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(54) **METHOD OF MANUFACTURING STRUCTURAL UNITS**

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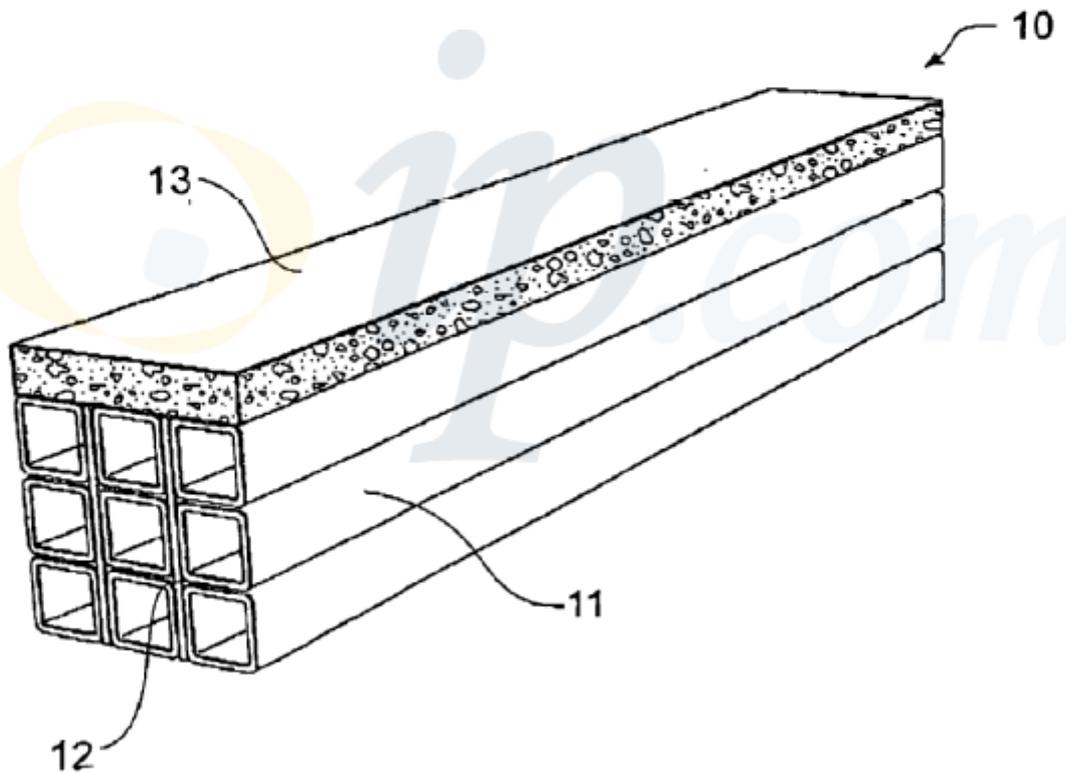
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(57) **ABSTRACT**

A method of producing an improved structural unit with anisotropic load characteristics includes producing a multiplicity of first building elements that are constructed from fiber-reinforced plastics material; producing at least one second building element that is of a different material to the first building elements; and adhering the first and second building elements together to form the improved structural unit.



