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Method of Constructing a Core in Modular Construction

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Abstract

5 A method of constructing a multi-storey concrete core in
a building constructed of modular units, including
arranging and connecting modular building units so that
framed walls of the building units form core perimeter
walls of a concrete core to be constructed; attaching
formwork on an inside of the core perimeter walls; and
applying wet concrete in the perimeter walls to form a
10 solid concrete core when the concrete dries.

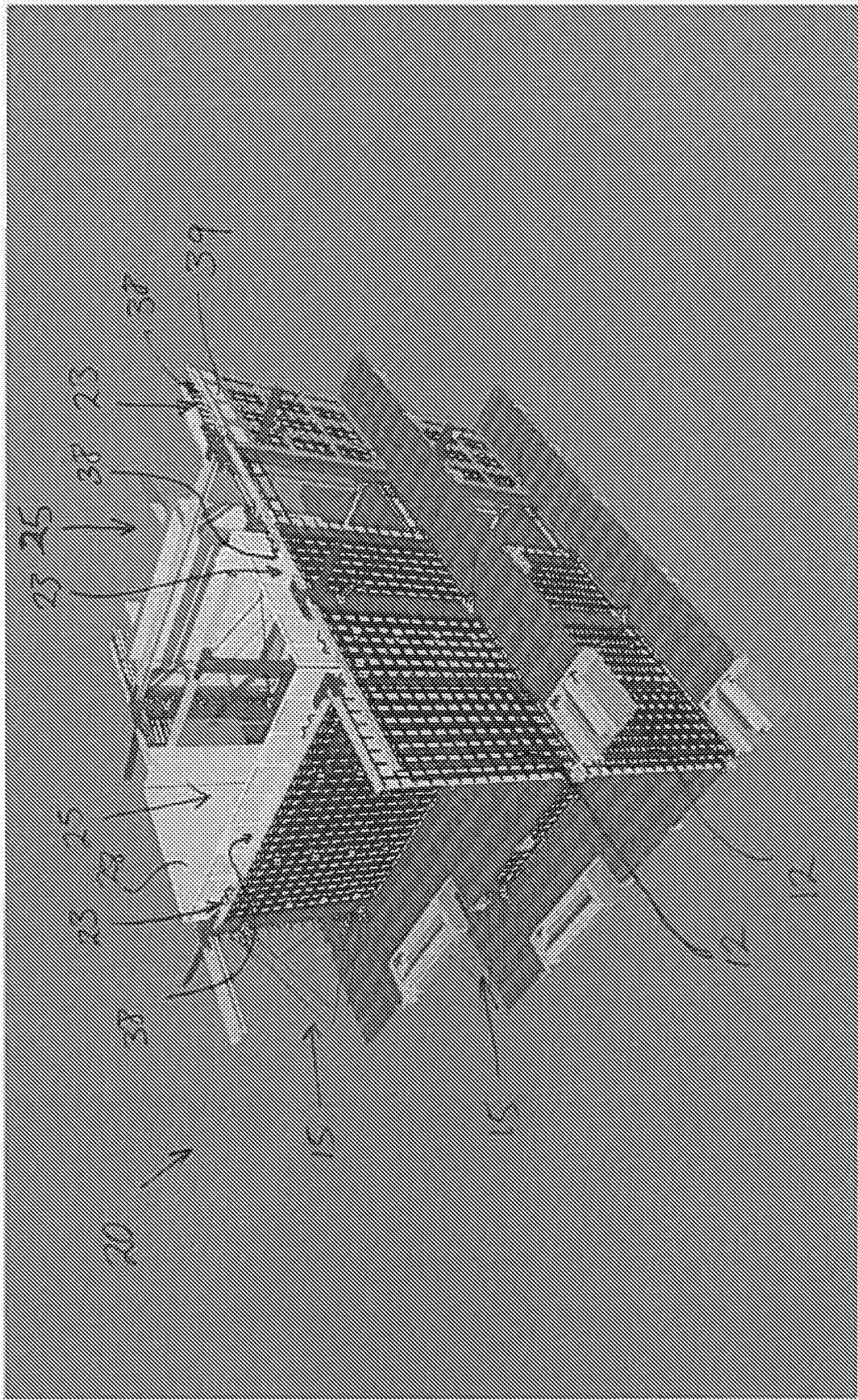


FIGURE 1

METHOD OF CONSTRUCTING A MULTI-STOREY CONCRETE
CORE IN A BUILDING

5 FIELD

The present invention relates to a method of constructing a multi-storey concrete core, particularly in a building constructed of modular building units.

10

BACKGROUND

Standard construction methods for building high rise structures, namely structures having more than two or three stories, include first constructing a concrete shear core that acts as a primary structural element for the building and against which the columns and transverse beams of each floor level is tied or otherwise connected for support. The concrete core is therefore usually located centrally of the building plan and is used to carry and protect many building services including lifts, electricity, gas and water conduits, etc.

A disadvantage in the construction of conventional concrete cores in building is that the concrete core takes a longer time to construct than each floor. For example, it typically takes one week to erect a concrete core per floor, while the remaining construction of one floor, including forming or erecting reinforced concrete surfaces to make the floors and walls only takes about one to two days. The concrete core is therefore erected first up to a certain height before the construction of each floor begins, and will soon catch up to the level of the core.

35 Typically construction techniques of a concrete core include erecting a "jump form" that provides a moveable formwork containing a hollow space that is reinforced

using reinforcing members and filled with concrete. One floor of concrete is usually poured at a time and will take a number of days to set before the climbing form is moved one floor up to start the process again for the core on the next floor above.

New construction methods aim at reducing the construction time and costs associated with building cores. The present invention aims to similarly improve on known construction techniques for constructing concrete cores in multi-storey buildings.

SUMMARY OF THE INVENTION

In accordance with the present invention there is provided a method of constructing a multi-storey concrete core in a building constructed of modular units, including:

arranging and connecting modular building units so that framed walls of the building units form core perimeter walls of a concrete core to be constructed;

erecting formwork on an inside of the core perimeter walls; and

applying wet concrete in the perimeter walls to form a solid concrete core wall when the concrete dries.

