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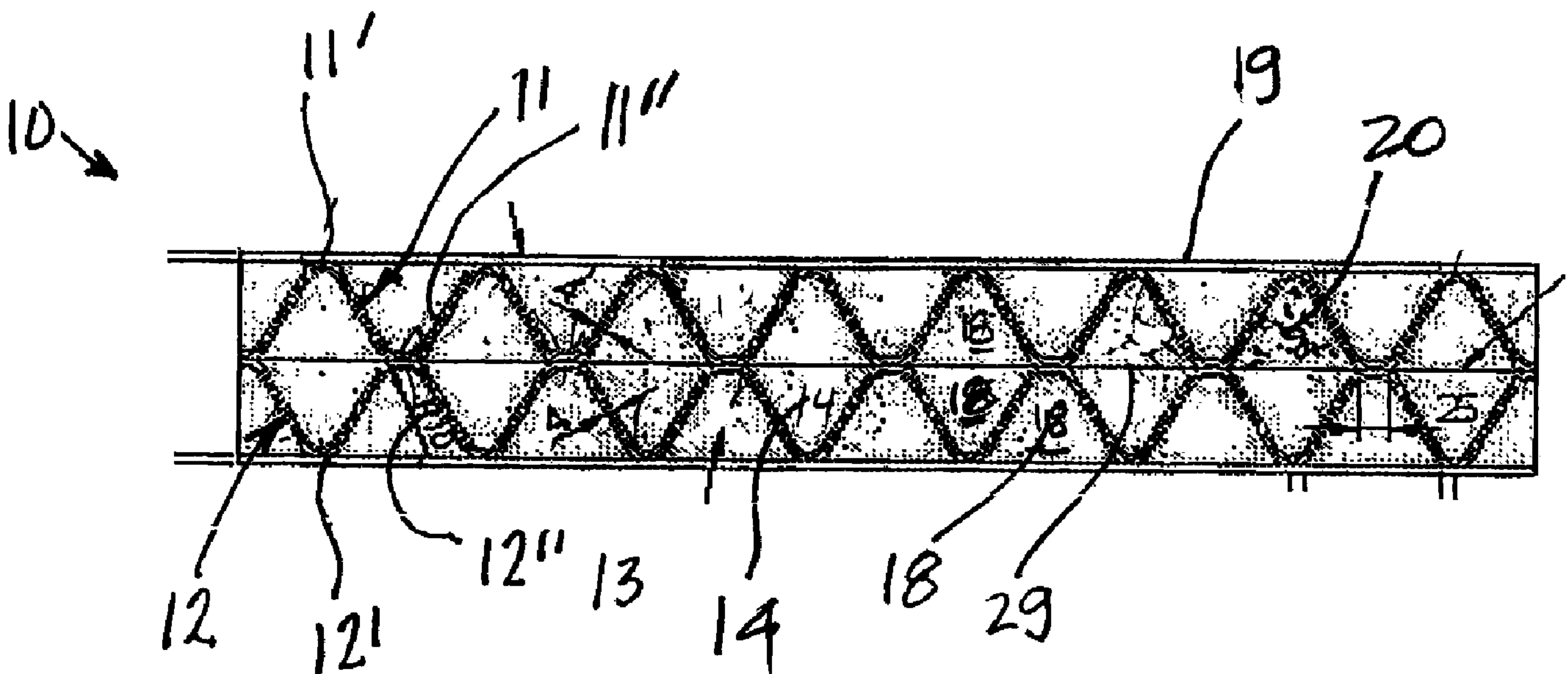
(71) Demandeur/Applicant:
BORAZGHI, HOSSEIN, CA

(72) Inventeur/Inventor:
BORAZGHI, HOSSEIN, CA

(74) Agent: OGILVY RENAULT LLP/S.E.N.C.R.L.,S.R.L.

(54) Titre : PANNEAU COMPOSITE THERMOPLASTIQUE RENFORCE DE FIBRES

(54) Title: FIBER REINFORCED THERMOPLASTIC COMPOSITE PANEL



(57) Abrégé/Abstract:

A fiber reinforced thermoplastic composite panel is described. One use of the panel is to construct bridge decks although the panel may have several other uses. It comprises two flat plates formed of commingled glass fiber reinforced polypropylene secured in spaced parallel relationship to a core. The core is formed by either two corrugated sheets interconnected together along connecting ridge sections or else by a plurality of elongated FRP channel members disposed transversely between the flat plates. The corrugated sheets or channel members form hollow core spaces between the two flat plates and the core material and these hollow spaces are filled with a filler material to add stability to the panel. Both the flat plates and the core material are formed of commingled glass fiber reinforced polypropylene (FRP).

FIBER REINFORCED THERMOPLASTIC
COMPOSITE PANEL

ABSTRACT

A fiber reinforced thermoplastic composite panel is described. One use of the panel is to construct bridge decks although the panel may have several other uses. It comprises two flat plates formed of commingled glass fiber reinforced polypropylene secured in spaced parallel relationship to a core. The core is formed by either two corrugated sheets interconnected together along connecting ridge sections or else by a plurality of elongated FRP channel members disposed transversely between the flat plates. The corrugated sheets or channel members form hollow core spaces between the two flat plates and the core material and these hollow spaces are filled with a filler material to add stability to the panel. Both the flat plates and the core material are formed of commingled glass fiber reinforced polypropylene (FRP).

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FIBER REINFORCED THERMOPLASTIC
COMPOSITE PANEL

TECHNICAL FIELD

5 The present invention relates to a fiber reinforced thermoplastic composite panel for use in the construction of bridge decks, as an example, and wherein the components of the panel are fabricated from commingled glass fiber reinforced polypropylene material.

10 The composite panel of the present invention was developed to replace current timber decks which are used in the construction of short span bridges and which could be more durable with an estimated service life of at least 75 years and which has less weight per surface area than these
15 timber slabs making it much easier to install and replace if necessary while providing an excellent fatigue resistance.

BACKGROUND ART

 Timber slabs conventionally used in these bridges
20 are made of standard E-P-S logs 9197x203x4268 mm WxHxL). The logs are typically arranged in a staggered formation every 406 mm (clear spacing of 209 mm). A wearing surface made of the same wood is furnished atop of the cross log strips (203x96x1800 mm WxHxL) are used. This makes the
25 total depth of the deck slab equal to 299 mm. The strips of the wearing surface are connected to the transverse logs using Ø10 bolts every 812 mm on the longitudinal direction.

 A review of the available literature into FRP composite bridge deck slabs reveal that some developments
30 have taken place in the last decade. Several demonstration projects have been completed and running in several countries, but with no mass production. The research in North America is still in its early stage, and no field application or demonstration has been made to date.