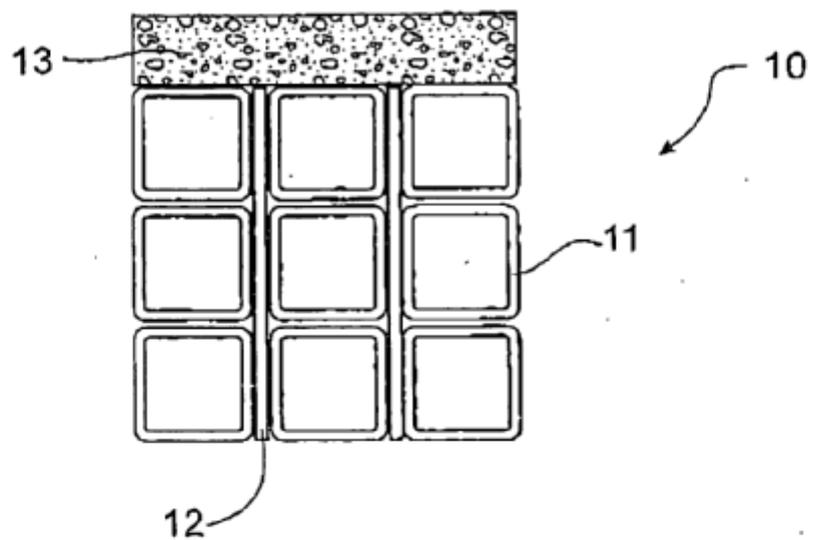


FIG. 1B

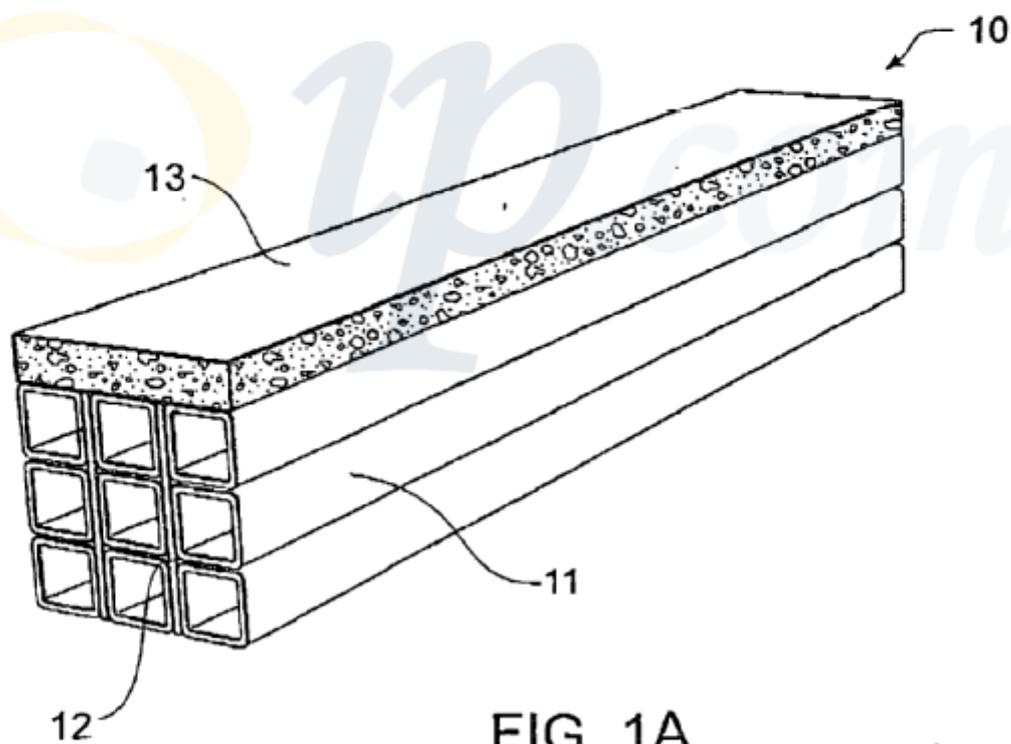


FIG. 1A

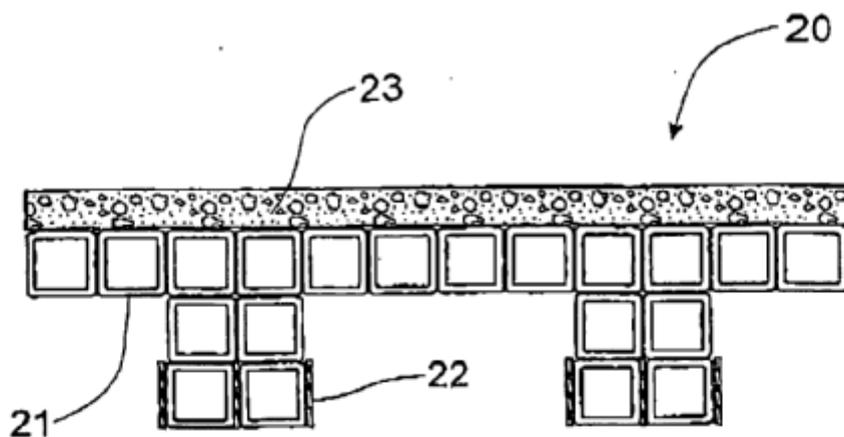


