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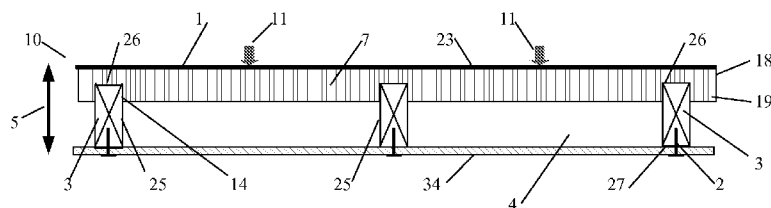
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(54) **Title:** A FRAME SUPPORTED STIFFENED PANEL

Fig. 2



(57) **Abstract:** Frame supported panels with an increased load carrying capacity derived from inducing newly discovered conditions on panels made from weaker, lighter and thinner materials. The fixed/continuous/dropped condition combines two other new conditions to increase a panel's load capacity many times based on the panel's interaction with frame members. This enables materials with attractive properties, such as an insulant or vapor barrier, to be used in structural applications. It also dramatically increases the load capacity of much thinner sections of traditional structural materials when used as part of a foam composite panel.

A FRAME SUPPORTED STIFFENED PANEL**CROSS REFERENCE TO RELATED APPLICATIONS**

[01] This application claims the benefit of the filing date of U.S. Provisional Application Nos. 62/018,551 filed June 28, 2014 and 62/033,420 filed August 5, 2014, and both have been incorporated herein.

TECHNICAL FIELD

[02] The inventive subject matter comprises increasing the load carrying capacity of frame supported panels by subjecting the panels to newly discovered conditions. Weaker, lighter and thinner panels can have a dramatic increase in stiffness, load strength and versatility by re-configuring the panel's shape and/or by sufficiently bonding the panel to frame members.

BACKGROUND ART

[03] There has been a long felt need to increase a panel's load capacity at little or no cost and especially that of foam or foam composite panels used as building panels for walls and roofs. Since many weaker, lighter and thinner panels have desirable properties there is a need to make them structural in order to consolidate these desirable properties into a structural product. This is especially true for polyurethane foam panels which can provide an air, vapor, moisture and thermal barrier, eliminate condensation, decrease thermal contraction and expansion and increase uplift resistance. As such, making polyurethane foam structural would provide a most comprehensive building panel.

[04] Increasing load capacity of panels has typically been accomplished by changing the panel's design with stronger or thicker materials, by using stronger material shapes or by shortening the span between frame members, all of which have limitations and/or increase the panel's costs. In addition, it is well known that a beam or panel in a continuous condition over two or more same sized spans can carry more than a 100% increase in load capacity as compared to the same panel over a single, same sized span.

[05] A continuous condition occurs when a beam or panel is continuous over two or more spans created by spaced apart supports or frame members. In this case the increased load capacity is caused by a reaction from a portion of a panel over one span to a sufficiently large force or load applied to the same panel over an adjacent span. As a load is applied to one span, the panel over the adjacent span(s) resists the load causing the panel to have an increased load capacity. As a result, plywood, form boards and walers all have an increased load capacity

when they are continuous over two or more same sized spans. The continuous condition has only been applied to panels that are entirely above the frame members. In other words the entire continuous configured panel is above the plane created by the top edge of adjacent frame members bearing the panel. As such, it is unknown how the load capacity of a continuous panel is affected if a portion of the panel is thickened and dropped below this plane.

[06] It is well know that the continuous condition has inside and outside spans and the insides spans have an inherently higher load capacity than the outside spans. This increased load capacity is presently wasted since most panels have only one or two inside spans and the panel's load capacity is determined by it's weakest span, which is the outside span. This is an unrecognized problem and a need exists to utilize this wasted load capacity.

[07] The continuous condition is derived from fundamental beam theory which is over 100 years old. This theory also teaches that a beam subjected to a fixed boundary condition can have a its load capacity increased up to 400%. A fixed boundary condition exists when the ends of a beam over a single span are fixed as opposed to being simply supported. In order to adequately fix the ends of a beam to prevent it from rotating, the entire perimeter of each end must be fixed to the frame members which only occurs if the beam is fixed to the frame member's sides, as opposed to their top. Fully fixed ends prevents beam rotation to enable the beam to use its full potential strength.

[08] While fundamental beam theory's fixed boundary condition suggests that a material used as a beam can have its load capacity increased by 400%, the theory is silent as to its practical application, techniques and the materials to which it is applicable. Since beams are structural components, the materials typically considered for use as beams are also structural such as steel, other metals, wood and reinforced concrete. Given that such materials are rigid and have a high modulus of elasticity, it has not been known whether the fixed boundary condition can be applied to pliable, soft or otherwise weaker materials such as foams.

[09] Despite the fact that mathematical exercises predicting an increased load capacity from a theoretical fixed boundary condition are widely known, there are few techniques by which to apply the theory and these are limited to steel, other metals and reinforced concrete. Beyond these materials there are no known techniques for attaining a 400% increase in load capacity in most other materials. As a result the practical application of the fixed boundary condition theory is unknown on most materials.

[010] Of the two conditions, the continuous condition is widely practiced whereas the fixed boundary condition remains mostly theory. The continuous condition is the most common connection of a panel to any type of solid or framed structure. It is extensively used to attach

sheathings, claddings, decks, coverings, etc. for buildings, furniture and other applications and for a variety of reasons. One important reason the continuous condition is so widely used is that it provides a continuous planar surface over frame members. On the other hand, a fixed boundary condition does not provide a continuous planar surface since its entire end perimeter theoretically needs to be fixed to the side of frame members. As such, the sole appeal of the fixed boundary condition is its theoretical increase in load capacity, which has been of little value since increasing load capacity is easily accomplished by increasing the thickness of a continuous conditioned panel. For example 1.6 centimeter (cm) thick plywood has about twice the load capacity as 1.3 cm plywood over the same span. Therefore, with such an easy and inexpensive solution to increasing a panel's load capacity there is no motivation to make the fixed boundary condition useful.

[011] It is well known that a fixed boundary condition can be induced on steel beams by either welding or with steel bolts. This is not the case with fasteners and adhesives used to fix non-metal materials to a frame. Prior art demonstrates that some increase in load capacity has been attained using fasteners and adhesives to fix wood to a frame, although nowhere near the 400% theoretical increase possible with a fixed boundary condition. Since the success with attaining an increase in load capacity by fixing wood to a frame is severely limited as compared to fixing steel, the likelihood of attaining an increase in load capacity by fixing a much weaker material such as a foam to a frame was unexpected.

