab in factory at an economic cost so that a maximum degree of utilization of the production equipment can be maintained.

[0012] A further object of the invention is to disclose a method and system that will make it possible to use spacer elements between the slabs that are all identical and of the same thickness, without having to be separately fitted and adjusted to different dimensions.

[0013] A further object of the invention is to disclose a composite slab which can be produced at an economic cost and has good sound insulation properties.

[0014] The method of the invention is characterized by what is presented in claim 1. The system of the invention is characterized by what is presented in claim 8. The composite slab of the invention is characterized by what is presented in claim 16.

[0015] In the method of the invention, the hollow-core slab is cast on a prestressing bed. According to the invention, the surface slab is cast directly onto the hollow-core slab so that the upper surface of the hollow-core slab acts as a mould for the lower surface of the surface slab, so that the lower surface of the surface slab is given a surface relief that is complementary to the upper surface of the hollow-core slab.

[0016] The system of the invention comprises an elongated prestressing bed and a first casting device for casting a hollow-core slab onto a prestressing bed. According to the invention, the system comprises a second casting device, which has been arranged to cast the a slab onto the upper surface of the hollow-core slab so that the upper surface of the hollow-core slab acts as a mould for the lower surface of the surface slab so as to give the lower surface of the surface slab a surface relief that is complementary to the upper surface of the hollow-core slab.

[0017] The composite slab comprises a hollow-core slab and a surface slab placed upon it and separated from it by spacer elements of an elastic material. According to the invention, the non-planar surface profile of the lower surface of the surface slab is, in the entire area of the lower surface, complementary to the non-planar surface profile of the upper surface of the hollow-core slab, so that any distortions of the shape of said surfaces, such as bulges and pits, are repeated in a mirror image fashion in the two opposite surfaces. The spacer elements are of equal thickness.

[0018] The invention provides the advantage that both the hollow-core slab and the surface slab can be cast on the same prestressing bed, thus allowing more effective space utilization in the factory and improving its degree of utilization. Further advantages include the facts that the surface slab need not be separately moved on the manufacturing premises and that no special conveyance equipment is needed for that purpose. A further advantage is that spacer elements having a predetermined height, i.e. an equal thickness, can be used, and that they need not be separately dimensioned for each particular mounting position. A composite slab is produced that is exactly of a standard thickness in its entire area and in which an equal load is applied to all spacer elements. The accuracy of the measurements of the structure also reduces the smoothing costs. Placed inside the hollow-core slab are conventionally prestressed prestressing steel bars placed longitudinally relative to the slab. Upward warping of the hollow-core slabs is reduced because the load of the surface slab is already on the slab when the prestressing tension is released.

[0019] In an embodiment of the method, after the surface slab has been cast and has reached a sufficient strength, the surface slab is raised above the hollow-core slab to form a clearance between the upper surface of the hollow-core slab and the lower surface of the surface slab. Next, the spacer elements are placed between the upper surface of the hollow-core slab and the lower surface of the surface slab. The surface slab is lowered onto the spacer elements.

[0020] In an embodiment of the method, a releasing medium adaptable to the shapes of the upper surface of the hollow-core slab is placed upon the hollow-core slab. The surface slab is preferably cast upon the releasing medium while the hollow-core slab is still in a substantially unhardened state. A releasing medium is needed especially when the surface slab is cast on top of a hollow-core slab that has been recently cast and has not yet hardened, because otherwise the slabs might stick to each other and could not be separated from each other after they had hardened. The releasing medium may be e.g. a liquid substance which can be sprayed as a thin layer onto the upper surface of the hollow-core slab. The releasing medium may also consist of a web-like thin film, e.g. a plastic film or paper or the like, which can be unreeled from a roll and applied onto the upper surface of the hollow-core slab and which adapts itself to the shapes of the upper surface.

[0021] In an embodiment of the method, the spacer elements comprise a number of equally thick spacer pieces, which are placed between the hollow-core slab and the surface slab in an area close to their longitudinal edges at a distance from each other.

[0022] In an embodiment of the method, after the composite slab has hardened, it is cut into a suitable size.

[0023] In an embodiment of the method, after the composite slab has been cut, the surface slab is cut at both ends so as to make it somewhat shorter than the hollow-core slab.

[0024] In an embodiment of the method, after the surface slab has been cast onto the hollow-core slab, the combination thus obtained is covered with a heat insulating covering to promote hardening.

[0025] In an embodiment of the system, the system comprises a hoisting device for moving the surface slab vertically in relation to the hollow-core slab.

[0026] In an embodiment of the system, the system comprises a spacer mounting device for setting the spacer elements between the upper surface of the hollow-core slab and the lower surface of the surface slab.

[0027] In an embodiment of the system, the system comprises an application device arranged to apply a releasing medium onto the upper surface of the hollow-core slab before the casting of the surface slab.

[0028] In an embodiment of the system, the spacer elements comprise a number of spacer pieces of equal thickness. The spacer mounting device has been arranged to place the spacer pieces in an area near the longitudinal edges of the hollow-core and surface slabs at a distance from each other.

[0029] In an embodiment of the system, the system comprises a cutting apparatus for cutting the hollow-core and surface slabs.

[0030] In an embodiment of the system, the cutting apparatus comprises a first cutting device for cutting the surface slab and a second cutting device for cutting the hollow-core slab.

