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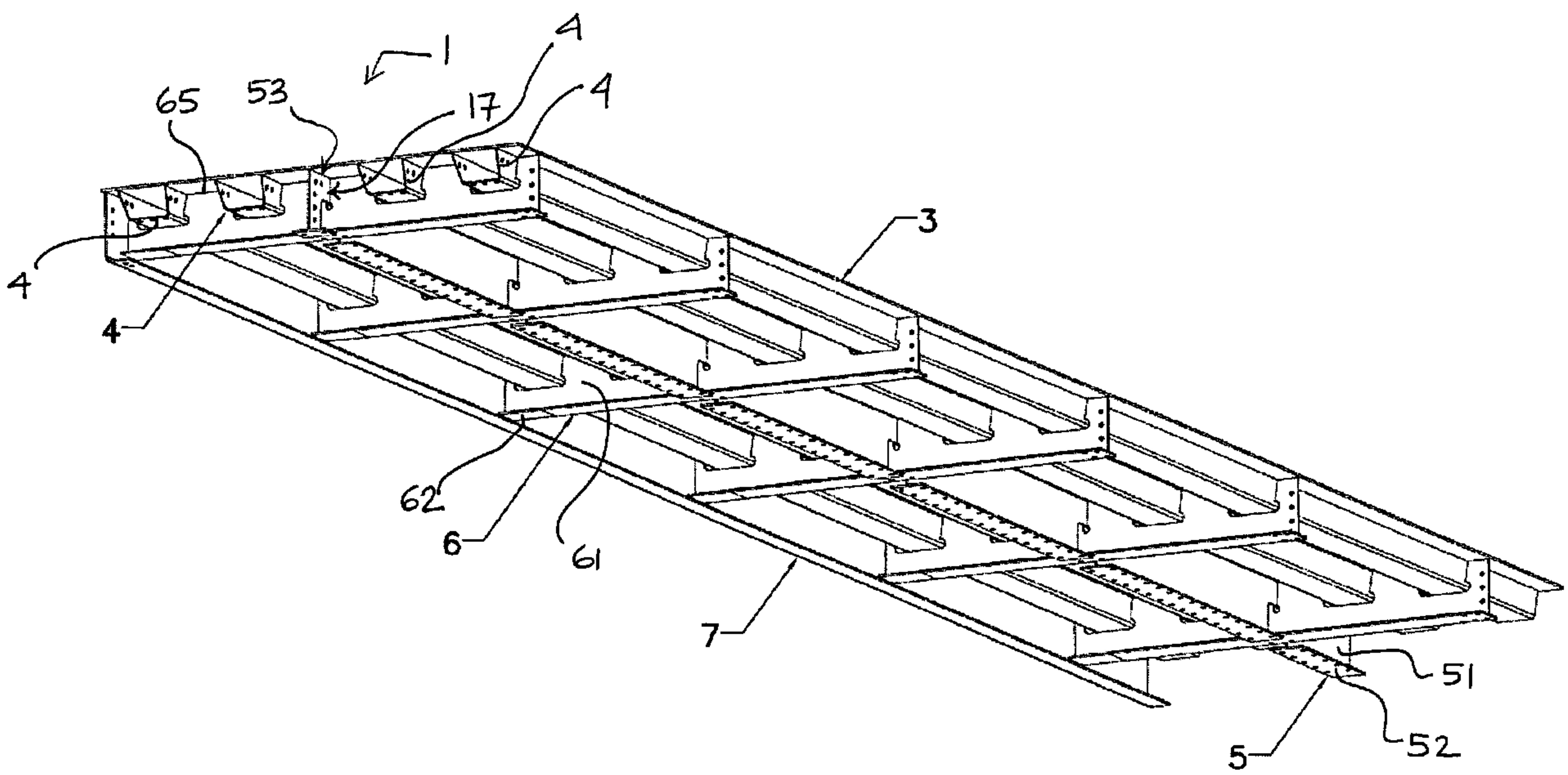


(57) **Abrégé/Abstract:**
A prefabricated bridge deck panel that can be affixed to pre-existing bridge girders. The bridge deck panel comprises an elongated metal deck plate stiffened longitudinally by longitudinal stiffening metal ribs. The bridge deck panel also comprises at least one inverted Tee rib underneath the deck plate. The vertical web member of the inverted Tee rib has its upper end structurally secured to the deck plate of the bridge deck panel. The panel also comprises spaced-apart transverse floor beams underneath the deck plate. The vertical web member of the transverse floor beams has recesses fitted over the longitudinal stiffening metal ribs, and interfits with the vertical web member of the inverted Tee rib. The upper end of the transverse floor beams is structurally secured to the deck plate. In use, the inverted Tee rib is laid on and secured to a pre--existing bridge girder.

ABSTRACT

A prefabricated bridge deck panel that can be affixed to pre-existing bridge girders. The bridge deck panel comprises an elongated metal deck plate stiffened longitudinally by longitudinal stiffening metal ribs. The bridge deck panel also comprises at least one inverted Tee rib underneath the deck plate. The vertical web member of the inverted Tee rib has its upper end structurally secured to the deck plate of the bridge deck panel. The panel also comprises spaced-apart transverse floor beams underneath the deck plate. The vertical web member of the transverse floor beams has recesses fitted over the longitudinal stiffening metal ribs, and interfits with the vertical web member of the inverted Tee rib. The upper end of the transverse floor beams is structurally secured to the deck plate. In use, the inverted Tee rib is laid on and secured to a pre-existing bridge girder.

BRIDGE DECK PANEL

FIELD OF THE INVENTION

The present invention generally relates to metal plate decks for bridges. More particularly, it concerns a bridge deck panel for use in short span bridges, multiple girder bridges or for rehabilitating existing concrete deck bridges.

DESCRIPTION OF THE PRIOR ART

Already known in the prior art are orthotropic bridge deck panels. A conventional orthotropic bridge deck consists of a longitudinally stiffened steel deck plate supported by a series of regularly spaced transverse floor beams. The stiffened deck plate is designed as a continuous member spanning between the transverse floor beams. The transverse floor beams span the width of the bridge and are supported by a pair of main longitudinal bridge members, such as deep plate-girders, box girders, steel trusses, steel or concrete arches, cable suspended bridge members or other suitable structural members.

Orthotropic bridge decks consist of flat, thin steel plates stiffened by a series of closely spaced longitudinal ribs at right angles, or orthogonal, to the floor beams. The rigidities of the ribs and floor beams are usually of unequal magnitude and their elastic behaviour is different in each of the two principal axes. This is called structural anisotropy. Due to the orthogonal nature of the beams and the anisotropic structural behaviour, the bridge deck system became known as orthogonal-anisotropic, or in short orthotropic.

Steel orthotropic decks are relatively costly solutions as bridge decks, resulting in their limited use to date. Their initial construction cost is usually at least twice that of an equivalent concrete slab bridge deck. Fewer than one hundred of the more than one half million bridges in North America have been constructed using this type of bridge deck system. The overall weight of an orthotropic deck is however much lighter, generally in the range of 25% to 40% of the weight of a comparable concrete deck slab. Orthotropic decks are typically utilized on very long span bridges where the strength and size of the supporting members is governed more by the dead weight of the bridge than the traffic load it is designed to carry. Thus on long span bridges, the lighter weight of orthotropic bridge decks result in significant overall savings in the bridge's main supporting member's strength demand, resulting in a lower structural cost that offsets the deck's higher initial cost.

Steel orthotropic decks are shop assembled into long panels spanning several transverse floor beams and transported by land or water to the bridge site. These panels usually require a significant amount of field welding to incorporate them as a structural unit with the transverse floor beams and to develop the continuity of both the top plate as well as the stiffening ribs. Much of the field welding is in the overhead position that is difficult to accomplish and must be completed using manual welding techniques.

Already known to the Applicant are US 2,645,985 (BEEBE *et al.)*, US 4,831,675 (NEDELCU), US 5,144,710 (GROSSMAN), US 5,463,786 (MANGONE *et al.*), US 5,664,378 (BETTIGOLE *et al.*), US 5,806,121 (MANGONE), US 5,987,680 (SAKAYA), JP 11021819 (SUGIZAKI), JP 8209628 (SUGIZAKI) and JP 7018630 (MORI *et al.*).

US 4,831, 675 (NEDELCU) discloses a double rib system formed by a steel deck plate, closed steel ribs and open steel ribs. The open steel ribs are connected to the closed steel ribs, rather than to the steel deck plate, therefore increasing the strength of the rib system and allowing a larger spacing of the transverse floor girders. This double rib system does not act compositely with the deck plate and does not provide a single bi-flexural structural unit.

Japanese patents JP 11021819 (SUGIZAKI) and JP 8209628 (SUGIZAKI) both disclose a steel floor plate formed by a deck plate, vertical ribs and transverse girders and ribs. The steel floor plate also includes a bridge main girder to be mounted directly on bridge pillars. This solution however does not provide a composite action between the bridge main girder and the deck plate and cannot be used to rehabilitate existing bridges.

Thus, there is still a need for an improved, lighter and more economically viable bridge deck panel suitable for use in shorter span bridges or multiple girder bridges that can be easily transported to bridge sites over land or by water and field assembled with a minimum amount of field welding. Lighter deck panels may allow for increase of the load capacity of an existing bridge and removal of load restrictions from existing bridges.

It would also be desirable to have a deck panel acting compositely with the bridge structure, providing a bi-flexural action that would allow for a thinner steel deck plate resulting in a lower steel deck cost and that would increase the composite main bridge girder depth.

It would also be desirable to have a deck panel that may be used to rehabilitate existing concrete bridge decks, be erected rapidly and that can reduce the duration of a temporary bridge closure.

SUMMARY OF THE INVENTION

An object of the present invention is to propose a bridge deck panel that satisfies at least one of the above-mentioned needs.

In accordance with the invention, that object is achieved with a prefabricated bridge deck panel that can be affixed to at least one main longitudinal bridge girder. The bridge deck panel comprises an elongated metal top deck plate stiffened longitudinally by longitudinal stiffening metal ribs, such as closed or open metal ribs. The bridge deck panel also comprises at least one inverted Tee rib extending longitudinally underneath the top deck plate. The inverted Tee rib has a vertical web member and a flange plate. The vertical web member of the inverted Tee rib has its upper end structurally secured to the top deck plate of the bridge deck panel. The bridge deck panel also comprises spaced-apart transverse floor beams extending transversally underneath the top deck plate, in an interfit relationship with the inverted Tee rib. Each transverse floor beam comprises a vertical web member and a flange plate. The vertical web member of the transverse floor beams has recesses fitted over the longitudinal inverted Tee metal ribs. The upper end of the vertical web of the transverse floor beams is structurally secured to the top deck plate. In use, the flange plate of the inverted Tee rib is laid on and secured to the at least one bridge girder.

The inverted Tee ribs allow for a positive connection between the top deck plate and the bridge girders resulting in a composite action between the deck system and the bridge girder. When in use, the top deck plate acts compositely with all of the main longitudinal bridge girders increasing their structural properties. In addition, inverted Tee ribs and transverse floor beams provide a continuous support to the top deck plate directly over the bridge girders thus creating biaxial bending in the top deck plate. The top deck plate also acts as the top flange of the transverse floor beams making the panels much stiffer. Finally, the bridge deck panels can accommodate roadway surface cross slopes, vertical curves in bridges, super-elevation and long vertical curves.

In accordance with a first preferred embodiment, the inverted Tee rib and the transverse floor beams of the deck panel are of substantially equal depth; wherein in use, the flange plate of the inverted T rib is laid on and secured to a main longitudinal bridge girder.

In accordance with a second preferred embodiment, the inverted Tee rib is deeper than the transverse floor beams; and in use, the flange plate of the inverted Tee rib is laid on and secured to transverse bridge members.

In accordance with a third preferred embodiment, the transverse floor beams are deeper than the inverted Tee rib; and in use, the flange plate of the inverted Tee rib is laid on and secured to transverse bridge members.

The present invention also concerns a method for installing a new deck on pre-existing main longitudinal bridge girders; the method comprises the steps of:

a) providing a plurality of prefabricated bridge deck panels as described in the first preferred embodiment;

b) mounting the bridge panels side-by-side and/or end-to-end on the main longitudinal bridge girders with the flange plate of the inverted T rib of each of said bridge deck panels laying on top of a portion of one of the main longitudinal girders; and

c) bolting the flange plate of inverted T ribs to the main longitudinal girder.

Preferably, the method may further comprise the step of:

d) bolting adjacent transverse floor beams and end to end inverted Tee ribs of the bridge deck panels using connecting plates; and

e) connecting end-to-end stiffening closed metal ribs of the bridge deck panels and sealing the void using, if needed, press fit closure blocks.

The present invention further concerns a method for installing a deck on transverse bridge girders, the method comprises the steps of:

a) providing a plurality of prefabricated bridge deck panels as described in the second or third preferred embodiment; and

b) mounting the bridge panels side-by-side and/or end-to-end on the main transverse bridge members with the flange plate of the inverted T rib of each of said bridge deck panels bridging a plurality of the transverse members.

c) bolting the flange plate of inverted tee ribs to transverse bridge members

This method may further comprise the steps of:

d) securing adjacent transverse floor beams and end-to-end inverted Tee ribs of the bridge deck panels using connecting plates; and

e) connecting end to end stiffening closed metal ribs of the bridge deck panels and sealing the voids using, if needed, press fit closure blocks.

Further aspects and advantages of the present invention will be better understood upon reading of preferred embodiments thereof with respect to the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

All the objectives and advantages of this invention will become more apparent from the specifications taken in conjunction with the accompanying drawings in which:

Figure 1 is a perspective view of four longitudinal steel bridge girders on which bridge deck panels are mounted, according to a first preferred embodiment of the invention;

Figure 2 is a perspective view of one of the panels of Figure 1 viewed from below the bridge structure;

Figure 3 is a cross section view of one of the longitudinal stiffening ribs of the panel shown in Figure 2 taken between two adjacent transverse floor beams;

Figure 4 is a cross section view of a longitudinal inverted Tee rib on a longitudinal girder taken between two adjacent transverse floor beams;

Figure 5 is a cross section view of a longitudinal edge stiffening rib taken between two adjacent transverse floor beams;

Figure 6 is a cross section view through a transverse floor beam taken at a longitudinal bridge girder;

Figure 7 is an elevation view of a transverse floor beam at a location where it crosses over a longitudinal bridge girder;

Figure 8 is an elevation view of a transverse floor beam at a location where it intersects with a longitudinal stiffening rib;

Figure 9A is an elevation view taken at the splice location between two adjacent bridge deck panels;

Figure 9B is a cross-section view taken along line A-A in Figure 9A, showing the transverse splice between two adjacent bridge deck panels;

Figure 10A shows the longitudinal splice detail connecting two longitudinal stiffening ribs between the ends of two bridge deck panels;

Figure 10B is a cross-section view taken along the lines B-B of Figure 10A;

Figures 11A are two different perspective views of a block made out of a compressible material used for closing the open ribs;

Figure 11B is a side view of two end to end bridge deck panels showing the block of Figure 11A mounted between the ends of the two bridge deck panels;

Figure 11C is a cross-section view taken along line C-C in Figure 11B;

Figure 12A shows the longitudinal splice detail connecting two inverted Tee ribs between the ends of two bridge deck panels;

Figure 12B is a cross-section view taken along line D-D in Figure 12A;

Figure 13A shows a longitudinal splice detail connecting two longitudinal edge stiffening ribs between the ends of two bridge deck panels;

Figure 13B is a cross-section view taken along line E-E of Figure 13A;

Figure 14 is a perspective view of four bridge deck panels according to a second preferred embodiment of the invention mounted on transverse girders;

Figure 15 is a close-up view of the interlocking of one inverted Tee rib shown in Figure 14 with a transverse floor beam;

Figure 16 is a perspective view of four bridge deck panels according to a third preferred embodiment of the invention mounted on transverse girders; and

Figure 17 is a close-up view of the interlocking of one inverted Tee rib shown in Figure 16 with a transverse floor beam.