[012] Composite action has been widely applied to wall, floor or roof assemblies, where increased load capacity or greater structural integrity of the frame members, assembly or diaphragm has been recognized by adequately bonding a sheathing to the frame members. It is also well known that polyurethane foam can be used to bond sheathing or claddings to frame members and thereby reduce racking and increase the structural integrity of an entire structural wall or roof section. However, no disclosure shows whether or not such bonding can increase the load capacity of the sheathing itself between frame members.

[013] It is well known that structural building panels, such as plywood sheathing, require a minimum load capacity and therefore determining load capacity is fundamental to the building panel's design. For 50 years polyurethane foam has been adhesively bonded to more rigid materials and used as building panels that required the determination of the panel's load capacity in order to meet building codes and be permitted for use. In many of these cases the polyurethane foam was also adhesively bonded to frame members. However, in no case has it been recognized that bonding polyurethane foam to both the rigid material panels and to the frame members results in an increased load capacity to the polyurethane foam/rigid material

composite panel. Nor has it been disclosed that polyurethane foam itself has an increased load capacity induced solely by its bond to frame members.

[014] Moreover, polyurethane foam has been used extensively throughout the world as thermal insulation installed by bonding it to sheathing, creating a composite panel, and simultaneously bonding that composite panel to studs or trusses. Yet it has been unrecognized that this same procedure produces a continuous composite panel having a dropped section (polyurethane foam) between the studs or trusses that is bonded to frame members in a possible fixed boundary condition. Despite literally thousands of people, who have researched, designed, marketed, applied or otherwise worked with polyurethane foam in this way, no one has recognized that polyurethane foam itself or as part of a composite panel bonded to frame members can increase the panel's load capacity. Instead, the prior art is either silent about a panel's load capacity or teaches increased load capacity of the entire frame diaphragm rather than of the panels themselves. For example:

[015] US 3,258,889 (Richard A. Butcher) discloses a structural wall comprised of polyurethane foam bonded to the back of an interior wallboard and to the sides of studs and teaches added stiffness of the framed wall that enables the use of thinner panels and lighter frame members. US 3,641,724 (James Palmer) discloses a wall section comprised of an exterior cover bonded to the sides of stud members by a polyurethane foam that increases the strength of the entire structure. US 4,471,591 (Walter E. Jamison) discloses a wall assembly with an exterior section comprised of polyurethane foam bonded to sheathing and to the sides of studs. US 4,748,781 & 4,914,883 (Stanley E. Wencley) discloses polyurethane fillets bonding a panel to frame members to provide an increased strength bonded structure.

[016] US 5,736,221 (James S. Hardigg, et al) discloses two half panels with each having a face and a web molded to the face's backside and the webs bonded together to provide a panel having bending strength in all directions. US 8,397,465 (Jeffrey M. Hansbro et al) discloses a wall assembly comprised of polyurethane foam panels bonded to the sides of structural members (studs) and to foam boards continuous over the structural member's edge. US 8,696,966 (Jason Smith) discloses a method of fabricating a wall structure whereby polyurethane foam is applied against a form and the foam expands to become a panel bonded to the edges and sides of support members (studs) within a wall frame. WO/2013/052997 (John Damien Digney) discloses a composite panel system reinforced with wire mesh and comprised of a structural cladding spaced apart from and bonded to a studded frame with polyurethane foam that is between and continuous over the studs.

[017] US 2014/0053486 (Anthony Grisolia et al) discloses a wall structure including support members inside the frame (studs) and a polyurethane foam panel both continuous over and between the support members. US 2014/0115988, US 2014/0115989 and US 2014/0115991 (Michael J. Sievers, et al) discloses a wall assembly of a frame assembly with vertical members (studs) and an insulating foam layer disposed between and on top of the vertical members. US 2014/0174011 (Jason Smith) discloses a method of fabricating a wall structure comprised of bonding polyurethane foam to the edge and sides of frame members. US 2015/0093535 (James Lambach et al) discloses a framed panel with a polyiso board continuous over frame members and bonded to the sides of frame members with polyurethane foam.

[018] None of the above or other prior art disclose that a continuous conditioned foam or foam composite panel has an increased load carry capacity solely due to a bond with frame members. Nor does the prior art disclose that there is sufficient rotational resistance in place to enable the panels to carry a larger load. Nor does the prior art disclose that a dropped section between frame members can increase the load capacity of a continuous conditioned panel. Nor are fillets, used as dropped sections, known for their ability to shorten a span so as to increase a panels' load capacity. Nor has it been disclosed that polyurethane foam can be used to create large, continuous panels over many spans to take advantage of the inside span's inherent increased load capacity.

[019] Despite bonding foam or foam composite panels to frame members and panels with a continuous/dropped configuration used extensively for decades as building panels that required the determination of the panel's load capacity, none of the new conditions of the inventive subject matter have been previously disclosed as a bases for increasing a panel's load capacity. As such, it has not been obvious by a person of ordinary skill in the art to combine a panel's continuous condition with a fixed boundary condition to increase the panels load capacity. Nor has it been obvious to add a dropped section to a continuous conditioned panel to increase the panel's load capacity. Nor has it been obvious that rotational resistance is necessary to facilitate increases in load capacity.

[020] The problems to be solved by this inventive subject matter are first: to increase the load carrying capacity of panels comprised of weaker, lighter and thinner materials, and second: to utilize the presently unrecognized increased load capacities of a panel's inside spans.

INVENTION SUMMARY

[021] The inventive subject matter is the application of four new conditions on weaker, lighter, thinner and less costly panels to enable them to become stiffer, stronger and more

versatile by the panel's interaction with its supporting frame members. The technical significance of these new conditions is that they enable non-structural materials to become structurally sufficient and thereby eliminate or at least lessen the need to be combined with traditional structural panels made of wood or steel. Since some of these non-structural materials have desirable properties such as lightness, an insulant, vapor barrier, durability, etc. these conditions makes it possible to create comprehensive panels. For example, polyurethane foam is a well known insulant that has vapor and moisture barrier properties and is typically used as insulation bonded to wood sheathing. Applying these new conditions on the polyurethane foam insulation can make the resulting panel as stiff as plywood and thereby eliminate the need for wood sheathing. Therefore, enabling weaker, lighter and thinner materials to be used as structural panels reduces costs and facilitates a new generation of multi-functional structural panels. The effectiveness of these new conditions is inversely related to a panel's flexural stiffness in that the smaller the flexural stiffness the greater the effect the conditions have in increasing a panel's load capacity. Panels with the lowest flexural stiffness can have thousands of times increases in load capacities.

[022] Due to the lack of literature on the application of fixed boundary conditions to beams or panels made of materials much weaker than steel or concrete, testing was initiated to study the effects of a fixed boundary and continuous condition on the load carrying capacity of foam panels and thin wood panels supported by a frame. The object was to determine whether these boundary conditions are applicable to such materials and if so, to what extent they affect the various material's load carrying capacity when used as panels. Several configurations were tested leading to the discovery of the four new conditions and their dramatic impact on increasing a panel's load capacity.