FIG. 2A

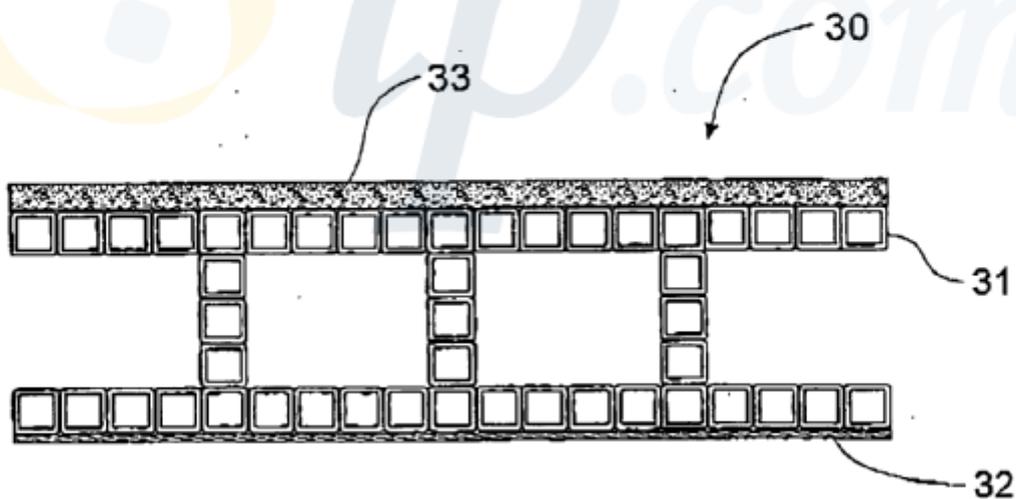


FIG. 2B

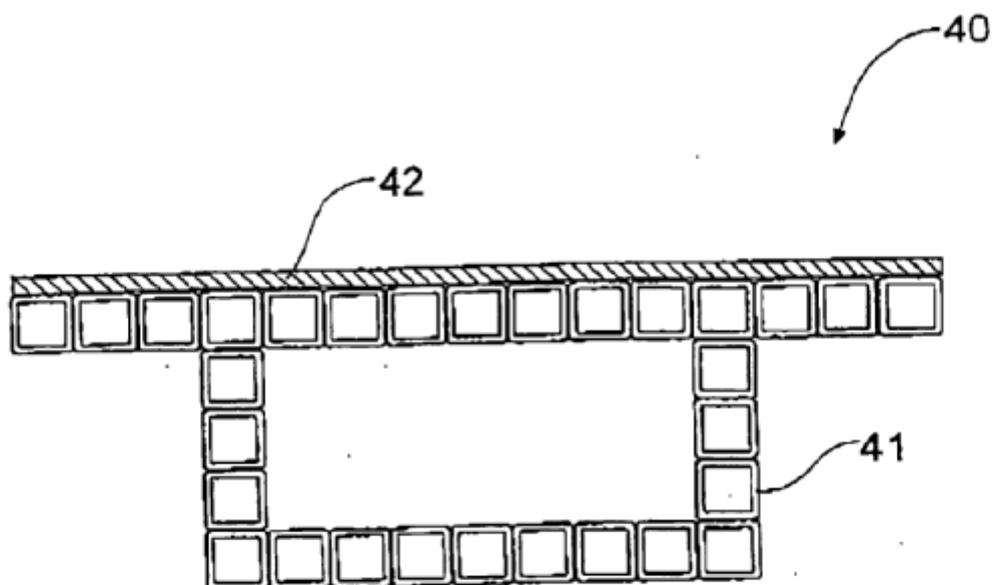


FIG. 3A

