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Other: **Online: WPI, EPODOC, TXTA**

(54) Title of the Invention: **Building system**
Abstract Title: **Hybrid steel and reinforced concrete building system**

(57) A method of constructing a multi-story reinforced concrete building comprises the steps of: installing vertical supports, which can span multiple stories of a building, around the periphery of the building; fixing beams 20 to and horizontally between the vertical supports, the beams 20 being provided in the plane of each floor of the building to be constructed; installing substantially planar spanning panels 22' between the beams 20, each ceiling section 22' including a reinforcing mesh on its upper surface; pouring concrete over the upper surfaces of the ceiling sections 22' to form floor slabs. Also claimed is a method of installing a set of panels using a cassette comprising a stack of panels. The method includes tilting the panels, lowering them until a panel is level with support beams associated with the floor the panel is to be mounted on and then lowering the rest of the stack. Also claimed is a beam comprising a tray and a mesh and filling the tray with concrete. Also claimed is a cassette with a stack of panels.

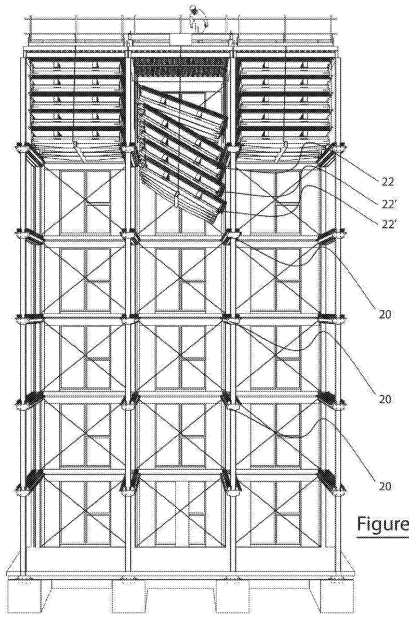

Figure 2b

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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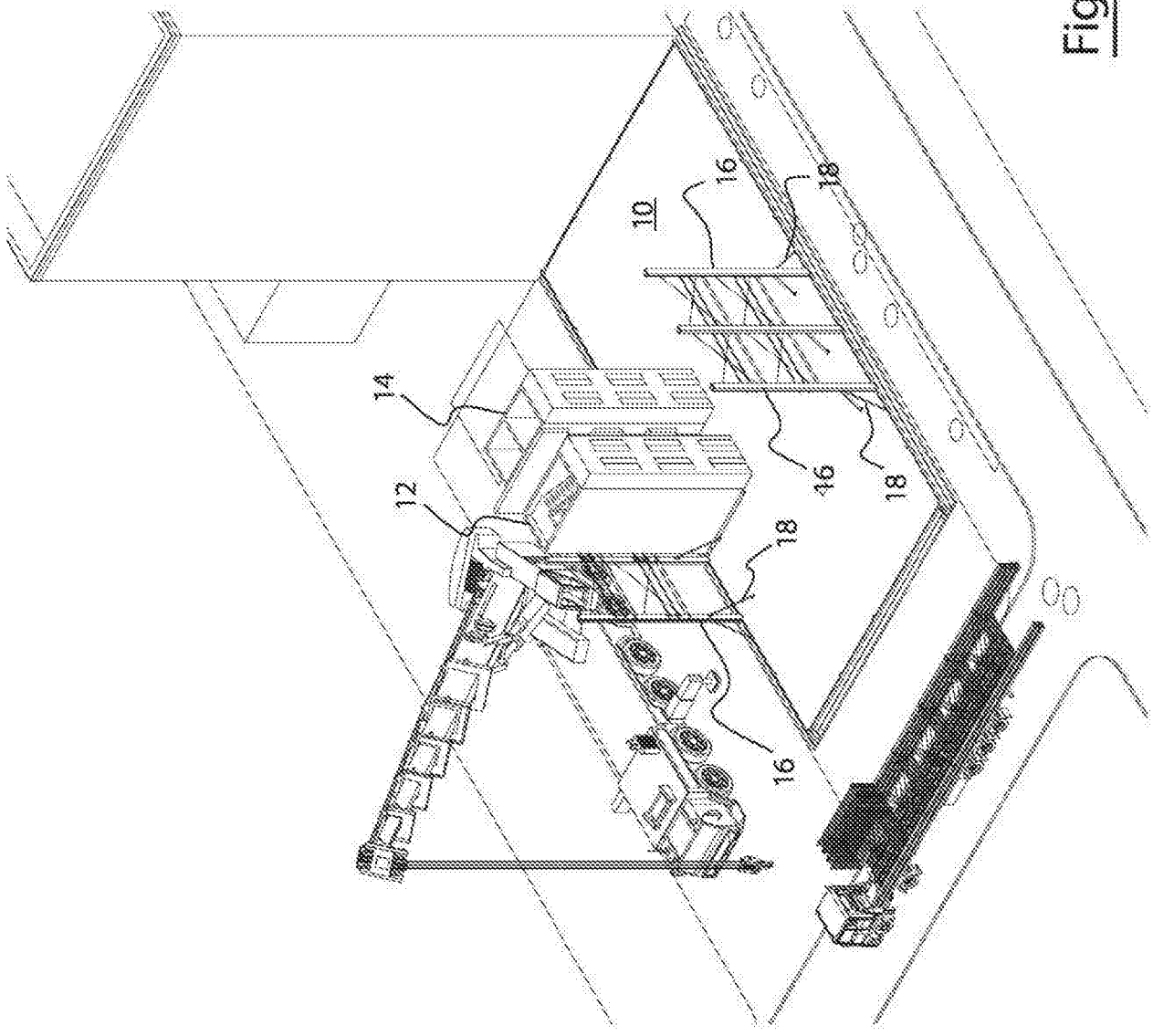

Figure 1a

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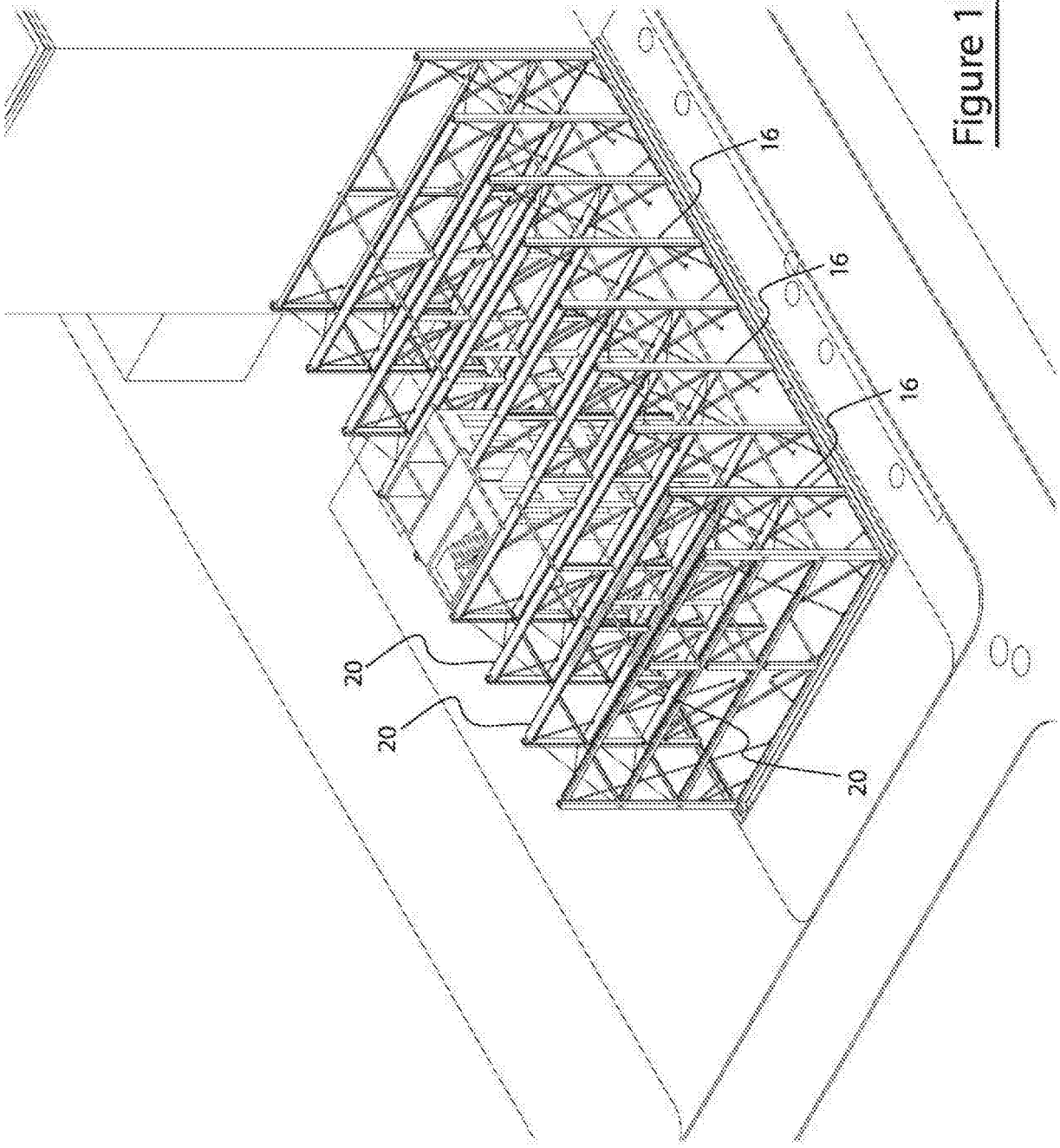

Figure 1b

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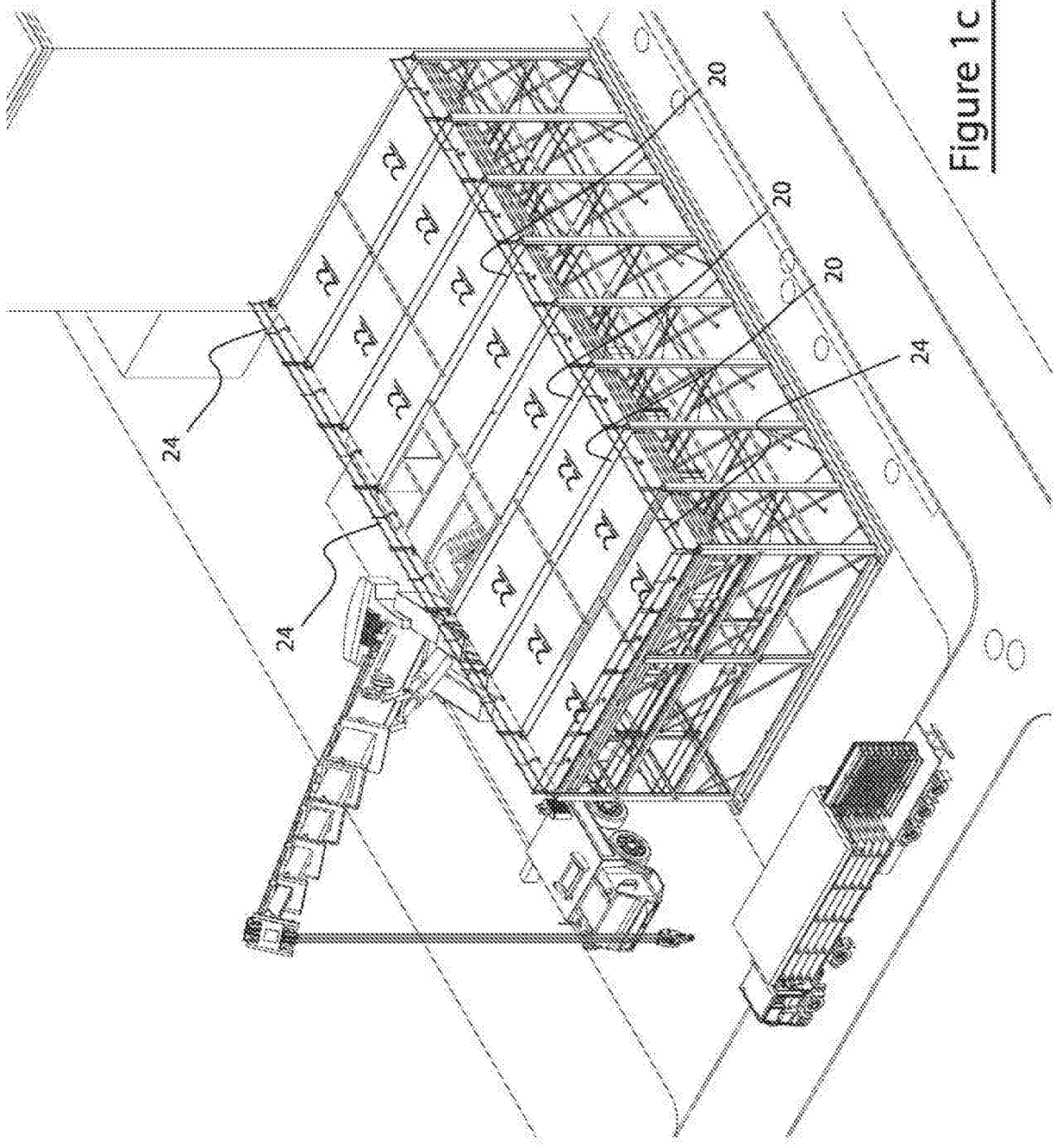

Figure 1c

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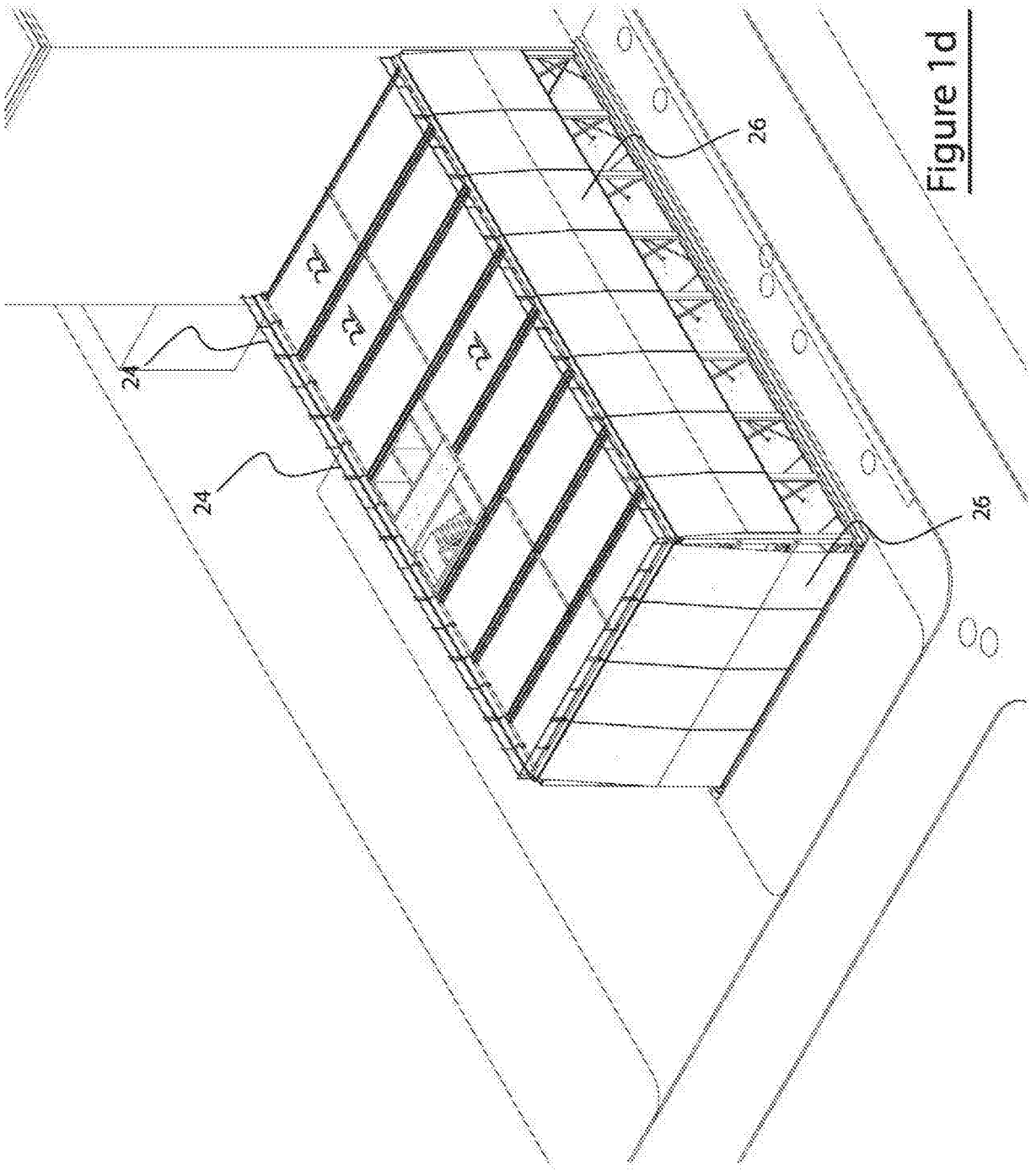

