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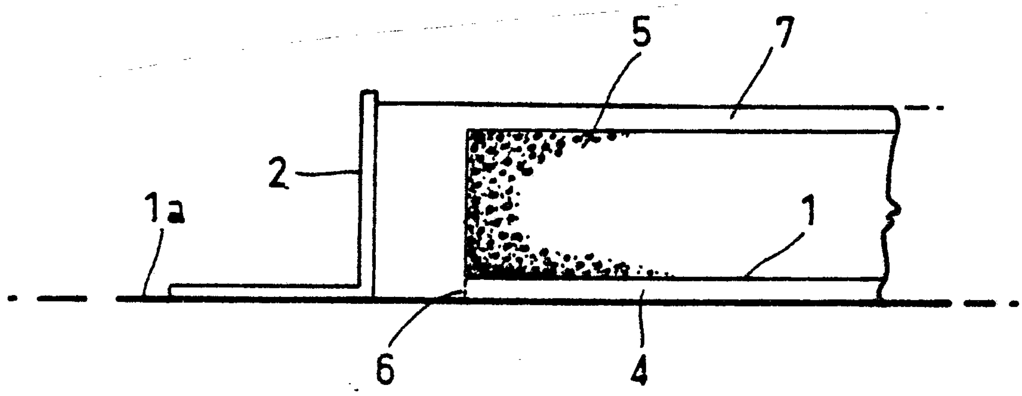

(57) Abstract

A structural member having a core material (5) made from a foamed or unfoamed slurry of cement and water into which is homogenously incorporated foamed polystyrene beads, and an outer thin skin (4, 7) of steel fibre reinforced cementitious material made from a cement, sand and water slurry. The thin outer skin (4, 7) exhibits high compressive tensile and flexural strength properties which combined with the ligthweight core (5) give structural panels or beams suitable for many structural applications including buildings. Individual panels (11) may be joined at their edges to form larger panels by post-tensioning cables (12) passing through the core of each panel.

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"STRUCTURAL MEMBERS"

This invention is concerned with an improved structural member and a construction method incorporating such a member and structures embodying same.

Of recent years, there has been a trend towards the construction of buildings from prefabricated components. There are certain cost advantages in the prefabrication of say structural panels at a remote site and then transporting these to a building site for rapid assembly and erection. In general handling and transportation of such prefabricated components, both weight and dimensions are the most important and often limiting factors.

It is known to fabricate building panels from aerated foamed concrete in an endeavour to save weight. It is also known to manufacture foam cored panels for the same reason. Foam cored panels may comprise a sheet of foamed plastics material such as polystyrene foam. The slab of foam is encapsulated within a concrete structural panel. If the panel has no structural requirements, the concrete "skins" on either side of the panel may be unreinforced or include only a light reinforcing mesh. On the other hand, load bearing panels of this type may include one or more layers of a substantial reinforcing mesh or even internal stiffening ribs of metal where a high flexural strength is required.

In general, the use of prefabricated structural panels of the type referred to above is limited to non-load bearing wall panels as there are serious difficulties associated with use as roofing panels. For a panel comprising a sheet or slab core of polystyrene foam, the Youngs Modulus of the core is much greater than the concrete on the outside. Thus, under flexural load, the concrete skin will have passed its elastic limit and failed before any contribution is made by the foam core. From a design consideration, panels of this type must therefore include ribs to provide adequate strength. In effect, internally (or externally) ribbed panels would have to be individually designed for each construction application and all point load situations compensated for.

Panels of the above type are generally difficult to construct as it is difficult to accurately position and maintain a foam core insert when dealing with wet concrete slurries.

Other problems include:-

1. Water resistance.
   Any imperfection in the outer skin of a roof panel will allow water to enter the cavity occupied by the foam insert. The trapped water can then find an imperfection in the inner skin and enter the interior of a building.
2. Fire resistance.
   The fire rating of polystyrene foam cored panel with a thin concrete skin is quite poor.
3. Visual effects.
   When the panel is damp, the position of the foam cores between ribs, ends etc. becomes clearly visible like a patchwork effect. Differing insulating properties over the surface of the panel gives rise to condensation "patterns" under certain conditions.
4. Access.
   In chasing a power or other service conduit through such prior art panels, obstructions such as ribs and the like will be encountered.

Other types of foam cored structural panels may be made with fibrous cement, plastics, metal or timber skins or combinations thereof but in the main these are used as non-load bearing structural members due to their inherent weaknesses.

In all casses, solid plastics foam cores contribute little if any physical properties to such structural panels and in the main, the core is provided only as a physical means for separation of the skins during manufacture.

Various proposals for structural panels have been made in respect of concrete skinned, low density cored panels. Those incorporating a slab or core of foamed plastics materials have been found to be quite unsuitable for the reasons outlined above.

Other proposals have contemplated the use of a conventional concrete skin and a core comprising a cementitious slurry incorporating foamed polystyrene beads. However none of the prior art proposals have really addressed the problems normally inherent in such panel structures.

Firstly, in use of a conventional concrete skin comprising cement, aggregate, sand and water, one could expect flexural strengths of around 2MPa with conventional concrete characteristics of high compressive strength combined with low tensile and flexural properties. In contrast, the present invention contemplates a cementitious skin having not only high compressive and tensile strengths but also flexural strength properties of the order of 8 MPa.

Secondly, while the incorporation of foamed polystyrene beads in cement slurry mixes has been proposed as a core material, the practical porblems of mixing a relatively low density material into a viscous medium of relatively high density have not really been addressed. At the present time, there are apparently no commercially available polystyrene foam/cement slurry cored structural panels in commercial usage and it is believed that the reason for this is that the practical problems of evenly mixing foam beads into a cement slurry have not been overcome on a commercial scale.

If a cement (or concrete) slurry is too fluid (too "wet"), the foam beads tend to remain near the surface during mixing or after mixing the beads rapidly migrate to the surface of the mix prior to removal from the mixer or during the pouring or casting step. This leads to a laminar weakness in the resultant panel in the region of greater bead concentration. When the mix is poured from a mixer such as a conventional concrete mixer, the initial portion of the pour has an excessively high bead concentration while the latter part comprises substantially entirely a cementitious slurry. Having poured the initial polystyrene bead rich mix into a mould or the like, the latter portion, comprising a substantially bead free slurry, when poured over the top of the initial layer migrates to the bottom of the mould leaving the upper layer rich in polystyrene beads and consequently lacking in physical strength.

Alternatively, if the mix is too viscous (too "dry") better homogenization is achieved at the expense of the physical properties of the cementitious binder and lack of workability of the core mix.

It is an aim of the present invention to overcome or alleviate the disadvantages of related prior art structural members and panels to provide a novel method of construction.

As used hereinafter the expression "sand" means particulate silicious material such as an alumino-silicate e.g. river or beach sand. The sand comprises a mixture of particle sizes from a maximum of say 3 mesh (Tyler) down to a fine dust e.g. 200 mesh (Tyler) or less. When used in cement mortars the sand gives the effect of a miniature mixed aggregate similar to conventional concrete mixes but on a substantially smaller scale.

According to one aspect of the invention there is provided a structural member comprising:-

an outer surface of fibre reinforced concrete; and

an inner core of cementitious material including low density particulate material.

Preferably the outer surface is reinforced with enlarged end fibres.

Preferably the enlarged end fibres comprise glass fibres.

Most preferably the enlarged end fibres comprise steel fibres.

Preferably the low density particulate material comprises a foamed plastics material.

Most preferably the low density particulate material comprises foamed polystyrene beads.

Preferably the inner core comprises a foamed cementitious material.

Preferably the inner core has a density of from $250kg/m^3$ - $800kg/m^3$.

Preferably the cementitious material is formed from a slurry of cement and water.

