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(54) **Composite beam**

(57) A composite beam element, which is used as a load-bearing horizontal structure in a prefabricated element frame of a building and which supports the slab structures of the horizontal levels of the building, said composite beam being connected and secured to a prefabricated column by means of a load-transmitting connecting part, and which element comprises a substantially closed box (1 - 3) of steel construction, inside which box is formed a space to be filled with concrete (8), said box consisting of a planar bottom flange (1), side walls

(2) and top flange (3) made of steel, which bottom flange extends past the side walls of the box and forms projecting parts (20), and which beam element is provided with longitudinal reinforcing bars. The upper surface of the box is provided with substantially rectangular openings (10), the edges (7) of which openings are bent downwards, with necks (15) remaining between said openings, and that two or more reinforcing bars (5) are fixed to the necks (15) in the upper surface of the box of the beam element, said bars being laid in the longitudinal direction of the beam element.

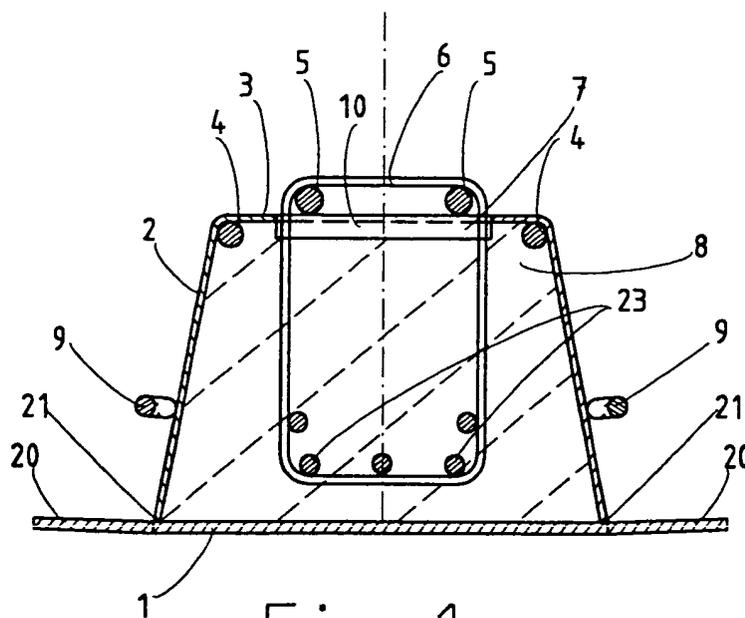


Fig 1

## Description

**[0001]** The present invention relates to a composite beam element which is used as a load-bearing horizontal structure in a prefabricated element frame of a building and which supports the slab structures of the floors of the building, said composite beam being connected and secured to a prefabricated column by means of a load-transmitting connecting part, and which element comprises a substantially closed box of steel construction, inside which box is formed a space to be filled with concrete.

**[0002]** In the load-bearing frames of buildings constructed from prefabricated elements, prefabricated beams and columns are generally used. The prefabricated beams are generally concrete elements of a length corresponding to the column spacing, prestressed reinforced concrete elements and steel/concrete composite beams. In most cases, the columns are prefabricated concrete elements or steel columns of a height extending through several stories. These main elements are connected to each other on site during installation by first erecting the prefabricated columns and then mounting the prefabricated beams between the columns. The level beam structures may also have a length extending across several intervals between columns, and in this case the prefabricated columns have a height equal to the floor-to-floor height. A feature common to both of these building frame systems is that the height dimension of the level beam structures is made as small as possible because the height of the beam limits the free floor-to-floor height of the building. Reinforced concrete beams and prestressed reinforced concrete beams always require a jaw of a height of 50 - 150 mm, which is used to support the hollow-core slabs. In steel composite beams, this jaw used to support the hollow-core slab consists of a steel plate having a thickness of 10 - 20 mm, in which case the beam height is almost the same as the height of the hollow-core slab, so the beam does not take up any space in the free floor-to-floor height. Prior-art steel beams consist of a prefabricated steel box in which the concrete does not participate in the load-bearing structure at all. This type of beam is a heavy and therefore expensive structure. Prior-art steel/concrete composite beams are manufactured either from profiled steel or from a closed steel box, which is filled with cast concrete either at the prefabricated element factory or on the construction site. The steel beam functions together with the concrete as a composite beam, allowing the material to be more effectively utilized, so the beam is advantageous as compared with a mere steel beam. A significant drawback associated with prior-art composite beams is the lack of construction-time stiffness, which is why the beam has to be propped up during construction time against the eccentric load imposed by the hollow-core slabs because the beam can not withstand this torsional load. The steel box disclosed in FI patent specifications 91181

and 107556 is open on one side, and therefore this solution does not provide resistance to installation-time loads. Thus the beams have to be propped up at installation time. This is an extra operation during the installation of the beams, and the method is expensive and laborious. Moreover, these beams have no prestress, and consequently their span length range is limited to lengths determined by the deflection.

