

[54] **BRACING FOR STRUCTURAL STEEL BUILDING FRAMES**
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[51] Int. Cl..... **E04b 1/68, E04b 1/98, E04h 3/00**
[58] Field of Search..... **52/573, 487, 235, 52/483-485**

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[57] **ABSTRACT**
A structural steel building frame including interconnected vertical and horizontal columns and beams is furnished with bracing against wind and seismic forces. The bracing comprises reinforced concrete panels connected to the columns and beams in such a way that only shear loads are transmitted from the frame to the panels and not gravity and compressive loads. A number of different types of connection means are disclosed, each of which resists relative movement between the interconnected panel and beam or column in the longitudinal direction of the beam or column, but allows relative movement in a direction perpendicular to the longitudinal direction of the beam or column.

7 Claims, 12 Drawing Figures

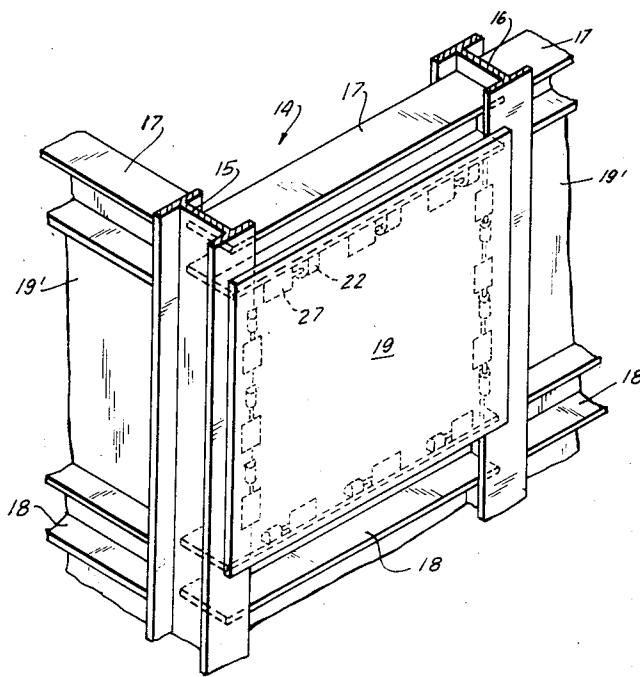


FIG. 1

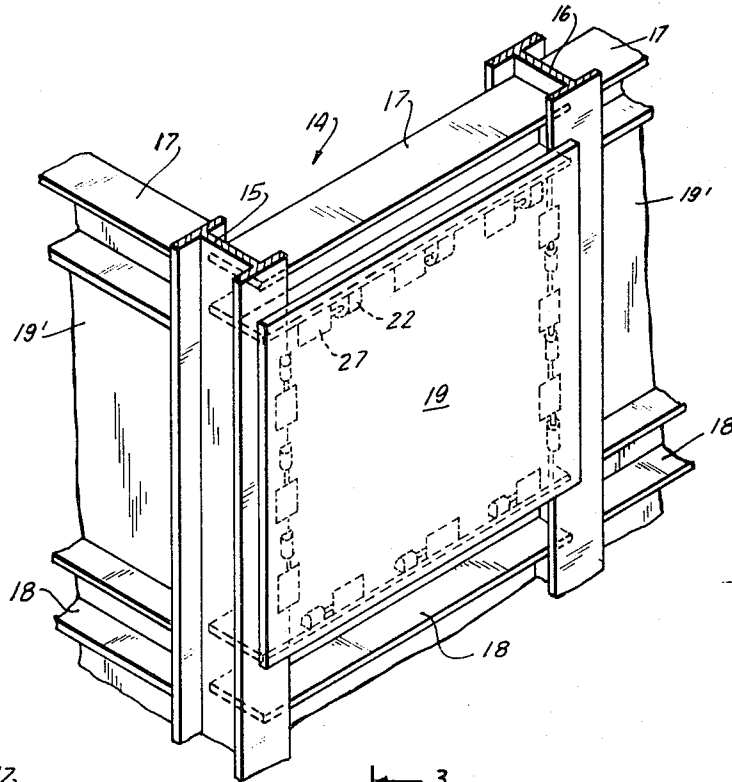


FIG. 2

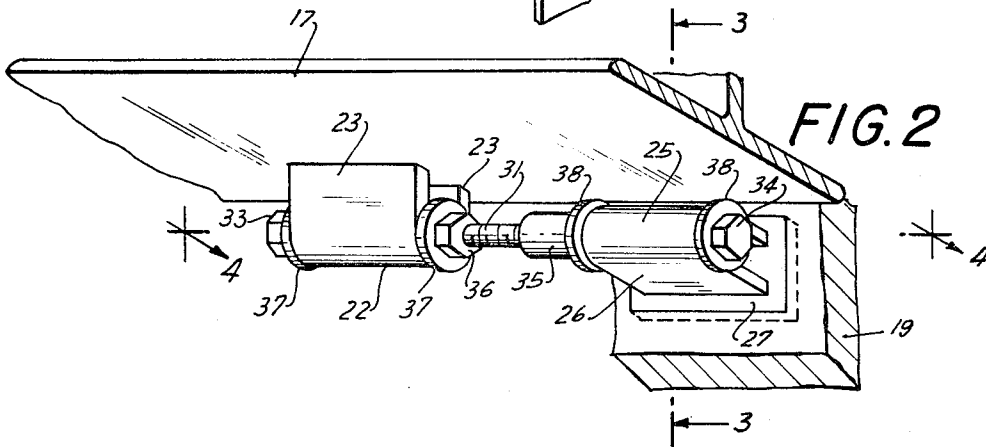
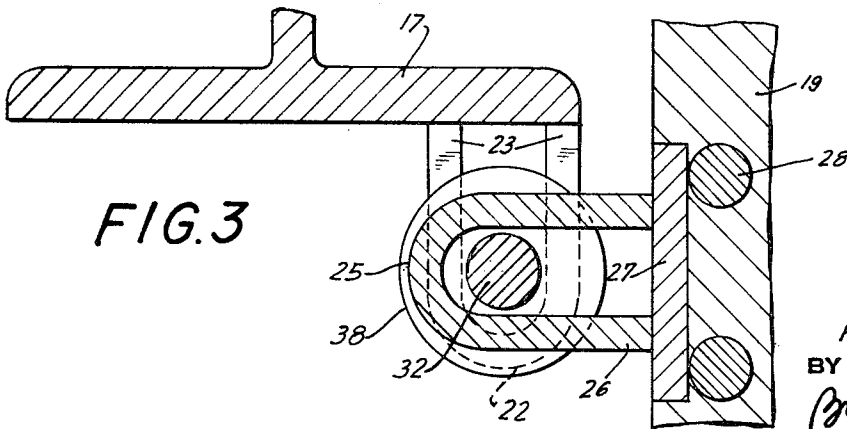