Most preferably the cementitious material is formed from a slurry of cement, sand and water.

Preferably said structural member includes reinforcing means selected from steel mesh, or elongate steel members.

Preferably said structural member includes one or more conduits to receive pre-stressing tensile members.

According to another aspect of the invention there is provided a method of constructing a structural member comprising:-

forming a first layer of fibre reinforced concrete against a shaping surface;

forming on said first layer a second layer of cementitious material containing low density particulate material; and

forming on said second layer a further layer of fibre reinforced concrete.

Preferably said first layer and said further layer are joined at least at the peripheral edges of said member.

Preferably said shaping surface comprises a male or female mould.

Preferably said first, second and further layers are formed by a spraying method.

Preferably reinforcing members are incorporated into said first and further layers and/or said second layer.

Various embodiments of the invention will now be described with reference to the accompanying drawings in which:-

FIGS. 1-3 illustrate a preferred method of constructing a structural panel according to the invention.

FIG. 4 illustrates a structural panel with conduits to receive pre-stressing tensile members.

FIG. 5 illustrates a composite structure.

FIG. 6 illustrates a structural beam member according to the invention.

FIGS. 7-8 illustrate alternative methods for connection of opposed skins of a layered structure.

FIG. 9 illustrates a partial cross section of a modular building construction illustrating a unitary roof member.

With reference to FIGS. 1-3, a preferred panel construction method will be described with reference to the construction of a simple rectangular panel in a female mould although it will be clear to a skilled addressee that more complicated two or three dimensional shapes may be constructed in either male or female moulds.

In FIG. 1, the bottom or base layer 1 is formed on any suitable surface such as a sheet plastics, steel or concrete surface 1a or the like. This surface may be smooth or decoratively textured and, if required, coated with a mould release agent to facilitate release of the finished panel from the mould surface. The mould frame suitably comprises lengths of angle section steel, aluminium or plastics material 2 or the like movably secured to the mould surface 1 to define the perimeter of the mould and/or to define apertures such as window apertures in a structural wall. The inwardly directed face of the angle iron 2 is lined with a spacer 3 of timber, foam plastics or the like to form a predetermined space of width x the purpose of which will be described later.

A cementitious skin mix is then prepared in a suitable mixer according to the ratio:

cement	:	-	800kg
water	:	-	160litres
sand	:	-	1500kg
steel fibres	:	-	160kg

The cement is preferably grey portland cement and the steel fibres are preferably enlarged end rectangular end fibres made by A.W.I. Fibresteel having dimensions 14mm long x 0.4mm thick x 0.6mm wide. If required, a quantity of conventional plasticizing agent may be employed to improve workability of the mix.

The skin material 4 is poured into mould to a required skin thickness and levelled, at least roughly by trowelling, screeding or the like.

A core mix is then prepared as follows according to the ratio :

water	:	200 litres
cement	:	400kg
foamed polystyrene beads:		$1m^3$

Again the cement is preferably grey portland cement and the foamed polystyrene beads have a diameter range of from 3-6mm with a density of approximately $15kg/m^3$.

The water and cement are added to a mixer such as a concrete mixer to form an homogenous slurry. Once the slurry is formed, the beads are then added and mixed thoroughly to form an homogenous slurry/bead mix. The viscosity of the slurry is such that the tendency of the beads to migrate to the surface during mixing is effectively negated.

As shown in FIG. 2, the mix is then poured into the mould to form a second layer 5 on top of the first "wet" or uncured layer 4. The surface of the cement/bead mix 5 is levelled in a manner similar to the first layer 4. The thixotropic nature of the cementitious mix 5 is such that there is no tendency for the beads to migrate to the surface of the second layer after pouring and levelling.

When the second layer has stiffened slightly or at least partially cured, spacer 3 is removed as shown in FIG. 3 and if required, edge 6 of first layer 4 is roughened by a suitable roughening tool. A final layer 7 substantially similar to that of layer 4 is then poured over the top of layer 5 and allowed to flow down the cavity between the edges of layers 4 and 5 and the mould wall formed by angle member 2. In this manner, the resultant panel is formed with a peripheral edge skin 8 integral with and similar to upper skin 7 and lower skin 4 respectively. The uppermost surface of skin 7 is screeded, trowelled or otherwise levelled and finished as desired.

In a typical structural panel, say a wall panel for a domestic dwelling, the panel may measure 2.5mm x 4m x 100mm thick. The panel may comprise an 80mm core with 10mm skins on either side.

In a modified form of the invention, the cementitious slurry for the core may include a foaming or aerating agent to further reduce the density of the composite core material. Such a slurry composition may comprise the slurry mix as described above with the addition of 2 litres of FRO.B (Trade Mark) - an organic foaming agent manufactured by Sika.

The water is placed in a conventional concrete mixer with the FRO.B foaming agent and with the mixer rotating, the aqueous mix is aerated by the introduction of compressed air at the rate of about 10 cu.ft./min. for about 3min. Two thirds of the cement is then added and during the mixing cycle, aeration is conducted for a further 3 mins. The remaining portion of the cement is then added and when mixed thoroughly, the foamed polystyrene beads are added. The resultant mix has a "wet" density of approximately $480kg/m^3$ and when cured a density of approximately $450kg/m^3$. In practice, core densities of between $250kg/m^3$ and $800kg/m^3$ will be found to be effective depending on the cost and engineering considerations of the structure. Foamed concrete slurries have the advantage of improved thixotropic properties which further reduces bead migration.

It will be noted that the viscosity of the core slurry is quite important to the effective practice of the invention. If the mix is too dry then addition of further water will not give the required viscosity and equally if the mix is too wet, addition of further cement results in the formation of cement "balls". Unlike conventional aggregate containing concrete mixes, the shear during mixing of a foamed polystyrene containing cement slurry is insufficient to adequately mix water or cement added during the latter part of the mixing cycle.

As little as eight hours after the panel casting operation is completed, the mould edges may be removed and the panel stripped from the moulding surface 1. The panels may then be stacked for complete curing prior to transportation and usage.

FIG. 4 illustrates a modification of the invention in which a panel 8 includes a plurality of pre-stressing tendons 9 such as wire rods cast within the core of the panel. Preferably the ends of tendons 9 are anchored at the panel edges by any suitable anchoring means 10 such as collets or the like cast into the panel edges.

Alternatively the core may include a mesh of reinforcing wire.

FIG. 5 illustrates a composite structure comprising a plurality of preformed panels 11 anchored together by post-tensioned tendons 12 passing through aligned conduits 13 cast into the core of the panels. In a typical end use application such a composite structure may comprise a suspended floor or roof structure comprising panels measuring 4m x 3m and 100mm thick (10mm skins and 80mm core). The panels are locked together with high tensile steel cables or rods running at right angles at about 2m centres. The tendons are tensioned to approximately 10 tons prior to anchoring by conventional means.

A particular advantage of such composite members is that in the event of compressive failure of portion of a panel, the pre-tensioned cables give support to the structure in a manner similar to a safety net. Being comprised of separate panels, destructive compressive point loads are confined to a single panel or portion thereof and propagation of stress induced cracks is limited. Any damaged area may be readily repaired (at least cosmetically) by a plastering operation.

Apart from panel construction, the present invention is applicable to other structural members such as the beam configuration illustrated in FIG. 6. The beam 14 effectively comprises an elongate member constructed substantially in accordance with the panel construction methods described above. The beam comprises an outer skin of fibre reinforced cementitious material 15 and an inner core 16 having a foamed or unfoamed cementitious material incorporating a low density particulate material.

The upper and lower skins 17, 18 respectively may include conventional reinforcing elements or pre-tensionable elements 19 engineered for the particular end use.

A particular advantage of such beam constructions is that the combination of a skin having high compressive, tensile and flexural strengths combined with a core of relatively inferior properties gives rise to a beam construction more highly resistant to a buckling mode of failure compared to a solid beam.