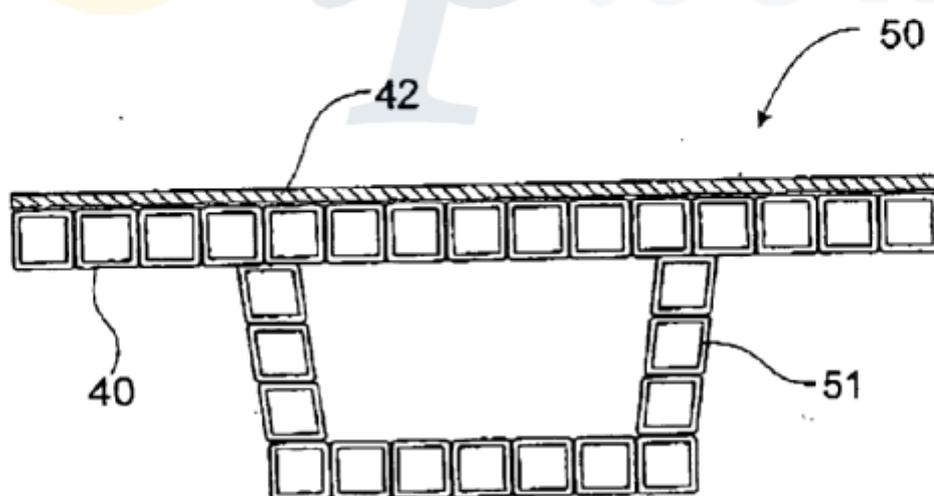


FIG. 3B

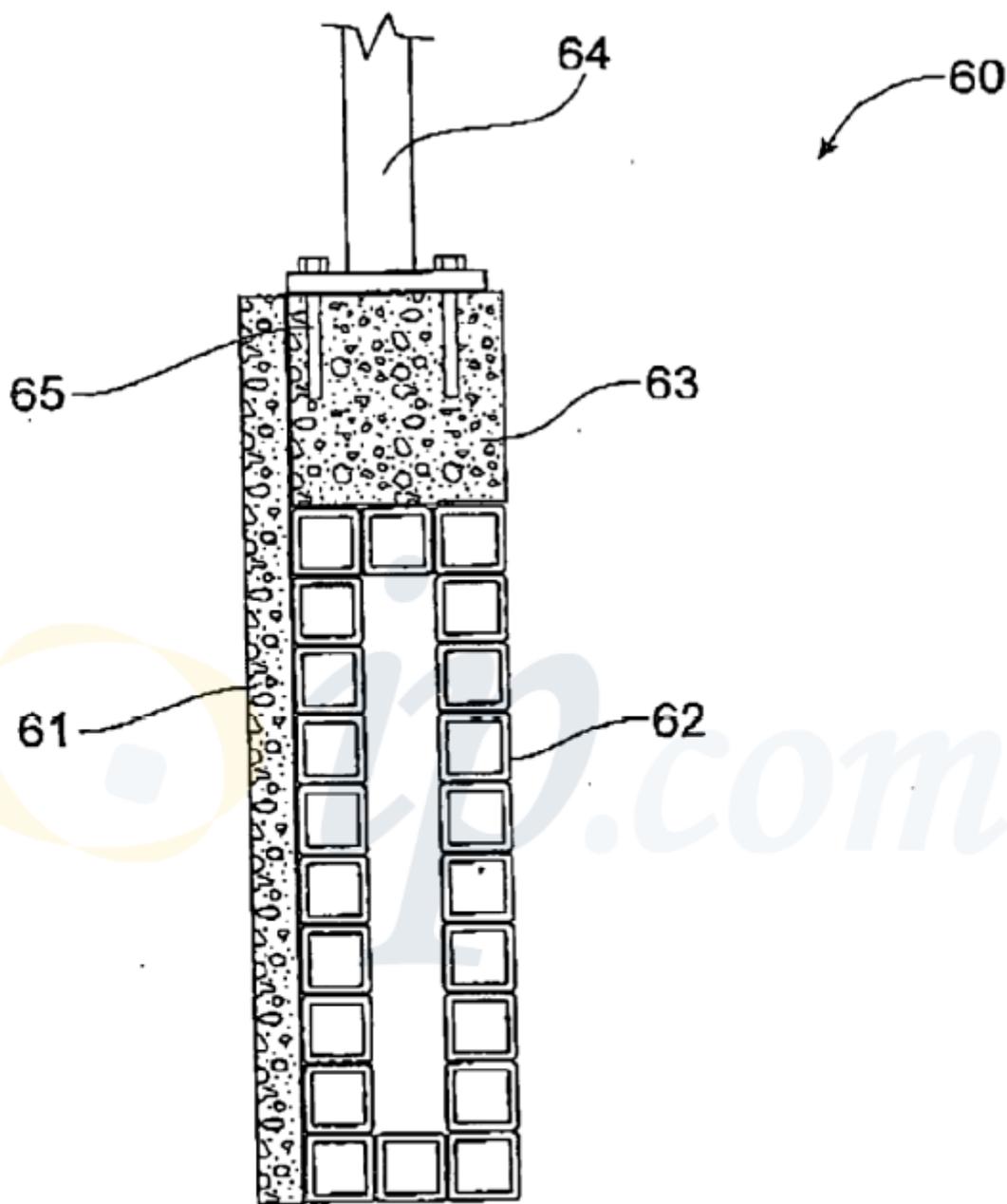


FIG. 4

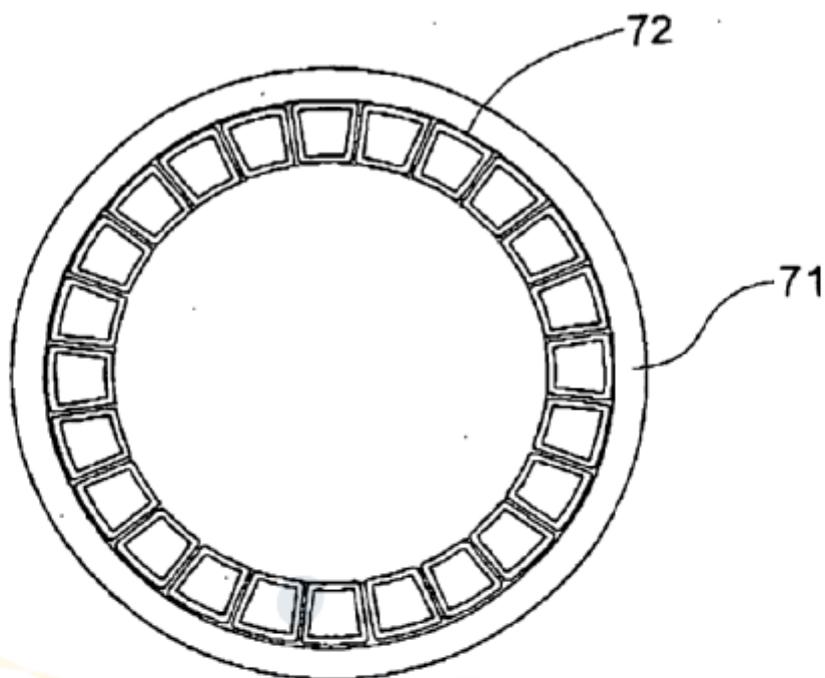