**[0003]** Another problem with steel/concrete composite beams is that the available span length of the beam has to be reduced because the deflection of the beam becomes too large as the span length is increased. Certain limits are set for the deflection, and the beam can not be used if the deflection exceeds this deflection limit. It is necessary to have a possibility to limit the deflection at different stages during the installation of the beam via structural design considering the technical strength requirements. The whole capacity of the composite beam and the surrounding hollow-core slabs must be put to effective use to allow the load-bearing capacity of the beam to be effectively optimized at various stages of the load history.

**[0004]** The level beams of the frame are subjected to a large torsional load during the installation of the beam as the hollow-core slabs are mounted unsymmetrically on top of the beam flange. On the edge beam of the level, all the hollow-core slabs are placed on one side of the beam. The torsional load of the beam can be put to effective use only by using a structure of the steel box type. Open profiles or mere reinforced concrete beams can not withstand the torsional load.

**[0005]** In addition to the beam's ability to withstand torsion, co-action between the concrete inside the beam, the steel box, the external joint grouting of the beam and the material of the hollow-core slabs is of primary importance to allow all the materials to be utilized in the final bending capacity of the beam.

**[0006]** In the design of a composite beam, the fire rating constitutes a significant requirement. The beam must be able to bear the loads of the slab even in a fire situation. The bottom flange of the beam is not protected against fire, and therefore the bottom flange does not function as a load-bearing structure in a fire situation. In the case of a fire, the other parts of the beam have to bear the entire load imposed on the beam during the fire.

**[0007]** The object of the present invention is to overcome the drawbacks of prior art and achieve a new type of composite beam, a so-called prestressed composite beam. In the invention, the composite beam consists of a closed steel box structure which has been filled with cast concrete already during manufacture in factory. In this way, a maximal resistance to torsion is achieved and installation-time propping of the beam can be omitted altogether.

**[0008]** The composite beam of the invention consists of a prefabricated steel box having the shape of a gently sloping letter A, which has a flange on its lower surface for supporting hollow-core slabs. The required de-

formed reinforcing steel bars are mounted inside the beam, of which bars the ones on the lower surface of the beam are prestressed.

**[0009]** This beam filled with cast concrete at the manufacturing stage in factory, whereupon the concrete hardens and a prestressing force is triggered by means of the deformed reinforcing steel bars, the composite beam being thus prestressed. Through prestressing, service state deflections of the beam can be reduced, and consequently longer span lengths are possible. In the case of short beam, the deformed reinforcing steel bars on the lower surface of the beam need not be prestressed, in which case the beam will function as a normal composite beam. In filling the beam with cast concrete, it is possible to use self-sealing materials, in which case vibration of the beam during casting can be omitted while also ensuring that every part of the beam is filled with concrete.

**[0010]** The features of the invention are presented in detail in the claims below.

**[0011]** Composite beams are generally fairly slim, which is why they undergo relatively large deflections. To reduce the deflections, the beams are provided already at the manufacturing stage with a pre-cambering, by giving the beam an upward curvature so that the own weight of the slabs will bend the beam back into horizontal alignment. The beam is only bent downwards under effective loads of the slabs, and thus the total deflection of the beam can be increased and the beam can be more effectively utilized. Pre-cambering a complex and unsymmetric beam is often a difficult and expensive task, and in most beam types it can not be accomplished at all, but in the composite beam of the invention it is relatively easy to make a pre-cambering.