FIG. 3



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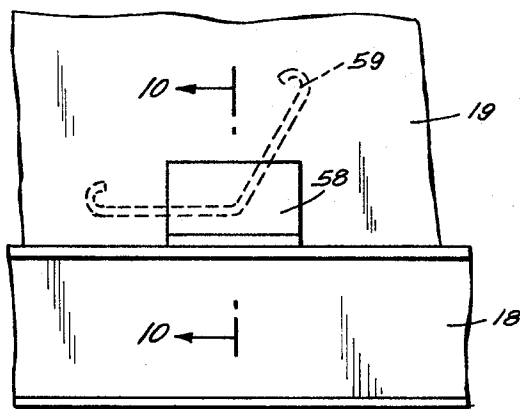
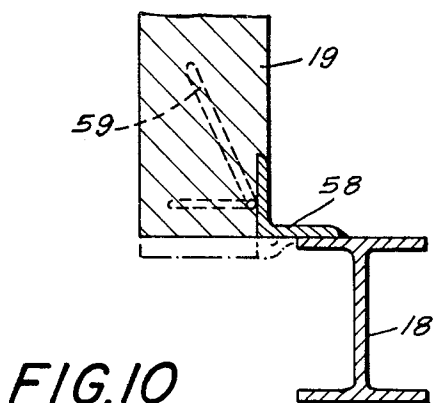
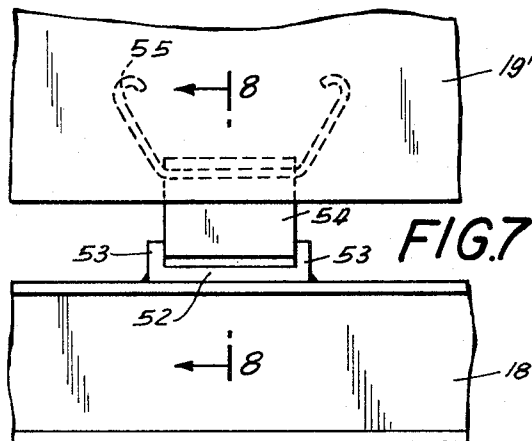
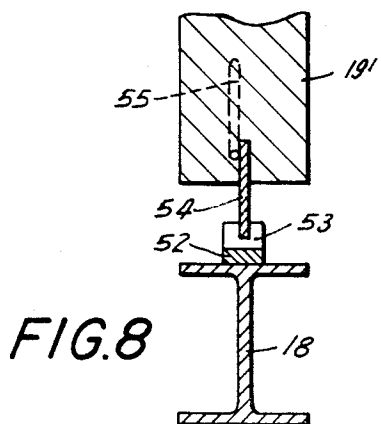
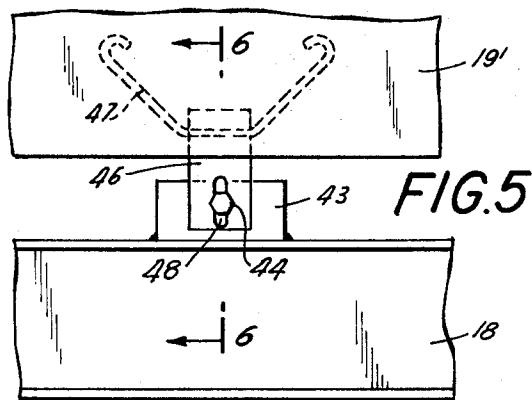
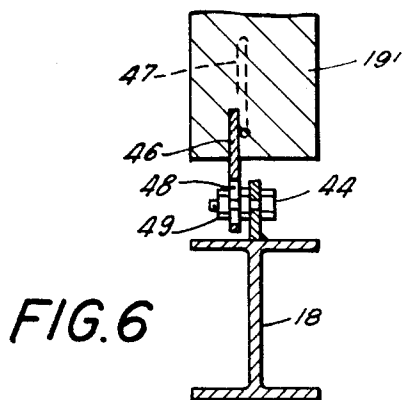


FIG. 9

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BRACING FOR STRUCTURAL STEEL BUILDING FRAMES

This invention relates to buildings having structural steel frames made up of interconnected vertical and horizontal elongated parts, commonly referred to as columns and beams, respectively, and more particularly to means for bracing such frames against lateral forces produced by wind or seismic effects.

In a typical high rise building of, say, 40 to 60 floors, the steel frame includes structural steel members whose purpose is to brace the frame against wind and other lateral forces on the building (hereinafter sometimes referred to as "wind-bracing"). The bracing strengthens the frame, stiffens the frame to prevent undue deflection, and dampens vibrations which may be set up in the frame. The cost of providing the bracing members is not insignificant, since they ordinarily constitute about one-third of the total weight of the steel frame. In addition, when the cost of installation is considered, the unit cost of the bracing material is often higher than that of the columns and beams.

It is a general object of the present invention to greatly reduce the cost of constructing structural steel frames for high rise buildings by eliminating, or significantly minimizing, the use of conventional steel bracing members.

It is another object of the invention to employ reinforced concrete panels for providing wind-bracing of a structural steel building frame. Such panels may be located within, or adjacent to, the rectangular openings defined by the interconnected columns and beams of the frame, and are connected in a special way to the columns and beams.

Use of these panels offers a number of advantages, all of which lead to reduced cost of the frame. The amount of steel used is greatly reduced, since only enough reinforcing steel need be used as is required by the strength requirements of the wind-bracing. The stiffness requirements of the bracing, which far exceed the strength requirements, are fulfilled by the concrete. In addition, the panels may serve as the exterior spandrel wall of the building and/or as permanent interior partitions. Furthermore, according to this invention, the cost of installing the panels is far less than the cost of installing conventional steel wind-bracing.

Additional objectives and features of the invention will be apparent from the following description in which reference is made to the accompanying drawings.