Figure 1d

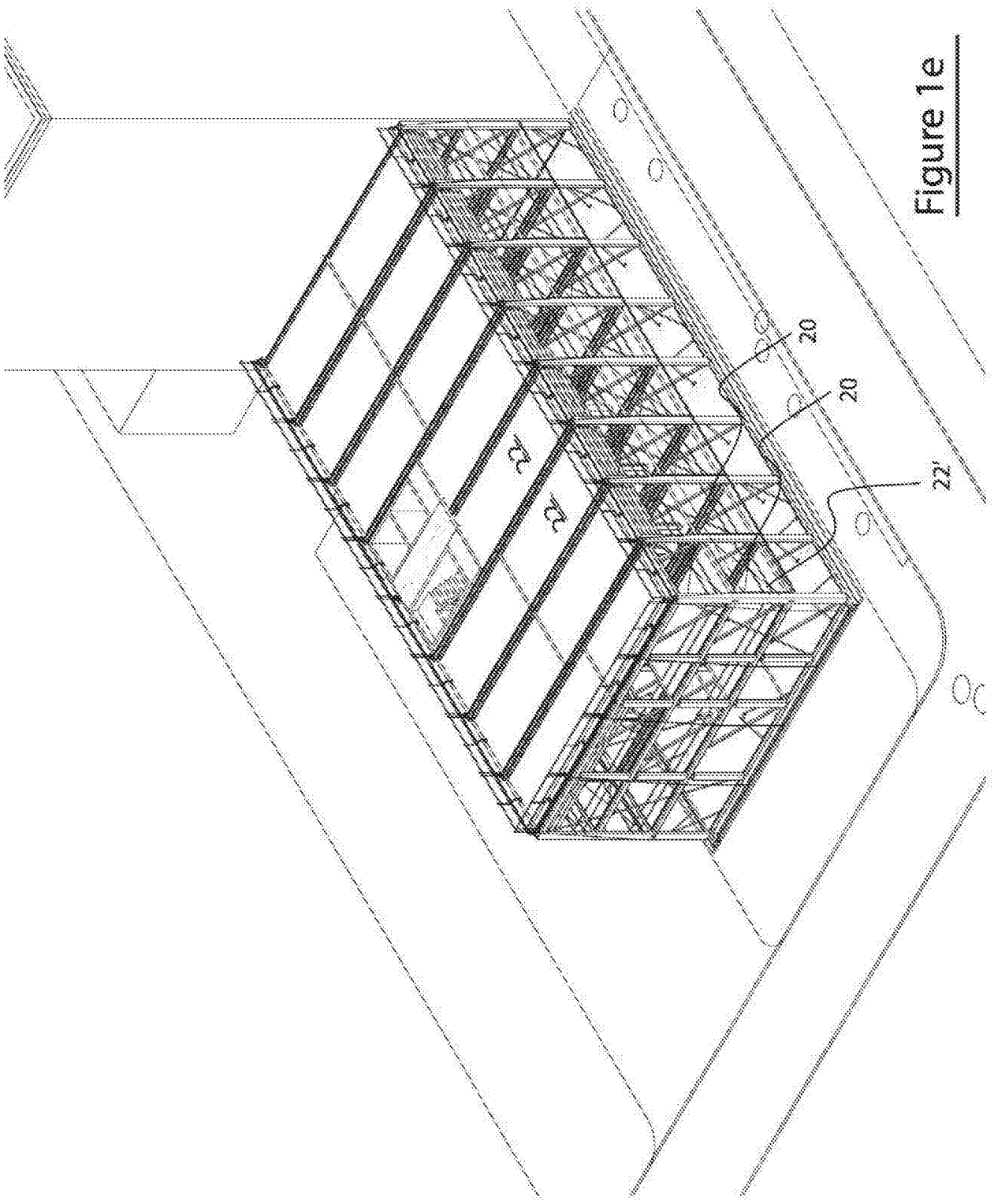

Figure 1e

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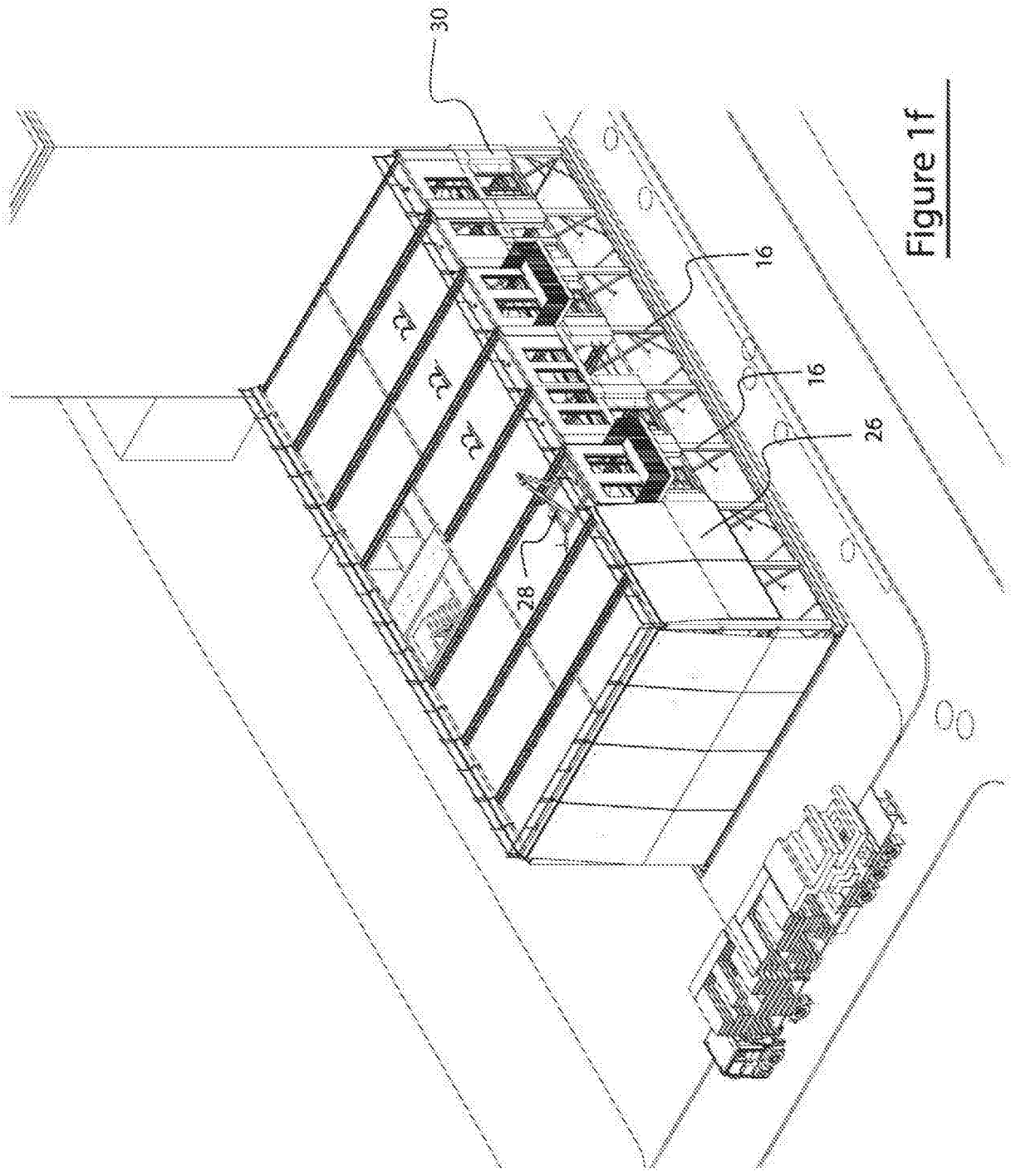

Figure 1f

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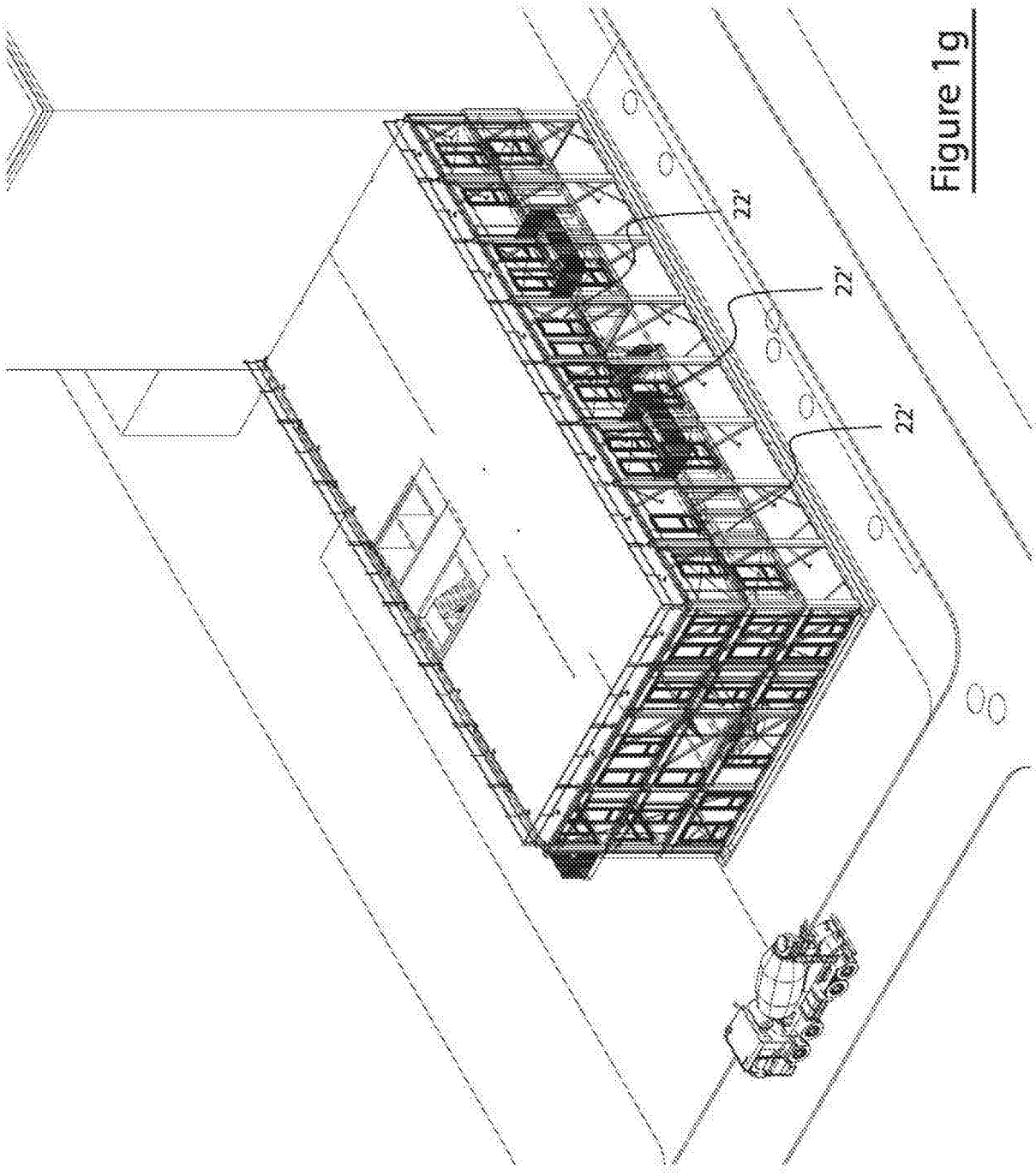