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Luke, S., et al, "The design, installation, and monitoring of an FRP bridge at West Mill Oxford", in Lightweight Bridge Decks, European Bridge Engineering Conference, Rotterdam, The Netherlands, March 27,-28, 2003, tested a modular bridge deck made of E-glass and polyester, the deck was made of several cells 500 mm wide each connected together using epoxy resin. The cross section of the cell was 225 mm deep and had triangular openings with 7.75 mm thick webs. The authors acknowledged that the triangular configuration used was not the optimum profile, which was the arched web profile, the manufacturing capabilities and cost-efficiency prohibited the fabrication of the arched profile. The deck was tested approved for only 40 t load as specified by the UK's BS-5400 code.

Hayes, M.D., Lesko, J., Haramis, J., cousins, T.E., Gomez, J., and Massarelli, P., "Laboratory and Field Testing of Composite Bridge Superstructure", Journal of Composites for Construction, ASCE, Vol. 4, No. 3, May 2000, pp. 120,-128, and Hayes, M.D., Ohanehi, D., Lesko, J., Cousins, T., and Witcher, D., "Performance of Tube and Plate Fiberglass Composite Bridge Deck", Journal of Composites for Construction, ASCE, Vol. 4, No. 2, May 2000, pp.48-55, tested 1224 mm wide bridge deck made of glass fiber and polyester. The deck was made up of 12 pultruded square tubes 102x102x6.36 mm thick sandwiched between two pultruded 9.53 mm thick plates. The section was thus 121 mm deep. The elements were all connected using epoxy adhesive, all mated surfaces were abraded before applying the epoxy and pressure was applied to the assembled deck until curing was complete. Additional lateral restraint was provided by through fiber bolts 25.4 mm in diameter at 300 mm spacing on the longitudinal direction of the deck.

Shekar, V., Petro, S.H., and GangaRao, H.V.S., "Fiber Reinforced Polymer Composite Bridges In West

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Virginia", 8th International Conference on Low-Volume Roads, Reno, Nevada, June 22-25, 2003, reported using E-glass and vinylester resin in construction of four highway bridge decks in the U.S. The cross-section of the decks used was
5 203 mm (8 in) deep using double trapezoidal and hexagonal connectors. The units were assembled at the production plant using polyurethane adhesive and mechanical pressure. Assembled sections were 2.43 m in width (in direction of the traffic) and their length were equal to the width of the
10 bridge in each case except for one bridge where the width was covered with two sections connected together longitudinally over the central beam. The decks had different spans in the four bridges (distance between beams) of 762, 889, 1829, and 2591 mm. The construction of the
15 largest deck (17x54 m) was completed in 6 days, about 10% of the time needed for conventional concrete deck, and using only five workers.

The first FRP bridge deck in New York State was placed in late 1999 to replace a deteriorated concrete deck
20 and allow for higher live load on the bridge, Chiewanichakorn, M., Aref, A.J., and Alampalli, S., "Failure Analysis of Fiber-Reinforced Polymer Bridge Deck System", Journal of Composites, Technology & Research, Vol. 25, No. 2, April 2003, pp. 121-129. The deck panels were made of E-
25 glass stitched fabric wrapped around foam blocks. The deck was designed using finite element analysis and stresses in the composite materials were limited to only 20% of their ultimate strength, deflection was also limited to Span/800. This extremely conservative design was due to the lack of
30 data and experience on composite bridge decks. Composite action between the FRP deck and the steel girders was deliberately eliminated during design. Field tests after installation showed as-designed stresses in the composites at about 2.9 MPa ($f_{ufrp} = 221 \text{ MPa}$).

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An important numerical study was reported by Gan, L.H., Ye, L., and Mai, Y., "Design and evaluation of various section profiles for pultruded deck panels", Composite Structures, Elsevier, Vol. 47, 1999, pp. 719-725, on the assessment of different cross-sectional configurations for pultruded FRP bridge deck panels. The authors used commercial finite element package ABAQUS to compare the behavior of seven shapes most used in research and application, hexagonal (honeycomb), triangular, rectangular, square, thick-top square, enhanced triangular, and enhanced channel were analyzed. The analysis was based on equal cross-sectional area for all seven shapes to reach the optimum cost-performance one since the area of the cross section is the main parameter governing the cost of the bridge deck. The overall depth of the shapes was also kept constant. The authors assumed orthotropic properties for the material and used 3-D block and shell elements for the static and buckling analyses, respectively.

20 SUMMARY OF INVENTION

It is a feature of the present invention to provide a fiber reinforced thermoplastic composite panel constructed of commingled glass fiber reinforced polypropylene (FRP) components and which provides several advantages over traditional wood timber slabs and over the known thick bridge panels have been constructed of synthetic materials such as E-glass, polyester and fiberglass fabrics.

Another feature of the present invention is to provide a fiber reinforced thermoplastic composite panel which is impermeable to moisture/water, which is non-corroding, which is environmentally friendly, which has a high fatigue and durability resistance and which provides a thinner wearing surface as opposed to wood timber decks.

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Another feature of the present invention is to provide a fiber reinforced thermoplastic composite panel which is lightweight, easy to install, which has a service life which is five times that of timber decks and which may
5 have several other uses such as in the construction of shelters, guard rails and a multitude of other applications.

According to the above features, from a broad aspect, the present invention provides a fiber reinforced thermoplastic composite panel which comprises two corrugated
10 sheets formed of commingled glass fiber reinforced polypropylene (FRP). Each of the corrugated sheets define a plurality of opposed and offset, spaced-apart connecting ridge sections and integrally formed intermediate trough sections therebetween. The two corrugated sheets are
15 interconnected in superimposition by connection means interconnecting at least some of the ridge sections disposed in abutting relationship and forming hollow core spaces by the trough sections formed therebetween. A flat plate constructed of FRP is connected to a respective one of
20 opposed sides of the interconnected corrugated sheets and secured to at least some of the ridge sections disposed on the opposed sides. A rigid filler material is disposed in the hollow core spaces defined by the trough sections between the two corrugated sheets and the two corrugated
25 sheets and the flat plates.

According to a still further broad aspect of the present invention there is provided a fiber reinforced thermoplastic composite panel comprising a pair of flat plates constructed of commingled glass fiber reinforced
30 polypropylene (FRP) interconnected in spaced parallel relationship by a plurality of elongated FRP channel members disposed transversely between the flat plates and spaced-apart in parallel relationship. Each channel member has a flat transverse wall and opposed connecting flanges

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extending at right angles along opposed longitudinal edges thereof. The flat plates are connected to the opposed connecting flanges by connection means. Diagonal braces are secured between the flat plates and each of the plurality of elongated FRP channels and span between adjacent ones of the channels. Hollow spaces are defined between the channel members, the flat plates and the diagonal braces. A filler material is disposed in the hollow spaces.