[023] While the continuous condition is well known, combining it with the fixed boundary condition is only known for a limited number of materials, all of which have a high modulus of elasticity. Specifically, continuous panels made of steel (metals), reinforced concrete and wood have all been sufficiently fixed to frame members such that some degree of increased load capacity was attained from the combination of the continuous and fixed boundary conditions. However, no prior art combines the continuous condition with the fixed boundary condition on low modulus of elasticity materials such as foam or foam composite panels. In addition, despite substantial prior art showing a polyurethane foam composite panel in a continuous condition and bonded to frame members, either the configuration didn't induce a fixed boundary condition or if it did, it was unrecognized. Finally, the techniques used on steel, reinforced concrete and wood to attain a fixed boundary condition are not transferable to foam.

[024] The continuous/dropped configuration has been used for such things as dropped ceiling tiles although it has not been recognized as a condition that can increase a panel's load capacity. The continuous/dropped configuration and condition has the top or outside section of a panel continuous over one or more spaced apart frame members while the bottom or inside section of the panel is thickened and dropped between the sides of frame members. This is distinguished from a continuous panel which is completely above the frame members or more precisely above a plane or a perimeter created by the frame member's top edges that are supporting the panel. A continuous/dropped panel may or may not be bonded to frame members. If it is sufficiently bonded to frame members to induce a fixed boundary condition, it becomes a fixed/continuous/dropped condition, another new condition of this inventive matter.

[025] The continuous/dropped configuration is the reverse of known dropped panels configurations used to increase the panel's load capacity. For example, to strengthen concrete floor panels a dropped or thickened section is added over the columns or beams, such as a capital, and a thinner section is over the spanned area. While the continuous/dropped panel configuration has been shown in numerous prior art disclosures, such as polyurethane foam bonded to the inside of sheathing, its ability to increase the panel's load capacity has gone unrecognized for at least 50 years.

[026] As used in this disclosure the term load capacity, also known as load carrying capacity, is a panel's maximum load it can carry, support or bear, or force it can withstand, over a given span before the panel deflects more than a given amount. Load tests, i.e. placing a load on a panel over a span, are well known in the art and are used to determine a panel's load capacity. As the amount of load increases on the panel over the span the panel reacts by rotating which causes deflection. Due to the problems caused by excessive deflection, load capacity is an important element of almost all frame supported panels, regardless of application. In many applications there is a maximum, allowable amount of deflection for a given load. For example wall panels may be required to carry a minimum lateral load of 1,915 pascal (Pa) without deflecting more than $L/240$ [Math 1]. For example, if span length "L" is 40.6 centimeter (cm), the panel cannot deflect more than $40.6/240$ [Math 1] or .17 cm when the given 1,915 Pa load is applied. A span is the distance between spaced apart frame members and therefore is both a length and a space. The term "one or more spans" refers to either a single, undivided space between frame members or to a multitude of spaces separated from each other by multiple spaced apart frame members.

[027] A panel's load capacity is determined by its material composition, shape, length of span and allowable deflection. For purposes of this disclosure, a panel's material composition

and shape comprise its “flexural stiffness” which is defined as EI [Math 2] (“E”, a material's modulus of elasticity, multiplied by “I”, the panel's moment of inertia). Flexural stiffness refers to a panel's material and the shape of its cross section and is stated in Newtons-square centimeter ($N\text{-cm}^2$).

[028] Formulas have been developed to predict deflection for a given load over a given span for beams with a simply supported condition, a continuous condition and a fixed boundary condition. These formulas have been found applicable to panels where the span is determined by two spaced apart frame members, similar to beam support members. The formulas provide a way to mathematically compare a panel's predicted load capacity under different conditions.

[029] A simply supported panel is over a single span with opposite ends of the panel supported by spaced apart frame members without any sufficient means for the panel to resist rotation. The panel may be unbonded or bonded to the frame members, although any such bond, such as nails, is insufficient to induce a fixed boundary condition on the panel and thereby the panel is unfixed. The maximum deflection formula for a simply supported condition is $d = 5wL^3/384EI$ [Math 3] where “d” is the amount of deflection in centimeters (cm), “w” the uniformly distributed load in pascal (Pa), “L” the span length in cm, “E” the material's modulus of elasticity in megapascal (MPa) and “I” the panel's moment of inertia in cm^4 . This formula provides the basis for determining a simply supported panel's load capacity per cm of panel to frame member interface as: $w = 76.8dEI/L^3$ [Math 4] for a uniformly loaded panel.

[030] A simply supported panel's load capacity can be increased by subjecting the panel to conditions that enable the panel to stiffen and thereby increase its load carrying capacity to support greater loads for a given deflection. One well known condition is a continuous condition whereby a panel is continuous over the top and bears on the top of three or more spaced apart supports, i.e. frame members, and is thereby continuous over two or more spans. The continuous condition increases a panel's load capacity by a reaction from the part of a panel over one span to a force or load applied to the same panel over an adjacent span. As a load is applied to one span, the panel over the adjacent span(s) resists the load causing the panel to have an increased load carrying capacity. A panel that is continuous over and supported by spaced apart frame members that create two or more spans, is a continuous panel in a continuous condition and has an increased, continuous conditioned load capacity, over each span, that is greater than the panel's simply supported load capacity. Such a panel may be unbonded or bonded to the frame members although any such bond is insufficient to induce a fixed boundary condition on the panel and thereby the panel is unfixed. To support a panel means the panel

bears on or is held up by supports, a frame or frame members and to support a load means to carry or bear a load.

[031] For clarification purposes, an increased load capacity or an increase in load capacity is a load capacity that has been increased from some previous amount of load capacity and results in a greater load capacity. For example a continuous conditioned panel has an increased load capacity above that of itself in a simply supported condition and thereby has a new, greater load capacity. Also, when a continuous panel over several spans is herein compared to a simply supported panel, the continuous panel's length is assumed to be shorted to that of the simply supported panel over a single span, while the panel's flexural stiffness, span length and load remain the same.

[032] The maximum deflection formula for a continuous conditioned panel over two equal spans with uniformly distributed loads is: $d = wL^3/185EI$ [Math 5] and therefore the panel's continued conditioned load capacity per centimeter of panel to frame member interface can be determined by the formula: $w = 185dEI/L^3$ [Math 6]. Comparing this to the simply supported formula shows that a continuous condition induces an increase in load capacity of about 141% above that of a simply supported panel. As such, a panel continuous over two spans has a load carrying capacity increase of 141% over the same shortened panel has over the same single span. This 141% increased capacity can be used to compare the increased load capacity of a continuous conditioned panel over a span to the panel's simply supported load capacity. The amount of increased capacity and formula may vary depending upon the circumstances such as unequal spans, different loads, additional support, etc. In those cases where a formula is non-existent, load testing can be used to determine the load capacity. Unless otherwise herein noted, loads are uniformly distributed loads and two or more spans shall be assumed to be equal spans and all load tests were conducted with the maximum deflection of $L/240$ [Math 1].