FIGS. 7 and 8 show yet another embodiment of the invention in which the outer skins 20, 21 of structural members 22 are tied together at predetermined intervals to enhance overall strength characteristics.

FIG. 7 shows columns 23 of integrally formed fibre reinforced cementitious material linking the upper and lower skins. Alternatively these columns may be replaced by ribs or the like.

FIG. 8 shows shaped metal ties 24 acting as internal links.

It will be clear to a skilled addressee that many modifications may be made to the invention. For example the core material may comprise any light weight particulate material such as wood chips and the like. Further the invention is not limited to planar panel constructions as in conventional laminating techniques utilizing pre-formed cores and skins. A particular advantage of the invention is that the structural members may be formed in a variety of planar or three-dimensional shapes (in male or female moulds) due to the ability to form "integral" members in a plastic state.

An example of the application of the invention to a building structure is examplified with reference to FIGS. 9-15.

FIG. 10 illustrates optional reinforcing members for use in the roof member of FIG. 9.

FIG. 11 illustrates a plan view of the building construction partially illustrated in FIG. 9.

FIG. 12 illustrates a cross section through A-A in FIG. 11.

FIG. 13 illustrates an end elevation in the direction of arrow B in FIG. 11.

FIG. 14 illustrates a partial sectional view of one corner of the roof member of FIG. 9.

FIG. 15 illustrates a partial plan view of the wall construction of one corner of the structure of FIG. 9.

In FIG. 9 the structure comprises a floor member 31 suitably of a cast in situ reinforced concrete raft floor or a member comprising a fibre reinforced skin and a low density core. The floor may be formed as shown in FIG. 5.

Around the perimeter of the floor member 31 and at selected locations on the underside of the floor are integral reinforcing beams 32 of greater thickness.

In a substantially square floor plan are located generally radially aligned upright blade-like columns 33 of a sandwich construction according to the invention. The sandwich construction suitably comprises outer skins of cementitious material reinforced with FIBRESTEEL (Regd. Trade Mark) enlarged end steel fibres. The inner core comprises a cement/expanded polystyrene bead mixture and if required may also include reinforcing in the form of rods or welded mesh. As an alternative to expanded foam beads, it is possible to use fragmented low density plastics material such as pulverized or chopped polystyrene foam, polyurethane foam, wood chips or similar materials. The construction of such cementitious sandwich members is described earlier in this specification.

A roof member 34 comprising a substantially pyramidical unitary construction is supported inwardly of its corners by the blade-like support columns 33. The roof member comprises a sandwich construction with an outer skin 35 of steel fibre reinforced concrete, an intermediate core 36 of concrete/expanded polystyrene bead mixture and an inner skin 37 also of steel fibre reinforced concrete.

Roof member 34 comprises a main portion 38 and a cantilevered perimetral portion comprising a downwardly extending portion 39 and a laterally extending portion 40. A lip 41 at the outer edge of perimetral portion defines a channel or trough with the outer surfaces of portions 39 and 40.

At the junctions of portions 38, 39 and 40 and in the region of lip 41 are substantially continuous pre-stressed reinforcing tendons 42 which serve to restrain the known tendency of the pyramidical structure to spread in a generally radial lateral direction. Such spreading forces are due to the horizontal vector component of forces directed down the sloping walls of a supported pyramid due to its own mass.

Any tendency of the structure to sag in the large flat sloping areas 38 is overcome by the combined effects of a number of dynamic forces which serve to cancel each other. Firstly the four substantially triangular roof faces are supported at their junctions by columns 33 over about half the length of the junctions. The cantilevered suspension of portion 40 about downwardly extending portion 39 exerts an elevating effect on the large flat area of portion 38. Cantilevered portion 40 acts somewhat as a lever about the upper outer corner 43 of column 33 which serves as a fulcrum. In addition, the sandwich structure of the roof member resists sagging by stressing of the inner and outer skins in tension and compression respectively.

Accordingly it can be seen that a roof structure as described provides a dynamically stable structure which is largely self-supporting without the need for rafters, bearers etc. or other reinforcement.

In constructing a building as shown, roof member 34 is formed as a unitary member on a male mould beside the building site by the method described hereinafter. Lifting attachment points such as bolts 44 are provided at say four equidistantly spaced positions during manufacture.

At the building site, the raft floor 31 is prepared_with columns 33 extending upwardly therefrom. When the roof structure is cured, mobile cranes then lift the roof structure into position on its supporting columns 33.

A ventilator and skylight structure 45 is suitably provided at the peak of the roof structure. External walls 46, preferably panels of concrete sandwich construction are situated in a channel 47 in the undersurface of cantilevered portion 40 and a channel 48 formed in the floor 31. Internal walls 49 suitably comprise panels of similar size and construction to outer wall panels 46 with an infil 51 of glass, plasterboard or timber. For humid climates, louvred slats or windows 52 are provided at some or most of the corners of the building. None of the external or internal walls are load bearing as the entire roof is supported on columns 33. Accordingly, the structure of the walls is greatly simplified thus giving rise to great cost benefits.

FIG. 10 illustrates an arrangement of reinforcing members which may be included in the roof structure of FIG. 9 if circumstances or local authorities require same. Arrangement 38a would be incorporated within roof portion 38 during the manufacture of the roof structure. Similarly arrangements 39a and 40a would be incorporated within portions 39 and 40 respectively. These arrangements may be welded from steel rod, bar, tubing etc. or they may be arranged loosely as individual members in the arrays as shown.

FIG. 11 illustrates a typical floor plan for a domestic dwelling which may be built in accordance with the invention.

FIG. 12 illustrates a cross section through A-A in FIG. 11.

FIG. 13 illustrates an end elevation of the structure of FIG. 11 in the direction of arrow B.

FIG. 14 illustrates a sectional view of one corner of the structure of FIG. 11. The gutter or trough formed between lip 41 and roof portions 39 and 40 provides an excellent integrally formed stormwater gutter. The very large capacity of gutters so formed permit such structures to be used in regions where heavy rainfall is experienced without the necessity for special plumbing. An aperture 53 is formed for connection to a downpipe.

FIG. 15 illustrates in plan view portion of the wall and support structure immediately beneath the portion of roof member shown in FIG. 14. As indicated above the outer and inner walls are preferably constructed from prefabricated concrete sandwich panels. The joins between abutting panels are then grouted with a cementitious or like material to form a substantially continuous wall surface suitable for decorative finishes.

A door 54 is suitably provided in the corner position illustrated. Installation of the door is achieved by affixing one of the door jambs 55 directly to support column 33 by any suitable means such as masonry anchors, screws, rivets or the like. An infil panel 56 comprising a glass sidelight is affixed in a frame attached to the outer wall panel in a manner similar to the door jamb.

The method of constructing panels or shaped members from concrete snadwich construction has been generally described earlier. However, in construction of large unitary members such as the roof structure described above or otherwise complex shaped objects not suitable for female moulding, the present invention permits a male mould to be employed. As very large structures are not easily transportable, it is desirable where possible to manufacture the structure on or at least adjacent a site where the structure is to be used.

For the roof structure described above, a male mould is constructed of say a timber frame and a plywood or like sheet material covering. A plastics membrane may be placed over the mould surface to act as a mould release agent otherwise a conventional release agent may be employed.

In a manner similar to formation of the panels described above, the three layers of cementitious material are built up one upon the other until the desired thickness is achieved. The top or outer surface is then screeded and/or trowelled off to obtain a smooth finish.

During construction of the roof structure, lifting bolts are located within the sandwich at desired positions. Further, if reinforcing elements are required such as rods, mesh or the arrays as shown in FIG. 10, these may be incorporated in the sandwich by say placing on top of the first layer and then spraying the successive second and third layers thereover.