While the invention will be described in conjunction with example embodiments, it will be understood that it is not intended to limit the scope of the invention to such embodiments. On the contrary, it is intended to cover all alternatives, modifications and equivalents as may be included as defined by the present description and appended claims.

DETAILED DESCRIPTION OF THE DRAWINGS

In the following description, similar features in the drawings have been given similar reference numerals and in order to lighten the figures, some elements are not referred to in some figures if they were already identified in a precedent figure.

Throughout the present description, by existing bridge girders, it is meant either the longitudinal main girders, or the transverse girders lying over main longitudinal girders, of the structure of a pre-existing bridge. Although the present invention was primarily designed to rehabilitate existing bridges, it may also be used for the construction of new metal bridges having new pre-existing main longitudinal girders. In other words, depending of the application, the bridge girders may be longitudinal or transversal girders. The bridge girders may have an “I” shape cross-section, a “U” shape cross-section, or any other shape as long as they have a top portion on which a flange of the inverted Tee rib can be laid on and secured to.

Referring to Figure 1, the assembly of three prefabricated bridge deck panels **1a, 1b, 1c** according to a first preferred embodiment of the invention is shown mounted on the center portion of four pre-existing longitudinal bridge girders **2.** For the sake of clarity, the roadway surface and the safety barriers have not been shown. This assembly is composed of two outer edge panels **1a, 1c** and one center panel **1b**. Although not clearly visible in Figure 1, the roadway surface preferably has a cross slope so that the outer bridge deck panels **1a** and **1c** are constructed with a slope and the center bridge deck panel **1b** is constructed with a double slope.

Referring also to Figure 2, each of the bridge deck panels **1** comprises an elongated metal top deck plate **3** stiffened longitudinally by longitudinal stiffening metal ribs **4**. At least one inverted Tee rib **5** extends longitudinally underneath the deck plate **3.** Each Tee rib **5** has a vertical web member **51** and a flange plate **52**, the vertical web member **51** having an upper end **53** structurally secured to the top deck plate **3**. The bridge deck panel **1** also has spaced-apart transverse floor beams **6** extending transversally underneath the deck plate **3**. Each transverse floor beam **6** has a vertical web member **61** and a flange plate **62**, the vertical web member **61** having cut-out **20** fitted under the longitudinal stiffening metal ribs **4**, and at least one recess **17** interfitting with the vertical web member **51** of the inverted Tee rib 5 (best shown in Figures 7 and 8). The upper end **65** of the vertical web member **61** of each transverse floor beam **6** is structurally secured to the deck plate **3**. In this first preferred embodiment, the inverted Tee rib **5** and the transverse floor beams **6** of the deck panel **1** are of substantially equal depth and in use, the flange plate **52** of the inverted T rib **5** is laid on and bolted to a main longitudinal flange of the main longitudinal girders **2**. In this way, the inverted Tee ribs **5** advantageously make a positive connection between the top deck plates **3** and the main longitudinal girders **2** resulting in composite action between the two elements. The top deck plates **3** act compositely with the longitudinal girders **2** increasing their structural properties. The inverted Tee ribs **5** also provide continuous support to the deck plate **3** directly over the main longitudinal girders **2** thus creating biaxial bending in the deck plate **3**. The top deck plate **3** is in biaxial bending due to the short spacing of the transverse floor beams **6** and the two way action caused by the rigidity of the longitudinal inverse Tee rib **5** connected continuously to the main girders **2**. Also, the top deck plate **3** acts as the top flange of the transverse floor beams **6** making these bridge deck panels **1** much stiffer.

As can be appreciated, the bridge deck panel **1** shown in Figure 2 is an edge panel such as the ones **1a**, **1c** shown on the right end side and left end side of the assembly of Figure 1. Such an edge panel is further provided with a stiffening open rib (L or I shape) **7** along a longitudinal edge of the metal deck plate **3**, and is devised to be installed at a lateral end of the bridge deck. In the assembly of Figure 1, the edge bridge deck panels **1a** and **1c** have one inverted Tee rib **5** while the center deck panel **1b** has two.

Still referring to Figure 2, the top deck plate **3** is stiffened longitudinally by the longitudinal stiffening ribs **4**, by the longitudinal inverted Tee rib **5** and at the outer edge of the panel by the stiffening open rib **7**. Preferably, the upper ends **53**, **65** of the inverted Tee rib **5** and of the transverse floor beams **6** are welded underneath the deck plate. This should also be the case for the stiffening open rib **7**. In other words, all three types of longitudinal stiffening ribs **4**, **5** & **7** are preferably continuously welded to the underside of the top deck plate **3**. As it can be appreciated, the top deck plate **3** is stiffened longitudinally by the longitudinal stiffening metal ribs **4,** the inverted Tee rib **5** and the stiffening open rib **7**.

As shown in Figure 3, the longitudinal stiffening metal ribs **4** preferably have trapezoidal cross section and are continuously welded to the top deck plate **3** with longitudinal stiffening metal rib partial penetration welds **8**. The longitudinal stiffening metal ribs **4** can be of either closed or open shape and are depicted in Figure 3 as a closed trapezoidal rib. A rib is defined as closed when the rib welded to a top plate **3** forms a closed hollow shape with the plate **3**. A trapezoidal closed metal rib will form a trapezoidal hollow. Closed ribs are generally composed of three segments, two web segments that are either vertical or more often at some other angle, usually between 0° and 30°, from the vertical and a third segment that acts as the bottom flange of the rib and may be either a straight element or a curved element in the form of an arc. Closed ribs are usually manufactured on a cold formed rolling line or by a brake press operation. Both these manufacturing methods will produce a curved radius at the joints between the web and flange segments. Closed ribs are preferred as they are more torsionally stiff and are capable of distributing a concentrated wheel load rolling on the top deck plate **3** over a larger proportion of the plate.

Open ribs can be of various shapes including a straight flat plate, a bent plate with a 90° bend forming an "L" shape or bent at some other angle, an inverted Tee, a bulb angle, or a combination of a vertical plate element and a bottom flange element such as a solid round or hollow pipe.

Referring to Figure 4, in this first preferred embodiment, a longitudinal inverted Tee rib **5** is always located directly over the top flange of each supporting main longitudinal steel bridge girder **2**. The longitudinal inverted Tee rib **5** can be manufactured from two plates creating a vertical web **51** and a bottom flange **52** to form a Tee section, or can be cut from a hot rolled "I" type beam section by splitting the "I" type section along the web into two sections. A split Tee **5** from a wide flange beam section is illustrated in Figure 4. The web **51** of the inverted Tee rib **5** is continuously welded with a partial penetration weld or fillet welds **9** to the underside of the top deck plate **3**. The bottom flange **52** of the longitudinal inverted Tee rib **5** has a series of matching fastener holes (such as bolt holes) with the longitudinal steel bridge girder **2** allowing the bridge deck panel **1** to be bolted with high strength bolts **10** to the top flange of the main longitudinal steel bridge girder **2** located directly under it. The high strength bolts **10** allow the deck panel 1 to act compositely with the longitudinal steel bridge girder **2** greatly increasing its stiffness and load capacity by increasing the effective depth "dg" of the longitudinal steel bridge girder **2** by the depth of the deck panel "dp" for a total effective composite dept of "dc".

Referring to Figure 5, the longitudinal edge stiffening rib **7** is preferably an open rib located at the outside edge of each of the two edge bridge deck panels **1a, 1c** of Figure 1. The stiffening open rib **7** has an L shape (or I shape) formed by a vertical web member **71** and an inward flange plate **72**, the vertical web member **71** of the L shape stiffening open rib thereby closing the deck panel. The stiffening open rib or longitudinal edge stiffener rib **7** is continuously welded with a fillet weld **11** to the underside of the top deck plate **3**. The longitudinal edge stiffening rib **7** structurally stiffens the top deck plate **3** beyond the last longitudinal stiffening metal rib **4** allowing connections (not shown) for a jersey type highway barrier to be made to the top of the top deck plate **3**. Advantageously, the edge stiffening ribs **7** are architectural features neatly closing off the edge of panels **1a**, **1c**.

In this preferred embodiment, the stiffening open rib **7** is designed to support two types of continuous jersey type barriers that may be used to act as bridge barriers or guardrails, either a poured in place concrete barrier or a precast concrete barrier. Both of these require anchorages to be fastened to the top of the top deck plate **3**. Several different types of anchorages are recommended and these would normally be shop installed and delivered to the bridge site ready for installation of the barriers. The stiffening open rib **7** is sized and positioned to eliminate the possibility of a permanent deformation occurring in the top deck plate **3** should a vehicular impact occur. Additionally, the stiffening open rib **7** can de designed with local stiffening elements (not shown) to accommodate the attachment of mileage marker posts, highway road sign posts, steel or aluminum barriers or guardrails or any other type of attachment that may be required.

Turning now to Figure 6, each transverse floor beam **6** is preferably a Tee section built up from a vertical web plate **61** and a bottom flange plate **62**. The top of the vertical web plate **65** is continuously welded with two partial penetration welds **14** to the top deck plate **3** and the bottom of the vertical web plate **61** is continuously welded with fillet welds **15** to the bottom flange plate **62**. Preferably, the transverse floor beams **6** are spaced at approximately 3 meter centers and this is designed to enable the bridge rail or barrier guard post connections to be framed directly into the end of the transverse floor beam **6**. This feature protects the deck plate **3** from being damaged by the barrier post connection due to a vehicle impact to the barrier. As shown in Figure 6, a portion of the web **51** and a length of flange **52** of the inverted Tee stiffening rib **5** are coped out forming a cope-out **16** to allow the transverse floor beam **6** to pass continuously through the inverted Tee stiffening rib **5**. The top deck plate **3** structurally acts as the top flange of the continuous transverse floor beams **6**. The transverse floor beams **6** are built into and form an integral part of the bridge deck panel **1**. Thus the length of each portion of the transverse floor beam **6** is equal to the width of the bridge panel **1** and must be spliced at panel joints to enable it to act as a continuous member.

Figure 7 shows an elevation of a transverse floor beam **6** at a location where it crosses over a longitudinal bridge girder **2**. The web **61** of the transverse floor beam **6** has a recess **17** to allow the web **51** portion of the inverted Tee stiffening rib **5** to pass through uninterrupted.

Figures 6 and 7 show that the transverse floor beams **6** are designed to sit directly on top and be attached to the top flange of the main longitudinal steel bridge girder **2** by means of high strength bolts **18**. The transverse floor beam **6** is usually designed to be of constant depth and have its bottom flange plate **62** parallel to the top deck plate **3**. As most bridge decks are constructed with a cross slope, a tapered shim **19** may be placed between the top flange of the longitudinal steel bridge girder **2** and the bottom flange plate **62** of transverse floor beam **6**. In some instances, the transverse floor beam **6** may be manufactured with a variable depth if all the longitudinal steel bridge girders **2** are at the same elevation so that it rests flush on the top flange of the longitudinal steel bridge girders **2** eliminating the need for a tapered shim **19**.

Referring to Figures 1, 6 and 7, one can appreciate that the transverse floor beams **6** span continuously over the main longitudinal girders **2** thereby increasing their relative stiffness. In addition, the closer spacing of the transverse floor beams **6** allow for smaller longitudinal stiffening rib **4** sizes allowing ribs **4** to be manufactured by the cold formed rolling process. The closer spacing of the transverse floor beams **6** also allows for the transverse floor beams **6** to be incorporated into the depth of the bridge deck panels **1a**, **1b**, **1c**. Furthermore, transverse floor beams **6** can be built to suit the varying elevations of the tops of girders **2** on existing bridges.

Figure 8 is an elevation of a transverse floor beam **6** at a location where it intersects with a longitudinal stiffening metal rib **4**. The vertical web plates **61** of the transverse floor beams **6** have a cut-out **20** in the shape of longitudinal stiffening rib **4** to allow it to pass uninterrupted through the transverse floor beam **6**. The web portion of the transverse floor beam **61** has fillet welds **21** on each side to the longitudinal stiffening rib **4**.

Figure 9A is taken at the transverse splice location between two adjacent bridge deck panels **1**. Each of the transverse floor beams **6** has two opposite side ends **66**, at least one of the side ends **66** being provided with fastener receiving holes **67** (such as a bolt or screw receiving holes) used for connecting the bridge deck panel **1** to a side end of a similar one of said bridge deck panel **1**. The bottom flange plate **62** of the transverse floor beam **6** is spliced using a bolted flange moment splice plate **22** and the vertical web plate **61** of the transverse floor beam **6** is spliced using a bolted shear splice plate **23**. The top deck plate **3** is spliced with a continuous longitudinal full penetration field weld or bolted connection **24** to join the bridge deck panels **1** together. This longitudinal full penetration field weld **24** is preferably produced using a ceramic backing bar **25** resulting in a weld with a high fatigue resistance. This longitudinal full penetration field weld **24** also acts as the top flange splice connection for the transverse floor beam **6**. Transverse floor beams can advantageously span between longitudinal bridge girders thereby shortening the longitudinal span of the deck plate.

Figure 10A shows the longitudinal splice detail connecting two end-to-end bridge deck panels **1** (shown partially) at a typical longitudinal stiffening metal rib **4**. Each of the longitudinal stiffening metal ribs **4** has opposite front **41** and rear **42** ends, each provided with at least one fastener receiving hole **43** used for connecting the bridge deck panel **1** to a rear end **42** or a front end **41** of a similar one of the bridge deck panel **1**. All transverse splice locations are located between two adjacent transverse floor beams **6** (not shown in Figures 10 A and 10B). The top deck plate **3** is spliced with a continuous transverse full penetration field weld (or bolted connection) **26** to join the panels **1** together. This longitudinal full penetration field weld **26** is preferably produced using a ceramic backing bar **27** resulting in a weld with a high fatigue resistance. The flange segments of the longitudinal stiffening ribs **4** are spliced using a bolted flange moment splice plate **28**. The web segments of the longitudinal stiffening ribs **4** are spliced using a bolted shear plate splice **29**. The web segments of the longitudinal stiffening ribs **4** are cut at a slope to create a hand hole to access the fastener receiving holes **43** for placing and tightening of the bolts. Once the bolts have been tightened, the trapezoidal opening is closed with a press fit closure block **30** (shown in Figure 11A) press-fitted into the opening of front end **41** and rear end **42** of the adjacent longitudinal stiffening metal ribs **4** to keep out moisture, foreign matter and wildlife out of this joint. The block **30** is made out of a compressible material (similar to a hard sponge) allowing it to be compressed to fit into the joint and spring back to completely fill the space (as shown in Figures 11A, 11B and 11C). As it can be appreciated, since the field splices of the longitudinal stiffening metal ribs **4** are designed to be bolted, deck panel installation is simplified.