[033] Another continuous condition occurs when a panel is continuous over three or more spans and the two outer spans have greater deflection than the spans in a two span condition. This occurs because the center or inside span is reacting to loads on outside spans on both sides which causes it's reaction to be split between two adjacent spans and thereby less effective than if reacting to a single span in a two span condition. On the other hand, since the inside span is supported by spans on both sides, it has a much higher load carrying capacity. As such, a panel continuous over three equal spans has a continuous condition increase of only 89% on the outside spans and a much higher increase of about 285% on the inside span over a simply supported panel. A panel continuous over four spans has a 100% increase in load capacity for its outside spans and about a 212% increase in load capacity for its inside spans. A panel

continuous over five or more spans has about a 90% increase in load capacity for its outside spans and up to about a 230% increase in load capacity for its inside spans over a simply supported panel. These increases are derived from well known formulas that determine the maximum deflection on continuous panels with uniformly distributed loads over equal spans.

[034] The third beam theory condition is a fixed boundary condition where a panel is over a single span with two opposite ends fixed to the sides of the supporting frame members to prevent the panel from rotating. A fixed boundary beam is always depicted as being fixed to the sides of frame members, suggesting that fixing the entire end perimeter is required to prevent rotation. A fixed boundary panel has five times the load capacity of the same simply supported panel which is a 400% increase. The maximum deflection formula for a fixed boundary conditioned panel is: $d = wL^3/384EI$ [Math 7] and the formula for the load capacity per centimeter of panel to frame member interface is: $w = 384dEI/L^3$ [Math 8].

[035] While a fixed boundary condition theoretically has a 400% increase in load capacity over a simply supported panel, it is a misnomer in that testing showed that the increase is really a variable from ranging from a 1% to 400%, depending upon the sufficiency of the panel to frame member bond. Therefore, for purposes of this disclosure, a fixed boundary condition is recognized as having some increase in load capacity up to 400% while a fully fixed boundary condition is one that has attained the full 400% increase in load capacity.

[036] In order to compare the effectiveness of the new conditions, it is necessary to compare their load carrying capacities with those of known conditions and specifically to the simply supported and the continuous conditioned panel. Where applicable, the above continuous conditioned percentage increases can be used to determine the continuous conditioned load capacity from a known simply supported load capacity. Or, load testing can be used on different continuous conditioned panels with a variety of different configurations of frame members, loads, spans, etc. Once a panel's simply supported and/or continuous conditioned load capacity is determined, it can be compared to any increased load capacity induced on the same panel by the new conditions. The load capacity induced on a panel by the various new conditions will have to be determined by load tests until such time formulas may be developed that consider all of the variables.

[037] While the techniques for applying both the simply supported and continuous condition to a panel of any material are obvious, "fixing" a panel is much more ambiguous, especially when applied to different materials and the historic inference that the entire perimeter of each panel end must be fixed to the side of frame members. Fixing a panel or a fixed panel is where a sufficient bond exists between the panel and frame members to induce a fixed boundary

condition on the panel. The object of fixing a panel is to prevent the panel from rotating. Given that different materials have different properties it is obvious that techniques to prevent rotating differ from material to material. For example, the techniques used to fix a steel or a concrete panel are very different from those used to fix a foam panel.

[038] As such, both the simply supported and the continuous conditions are easy to apply and widely used. The fixed boundary condition, on the other hand, is little used outside of structural steel frames, reinforce concrete, reinforced resins and to some degree wood applications. Structural steel connections can be fixed by welding or multiple bolts to prevent rotation while reinforced concrete and reinforced resin connections are inherently fixed. Wood has had limited success in that only small increases in load capacity have been disclosed to date.

[039] Beyond this there is a lack of prior art concerning the practical application of the fixed boundary condition to other materials, especially materials having a low modulus of elasticity or panels having a low flexural stiffness. In addition, given that steel, reinforced concrete and reinforced resin all have a higher modulus of elasticity than wood, and wood has had much less success in attaining a fixed boundary condition, this suggests that the fixed boundary condition's application may decrease with a material's modulus of elasticity. As such, it appears the fixed boundary condition is fully applicable to steel and reinforced concrete and only partially applicable to wood and by extension inapplicable to foam. For these reasons the ability to increase the load capacity of a foam with a fixed boundary condition was unexpected.

[040] Substantial testing was undertaken as part of this disclosure and unless otherwise noted all testing herein referred to was done for this disclosure. Testing revealed that a fixed boundary condition is not only applicable to weak, light and thin materials but is easily attained through certain material appropriate techniques. Through testing it was found that a fixed boundary condition was actually easier to induce on materials having a low modulus of elasticity or panels having a low flexural stiffness than on panels with much higher flexural stiffness. In fact, techniques were developed that enable far more than a 400% increase in load capacity on weaker material panels so that a material such as foam can be transformed into a multi-functional structural panel with a load capacity greater than plywood. Testing also found that a fixed boundary condition may be obtained by sufficiently bonding a panel to the frame member's sides and/or top edges and that it also applies to continuous panels.

[041] Several findings were made including that an adhesive bond alone or in conjunction with fasteners does not necessarily produce an increase in a panel's load capacity. Rather, in order to attain any degree of a fixed boundary condition on a panel, a sufficiently high bonding strength must be present on each of at least two spaced apart frame members creating the span

and the sufficiency of the bonding strength is dependent upon the panel's flexural stiffness. The higher the panel's flexural stiffness the higher the required bonding strength to induce a fixed boundary condition. Moreover, the required bonding strength was also found to be a multiple of the load supported over a span and the greater the span the greater the multiple. Therefore, as a panel's load capacity decreases, the bonding strength must be increased. As a result of these and other findings, techniques were developed to obtain sufficiently high bonding strengths.

[042] As used herein, a bond or bonding is something that binds, fastens, confines, or holds together and may also refer to using an adhesive, cementing material, or fusible ingredient that combines, unites, or strengthens and also to a bonding technique such as thermal bonding. Adhesive refers to both a substance and/or technique that causes something to adhere to a material or that is designed to adhere to produce an adhesive bond. Bonding strength is herein defined as the amount or degree of bond between a panel and frame members and is measured in newtons (N) as derived from a bonding capacity multiplied by a bonding area.