10 BRIEF DESCRIPTION OF DRAWINGS

The invention will now be described with reference to the accompanying drawings in which:

FIG. 1 is an end section view of a fiber-reinforced thermoplastic composite panel constructed in accordance with one embodiment of the present invention;

FIG. 2A is a fragmented top view of Figure 1;

FIG. 2B is an enlarged section view showing the construction of the corrugated sheets and their connections together and to the opposed FRP flat plates;

FIG. 3 is a schematic view showing a test platform to illustrate how a fiber reinforced thermoplastic composite panel constructed in accordance with the embodiments of the present invention was tested to determine its performance characteristics;

FIG. 4 is a graph showing the results of the tests;

FIG. 5 is a further graph showing the results of the tests;

FIG. 6 is an end section view showing the construction of a fiber-reinforced thermoplastic composite panel in accordance with a second embodiment of the present invention; and

FIG. 7 is a graph illustrating the performance characteristics of both composite panels when tested on the

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test platform as illustrated in Figure 3 under increasing loads.

DESCRIPTION OF PREFERRED EMBODIMENTS

5 Referring now to the drawings and more particularly to Figures 1 and 2, there is shown generally at 10 a fiber reinforced thermoplastic composite panel constructed in accordance with one embodiment of the present invention. The panel comprises two corrugated sheets 11 and 10 12 formed of commingled glass fiber reinforced polypropylene (FRP) by a continuous roll forming process. Each of the corrugated sheets 11 and 12 define a plurality of opposed and offset spaced-apart connecting ridge sections 11', 11" and 12' and 12" and integrally formed intermediate trough 15 sections 13 and 14 formed between the connecting ridge sections. The two corrugated sheets 11 and 12 are interconnected in superimposition, as hereinshown, by connection means which is hereinshown by high tensile bolts 15 interconnecting abutting ridge sections together. A web 20 of FRP material having a thickness of about 1.6 mm is shown at 29 and interconnected by the bolts 15 between the connecting ridges between opposed drop sections 11' and 12', as shown in Figure 2B, whereby to provide stability in the assembly of the two corrugated sheets 11 and 12. 25 Additionally, an epoxy glue 16 can be interposed between the abutting connecting ridge sections. These ridge sections also have a flat top wall 17 to provide good contact and flat surfaces for the securement of the tensile bolts 15 as is better seen in Figure 2B.

30 Hollow core spaces 18 are defined by the trough sections 11" and 12". Flat plates 19 and 19' constructed of FRP material are connected to a respective one of opposed sides of the interconnected corrugated sheets 11 and 12 and secured to at least some of the ridge sections 11' and 11",

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herein all ridge sections by tensile bolts 15. A filler material 20 is disposed in the hollow core spaces 18 defined by the trough sections 11" and 12" between the two corrugated sheets and the two corrugated sheets and the flat plates 19 and 19'. The filler material can be an expanding soft foam material or light concrete or sand.

In the embodiment of the panel as shown by reference numeral 10, the corrugated sheets 11 and 12 have a thickness of 4.0 mm and the flat plates 19 and 19' have a thickness of 5.0 mm. The fastener bolts 15 are spaced-apart a distance of 150 mm to interconnect all of the ridges 11' and 12' in abutting relationship. The panel as herein formed is a bridge deck panel and was tested on the test platform 25, as illustrated in Figure 3, and the panel was made of flat plates 19 and 19' fabricated in one piece having 1,200x3,300 mm each and the web sections or the core between these flat plates was fabricated in half sizes (600x1650 mm), and joined together, as above-described, to form full webs in the longitudinal direction (600x3300 mm). Tests have shown that the panel 10 was capable of resisting a load of 515 kN between two points, herein designated by reference numerals 26 and 27, spaced-apart a distance of 1800 mm which is representative of a pair of truck axles. After tests it was observed that the panel 10 recovered all deformation upon the removal of the load exerted by the pistons 28 and 28', each having been loaded to 110 kN. It is to be noted that this panel is considered to be a very lightweight structural panel as opposed to timber bridge decking structures. The panel also, as previously mentioned, has several applications such as providing supports in mine shafts or for the construction of shelters for military application. Such a panel has been found to resist direct impact by 55 mm caliber bullets.

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With reference to Figure 3, finite element analysis (FE) was performed using known commercial software package SAP2000TM to predict deflections and stresses in the deck profile. The analyses were made on ¼ model to make use
5 of the symmetry of the bridge deck and loading. The model of the deck was 725 mm in the longitudinal direction (1/2 span of 1450 mm between bridge girder), and 625 mm wide (1/2 of 1250 mm which is equivalent to the width of three timber log spacing carrying the wheel load), and 204 mm deep (equal
10 to the depth of timber deck currently used). The maximum deflection, including any possible local buckling of the top flange or webs was the governing parameter in the analysis. As specified by CHBDC, the maximum allowable deflection in the deck is $L/400$ which gives: $1450/400 = 3.63$ mm.
15 Stresses and strains in the materials at the service load level were much less than the material ultimate capacity.

The load transfer posts 28 and 28' were secured to a hydraulic actuator mounted on a loading steel frame to apply the loading to the deck panel. The deck panel 10 was
20 placed on three parallel I-beams 1.5 m wide, with 83 mm wide flanges. The two loading areas were 250x600 mm and were separated by 1.8 m center in center, which represents the width of truck axle. Plywood boards of 20 mm were placed between the supporting I-beams and the slab, and between the
25 loading steel plates and the slab to insure no compressive force will be exerted on the heads of deck bolts. In field applications, bolts can be protected by using a soft inexpensive wearing layer such as asphalt. The deck was simply deposited on the supports and was retained laterally
30 by steel clamps on each side. The deck was instrumented with 34 electrical strain gauges on the FRP on the top and bottom surfaces, and on the webs. In addition, nine LVDT were used to measure the deflection at different spots.

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The panel or deck 10 was loaded four times with increasing load in each test at 220, 380, 450 and 515 kN. It was observed that the panel displayed a linear behavior in all the four tests. The four elastic lines were almost identical in slope, indicating no loss of stiffness due to the repeated loading and unloading. During the test of 380 kN, it was observed that the loading steel plates (25 mm thick) started to bend upward. The panel withstood the four tests and showed typical flexure behavior with no buckling or failure in bolts.

Figure 4 shows the load-deflection curves for the test. It should be noted that the three lines to the left represent the deformation at the supports, which is due to the compression of the plywood strips above the I-beams. Taking this into consideration, the net maximum deflection should be around $28-6=22$ mm, as indicated by the dashed lines. At the service load level, the net maximum deflection was approximately 9 mm ($14-5$ as indicated by the dashed lines) or $L/160$ (the target $L/400$ is 3.6 mm). The difference can be easily justified due to the use of very soft foam instead of stiff one used. In addition, the absence of rubber pad under the steel loading plate caused the deformation to be almost uniform under the plate, which in return extended the deflection line much farther outside the plate area.