In one embodiment the method includes pneumatically propelling wet concrete through a core perimeter wall and against the formwork. This method can be used when the modular units are only partly finished, and internal walls such as plasterboard have not yet been erected so that a person can propel the wet concrete from inside a modular unit and through the core perimeter wall against the formwork.

In an alternative embodiment, the method includes pouring wet concrete into the perimeter walls from a point above the perimeter wall. In this embodiment additional formwork

will be required on the other side of the perimeter wall to the first formwork in order to confine poured wet concrete in the space of the perimeter wall between the first formwork and the additional formwork. This method is
5 suitable for use where the modular units are finished before transporting to a construction site, and the internal wall surface at the perimeter wall of the modular unit can act as the additional formwork. The internal wall surface in this case may comprise a sheet of plasterboard,
10 which will face the inside of the modular unit, against another more rigid sheet (timber, composite or metal) that will act as formwork to hold the wet concrete as it dries in a cavity of the perimeter wall.

15 In yet another embodiment the method could include a combination of pneumatic propulsion of wet concrete and pouring. In particular, where pneumatic propulsion of wet concrete in high areas becomes difficult, the higher parts of the core perimeter walls can be finished by pouring. In
20 these high areas, additional formwork is erected opposite the first formwork to form a perimeter wall cavity at only an upper end of the perimeter wall.

In an embodiment of the invention the formwork may be
25 erected and attached to an inside of the core before the modular building units are arranged and connected on site. In other words the formwork may be erected on certain framed walls that will form the core perimeter walls off site and in a factory setting where the modular units will
30 be largely constructed and finished.

Alternatively, the formwork could be erected after arranging and connecting modular building units on site. The formwork erected on an inside of the core perimeter
35 walls may be sacrificial formwork, for example in the form of a plywood or other planar material that will remain a part of the core construction. Alternatively, the formwork

may comprise pre-cast concrete panels erected on the inside of the core perimeter walls.

5 Preferably, the method includes arranging the units so that the framed walls partially or fully form an enclosed perimeter of the core. In this manner a hollow concrete column, typically rectangular in cross section, can be constructed to extend along the height of the building. A partial perimeter may be formed with the framed walls if
10 an access opening is required to be formed along one side of the perimeter.

Preferably the method includes providing the modular unit having reinforcement pre-fixed to the framed walls.
15 Alternatively, the method could include inserting reinforcement, such as in the form of rebar, at the framed walls to reinforce the concrete core.

Arranging and connecting the modular building units could include arranging the units to form core perimeter walls
20 in a single storey arrangement before pneumatically propelling the wet concrete, or alternatively or additionally could include arranging the units to form core perimeter walls in a multi-storey arrangement. Accordingly, the wet concrete may be propelled towards a
25 single storey arrangement of modular building units or towards a core perimeter wall spanning more than one storey.

In order to ensure modular connection of the building
30 units vertically, the method may include leaving exposed from the concrete core an upper connector of the framed wall that will allow connection of a lower modular unit having a framed wall that has formed a core perimeter wall of a concrete core to be connected to an upper modular
35 unit, which will be vertically connected above the lower modular unit before it too may form a part of an upper core perimeter wall of the core.

After pneumatically propelling the wet concrete at the formwork on the framed wall the method can also include finishing off the core perimeter wall surface. The wall surface may be finished by hanging plasterboard and/or troweling the wet concrete to vertically level off the core perimeter wall. The excess concrete trowelled off the core perimeter wall may be recycled and used as building ballast.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the invention may be more clearly ascertained, embodiments will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic representation of a multi-storey building having a concrete core constructed according to the method of the present invention;

Figure 2 is an isometric view of a single level in the representation of figure 1.

Figure 3 is a plan drawing illustrating a concrete core formed from connected modular building units in accordance with the invention;

Figure 4 is a first upper isometric view of a modular building unit having a concrete core wall made in accordance with the method of the present invention;

Figure 5 is a second upper isometric view of a modular building unit having a concrete core wall made in accordance with the method of the present invention;

Figure 6 is a top sectional view of a first embodiment of a concrete core wall formed in accordance with the invention; and

5 Figure 7 is a top sectional view of a second embodiment of a concrete core wall formed in accordance with the invention.

10 DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

A multi-story concrete core 10 is illustrated in the drawings either as partially formed within the framed walls 12 of a modular building unit 15 (figures 3 to 5) or formed in its entirety as part of a multi-storey building 20 constructed by connecting modular building units 15 side-by-side and one on top of the other to form a greater building.

The concrete core in a building constructed of the modular units is intended to be used to provide services including amenities (gas, electricity and water, plumbing) and/or to be used as a lift well or a stairwell.

The currently described method for constructing a multi-storey concrete core in a building constructed of modular building units provide significant advantages in the construction of a multi-storey building. Firstly, the current method does not require a "climbing form" used in known construction techniques for concrete cores.

30 Furthermore, the concrete core can be formed at the same time as constructing the floors and walls of the same level. The concrete core is built at the same time as each level or multiple stories of the concrete core can be built at the same time as building multiple stories of the building. This provides significant time savings in the construction time of a multi-storey building.

Another advantage is that much of the construction of the concrete core can be carried out off-site which provides for, not only further time savings, but also greater
5 quality control of the interconnecting components forming the framework of the concrete core, which in turn lead to less room for error in the construction of the concrete core.

10 Figure 1 illustrates a multi-storey building 20 formed by interconnecting modular building units 15. To show greater clarity, Figure 2 illustrates a single storey of the multi-storey building illustrated in Figure 1.

15 The modular building units 15 are interconnected at structural columns 16 in each building unit 15. Specifically, the structural columns 16 are provided with end flange plates 17 that are aligned and abut
20 corresponding end flange plates on a upper or lower level and then fastening means, for example in the form of bolts, are used to fasten the end plates together in order to connect one building unit 15 above another building unit 15.

25 Similar techniques are used to interconnect building units adjacent each other in a side-by-side arrangement, and namely tie plates (not shown) bridge and bolt together adjoining units 15.

30 It is practical to complete as much of the building unit off site as possible. For example, the wall and floor finishes may be completed in a warehouse offsite so that the modular unit is partially completed before shipping
35 the entire modular unit on site and connecting it to other modular units which are all then fitted out with the conveniences and finishings of the multi-storey building, whether it be residential, commercial, or otherwise.