[043] Once testing provided a better understanding of a fixed boundary condition and possible techniques, four new conditions were developed to make the fixed boundary and the continuous conditions more effective and applicable to other materials. Each of these four new conditions provide a panel with an increased load capacity by the panel's interaction with the frame members and in particular the panel being continuous over frame members, fixed to frame members and having a dropped section between frame members, or any combination thereof. The first new condition is the fixed/continuous condition and combines the fixed boundary and the continuous conditions. The second new condition is the continuous/dropped condition which adds a dropped section to the panel over the span. The third new condition is the fixed/continuous/dropped condition which combines the fixed boundary and the continuous/dropped conditions. These new conditions enable weaker, lighter and thinner panels to easily attain as much as a 500,000% or more increase in load capacity and thereby may be substituted for panel materials having a much higher modulus of elasticity. The fourth new condition is the enhanced continuous condition which capitalizes on the much higher load capacities of the inside span.

[044] The first new condition, the fixed/continuous condition, combines the fixed boundary and the continuous conditions and is most effective on low modulus of elasticity materials such as foam. The fixed/continuous condition is a panel supported by spaced apart frame members with a continuous section that is continuous over and fixed to the top edges of the frame members. Unlike the fixed boundary or the continuous conditions, the fixed/continuous condition may be induced on a panel over a single or multiple spans. The fixed/continuous

panel is sufficiently bonded to the frame member's top to induce a fixed boundary condition and is continuous over at least part of the supporting frame members. Although the panel is bonded to the frame member's top as opposed to it's side, which will limit the degree of fixed boundary condition attained, combining the conditions can more than compensate for such reduction since more than a 400% increase in load capacity is possible. As a result, a fixed/continuous conditioned panel has a substantial increase in load capacity over that of a continuous panel.

[045] The second new condition, the continuous/dropped condition, occurs when a panel has a continuous section and a dropped section which combine to form a thickened section. The continuous/dropped condition is a panel supported by spaced apart frame members with a continuous section that is continuous over the frame member's top edges and a dropped section that is between the frame member's sides and in contact with the continuous section. The panel is not fixed to the frame members. The continuous section is that part of the panel that is continuous over frame members and over spans created by spaced apart frame members supporting the panel and thereby the panel has a continuous condition. All continuous panels have a continuous section. The dropped section is that part of the panel below, behind or otherwise adjacent to the continuous section and is between the sides of frame members and thereby below or behind the plane created by the frame member's top edges. It is the dropped section and its relationship with the frame members that provide the increased load capacity above that provided by a continuous condition. While the continuous condition relies solely upon the rotational resistance provided by a portion of the panel over an adjacent span for its increase in load capacity, the continuous/dropped panel relies upon a thickened panel section over the span and, where it exists, the rotational resistance from an adjacent span. The continuous/dropped condition may be applied to both a simply supported panel and a continuous conditioned panel by adding a dropped section and therefore the simply supported panel and the continuous conditioned panel may be called continuous sections.

[046] Sufficiently bonding a continuous/dropped panel to frame members induces a fixed boundary condition on the panel that further increases a panel's load capacity. This combination is called a fixed/continuous/dropped condition and may be induced on a panel over a single or multiple spans. The fixed/continuous/dropped condition is a panel supported by spaced apart frame members with a continuous section that is continuous over the top edges of the frame members and a dropped section situated between the frame member's sides and in contact with the inside of the continuous section. The panel is fixed to the top edges and/or the sides of the frame members. The dropped section may be situated in any number of spans in a continuous dropped or a fixed/continuous/dropped condition. The term one or more dropped sections shall

mean that either a single dropped section may be situated in any number of the spans or more than one dropped sections, such as two fillets, may be situated in any number of the spans.

[047] A major advantage of both the continuous/dropped condition and the fixed/continuous/dropped condition is that a panel's load capacity can be increased without increasing the structural section's thickness. Of all the new conditions, the fixed/continuous/dropped condition can provide the greatest increase in load capacity by 500,000% or more in some situations. This is due in part to the additional bonding area made available by the dropped section's interface with the frame members, which can substantially increase the degree of fixed boundary condition induced on the panel. It was also discovered that fillets can be used as dropped sections to both further increase the bonding area and to effectively shorten the span which greatly affects a panel's load capacity.

[048] For example, a fixed/continuous/dropped condition induced on a 2.5 cm thick continuous panel with a load capacity of about 138.8 Pa over a 36.8 cm span can be increased about 500% to 833 Pa by adding a 2.5 cm dropped section. A partial fixed boundary condition is also induced causing another two times increase in load capacity to about 1,666 Pa. Finally, fillets can be used to effectively shorten the span by 5 cm to 31.8 cm which increases the load capacity to 3,064 Pa. As a result, the fixed/continuous/dropped condition increased the panel's continuous load capacity by 2,100% from 138.8 Pa to 3,064 Pa .

[049] The fourth new condition, the enhanced continuous condition, greatly improves the effective load carrying capacity of a panel by increasing the load capacity of the outside spans to correspond to that of the inside spans. Presently a panel's load capacity rating is determined by its weakest section which is the panel's outside spans. Due to span reaction, the inside span's load capacity can be as much as a 220% increase over that of the outside spans, which is wasted since the weakest spans control. By increasing the load capacity of the two outside spans to correspond to its inside spans, the panel has a much higher load carrying capacity rating. While this may be of little value for traditional panels spanning three or four spans, it's exceptionally beneficial to panels created to span six or more spans, since the cost of increasing the outside span's load capacity is negligible as compared to increasing the entire panel's load capacity. By using polyurethane foam as part of a composite panel, it is possible to create a single panel with numerous inside spans covering an entire wall, roof or even much of an entire building.

[050] The structural section disclosed herein is a single faced structural section comprised of one or more frame members providing some degree of a frame with one or more panels continuous over the top or outside of the frame and, where necessary, rotational resistance members attached to the bottom or inside of the frame members. As used herein, a frame is

comprised of one or more individual frame members that may or may not be in contact with one another and that provide a partial or full border for a panel or structural section. A frame may include individual frame members internal to the border, such as studs between a top and bottom plate and/or frame members external to the border such as rafters extending beyond a top plate. A panel may be cantilevered beyond a frame member or a frame's border. The terms spaced a distance apart or spaced apart frame members shall mean that at least part of the frame member's sides are not in contact with those of an adjacent frame member, or itself, such that a span, i.e. a distance and a space exists between the frame members.

[051] A major finding was that the bonding strength necessary to induce a fully fixed boundary condition is a function of the panel's flexural stiffness. The higher the flexural stiffness, the greater the required bond, meaning that 13 mm plywood for example, will require a bond strength many times greater than that needed for 50 mm foam. This explains why fasteners used to attach wood panels to frame members have little or no impact on increasing the panel's load capacity. It also exposes the ability of low flexural stiffness panels to be much more susceptible to a load capacity increase induced by a fixed boundary condition.