[0031] In an embodiment of the system, the system comprises guide rails disposed near the prestressing bed in a direction parallel to the longitudinal direction of the prestressing bed, and a first casting device, a second casting device, the hoisting device, the spacer mounting device, the device for applying a releasing medium and/or the cutting apparatus are mounted on a frame arranged to be movable along the guide rails.

[0032] In the following, the invention will be described in detail by the aid of a few examples of its embodiments with reference to the drawings, wherein

Fig. 1, 3, 4, 6 -10 present different steps comprised in the method of the invention as performed using an embodiment of the system of the invention, in a diagrammatic view as seen from one end of a composite slab being manufactured,

Fig. 2 presents a hollow-core slab comprised in an embodiment of the composite slab of the invention as seen from one end,

Fig. 5 presents an end view of a hollow-core slab comprised in an embodiment of the composite slab of the invention and a surface slab cast upon it,

Fig. 11 presents an embodiment of the composite slab of the invention, and

Fig. 12 presents the composite slab of Fig. 11 in side view.

[0033] In Fig. 1, a hollow-core slab 1 is first cast on a fixed prestressing bed 4 by the extrusion method as known in prior art, using a first casting device 10. The prestressing bed 4 is an elongated mould made of steel, and the hollow-core slab 1 is cast onto the planar, horizontal upper surface of this mould. On both longitudinal sides of the prestressing bed 4 there are guide rails 17, 18 along which the first casting device 10 is moved longitudinally with respect to the prestressing bed 4. If Fig. 1, the first casting device 10 is presented diagrammatically, and in structure it may be an extruder as known in the art. The first casting device 10 comprises a first frame 19 extending transversely across the prestressing bed like a portal and provided with wheels supporting it on the guide rails 17, 18. Mounted on the frame 19 are various pieces of equipment. A supply funnel supplies concrete to power-driven extrusion screws (not shown in the figure), which form the longitudinal hollow spaces in the hollow-core slab. The device 10, driven by the thrust of the extrusion screws, advances along the top of the prestressing bed. Moreover, the device is provided with a vibrator or some other compacting device (not shown) for compacting the concrete. The casting device 10 further comprises side templates 26 which shape the side surfaces of the hollow-core slab, and a top template 27 which shapes the upper surface 5 of the hollow-core slab.

[0034] Fig. 2 shows a somewhat exaggerated view of the shapes of a hollow-core slab 1 as it is after the casting. The lower surface of the hollow-core slab 1 becomes even as it lies against the prestressing bed 4, whereas the upper surface 5 always has various surface defects, defects of smoothness and planarity, pits and bulges.

[0035] Fig. 3 illustrates a step comprised in the method wherein a releasing medium 7 is sprayed onto the upper surface 5 of a hollow-core slab 1 that has just been cast and has not yet hardened. The purpose of the releasing medium 7 is to prevent the surface slab 3, to be cast next onto the hollow-core slab, 1 from sticking to the latter. The releasing medium 7 is sprayed by means of a spraying device 14. The spraying device 14 is mounted on second frame 20 extending transversely across the prestressing bed like a portal. The second frame is provided with wheels supporting it on the guide rails 17, 18 so that the spraying device 14 can be moved in the longitudinal direction of the hollow-core slab.

[0036] The releasing medium 7 may alternatively consist of a thin material, such as plastic film or paper, in the form of a web, which adapts itself perfectly to the shapes of the upper surface 5. In this case, the second frame 20 carries a reeling device (not shown in the figures) from which the rolled-up web material can be unrolled onto the upper surface 5 while the frame 20 is moved longitudinally relative to the hollow-core slab.

[0037] Fig. 4 illustrates the next step in the method, wherein a reinforced concrete surface slab 3 is cast directly onto the upper surface 5 of the hollow-core slab 1 so that the upper surface 5 of the hollow-core slab functions as a mould for the lower surface 6 of the surface slab 3. The surface slab 3 is cast using a second casting device 11, which is a so-called slipforming casting device. The slipforming casting device 11 comprises a third frame 21 extending transversely over the prestressing bed and provided with wheels supporting it on the guide rails 17, 18.

[0038] The lateral and top surfaces of the surface slab 3 are likewise formed by means of side templates 28 and a top surface template 29. The surface slab 3 is cast so as to make it somewhat narrower than the hollow-core slab 1 to ensure that the joints between the hollow-core slabs can be later successfully sealed on the building site. The lower surface 6 of the surface slab 3 is formed into a shape that is perfectly complementary to the upper surface 5 of the hollow-core slab 1.

[0039] Fig. 5 is a somewhat exaggerated presentation of the combination of a hollow-core slab 1 and a surface slab 3 after a casting operation as illustrated in Fig. 4. The non-planar surface profile of the lower surface 6 of the surface slab 3 is in its entire area complementary to the non-planar surface profile of the upper surface 5 of the hollow-core slab 1, so that any deformations in the upper surface 5 of the hollow-core slab 1, such as bulges and pits, are repeated in a mirror image fashion in the lower surface 6 of the surface slab 3. Thus, the lower surface 6 of the surface slab 3 is a kind of three-dimensional negative of the upper surface 5 of the hollow-core slab 1.

[0040] Fig. 6 illustrates the next step in the method, wherein the hollow-core slab 1 and the surface slab 3 placed on top of it are covered with a heat insulating covering 25 to promote hardening. After the concrete has hardened, the covering is removed.