Figure 1g

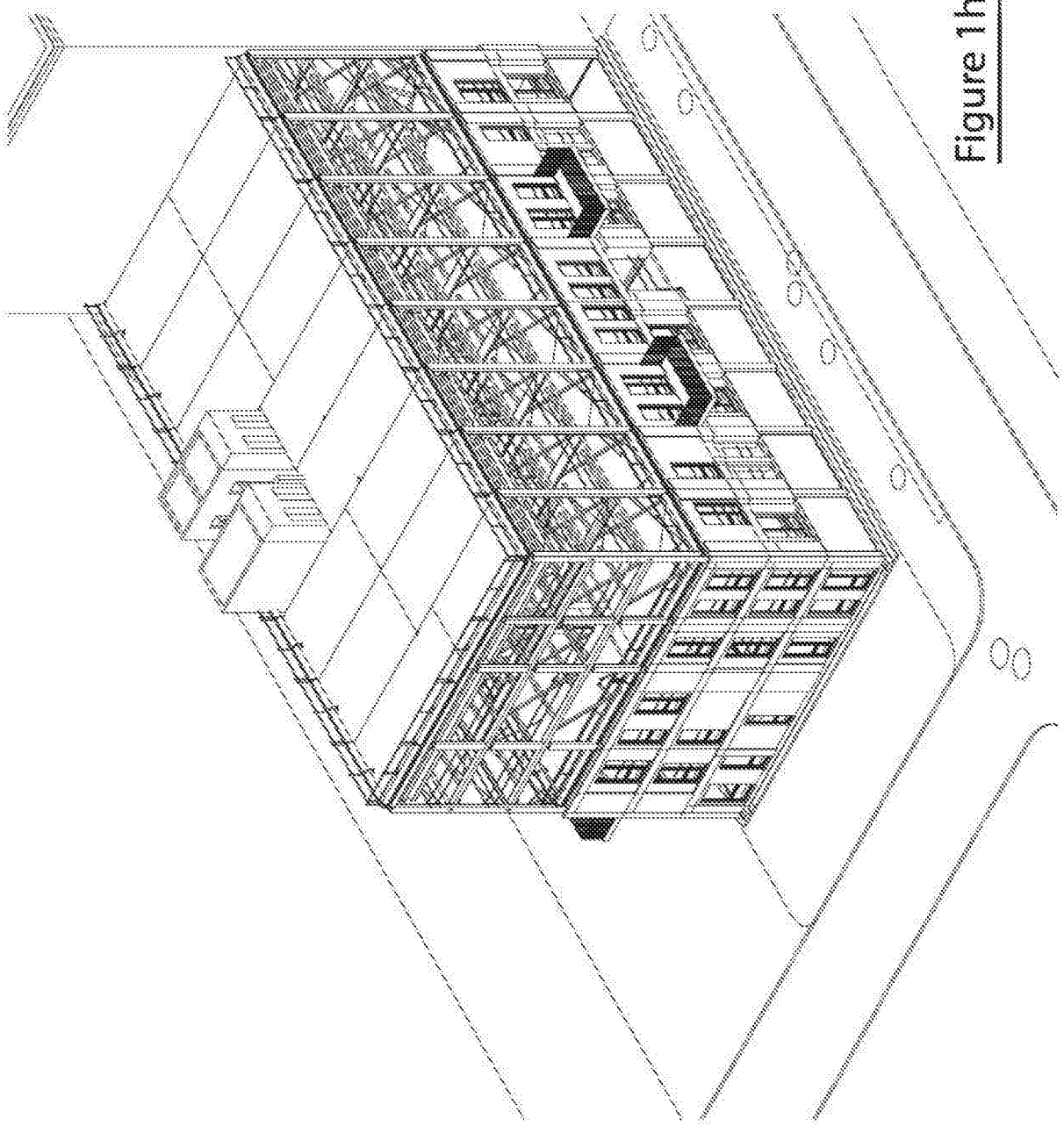

Figure 1h

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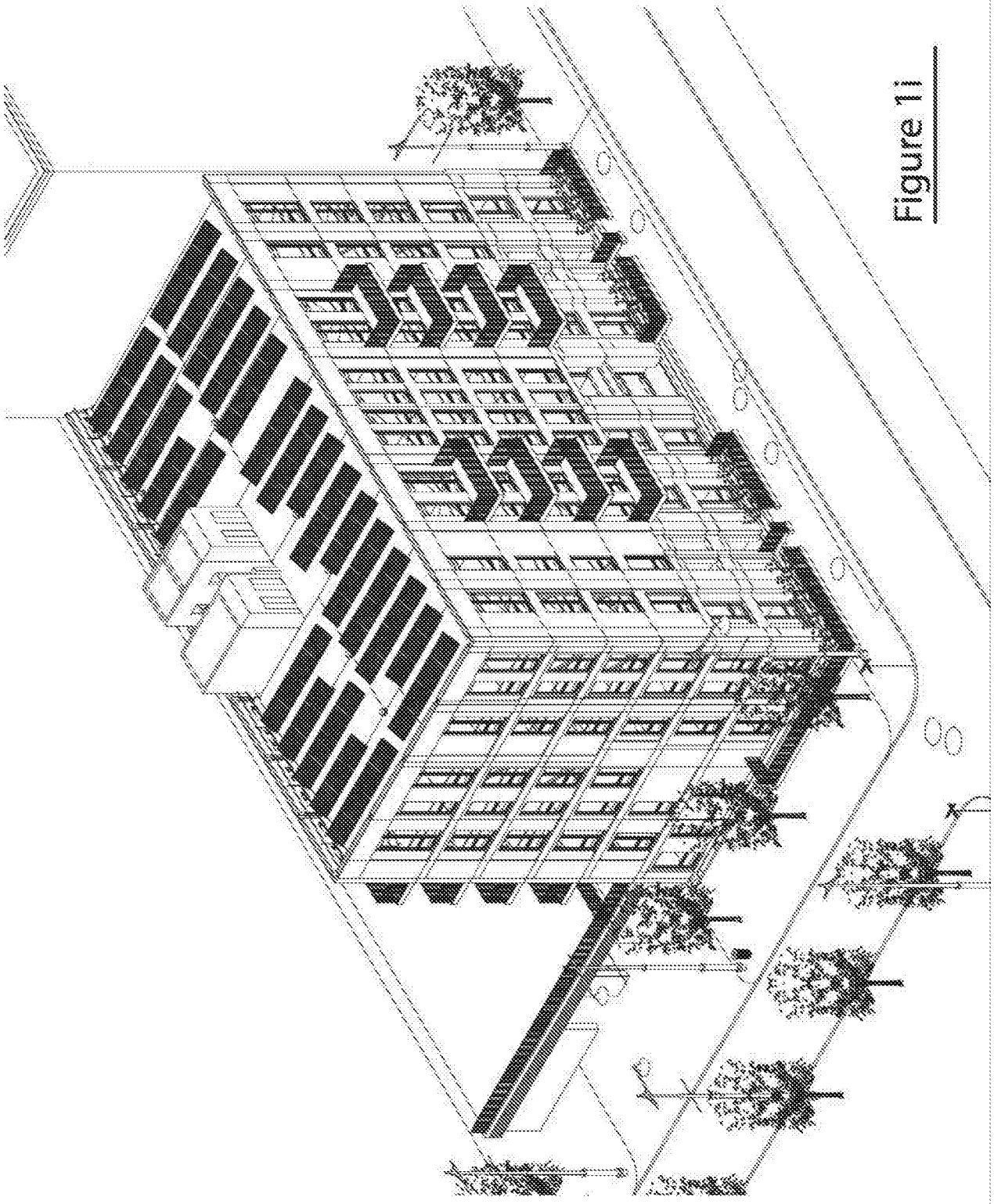

Figure 1i

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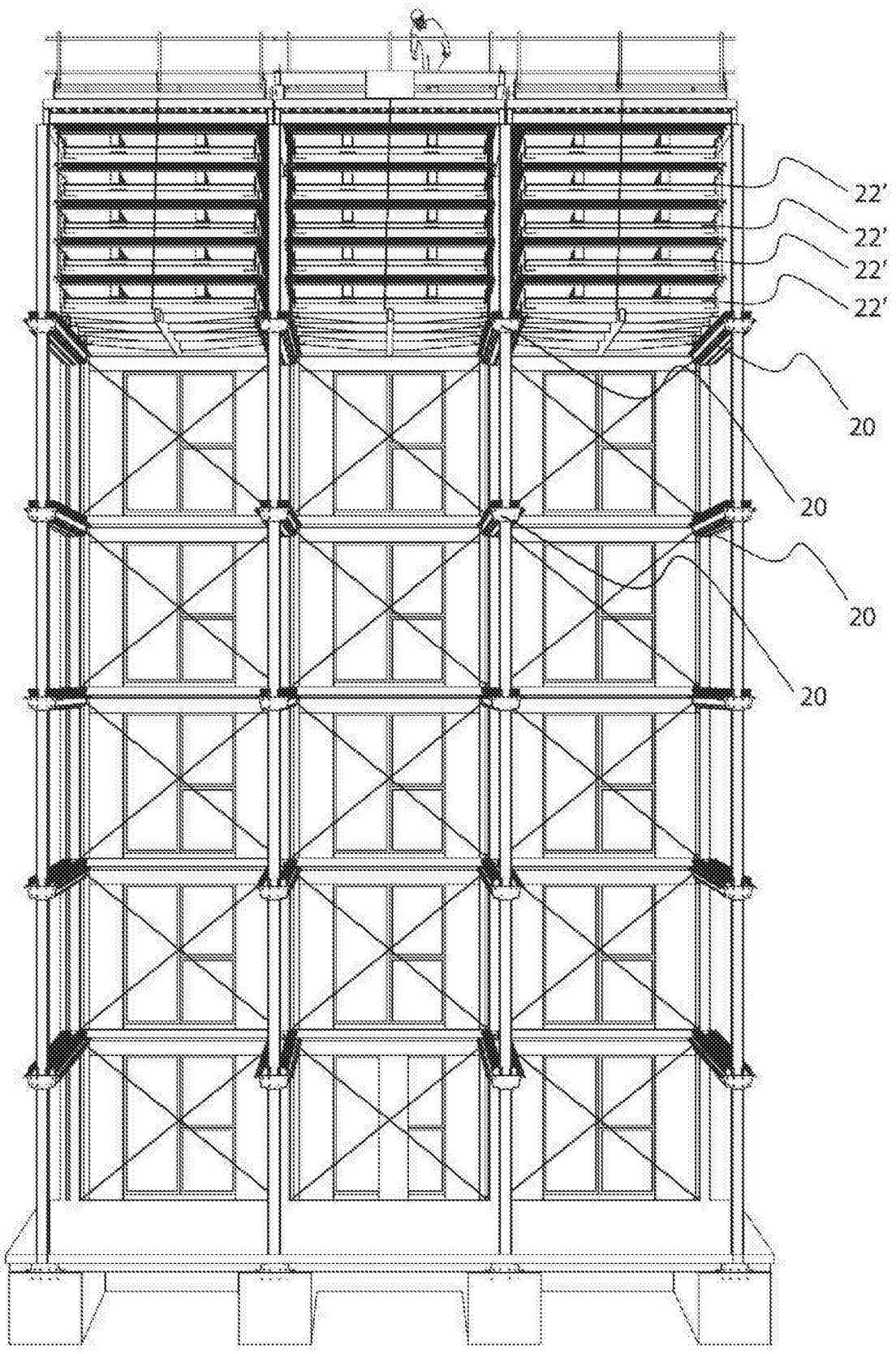

Figure 2a

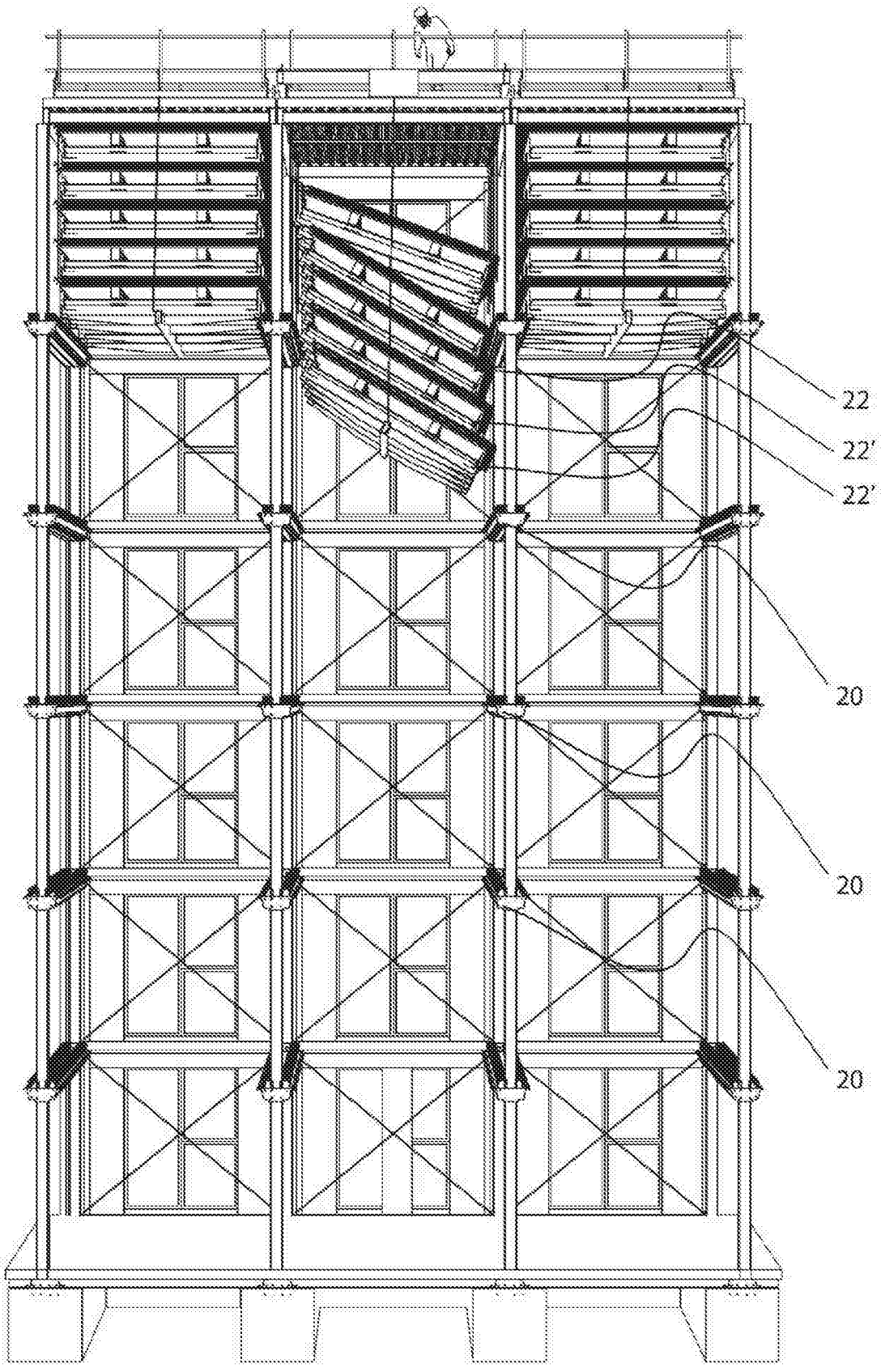

Figure 2b

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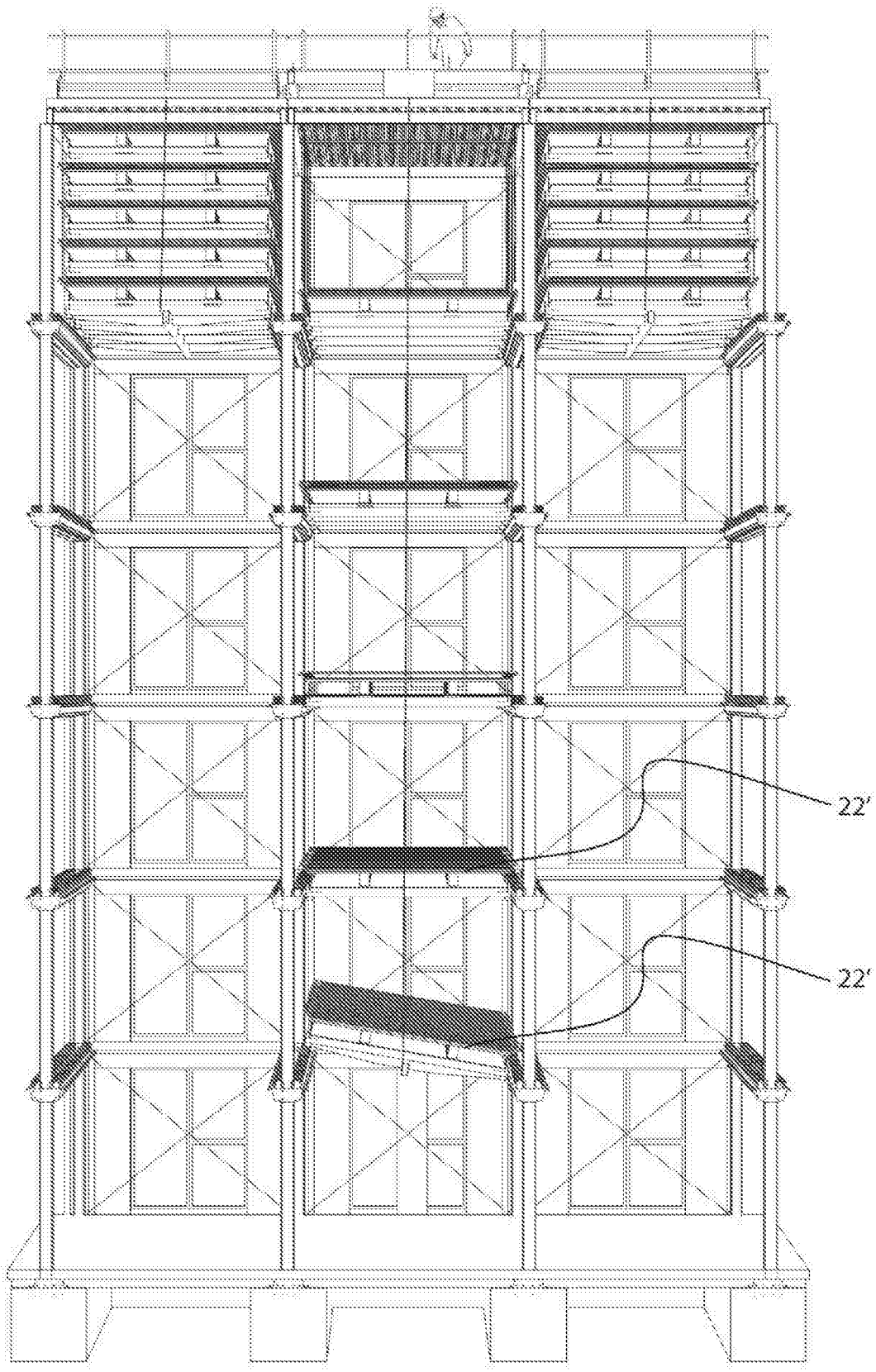