If required, conduits for electrical cables and the like may also be incorporated in the panels or roof structure during construction.

For certain structural applications where extra strength or rigidity is required in the sandwich construction, "ribs" may be formed by building up the thickness of portions of the first layer of steel fibre reinforced concrete or tensile members may be incorporated into the member.

It is envisaged that the present invention has application to virtually all presently employed structurally reinforced members such as floors, structural beam members including "I" beams, box beams and the like as well as piers, columns, foundations etc. In applications where excessive load requirements are necessary, pre or post stressing tendons may be incorporated into the structural member. In a manner similar to that described above, a first layer of steel fibre reinforced cementitious material is formed against a mould surface, the reinforcing tendons are placed in position against the surface of the first layer and additional steel fibre reinforced cementitious material is sprayed over the tendons to substantially encapsulate them.

A second layer of cementitious material containing low density particulate plastics material is then formed over the first layer. If required, channel-like depressions may be formed in the second layer in the region where additional reinforcing tendons are to be placed. The channel-like depressions are then at least partially filled with a steel fibre reinforced cementitious material prior to positioning of the additional tendons. A further layer of steel fibre reinforced cementitious material is then formed over the exposed surface to encapsulate the tendons. The tendon reinforced "skins" of the sandwich structure so formed are thus substantially identical in construction.

By using steel fibre reinforced skins in tendon reinforced structural members it is possible to place the tendons at considerably greater spacing than would otherwise be required. When point loads are applied to the "skin" the forces are dissipated for some considerable distance through the fibre reinforced skin on either side of the tendon thus permitting the greater spacing of tendons. Structural members so formed have considerably lower mass than members of equivalent mechanical properties formed by prior art methods. In addition, substantial cost savings can be achieved by the reduction in the number of steel tendons which would otherwise be required.

Wall panels may be constructed as follows for most applications.

Skin 1	6-20mm thickness
Core	25-80mm thickness
Skin 2	6-20mm thickness

Wall panels constructed with two 10mm thick skins and a 50mm core have been found to have a significantly greater load bearing capacity than an equivalent 110mm thick clay brick wall.

It is believed that panels up to 5m x 10m with a 10mm/50mm/10mm thickness and two lifting points can be easily handled. Such a panel has an estimated weight of 3 tonnes compared with an estimated weight of around 9 tonnes for an equivalent clay brick panel.

Similarly, roof panels may suitably be selected from the following range.

Skin 1	8-20mm thickness
Core	50-100mm thickness
Skin 2	8-20mm thickness

Practical size limitations for handling a roof panel are considered to be of the order of a 10m x 10m member supported at three or four points. A panel of this size weighs approximately 7 tonnes.

Roof panels constructed in accordance with the above thickness ranges should be supported safely with span distances of around 6 metres.

The many advantages accruing from the various aspects of the present invention will be readily apparent. The main advantage is that structural members prepared with the sandwich construction method offer a significant weight reduction without substantial reduction in mechanical properties when compared with an equivalent member of conventional reinforced concrete or similar construction.

In addition to weight reduction substantial cost benefits accrue from the invention. These relate to simpler handling, lower reinforcing steel content, lower labour content and in many cases, an overall reduction in concrete content. In many suspended reinforced concrete members, much of the concrete and reinforcing steel is necessary just to support the weight of the members, apart from the load intended to be carried by the members. The relatively lower density of a member according to the invention thus requires less concrete and reinforcing steel for self-supporting purposes.

Another advantage of the sandwich structure of the invention compared with prior art prefabricated members incorporating blocks or slabs of foam is that the flexural and compressive characteristics of the core are not greatly different to the skins. The interstices between the foamed plastics beads comprises a substantially continuous rigid cementitious structure. Engineered designs using prefabricated prior art members are generally constrained by predetermined sheet or panel dimensions.

A further advantage is the immense flexibility in design of structural components using the method according to the invention. For example, in an "on the job" situation, modifications to skin or core thicknesses may readily be made to suit varying engineering requirements.

A still further advantage is that waterproofing, sound, thermal insulating and fire rating properties are all substantially improved over prior art cored concrete members.

The surprisingly unexpected superior physical strengths of structural members made in accordance with the invention is believed to arise from the use of relatively thin skins of cementitious materials having high compressive tensile and flexural strengths compared with prior art concrete skins. By utilizing fibres having a length substantially similar to or longer than the thickness of the skin, the fibres are substantially aligned in a two-dimensional plane thus alleviating shrink cracking normally associated with curing of thin layers of cementitious slurries.

In an alternative construction method, roof and wall panels are manufactured to predetermined engineering specifications and dimensional shape requirements. The panels are transported to a building site where a preformed concrete or concrete sandwich foundation has been formed. Abutting walls are erected by a crane and temporarily held in place by angle brackets bolted to adjacent abutting edges of the wall panels.

Steel pins are simply driven through holes drilled in the surface of one wall and the abutting edge of the adjoining wall. The brackets are removed and the bolt and pin holes simply plastered over. If required, additional pins may be driven at an angle through the lower edge of the wall into the floor and similarly plastered over.

The roof panels are then hoisted into position on the outer and any inner load bearing walls and similarly pinned. Abutting edges of the roof panels may be joined with a waterproof caulking compound and, if required, adjacent edges may be tied by a plate spanning the joint.

The pins may comprise a simple steel rod of say 10mm diameter by 200-300mm in length. The pins merely serve to locate the panels relative to each other and do not provide a tensionable joint. The resultant structure is found to be extremely stable with merely the pinned joints. The weight of the roof panels is sufficient to lock the arrangement together and the excellent thermal properties of the panels substantially alleviates thermally induced expansion and contraction at the wall and roof panel joints.

The structure may then be finished in a conventional manner with appropriate doors, windows, trim fittings etc. and a suitable decorative finish such as paint applied to the internal and external surfaces. Utility services such as plumbing, electrical wiring etc. are suitably precast into the panels during manufacture.

On present day labour and material costs, it can be deomonstrated that an overall cost saving of 20-25% can be achieved in a low cost domestic dwelling of $100m^2$. It is anticipated that this cost advantage would be improved with larger dwellings.

It will be readily apparent to a skilled addressee that many variations and modifications may be made to the invention without departing from the spirit and scope thereof.

CLAIMS:

1. A structural member comprising:-
an outer surface of fibre reinforced concrete; and
an inner core of cementitious material including low density particulate material.

2. A structural method as claimed in claim 1 wherein the outer surface is reinforced with enlarged end fibres.

3. A structural member as claimed in claim 1 or claim 2 wherein the enlarged end fibres comprise glass fibres.

4. A structural member as claimed in claim 1 or claim 2 wherein the enlarged end fibres comprise steel fibres.

5. A structural member as claimed in any preceding claim wherein the low density particulate material comprises a foamed plastics material.

6. A structural member as claimed in any preceding claim wherein the inner core comprises a foamed cementitious material.

7. A structural member as claimed in any preceding claim wherein the inner core has a density of from $250kg/m^3$ - $800kg/m^3$.

8. A structural member as claimed in any preceding claim wherein the cementitious material is formed from a slurry of cement and water.

9. A structural member as claimed in any one of claims 1-7 wherein the cementitious material is formed from a slurry of cement, sand and water.

10. A structural member as claimed in any preceding claim wherein said structural member includes reinforcing means selected from steel mesh or elongate steel members.

11. A structural member as claimed in any preceding claim wherein said structural member includes one or more conduits to receive pre-stressing tensile members.

12. A method of constructing a structural member comprising:-

forming a first layer of fibre reinforced concrete against a shaping surface;

forming on said first layer a second layer of cementitious material containing low density particulate material; and,

forming on said second layer a further layer of fibre reinforced concrete.