**[0012]** In the following, the invention will be described in detail by the aid of an example with reference to the attached drawings, wherein

Fig. 1 space a composite beam according to the invention as seen from one end and sectioned at the middle, when the box of the beam has been made in factory and the steel box of the beam has been filled with cast concrete in factory;

Fig. 2 presents a short section of the length of the composite beam according to the invention in top view,

Fig. 3 presents the composite beam of the invention in end view and sectioned at the middle when the beam has been installed and the hollow-core slabs mounted and grouting performed;

Fig. 4 presents a top view of a short length of the composite beam of the invention when installed;

Fig. 5 presents a side view of the beam of the invention at manufacturing stage before the welding

together of the parts of the beam preform, and

Fig. 6 presents a side view of the beam of the invention at manufacturing stage after the parts of the beam preform have been welded together.

**[0013]** Figures 1 and 2 present a portion of the a composite beam according to the invention which is manufactured e.g. in a prefabricated element factory, consisting of the following parts: Part 1 is the bottom flange of the beam and consists of a rectangular steel plate. Parts 2 and 3 are the web and the top flange of the beam, which consist of a steel plate bent into the shape of a gently sloping letter A, welded onto part 1 and forming with part 1 a closed box structure, inside which a space for concrete is thus formed. The surface of part 3 is provided with rectangular openings 10 spaced at even distances, the edge 7 of the opening being bent downwards to form a rectangular shoulder, which also forms a mold ensuring that the concrete cast into the beam will not quite reach the level of the surface of the box. Welded fast to the box 2 are two deformed steel bars 4, which are located inside the box at the upper corners of the box 2. Welded to the top surface of the box 3 are two deformed steel bars 5 on the neck 12 between the openings 10. Suspended on the deformed steel bars 5 are rectangular deformed steel hooks 6 extending through the openings 10 in the top surface of the beam. The steel hooks 6 serve to support reinforcing bars 23, the number of which is at least two and at most the number required by the beam strength, arranged in at least two tiers. The reinforcing bars 23 are made from high-strength deformed steel bars and they can be prestressed. Welded to the lateral surfaces 2 of the beam is a deformed reinforcing steel bar 9 shaped in the form of a gently sloping trapezoid pattern.

**[0014]** The composite beam to be produced at a prefabricated element factory can be made torsionally rigid by filling the box-like steel frame 1 - 3 with concrete 8. The openings 10 in the upper surface of the beam do not render the structure less box-like with respect to material strength, because the neck 12 between the openings 10 is designed to be sufficiently strong to receive the torsional loads. The composite beam to be produced at a prefabricated element factory is prestressed by means of reinforcing bars 23 made of high-strength steel A700HW. The reinforcing bars 23 function as the part carrying the ultimate-state tensile capacity of the beam, and in a fire situation they function alone as the active part on the tension side of the beam. Two of the reinforcing bars 23, i.e. the ones fastened to the bottom corners of the hook 6, are welded onto the plate-like end plate of the beam box to provide a fire situation shear capacity.

**[0015]** Fig. 3 visualizes a situation during installation of the composite beam. The hollow-core slabs 13 are mounted on the projecting part 20 of the bottom flange 1 of the beam. The projecting part 20 of the bottom

flange of the beam bends upwards when the web plate 2 is being welded onto the bottom flange at point 21. As the bottom flange is bent upwards, the hollow-core slab is first seated on the end of the projecting part of the bottom flange, from where the point of support of the hollow-core slab is shifted onto the entire projecting part of the bottom flange. In this way, breakage of the end of the hollow-core slab is prevented because the end of the hollow-core slab does not touch the supporting point first. Joint grouting and surface grouting 14 of the beam are carried out, filling the space around the beam with cast concrete.

**[0016]** The composite effect between the concrete 8 inside the beam and the steel box 1 - 3 of the beam is created by means of reinforcing bars 4. The composite effect between the concrete 14 on the outside, the hollow-core slabs 13 and the ferroconcrete core presented in Fig. 1 is created by means of the aggregate interlock between the grouting neck of the opening 10 and the bars 5 laid in the longitudinal direction of the beam and the hooks 6. For the composite effect, the concrete of the openings 10 is additionally used, which functions via aggregate interlock, forming in the composite effect an element transferring the shear force.

**[0017]** Figures 5 and 6 illustrate the principle of manufacturing the parts 1 - 3 of the beam and a method for pre-cambering the beam. In part 2 of the beam, a required number of cutouts 22 are made on both sides along the length of the beam. The cutout has the shape of a sharp letter V, and it extends across the whole width of part 2. When the bottom flange 1, the web and the top flange of the beam are welded together, part 2 is bent so that the edges of the cutouts 22 meet. In this way, the beam is given an upwards curvature as shown in Fig. 6, and a pre-cambering required in each case can be formed in the beam by adjusting the number and size of the cutouts 22.