FIG. 5B

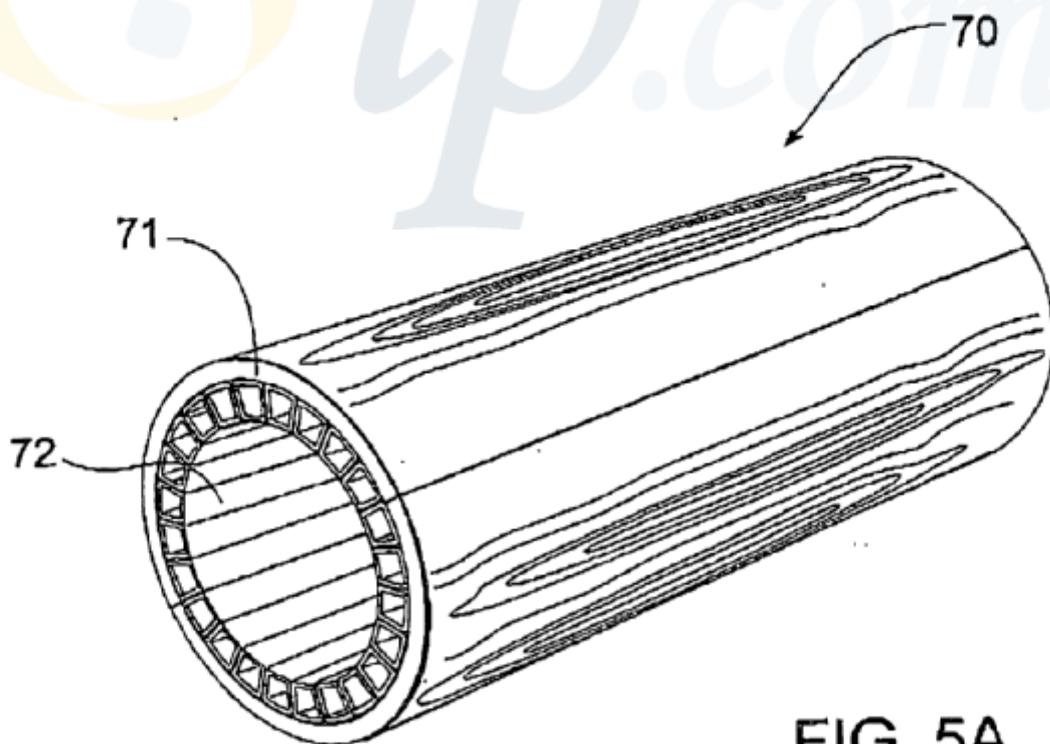
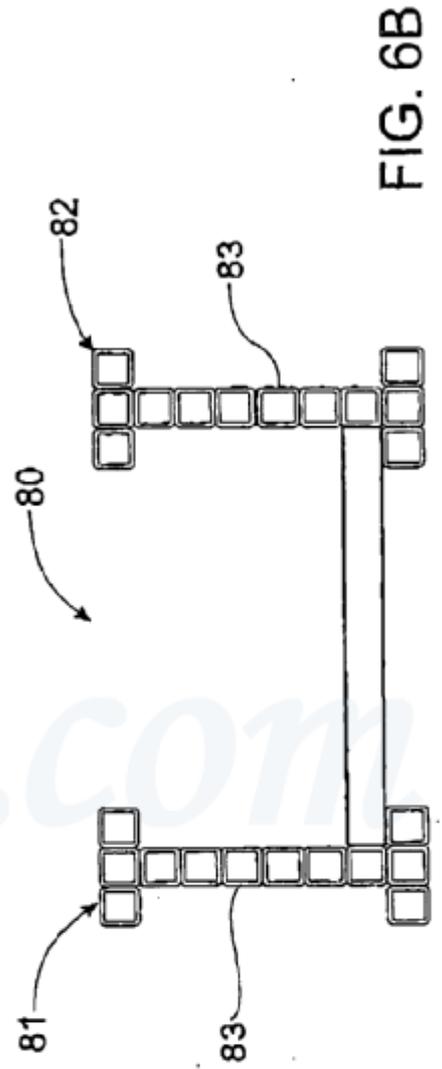
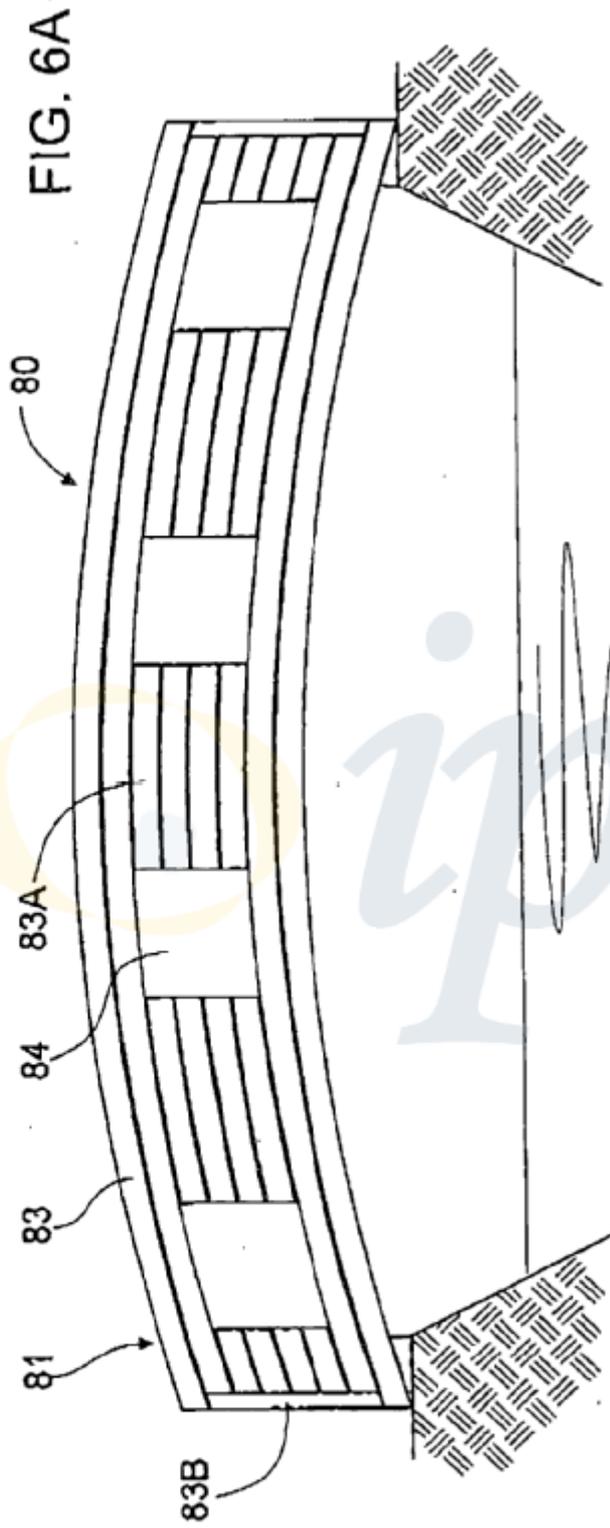