Figures 12A and 12B show the longitudinal splice detail connecting two end-to-end bridge deck panels **1** (shown partially) at an inverted Tee rib **5** that is connected to a longitudinal steel bridge girder **2**. The top deck plate **3** is spliced using the same details as shown in Figure 10A. The flange plate **52** of the inverted Tee rib **5** is provided with fastener receiving holes **54** used for securing the inverted Tee rib **5** to the main longitudinal bridge girder **2**. The web portion **51** of inverted Tee rib **5** is spliced using a bolted shear splice plate **31**. Since the flange portion **52** of the inverted Tee rib **5** is continuously attached to the longitudinal steel bridge girder **2** by the high strength bolts **10**, the flange of the longitudinal bridge girder **2** acts as the splice detail for the inverted Tee rib **5**.

Figures 13A and 13B show the longitudinal splice detail connecting two end-to-end bridge deck panels **1** at longitudinal edge stiffening open rib **7**. The top deck plate **3** is spliced using the same details as shown in Figure 10A. The web segment is spliced using a bolted shear splice plate **32**. The flange segment of the longitudinal edge stiffening rib **7** is spliced using a bolted flange plate moment splice **33**.

Referring to Figure 14, an assembly of three deck bridge panels **1** according to a second preferred embodiment of the invention, is shown mounted on spaced apart transverse bridge girders **2** (two being shown on Figure 14). In this second preferred embodiment, the inverted Tee ribs **5** of the bridge deck panels **1** are deeper than the transverse floor beams **6**. As shown in use, the flange plate **52** of the inverted Tee rib **5** is laid on and secured to the plurality of spaced apart transverse bridge girders **2**. Referring to Figure 15, it can be appreciated that as in the first preferred embodiment, the inverted Tee ribs **5** and the transverse floor beams **6** which are crossing each other are always in an interfit or interlock relationship with each other. In this second embodiment, this interlocking relationship is obtained by using cut outs made in the web member **51** of the inverted Tee ribs **5** that allow the transverse floor beams **6** to pass continuously through the vertical web plate **51** of the inverted Tee rib **5.**

This second preferred embodiment of the bridge deck panels is used principally in the rehabilitation of existing bridges. Many existing bridges were built using two main longitudinal support members that in turn support a series of transverse girders **2** spaced at approximately equal intervals. These pre-existing transverse girders **2** support longitudinal stringers that carry a concrete slab (not shown in Figure 14). The stringers and slab often need to be replaced at the same time. The bridge deck panel is a replacement allowing the field work to be performed off peak hours and maintaining the bridge open for traffic during heavy use hours. For these types of deck replacements, there are no existing longitudinal girders and it is more practical and economical or both to build the longitudinal inverted Tee rib **5** directly as a deeper section incorporating the longitudinal girder **2** into the Tee rib **5**. This eliminates the need to build the longitudinal girder **2** and the necessity for a connection between the longitudinal girder **2** and the Tee rib **5**. Figures 14 & 15 show this variation of the deck panel, where the deeper inverted Tee rib **5** incorporates the longitudinal girder. Figure

15 is a close-up view of the interlocking of one inverted Tee rib **5** with a transverse floor beam **6**.

Referring now to Figure 16, an assembly of three deck panels **1** according to a third preferred embodiment of the invention is shown mounted on transverse girders **2**. In this embodiment, the bridge deck panel **1** has transverse floor beams **6** deeper than the inverted Tee rib **5**. As shown in use, the flange plate **52** of the inverted Tee rib **5** is laid on and secured to the transverse bridge girders **2** (two being shown on Figure 16). This third preferred embodiment of the bridge deck panels **1** is also used for the rehabilitation of the same type of existing bridge as described above. Bridge deck panels **1** having deeper transverse floor beams **6** are used when the existing bridge needs to be widened to add traffic lanes, sidewalks or cycle paths. The added bridge width is cantilevered off of the deck's transverse floor beam **6** beyond the width of an existing bridge girder. The depth of the new transverse floor beam **6** often needs to be increased to limit the tip deflection of the cantilever or to minimize the perception of vibrations for pedestrians or cyclists using the walkway. In these instances, the transverse floor beams **6** may be made deeper than the longitudinal Tee rib **5**. For this application, the longitudinal inverted Tee rib **5** is made continuous and passes through cut-outs in the web **61** of the transverse floor beam **6**. Figures 16 and 17 show this variation of the deck panel with the bridge transverse girders **2** extending beyond the depth of the inverted Tee rib **5**.

The second and third embodiment can be used with connecting plates and elements such as flange moment splice plates, shear splice plates, ceramic backing bars and closure blocks such as described above. Preferably, the upper ends **53** and **65** of the inverted Tee rib **5** and transverse floor beams **6** are also welded to the deck plate **3**, and the flange plate **52** of the inverted Tee ribs **5** has fastener receiving holes to be bolted to the top portion of the bridge transverse girders **2** (not shown in Figures 14 and 16).

Referring to Figures 1 to 16, one will understand that mounting side-by-side or end-to-end a plurality of the prefabricated bridge deck panels **1** according to any one the three preferred embodiments described above allows forming a bridge deck on girders **2** of a bridge, may they be longitudinal or transversal bridge girders **2.** Both the longitudinal and transversal splices of the top deck plate **3** are advantageously configured so that the field weld can be completed using automated welding equipment from the top surface of the deck.

In use, the top deck plate **3** has smaller local deflections, rib to rib, caused by concentrated wheel loads when compared to conventional orthotropic decks due to the beneficial action of biaxial bending. The top deck plate **3** is in biaxial bending due to the short spacing of the transverse floor beams **6** and the two way action caused by the rigidity of the longitudinal inverse Tee rib **5** connected continuously to the main longitudinal bridge girders **2**. The longitudinally stiffened deck top plate **3** has smaller longitudinal deflections compared to conventional orthotropic decks due to their inherent shorter span and the combined effects of biaxial bending and the composite action of the top deck plate **3** with the longitudinal main bridge girders **2** decreases the overall deflection of the bridge.

Although the present invention has been explained hereinabove by way of preferred embodiments thereof, it should be understood that the invention is not limited to these precise embodiments..

CLAIMS

1. A prefabricated bridge deck panel to be affixed to at least one bridge girder, the bridge deck panel comprising :
   - an elongated metal top deck plate stiffened longitudinally by longitudinal stiffening closed metal ribs;
   - at least one inverted Tee rib extending longitudinally underneath the top deck plate, said Tee rib having a vertical web member and a flange plate, the vertical web member having an upper end structurally secured to the top deck plate; the flange plate of the inverted Tee rib being perforated with a plurality of bolt holes, for bolting the inverted Tee rib to the at least one bridge girder; and
   - spaced-apart transverse floor beams extending transversally underneath the top deck plate in an interfit continuous relationship with the inverted Tee rib, each transverse floor beam comprising a vertical web member and a flange plate, the vertical web member having recesses fitted over the closed metal ribs and an upper end structurally secured to the top deck plate,

   whereby in use, the flange plate of the inverted Tee rib is laid on and bolted to said at least one bridge girder, the bridge deck panel acting compositely with the at least one bridge girder .

2. A bridge deck panel according to claim 1, further comprising a stiffening open rib along a longitudinal edge of the metal deck plate.

3. A bridge deck panel according to claim 2, wherein the stiffening open rib has an L shape formed by a vertical web member and an inward flange plate, the vertical web member of the L shape stiffening open rib thereby closing the deck panel.

4. A bridge deck panel according to anyone of claims 1 to 3, wherein said upper ends of the inverted Tee rib and of the transverse floor beams are welded underneath the top deck plate.

5. A bridge deck panel according to anyone of claims 1 to 4, wherein each of said transverse floor beams has two opposite side ends, at least one of said side ends being provided with at least one fastener receiving hole used for connecting the bridge deck panel to a side end of a similar one of said bridge deck panel.

6. A bridge deck panel according to anyone of claims 1 to 5, wherein each of the stiffening closed metal ribs has opposite front and rear ends, each provided with at least one fastener receiving hole used for connecting the bridge deck panel to a rear end or a front end of a similar one of said bridge deck panel.

7. A bridge deck panel according to claim 6, comprising closure blocks press-fitted in said front and rear end of the closed metals ribs.

8. A bridge deck panel according to anyone of claims 1 to 7, wherein the plurality of bolt holes are perforated continuously along the length of the flange plate for bolting the inverted Tee rib to at least one bridge girder.

9. A bridge deck panel according to anyone of claims 1 to 8, wherein the inverted Tee rib and the transverse floor beams of the deck panel are of substantially equal depth; and wherein in use, the flange plate of the inverted T rib is laid on and secured to a main longitudinal one of said girders.

10. A bridge deck panel according to claim 9, wherein the flange plates of the transverse floor beams are perforated with bolt holes at predetermined location, for bolting the transverse floor beams to the at least one bridge girder.

11. A bridge deck panel according to anyone of claims 1 to 8, wherein said at least one girder comprises a plurality of spaced apart transverse members; said inverted Tee rib is deeper than the transverse floor beams; and wherein in use, the flange plate of the inverted Tee rib is laid on and bolted to said plurality of spaced aparttransverse bridge members.

12. A bridge deck panel according to anyone of claims 1 to 8, wherein said at least one girder comprises a plurality of spaced apart transverse members, said transverse floor beams are deeper than the inverted Tee rib; and wherein in use, the flange plate of the inverted Tee rib is laid on and bolted to the transverse bridge members.

13. A bridge deck comprising a plurality of said prefabricated bridge deck panels according to anyone of claims 1 to 12, mounted side-by-side and/or end-to-end on girders of a bridge.

14. A method for installing a deck on main longitudinal bridge girders, the method comprising the steps of:

a) providing a plurality of prefabricated bridge deck panels as defined in claim 9;

b) mounting said bridge deck panels side-by-side and/or end-to-end on said main longitudinal bridge girders with the flange plate of the inverted T rib of each of said bridge deck panels laying on top of a portion of one of said main longitudinal girders; and

c) bolting the flange plate of inverted T ribs to the main longitudinal bridge girders.

15. A method as defined in claim 14, further comprising the step of ;

d) bolting adjacent transverse floor beams and end-to-end inverted Tee ribs of the bridge deck panels using connecting plates; and

e) sealing end-to-end stiffening closed metal ribs of the bridge deck panels using press fit closure blocks.

16. A method for installing a deck on transverse bridge girders, the method comprising the steps of:

a) providing a plurality of prefabricated bridge deck panels as defined in claim 11 or 12; and

b) mounting said bridge panels side-by-side and/or end-to-end on said main transverse bridge members with the flange plate of the inverted T rib of each of said bridge deck panels bolted to a plurality of following ones of said transverse members; and

c) bolting the flange plate of inverted Tee ribs to transverse bridge members.

17. A method as defined in claim 16, further comprising the step of:

d) bolting adjacent transverse floor beams and end-to-end inverted Tee ribs of the bridge deck panels using connecting plates; and

e) sealing end-to-end stiffening closed metal ribs of the bridge deck panels using press fit closure blocks.

18. A prefabricated bridge deck panel to be affixed to at least one main longitudinal bridge girder, the bridge deck panel comprising:

- an elongated metal top deck plate stiffened longitudinally by longitudinal stiffening metal ribs;
- at least one inverted Tee rib extending longitudinally underneath the top deck plate, said Tee rib having a vertical web member and a flange plate, the vertical web member having an upper end structurally secured to the top deck plate; the flange plate of the inverted Tee rib being perforated with a plurality of bolt holes, for bolting the inverted Tee rib to the at least one bridge girder; and

- spaced-apart transverse floor beams extending transversally underneath the top deck plate in an interfit continuous relationship with the inverted Tee rib, each transverse floor beam comprising a vertical web member and a flange plate, the vertical web member having recesses fitted over the longitudinal stiffening metal ribs and an upper end structurally secured to the top deck plate,

whereby in use, the flange plate of the inverted Tee rib is laid on and bolted to said at least one bridge girder, the bridge deck panel acting compositely with the at least one bridge girder.