Alternatively, each modular building unit may be finished in its entirety in the warehouse and offsite before transporting to the building site where the units are connected to each other in their finished state so that only the services need to be connected to each unit.

In the presently described construction method of building a multi-storey concrete core in a building constructed of modular units, the modular units may be provided in a basic framed state or a semi-completed state before the framed walls forming the core perimeter walls are completed. In this unfinished state the method can include pneumatically propelling wet concrete through the perimeter wall and against the formwork from a position standing inside a modular unit facing the formwork. The present method also provides for modular units transported and erected at a construction site in an entirely finished state with finished internal walls. In this state wet concrete is poured into the perimeter wall from a point above the perimeter wall.

The method of constructing the multi-storey concrete core includes arranging and connecting modular building units so that framed walls of the building units form core perimeter walls of the concrete core that is to be constructed.

Figure 3 illustrates a plan of modular building units that have been arranged and connected across one level. Surrounding the space where the core is to be provided are framed walls belonging to the building units immediately surrounding the core space. Accordingly, the framed walls surrounding the core space have a double purpose to both form walls of the building unit but to also form the core perimeter walls of the concrete core. Accordingly, there is no need to erect additional framework to form the concrete core because the core

perimeter walls 23 defined by the framed walls 12 of the building unit 15 immediately surrounding the core space 25 act as both a wall for the concrete core and a wall for the immediately adjoining building unit 15.

5

It is understood that the modular building units may define a variety of internal building spaces, from entire residential apartments, to hallways and common areas, to commercial offices, and to amenity blocks such as bathroom facilities.

10

Once the building units 15 have been arranged and connected together across one level formwork 28 is erected on an inside of the core perimeter walls 23.

15

Alternatively, the formwork 28 may be erected off site and during fabrication of the modular units. The formwork defines an inner wall of the core. The formwork may be formwork that is removed after the application of concrete or, and more typically, the formwork may be sacrificial formwork that remains as part of the concrete core walls.

20

In a first embodiment, after the formwork is in place the concrete core is constructed by pneumatically propelling wet concrete against the formwork 28 on the core perimeter wall and in a direction towards the core which, when dry will form a solid concrete core wall 11.

25

The pneumatic propulsion of wet concrete is also known as "shotcreting" where fluid concrete is "shotcreted" particularly in applications where a vertical surface is to be applied with concrete. The consistency and density of the concrete is such that makes it suitable for pneumatic propulsion against a surface. Additionally, the concrete may be provided with additives, chemicals or particulate material, that can be added to enhance or improve the characteristics of the concrete core or to provide a particularly desired finished surface on the

30
35

core. Such additives are known in the field of concrete. The application of concrete by pneumatic propulsion provides the advantage that formwork need only be provided on one side of the perimeter wall defining a perimeter wall forming the concrete core. Furthermore, it allows the concrete core to be formed at the same time or after the frame floors and walls of a level are erected.

The concrete propulsion application process is easier than pouring concrete down into movable formwork because an operator can stand on the same level as the level at which the core is to be constructed and direct a hose substantially horizontally towards the formwork at the core. Standard shotcrete equipment is envisaged to be used where wet concrete is pumped under pressure from a source of wet concrete (typically from a rotating drum in a concrete truck) and the wet concrete under pneumatic pressure is forced through a hose to an end nozzle from which it is sprayed under a sufficient force to be propelled against a surface located 200 to 500mm away from the nozzle for optimum controlled results. The wet concrete is propelled through the framed wall, which may include non-structural framework, to impact the formwork on the other side of the framed wall.

In a second embodiment, the wet concrete can be poured into a perimeter wall cavity from a point above the perimeter wall. In this embodiment additional formwork, shown in Figure 2, will be required to be erected on the other side of the perimeter wall to the first formwork in order to confine poured wet concrete in the perimeter wall cavity. This method is suitable for use where the modular units are substantially entirely finished off site and then transported to a construction site.

The internal wall surface at the perimeter wall of the

modular unit can act as the additional formwork 39. The internal wall surface in this case may comprise a sheet of plasterboard, which will face the inside of the modular unit, against another more rigid sheet acting as the structural formwork to hold the wet concrete as it dries in a cavity of the perimeter wall. The more rigid sheet can comprise a range of materials known for use as formwork, which are described in more detail further below.

Figures 1 and 2 illustrates multi storey concrete cores (lift well 55 and stair well 56) in the building formed by modular building units 15 where the cores are prepared to be constructed by a hybrid of the pneumatic propulsion and pouring techniques for wet concrete. This hybrid technique is suitable where pneumatic propulsion of wet concrete is difficult to control and apply in high areas such as near ceilings. Figure 1 illustrates the higher part of the core perimeter walls, extending approximately 300mm downwards from the ceiling, can be finished by pouring concrete on top of the shotcreted concrete. In this higher area, additional formwork 39 in the form of a formwork skirt depending from the ceiling, is erected opposite the first formwork 28 to form a perimeter wall cavity 38 at only an upper end of the perimeter wall. Concrete is then poured from above perimeter wall into the cavity 38.

Figures 4 and 5 illustrate different isometric views of a building unit 15. The building unit 15 includes structural columns 16 and beams 18, as well as non-structural framework 19 that together form the framed walls 12 of the building unit. Connections plates 17 are used to connect columns to columns and columns to beams and to connect columns of one building unit 15 to another building unit. Also illustrated are flooring bearers 21 and flooring 22. An outside shear wall 27 of the building unit is illustrated as being formed as a concrete panel

which can be pre-cast and erected on the building unit onsite and then an internal concrete wall is poured or shotcreted against it.

5 Figures 4 and 5 show framed walls 12 defining some of the perimeter walls 23 of core 10 and specifically, if the core is intended to be a square or rectangular form, the perimeter walls 23 form one side of the core 10 and two opposite partial side walls of the core 10. The building
10 units 15 can be arranged so that the framed walls 12 partially or fully form an enclosed perimeter of the core. The core is in this manner formed on a level by level basis, or could even be formed two levels at a time, and creates the hollow concrete core column that extends the
15 height of the building. The perimeter may be formed partially in some sections if an access opening is required on one side of the perimeter, for example to form a lift opening or a utilities door.