Figure 2c

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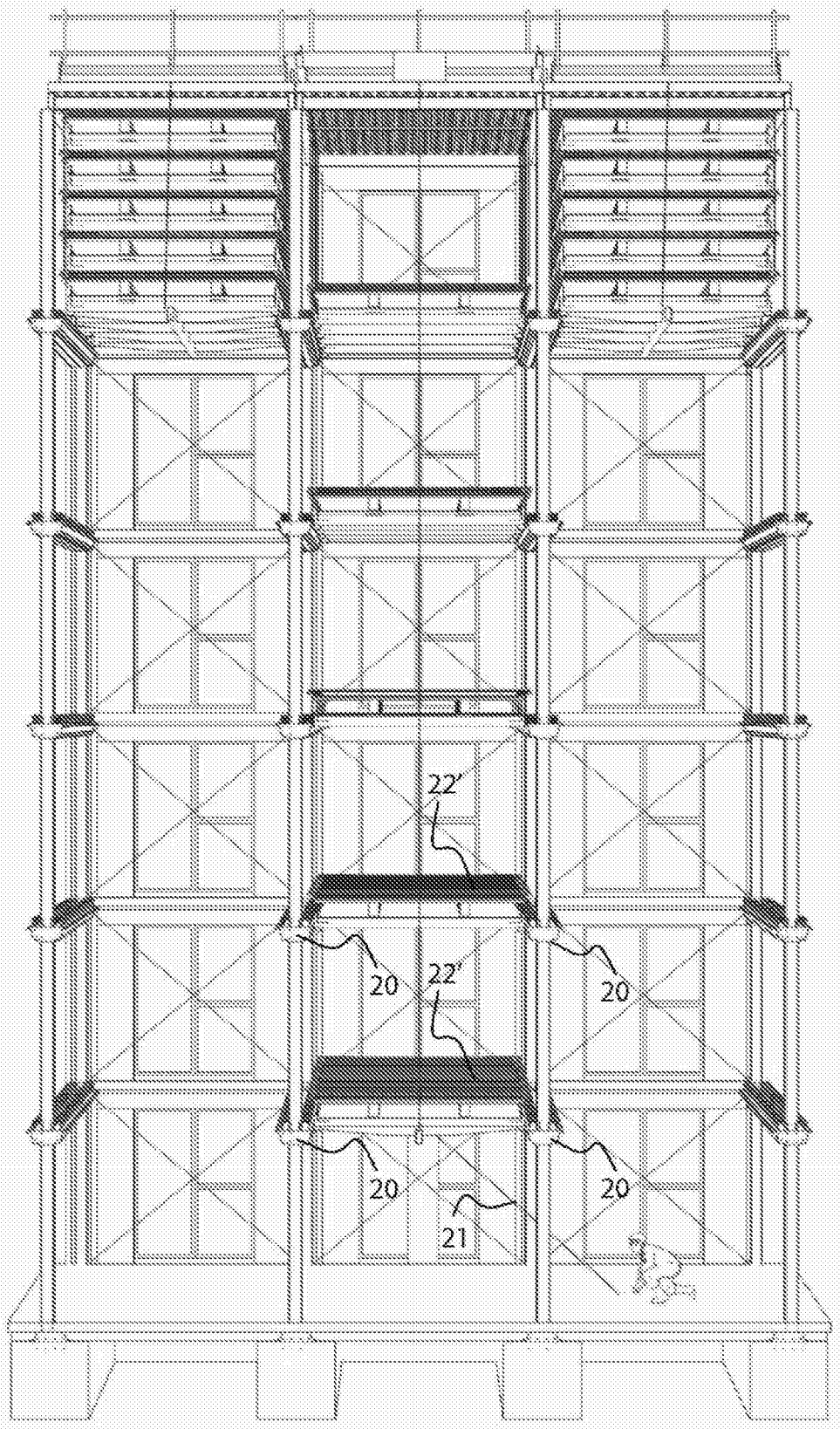

Figure 2d

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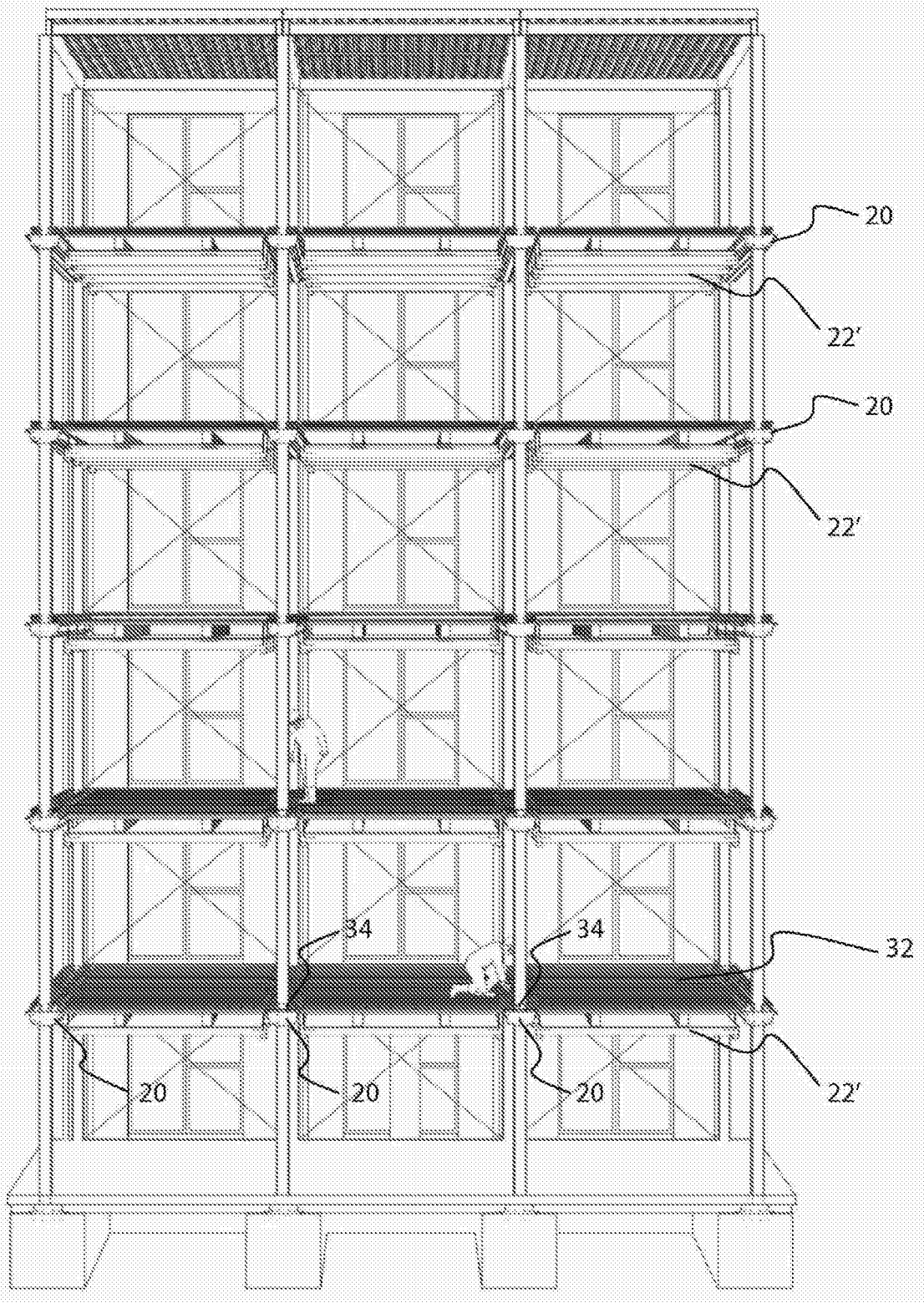

Figure 2e

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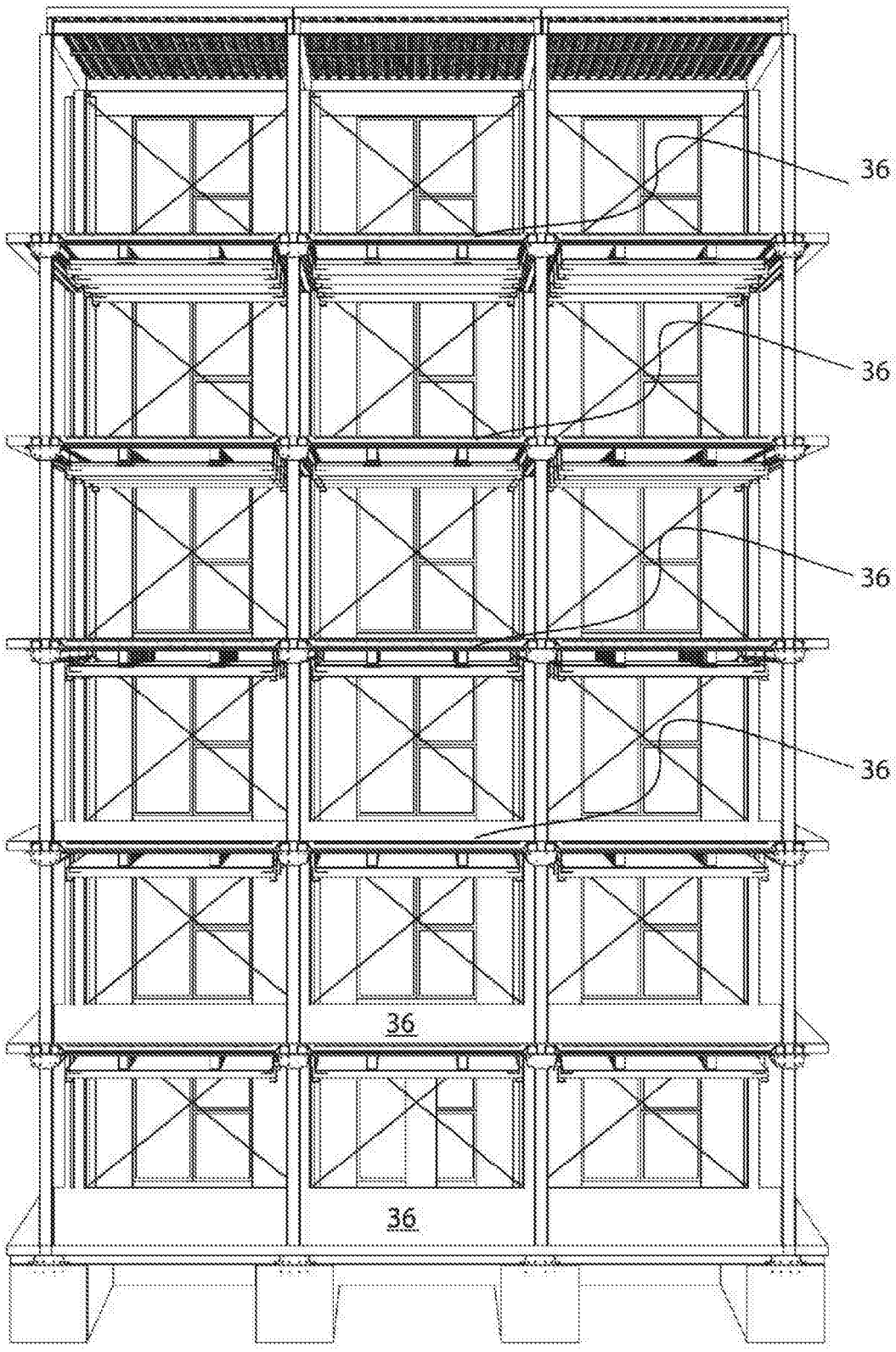