[0041] Fig. 7 illustrates a step in the method wherein the surface slab 3, which has now reached a sufficient strength, is cut at both ends by means of a first cutting device 15 to make it somewhat shorter than the designed length of the hollow-core slab 1 under it. The waste portions thus cut off are removed, whereupon the hollow-core slab 1 is cut to its fixed length using a second cutting device 16. The cutting devices 15 and 16 may be e.g. circular saws movably mounted on a fourth frame 22 extending like a portal transversely across the prestressing bed 4 and provided with wheels supporting it on the guide rails 17, 18.

[0042] Fig. 8 a step in the method wherein the surface slab 3 is raised vertically above the hollow-core slab 1 by means of a hoisting device 12 so as to create a clearance between the upper surface 5 of the hollow-core slab and the lower surface 6 of the surface slab. The hoisting device 12 has been arranged to raise and lower the surface slab exactly vertically so that no lateral displacement occurs between the surface slab 3 and the hollow-core slab 12. With the surface slab 3 raised to a sufficient height, spacer elements 2 are inserted between the upper surface 5 of the hollow-core slab and the lower surface 6 of the surface slab by using a spacer mounting device 13. The spacer mounting device 13 comprises e.g. a transferring arm arranged to be movable in a horizontal direction and provided with gripping elements at one end for gripping the spacer 2. The transferring arm is inserted into the clearance between the upper surface 5 of the hollow-core slab and the lower surface 6 of the surface slab and it sets the spacer into a predetermined position. The hoisting device 12 and the spacer mounting device 13 are mounted on a fifth frame 23, which extends transversely across the prestressing bed like a portal and is provided with wheels that support it on the guide rails 17, 18.

[0043] The hoisting device 12 comprises grapples which grip the edges of the surface slab. The hoisting device 12 is preferably so implemented that it will raise only a portion of the surface slab while the rest of the surface slab remains resting on the hollow-core slab. In this way, the hoisting device 12 can be implemented as a device having a length of a few meters. To mount spacer elements 2 over the entire length of the composite slab, such a hoisting device is moved longitudinally with respect to the surface slab. Raising the surface slab 3 by this point load method in a given portion of it will cause the surface slab to bend, which is why it is necessary to provide at least one, preferably two other supporting points between the lifting point and the point where the two slabs meet, to prevent damage to the surface slab 3.

[0044] As illustrated in Fig. 9, the surface slab 3 is then lowered onto the spacer elements 2 by means of the hoisting device 12. All the spacer elements 2 are pieces having the same thickness. The spacer elements 2 are made of a suitable elastic material, e.g. neoprene rubber or the like, which damps the transmission of sound. The spacer mounting device 13 sets the spacers in the area of the longitudinal edges 8, 9 of the hollow-core and surface slabs at a distance from each other.

[0045] In Fig. 10, a finished composite slab, consisting of a hollow-core slab 1 and a surface slab 3 placed upon it and separated from it by spacer elements 2, is lifted off the prestressing bed 4.

[0046] Fig. 11 shows a finished composite slab according to the invention in end view and Fig. 12 in side view. The distortions of the shape of the upper surface 5 of the hollow-core slab 1, such as bulges and pits, are repeated as a 3D negative in the lower surface 6 of the surface slab 3, and the distance s between the surfaces 5 and 6 is the same at all points. Therefore, the same load is applied from the surface slab to all the spacer elements 2, these being of equal thickness.

[0047] The invention is not restricted to the examples of its embodiments described above; instead, many variations are possible within the scope of the inventive idea defined in the claims.

Claims

1. Method for manufacturing a composite slab comprising a hollow-core slab (1) and a surface slab (3) placed upon it and separated from it by spacer elements (2) of elastic material, in which method the hollow-core slab is cast upon a prestressing bed (4), **characterized in that** the surface slab (3) is cast directly onto the hollow-core slab (1) so that the upper surface (5) of the hollow-core slab functions as a mould for the lower surface (6) of the surface slab (3), thus giving the lower surface (6) of the surface slab a surface relief that is complementary to the upper surface (5) of the hollow-core slab.

2. Method as defined in claim 1, **characterized in that**, after the surface slab (3) has been cast and has reached a sufficient strength, the surface slab (3) is raised above the hollow-core slab (1) to form a clearance between the upper surface (5) of the hollow-core slab and the lower surface (6) of the surface slab; the spacer elements (2) are placed between the upper surface of the hollow-core slab and the lower surface of the surface slab; and the surface slab is lowered onto the spacer elements.

3. Method as defined in claim 1 or 2, **characterized in that** a releasing medium (7) adaptable to the shapes of the upper surface (5) of the hollow-core slab is applied upon the hollow-core slab (1) and a surface slab (3) is cast onto the releasing medium while the hollow-core slab is still in a substantially unhardened state.

4. Method as defined in any one of claims 1-3, **characterized in that** the spacer elements (2) comprise a number of spacer pieces of equal thickness, which are placed between the hollow-core slab (1) and the surface slab (3) in an area close to their longitudinal edges (8, 9) at a distance from each other.

5. Method as defined in any one of claims 1-4, **characterized in that**, after the composite slab has hardened, it is cut into a suitable size.

6. Method as defined in claim 5, **characterized in that**, after the composite slab has been cut, the surface slab (3) is cut at both ends so as to make it somewhat shorter than the hollow-core slab (1).