With respect to stress levels during the tests, the stresses recorded in the composite parts were generally low. For the test of 515 kN, stress measurements are presented in Figure 5 with a maximum of 80 MPa tensile stresses on the bottom surface under the loading area. This level of stress accounts for only 27% of the capacity of the material in tension (300 MPa). The maximum compressive stress was 35 MPa at the side of the loading area, or 25% of the capacity of the material in compression (140 MPa). Some

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cracking noises were heard near the end of the test (around 400 kN) and few sharp snaps occurred, probably due to plywood breaking, but without any visible damage to the deck. In conclusion, the deck panel 10 tested was able to
5 withstand more than double the service load. The recorded deflections were higher than the allowable limits, but that was acceptable when considering the very soft foam used, and the absence of rubber pads under the rigid loading steel plates. The stress levels in the deck were relatively low,
10 which provides enough room for fatigue and creep effects that will take place under service condition, without jeopardizing the integrity of the deck.

With reference now to Figure 6, there is shown a much simpler design of the present invention and having
15 fewer assembly elements. The corrugated sheets 11 and 12 as used in the core design of Figure 1 are substituted by a core design having a plurality of elongated FRP channel members 30 which are disposed transversely between the opposed flat plates 31 and 32 formed of commingled glass
20 fiber reinforced polypropylene FRP. These channel members 30, also constructed of FRP, are spaced apart in parallel relationship and each channel member 30 has a flat transverse wall 33 and opposed connecting flanges 34 and 34' extending at right angles along opposed longitudinal edges
25 of the flat transverse wall 33. The flat plates 31 and 32 are connected to the opposed connecting flanges 34 and 34' by connection means constituted by high tensile bolts 35.

Diagonal braces 36 are secured between the flat plates 31 and 32 and each of the plurality of elongated FRP
30 channels 30 and span between adjacent ones of the channels. Hollow spaces 37 are defined between the channel members 30, the flat plates 31 and 32 and the diagonal braces. A filler material 38, such as an expanding soft foam material as previously described, is injected in these hollow spaces 37

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to add rigidity to the panel 50 as shown in Figure 6. As previously described, this filler material can also be light concrete or sand, depending on the application of the panel.

It is pointed out that the elongated FRP channel members 30 are integrally formed in a continuous roll forming machine developed by AS Composite Inc. These channel members are formed as U-shaped channel members 30 with the opposed connecting flanges 34 and 34' projecting from a common side of the flat transverse wall 33. The diagonal braces 36 each extend from a free end edge of one of the connecting flanges, such as connecting flange 34' to an opposed end edge such as designated by reference numeral 39 of an adjacent channel member. Accordingly, there is constructed a non-metallic panel, other than the high tensile bolts utilized to interconnect the opposed flat plates to the elongated FRP channel members. However, it is preferred that these bolts be non-corrosive high tensile type bolts.

Some of the advantages of the panel constructed in accordance with the second embodiment is that it eliminates longitudinal splices in the fabrication of the web. Also, this design eliminates the use of epoxy adhesives and half the amounts of tensile bolts the assembly is much faster. The use of the U-shaped channel members 30 also eliminates the need for pre-drilling bolt holes.

A prototype was constructed in accordance with the panel 50 of the second embodiment. The prototype was 1.2 m wide, 3.2 m long and 0.25 m thick. The base materials used was TwinTex^R fabric (commingled glass fiber reinforced polypropylene) consolidated and formed to the desired shape. The panel consisted of two 4.0 mm flat plates 31, 32 separated in the middle by multiple channel members 30 spaced 125 mm apart and diagonal braces 36. These individual parts are connected together by high tensile

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bolts 35. Expanding soft foam 38 was used to fill the inner space 37 to prevent buckling of the channels.

The panel was tested under both monotonic and cycling loading with one load on each span representing truck wheel (two loads representing truck axle). Static (monotonic) loading test was performed first and a total load of 510 kN was reached (limit of hydraulic actuator) and the slab suffered no visible damage. The slab recovered all the deformation upon load removal. The deflection recorded was much less than that of the first panel 10 and was within target. Fatigue test was performed until failure of the slab at a frequency of 1 Hz and a load of 1-110 kN on each span. A total of 2 million cycles were achieved without significant damage, the slab failed soon thereafter when the load was doubled in value.

Figure 7 is a graph illustrating the deflection comparison between the panel 10 constructed in accordance with the first embodiment and the panel 50 constructed in accordance with the second embodiment. This graph clearly shows the superior performance of the panel 50 constructed in accordance with the second embodiment representative by the curves 60 as opposed to the curves 61 of the first embodiment.

It is within the ambit of the present invention to cover any obvious modifications of the preferred embodiment described herein, provided such modifications fall within the scope of the appended claims.

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CLAIMS,

1. A fiber reinforced thermoplastic composite panel comprising two corrugated sheets formed of commingled glass fiber reinforced polypropylene (FRP), each said corrugated sheet defining a plurality of opposed and offset, spaced-apart connecting ridge sections and integrally formed intermediate trough sections therebetween, said two corrugated sheets being interconnected in superimposition by connection means interconnecting at least some of said ridge sections disposed in abutting relationship and forming hollow core spaces by said trough sections formed therebetween, a flat plate constructed of FRP is connected to a respective one of opposed sides of said interconnected corrugated sheets and secured to at least some of said ridge sections disposed on said opposed sides, and a filler material disposed in said hollow core spaces defined by said trough sections between said two corrugated sheets and said two corrugated sheets and said flat plates.

2. A fiber reinforced thermoplastic composite panel as claimed in claim 1 wherein said connecting ridge sections have a flat top section.

3. A fiber reinforced thermoplastic composite panel as claimed in claim 2 wherein said flat top section of said ridges in abutting relationship are interconnected by fastener elements.

4. A fiber reinforced thermoplastic composite panel as claimed in claim 3 wherein a web of FRP material is interconnected between said connecting ridge sections lying intermediate said flat plates on said opposed sides, by fastening means.

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5. A fiber reinforced thermoplastic composite panel as claimed in claim 3 wherein an epoxy adhesive is disposed between said flat top sections of said ridge sections disposed in abutting relationship.

6. A fiber reinforced thermoplastic composite panel as claimed in claim 3 wherein said panel is a bridge deck slab.

7. A fiber reinforced thermoplastic composite panel as claimed in claim 3 wherein said filler material is an expanding soft foam material.

8. A fiber reinforced thermoplastic composite panel as claimed in claim 6 wherein said corrugated sheets have a thickness of 4.0 mm, said flat plates have a thickness of 5.0 mm, said fastener elements are spaced-part a distance of 150 mm to interconnect all of said ridges in abutting relationship, and wherein said panel is capable of resisting a load of 515 kN between two points spaced apart a distance of 1800 mm representative of a pair of truck axles with said panel recovering all deformation upon the removal of said load.

9. A fiber reinforced thermoplastic composite panel as claimed in claim 1 wherein said panel is a multi-application lightweight structural panel.

10. A fiber reinforced thermoplastic composite panel as claimed in claim 9 wherein said panel is used in the construction of one of a mine shaft support structure or a military shelter.