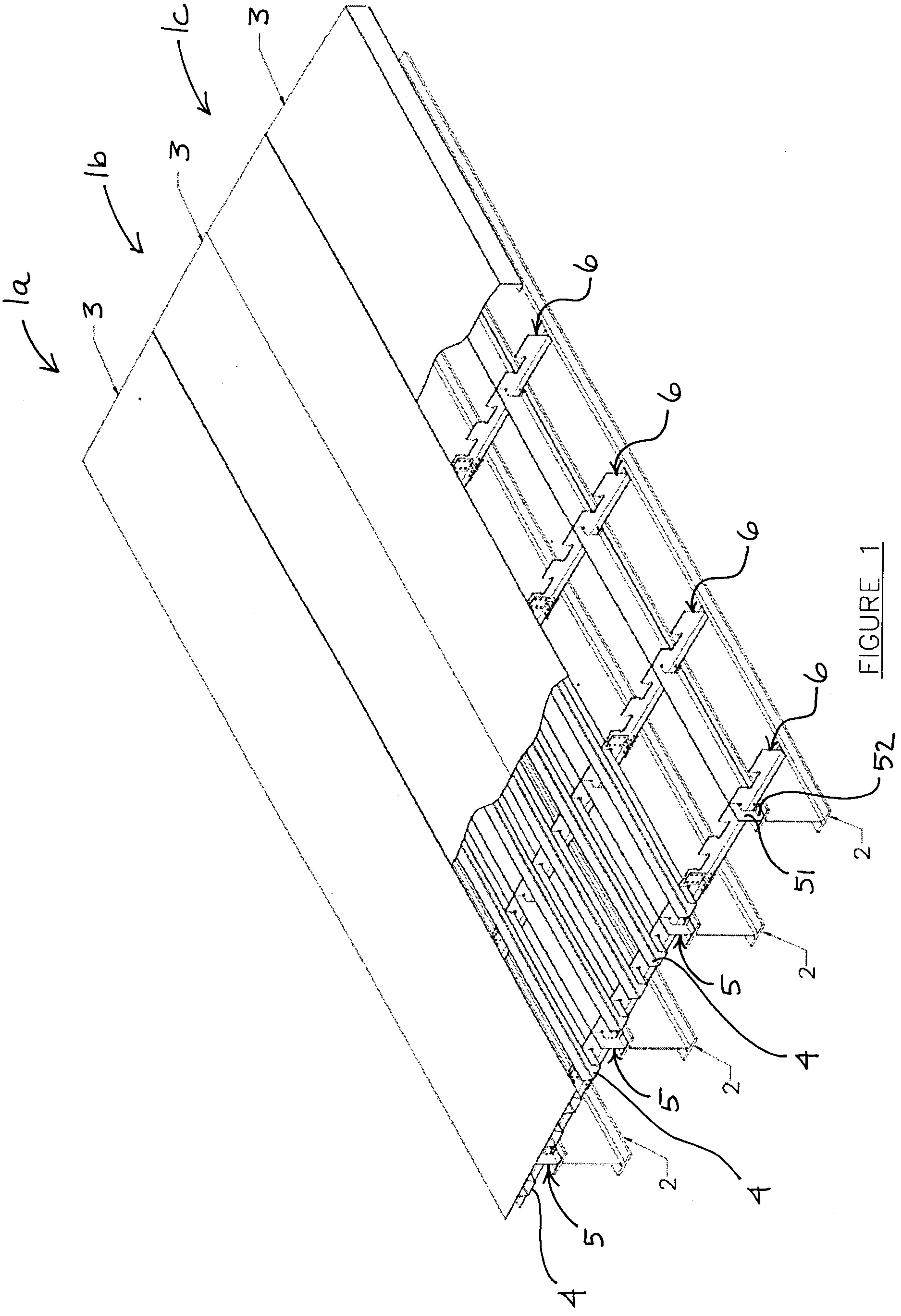


FIGURE 1

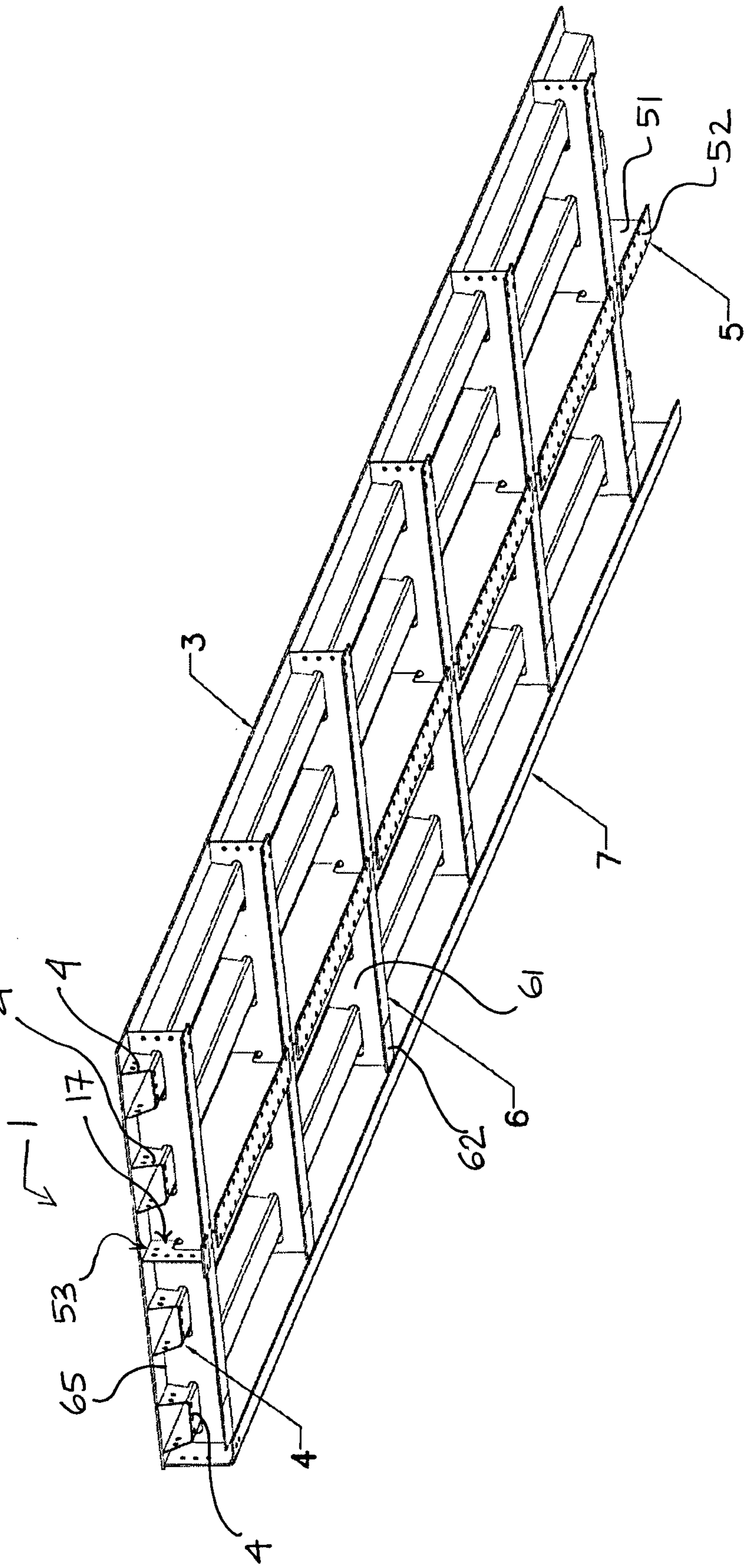


FIGURE 2

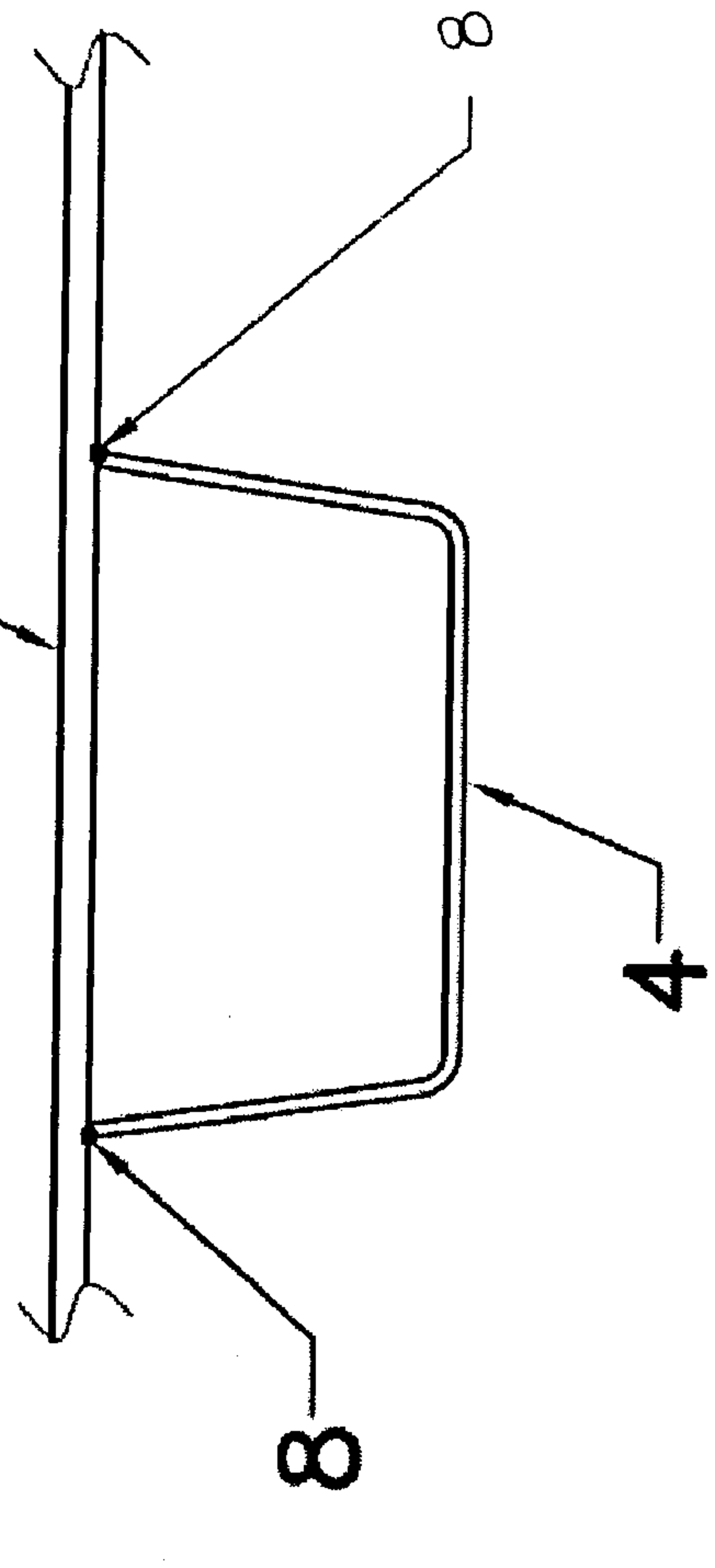


FIGURE 3

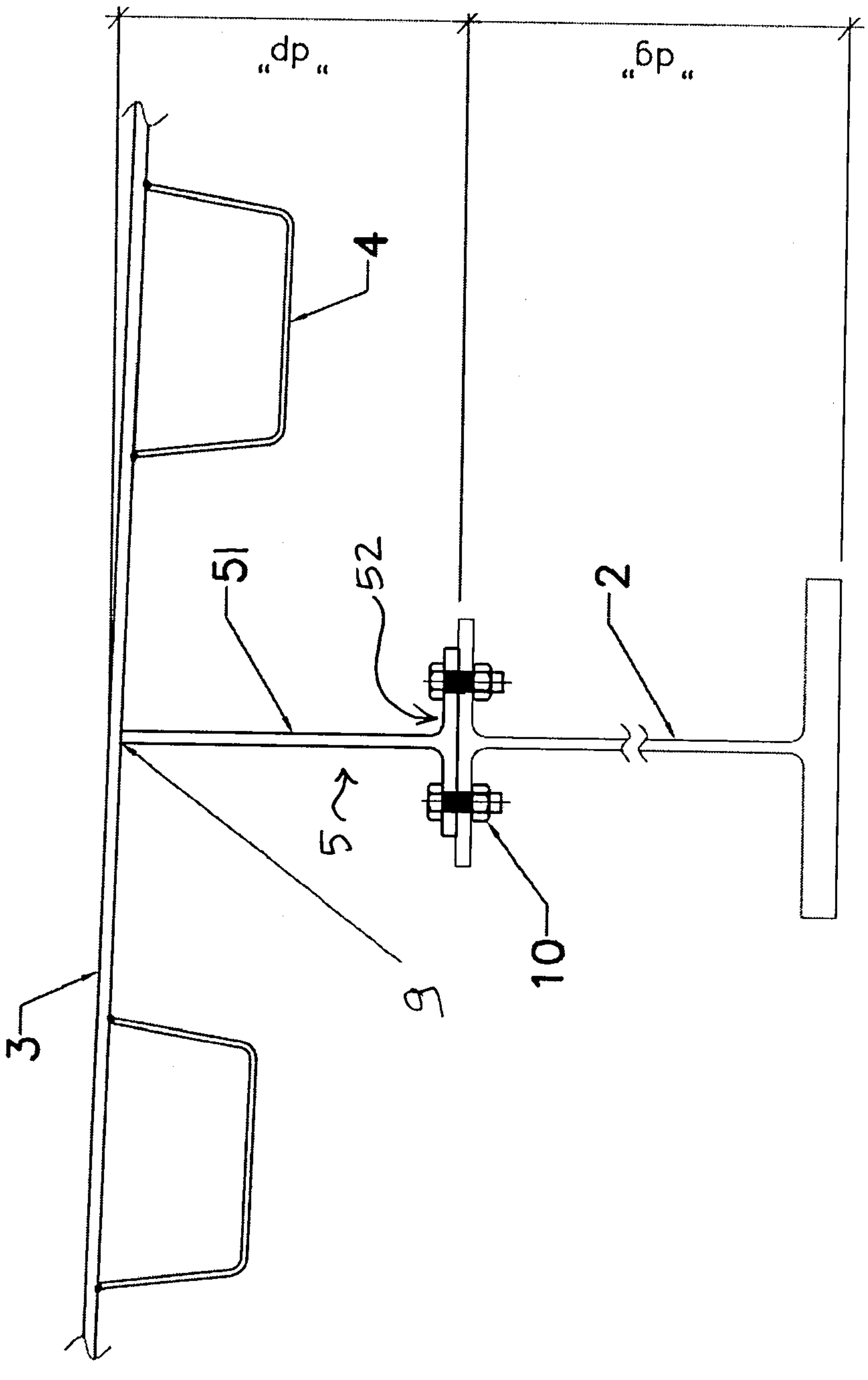


FIGURE 4