Method as defined in any one of claims 1 - 6, **characterized in that**, after the surface slab (3) has been cast upon the hollow-core slab (1), the combination thus obtained is covered with a heat insulating covering (25) to promote hardening.

8. System for manufacturing a composite slab comprising a hollow-core slab (1) and a surface slab (3) placed upon it and separated from it by spacer elements (2) of elastic material, said system comprising an elongated prestressing bed (4) and a first casting device (10) for casting the hollow-core slab onto the prestressing bed, **characterized in that** the system comprises a second casting device (11), which has been arranged to cast the surface slab (3) onto the upper surface (5) of the hollow-core slab so that the upper surface of the hollow-core slab acts as a mould for the lower surface (6) of the surface slab so as to give the lower surface of the surface slab a surface relief that is complementary to the upper surface of the hollow-core slab.

9. System as defined in claim 9, **characterized in that** the system comprises a hoisting device (12) for moving the surface slab (3) vertically with respect to the hollow-core slab (1).

10. System as defined in claim 8 or 9, **characterized in that** the system comprises a spacer mounting device (13) for setting the spacer elements (2) between the upper surface (5) of the hollow-core slab (1) and the lower surface (6) of the surface slab (3).

11. System as defined in claim 10, **characterized** in that the system comprises a device (14) for the application of a releasing medium, said device being arranged to apply a releasing medium (7) onto the upper surface (5) of the hollow-core slab (1) before the surface slab (3) is cast.

12. System as defined in claim 10 or 11, **characterized in that** the spacer elements (2) comprise a number of spacers of equal thickness; and that the spacer mounting device (13) has been arranged to set the spacers in an area close to the longitudinal edges (8, 9) of the hollow-core and surface slabs at a distance from each other.

13. System as defined in any one of claims 8 - 12, **characterized in that** the system comprises a cutting apparatus (15, 16) for cutting the hollow-core and surface slabs.

14. System as defined in any one of claims 8 - 13, **characterized in that** the cutting apparatus (15, 16) comprises a first cutting device (15) for cutting the surface slab and a second cutting device (16) for cutting the hollow-core slab.

15. System as defined in any one of claims 8 - 14, **characterized in that** the system comprises guide rails (17, 18) disposed near the prestressing bed (4) in a direction parallel to the longitudinal direction of the prestressing bed, and that the first casting device (10), the second casting device (11), the hoisting device (12), the spacer mounting device (13), the device (14) for the application of a releasing medium and/or the cutting apparatus (15, 16) are/is mounted on a frame (19, 20, 21, 22, 23) arranged to be movable along the guide rails (17, 18).

16. Composite slab comprising a hollow-core slab (1) and a surface slab (3) placed upon it and separated from it by spacer elements (2) of an elastic material, **characterized in that** the non-planar surface profile of the lower surface (6) of the surface slab (3) is, in the entire area of the lower surface, complementary to the surface profile of the non-planar upper surface (5) of the hollow-core slab (1), so that any distortions of the shape of the said surfaces, such as bulges and pits, are repeated in a mirror image fashion in the two opposite surfaces; and that the spacer elements (2) are of equal thickness.