**[0018]** The invention is not limited to the embodiment described above; instead, it can be varied within the scope the claims presented below. Thus, the cross-section may also have a rectangular form or it may have the form of a more gently or more steeply sloping letter A. The total number of reinforcing bars may vary according to application, and the corresponding parts of the composite beam follow the selected form, and thus the form of the composite beam is not limited the forms described above.

## Claims

1. Composite beam element, which is used as a load-bearing horizontal structure in a prefabricated element frame of a building and which supports the slab structures of the horizontal levels of the building, said composite beam being connected and secured to a prefabricated column by means of a load-transmitting connecting part, and which element

comprises a substantially closed box (1 - 3) of steel construction, inside which box is formed a space to be filled with concrete (8),

said box consisting of a planar steel bottom flange (1), side walls (2) and a top flange (3), which bottom flange extends past the side walls of the box and forms projecting parts (20), and

which beam element is provided with longitudinal reinforcing bars, **characterized in that**

the upper surface of the box is provided with substantially rectangular openings (10), the edges (7) of which openings are bent downwards, with necks (15) remaining between said openings, and that two or more reinforcing bars (5) are fixed to the necks (15) in the upper surface of the box of the beam element, said bars being laid in the longitudinal direction of the beam element.

2. Element according to claim 1, **characterized in that**

the element comprises second longitudinal reinforcing bars (23) arranged inside the box in one or more tiers, and that

from the longitudinal reinforcing bars (5) of the beam element, substantially rectangular hooks (6) are suspended through the openings (10) of the box, said hooks supporting the second longitudinal reinforcing bars (23) of the beam element.

3. Element according to claim 2, **characterized in that** at least the second reinforcing bars (23) are made of high-strength steel, and they are prestressed to increase the deflection capacity of the beam element.

4. Element according to claim 1, **characterized in that** it has third reinforcing bars (4) fixed to the upper corners of the box (1 - 3), said bars functioning as bonding elements in the formation of a composite effect between the concrete (8) inside and the steel box (1 - 3) outside.

5. Element according to claim 1, **characterized in that** the longitudinal reinforcing bars (5) of the element, the steel hooks (6) and the trapezoid bars (9) together with the concrete introduced into the box (8) from the grouting concrete (14) through the opening (10) form the composite effect with respect to material strength between the composite beam box (1), (2), (8) and the external grouting concrete (14).

6. Element according to claim 1, **characterized in that** it comprises a reinforcing bar (9) bent into the form of a trapezoid pattern and welded to the lateral surface of the box (3), which bar (9) forms a slot (16) in which is mounted a tie bar (12), whose end (17) is so shaped that it can not rise out of the slot

(16) formed by the reinforcing bar (9) once the tie bar has been forced into the slot.

7. Element according to claim 1, **characterized in that** the composite beam element consists of the closed steel box (1) (2) and (3) and the concrete (8) cast inside it, which box together with the cast concrete forms a structure of the element receiving installation-time torsional loads, and the beam element is therefore not provided with additional supports during installation. 5  
10
8. Element according to claim 1, **characterized in that** additional deformed steel bars (18) can be mounted in the grouting (14) above the box (3), and that the bending capacity of the beam element can be adjusted via the number of additional deformed steel bars (18) and the size of the reinforcing bars (4) and (5) welded to the beam element. 15  
20
9. Element according to claim 1, **characterized in that** the ones of the prestressed reinforcing bars that are located at the corners of the hook are fastened, e.g. welded onto the end plate to provide for fire situation shear capacity. 25
10. Element according to claim 1, **characterized in that** there are no apertures or holes in the bottom and lateral surfaces (1) and (2) of the steel box, thus allowing the use of self-sealing concrete materials in the internal (8) concreting, which ensures that every part of the interior space is filled with concrete. 30
11. Element according to claim 1, **characterized in that** the projecting part (20) of the bottom flange can be bent upwards e.g. by the welding tensions produced by a weld (21), and that during the installation of a hollow-core slab the camber of the bottom flange (20) prevents the end of the hollow-core slab from being damaged when the slab is being mounted. 35  
40
12. Element according to claim 1, **characterized in that** pre-cambering of the beam is accomplished by making a required number of cutouts (22) in the side wall, such as the web plate (2), which cutouts are closed by bending the beam element during assembly and the edges (22) are fastened, e.g. welded together, thus creating an upward curvature in the bottom flange (1) of the beam element. 45  
50
13. Element according to claim 12, **characterized in that** the box (2, 3) can be bent into an A-shaped form by using a tool having a length smaller than the total length dimension of the box, especially only a length corresponding to the spacing between cutouts (22). 55