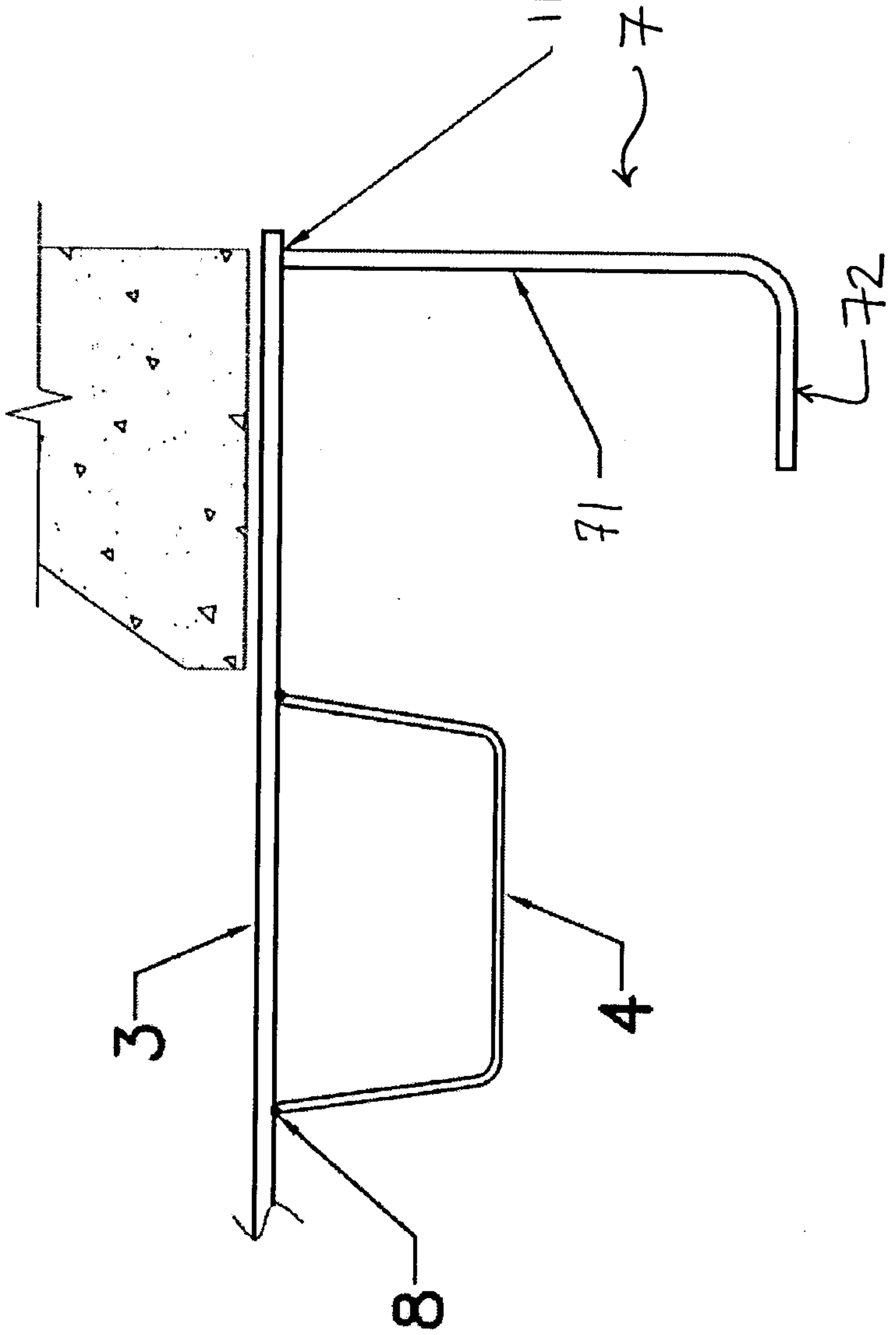


FIGURE 5

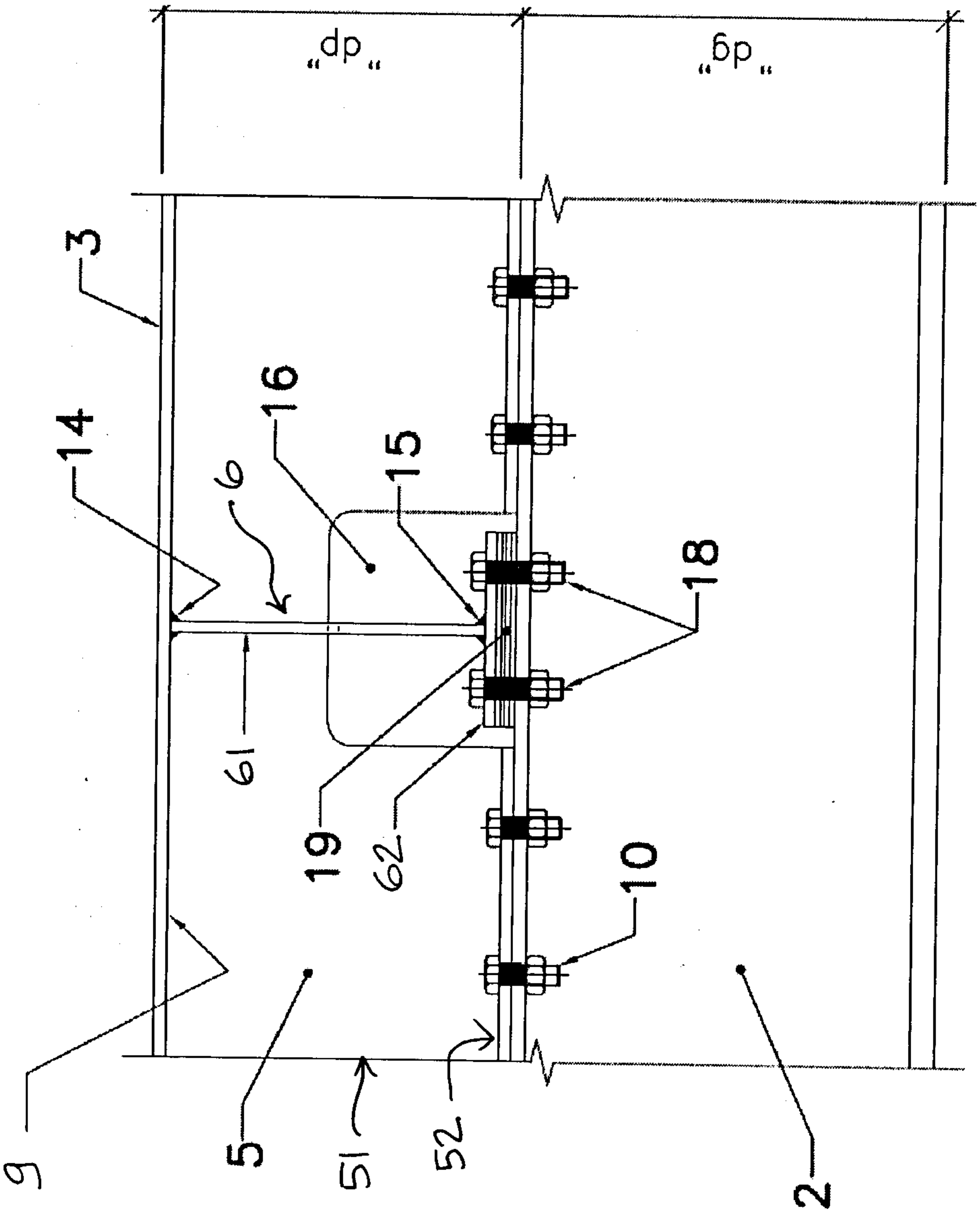


FIGURE 6

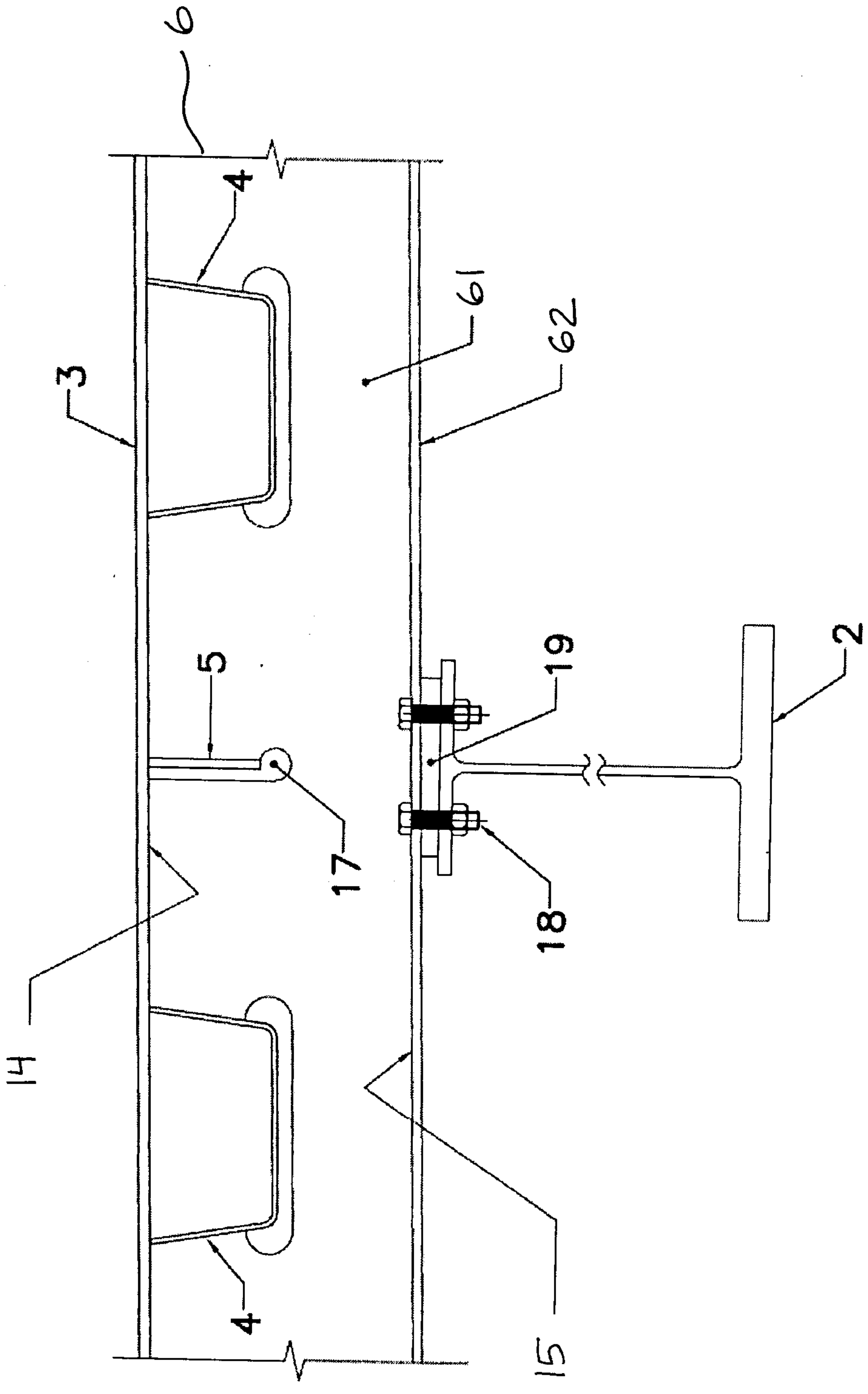


FIGURE 7

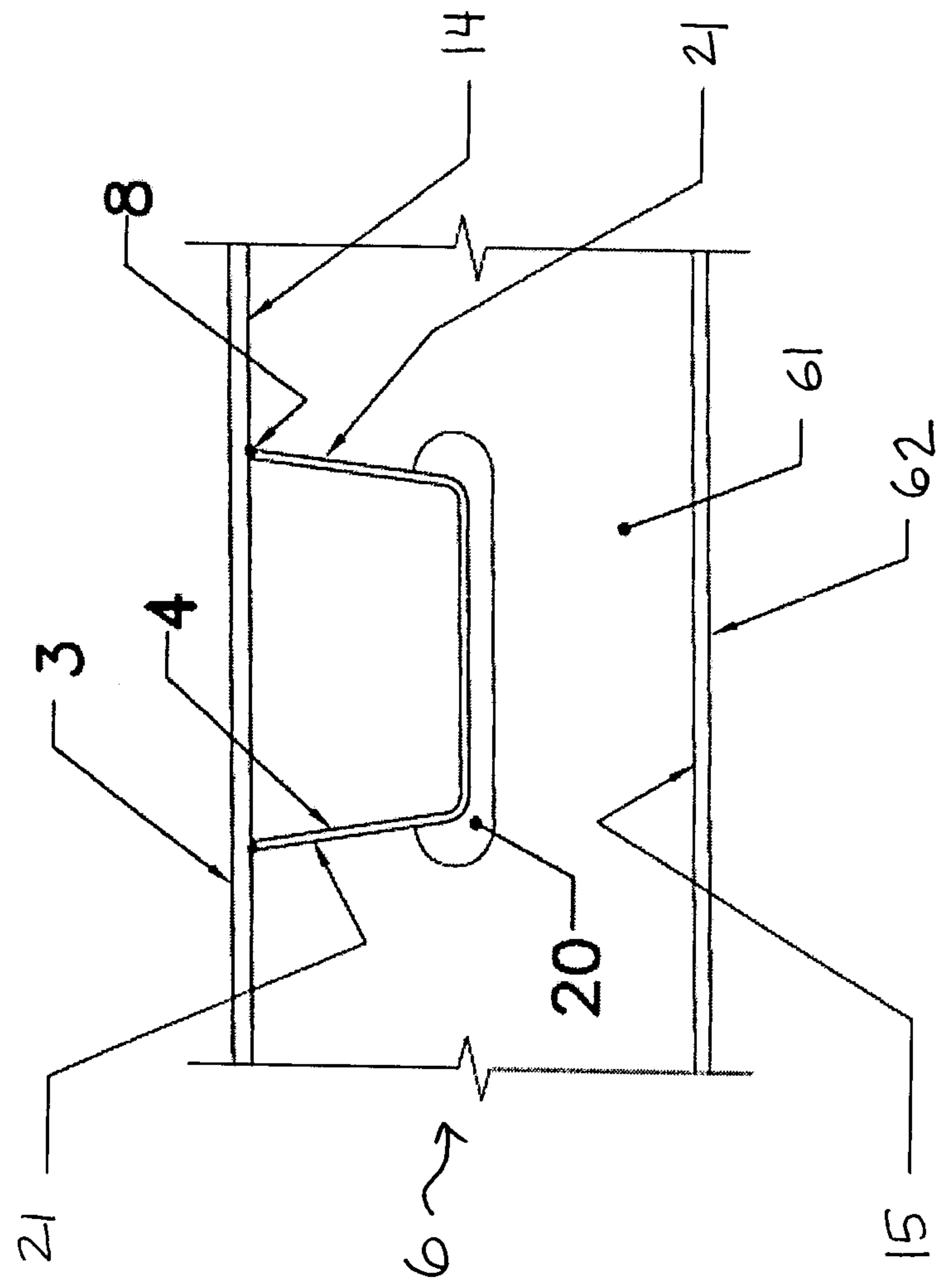
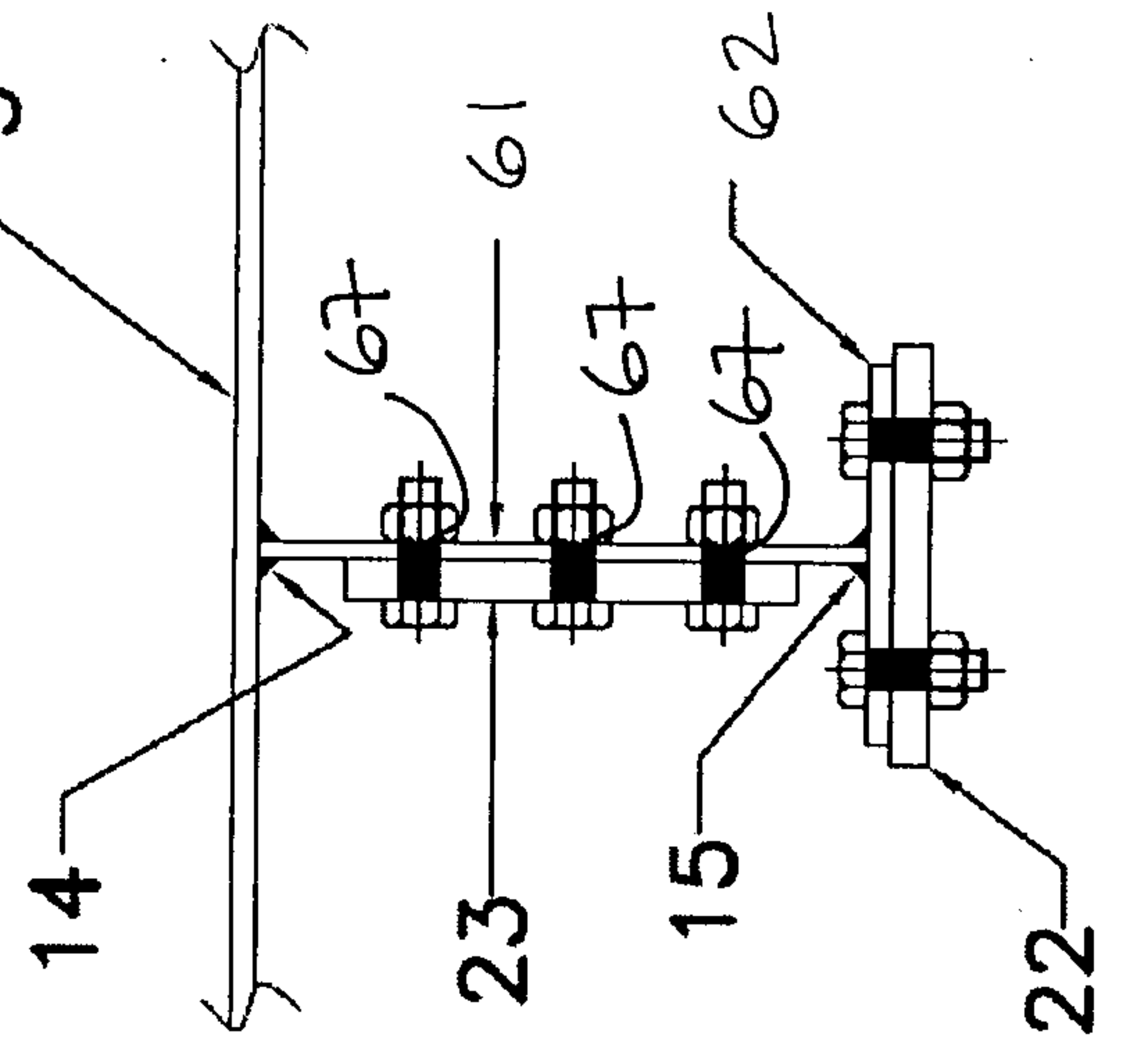