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11. A fiber reinforced thermoplastic composite panel as claimed in claim 10 wherein said filler material is one of a light concrete or sand.

12. A fiber reinforced thermoplastic composite panel comprising a pair of flat plates constructed of commingled glass fiber reinforced polypropylene (FRP) interconnected in spaced parallel relationship by a plurality of elongated FRP channel members disposed transversely between said flat plates and spaced-apart in parallel relationship, each said channel members having a flat transverse wall and opposed connecting flanges extending at right angles along opposed longitudinal edges thereof, said flat plates being connected to said opposed connecting flanges by connection means, diagonal braces secured between said flat plates and each of said plurality of elongated FRP channels and spanning between adjacent ones of said channels; hollow spaces defined between said channel members, said flat plates and said diagonal braces; and a filler material in said hollow spaces.

13. A fiber reinforced thermoplastic composite panel as claimed in claim 12 wherein said opposed connecting flanges are integrally formed with said flat wall.

14. A fiber reinforced thermoplastic composite panel as claimed in claim 13 wherein said channel members are U-shaped channel members with said opposed connecting flanges projecting from said opposed longitudinal edges to a common side of said flat wall.

15. A fiber reinforced thermoplastic composite panel as claimed in claim 14 wherein said diagonal braces each extend from a free end edge of one of said connecting flanges at one end of a channel member diagonally to an

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opposed end edge at an opposite end of an adjacent channel member.

16. A fiber reinforced thermoplastic composite panel as claimed in claim 13 wherein said connecting means is constituted by high tensile bolts.

17. A fiber reinforced thermoplastic composite panel as claimed in claim 12 wherein said filler material is an expanding soft foam material.

18. A fiber reinforced thermoplastic composite panel as claimed in claim 12 wherein said diagonal braces are flat elongated brace plates constructed of FRP.

19. A fiber reinforced thermoplastic composite panel as claimed in claim 12 wherein said panel is a non-metallic bridge deck.

20. A fiber reinforced thermoplastic composite panel as claimed in claim 12 wherein said filler material is one of light concrete or sand.