FIG. 5A



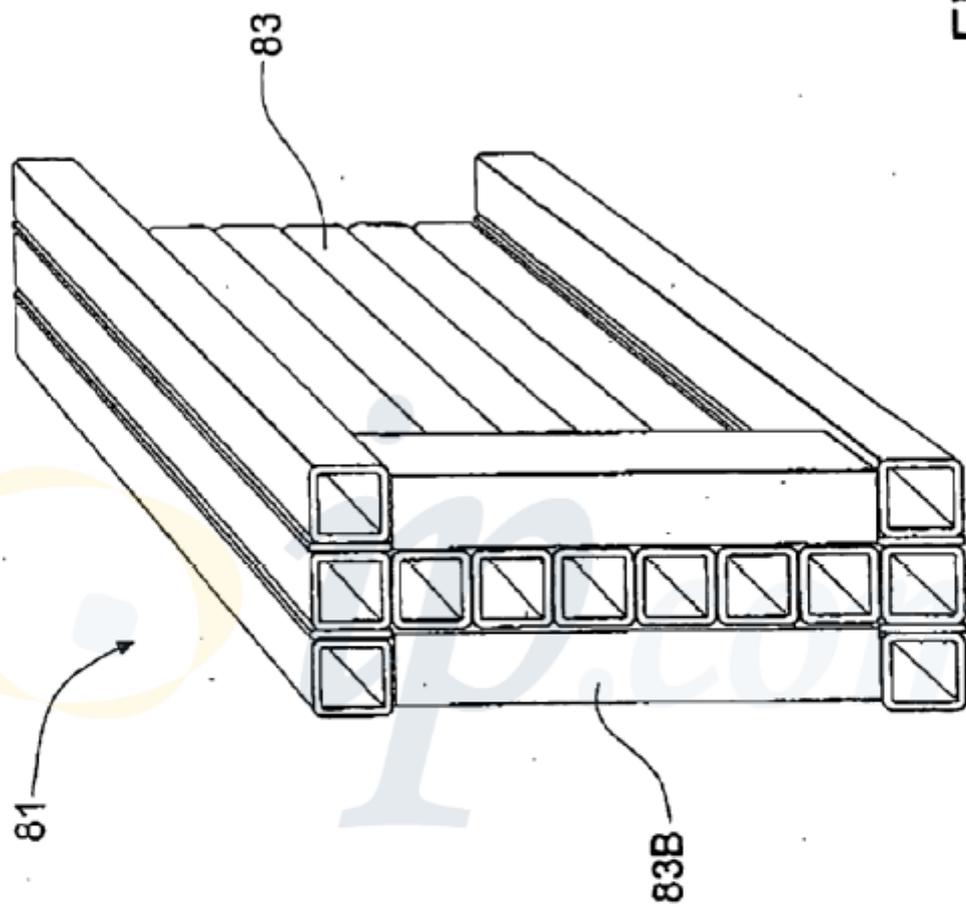


FIG. 6C

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FIELD OF THE INVENTION

THIS INVENTION relates to a method of manufacture of structural units. In particular, the invention relates to structural units constructed at least partially from fibre-reinforced plastics.

BACKGROUND OF THE INVENTION

The superior physical properties of fibre-reinforced plastic are well recognised. However, to date, there have been difficulties with producing viable structural elements of fibre-reinforced plastic due to cost constraints.

One approach used to produce fibre-reinforced plastic structural elements has been to use large moulds to produce the structural element. However, the mould that is required is specific to that application. Therefore, if another structural element needs to be produced, another mould is required reducing cost effectiveness. Further, this type of manufacture of fibre-reinforced plastics to produce structural elements is difficult due to shrinkage and high temperatures, making the moulds difficult to produce.

Another approach to producing fibre-reinforced plastic structural elements has been through the use of pultrusion. This method suffers significantly less from the problems of shrinkage or temperature control. However, the dies and machines needed are expensive to produce. Further, the dies are specific to a single application and pultrusion can only be used for structures of continuous cross-section. That is, many complex shapes cannot be produced using pultrusion.

One problem associated with both methods is that any structure that is produced is limited to the inherent physical characteristics of the type of fibre-reinforced plastics. In many instances, this limits the use of fibre-reinforced plastic for a particular application.

For a representative example of the prior art approach to composite structures, reference may be made to U.S. Pat. No. 5,794,402, in the name of Dumlao et al. This patent describes a modular structural section including a beam and a load bearing deck formed of a polymer matrix composite material. The deck is described as a sandwich panel having a lower surface, an upper surface and a core of hollow, elongate core members.

The Dumlao method bonds together fibre composite modules made of specific resin and fibres to make a larger structure. The larger structure is made only from the materials of the individual modules and, therefore, has essentially the properties of the specific resin and fibres. The larger structure does not have any particular structural advantages compared to the modules.

OBJECT OF THE INVENTION

It is an object of the invention to overcome or alleviate one or more of the above disadvantages or provide the consumer with a useful or commercial choice.

It is a further object of the invention to enable structural units to be produced that have improved load carrying characteristics,

It is a still further object of the invention to allow structural units that use fibre-reinforced plastic to be produced cost effectively.

SUMMARY OF THE INVENTION

In one form, though not the only or broadest form, the invention resides in a method of producing an improved structural unit with anisotropic load characteristics, said method including the steps of:

- - producing a multiplicity of first building elements that are constructed from fibre-reinforced plastics material;
 - producing at least one second building element that is of a different material to said first building elements; and
 - adhering said first and second elements together to form the improved structural unit.

The inventor has found that a surprising advantage is obtained by bringing together disparate materials with quite different characteristics to form structural units that can be built into structures. The properties of the structures, such as stiffness, strength and mass, are tailorable by selection of the materials of the first and second building elements. The properties are tailorable as both the first and second building members are able to withstand loading in their own right. That is, the individual building element would be able to be loaded if they were not adhered together.

The first building elements may be produced using polyester, vinylester or epoxy resin plastics and produced using a glass, carbon or kevlar fibre. Preferably, the first building elements are pultruded.

The second building elements may also be produced using fibre-reinforced plastic but with a different plastic and/or fibre to that of the first building elements. The second building element may also be produced from any suitable material such as concrete, timber, plastics, metal or the like, The concrete may be prefabricated or cast in situ.

The second building element may be used to improve the load carrying characteristics of the structural unit. The second building element may provide additional tensile, sheer or compressive strength to the structural member.

Preferably, the first and/or second building elements have at least two sides of its outer periphery that are substantially flat.