Figure 2f

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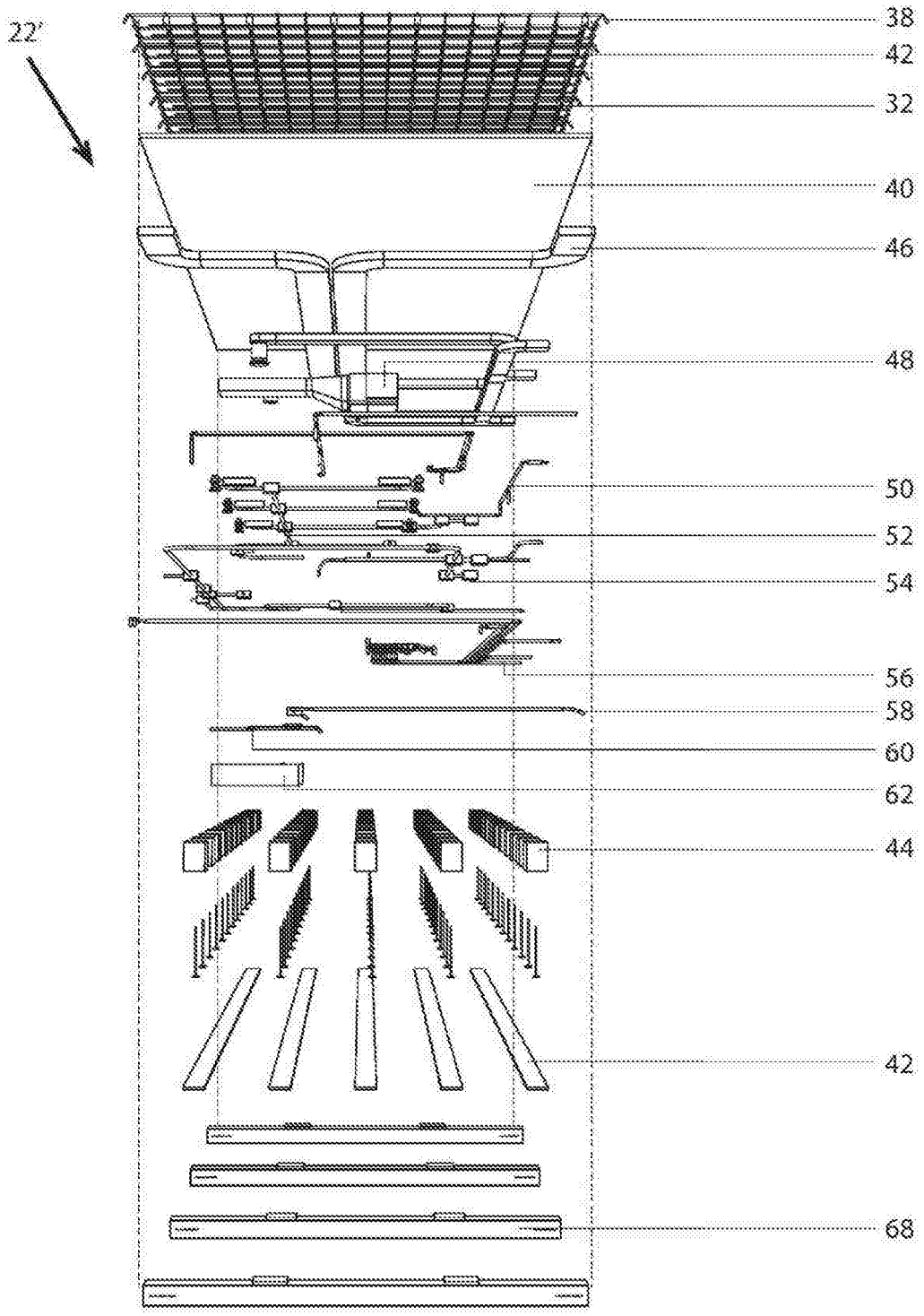

Figure 3

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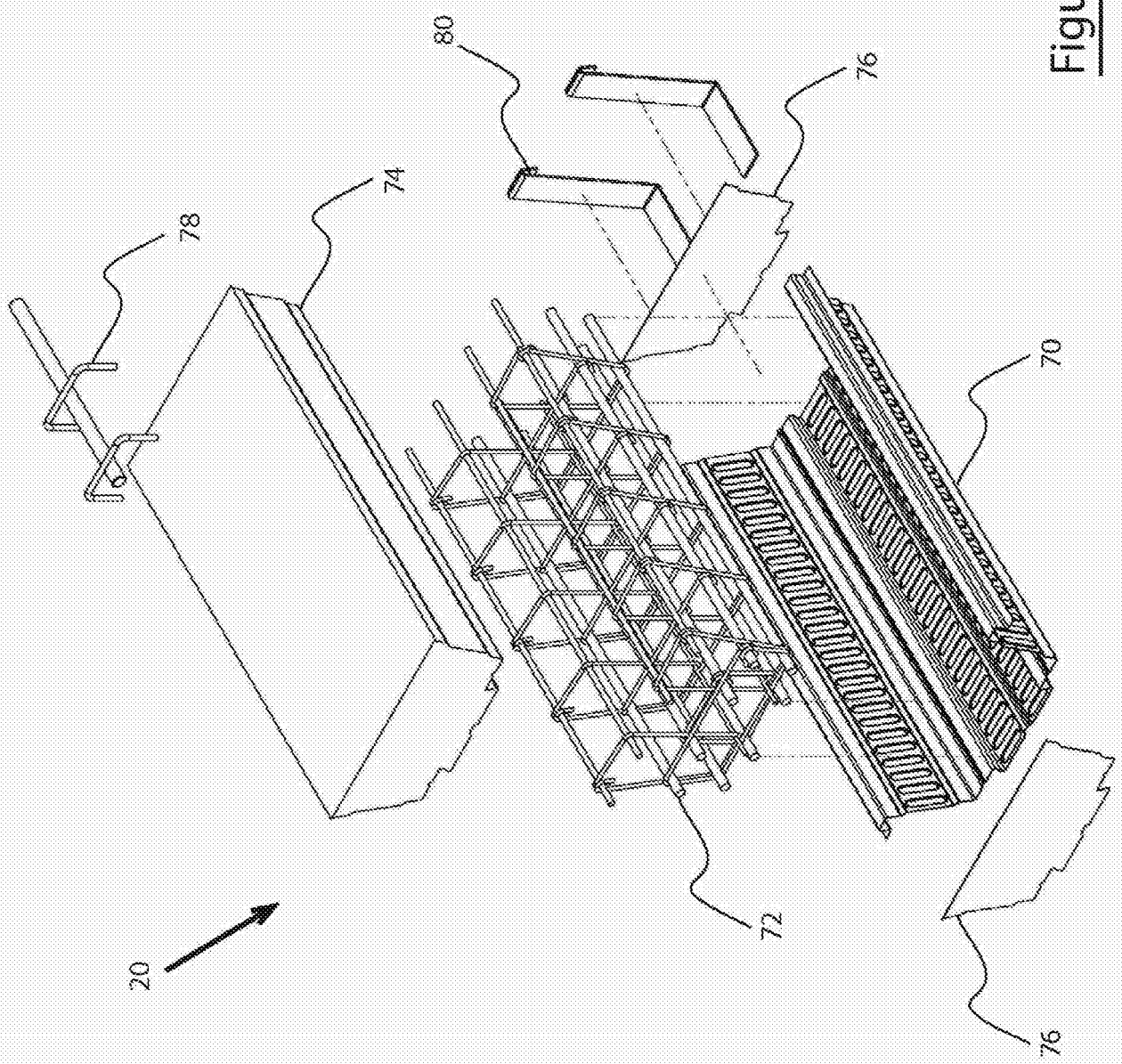

Figure 4a

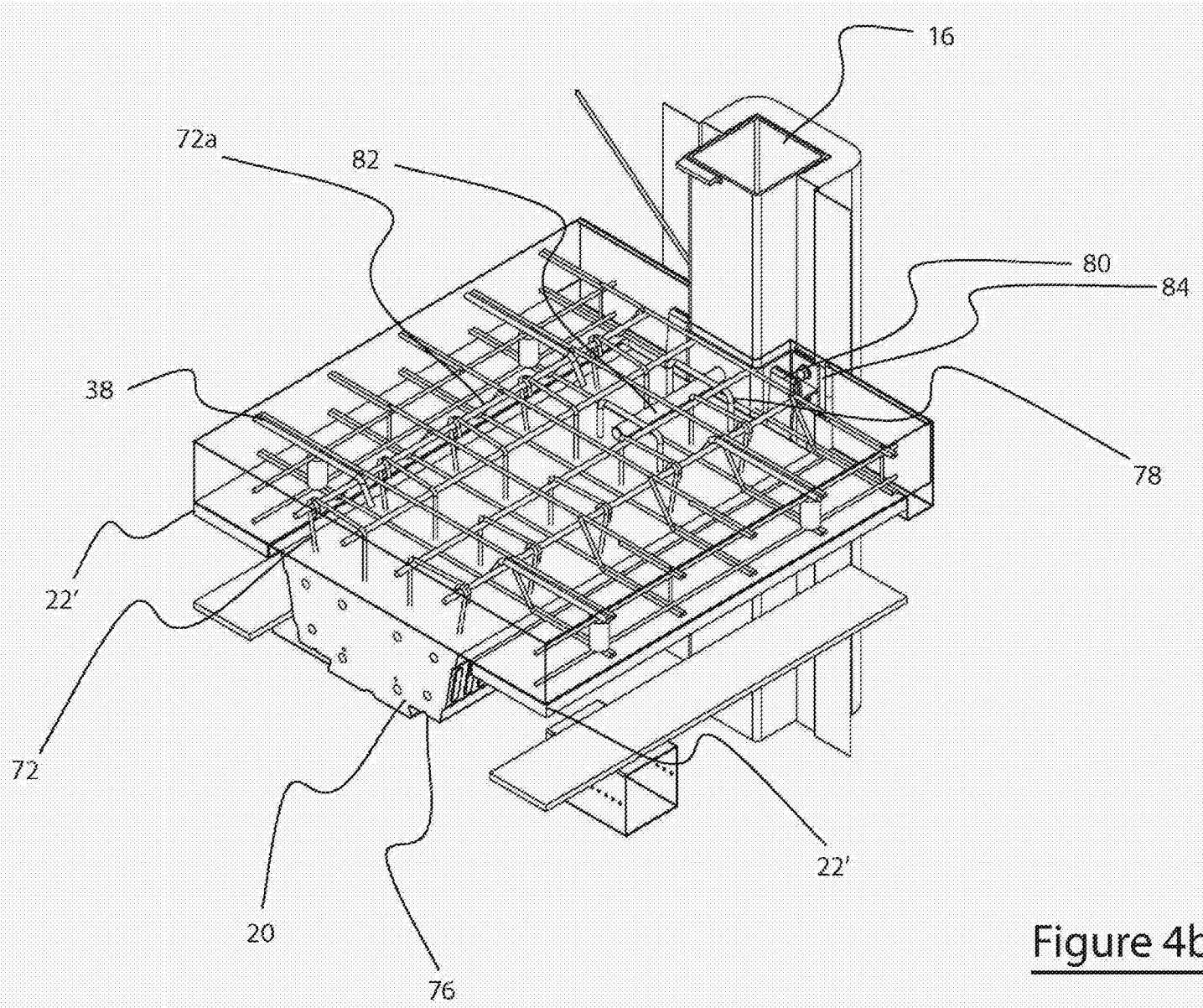

Figure 4b

BUILDING SYSTEM

The present invention relates to a building system for creating reinforced concrete structures.

BACKGROUND TO THE INVENTION

Reinforced concrete buildings are well known. In the usual construction process, a steel rebar cage is first constructed, in some cases pre-stressed, and then concrete is poured into the rebar cage. Shuttering sheets are provided before the concrete pour, so that while the concrete sets, the concrete is retained in position until it dries. This shuttering can often be removed and re-used once the concrete has set, but in some cases it is left in place and becomes a permanent (but ultimately redundant) part of the finished structure.

Shuttering which is left in place adds significant material cost to the building, but re-usable shuttering also has disadvantages because it needs to be stored when not in use and transported to and from the building site at the right times. Shuttering is often hired for building projects, but non-availability of the correct shuttering at the right time can lead to delays which can have a significant knock-on effect.

Known reinforced concrete construction processes generally involve constructing the building floor-by-floor, working upwards, with each floor having a rebar structure laid, and then shuttering installed and concrete poured, before removing the shuttering when the concrete is set. The reason for this 'bottom up' construction technique is that the steel structure is effectively unsupported until the concrete is added.

Steel-framed buildings are also well known. In this type of building, steel beams and columns rather than reinforced concrete provide the structural strength. 'Rib deck' beams are used to provide structural strength in each floor, and concrete is then poured over the rib deck beams. In a steel-frame building, this concrete is not structural, but rather is there to provide a smooth floor surface over the structural steel rib deck.

Steel-framed construction has some advantages compared with reinforced concrete. For example, it is generally quicker because multiple floors can be constructed at once, the concrete pour not being required to give each floor structural strength. However, attempts

to create a free-standing steel structure generally involve the use of complex fabrications to join steel components together. This adds significantly to the material cost of the build, since a custom-fabricated steel component can cost typically five or six times as much per tonne as compared with a standard steel beam without any drilling or other adaptations. Steel-framed buildings in general carry a much higher material cost as compared to reinforced concrete. A further advantage of concrete is that it can be transported to site easily and pumped, whereas specialist transport, possibly including escorts or road closures, is required for very large steel fabrications.

Building projects of all types generally have complex dependencies between stages. What this means is that a delay in completing one stage of the project will have a knock-on effect and can result in a much longer delay overall. The dependencies arise for a variety of reasons. For example, some internal building components are not water-resistant and therefore cannot be installed until the building is adequately waterproof. It is also generally not possible to do much work whilst concrete is setting, partly because the wet concrete surfaces must be left undisturbed and partly because the shuttering structures obstruct the site and prevent many installation jobs.

It is an object of the present invention to provide a building system which provides for a shorter build time without significantly increased material cost, which reduces the problems associated with temporary shuttering for concrete, and in which the build stages are substantially de-coupled to avoid knock-on delays.

STATEMENT OF INVENTION

According to a first aspect of the present invention, there is provided a method of constructing a multi-story reinforced concrete building, the method comprising the steps of:

installing vertical supports around the periphery of the building, each vertical support being sufficiently tall to span multiple stories;

fixing beams to the vertical supports, each beam running substantially horizontally between vertical supports, the beams being provided in the plane of each floor of the building to be constructed and being spaced apart horizontally;

installing substantially planar spanning panels between the beams, each spanning panel including a reinforcing mesh on its upper surface;

pouring concrete over the upper surfaces of the ceiling sections to form floor slabs.

As compared with existing building techniques, the method according to the invention has several advantages. The result is effectively a hybrid building, which is supported primarily by the steel frame during construction, but becomes a reinforced concrete building when completed. The construction process is fast and efficient because multiple floors can be constructed in one operation, but the material cost is kept low by the use of reinforced concrete. Also, the number of very large components requiring specialist transport is minimised, since the structure of the floor comes from concrete which is easily transported and poured. Because the spanning panels do not provide structure in themselves, unlike traditional rib deck, their size can be made small so that they can be transported on, for example, a standard flatbed lorry which does not require an escort.

A framework spanning multiple stories can be constructed, and then concrete poured to form the floor slabs for all of those stories. This reduces the time which is spent waiting for concrete to set before work can proceed on upper stories. It is envisaged that the vertical supports may span, for example, around three to five stories and therefore a five-story building could be constructed in one iteration of the method of the invention. Taller buildings can be constructed by iterating the method, building three to five floors at a time. This is still far more efficient than building a single floor at a time.

At the same time, because the concrete is poured onto reinforcing mesh which is provided on the upper surface of spanning panels, minimal temporary shuttering is required. In particular, very little if any shuttering needs to be installed vertically. In an embodiment, the concrete floor slabs are shuttered at their edges by horizontal cross braces on the vertical supports.

Pre-fabricated vertical wall cladding can be added at substantially any stage – the vertical walls are not required to support the floors, and therefore do not need to be cast in-situ.

Preferably, additional reinforcing bars may be added, spanning between horizontally adjacent spanning panels, before the floor slabs are poured. This means that the finished

reinforced concrete floor slab is essentially similar to known reinforced concrete floor slabs. The method of the invention allows for a much more efficient modular construction, since the reinforcing structure of each floor slab is built up from multiple smaller sections, but the additional reinforcing bars ensure that the structural integrity is at least as good as existing traditionally-constructed reinforced concrete buildings.

It is envisaged that the building may be constructed according to the method of the invention on a poured concrete ground slab, which may be constructed essentially by conventional means.

Prefabricated lift shafts, stair cores and/or service risers may be installed on site as part of the vertical support installation stage.