13. A method as claimed in claim 12 wherein said first layer and said further layer are joined at least at the peripheral edges of said member.

14. A method of constructing a structural member as claimed in claim 12 or 13 wherein said shaping surface comprises a male or female mould.

15. A method of constructing a structural member as claimed in any one of claims 12-14 wherein said first, second and further layers are formed by a spraying method.

16. A method of constructing a structural member as claimed in any one of claims 12-15 wherein reinforcing members are incorporated into said first and further layers and/or said second layer.

17. A structure incorporating structural members as claimed in any one of claims 1-11.

18. A structural member made in accordance with the method of any one of claims 12-16.

19. A structural member substantially as hereinbefore described and/or illustrated.

20. A method for manufacturing a structural member substantially as hereinbefore described and/or illustrated.

21. A method for constructing a structure substantially as hereinbefore described and/or illustrated.

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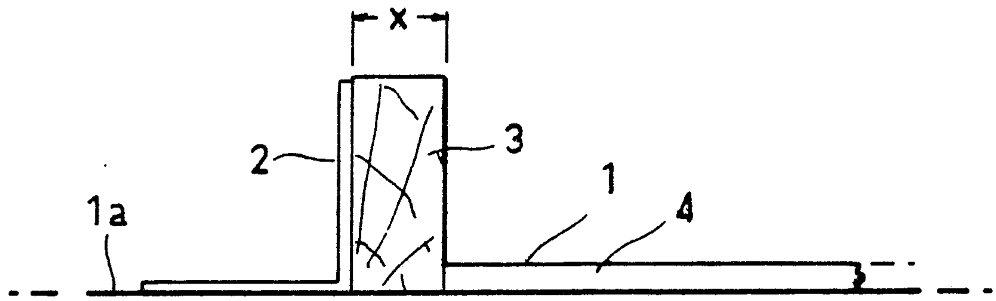


FIG 1

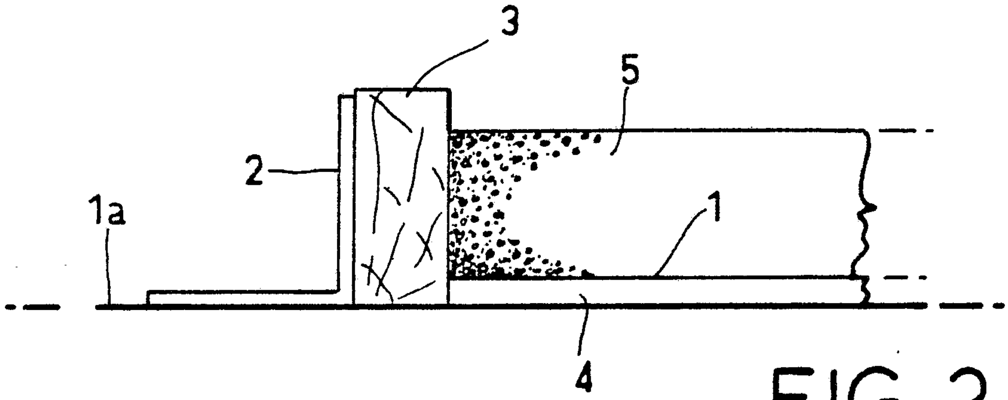
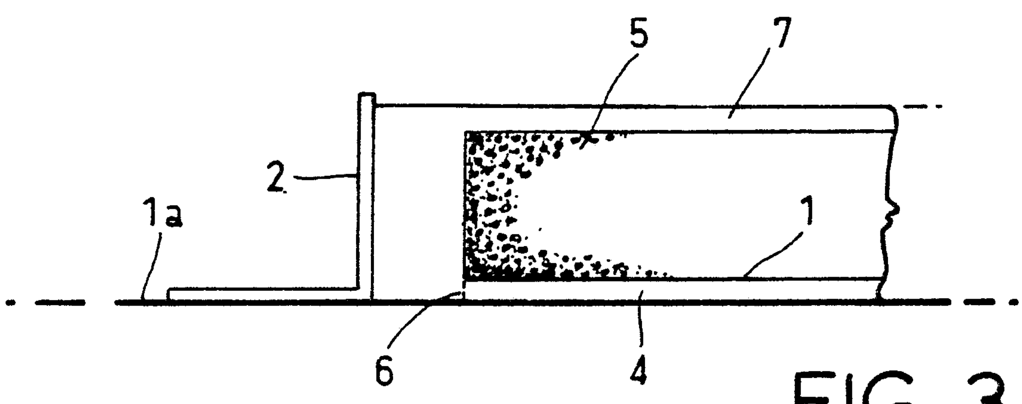


FIG 2



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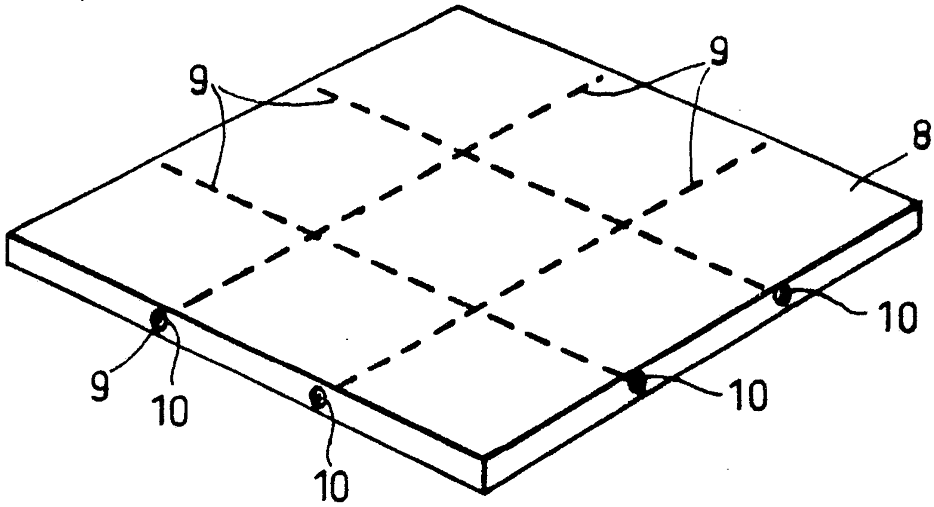

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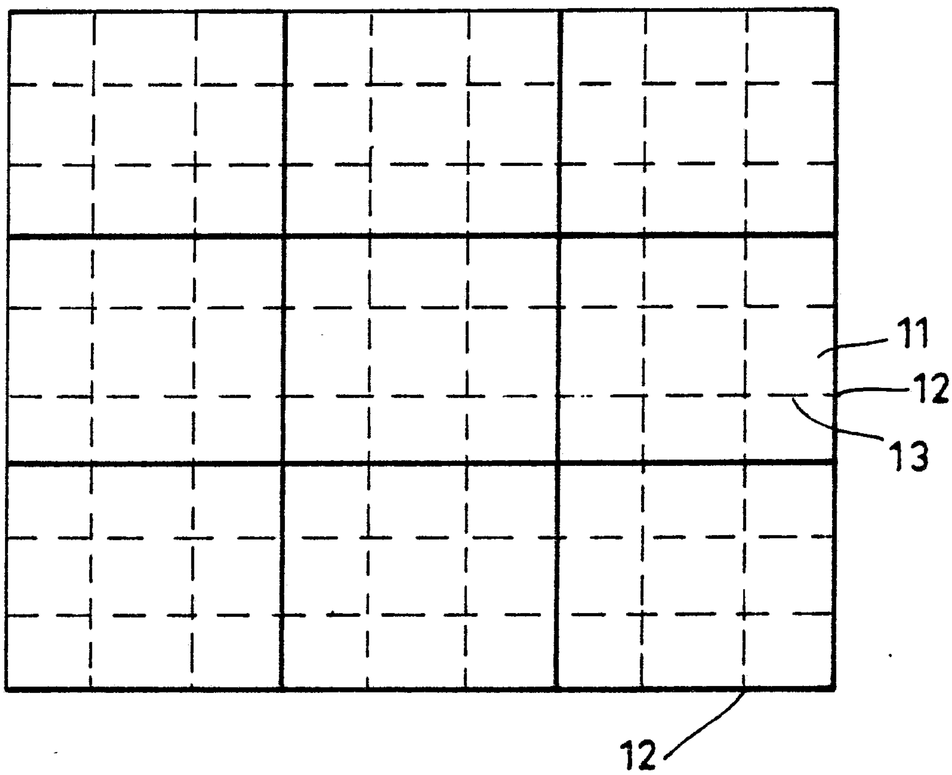