The second building element may be placed between two first building elements. Alternately, the second building element may be located adjacent said first building elements.

The first building elements may be of uniform cross-section throughout their length. The first building elements may be tubular. The first building elements are produced using standard shapes and/or lengths.

The first and second building elements may be of a variety of different shapes and/or different sizes.

Preferably, the building elements are adhered together using adhesive. The adhesive may be used not only to bond building elements together, but to absorb stresses and/or potential cracking that may occur when two different materials are combined together. The adhesive may be epoxy resin.

The building elements may be adhered to each other to enable the structural unit to be curved.

Bulkheads, diaphragms, strong points and/or internal ties can be used to produce the structural units.

The structural units produced using this method may be used in conjunction with each other to produce an improved structure.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention, by way of example only, will be described with reference to the accompanying drawings in which:

FIG. 1A is a perspective view of a beam according to a first embodiment of the invention;

FIG. 1B is transverse cross-sectional view of the beam according to FIG. 1A;

FIG. 2A is a transverse cross-sectional view of a floor slab unit according to a second embodiment of the invention;

FIG. 2B is a transverse cross-sectional view of a floor slab unit according to a third embodiment of the invention.

FIG. 3A is a transverse cross-sectional view of a girder according to a fourth embodiment of the invention.

FIG. 3B is a transverse cross-sectional view of a girder according to a fifth embodiment of the invention;

FIG. 4 is a transverse cross-sectional view of a curb unit for bridges according to a sixth embodiment of the invention;

FIG. 5A is a perspective view of a pole according to a seventh embodiment of the invention;

FIG. 5B is a transverse cross-sectional view of a pole for bridges according to a sixth embodiment of the invention;

FIG. 6A is a side view of a pedestrian bridge according to an eighth embodiment of the invention;

FIG. 6B is a transverse cross-sectional view of the pedestrian bridge of FIG. 6A;

FIG. 6C is perspective view of a rail of the pedestrian bridge of FIG. 6A; and FIG. 7 is a side view of a pedestrian bridge according to a ninth embodiment of the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

FIGS. 1A and 1 B show a beam **10** produced using two different standard types of pultruded fibre-reinforced plastic members **11** and **12** and a concrete member **13**.

One type of fibre-reinforced plastic member **11** is tubular and substantially square in transverse cross-section. These fibre-reinforced plastic members **11** are constructed from polyester plastics and glass fibre making them relatively cheap to manufacture.

The other type of fibre-reinforced plastics member **12** is substantially planar and constructed from vinylester plastics and carbon fibre and is substantially stronger than the other fibre-reinforced members **11**.

The concrete member **13** is prefabricated prior to the beam being formed.

The beam **10** is produced by gluing the fibre-reinforced members **11** and **12** and concrete member **13** together using epoxy resin. The combination of the two different fibre-reinforced plastic members **11** and **12** provides the beam **10** with excellent tensile strength whilst the concrete member **13** provides the beam **10** with excellent compressive strength. This allows a lightweight, structural beam **10** to be produced quickly and easily with reduced cost.

The beam **10** has considerable advantages compared to the known prior art composite modules. Careful selection of the fibres and resins for the fibre-reinforced members **11** and **12** allows the properties of the beam to be tailored to provide the desired strength, stiffness, mass, etc. It will be appreciated that selection of the glue for bonding the fibre-reinforced members and the concrete member **13** is important to allow for variations between thermal expansion properties of different materials. The glue also absorbs stresses that can lead to cracking which is known to be a problem in prior art composites.

FIG. 2A shows a floor slab **20** comprising two different standard types of pultruded fibre-reinforced plastic members **21** and **22** and a prefabricated concrete slab **23**.

The fibre-reinforced members **21** are tubular and substantially square in transverse cross-section. These fibre-reinforced plastic members **21** are constructed from vinylester plastics and glass fibre giving them good tensile strength properties.

The fibre-reinforced plastics members **22** are substantially planar and constructed from epoxy resin plastics and carbon fibre and are substantially stronger than the other fibre-reinforced members **21**.

The fibre-reinforced members **21** and **22** and concrete member **23** are adhered together using epoxy resin. The fibre-reinforced members **22** are located between the fibre-reinforced members **21** and are located at the base of the floor slab **20** to increase the tensile strength properties of the floor slab **20**. The concrete slab **23** provides compressive strength to the floor slab. Hence, a modular lightweight floor slab **20** can be produced quickly and easily.

A variation of the floor slab **20** of FIG. 2A is shown in the floor slab **30** of FIG. 2B. Again, two different standard types of fibre-reinforced plastics member **31** and **32** and a cast in situ concrete slab **33** are used to produce the floor slab **30**.

In this embodiment, the fibre-reinforced members **31** and **32** are arranged in a different fashion according to differing load requirements of the floor slab.

The fibre-reinforced member **32** is elongated and extends along the base of the floor slab **30**. In this embodiment, it is more practicable to locate the fibre-reinforced member **32** along the base of the floor slab as it reduces labour time in constructing the slab without substantially decreasing the structural properties of the floor slab **30**.

FIG. 3A shows a girder **40** comprising fibre-reinforced plastic members **41** and a steel sheet **42**.

The fibre-reinforced plastic members **41** are tubular and substantially square in transverse cross-section. These fibre-reinforced plastic members **41** are constructed from polyester plastics and glass fibre.

The steel sheet **42** is constructed of an impact resistant steel and has anti-slip indentations (not shown) located on its upper surface.

The girder is produced by adhering the fibre-reinforced members and steel sheet together using epoxy resin. The fibre-reinforced members provide tensile strength whilst the steel provides compressive strength and wear resistant surface.