[052] The testing led to several unexpected results such as a typical 32 kilogram per cubic meter (kg/m^3) density polyurethane foam has a sufficient bonding capacity to induce a fixed boundary condition on itself or other foams that increases the foams load capacity by many times. Prior to this it was unrecognized that polyurethane foam could induce a fixed boundary condition on itself or anything else. Another unexpected result was that a foamed composite panel sufficiently bonded to frame members can induce a fixed boundary condition on the flexural stiffness of the entire composite panel, not just on the foam.

[053] Another unexpected result was that material appropriate fillets can significantly increase a panel's load capacity by several hundred or thousand percent by increasing the degree of fixed boundary condition and/or by effectively shortening the span.

[054] Another unexpected result was that a dropped section can increase a continuous panel's load capacity by several hundred percent.

[055] Another unexpected result is that increases in load capacities induced by conditions are in series, with each subsequent condition a multiple of prior induced conditions such that a panel's load capacity may be increased thousands of times by compounding conditions.

[056] Another unexpected result is the finding that the degree of increased load capacity induced on a panel by these new conditions is inversely related to the flexural stiffness of the panel's continuous section.

[057] Another unexpected result was that the inducement of a fixed/continuous condition on a panel can increase the panels load capacity to more than the combined 540% increase by the fixed boundary condition (400%) and the continuous condition (140%).

[058] Another unexpected result was that polyurethane foam can splice individual panels into a large, single panel with multiple spans and induce a continuous conditioned structural continuity over the spans to make all but two inside spans that have an inherently higher load carrying capacity that was previously wasted and a previously unknown problem.

[059] It was also found that the bonding strength required for a fully fixed boundary condition was a multiple of the load and the longer the span, the greater the multiple. For example, a panel over a 36.8 cm span may require a bonding strength of 50 to 90 times the load on that span whereas the same panel over a 61 cm span may require a bonding strength over 200 times the load. Again, the higher the material's flexural stiffness and the longer the span, the greater the required bond strength to induce a fixed boundary condition. This also shows that increasing bonding strength can offset a longer span's decrease in load capacity.

[060] Accordingly, one advantage of the inventive subject matter is that weaker, thinner, lighter, more versatile and less expensive materials can be used as structural panels.

[061] Another advantage is that polyurethane foam bonded to a cladding and frame members can become a comprehensive structural panel that provides a finished exterior, continuous and cavity insulation as well as an air, moisture and vapor barrier, increased uplift resistance and the elimination of condensation and thermal expansion/contraction.

[062] Another advantage is that adding fillets can increase a panel's load capacity by several thousand percent above that of the same simply supported panel.

[063] Another advantage is that a panel can have a substantial increase load capacity without thickening its structural section.

[064] Another advantage is that panels may be created to cover numerous spans to utilize the existing increased load capacity of inside spans which is presently wasted.

[065] Another advantage is that a low cost spray-up process may be used to manufacture comprehensive building panels.

[066] Another advantage is that frame members may be much thinner since the frame member's sides can support a panel and thinner frame members can be supported by the panel's dropped section.

[067] Another advantage is that a prefabricated slotted panel may have its load capacity increased multiple times by simply being sufficiently bonded to frame members.

[068] Another advantage is that thin ribbed panels can be made structurally sufficient and have a substantial increase in load capacity by being filled with and bonded to frame members with polyurethane foam.

[069] Another advantage is that a fixed/continuous/dropped condition can greatly reduce thermal expansion and contraction on susceptible claddings.

[070] Another advantage is that the new conditions induced on a panel act in series such that each incremental increase in load capacity is compounded by the next condition that can increase a panel's load capacity by several thousand percent.

[071] Another advantage is that a polyurethane foam bonding a cladding to frame members creates a composite panel and the induced conditions multiply the entire panel's load capacity as opposed to only the foam's load capacity.

[072] Other objects, advantages and features of the inventive subject matter will be self evident to those skilled in the art as more thoroughly described below.

BRIEF DESCRIPTION OF THE DRAWINGS

[073] Fig. 1 is a frame supported continuous panel over multiple spans

[074] Fig. 2 is a frame supported continuous/dropped panel over multiple spans.

[075] Fig. 3 is a continuous/dropped panel supported by a rotational resistance member.

[076] Fig. 4 is a simply supported panel over a single span with a shortened span.

[077] Fig. 5 is a frame supported fixed/continuous/dropped panel with fillets.

[078] Fig. 6 is a fixed/continuous/dropped panel with a thickened section and fillets.

[079] Fig. 7 is a section view of a circular fixed/continuous/dropped panel supported by a single frame member and with fillets as the dropped section.

[080] Fig. 8 is a bottom view of Fig. 7 showing the circular panel and the single, circular frame member.

[081] Fig. 9 is a ribbed foam composite panel bonded to the top of frame members with polyurethane foam.

[082] Fig. 10 is a ribbed structural section with a polyurethane foam dropped section to reinforce the ribs and the skin and induce a fixed/continuous/dropped condition on the skin.

[083] Fig. 11 is a perspective of a ribbed foam composite panel bonded to frame members to induce a fixed/continuous/dropped condition on the composite panel.

[084] Fig. 12 is a combined ribbed foam composite panel and a ribbed structural section that has increased load capacity for both the panel and the cladding.

[085] Fig. 13 is a continuous panel with a blocked rotational resistance members.

- [086] Fig. 14 is a frame supported fixed/continuous/dropped panel with brick cladding.
- [087] Fig. 15 is an enhanced continuous conditioned panel with increased load capacity induced on the outside spans to correspond to that of the inside spans.
- [088] Fig. 16 is two individual fixed/continuous/dropped panels with a seam between them.
- [089] Fig. 17 is the two panels of Fig. 16 merged into a single structurally continuous panel.
- [090] Fig. 18 is a slotted, rib embedded panel with a finished cladding.
- [091] Fig. 19 is a frame supported panel notched to create a continuous/dropped condition.
- [092] Fig. 20 is a foam core sandwich panel in a fixed/continuous/dropped condition.
- [093] Fig. 21 is ribbed siding being attached to a frame member.
- [094] Fig. 22 is the ribbed siding of Fig. 21 bonded to a frame member with polyurethane foam that creates a foam composite panel with increased load capacity.
- [095] Fig. 23 is a section view of a cladding spacer attaching cladding to a frame member.
- [096] Fig. 24 is a section view of Fig. 23 showing a filled in spacing.
- [097] Fig. 25 is a surface onto which cladding is positioned face down.
- [098] Fig. 26 is Fig. 25 with a frame positioned above the cladding.
- [099] Fig. 27 is Fig. 26 with the addition of polyurethane foam to bond everything together.
- [0100] Fig. 28 is a panel in a fixed/continuous/dropped condition to minimize the cladding's thermal expansion and contraction.
- [0101] Fig. 29 is a panel in a fixed/continuous/dropped condition with mesh embedded in the polyurethane foam as an anti-penetration barrier.
- [0102] Fig. 30 is a perspective of the backside of a panel showing thin frame members bonded to the panel and to the rotational resistance members.