In the drawings:

FIG. 1 is a fragmentary perspective view of a structural steel building frame provided with a wind-bracing panel according to this invention;

FIG. 2 is an enlarged fragmentary perspective view of a portion of FIG. 1, as viewed from the opposite side of the panel, showing a preferred form of connection means between the panel and the frame;

FIG. 3 is a cross-sectional view taken on line 3—3 of FIG. 2;

FIG. 4 is a view partially in cross-section taken along line 4—4 of FIG. 2;

FIGS. 5 and 6 are elevational and cross-sectional views, respectively, of an alternative connection means;

FIGS. 7 and 8 are elevational and cross-sectional views, respectively, of another alternative connection means;

FIGS. 9 and 10 are elevational and cross-sectional views, respectively, of a further alternative connection means; and

FIGS. 11 and 12 are elevational and cross-sectional views, respectively, of an additional alternative connection means.

FIG. 1 illustrates a portion of a typical structural steel frame 14 for a building, comprising vertical columns 15 and 16 interconnected in conventional manner, as by rivets, bolts or welding with horizontal beams or girders 17 and 18. In place of some or all of the usual structural steel trusses and other types of wind-bracing, the invention employs one or more reinforced concrete panels 19, i.e., cast concrete panels having steel reinforcing bars embedded therein. These panels may be precast or cast in place, and if desired may be prestressed. Panel 19 is larger than a rectangular opening defined by the interconnected horizontal and vertical parts 15—18, and is shown on the outside of the frame. However, the panels may be about the same size or slightly smaller than the rectangular openings of the frame and arranged within the openings, as indicated by panels 19'. Also, the panels may be arranged inside or outside the frame.

Panels 19 and 19' are secured to the frame 14 by special connecting means, five different examples of which are described below. Each connecting means connects a panel to one of the elongated parts (beams 17, 18 or columns 15, 16) in such a way that only forces parallel to the longitudinal direction of the frame part are transmitted between the panel and that frame part, and substantially no forces perpendicular to the longitudinal direction of the frame part are transmitted. As a result, any lateral force or shear load on frame 14, such as is produced by wind, tending to rotate the beams and columns about their points of interconnection is resisted by panels 19, 19'. On the other hand, purely compressive forces, whether they be gravity loads on beams 17 and 18, or transverse loads on columns 15 and 16, are for the most part not transmitted to panels 19, 19', but instead are carried almost exclusively by the columns and beams, respectively. The connecting means accomplish this result because each connecting means prevents relative movement between a panel 19 and the frame part with which the connector is associated in a direction parallel to the longitudinal direction of the frame part, but permits relative movement between the panel and frame part in a direction perpendicular to the longitudinal direction of the frame part.

The connecting means preferred at the present time is shown in FIGS. 1—4, FIGS. 2—4 illustrating it associated with a beam 17. The connecting means includes a, preferably steel, U-shaped piece 22, the arms of which define a pair of spaced-apart plates 23 adapted to accommodate an elongated, rigid and non-compressible member 24 between them. The free ends of the arms 23 of piece 22 are secured, as by welding, to the downwardly facing flange of beam 17. A similar U-shaped piece 25 is arranged with its arms 26 perpendicular to the arms or plates 23 of piece 22, the free ends of arms 26 being secured, as by welding, to an exposed face of a plate 27 the remainder of which is embedded in panel 19. For additional strength, plate 27 may be welded to reinforcing rods 28 within panel 19.

Arms or plates 26 of piece 25 also accommodate the member 24 between them.

As may be seen most clearly in FIG. 4, member 24 comprises two threaded bolts 31 and 32, bolt 31 passing through piece 22 and bolt 32 passing through piece 25. The heads 33 and 34, respectively, of the bolts face away from each other so that the threaded ends of the bolts are adjacent to each other and are joined by an internally threaded coupling 35. The diameter of each bolt 31 and 32 is slightly less than the spacing between the plates 23 and 26, respectively, flanking it (see FIG. 3). As a result, bolt 31 is free to slide laterally toward and away from beam 17, and bolt 32 is free to slide laterally toward and away from panel 19.

A nut 36 is positioned on bolt 31 so that bolt head 33 and nut 36 cooperate to hold U-shaped piece 22 snugly between a pair of washers 37. Nut 36 is not, however, tightened so much that bolt 31 is prevented from moving laterally toward and away from beam 17. Nut 36 and head 33 do, however, prevent longitudinal movement between bolt 31 and piece 22. Coupling 35 is positioned on bolt 32 so that bolt head 34 and coupling 35 cooperate to hold U-shaped piece 25 snugly between a pair of washers 38. Thus, coupling 35 and head 34 prevent longitudinal movement between bolt 32 and piece 25. If desired, coupling 35 could be tightened sufficiently to also prevent lateral movement of bolt 32 with respect to piece 25. However, preferably such lateral movement is permitted to allow for differences in thermal expansion and contraction between frame 14 and panel 19.