20 Before propelling wet concrete against the formwork reinforcement is usually inserted in the form of rebar and other types of reinforcing steel rods, in the framed walls to reinforce the concrete material forming the core. Reinforcement with steel rods is usually applied in
25 accordance with engineering specifications horizontally and vertically within the framed wall to be embedded within the concrete wall 11 of the core 10. In the preferred embodiment, reinforcing bars are tied in position to the framed walls off site. The modular units
30 are therefore delivered to site and assembled with reinforcement already in place.

As discussed earlier, the modular building units 15 can be arranged in a single storey arrangement where the concrete
35 core is constructed by pneumatically propelling wet concrete for every storey, or the building units could alternatively be arranged in a multi-storey arrangement

where wet concrete may be propelled against a perimeter wall defining the core walls that may span more than one storey.

5 Generally, the concrete core walls are constructed on building units already connected in a multi-storey arrangement so that the inter-connections between upper and lower units are embedded in the concrete walls.

10 The method could also further include trowelling the wet concrete as or soon after it is pneumatically propelled against the formwork on the perimeter wall 23. Not only will troweling the wet concrete level off the vertical perimeter wall, but the excess concrete trowelled off the
15 core perimeter wall could be recycled and used for other purposes in the building, for example used as building ballast.

Figures 6 and 7 show two different embodiments of a cross
20 section of a concrete wall 11 forming the core, and specifically illustrate different combinations of materials that could constitute the concrete wall 11.

Figure 6 illustrates the concrete wall 11 having an inner
25 surface 30, where the inner surface faces into the core 10, and an outer surface 32, which surface faces the opposite side of concrete wall 11 to the core 10 and namely faces the inside of the building unit 15. Figure 6 illustrates the structural framework of the perimeter
30 walls 23 and namely two hollow steel structural columns 16 and horizontal and vertical structural reinforcement 34.

Steel sheeting (about 1mm thick) on the inner surface 30 forms the formwork 28 against which wet concrete is
35 shotcreted. The steel sheeting is fixed against the framework of core perimeter walls 23 using standard techniques including formwork framing whereby steel

sheeting is fixed to square hollow sections 36 forming the formwork framing that are vertically fixed to various points on the perimeter walls 23.

5 Shotcreted concrete 40 is illustrated in Figures 6 as forming the infill of wall 11. The concrete infill 40 is applied by propelling wet concrete from the outer surface 32 side of the concrete wall 11 towards the formwork 28 in order to build up the mass of concrete 40 in the concrete wall 11. As the wet concrete is propelled against the formwork the build-up of wet concrete is trowelled to form the vertical outside surface 42 of the concrete 40. A plaster support frame 44 forms part of the modular unit and after application of the concrete protrudes out of the concrete wall 11 and into the building unit 15. Frame 44 is used to support plasterboard 46 in a manner so as to be spaced from the outside surface 42 of the concrete wall 11. Space 50 between the concrete wall 11 and plasterboard 46 is to allow for insulation infill, electrical wiring and the like.

Figure 7 illustrates a different embodiment of a concrete wall 11 where only one steel hollow support column 16 is provided, which may occur on a straight section of the perimeter wall. In this embodiment rather than the formwork being formed by steel sheeting the formwork is sacrificial formwork in the form of a board product. The formwork board is similarly mounted on square hollow sections 36 that are fastened onto the steel framework of the core perimeter walls 23. Reinforcement 34 is added to the framework and embedded into the wet concrete that is propelled against formwork 28 under pneumatic pressure. In this example the outer surface 32 of the concrete wall 11 is lined with a packing material, that is packing board 48 and a channel 52 is mounted between the packing board 48 and the plaster board 46, which is for reducing noise transmission across the concrete wall 11.

To reiterate, the present method of constructing a core in a building constructed of modular units minimises as much as possible the time spent in building a core, which in conventional core construction techniques is where construction time is often delayed. The method also allows as much as possible of the modular units and core construction to be prepared offsite before the final application of wet concrete to form the core is carried out on site. As discussed, the formwork may be attached to the core perimeter walls onsite but may also be attached offsite if more convenient.

As already shown the formwork may take the form of any planar surface suitable for use as formwork including board, whether it be a timber plywood, timber sheeting, metal sheeting or pre-fabricated concrete panel.

The concrete core walls formed by the method described herein are very strong core walls capable of supporting an anchoring columns and beams tied to the wall and spanning multi stories and into the high rise building heights. It is understood that the method of constructing concrete core walls described herein apply equally to concrete walls that may be shear walls, such as boundary walls and not walls defining building cores.

Furthermore, the savings in materials are recognised in that the core perimeter walls are also the framed walls of the modular building units so that material is saved compared to providing a framework for the core walls alone.

The present method and product achieved provides advantages in cost savings, time savings and improved quality over current techniques used in core construction.

It will be understood to persons skilled in the art of the

invention that many modifications may be made without departing from the spirit and scope of the invention.

CLAIMS:

1. A method of constructing a multi-storey concrete core in a building constructed of modular units, including:
5 arranging and connecting modular building units so that framed walls of the building units form core perimeter walls of a concrete core to be constructed;
 attaching formwork on an inside of the core perimeter walls; and applying wet concrete in the perimeter walls
10 to form a solid concrete core when the concrete dries.
2. The method claimed in claim 1, including applying wet concrete by pneumatically propelling wet concrete through a core perimeter wall and against the formwork.
15
3. The method claimed in claim 1 or claim 2, including applying wet concrete by pouring wet concrete into the perimeter walls from a point above the perimeter wall.
- 20 4. The method claimed in any one of the preceding claims, including attaching the formwork to an inside of the core perimeter walls before the modular building units are arranged and connected on site.
- 25 5. The method claimed in any one of the preceding claims, including using sacrificial formwork.
- 30 6. The method claimed in any one of the preceding claims, including attaching additional formwork to a side of the core perimeter wall opposite the formwork on an inside of the core perimeter wall, to form a perimeter wall cavity into which concrete can be poured.
- 35 7. The method claimed in any one of the preceding claims, including arranging the units so that the framed walls partially or fully form an enclosed perimeter of the core.