The vertical supports may comprise vertical columns and horizontal cross-braces. The horizontal cross-braces are preferably disposed at the level of each floor slab and so can act as shuttering at the edges of the slab. In particular, each vertical support may be substantially in the shape of an 'H'.

Temporary props may be installed at the base of the vertical supports, substantially diagonally between the vertical columns and the ground. The props allow the supports to stand vertically, before the horizontal beams are fixed and before any concrete is poured.

Intermediate vertical columns may be provided for supporting the horizontal beams at points between the vertical supports. The intermediate columns are preferably a single story high, and so multiple columns are installed, one on top of another, in a multi-story structure.

The horizontal beams are preferably pre-cast concrete and steel composite beams. Temporary props may be provided to support the horizontal beams before concrete is poured. The temporary props are preferably fixed substantially diagonally, between vertically-adjacent horizontal beams, and between the lowest horizontal beams and the ground slab.

The temporary props may be removed as soon as the concrete is set. The set concrete joins the different parts of the steel frame structure together, making the temporary props no

longer necessary. The temporary props are preferably clamped to the steel structure with releasable clamps, so that installation and removal is fast and easy, and the props can be reused multiple times. The temporary props are generally in the form of elongate bars, and take up minimal storage space as compared with known shuttering systems. In addition, the elongate bars themselves preferably have no complex fabricated features, and are therefore cheap to buy, and much of the purchase cost can be recovered even if they are scrapped after use.

The substantially planar spanning panels are preferably provided as part of a multi-story ceiling cassette. Each ceiling cassette preferably includes enough spanning panels to provide for the number of ceilings / floors spanned by each vertical support. For example, the ceiling cassette may include three to five spanning panels, each spanning panel forming a section of a ceiling on a different floor of the finished building. The ceiling cassette may then be 'unfolded' from the top of the structure, each spanning panel being placed on each story between the horizontal beams. The top spanning panel in the ceiling cassette may be a roof member, designed to ultimately form the external roof of the finished building. Usually, there would be no concrete pour and therefore no reinforcing mesh on the upper surface of the roof member. Instead, a waterproof roofing material may be installed between and over the roof members.

With a taller building where the method is iterated multiple times, the top spanning panel of the ceiling cassettes installed in the lower sections will ultimately form an internal floor and ceiling. Therefore, the top spanning panel will be provided with a reinforcing mesh in the same way as the other spanning panels. In either case, it is preferable for the top spanning panel in each cassette to be water-resistant at least to a sufficient extent to protect the interior of the building during construction. This allows internal work, which must be protected from the weather, to be carried out independently of the installation of external cladding. This decouples the stages of the building project and makes it less likely that a delay to one stage would have a severe knock-on effect on the whole project.

Ceiling cassettes may also include safety rails / guarding around the top spanning panel. This allows safe working on the roof of the building (or the top of the partly-constructed building in the case of taller structures where the method is iterated). Temporary guarding

may also be provided fixed to the vertical supports, to allow safe working from intermediate floors of the partly completed building.

Ceiling cassettes may further include folded or rolled temporary waterproof sheeting, which can be unfurled over the side of the building from the top spanning panel when the ceiling cassette is in place. Preferably, this is done before the ceiling cassette is unfolded to deploy individual spanning panels. The temporary waterproof sheeting can be unrolled over the side of the building to protect the interior from rain and other weather before external wall cladding is installed. Again, this helps to decouple stages of the building process, allowing internal work to continue irrespective of any delays to the installation of cladding. As well as protecting the internal ceiling spanning panels which unfold from the ceiling cassette, the waterproof sheeting means that the internals of a building, including dry lining, joinery, electrics, plumbing, and even decoration and furnishing can potentially be completed before the external cladding is installed, if necessary.

Prefabricated wall cladding panels can be installed on the building at substantially any stage of the process, before or after the concrete floors have been poured. To facilitate the installation of the wall cladding, a support structure may be installed on the top ceiling member, fixed to the roof of the building and extending over the edge of the building. The support structure may be substantially in the form of an 'A frame'. The support structure may be used to hoist the wall cladding panels from the ground, to move each panel into its correct position for fixing to the building, without requiring the use of a crane.

The reinforcing mesh on each spanning panel may include interlocking sections extending outwardly from the edge of the mesh, for interlocking with adjacent reinforcing meshes. The interlocking sections preferably link with reinforcing meshes on the horizontal beams, to hold each spanning panel in place before the floor slabs are cast, and to form a continuous rebar mesh when the components are in place and interlocked. Once the floor slabs are cast, the interlocking sections ensure that the floor slab is in the form of a continuous strong reinforced slab with similar structural properties to traditionally-constructed reinforced slabs which are cast in-site on continuous rebar cages. The interlocking sections may be substantially in the form of hooks.

A shuttering layer may be included in each ceiling panel, directly below the reinforcing mesh. The shuttering layer is preferably made from cardboard, for example in a corrugated or honeycomb structure. The cardboard may be waxed to prevent it becoming soggy on contact with wet concrete. Cardboard is an ideal material because it is cheap, has very low mass, and can be made from recycled materials. It is envisaged that the shuttering will remain as a permanent but redundant part of the building, since it would be difficult to remove bearing in mind the other components which are ideally included in each ceiling panel. Low cost and environmental sourcing are therefore important considerations.

Alternatively or additionally, a layer of OSB, MDF or a similar engineered board may be provided to give the shuttering layer additional strength. The strength required in embodiments will depend on the size of each ceiling panel and the amount of concrete which is to be supported above the shuttering layer.

A services void may be provided below the shuttering, and a plasterboard ceiling below that. The plasterboard may be attached to the underside of trips of OSB (oriented strand board) or a similar engineered board, which is spaced from the shuttering by spacers to form the services void. The spacers may be made from cardboard, for example in a honeycomb structure. Services (e.g. conduit for electrical wiring, ducting for air conditioning etc.) may be provided in the void as required.

Clips may extend vertically downwards from the reinforcing mesh, specifically from the interlocking sections. The clips may be used to attach temporary support beams below the plasterboard layer while the concrete sets. Once the concrete has set, the temporary support beams can be removed and reused, but the vertical clips remain in place, cast into the concrete. Where the clips extend below the plasterboard ceiling, they may be cut off (e.g. with wire cutters) when no longer required.

The spanning panels of each ceiling cassette may be joined together by cables. The cables may be used to control the lowering of the spanning panels from the top of the building, so that each panel rests in position on the plane of each floor. Preferably, cables may be provided which are offset from either side of a centreline of each spanning panel. This allows the spanning panels to be tilted to allow them to pass down through the building, between the horizontal beams. Once each panel is just above the plane of its floor, it can be

tilted back to a horizontal position and then lowered onto the horizontal beams. Preferably, the interlocking sections extending from the reinforcing mesh hook onto the horizontal beams and hold the spanning panels in position before concrete is poured.

In one embodiment, the ceiling cassettes are provided with releasable cables which hold each spanning panel at a vertical height just above its final installed location between the horizontal beams. The panels may be lowered into place while tilted, then straightened into the horizontal plane, and then the releasable cables can be released allowing the interlocking sections of the spanning panels to drop over the horizontal beams.

The horizontal beams are preferably pre-cast concrete and steel composite beams, formed substantially as an elongate tray, a reinforcing mesh within the tray and concrete poured over the mesh into the tray. Preferably, the reinforcing mesh extends above the level of the pre-cast concrete, and includes substantially horizontal (i.e. parallel to the elongate beam) reinforcing bars spaced from the level of the concrete by substantially vertical reinforcing bars. The interlocking sections which extend from the spanning panels preferably hook over the horizontal reinforcing bars of the horizontal beams. The reinforcing mesh on the spanning panels therefore links to the reinforcing mesh extending above the pre-cast concrete on the horizontal beams, to form a continuous reinforcing structure for a continuous cast concrete floor slab in the finished building.

Hooks may be provided on the ends of each horizontal beam, for joining the horizontal beams to the vertical support sections before concrete is poured. Preferably, the hooks are cast into the concrete when the pre-cast beam is manufactured. This obviates the need to add fixings to the beams after manufacture, during the building process. The hooks on the horizontal beams preferably hook over brackets provided on the vertical support sections. The brackets may be in the form of a two-part collar which can be clamped around the vertical support section. Ideally, minimal drilling is required on the vertical support section. In a preferred embodiment, a single hole is drilled through both parts of the clamp and the vertical support section, to hold each bracket in place by means of a bolt or a pin, for example.

When concrete is poured over the horizontal beams and spanning panels, the result is a floor slab which is structurally similar to known buildings. A continuous rebar mesh exists

between the beams, spanning panels and vertical supports, and so although a modular construction technique is used with novel 'hooked' fixings between parts, the finished building is of conventional construction, and so safety and integrity can be assured with high confidence.

According to a second aspect of the invention, there is provided a method of installing spanning panels in a multi-story building, the building including spaced-apart horizontal beams for supporting the spanning panels between the beams, the beams being spaced apart in multiple substantially horizontal floor planes corresponding to a position of each spanning panel when the building is constructed, and the method including the steps of:

providing a ceiling cassette in the form of a stack of spanning panels, and positioning the ceiling cassette at the top of the building;

titling the spanning panels out of a horizontal plane;

lowering the spanning panels between horizontal beams, while they are in the tilted position;

de-tilting each spanning panel back into a horizontal plane at a point when it is above and adjacent to the horizontal beams of its respective floor plane;

lowering each spanning panel to rest on its respective horizontal beams.

The spanning panels may be lowered from the top of the building using cables. In particular, cables may be attached to the spanning panels offset from either side of a centreline, for controlling the tilting of the spanning panels from the roof.

Because the spanning panels are designed to be supported on the horizontal beams, the spanning panels will be slightly wider than the gap between the beams (or at least, some part of the spanning panel, for example the reinforcing mesh, is wider than the gap between the beams). However, by tilting the spanning panel, the horizontal footprint of the spanning panel can be reduced so that it may pass between the beams on the upper floor planes. When each spanning panel is above its respective horizontal beams, it can be tilted back into the horizontal plane so that either side of the spanning panel will rest on an adjacent horizontal beam. In some embodiments, only a top part of the spanning panel, e.g. a

reinforcing mesh, will 'rest' on the horizontal beams, so the bulk of the spanning panel will 'hang' between the beams.

Ideally, a stop is provided to prevent each individual spanning panel from being lowered further than its respective horizontal beams. In some embodiments, a stop is provided which stops the spanning panel at a point just above (for example, 10cm above) the horizontal beams. When each spanning panel is in position, just above its respective beams, the stops can be removed to allow the spanning panels to drop into position. The stops may simply be cables which enforce a maximum vertical separation between spanning panels.

Preferably, a reinforcing mesh is provided on an upper surface of each spanning panel, the method further comprising the step of pouring concrete over the upper surface of the spanning panel in each horizontal plane.

According to a third aspect of the invention, there is provided a multi-story ceiling cassette including two or more substantially planar spanning panels, the spanning panels being joined to each other and stacked on top of each other, the spanning panels being movable apart from each other for positioning each spanning panel in a respective substantially horizontal floor plane, and each spanning panel including:

a reinforcing mesh on an upper surface of the spanning panel;

a water-resistant shuttering layer beneath the reinforcing mesh;

a services void beneath the shuttering layer; and

a ceiling board beneath the services void.

The water-resistant shuttering layer is preferably made of cardboard, for example waxed cardboard which has good water-resistant properties. The services void may be formed by spacer blocks between the shuttering layer and the ceiling layer, and the spacer blocks may also be made from cardboard, for example in a honeycomb structure.

The ceiling board may be plasterboard.

Clips or ties may depend substantially vertically from the reinforcing mesh, for attaching temporary support bars beneath the ceiling board. The temporary support bars may be, for

example, aluminium box section. These support bars provide additional strength when concrete has been poured over the reinforcing mesh but not yet set. When the concrete has set, the support bars may be removed. Preferably, the vertical clips are thin enough to be cut off with wire cutters at either side of the ceiling boards, once the concrete has set, the temporary support bars removed, and the clips are no longer required.

The spanning panels are preferably joined together by cables for controlling the lowering of the spanning panels from the top of the building, for example in accordance with the second aspect of the invention. Most preferably, cables are provided which are offset from either side of a centreline of each spanning panel. These allow the panel to be tilted so that it may pass between adjacent horizontal beams and lowered to a lower floor plane.

The reinforcing mesh of each spanning panel preferably includes interlocking sections extending outwardly from the edge of the mesh, for interlocking with adjacent reinforcing meshes. In some embodiments, each spanning panel effectively hangs from horizontal beams on either side, by means of the interlocking sections on the reinforcing mesh.

Embodiments of the second and thirds aspects of the invention may be used in embodiments of the first aspect of the invention. Likewise, it will be apparent that preferable or optional features of the spanning panels and ceiling cassette in the first aspect of the invention may be incorporated in embodiments of the second and third aspects of the invention.

According to a fourth aspect of the invention, there is provided a prefabricated composite beam including:

an elongate tray;

a reinforcing mesh disposed within the tray and extending above the top of the tray; and

concrete substantially filling the tray and covering the part of the reinforcing mesh which does not extend above the top of the tray.

The composite beam is pre-cast and can provide a structural horizontal beam component during construction of a building. At the same time, the reinforcing mesh extending from

the top of the tray can form part of in-situ cast structures. A single slab can be cast across a number of the beams of the invention and across other components (e.g. spanning panels), which may be supported by the beams before the slab is cast.

The tray, which is preferably steel, acts as shuttering during casting of the pre-cast beam, but also becomes a permanent part of the structure of the beam. The tray preferably includes indentations rather than a smooth inner surface. Such a tray has reinforcing properties and means that a smaller quantity of reinforcing mesh can be used to make the beam. Beams of this type are easy and cheap to make – no special moulds are required, and the beams can even be cast on site if necessary.

The part of the reinforcing mesh which extends above the top of the tray may include reinforcing bars which run substantially parallel with the elongate extent of the tray, and further reinforcing bars for spacing the parallel bars from the top of the tray. The parallel bars may interlock with rebar 'hooks' on other components, in effect the parallel bars forming a rail so that the composite beam may be used to support spanning panels by hanging the panels from the rail during construction. When all spanning panels are fitted, a concrete slab may be poured over the beams, spanning panels, and any other components, and the parallel bars form part of a traditional rebar cage within an in-situ poured reinforced concrete floor slab.

The prefabricated beam may include a hook extending away from each end of the beam and above the beam, part of the hook being cast into the concrete of the beam.

Again, the hook allows the prefabricated beam to be easily attached to and supported on other components, for example steel structural columns. Once a concrete slab is poured over the beam, the hooks become embedded in the concrete and effectively form part of a rebar mesh.

Preferably, two hooks are provided at each end of the beam. In some embodiments, part of the reinforcing mesh which extends above the tray includes at least one loop or staple at each end of the beam. The two hooks may be positioned at either side of the loop / staple. In use, the beam may be connected to another component by passing a pin through the loops and fixing the pin to the other component (which may be as simple as drilling a hole in

the other component and inserting an end of the pin into the hole). The hooks on the beam may also rest on a rail or flange fixed to the other component. Again, when concrete is poured over the beam, the pin and hooks become cast into the concrete and form part of a reinforcing mesh.