It will be seen, therefore, that member 24 prevents relative movement between panel 19 and beam 17 in a direction parallel to the longitudinal direction of the beam, but permits movement between the panel and the beam in a direction perpendicular to the longitudinal direction of the beam. In addition, it should be pointed out that arrangement of U-shaped pieces 22 and 25 perpendicular to each other, as shown in FIG. 3, greatly reduces the precision required in securing these pieces to the frame parts and panel, respectively, since there is a considerable amount of leeway for aligning bolts 31 and 32. In practice, panel 19 may be lifted into position carrying bolt 32 and coupling 35, and bolt 31 carrying nut 36 may be within piece 22. Bolt 31 and 32 are then moved within their respective U-shaped pieces until they are aligned, whereupon they are joined by coupling 35.

As indicated in FIG. 1, each beam and column may be provided with several connecting means of the type just described. The connection to a column is precisely the same as that to a beam, as may be seen by rotating FIG. 2 through 90°. In addition, connection to a beam, e.g., beam 18, below beam 17 is the same, as may be seen by rotating FIG. 2 through 180°. The connecting means just described can be used with a panel 19 which fits within a rectangular opening of the frame 14, as well as with a panel arranged outside or inside the frame opening.

FIGS. 5 and 6 show another form of connecting means for connecting a panel 19' to a beam 18. A rigid plate 43 is fixed, as by welding, to beam 18, the plate being in a plane parallel to both the longitudinal direction of the beam and the plane of the panel. A bolt 44 fits snugly through a hole in plate 43, and is fixed to the plate by a nut 45. Another rigid plate 46 is partially embedded in panel 19' and projects therefrom in a plane

parallel to the plane of plate 43. To insure a good bond between plate 46 and panel 19', the plate may be welded to a bent rod 47 embedded within the panel. Plate 46 is formed with a slot 48 perpendicular to the longitudinal direction of beam 18. Bolt 44 passes through slot 48, and a nut 49 keeps the bolt from slipping out of the slot. The diameter of the bolt is almost as large as the width of the slot so that the bolt can slide along the length of the slot. It will be appreciated that this connecting means prevents relative movement between panel 19' and beam 18 in a direction parallel to the longitudinal direction of the beam, but permits relative movement between the panel and the beam in a direction perpendicular to the longitudinal direction of the beam.

Another type of connecting according to the invention is illustrated in FIGS. 7 and 8. A rigid channel-shaped member 52 is fixed to beam 18, the channel presenting two end walls 53 spaced apart in the longitudinal direction of beam 18. A rigid plate 54 is partially embedded in panel 19' and projects therefrom in a plane parallel to both the longitudinal direction of the beam and the plane of the panel. Plate 54 may be welded to a bent rod 55 embedded in panel 19'. Plate 54 fits relatively snugly between walls 53, to prevent relative movement parallel to the longitudinal direction of beam 18, but plate 54 is permitted to move toward and away from beam 18 without completely leaving the space between walls 53.

In FIGS. 5-8, it has been assumed that panel 19' fits within a rectangular opening in frame 14. However, these connecting means can also be used with a panel, such as panel 19 in FIG. 1, larger than and arranged outside an opening in the frame.

In FIGS. 9 and 10, an angle member 58 formed of a relatively flexible material is fixed to both beam 18 and panel 19. The angle member is partially embedded in panel 19 and welded to a bent rod 59 embedded in the panel, and is welded to beam 18. The angle has no flexibility along its length, i.e., in a direction parallel to the longitudinal direction of the beam, but it is flexible in a direction perpendicular to the longitudinal direction of the beam. As a result, angle 58 can bend, as indicated in broken lines in FIG. 10, to permit relative movement between panel 19 and beam 18 in a direction perpendicular to the longitudinal direction of beam 18.