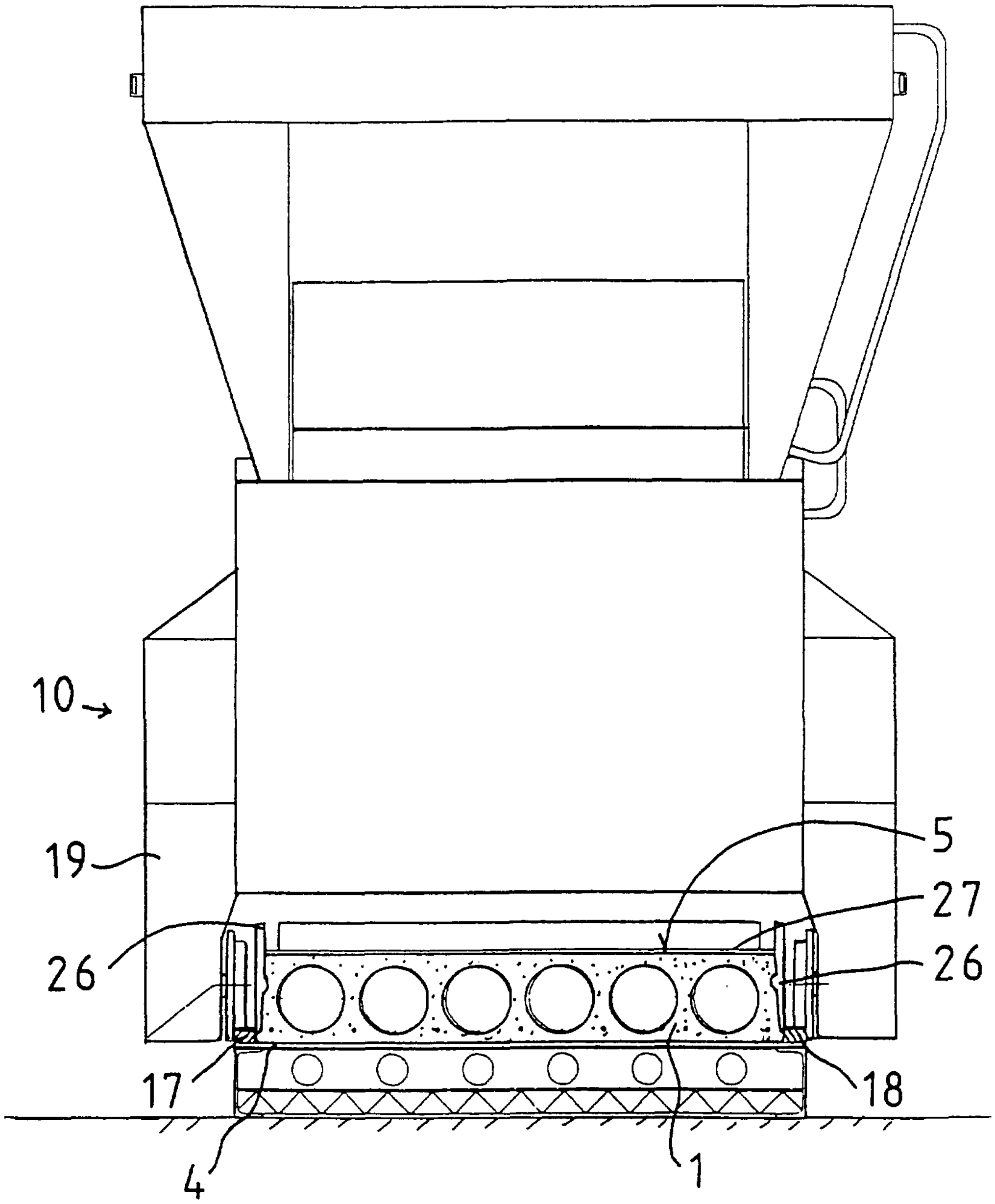

Fig 1

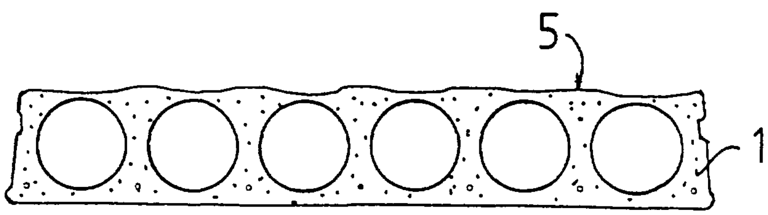

Fig 2

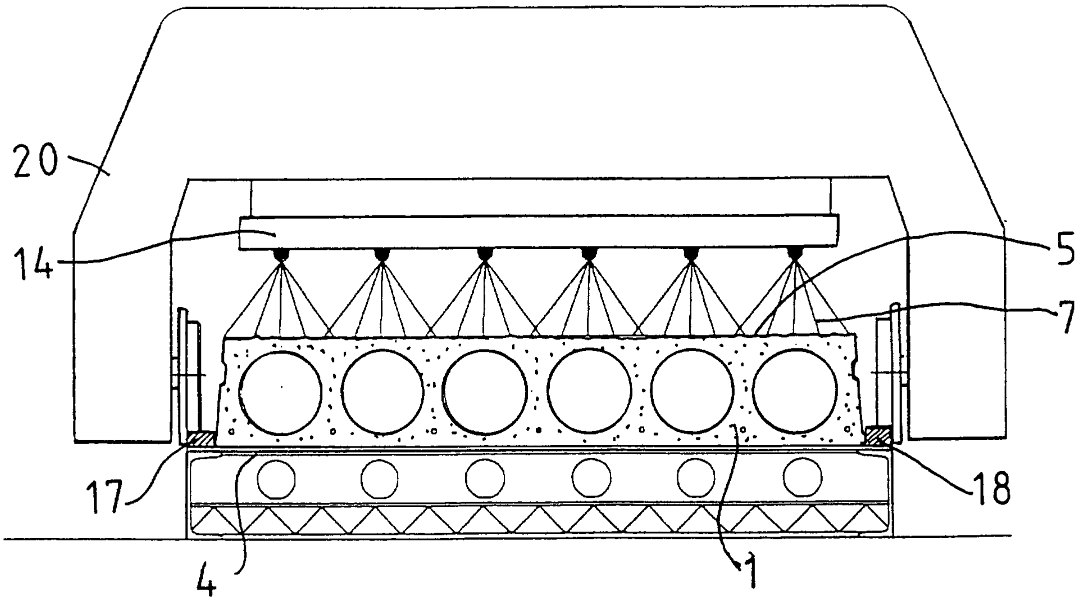

Fig 3

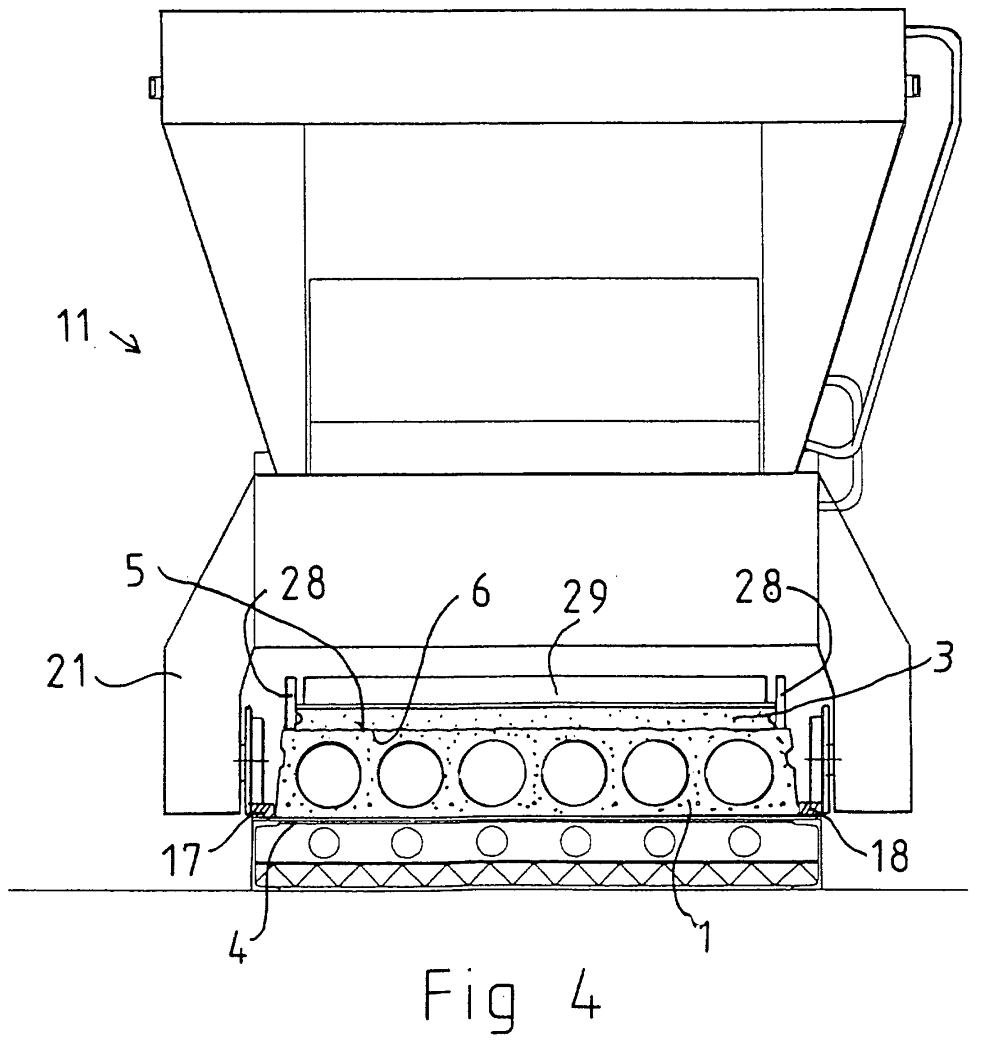

Fig 4