According to a fifth aspect of the invention, there is provided a method of fixing a horizontal beam to a vertical support column,

the horizontal beam including a reinforcing mesh extending above its upper surface, and attachment means for fixing the beam to the vertical support, the attachment means extending above the upper surface of the beam,

and the vertical support column including attachment means for interfacing with the attachment means of the horizontal beam,

and the method comprising the steps of:

attaching the attachment means of the horizontal beam to the attachment means of the vertical support;

pouring concrete over the horizontal beam to cover the reinforcing mesh and the attachment means.

The attachment means on the beam may include staples or loops extending from the upper surface of the beam, and the method may further include the step of drilling a hole through the vertical support, and providing a pin through the hole in the vertical support and also through the loops of the beam.

The attachment means of the vertical support may include a flange for supporting a hook. The flange may be provided as part of a bracket, and the method may include the step of clamping the bracket around the vertical support. A hole may be drilled through the bracket and through the vertical support, and the pin passed through the loops in the beam, the hole in the bracket, and the hole in the vertical support.

Embodiments of the fourth and fifth aspects of the invention may be used in embodiments of the first aspect of the invention. Likewise, it will be apparent that preferable or optional

features of the prefabricated beam and the method of fixing the beam to the vertical support in the first aspect of the invention may be incorporated in embodiments of the fourth and fifth aspects of the invention.

DESCRIPTION OF THE DRAWINGS

For a better understanding of the present invention, and to show more clearly how it may be carried into effect, preferred embodiments will now be described by way of example only, with reference to the accompanying drawings in which:

Figure 1a shows a first stage of construction of a reinforced concrete building, according to the method of the invention;

Figure 1b shows a second stage of construction of a reinforced concrete building, according to the method of the invention;

Figure 1c shows a third stage of construction of a reinforced concrete building, according to the method of the invention;

Figure 1d shows a fourth stage of construction of a reinforced concrete building, according to the method of the invention;

Figure 1e shows a fifth stage of construction of a reinforced concrete building, according to the method of the invention;

Figure 1f shows a sixth stage of construction of a reinforced concrete building, according to the method of the invention;

Figure 1g shows a seventh stage of construction of a reinforced concrete building, according to the method of the invention;

Figure 1h shows an eighth stage of construction of a reinforced concrete building, according to the method of the invention;

Figure 1i shows a finished reinforced concrete building, constructed according to the method of the invention;

Figure 2a shows a first sub-stage of the stage of construction of a reinforced concrete building shown in Figure 1e;

Figure 2b shows a second sub-stage of the stage of construction of a reinforced concrete building shown in Figure 1e;

Figure 2c shows a third sub-stage of the stage of construction of a reinforced concrete building shown in Figure 1e;

Figure 2d shows a fourth sub-stage of the stage of construction of a reinforced concrete building shown in Figure 1e;

Figure 2e shows a fifth sub-stage of the stage of construction of a reinforced concrete building shown in Figure 1e;

Figure 2f shows a sixth sub-stage of the stage of construction of a reinforced concrete building shown in Figure 1e;

Figure 3 is an exploded view of a spanning panel according to aspects of the invention;

Figure 4a is an exploded view of a pre-cast concrete and steel composite beam; and

Figure 4b shows the composite beam of Figure 4a, together with a vertical support and two adjacent spanning panels.

DESCRIPTION OF THE EMBODIMENTS

Referring firstly to Figure 1a, construction of a building according to the method of the invention begins by preparing foundations and casting a concrete ground slab 10. This is done in a conventional manner and will not be described in detail. A prefabricated stair core 12 and lift shaft 14 are provided on the ground slab.

Vertical supports 16 are then installed around the periphery of the ground slab. Each vertical support is in the form of a pair of vertical columns connected together with horizontal cross-braces. The cross-braces are positioned at the level of the floors of the finished structure. Note also that safety guarding is provided on the vertical supports, to allow safe working from the floors of the partially completed building.

The vertical supports 16 are substantially in the form of H-frame columns. Temporary diagonal support props 18 are fixed between the ground slab and the vertical supports 16, in order to keep the vertical supports 16 upright at this early stage of the build process.

Figure 1a shows just three vertical supports 16 installed. However, it will be understood that vertical supports 16 are to be installed around the entire periphery of the ground slab at this stage of the build.

In Figure 1b, all of the vertical supports 16 have been installed. In addition, horizontal pre-cast concrete and steel composite beams 20 have been fixed between opposing vertical supports 16. The horizontal composite beams 20 are installed at the level of each floor in the finished structure. It will also be noted that the horizontal composite beams 20 are at the same vertical height as the horizontal cross braces which form part of the H-frame vertical supports.

The manner of fixing between the composite beams 20 and the vertical supports 16 is described in more detail below, with reference to Figure 4b.

Referring now to Figure 1c, ceiling cassettes 22 are lifted to the top of the structure, and placed between the uppermost horizontal beams 20. Each ceiling cassette 22 includes enough planar spanning panels for all stories of the building or part of the building which is being constructed. The ceiling cassettes 22 form a working platform at the top of the building, and safety guarding 24 is installed around the edge of the platform, on the uppermost spanning panels, to ensure safe working from the platform.

In Figure 1d, temporary waterproof sheeting 26 has been unfurled from the platform at the top of the building, to protect the interior of the building before external wall cladding is installed. Note that in the Figures, the waterproof sheeting 26 is only shown in Figure 1d to ensure that other important detail is not hidden from view. However, it will be understood that the waterproof sheeting may remain deployed as appropriate during the building process, whenever there is a need to protect the interior of the building when wall cladding has not yet been installed. One of the major advantages of providing this temporary waterproof sheeting is that it helps to 'decouple' the stages of the build process, allowing more flexibility as to the order in which the stages are performed. For example, if

installation of wall cladding is delayed for some reason, further operations which depend on dry conditions inside the building can continue – for example, build-out of internal walls, wiring, plumbing, decorating and even potentially furnishing.

In Figure 1e, the individual spanning panels 22' of each ceiling cassette 22 are lowered to rest onto the horizontal beams 20 on each floor. This process is described in greater detail below with reference to Figures 2a to 2f.

Figure 1f shows wall cladding panels 30 being lifted into place and fixed to the vertical supports 16. An A-frame structure 28 is positioned on the working platform at the top of the building, and is used as a support for a pulley to lift each cladding panel 30 into place. Note that no large equipment, e.g. a crane is required for this task, which can take place concurrently with other tasks. Each sheet of temporary waterproof sheeting 26 can be removed just before cladding is installed on that section of wall, to ensure that the inside of the building remains protected from the weather at all times.

In Figure 1g, all of the spanning panels 22' of the ceiling cassettes 22 have been lowered to the appropriate floor level. At the top of each ceiling panel 22' is a steel rebar cage, and there is also a rebar cage protruding from the upper surface of each horizontal composite beam 20. The rebar cage of each spanning panel 22' includes hooks which hook over sections of the rebar cage of the horizontal composite beams 20. When the spanning panels 22' are in place, resting between the beams and retained by the hooks on the rebar cages, additional 'stitching' lengths of rebar are installed, each 'stitching' rebar spanning at least two adjacent spanning panels 22' and the horizontal beam 20 between the panels 22'. Once all the 'stitching' lengths are in place, concrete floor slabs are poured on each floor. The horizontal cross-braces of the H-frame vertical supports 16 act to shutter the concrete around the edge of the slabs, keeping the concrete in place while it sets. When the concrete has set, the end result is a continuous reinforced concrete floor slab, with similar structural properties to floor slabs made by more conventional means. However, in the method of the invention this is achieved by using relatively small prefabricated sections which can more easily be transported to site and more quickly assembled. It will be noted that all components used in the construction of the building have been transported to site on flatbed lorries, which are small enough to travel in ordinary traffic without the

requirement to notify the police in advance. The main structure of the building comes from concrete, which is extremely easy to transport and pump into place.

The method of the invention may be used to construct a range of different buildings, from around three stories upwards. It is envisaged that generally buildings will be constructed according to the method around three to five stories at a time. In this example, Figure 1h shows another three stories being constructed on top of the first three stories constructed in Figures 1a to 1g. Figure 1i shows a finished six-story building constructed with two iterations of the inventive method.

Referring now to Figures 2a to 2f, the process of deploying the individual spanning panels 22' of the ceiling cassettes 22 will now be described in more detail. The spanning panels 22' which make up each ceiling cassette 22 are joined together by cables, which can be released from the top of the structure to lower and position the spanning panels 22'. As shown in Figure 2b, the spanning panels 22' are tilted to allow them to pass between adjacent horizontal composite beams 20. When each spanning panel 22' is above its respective pair of beams 20, it can be tilted back into the horizontal plane as shown in Figures 2c and 2d. Cables hold the panels 22' in position, just above their intended resting position between the horizontal beams 20. When all the panels are aligned, these cables can be released by pulling a release cord 21, to allow the panels to drop down and rest between the beams 20, as shown in Figures 2d and 2e.

Referring to Figure 2e, note that the upper surface of each spanning panel 22' is provided with a rebar mesh 32. Likewise, the upper surface of each horizontal beam 20 is provided with a rebar mesh 34. In this example, on each floor, three spanning panels 22' span between four horizontal beams 20 to form a continuous rebar cage across the upper surface of all components. In Figure 2e, 'stitching' rebars are being added which span between the rebar mesh 32 of pairs of adjacent spanning panels 22' and the rebar mesh 34 of the composite beam 20 running between the panels 22'. When the stitching rebars have been installed, concrete is poured over the continuous rebar cage to form a concrete floor slab. In Figure 2f, this has been done on each of the six floors of the example building. Each concrete floor slab 36 is has substantially the same structural properties as a conventionally-constructed reinforced concrete floor slab.

Referring now to Figure 3, a spanning panel 22' which is part of the ceiling cassette 22 is shown in exploded view, and will be described in more detail. The uppermost component is the rebar cage 32. The rebar cage 32 includes hooks 38 which protrude from the edges of the rebar cage, and bend downwardly. The hooks are designed to hook over parts of a rebar cage on an adjacent horizontal beam, specifically a reinforcing bar which runs along the horizontal beam 20, substantially parallel to the edge of the spanning panel 22', when the beam 20 and panel 22' are in position and ready for the concrete pour.

Immediately below the rebar cage 32 is a waterproof shuttering layer 40. Spacers 42 keep the rebar mesh 32 spaced from the shuttering layer 40. The shuttering layer 40 in this embodiment is made from waxed cardboard, which is cheap, environmentally friendly and lightweight. This makes cardboard makes a good choice of material for this purpose, because the shuttering layer becomes a permanent but redundant part of the building once the concrete floor slab has set.

Below the shuttering layer, a services void is provided. The services void is defined by the shuttering layer 40 at its uppermost extent, and strips of OSB (oriented strand board) 42 at its lowermost extent. The OSB strips 42 are spaced from the shuttering layer 40 by cardboard honeycomb spacer blocks 44, to define a services void of appropriate depth. The services void can contain, for example, ventilation ductwork 46, cooling plant 48, water pipes, sprinklers 50, lighting circuits 52, power circuits 54, heating ducting 56, fire alarm cabling, sensors and sounders 58, containment for data and other cables 60, etc.

In this example, a shutter for a party wall downstand 62 is also included.

A layer of plasterboard 64 is fixed to the underside of the OSB strips 42. The plasterboard layer 64 forms the ceiling of the room below the ceiling panel 22'.

Ties 66 are provided on either side of the spanning panel 22'. The ties connect with the rebar cage 32 on the upper surface of the panel 22', depending from either side of the rebar cage 32. Temporary reinforcing bars 68 can be attached to the ties, to support the mass of the concrete while it sets. When the concrete has set, the temporary reinforcing bars 68 can be removed. The ties 66 remain in place in the ceiling, but can simply be snipped off

with wire cutters where they protrude below the plasterboard layer 64. The temporary reinforcing bars in this embodiment are in the form of aluminium box section.

Referring now to Figures 4a and 4b, the composite concrete and steel beams 20 will now be described in more detail. Figure 4a is an exploded view of the composite beam 20, and Figure 4b shows the complete beam and the interfaces with adjacent components.

The beam includes a steel tray 70. In this embodiment, a ComFlor (RTM) 225 rib deck section is used. However, the section is actually upside-down as compared with its orientation in a traditional rib-deck floor in a steel-frame building. A rebar cage 72 is provided within the steel tray 70, around half of the height of the rebar cage 72 being within the steel tray 70 and about half protruding from above the level of the tray 70. The tray is filled with concrete 74 to cover the part of the rebar cage which is inside the tray 70. This creates a composite reinforced concrete and steel beam which has a rebar cage protruding from its upper surface. End plates 76 provide shuttering to contain the concrete while it sets. A pair of staples 78 are cast into the concrete on the upper surface of the beam and a pair of hooks 80 are cast into the concrete on each end, extending through gaps in the end plates 76.

Figure 4b shows how the beam 20 interfaces with other parts. Specifically, the hooks 38 of adjacent spanning panels 22' hook over a substantially horizontal reinforcing bar 72a, part of the rebar cage which protrudes from the upper surface of the beam 20. The hooks 80 on the end of the beam 20 rest on a flange of a bracket 84 which is fixed to the vertical support 16. A pin 80 passes through a hole drilled through the bracket 84, and through the vertical support 16, and through the staples 78 which are cast into the concrete of the beam 20. All of the pin 82, hooks 38, hooks 80 and staples 78 are cast into the concrete floor slab once it is poured. During construction, the parts are held together by hooks and brackets, but once the concrete floor slab is poured the parts effectively form a continuous reinforced concrete structure, which has conventional and well-understood structural properties.

The building system of the invention provides a method of constructing a building which is fast and heavily decoupled. The use of large fabrications requiring specialist transport is avoided, and the number of complex parts is minimised. The finished building however has

conventional structural characteristics in that the structure is provided by steel columns and continuous concrete and steel rebar floor slabs.

CLAIMS

1. A method of constructing a multi-story reinforced concrete building, the method comprising the steps of:

installing vertical supports around the periphery of the building, each vertical support being sufficiently tall to span multiple stories;

fixing beams to the vertical supports, each beam running substantially horizontally between vertical supports, the beams being provided in the plane of each floor of the building to be constructed;

installing substantially planar spanning panels between the beams, each spanning panel including a reinforcing mesh on its upper surface;

pouring concrete over the upper surfaces of the spanning panels to form floor slabs.

2. A method as claimed in claim 1, in which each planar spanning panel has a width of no more than 2.5 metres.

3. A method as claimed in claim 1 or claim 2, in which additional reinforcing bars are installed after the spanning panels are installed and before the concrete is poured, each additional reinforcing bar spanning between at least two horizontally-adjacent spanning panels.

4. A method as claimed in any of the preceding claims, in which any of prefabricated lift shafts, stair cores, and service risers are installed as part of the vertical support installation step.

5. A method as claimed in any of the preceding claims, in which the vertical supports comprise vertical columns and horizontal cross-braces.

6. A method as claimed in claim 5, in which each vertical support is substantially in the shape of an 'H'.

7. A method as claimed in any of the preceding claims, in which temporary props are provided for supporting the vertical supports before the horizontal beams are fixed.

8. A method as claimed in claim 7, in which the temporary props are provided substantially diagonally between the vertical supports and the ground.

9. A method as claimed in any of the preceding claims, in which intermediate vertical columns are provided for supporting the horizontal beams at points between the vertical supports.