A panel can also be connected to a column or beam as illustrated in FIGS. 11 and 12. A rigid bar 62 projects from and is fixed to beam 18. Crushable material 63, such as a suitable foamed plastic, is secured to beam 18 on each side of bar 62 and also to the upper surface of bar 62 facing away from beam 18. The edge of panel 19' is formed with a recess 65 in the region of bar 62, the recess being much larger than needed to accommodate the bar. Channels 64 are provided, from an exterior face of the panel to the interior of recess 65, through which a flowable but hardenable material 66, such as grout or concrete, can be introduced into recess 65. Material 66 fills the recess, engaging bar 62, crushable material 63, and the walls of the recess. Once material 66 hardens, obviously no relative movement is possible between panel 19' and beam 18 in a direction parallel to the longitudinal direction of the beam. However, movement in a direction perpendicular to the longitudinal direction of the beam is permitted by the pres-

ence of crushable material 63 covering the upper face of bar 62.

In FIGS. 5-12, the panel is shown connected to a beam defining the lower edge of an opening in frame 14. However, the same connecting means can be used to connect the panel to a column (rotate the figures 90°) or to a beam defining the upper edge of an opening (rotate the figures 180°).

The invention has been shown and described in preferred form only, and by way of example, and many variations may be made in the invention which will still be comprised within its spirit. It is understood, therefore, that the invention is not limited to any specific form or embodiment except insofar as such limitations are included in the appended claims.

What is claimed is:

1. A building having a steel frame including interconnected vertical and horizontal elongated structural parts defining rectangular openings in the frame, and bracing means between said vertical and horizontal parts, said bracing means comprising a reinforced concrete panel arranged in registry with one of the openings in said frame, and means for connecting said panel to the vertical and horizontal parts defining said one opening, there being separate connecting means connecting said panel to each of said vertical and horizontal parts defining said one opening, each said connecting means including a member coupled to its respective structural part and a member coupled to said panel, one of said members having a pair of abutments spaced apart in a direction parallel to the longitudinal direction of its respective structural part, said abutments having a dimension transverse to the longitudinal direction of the respective structural part, the other of said members fitting snugly between said pair of abutments so as to prevent relative movement between the members in a direction parallel to the longitudinal direction of said structural part, and one of said members being smaller than the dimension of said abutments in a direction transverse to the longitudinal direction of said structural part so as to permit relative movement between the two members in a direction transverse to the longitudinal direction of said structural part.

2. A building as defined in claim 1 wherein one of said connecting means includes an elongated rigid and non-compressible member extending parallel to the plane of said panel, and means for connecting said member to said panel so that the member is substantially immovable longitudinally with respect to said panel, wherein the other of said connecting means includes a pair of spaced-apart plates rigidly connected to, and projecting substantially perpendicularly from, a part of said frame, said member being located between said plates and slidable laterally toward and away from

said frame part, and said abutments include means carried by said elongated member and cooperable with said plates for preventing longitudinal movement of said member with respect to said plates and said frame part.

3. A building as defined in claim 2 wherein said plates are the arms of a U-shaped element, the free ends of said arms being fixed to said frame part.

4. A building as defined in claim 2 wherein said elongated member includes a rod at least partially externally threaded, and said means carried by said member is an element threadably engaging said rod.

5. A building as defined in claim 1 wherein said connecting means includes a first member fixed to and projecting from said panel, a second member fixed to and projecting from a part of said frame, a slot in one of said members, said slot being in a plane substantially parallel to the plane of said panel and being substantially perpendicular to the longitudinal direction of said frame part, the sides of said slot defining said abutments, and a pin carried by the other of said members, said pin having a cross-sectional dimension about equal to the width of said slot and being arranged for sliding movement along the length of said slot, whereby said members cannot move with respect to each other in the longitudinal direction of said frame part but can move with respect to each other in a direction substantially perpendicular to the longitudinal direction of said frame part.

6. A building as defined in claim 1 wherein said connecting means includes a first member fixed to and projecting from said panel, and a second member fixed to and projecting from a part of said frame, one of said members having projecting walls defining said abutments spaced apart in the longitudinal direction of said frame part, and the other of said members being slidably arranged between said walls and having a dimension about equal to the spacing between said walls, whereby said members cannot move with respect to each other in the longitudinal direction of said frame part but can move with respect to each other in a direction substantially perpendicular to the longitudinal direction of said frame part.

7. A building as defined in claim 1 wherein said connecting means includes a recess in said panel, the sides of said recess defining said abutments, a member fixed to a part of said frame and projecting into said recess, said member having a surface facing away from said frame part, a layer of crushable material covering only said surface, and a hardened rigid material filling said recess and engaging said member and crushable material.

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