The girder is typically used as the body for a trailer of an articulated vehicle. The girder is lightweight and has good strength and wear characteristics.

FIG. 3B shows a girder **50** that is a variation of the girder **40** of FIG. 3A. The girder **50** uses different shaped fibre-reinforced plastic members to produce a different shaped lower section of the girder. This is useful for a different wheel configuration for a trailer of an articulated vehicle.

FIG. 4 shows a curb unit **60** for a concrete bridge **61**. The curb unit is produced using fibre-reinforced plastic members **62**, a concrete block **63** and post **64**.

The fibre-reinforced members **62** are constructed from polyester plastics and glass fibre and are shaped as described previously.

The fibre-reinforced members **62** are adhered to each other and to the concrete block **63**. The post **64** is attached to the concrete block **63** using conventional fastenings **65**.

The curb unit **60** is then attached to a side of a bridge **61** using adhesive. The curb unit is lightweight and strong and can resist force applied to the pole **64** in any direction due to the construction of the curb unit **60**.

FIGS. 5A and 5B show a pole **70** comprising two laminate wood halves **71** and twenty-four fibre-reinforced plastic members **72**.

The fibre-reinforced members **72** are made from polyester plastics and glass fibre. They are tubular and have a curved top and bottom surface.

The pole **70** is produced by adhering the fibre-reinforced plastic members **72** together and then adhering the laminate wood halves **71** to the fibre-reinforced members **72**.

The pole **70** that is produced looks similar to an actual timber pole but is lightweight, strong and is can be made more fire resistant.

FIG. 6A and FIG. 6B show a pedestrian bridge **80** comprising a pair of rails **81** and **82** constructed from fibre-reinforced plastics members **83**.

The fibre-reinforced members **83** are made from vinyl ester plastics and glass fibre. They are tubular and rectangular in cross-section.

The rails **81** and **82** are constructed by banding the fibre-reinforced plastics members **83** prior to adhering them to each other. This press stresses the fibre-reinforced members as well as creating a desired shape. Shorter fibre-reinforced members **83A** can be used to create windows **84** within the rails.

FIG. 6C shows the rail where plastic fibre members **83B** have been adhered transverse to the other plastic fibre members **83**. These transverse members can be applied along the length of the member **83** to provide additional stiffening to the rail to prevent distortion and buckling and assist in carrying shear forces.

FIG. 7 shows a further embodiment of a pedestrian bridge **90** constructed from fibre-reinforced plastic members **91**. The lower fibre-reinforced plastics members **91A** do not extend the length of the bridge to provide additional clearance under the bridge **90**.

An advantage of this method of producing the variety of structural units, in those described above, is that structural units can be made according to specific engineering requirements. Different materials can be combined with fibre-reinforced plastic to produce the desired anisotropic load characteristics of the structural units.

Further, this method can be used to produce structural units that use fibre-reinforced plastic relatively cheaply and easily, whereas previously it has been impractical to do so due to cost. This method employs relatively small transverse cross-sectional shaped lengths of pultruded material that can be manufactured cost effectively due to economies of scale, This cost saving can be achieved as standard shapes are used for a variety of applications without the need to manufacture new dies,

It should be appreciated that various other changes and modifications may be made to the embodiments described without departing from the spirit or scope of the invention.

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1. A method of producing an improved structural unit with anisotropic load characteristics, said method comprising: producing a multiplicity of first building elements that are constructed from pultruded fiber-reinforced plastics material; producing at least one second building element that is of a different material to said first building elements; and adhering said first and second building elements together to form a structural unit having anisotropic load characteristics.
2. The method of claim 1 wherein the first building elements are produced using polyester, vinylester or epoxy resin plastics and produced using a glass, carbon or kevlar fiber.
3. The method of claim 1 wherein the second building elements are produced using fiber-reinforced plastic but with a different plastic and/or fiber to that of the first building elements.
4. The method of claim 1 wherein the second building element is produced from concrete, timber, plastics, metal or the like.
5. The method of claim 4 wherein the concrete maybe prefabricated or cast in situ.
6. The method of claim 1 wherein the second building element is used to improve the load carrying characteristics of the structural unit.
7. The method of claim 1 wherein the second building element provides additional tensile, sheer or compressive strength to the structural member.
8. The method of claim 1 wherein the first and/or second building elements have at least two sides of its outer periphery that are substantially flat.
9. The method of claim 1 wherein the second building element is placed between two first building elements.
10. The method of claim 1 wherein the second building element is located adjacent said first building elements.
11. The method of claim 1 wherein the first building elements are tubular.
12. The method of claim 1 wherein the first building elements are produced using standard shapes and/or lengths.
13. The method of claim 1 wherein the first building element is shaped differently to the second building element.
14. The method of claim 1 wherein the building elements are adhered together using adhesive.
15. The method of claim 14 wherein the adhesive absorbs stresses and/or potential cracking between the two building elements.
16. The method of claim 15 wherein the adhesive is an epoxy based.
17. The method of claim 1 wherein the building elements are adhered to each other so that the structural unit is curved.
18. The method of claim 1 wherein bulkheads, diaphragms, strong points and/or internal ties are used to produce the structural units.
19. A structural unit produced in accordance with claim 1.

20. A structural unit comprising: a multiplicity of first building elements that are constructed from pultruded fiber-reinforced plastics material; at least one second building element that is of a different material to said first building elements; and the first and second building elements being adhered together to form a structural unit having anisotropic load characteristics.