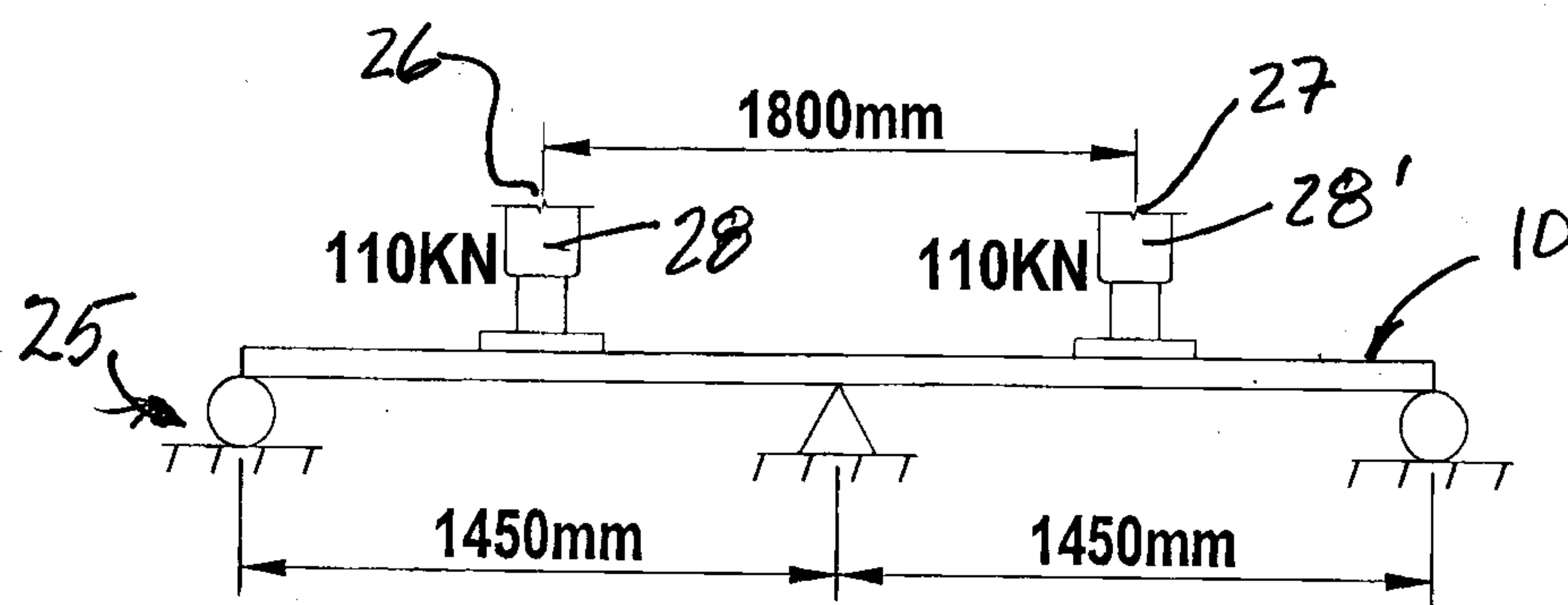
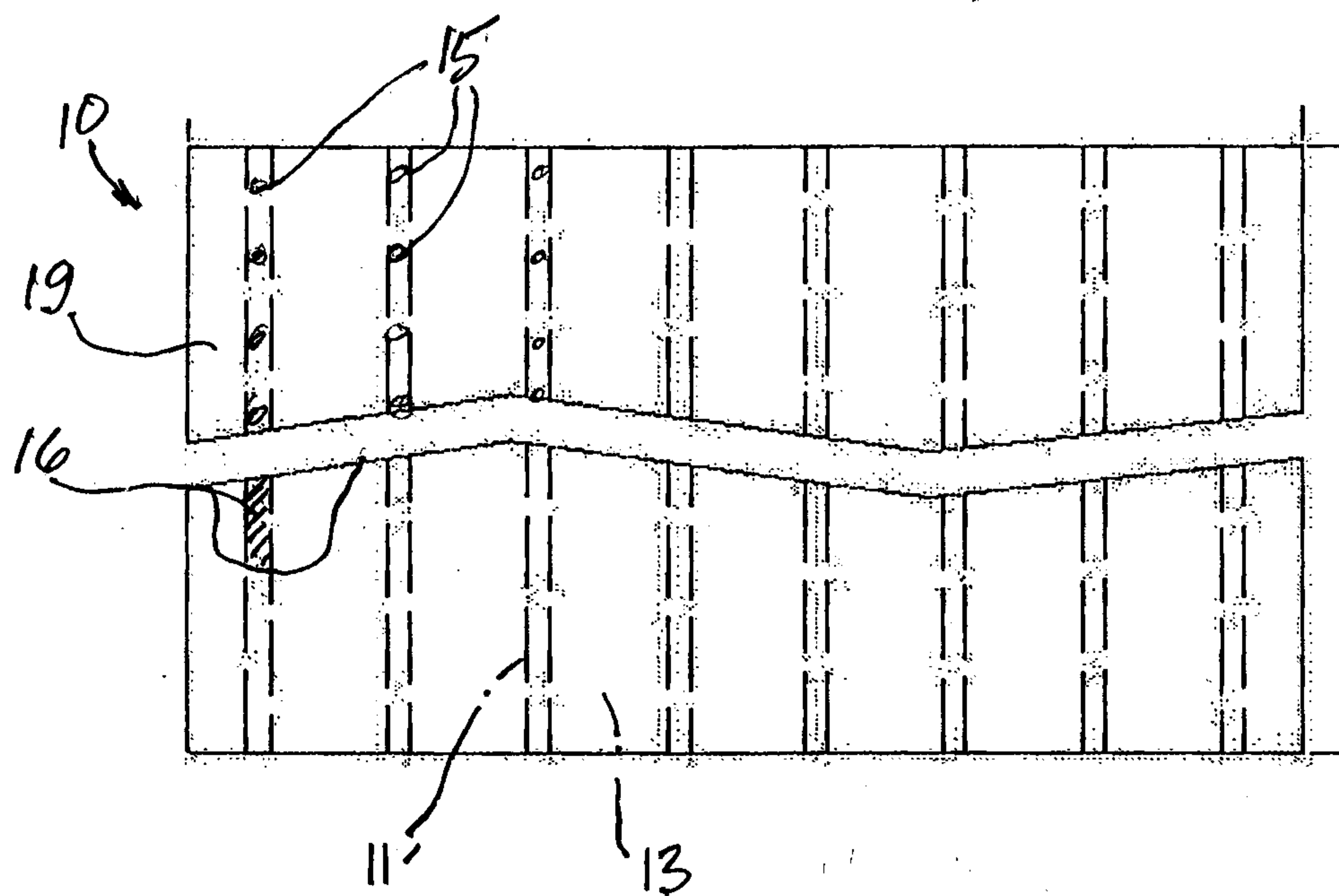
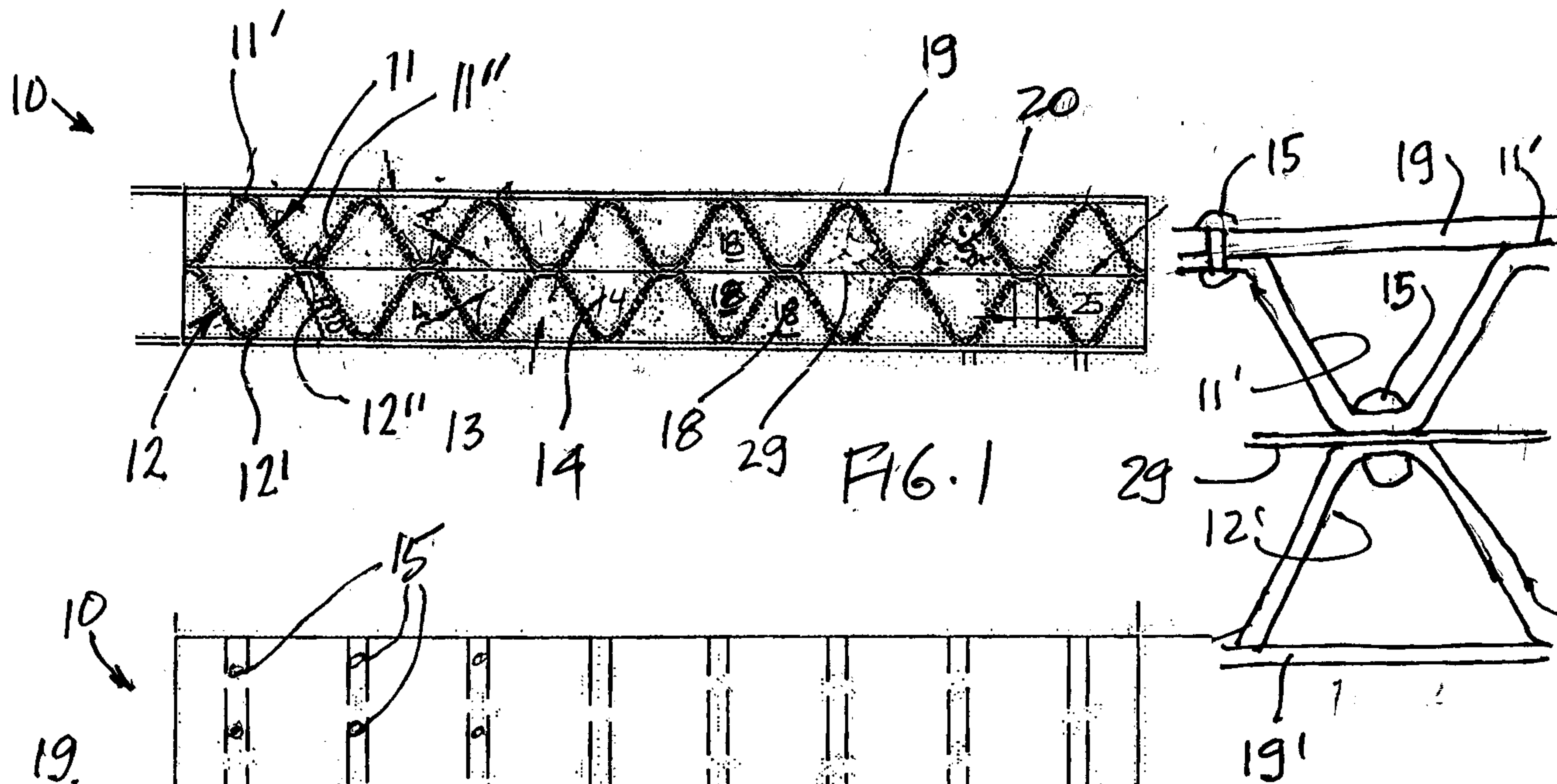