DESCRIPTION OF PREFERRED EMBODIMENT

[0103] The inventive subject matter is the application of four new conditions on weaker, lighter, thinner and less costly panels to enable them to become stiffer, stronger and more versatile by re-configuring the panel's shape and/or by sufficiently bonding the panel to frame members. Two newly discovered conditions are a fixed/continuous condition and a continuous/dropped condition and when combined these two conditions create the third new condition called a fixed/continuous/dropped condition which is the emphasis of this invention. A fourth condition, an enhanced continuous condition, may be applied to each of the other three conditions. The effectiveness of these new conditions is inversely related to a panel's flexural stiffness in that the smaller the flexural stiffness the greater the effect the conditions have on

increasing a panel's load capacity. As a result, low flexural stiffness and typically non-structural materials, such as a foam insulant, may be converted into structural panels to facilitate a new generation of multi-functional structural panels for a variety of applications.

[0104] Several tests were undertaken on panels made of a low modulus of elasticity materials or panels with a low flexural stiffness. In one test, a simply supported 40.6 cm wide and 7.6 cm thick EPS foam board was load tested over a 41.9 cm span and found to carry 445 Pa before deflecting about .17 cm (.17 cm deflection $\approx$ 41.9 cm divided by 240). The same 40.6 cm wide foam board was then glued to the sides of two frame members spaced 41.9 cm apart with a polyurethane foam poured into a 3.2 cm deep by .65 cm wide gap between the sides of the frame members and the foam board. When load tested, the EPS foam board carried a uniformly distributed load of 2,107 Pa before deflecting .17 cm. As such, the fixed EPS foam board carried 4.7 times, or a 370% increase in load above the simply supported foam board.

[0105] The finding that an EPS foam panel's load capacity can be increased about 400% if it is sufficiently bonded, i.e. fixed, as opposed to nailed to frame members is consistent with the fixed boundary condition from fundamental beam theory used to predict deflection. This finding was unexpected since EPS foam has such a low modulus of elasticity as compared to steel and reinforced concrete with which fixed boundary conditions are well known.

[0106] The testing continued on the EPS foam board by cutting the 3.2 cm deep adhesive bond along both frame members about .65 cm and testing for load carrying capacity. When the adhesive bond was cut back from 3.2 cm to a 2.6 cm deep bond, the EPS foam board could only carry about a 1,293 Pa load before deflecting to .17 cm and when the adhesive bond was further cut to a 1.9 cm deep bond only a 910 Pa load was carried. This continued with a 1.3 cm deep adhesive bond supporting a 814 Pa load and to a .65 cm deep adhesive bond having a 718 Pa load carrying capacity, all before deflecting .17 cm. Finally, when the EPS foam board was only slightly bonded to the frame members it carried the same load it carried when simply supported.

[0107] From this it became evident that the foam board's load carrying capacity was directly related to the degree or the strength of the adhesive bond between the foam board and the frame members. As such, the fixed boundary condition actually has degrees of bonding strength that result in degrees of increases in load capacity. Depending upon the bonding strength the degree of increase in load capacity ranges from zero, where the bond is insufficient to prevent rotation, up to about a 400% increase in load capacity induced by a fully fixed boundary condition. For clarification purposes, a fixed boundary inducing a 400% increase in load capacity is herein referred to as a "fully fixed boundary". Otherwise a "fixed boundary" condition will mean that some increase in load capacity is present as induced by the fixed boundary condition.

[0108] As such, testing revealed that both a minimum bond must be present and that a direct relationship exists between the bonding strength and the amount of load capacity increase attained by a fixed boundary condition. This means that the degree by which a panel is bonded to the frame members can be predetermined and enables the regulation of the panel's load capacity. It also means that other adhesive materials may be used since the polyurethane foam was used such that the type of adhesive material was irrelevant as long as it's capable of providing a sufficient bond between the foam board, as a panel, and the frame members.

[0109] Four types of foam boards were tested: expanded polystyrene (EPS), extruded polystyrene foam (XPS), polyurethane foam (about a 32 kg/m³ density) and a paper/plastic coated EPS panel. The 32 kg/m³ density polyurethane foam bonded to claddings with and without ribs was also tested, as was plywood up to .9 cm thick and thin plastic. From this testing, all of the panels performed similarly and each of the foam panels were able to attain about a 400% load capacity increase, or more, when sufficiently bonded or fixed to the frame members. The .9 cm and .56 cm thick plywood panels did attain an increased load capacity from the fixed boundary condition, although far below 400%. The polyurethane foam board began as a two part liquid that was poured in place and expanded to bond to the frame members and to the cladding material while transforming itself into a solid panel. The references to calculations and predicted loads as used herein refer to the utilization of the appropriate simply supported, continuous conditioned and fixed boundary conditioned deflection formulas.

[0110] Bonding a panel to frame members does not necessarily induce a fixed boundary condition. Rather, a sufficient bond is necessary and testing showed that bonding strength is a crucial factor in the inducement of a fixed boundary condition on a panel to increase its load capacity. Bonding strength is determined by the bonding material's bonding capacity, multiplied by the size of the bonding area between the panel and frame member. For example a polyurethane foam with a 20 N/cm² bonding capacity applied over two square centimeters (2 cm²) of bonding area equals 40 N of bonding strength between the panel and frame member. Each continuous panel has an interface or contact area on at least the frame member's top edge and along the frame member's sides when a dropped section is present. Interface is the amount of panel to frame member contact area over a section view of the frame member and is stated per centimeter of the panel to frame member border which is transverse to the interface. For example a 61 cm by 280 cm continuous panel over seven frame members that have a 5 cm wide top edge and spaced 40.6 cm apart (spans) has a 61 cm border with each frame member. The interface is 5 cm², the width of the top edge, for each of the 61 cm of border. If the panel has a 2.5 cm dropped section on both sides of the frame members, the interface increases to 10 cm²

per centimeter of border. The bonding area is the amount of the 5 cm² or 10 cm² respectively that is actually sufficiently bonded.