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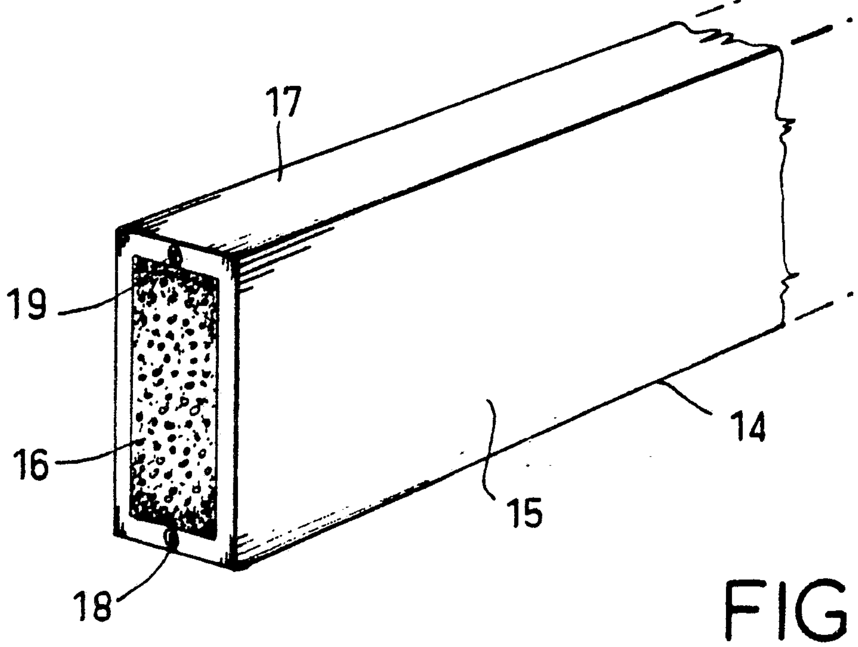


FIG 6

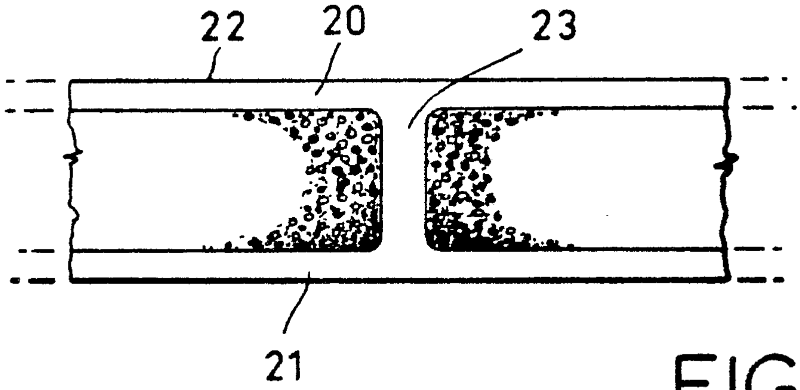
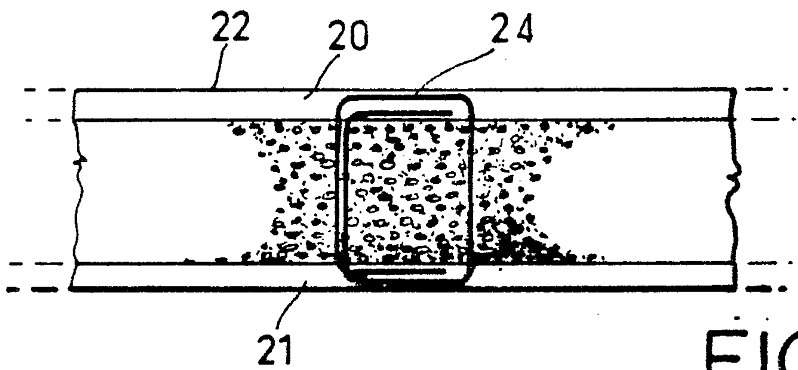


FIG 7



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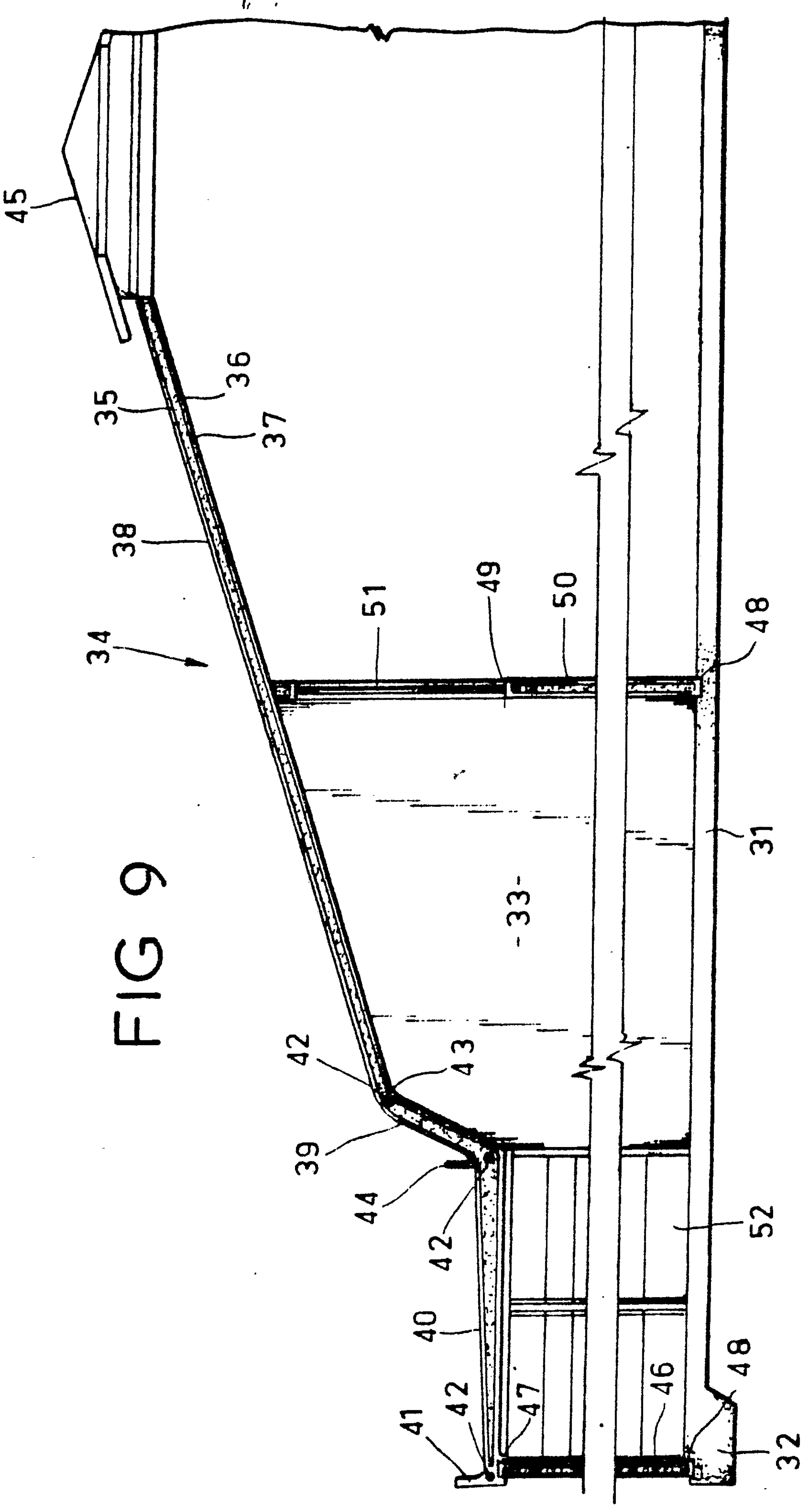
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FIG 9