- 5 8. The method claimed in any one of the preceding claims, including arranging the units to form core perimeter walls in a multi-storey arrangement before pneumatically propelling the wet concrete.
9. The method claimed in any one of the preceding claims, including inserting reinforcement in the framed walls to reinforce the concrete core.
- 10 10. The method claimed in any one of claims 1 to 8, including providing the modular building units having reinforcement pre-fixed to the framed walls.
- 15 11. The method claimed in any one of the preceding claims, including mounting plasterboard in front of the concrete core wall to finish the concrete core wall on an inside of a building unit.
- 20 12. The method claimed in any one of the preceding claims, including troweling the wet concrete to vertically level off the core perimeter wall.
- 25 13. The method claimed in claim 12, including recycling excess concrete trowelled off the core perimeter wall as building ballast.
14. A concrete core in a multi-storey building constructed of modular units, constructed according to the method of any one of claims 1 to 13.

EDITORIAL NOTE

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- There are 6 pages of Drawings which are not page numbered

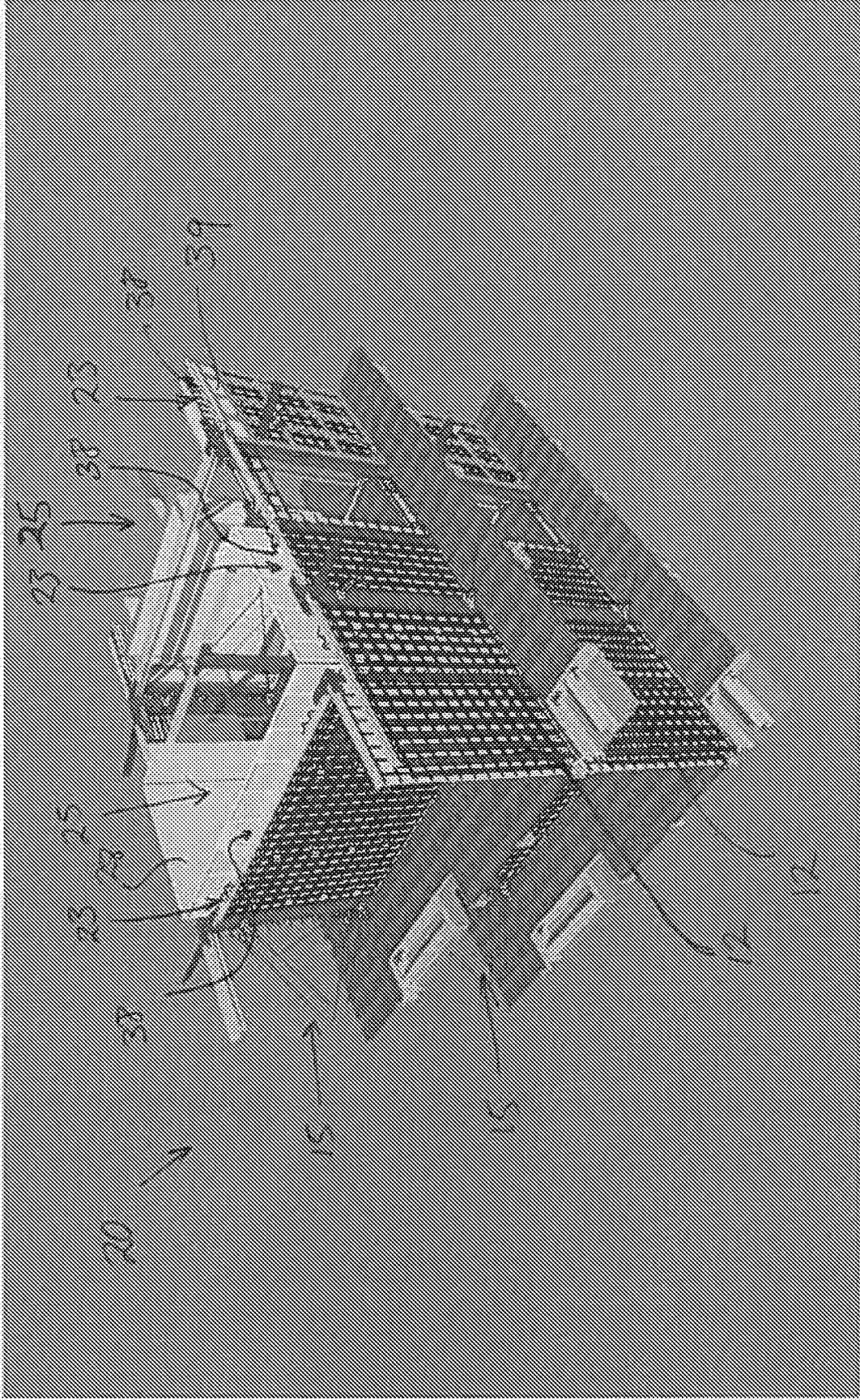


FIGURE 1

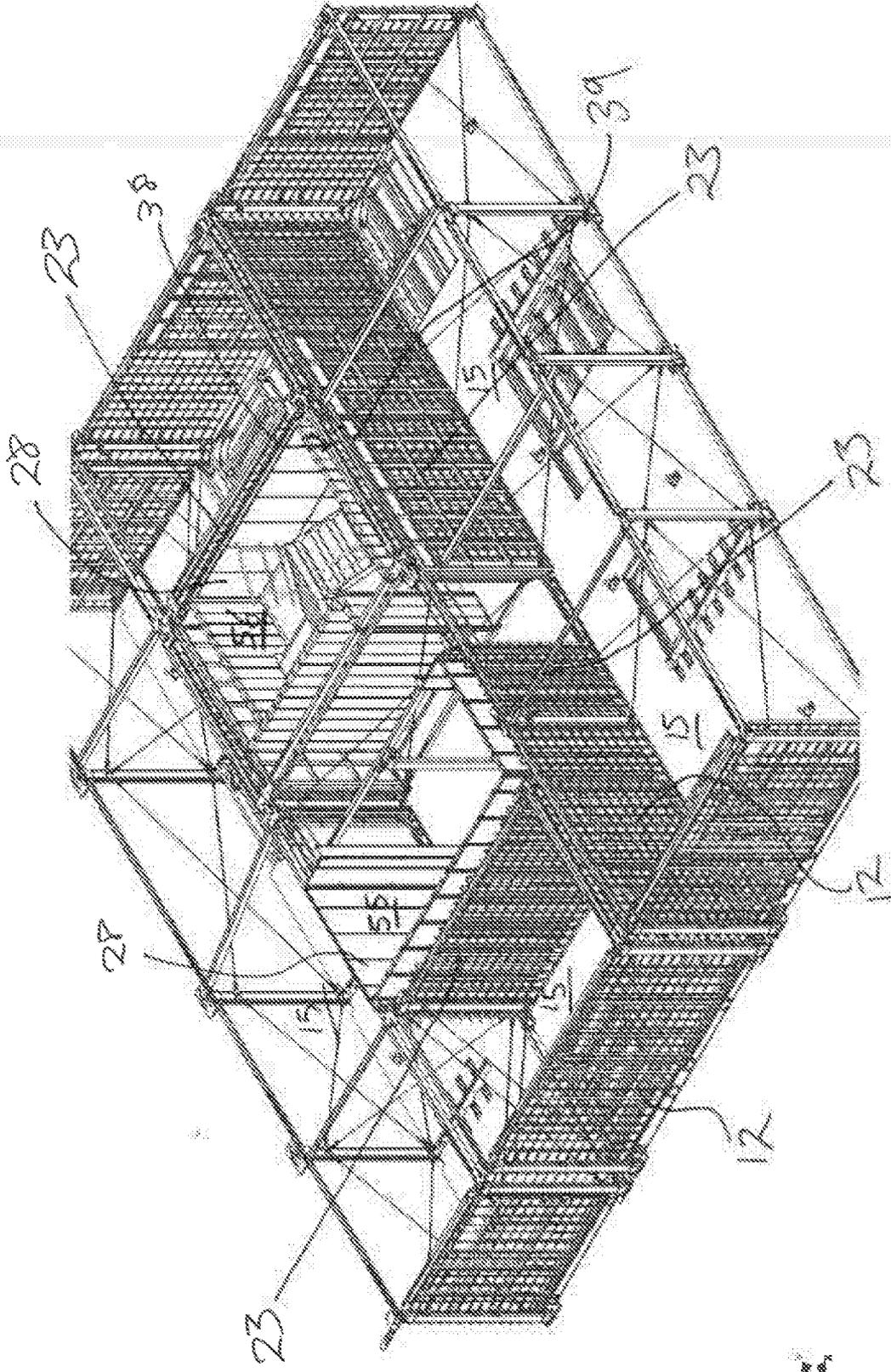


FIGURE 2

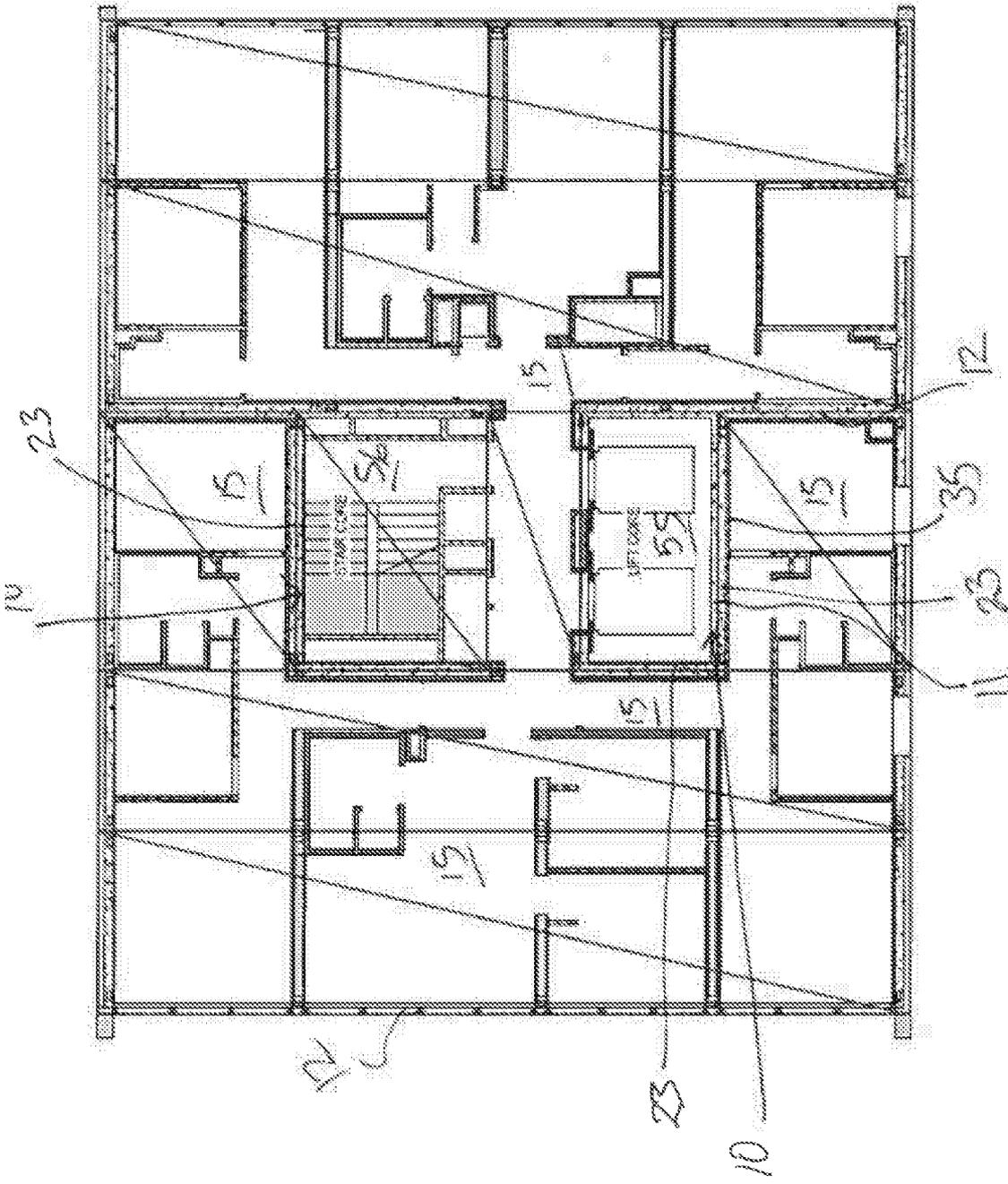


FIGURE 3

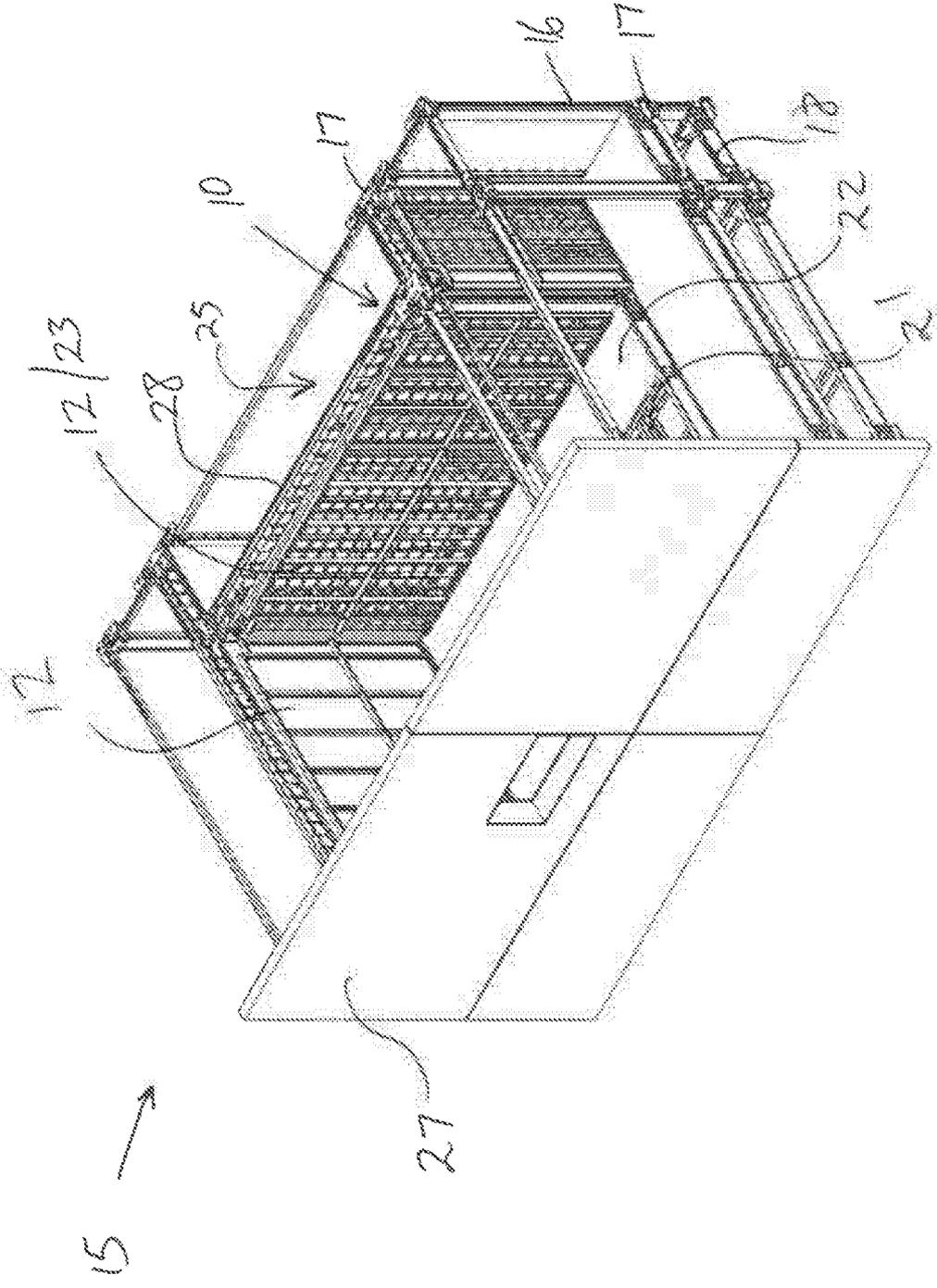


FIGURE 4

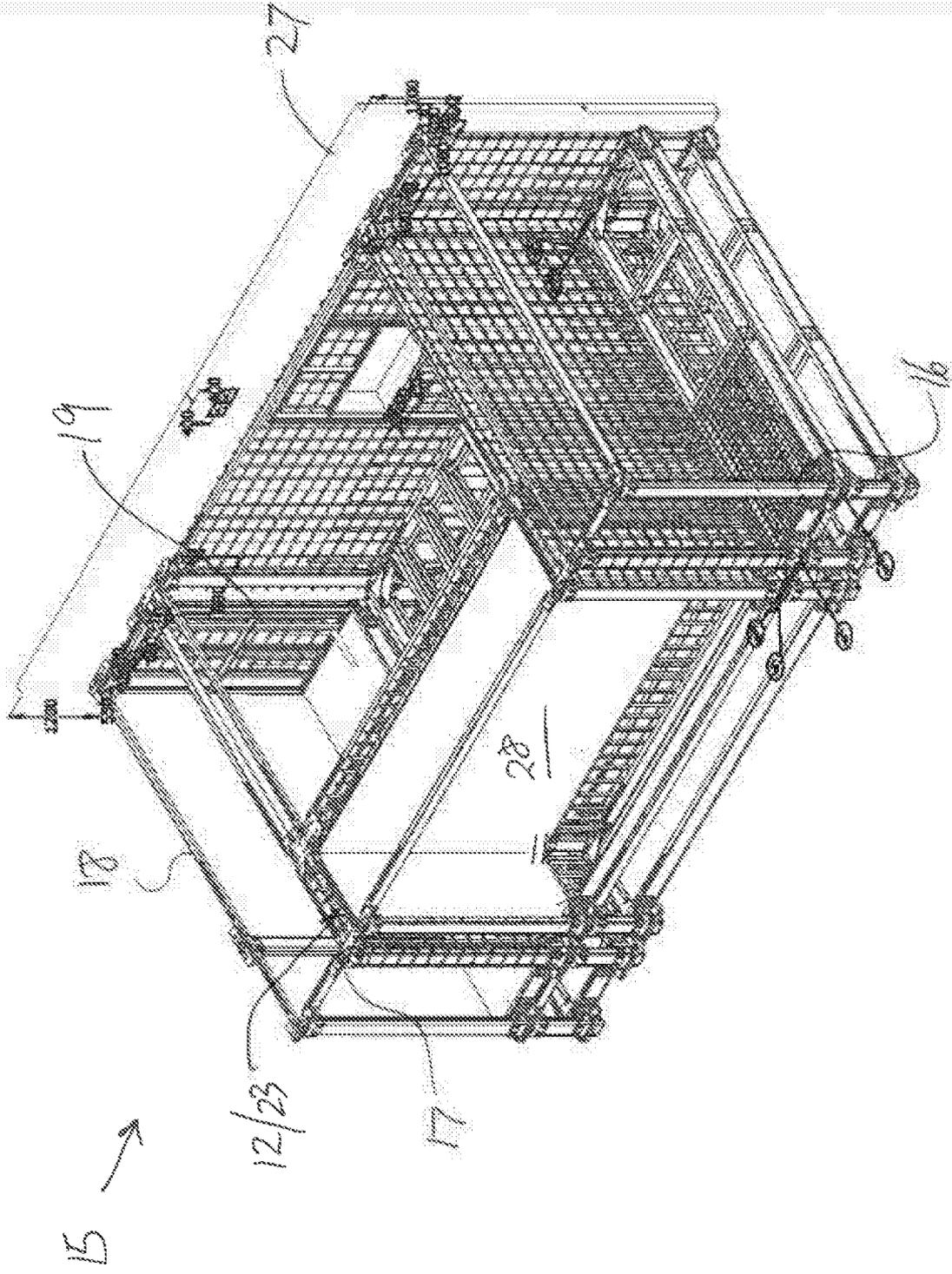


FIGURE 5

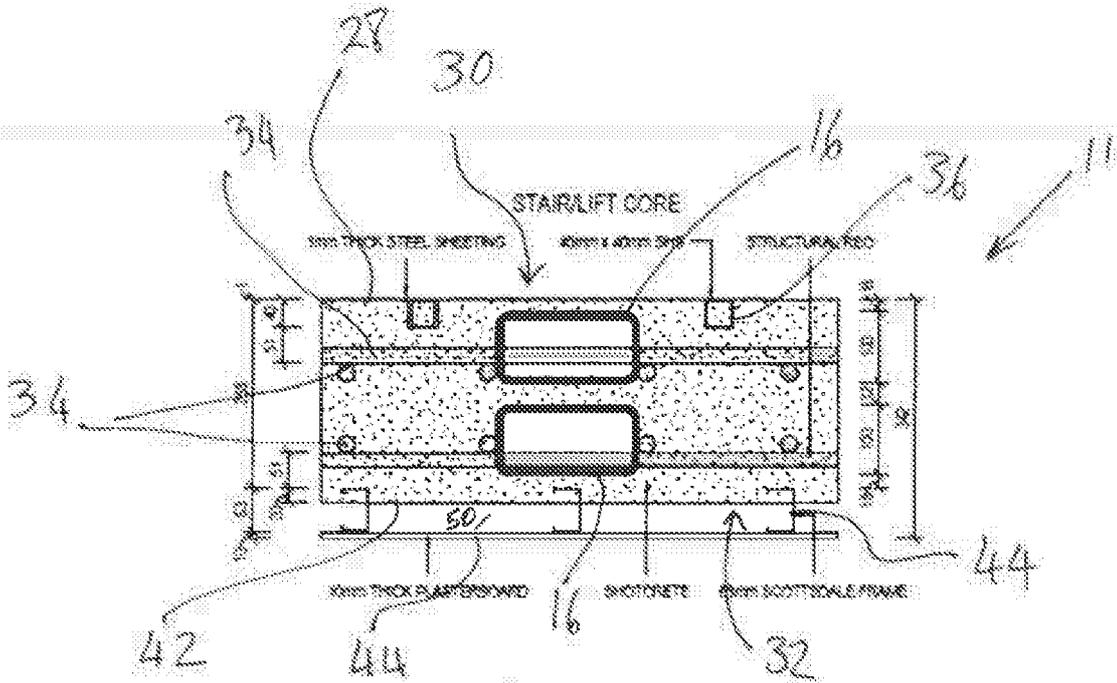


FIGURE 6

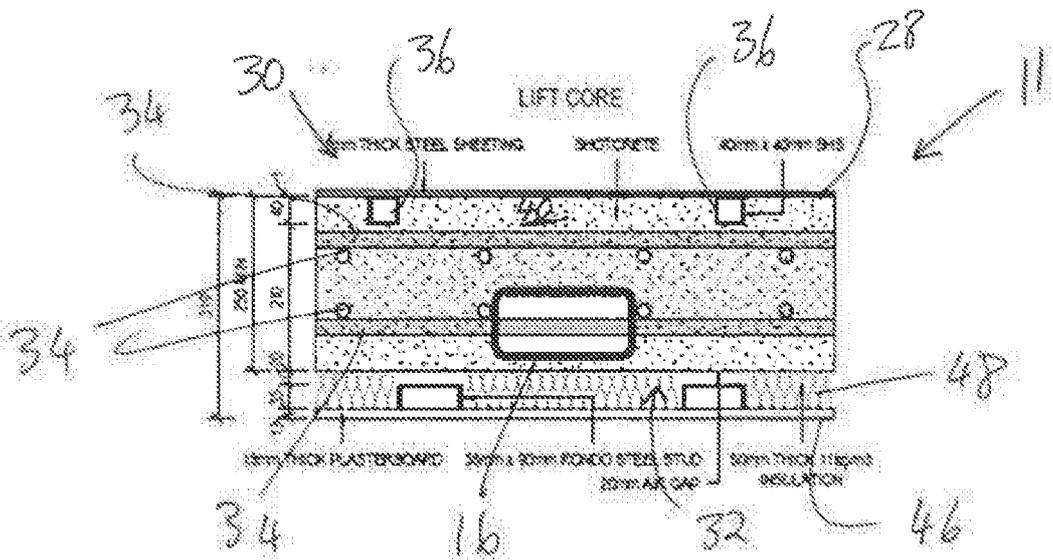


FIGURE 7