10. A method as claimed in claim 9, in which the intermediate vertical columns are a single story high.

11. A method as claimed in any of the preceding claims, in which temporary props are provided to support the horizontal beams before concrete is poured, the temporary props being removed after the concrete has set.

12. A method as claimed in claim 11, in which the temporary props are fixed substantially diagonally between vertically-adjacent horizontal beams, and between the lowermost horizontal beams and the ground.

13. A method as claimed in claim 11 or claim 12, in which the temporary props are clamped to the horizontal beams with releasable clamps.

14. A method as claimed in any of claims 11 to 13, in which the temporary props are substantially in the form of elongate bars.

15. A method as claimed in any of the preceding claims, in which the horizontal beams are pre-cast concrete and steel composite beams.

16. A method as claimed in any of the preceding claims, in which vertically adjacent spanning panels are provided as part of a multi-story ceiling cassette, each ceiling cassette including two or more substantially planar spanning panels, the planar

spanning panels being joined to each other and initially proximal to each other, the spanning panels being moved apart from each other once the horizontal beams are in position so that the spanning panels of each ceiling cassette are disposed vertically in line with each other, each spanning panel of the cassette being positioned on a different floor plane.

17. A method as claimed in claim 16, in which each ceiling cassette includes enough spanning panels to provide for the number of floors spanned by each vertical support.

18. A method as claimed in claim 16 or claim 17, in which the uppermost spanning panel of each ceiling cassette includes a water-resistant layer.

19. A method as claimed in any of claims 16 to 18, in which safety guarding is provided on at least some of the uppermost spanning panels of each ceiling cassette.

20. A method as claimed in any of claims 16 to 19, in which the uppermost spanning panel of at least some of the ceiling cassettes is provided with a deployable waterproof sheeting material for deploying over the side of the building during construction.

21. A method as claimed in claim 20, in which the waterproof sheeting material is deployed over the side of the building from the uppermost spanning panel of at least some of the ceiling cassettes before wall cladding is installed, the waterproof sheeting being removable for installation of wall cladding.

22. A method as claimed in any of claims 16 to 21, in which the spanning panels of each ceiling cassette are joined together by cables, for controlling the lowering of the spanning panels from the top of the building.

23. A method as claimed in claim 22, in which at least two cables are provided which are offset from either side of a centreline of each spanning panel.

24. A method as claimed in claim 23, in which each spanning panel is tilted by releasing the cable attached at one side of the centreline to a greater extent than the cable at the other side of the centreline, the spanning panel being lowered between the horizontal beams in a tilted position, and the spanning panel then being moved into a horizontal position by releasing each cable to the same extent, when the ceiling panel is in place above the horizontal beams of its respective floor.

25. A method as claimed in any of the preceding claims, in which the reinforcing mesh on each spanning panel includes interlocking sections extending outwardly from the edge of the mesh, for interlocking with adjacent reinforcing meshes.

26. A method as claimed in claim 25, in which reinforcing meshes are provided on upper surfaces of the horizontal beams, and the interlocking sections of the spanning panels interlock with the reinforcing meshes of the beams, for holding each spanning panel in place before the concrete is poured over the reinforcing meshes.

27. A method as claimed in claim 25 or claim 26, in which the interlocking sections are substantially in the form of hooks.

28. A method as claimed in any of claims 1 to 27, in which the horizontal beams are pre-cast concrete and steel composite beams, formed substantially as an elongate tray, a reinforcing mesh within the tray and concrete poured over the mesh into the tray.

29. A method as claimed in claim 28, in which the reinforcing mesh extends above the level of the pre-cast concrete, and includes substantially horizontal reinforcing bars spaced from the level of the concrete by substantially vertical reinforcing bars.

30. A method as claimed in any of the preceding claims, in which hooks are provided on the ends of each horizontal beam, for joining the horizontal beams to the vertical support sections before concrete is poured.

31. A method as claimed in claim 30, in which a bracket is clamped around the vertical support section, and the horizontal beam is then hooked onto the bracket to retain the horizontal beam in position before concrete is poured.

32. A method as claimed in claim 31, in which the bracket is in the form of a two-part collar which is clamped around the vertical support section.

33. A method as claimed in any of the preceding claims, in which a shuttering layer is provided as part of each spanning panel, directly below the reinforcing mesh.

34. A method as claimed in claim 33, in which the shuttering layer includes cardboard.

35. A method as claimed in claim 33 or claim 34, in which the shuttering layer includes OSB (oriented strand board), MDF (medium-density fibreboard), or another engineered board.

36. A method as claimed in any of claims 33 to 35, in which a services void is provided below the shuttering, and a ceiling is provided below the services void.

37. A method as claimed in claim 36, in which the ceiling is a plasterboard ceiling.

38. A method as claimed in claim 36 or claim 37, in which spacers are provided between the ceiling and shuttering to form the services void.

39. A method as claimed in claim 38, in which the spacers comprise cardboard.

40. A method as claimed in any of the preceding claims, in which clips for attaching temporary support beams below the ceiling are provided on each ceiling member, each clip extending vertically downwards from the reinforcing mesh.

41. A method as claimed in claim 40, in which temporary support beams are attached to the clips before the concrete is poured, and then removed once the concrete has set.

42. A method as claimed in any of the preceding claims, in which prefabricated wall cladding panels are installed on the building before the concrete floors are poured.

43. A method as claimed in any of claims 1 to 41, in which prefabricated wall cladding panels are installed on the building after the concrete floors are poured.

44. A method as claimed in claim 42 or claim 43, in which a support structure is installed on at least some of the uppermost spanning panels, for hoisting the wall cladding panels from the ground.

45. A method as claimed in claim 44, in which the support structure is substantially in the form of an 'A' frame.

46. A building constructed according to the method of any of claims 1 to 45.

47. A method of installing ceiling spanning panels in a multi-story building, the building including spaced-apart horizontal beams for supporting the spanning panels between the beams, the beams being spaced apart in multiple substantially horizontal floor planes corresponding to a position of each spanning panel when the building is constructed, and the method including the steps of:

providing a ceiling cassette in the form of a stack of spanning panels, and positioning the ceiling cassette at the top of the building;

tilting the spanning panels out of a horizontal plane;

lowering the spanning panels between horizontal beams, while they are in the tilted position;

de-tilting each spanning panel back into a horizontal plane at a point when it is above and adjacent to the horizontal beams of its respective floor plane;

lowering each spanning panel to rest on its respective horizontal beams.

48. A method as claimed in claim 47, in which the spanning panels are lowered from the top of the building using cables.

49. A method as claimed in claim 47 or claim 48, in which the tilting and de-tilting of the spanning panels is controlled from the top of the building using cables.

50. A method as claimed in any of claimed 47 to 49, in which each spanning panel includes a reinforcing mesh on its upper surface, the method further comprising the step of pouring concrete over the upper surface of the spanning panels in each horizontal ceiling plane.

51. A multi-story ceiling cassette, the ceiling cassette including two or more substantially planar spanning panels, the planar spanning panels being joined to each other and initially proximal to each other, the spanning panels being movable apart from each other for positioning each spanning panel on a respective substantially horizontal ceiling plane, and each spanning panel including:

a reinforcing mesh on an upper surface of the spanning panel;

a water-resistant shuttering layer beneath the reinforcing mesh;

a services void beneath the shuttering layer; and

a ceiling board beneath the services void.

52. A ceiling cassette as claimed in claim 51, in which the water-resistant shuttering layer is made substantially from cardboard.

53. A ceiling cassette as claimed in claim 51 or claim 52, in which the services void is formed by spacer blocks between the shuttering layer and the ceiling board.

54. A ceiling cassette as claimed in claim 52, in which the spacer blocks are made from cardboard.

55. A ceiling cassette as claimed in any of claims 51 to 54, in which clips depend substantially vertically from the reinforcing mesh, for attaching temporary support bars beneath the ceiling board.

56. A ceiling cassette as claimed in any of claims 51 to 55, in which the spanning panels are joined together by cables, for controlling the lowering of the spanning panels from the top of the building.

57. A ceiling cassette as claimed in claim 56, in which at least two cables are provided which are offset from either side of a centreline of each spanning panel.

58. A ceiling cassette as claimed in any of claims 51 to 57, in which the reinforcing mesh on each spanning panel includes interlocking sections extending outwardly from the edge of the mesh, for interlocking with adjacent reinforcing meshes.

59. A prefabricated composite beam, including:

an elongate tray;

a reinforcing mesh disposed within the tray and extending above the top of the tray; and

concrete substantially filling the tray and covering the part of the reinforcing mesh which does not extend above the top of the tray.

60. A prefabricated beam as claimed in claim 59, in which the part of the reinforcing mesh which extends above the top of the tray includes reinforcing bars which run substantially parallel with the elongate extent of the tray, and further reinforcing bars for spacing the parallel bars from the top of the tray.

61. A prefabricated beam as claimed in claim 59 or claim 60, including a hook extending away from an end of the beam and above the beam, part of the hook being cast into the concrete of the beam.

62. A prefabricated beam as claimed in claim 61, in which at least one hook is provided at each end of the beam.

63. A prefabricated beam as claimed in claim 62, in which two hooks are provided at each end of the beam.

64. A prefabricated beam as claimed in any of claims 59 to 63, in which the tray includes a flange running along each elongate side of the beam.

65. A prefabricated beam as claimed in claim 64, in which the flange runs below the level of the top of the tray.

66. A prefabricated beam as claimed in any of claims 59 to 65, in which the part of the reinforcing mesh which extends above the tray includes at least one loop at each end of the beam.

67. A method of fixing a horizontal beam to a vertical support column,

the horizontal beam including a reinforcing mesh extending above its upper surface, and attachment means for fixing the beam to the vertical support, the attachment means extending above the upper surface of the beam,

and the vertical support including attachment means for interfacing with the attachment means of the horizontal beam,

and the method comprising the steps of:

attaching the attachment means of the horizontal beam to the attachment means of the vertical support;

pouring concrete over the horizontal beam to cover the reinforcing mesh and the attachment means.

68. A method as claimed in claim 67, in which the attachment means on the beam include loops extending from the upper surface of the beam, and the method includes the step of drilling a hole through the vertical support, and providing a pin through the hole in the vertical support and also through the loops of the beam.

69. A method as claimed in claim 67 or 68, in which the attachment means of the vertical support includes a flange for supporting a hook.

70. A method as claimed in claim 69, in which the flange is provided as part of a bracket, and the method includes the step of clamping the bracket around the vertical support.

71. A method as claimed in claim 70 when dependent on claim 68, in which the hole is drilled through the bracket and through the vertical support, and the pin is passed thorough the loops in the beam, the hole in the bracket, and the hole in the vertical support.

72. A method of constructing a multi-story reinforced concrete building, substantially as described herein with reference to and as illustrated in Figures 1a to 4b of the accompanying drawings.

73. A method of installing spanning panels in a multi-story building substantially as described herein with reference to and as illustrated in Figures 2a to 2f of the accompanying drawings.

74. A multi-story ceiling cassette substantially as described herein with reference to and as illustrated in Figures 2a to 3 of the accompanying drawings.

75. A prefabricated composite beam substantially as described herein with reference to and as illustrated in Figures 4a to 4b of the accompanying drawings.

76. A method of fixing a horizontal beam to a vertical support column substantially as described herein with reference to and as illustrated in Figure 4b of the accompanying drawings.

Intellectual Property Office

Application No:	GB1518496.3	**Examiner:**	Mr Kunal Saujani
Claims searched:	1-46	**Date of search:**	11 March 2016

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1, 2, 4-8, 11, 15-23, 28, 33-39, 42-46	WO 2009/017354 A2 (BARO CONSTRUCTION) - See Figures and paragraph [44] noting frameworks which receive concrete in situ and being part of multi panel cassettes.
X	1, 2, 4-8, 11, 12, 14, 28, 33-38, 42-46	EP 2876226 A1 (LEBOURGEOIS) - See in particular Figures 10, 14 and 15 noting horizontal portions 50 supporting floor part that has mesh 40 onto which concrete is cast.
A	-	WO 2014/059463 A1 (MERHIS) - See Figure 1 and paragraph [0079] and [0096] noting vertical members 2 which support horizontal members onto which panels made from concrete reinforced with metal bars are supported
A	-	US 3613325 A (YEE) - See Figure 1 noting a building with meshed concrete panels mounted on horizontal beams linked with vertical columns.
A	-	WO 2009/150589 A1 (COGEFRIN) - See Figure 1 noting a panel with embedded mesh.
A	-	WO 2014/165913 A1 (BFRE PTY) - See Figures for a panel with mesh 50 embedded in.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

E04B; E04G

Intellectual Property Office

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC, TXTA

International Classification:

Subclass	Subgroup	Valid From
E04B	0001/35	01/01/2006
E04B	0005/17	01/01/2006
E04C	0003/293	01/01/2006

Intellectual Property Office

Application No:	GB1518496.3	**Examiner:**	Mr Kunal Saujani
Claims searched:	47-50	**Date of search:**	13 June 2016

Patents Act 1977
Further Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	WO 99/22082 A2 (DDC PLANUNGS) - See in particular Figure 4 noting a panel tilted before being located between walls.
A	-	WO 2009/017354 A2 (BARO CONSTRUCTION) - See whole document.
A	-	KR 100818863 B1 (LEE CHANG) - See Figure noting tilted lowering of panel.

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E04B	0001/35	01/01/2006
E04B	0001/16	01/01/2006
E04B	0005/04	01/01/2006
E04B	0005/16	01/01/2006
E04B	0005/17	01/01/2006

Intellectual Property Office

Subclass	Subgroup	Valid From
E04C	0003/20	01/01/2006
E04C	0003/293	01/01/2006
E04G	0011/38	01/01/2006

Intellectual Property Office

Application No:	GB1518496.3	**Examiner:**	Mr Kunal Saujani
Claims searched:	51-58	**Date of search:**	13 June 2016

Patents Act 1977
Further Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	GB 1083253 A (HUTTER & SCHRANTZ) - See Figure 2 noting a panel with a mesh 16.
A	-	FR 2516962 A1 (ING COORDINATION) - See in particular Figure 1 noting a panel with a waterproof layer FC on a mesh TS and shuttering
A	-	US 4799348 A (BRAMI et al) - See Figure 1 noting a panel with a mesh 11 located on top of a shuttering layer 5.

Categories:

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Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC[X] :

Worldwide search of patent documents classified in the following areas of the IPC

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The following online and other databases have been used in the preparation of this search report

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International Classification:

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E04B	0005/04	01/01/2006
E04B	0005/16	01/01/2006
E04B	0005/17	01/01/2006

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Subclass	Subgroup	Valid From
E04C	0003/20	01/01/2006
E04C	0003/293	01/01/2006
E04G	0011/38	01/01/2006

Intellectual Property Office

Application No:	GB1518496.3	**Examiner:**	Mr Kunal Saujani
Claims searched:	59-66	**Date of search:**	13 June 2016

Patents Act 1977
Further Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	59, 60, 66	CN 201738443 U (ZHONGSHAN) - See Figures 1-6 noting a mesh 1 located within tray formed by parts 2-4 and the tray filled with concrete leaving part of the cage above the tray.
X	59, 60, 66	JP H08170367 A (OHBAYASHI) - See Figures 1-3 noting a tray 11 holding a mesh 13 which is partially embedded by concrete 18.

Categories:

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Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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Field of Search:

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