FIG 11

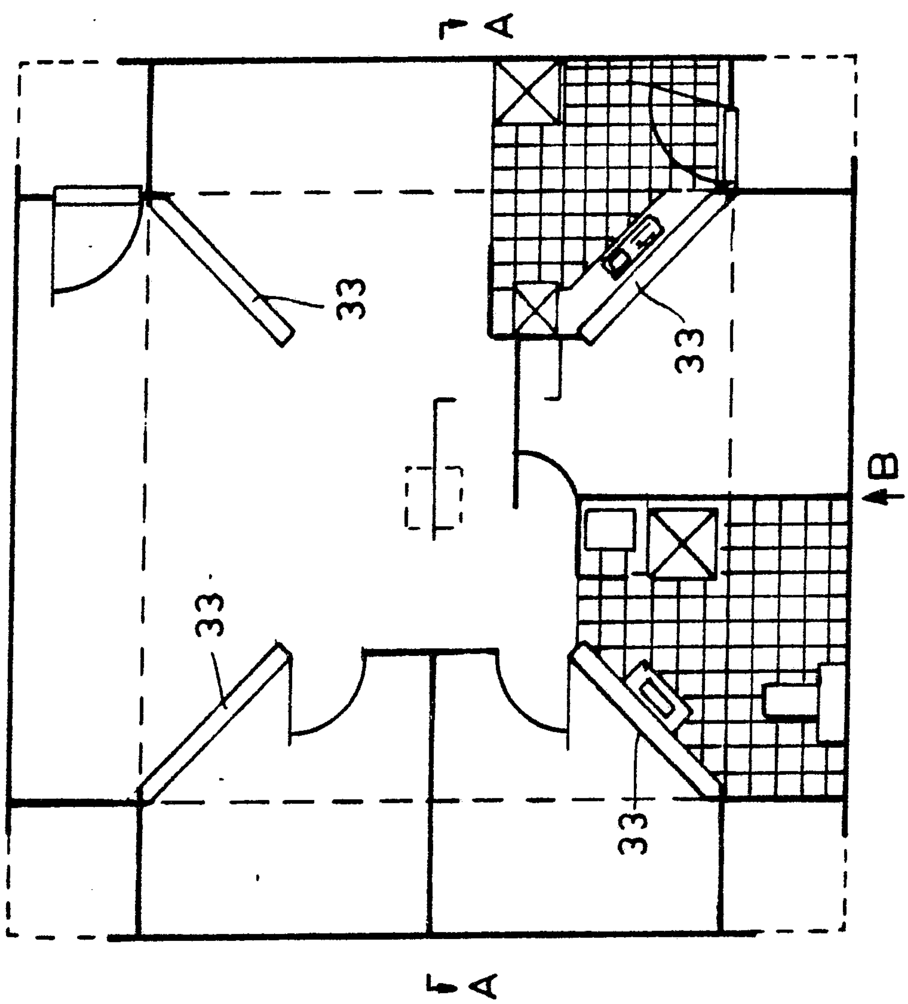
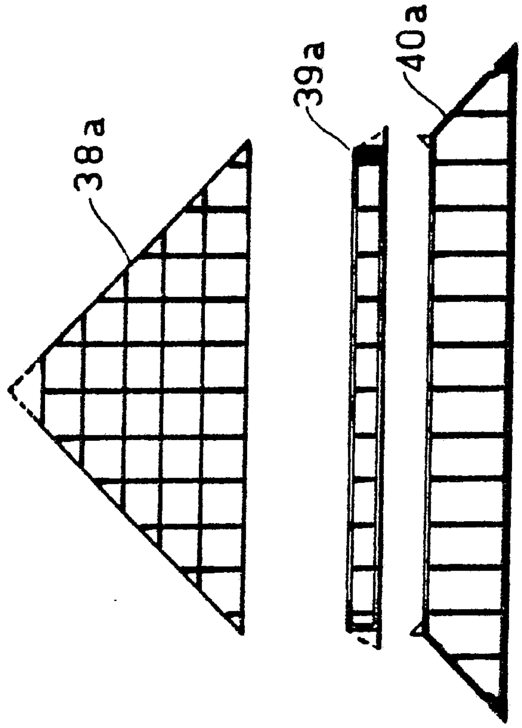


FIG 10



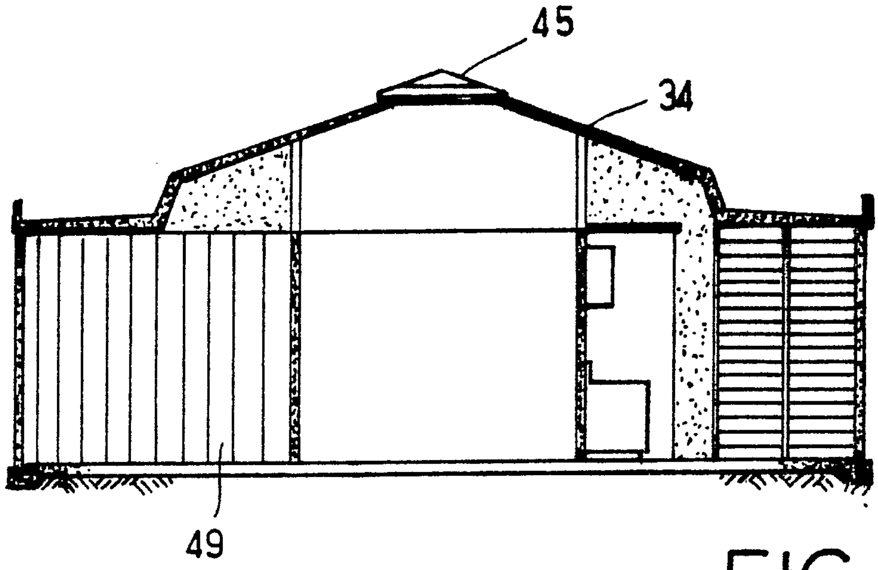
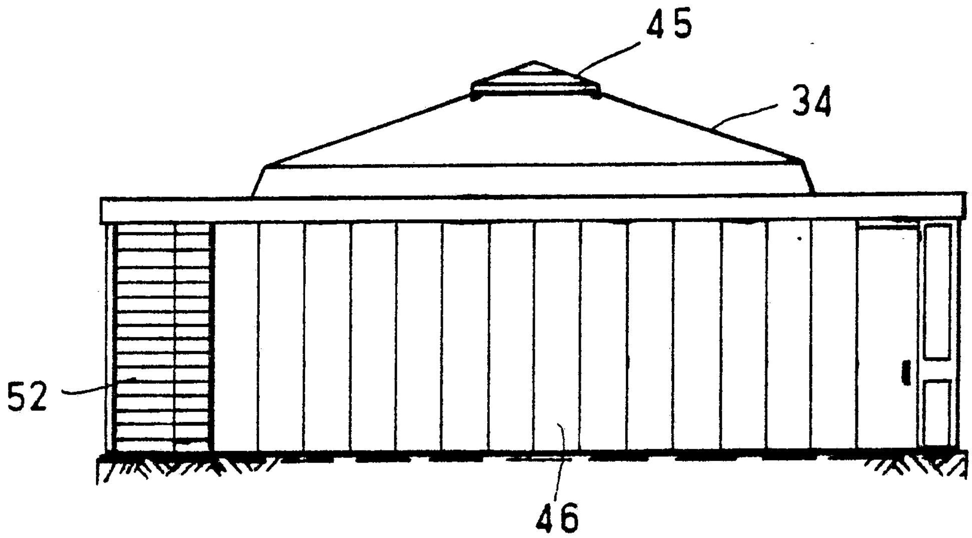