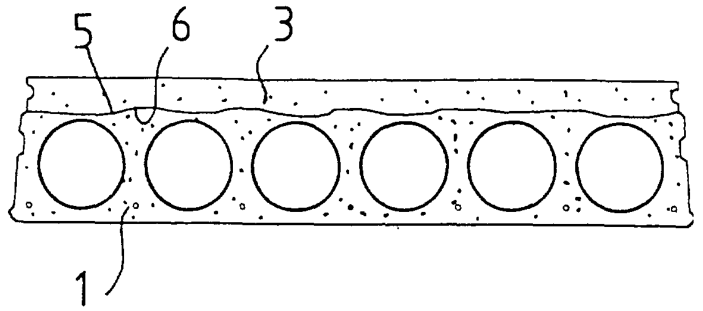

Fig 5

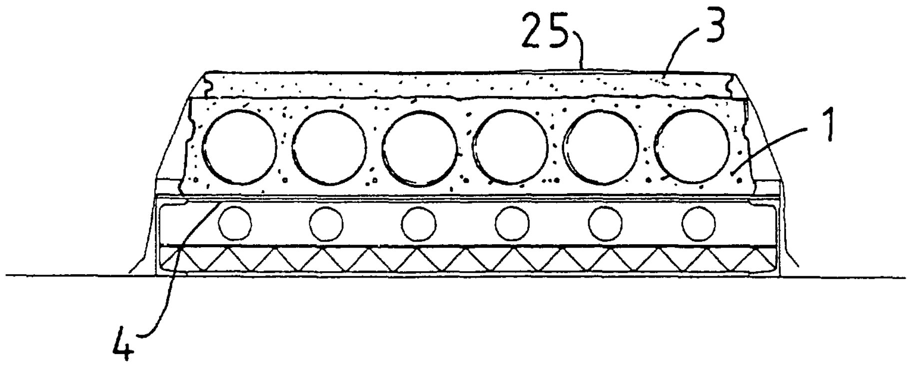

Fig 6

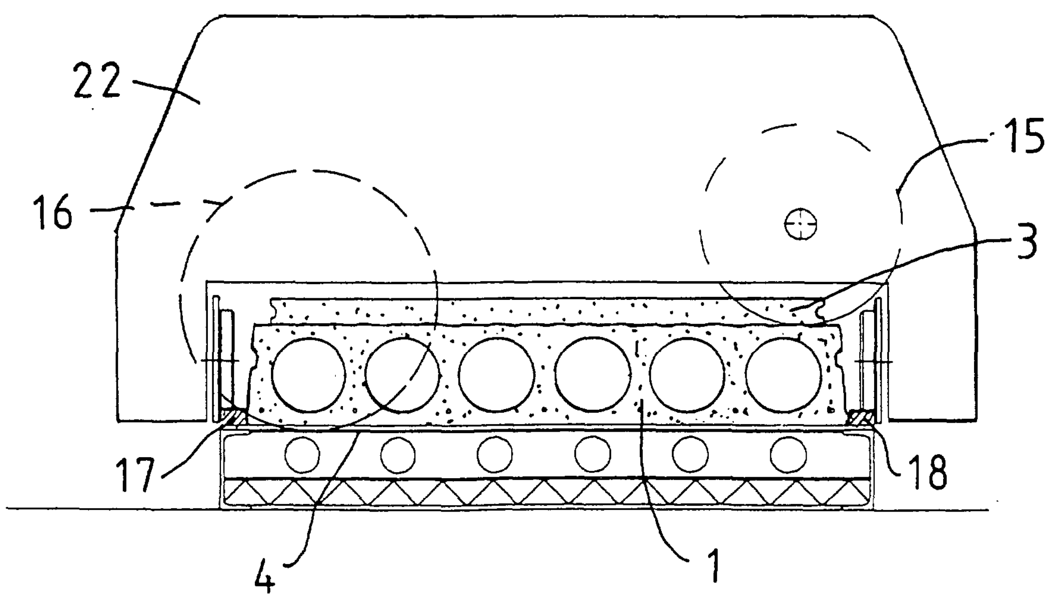

Fig 7

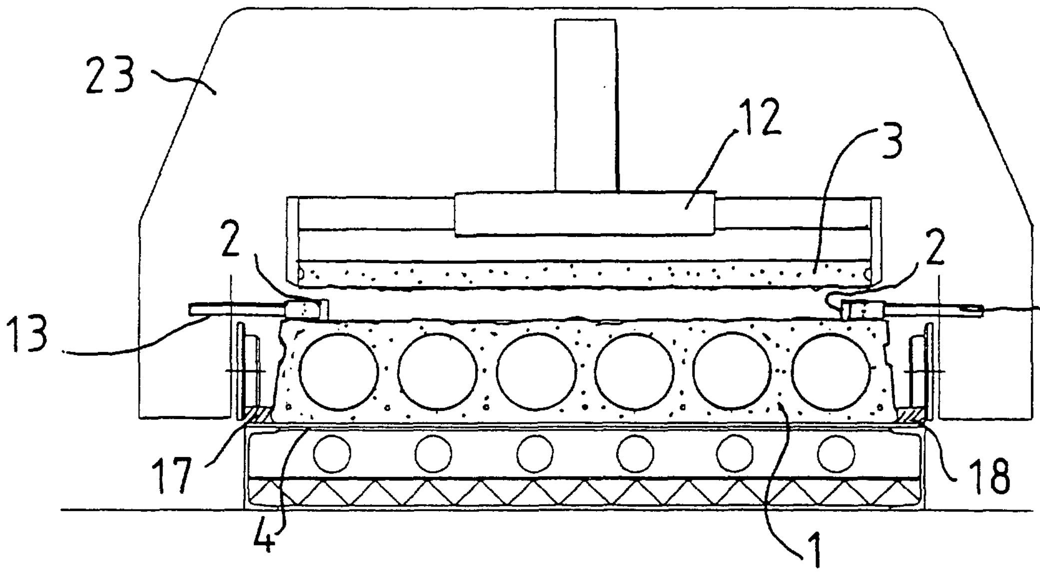

Fig 8