FIGURE 8



SECTION A–A

FIGURE 9B

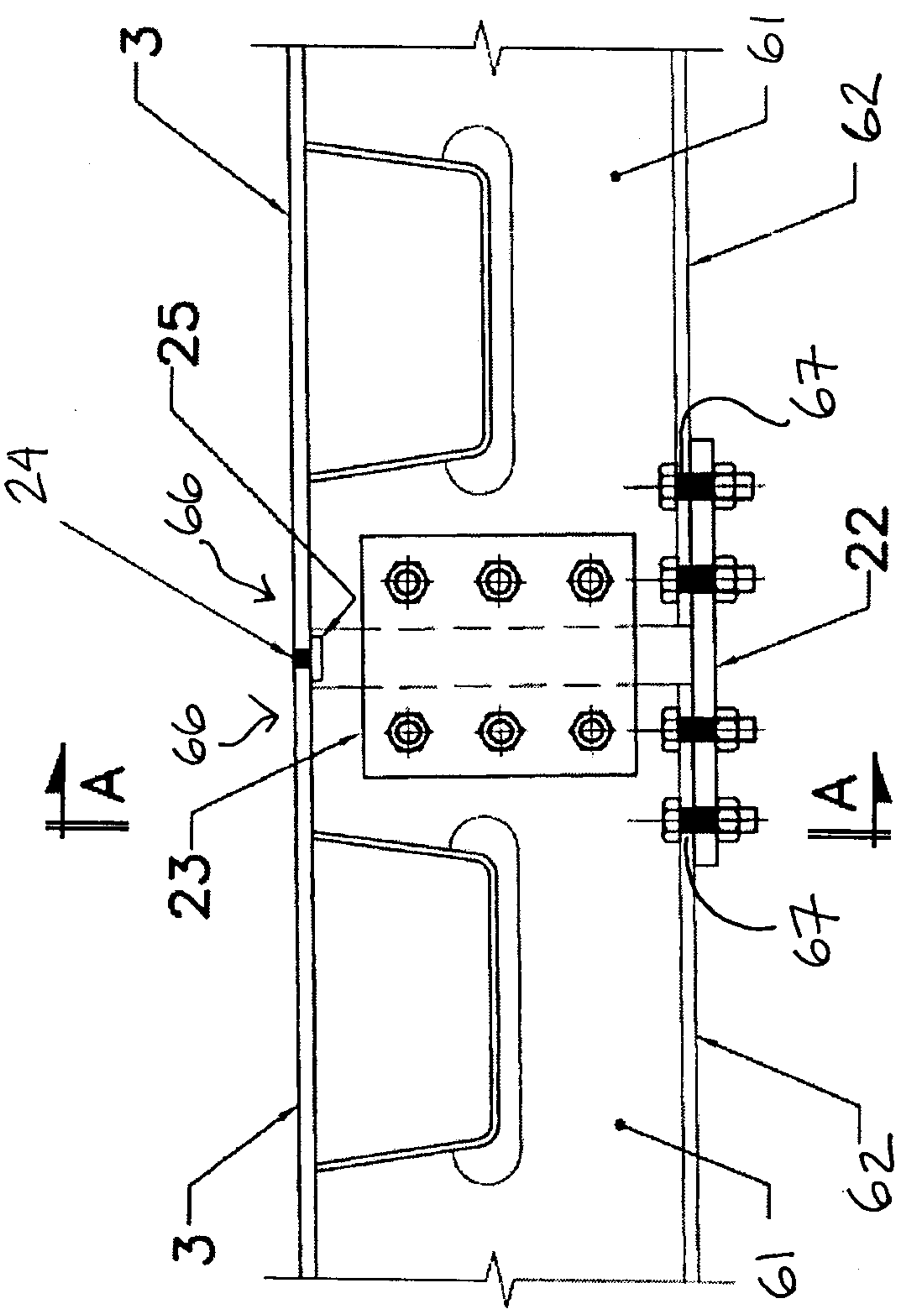
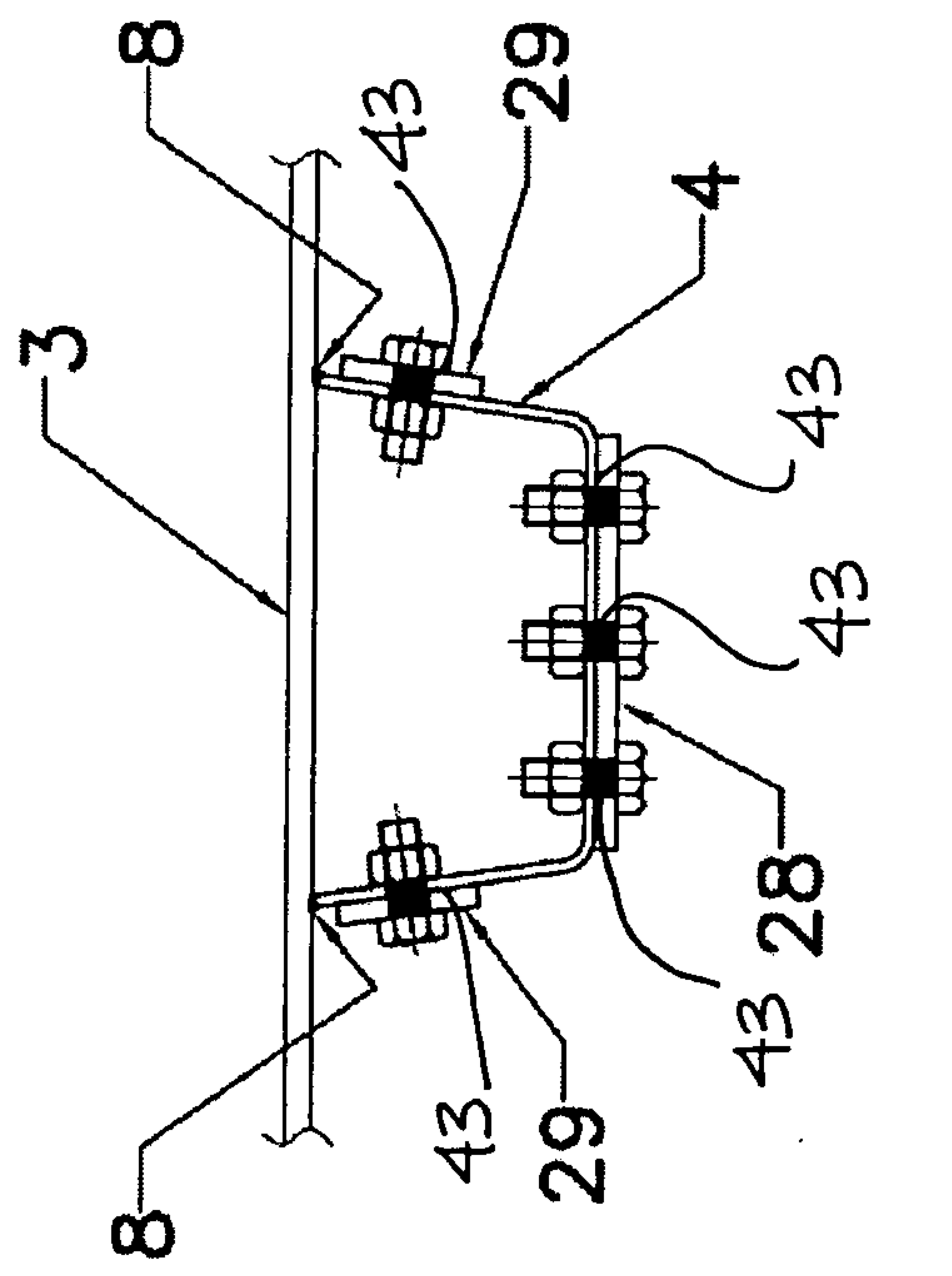