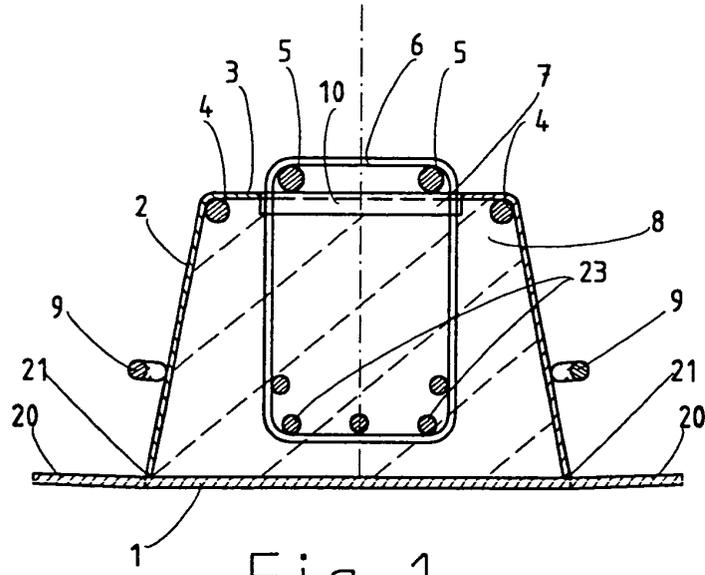


Fig 1

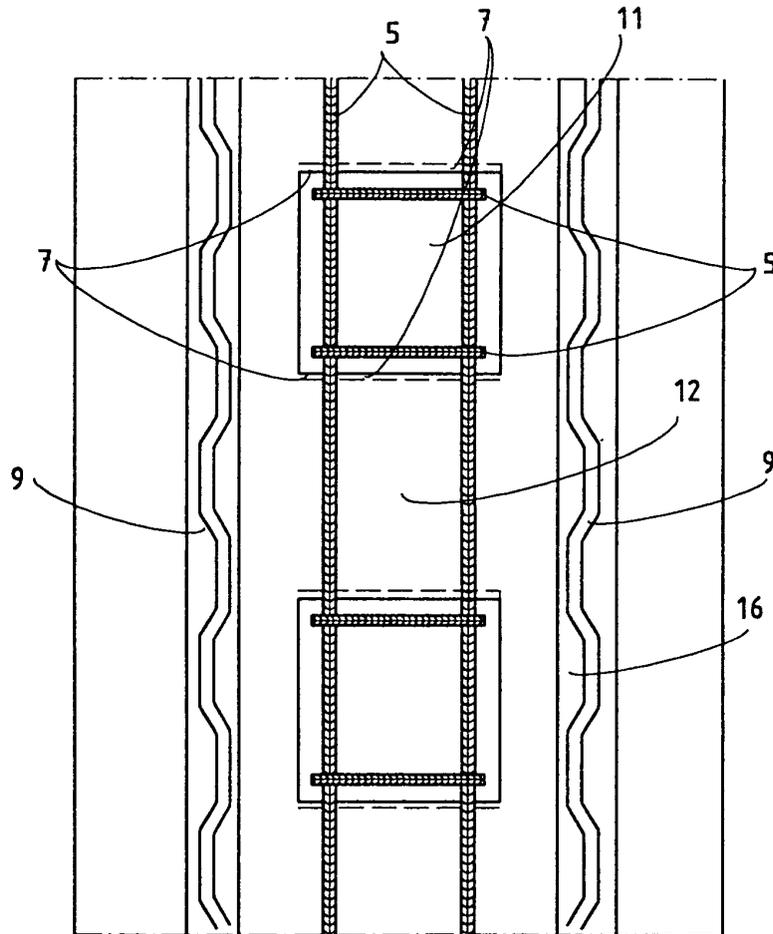


Fig 2

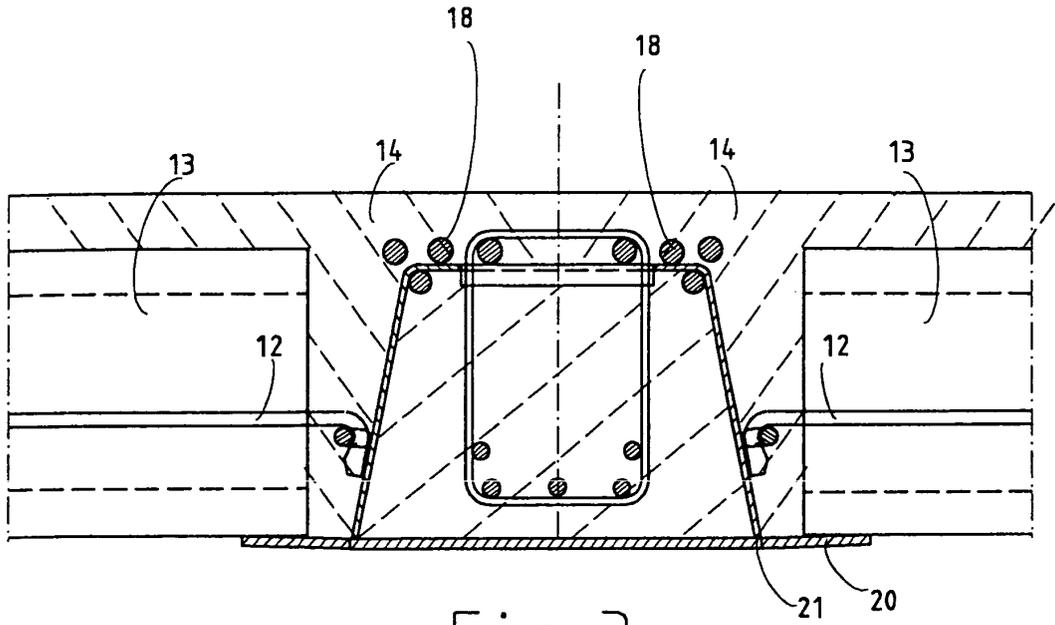


Fig 3

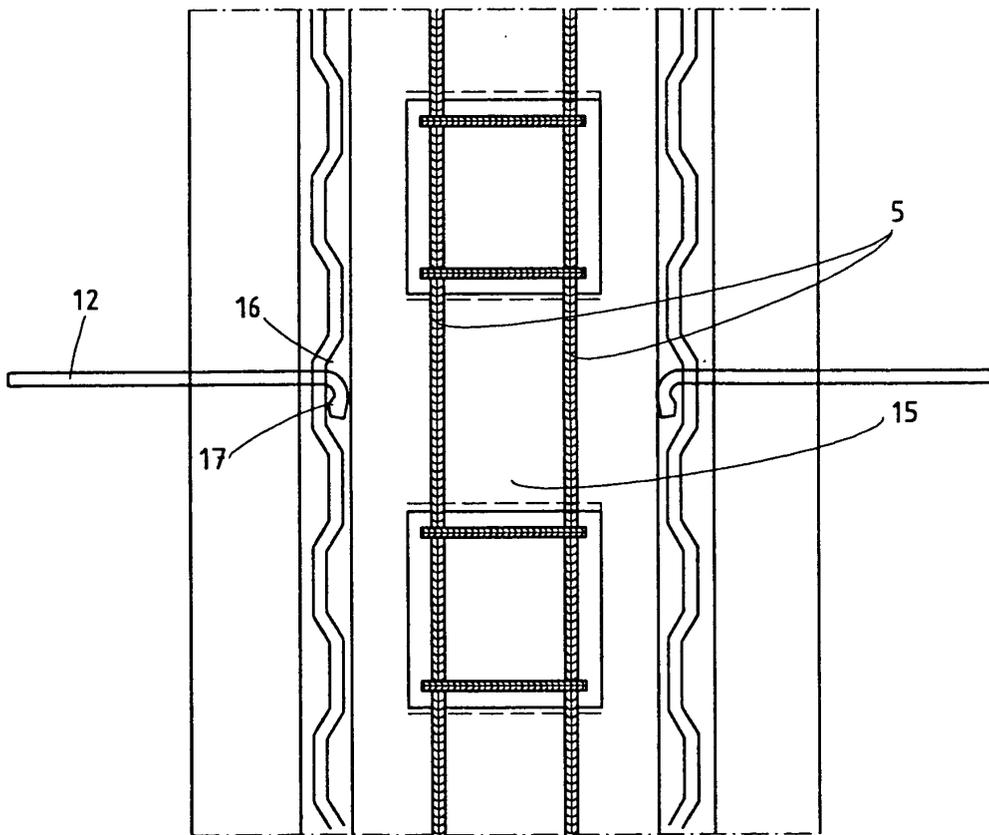