FIG. 3

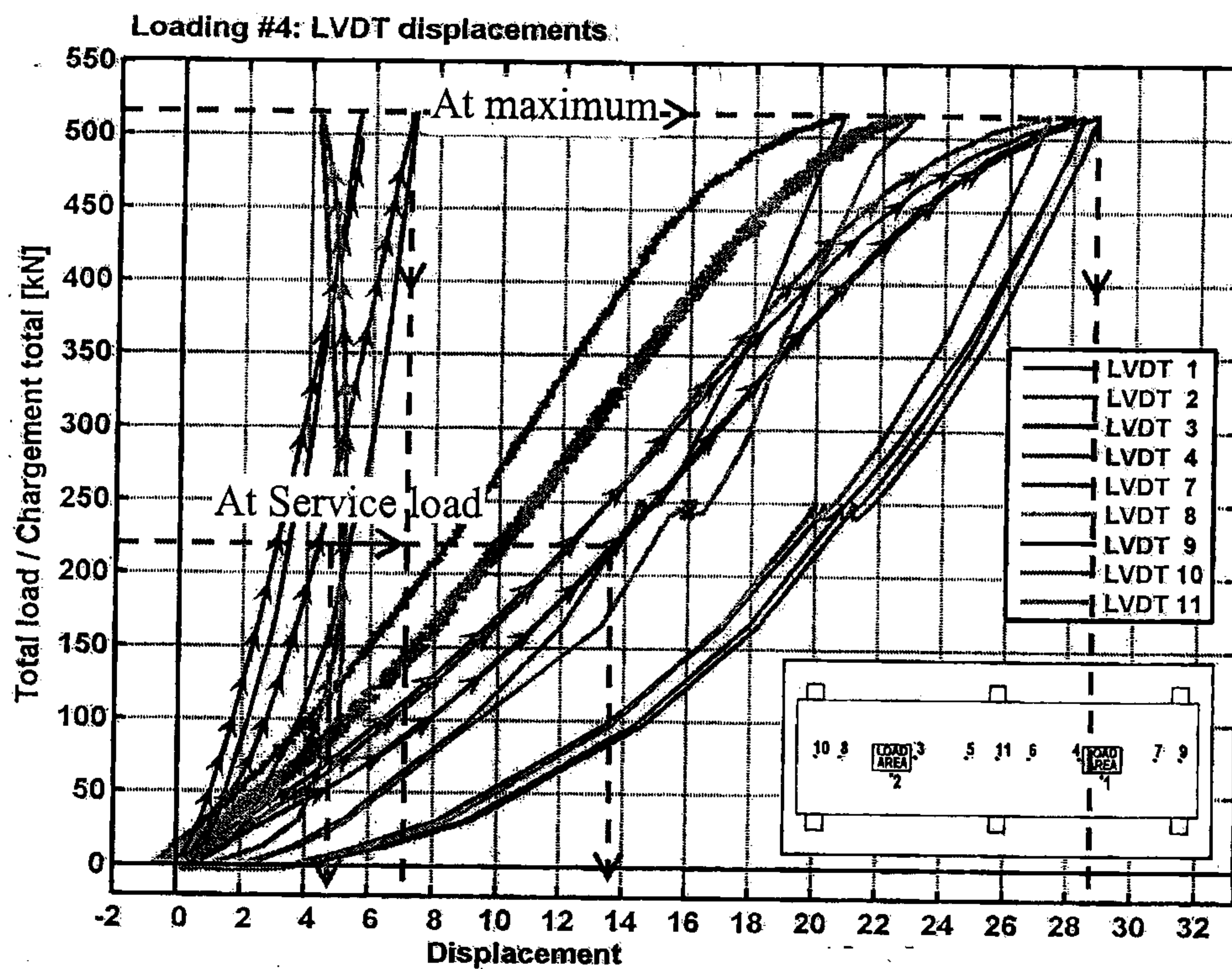


FIG. 4

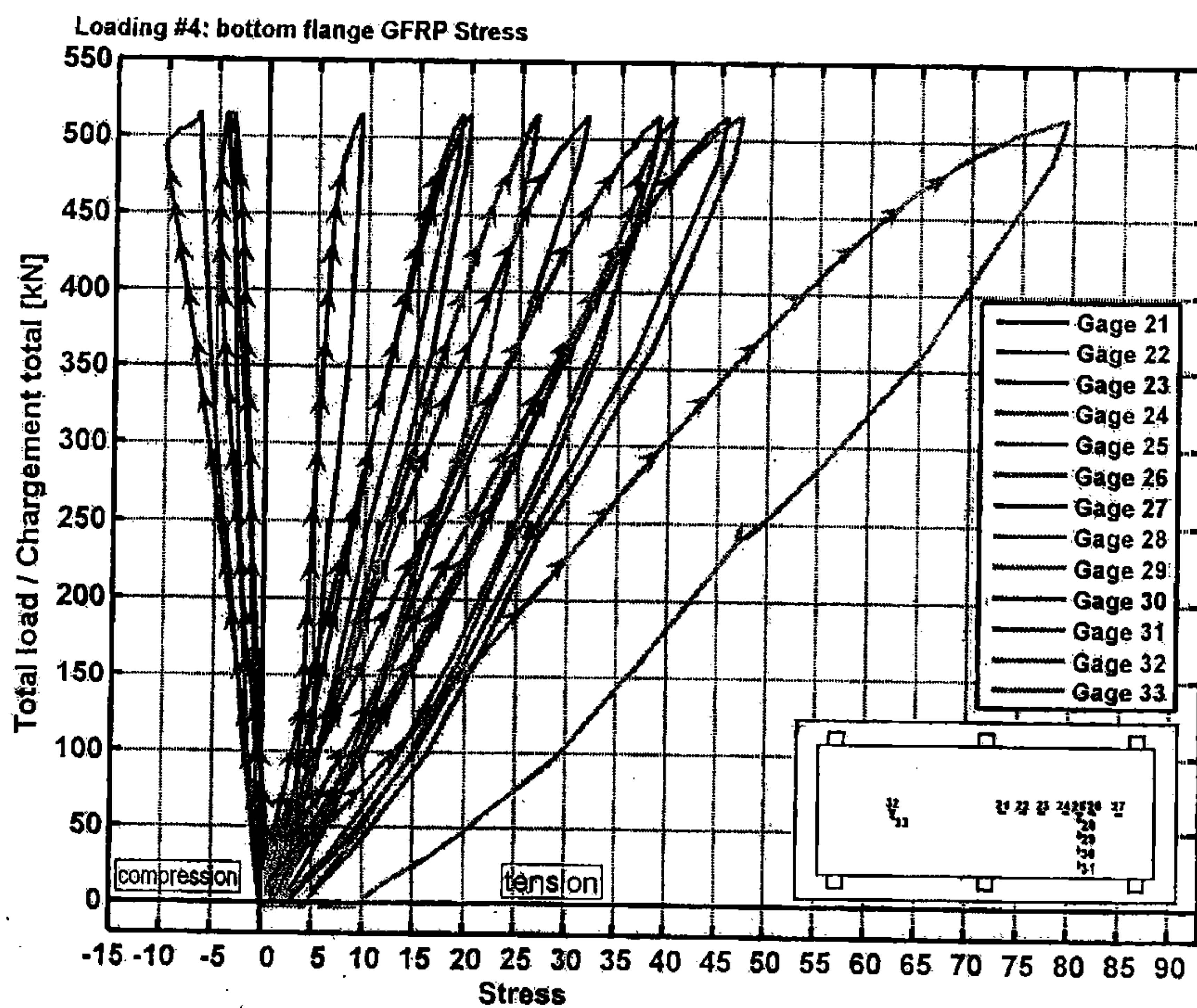


FIG. 5

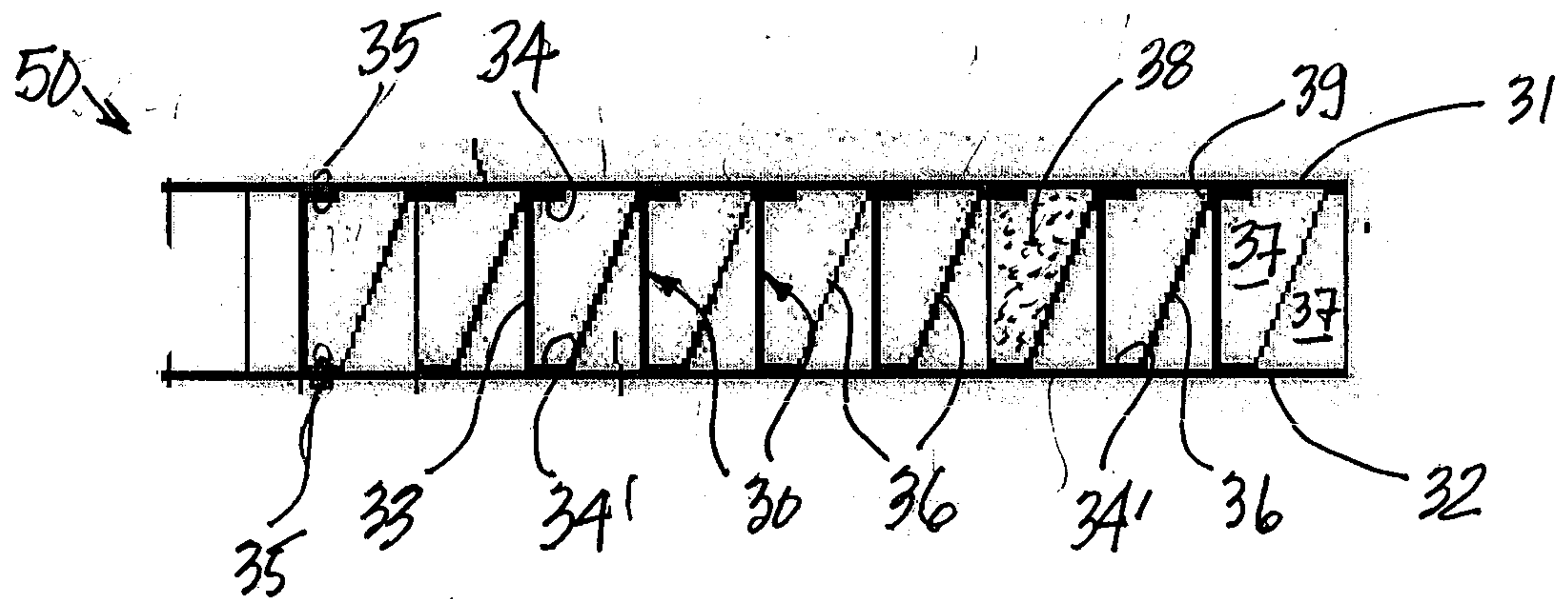