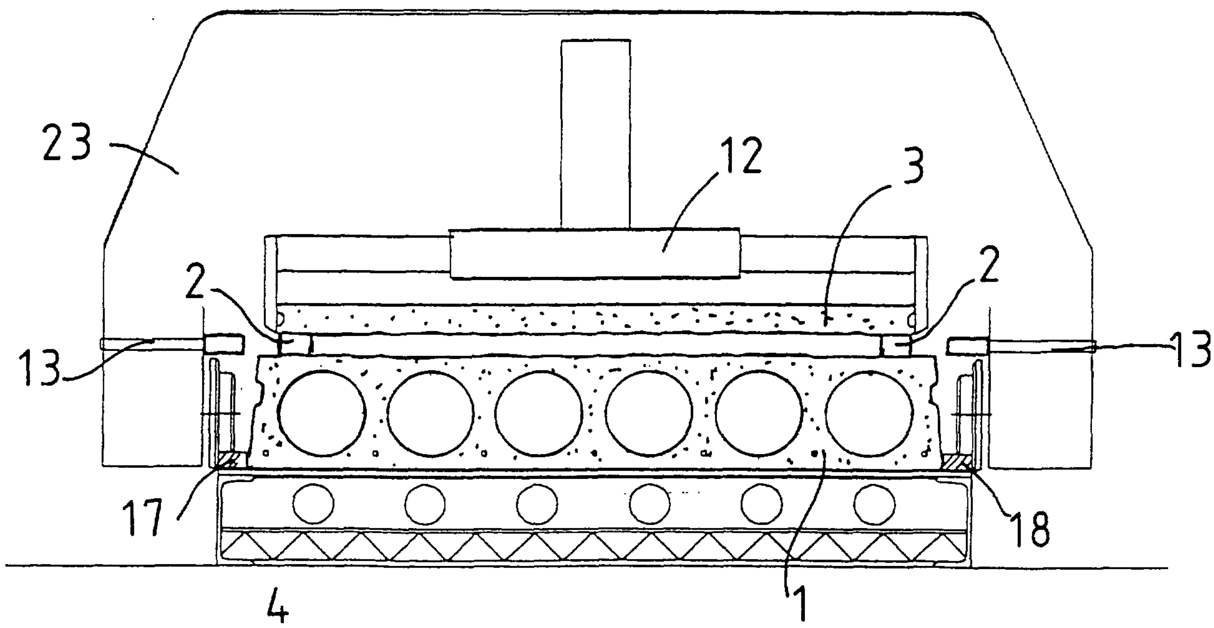

Fig 9

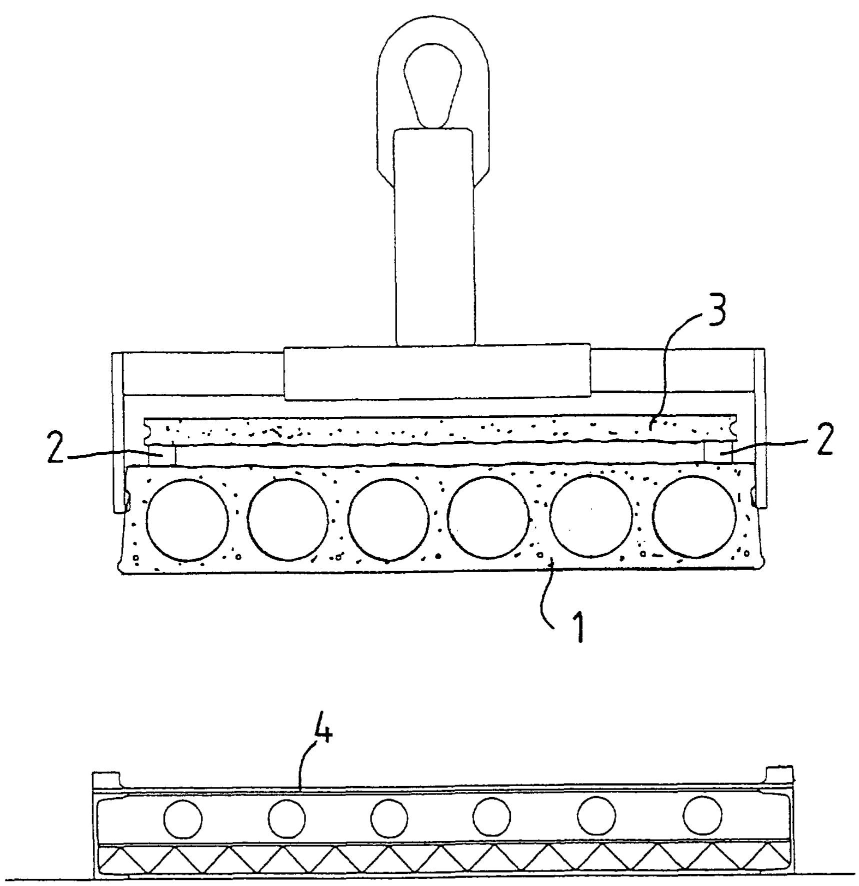

Fig 10

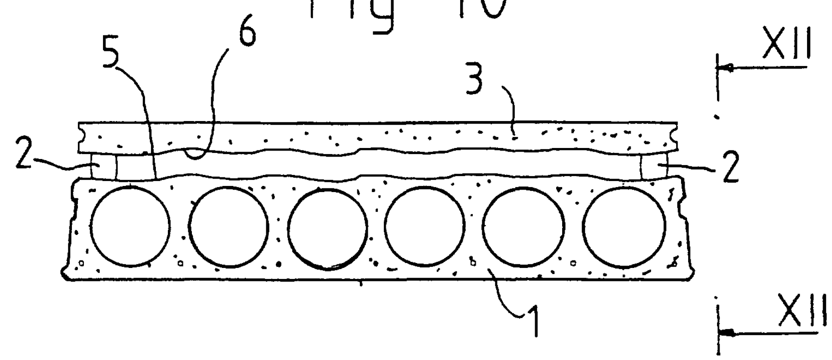

Fig 11

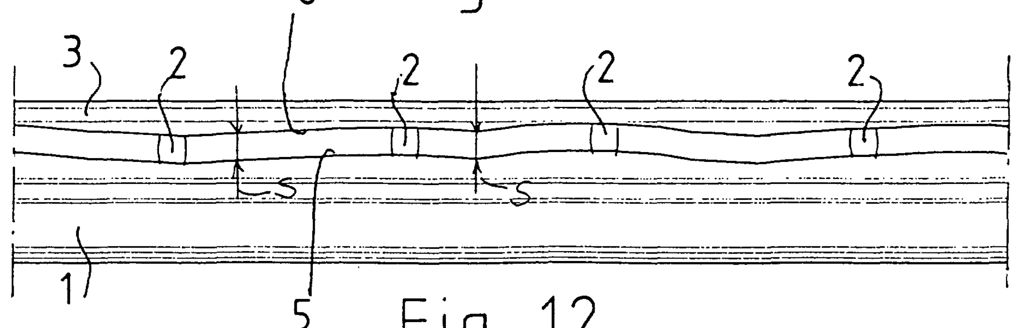

Fig 12

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 66 0158

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	12 February 2001	Bollen, J

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