FIGURE 9A



SECTION B–B

FIGURE 10B

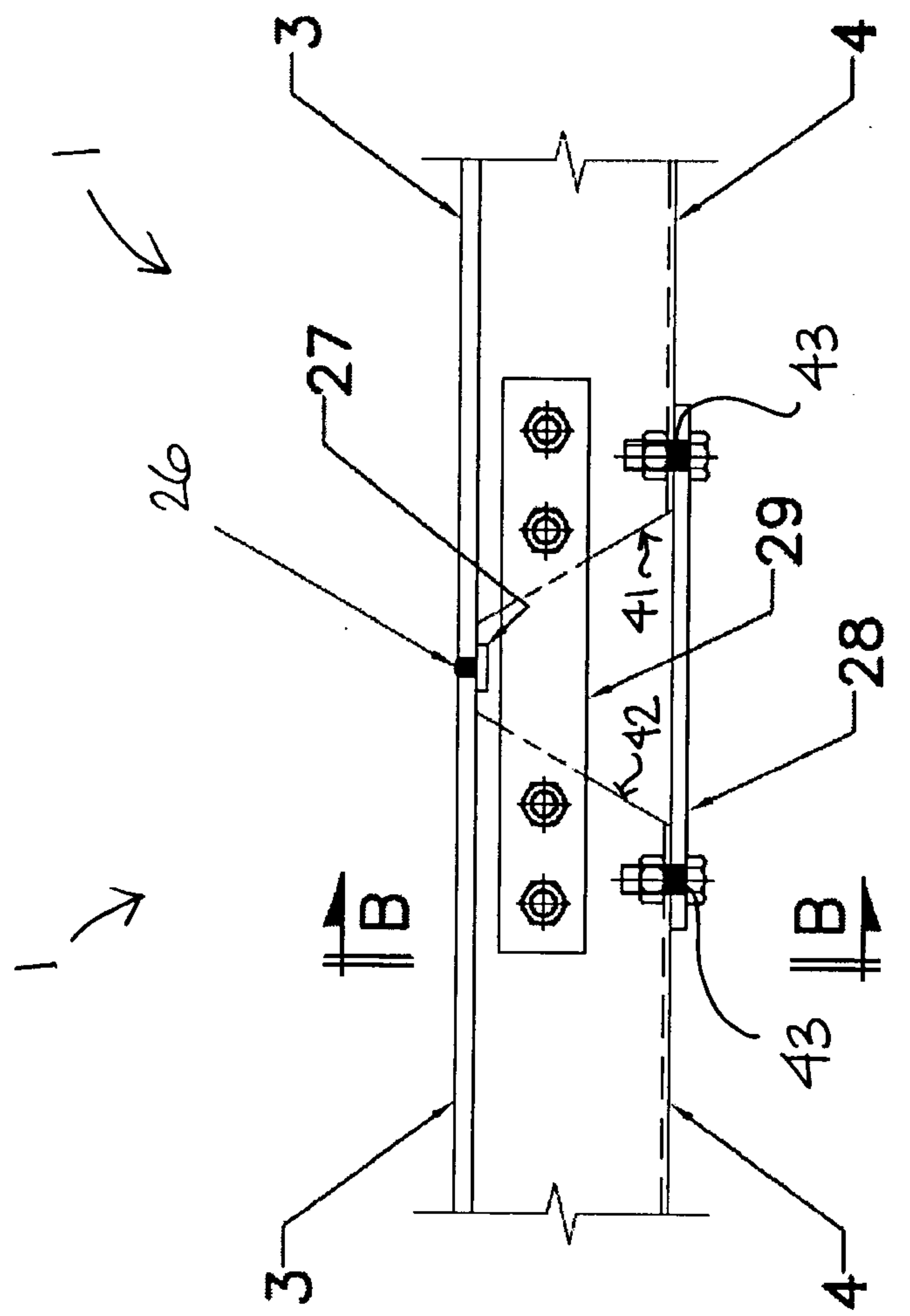


FIGURE 10A

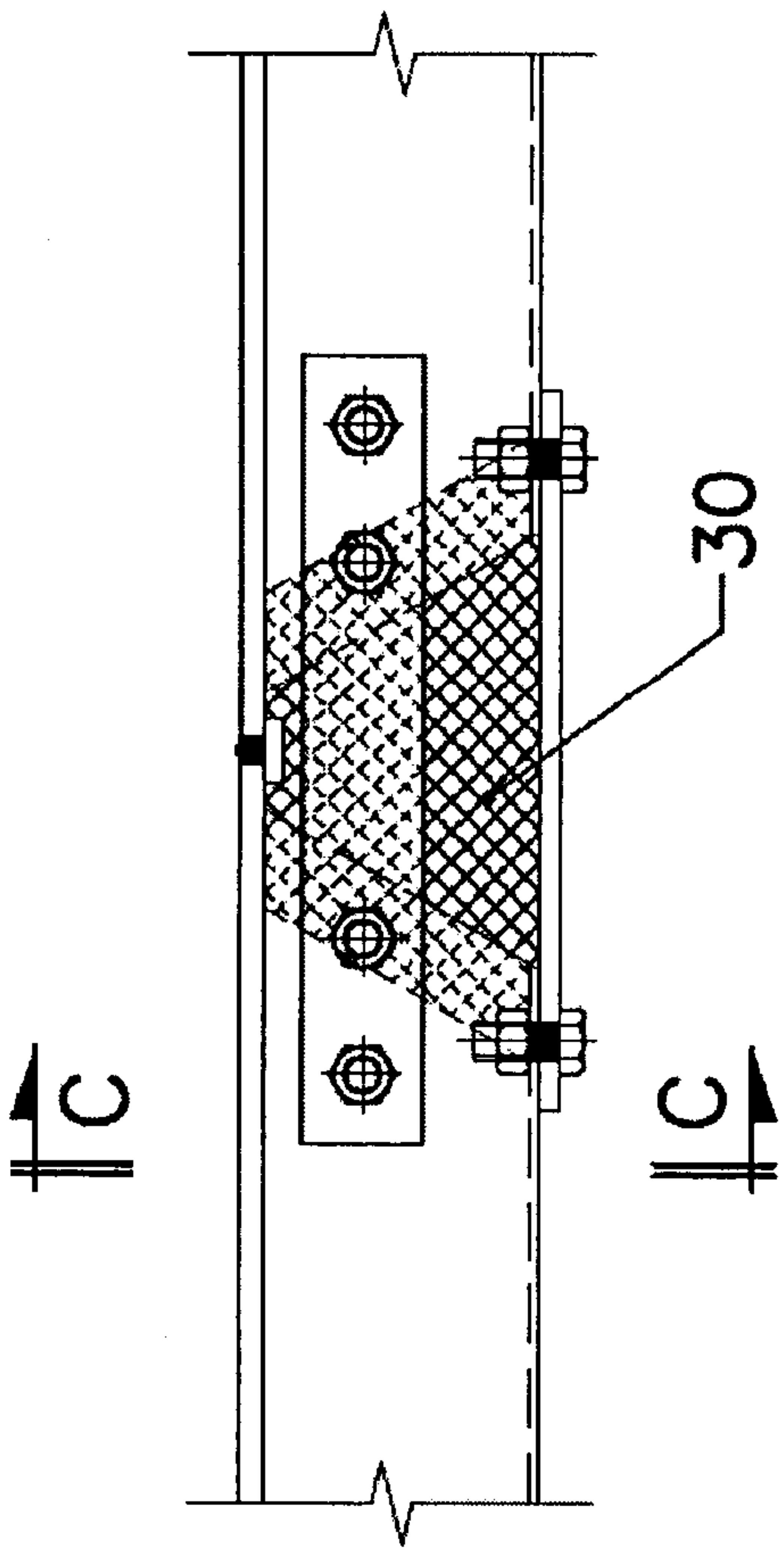
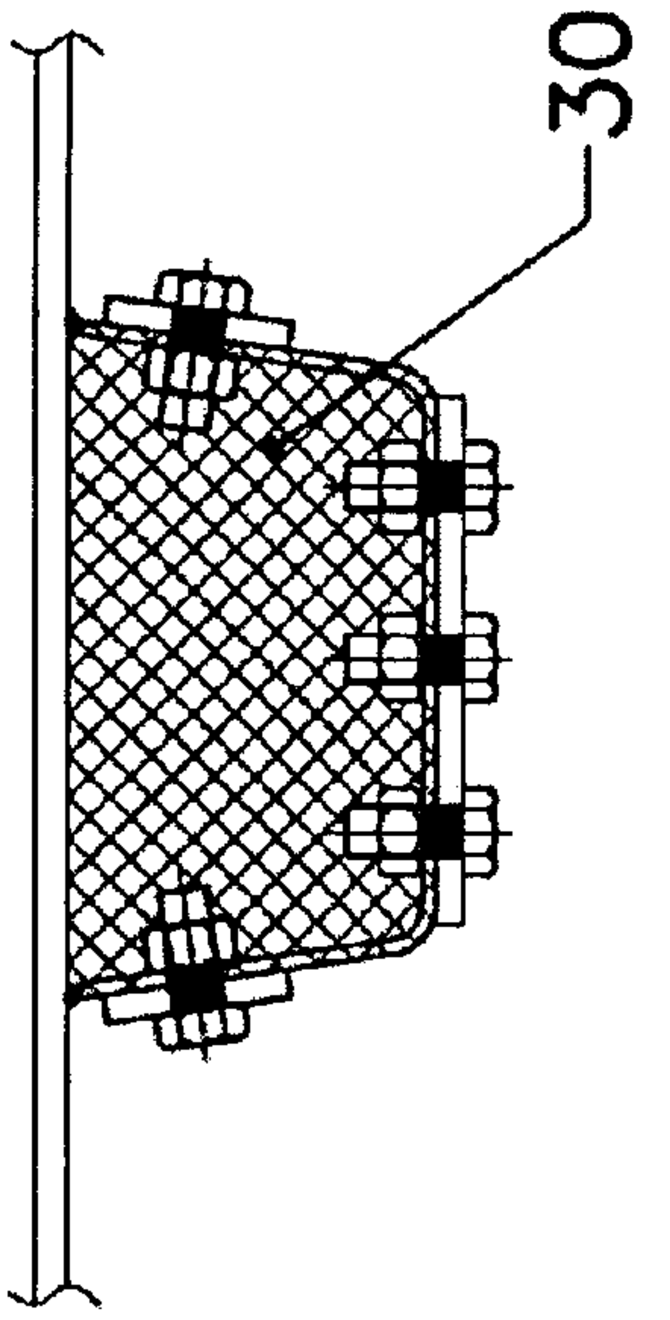


FIGURE 11B



SECTION C—C

FIGURE 11C

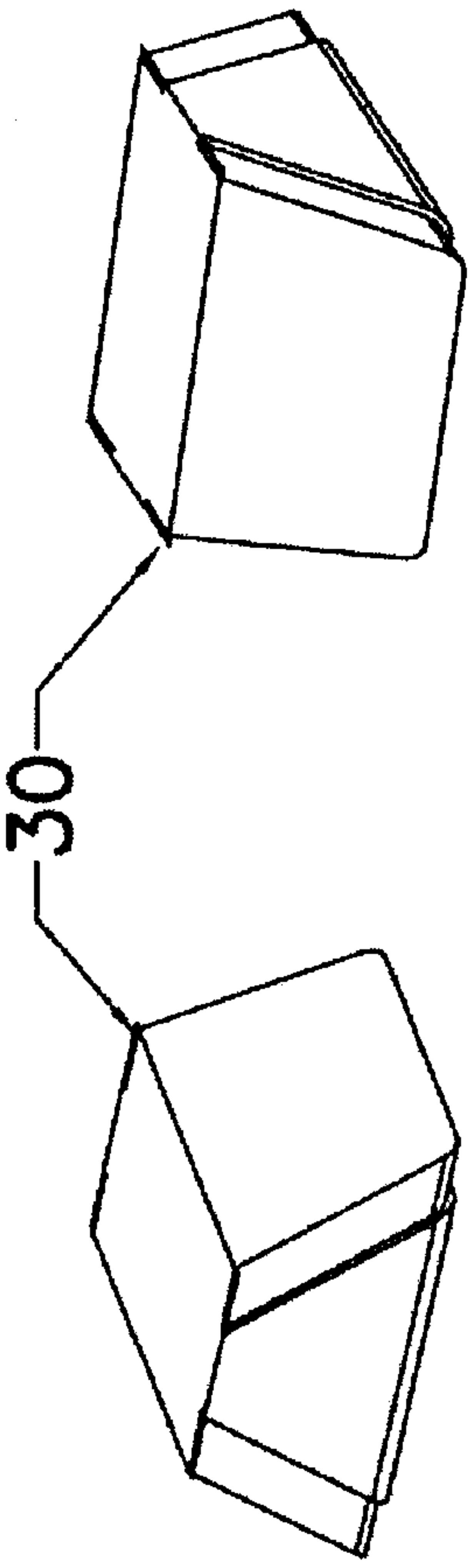
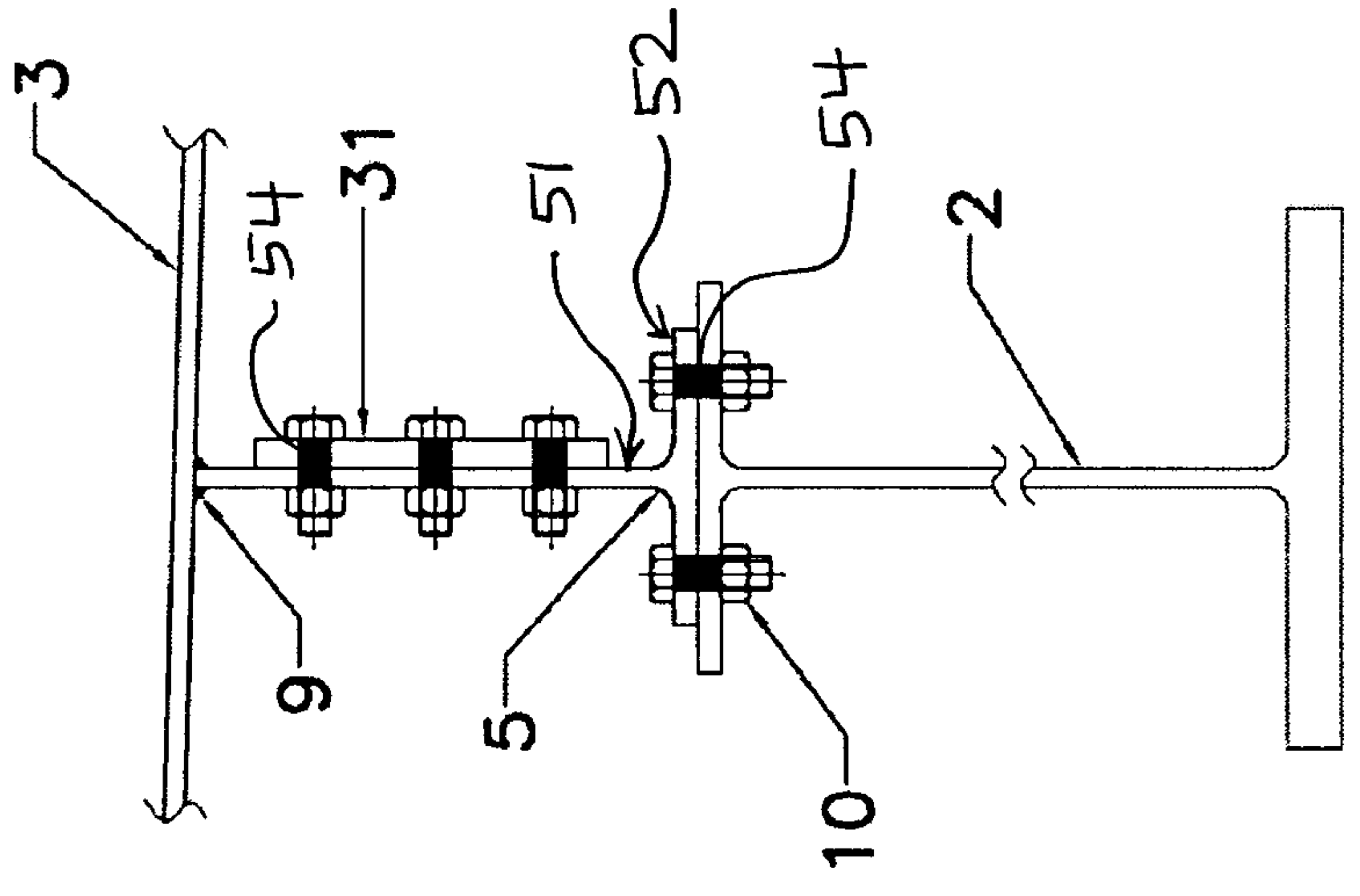