FIG 12

FIG 13



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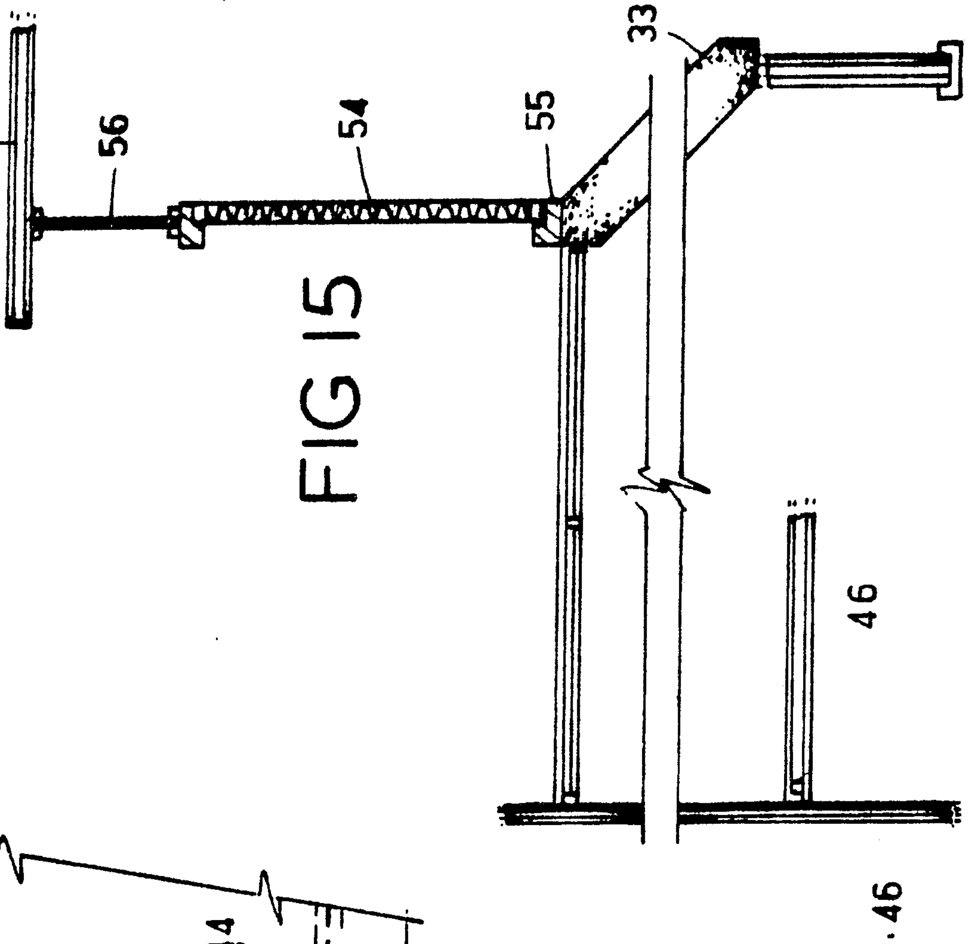

FIG 15

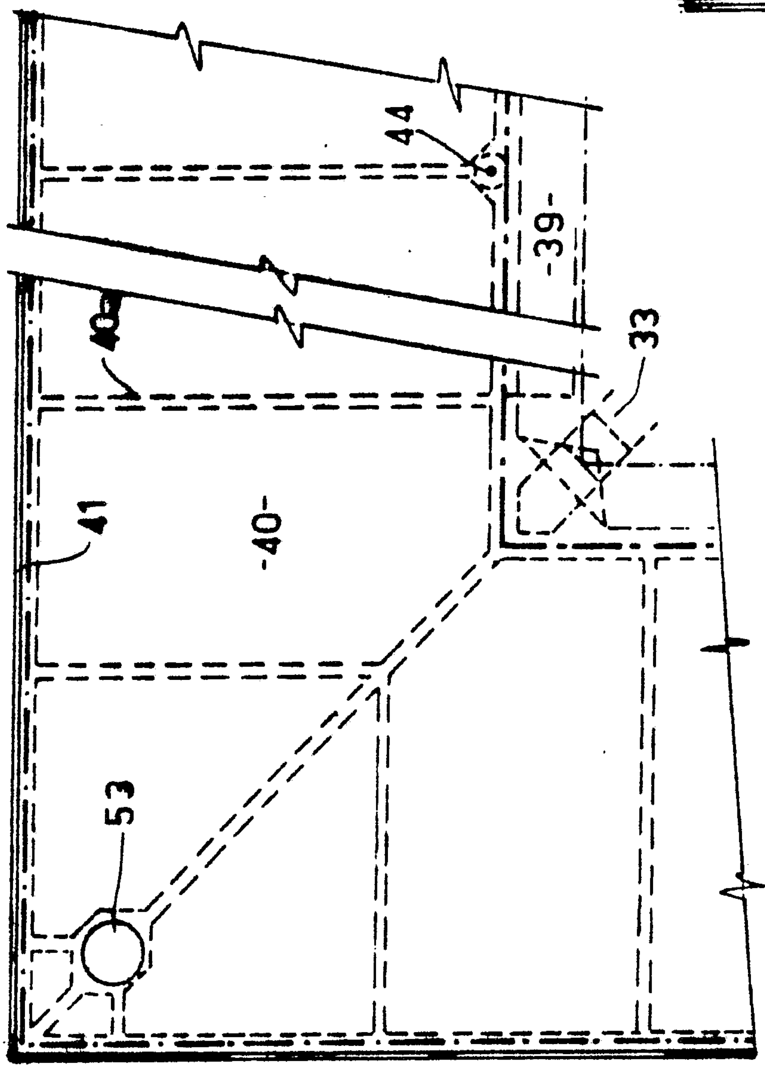

FIG 14

INTERNATIONAL SEARCH REPORT

International Application No PCT/AU83/00142

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.^{3} E04C 2/04, 2/06, 3/29; B28B 1/52; B32B 13/02, 13/04; C04B 39/00

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
IPC	E04C 2/04, 2/06, 3/29; B32B 13/02
US Cl.	52/725, 52/785, 264/241

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

AU: IPC as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	AU, B, 38819/78 (520177) (TILLY) 14 February 1980 (14.02.80), see page 11	(1, 12)
X	AU, B, 72090/74 (507249) (TILLY) 12 February 1976 (12.02.76), see page 3	(1, 12)
A	GB, A, 1546102 (MACPHERSON) 16 May 1979 (16.05.79)	(1)
A	GB, A, 1445787 (TORVALE HOLDINGS LIMITED) 11 August 1976 (11.08.76)	(1)
A	US, A, 4335177 (TAKEUCHI) 15 June 1982 (15.06.82)	(1)
A	AU, A, 31887/77 (MASO-THERM CORPORATION) 22 June 1979 (22.06.79)	(1, 12)

* Special categories of cited documents: [15]
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
11 January 1984 (11.01.84)	12 January 1984 12-1-1984
International Searching Authority [1]	**Signature of Authorized Officer** [20]
Australian Patent Office	R.M. DORNING RM Dorning