FIG. 6

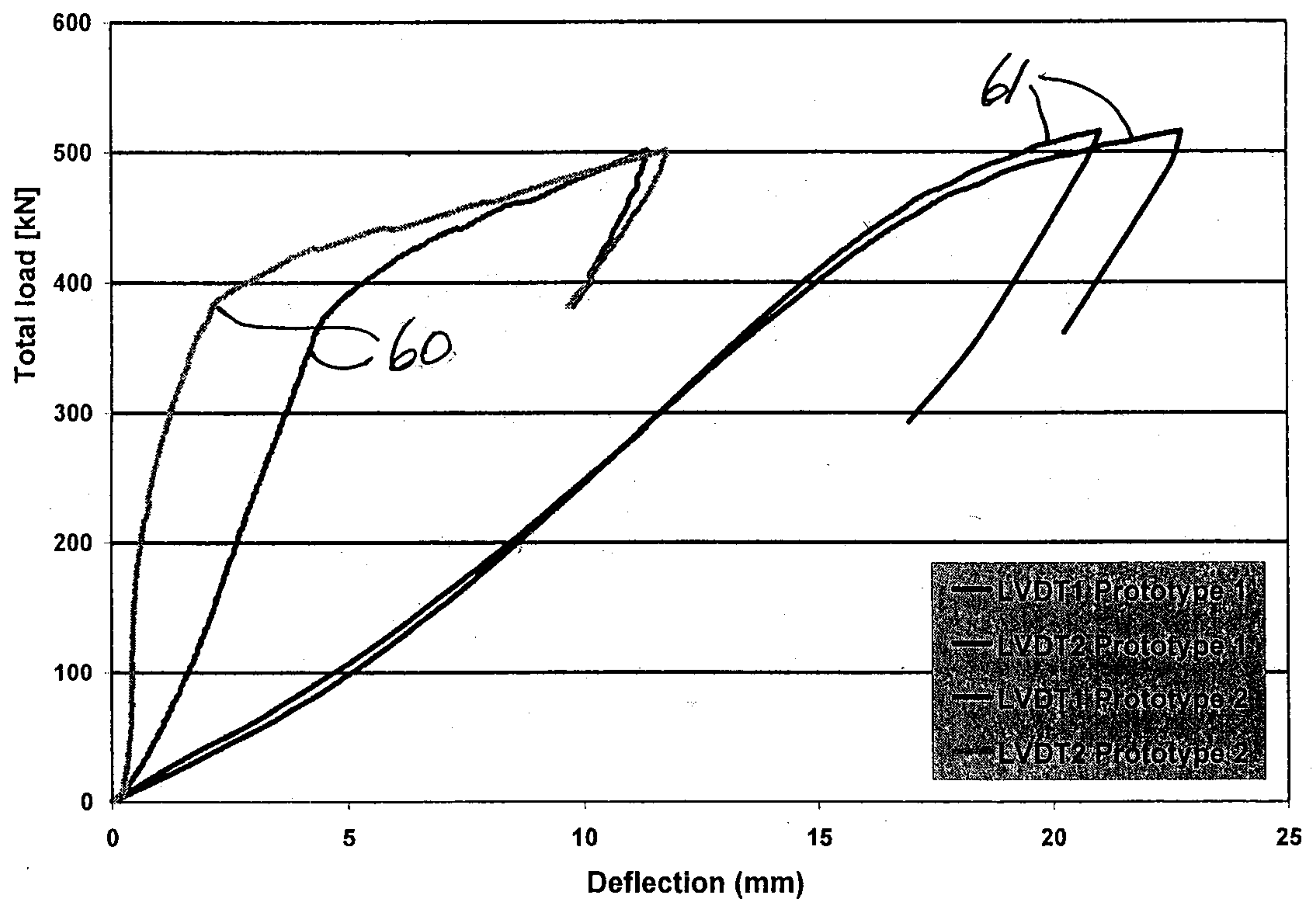


FIG. 7

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