FIGURE 11A



SECTION D–D

FIGURE 12B

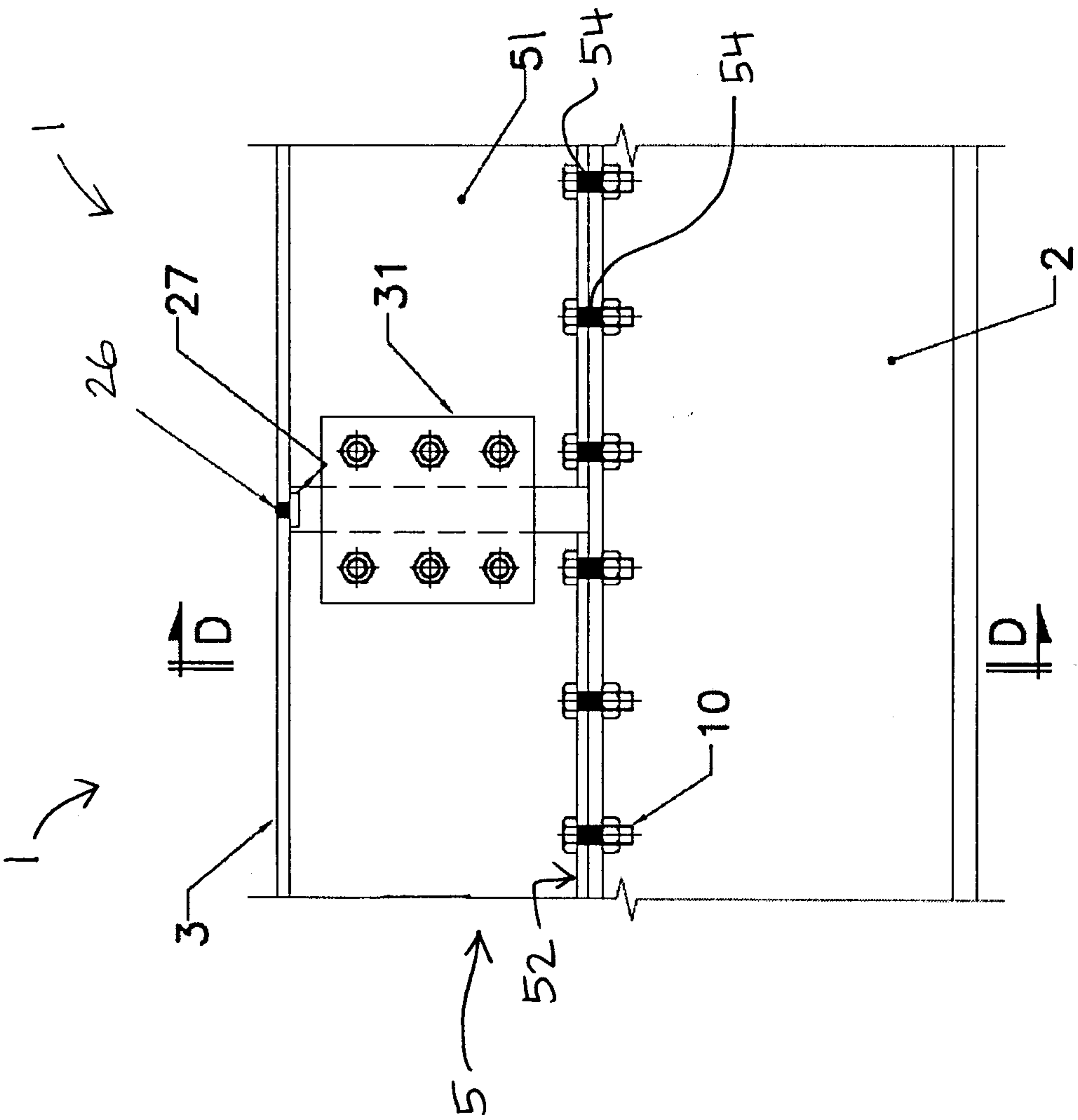


FIGURE 12A

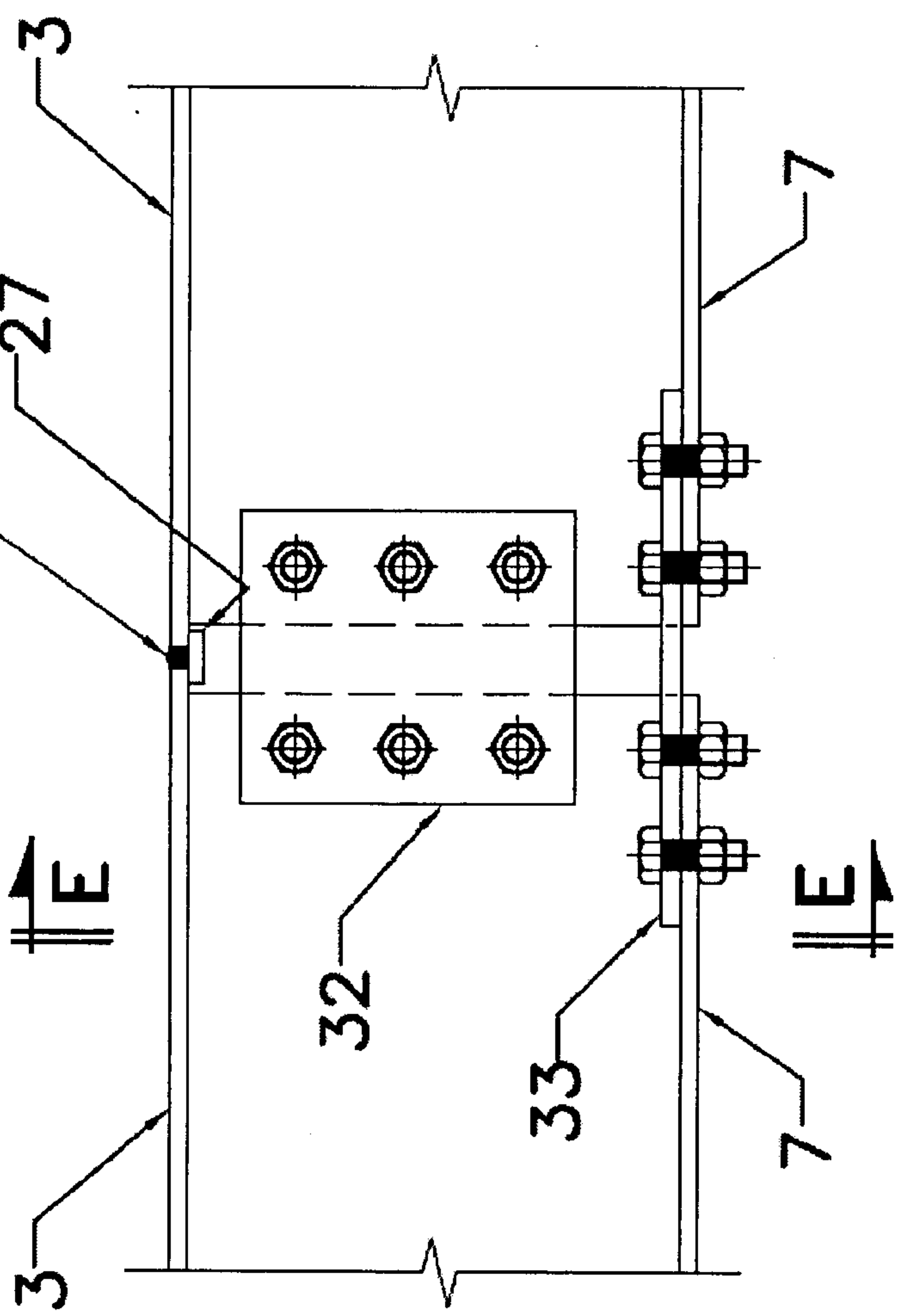
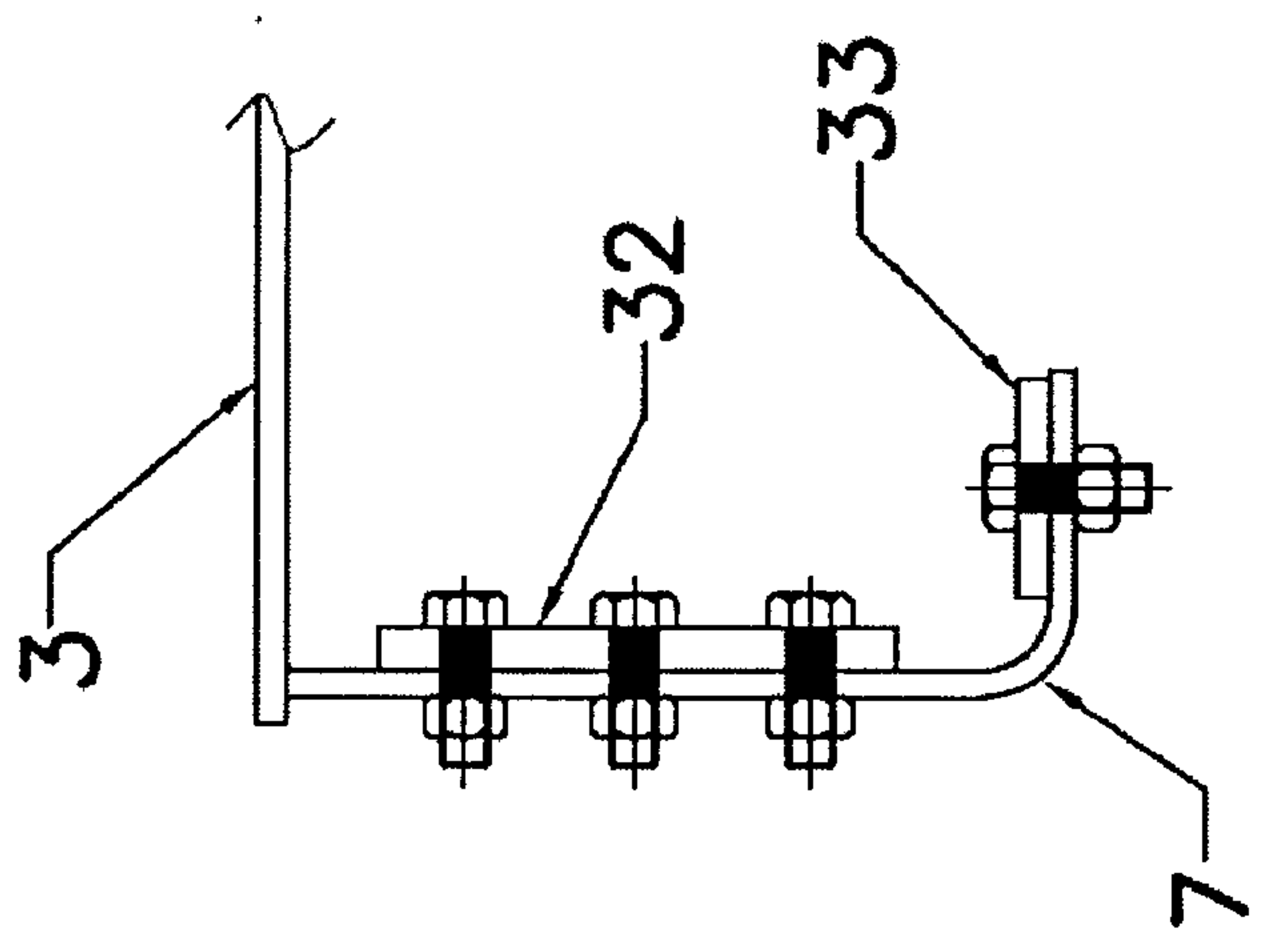


FIGURE 13A



SECTION E–E

FIGURE 13B

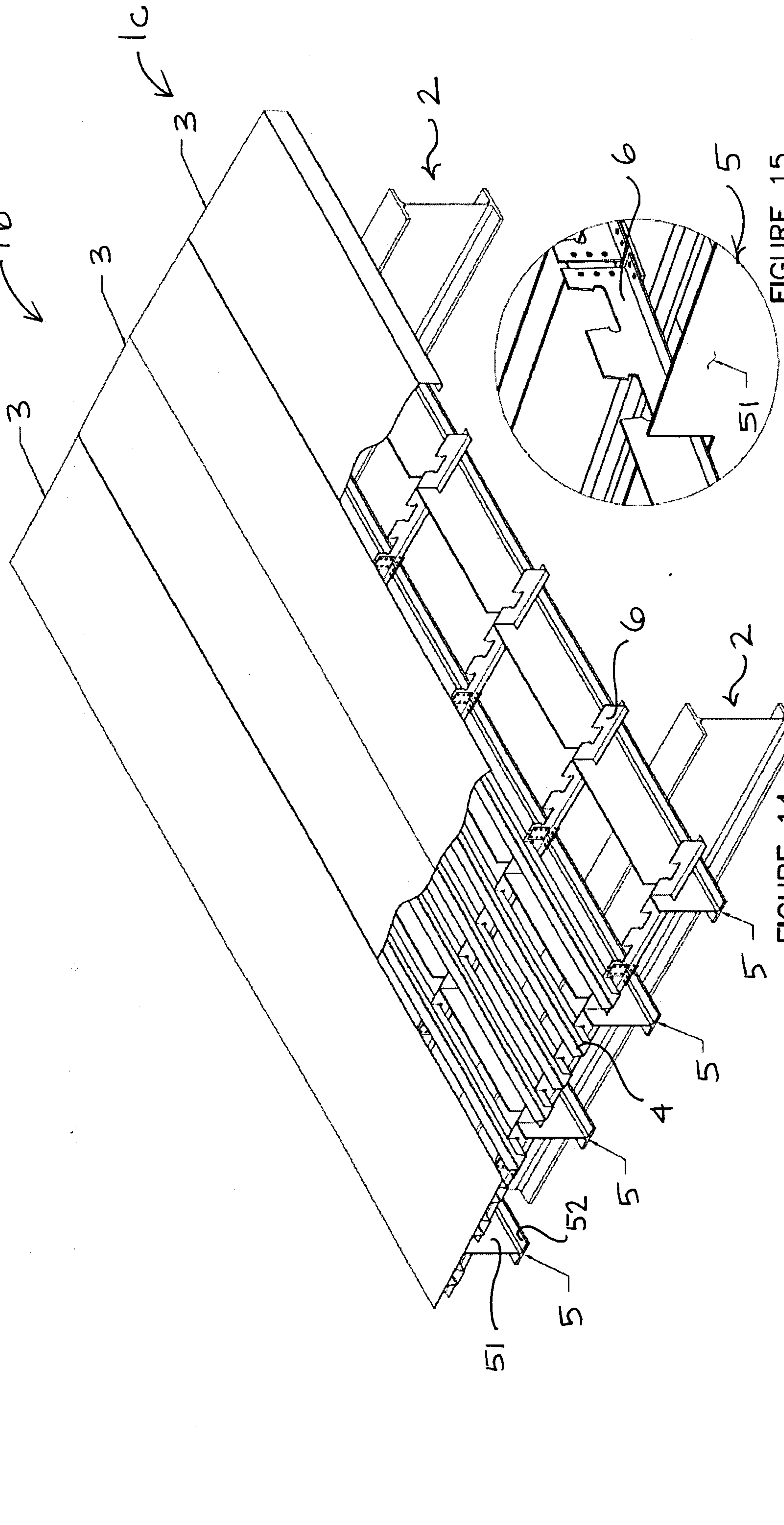


FIGURE 14

FIGURE 15

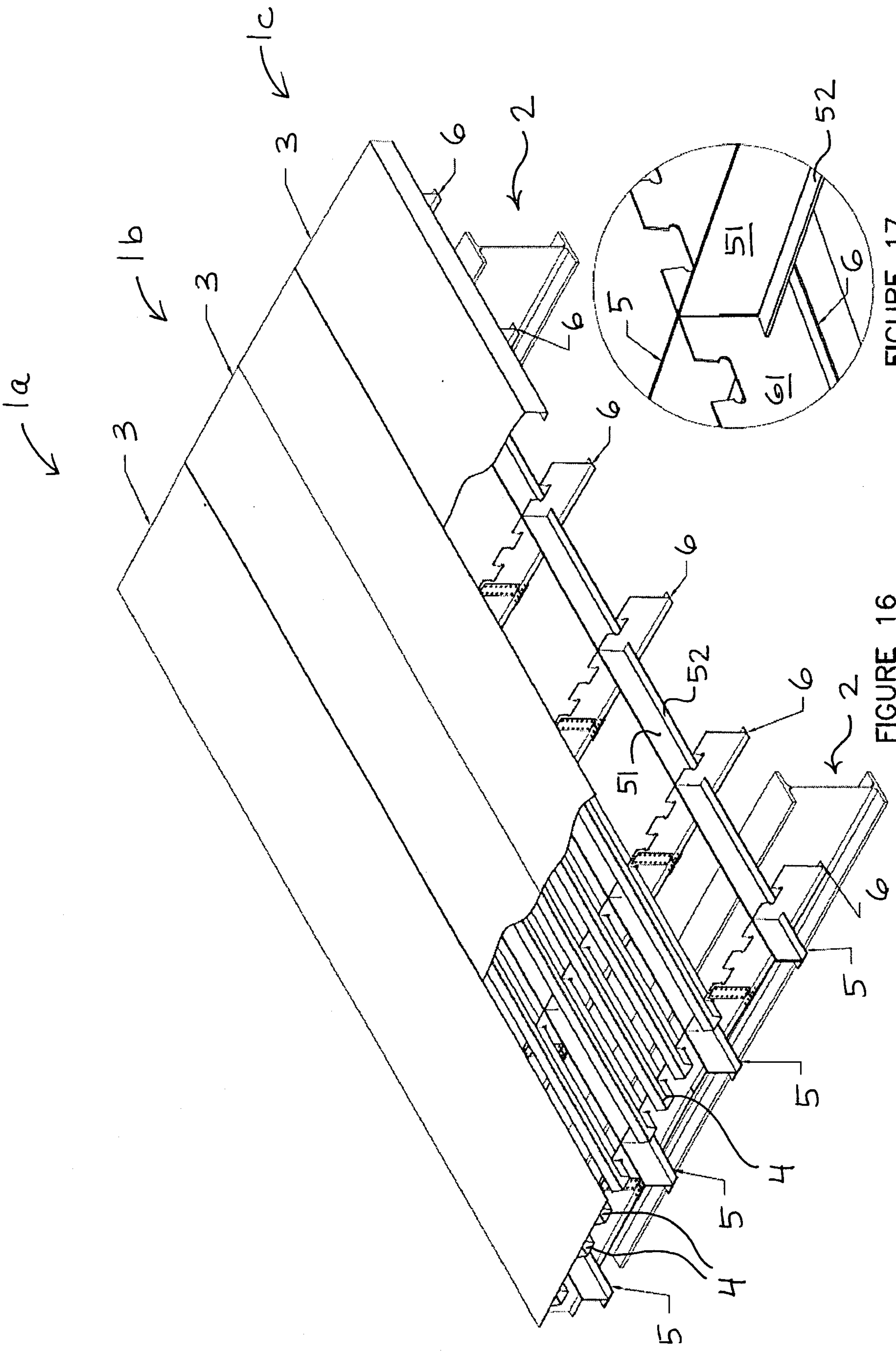


FIGURE 16

FIGURE 17


1
65
53
17
4
4
4
4
4
3
62
6
61
7
51
52
5