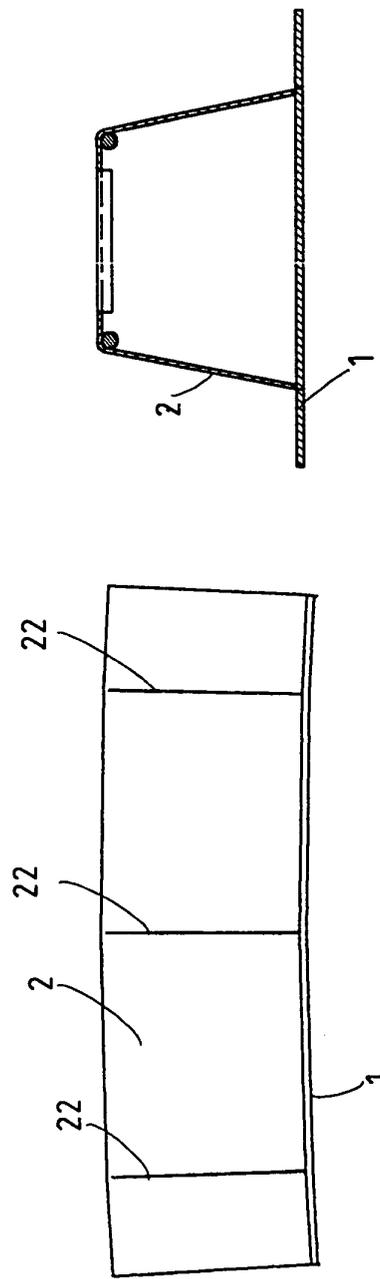
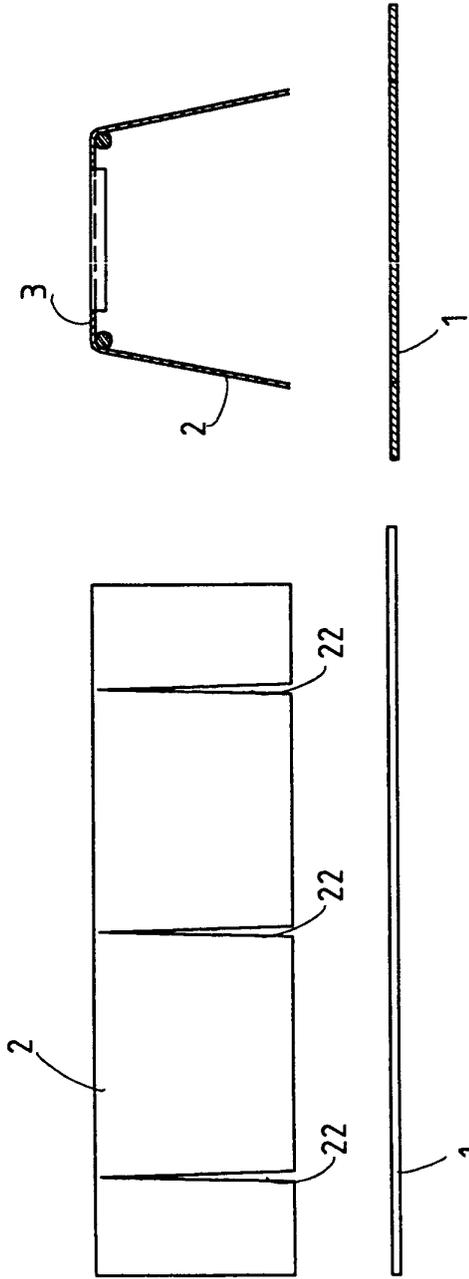


Fig 4





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Application Number  
EP 03 07 8411

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Place of search MUNICH		Date of completion of the search 2 February 2004	Examiner Vratsanou, V
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