[0111] In order to carry or support an increased load using the fixed boundary condition, it is important that the panel be “fixed” to the frame members. Fixed is herein defined as a sufficiently high bond or bonding strength between the panel and frame members that induces a fixed boundary condition on the panel. Sufficiently bonded is herein referred to as being fixed. Bonding technique is any bonding material and/or technique that can be used to prevent a panel from rotating. Bonding materials include any type of adhesive or other material that can cause a bond between a panel and frame member. An example of a technique is a panel's dropped section, tightly fitted between the sides of two frame members that prevents the panel from rotating. Bonding techniques are material appropriate in that some bonding techniques only apply to certain panel and/or frame member materials. An adhesive or an adhesive bond are types of bonding technique.

[0112] In order to achieve a sufficient bond it is important that the bonding technique has a minimum bonding capacity of at least 7 N/cm² and preferably at least 10.5 N/cm² and more preferably at least 14 N/cm² and even more preferably at least 17.5 N/cm². The problem with bonding capacities of less than 7 N/cm² is that they require larger bonding areas to induce a sufficient bond in most situations. Since steel can be a panel material and welding is a bonding technique, the maximum bonding capacity is that of a steel weld on stainless steel or about 40,000 N/cm².

[0113] Testing found that the bonding strength required for any degree of a fixed boundary condition is a multiple of the load to be carried and the multiple increases as the span increases. In one test two, 5.1 cm polyurethane foam panels were bonded to the sides of frame members with a 420 N bonding strength. The first panel had a 36.8 cm span and the second panel a 57.2 cm span. The 36.8 cm panel carried a fully fixed boundary condition load of 2,308 Pa (.2308 N/cm²) which is 8.5 N per interface cm (36.8 cm multiplied by .2308 N/cm²). The bonding strength was then decreased by cutting back the bonding area until reaching about 394 N when the bonding strength became insufficient to support the 2,308 Pa load. At the 394 N bonding strength, the bond to load factor was 46 (394 N divided by 8.5 N). When the 57.2 cm panel was tested, it supported 570 Pa (.057 N/cm²) which is 3.26 N per interface cm (57.2 cm multiplied by .057 N/cm²) and less than a predicted fully fixed boundary condition of 613 Pa. The 57.2 cm panel had a bond to load factor of 129 (420 N divided by 3.26 N), which is 2.8 times larger than the 46 bond to load factor for the 36.8 cm span. As such, the longer the span, the greater the required bonding strength.

[0114] In one embodiment of this inventive subject matter a fixed boundary condition is combined with a continuous condition to induce an increase in load capacity on a frame supported panel. Fig. 1 shows a panel 1 comprised of polyurethane foam 7 bonded to a cladding 23 to create a composite panel 1 that is also bonded to the top edge 26 of frame members 3. The panel 1 is continuous over two or more spans 6 and, as a continuous panel, the entire panel 1 consists of a continuous section 18 that is above the top edges 26 and outside the space 4 formed between the frame member's sides 25. Assuming the polyurethane foam 7 is fixed to the top edge 26 of the frame members 3, a fixed boundary condition is induced on both the polyurethane foam 7 and the composite panel 1. The fixed boundary condition induces an increased load capacity that enables the panel 1 to support a greater load 11 than possible by the continuous condition. Load 11 is represented in the drawings by a downward pointing arrow. Fig. 1 also shows the panel 1 and frame members 3 comprise a structural section 10 with a thickness 5 (signified by a two way arrow). A rotational resistance member 34 is shown fastened 2 to the frame member's bottom edge 27 to enable the panel 1 to carry the increased load capacity. While the foam 7 in Fig. 1 is a self-bonding polyurethane foam, it may be any type of foam that is sufficiently bonded in any manner to the cladding 23 and is thereby fixed to the frame members 3.

[0115] Combining the fixed boundary condition with the continuous condition is herein called a fixed/continuous condition. Testing was conducted on several fixed/continuous conditioned panels to determine how the combined conditions affect load capacity as compared to a simply supported and a continuous conditioned panel. The first test was of 2.5 cm thick by 9.5 cm wide (frame member interface) by 44.5 cm long polyurethane foam panels with a 894 N-cm² flexural stiffness and supported by frame members and rotational resistance members. When simply supported over a 36.8 cm span, the panel supported 58 Pa load before deflecting .15 cm ($L/240$ [Math 1]). This was consistent with the calculated load for a 6.55 MPa modulus of elasticity polyurethane foam. When the same panel was bonded to the top of the frame members using the same polyurethane foam with a bonding capacity of 20.7 N/cm², the panel supported 330 Pa over the single 36.8 cm span before deflecting .15 cm. Therefore, the fixed panel carried 272 Pa more or a 469% increase over what the simply supported panel could support. This was unexpected in that it is more than a 400% fixed boundary increase and because typical 32 kg/m³ polyurethane foam was found to produce a sufficient bonding strength to induce a fully fixed boundary condition on itself.

[0116] Similar testing was performed on an XPS foam board and a plywood panel. A 1.9 cm thick by 20.3 cm wide XPS foam board with a 867 N-cm² flexural stiffness and spanning 61 cm.

The foam board carried 12 Pa when simply supported and 105 Pa when bonded to the 3.8 cm top edge of frame members with 32 kg/m³ polyurethane foam that has a 20.7 N/cm² bonding capacity. Therefore a 78.7 N bonding strength produced a 775% increased load capacity over the simply supported panel, far more than a 400% increase theoretically possible from a fully fixed boundary condition. The plywood panel was a .87 cm thick by 20.3 cm wide by 61 cm long panel with a flexural stiffness of about 64,300 N-cm² and was tested over a 61 cm span. When simply supported the plywood carried 1,226 Pa. The panel was then bonded with an 128 kg/m³ polyurethane foam, having an 82.7 N/cm² bonding capacity, to a 8.9 cm frame member's top edge for a bonding strength of 736 N (82.7 N/cm² multiplied by 8.9 cm). When provided this sufficient bonding, the panel carried a 2,332 Pa load over the same span which was a 90% increase over the simply supported load.

[0117] From the above, increasing the load capacity of the XPS foam board was much easier than for the plywood. While the XPS foam board needed only 78.7 N bonding strength to induce a 775% increase in load capacity, the plywood needed 736 N bonding strength to induce only a 90% increased load capacity. From this it is evident that the higher a panel's flexural stiffness, the greater the necessary bonding strength to induce a fixed boundary condition on the panel. All of the various foams, plastic and wood panels were able to show substantial increases in load capacity over different spans when induced with a fixed/continuous condition.

[0118] Testing was conducted for several continuous panels with uniformly distributed loads over two equal spans. The first test was of a 2.5 cm thick by 9.5 cm wide by 88.9 cm long polyurethane foam continuous panel over three spaced apart frame members creating two 36.8 cm spans. This panel supported 139 Pa over each span before deflecting .15 cm, which is 141% of the increase over the simply supported load. When bonded with 32 kg/m³ polyurethane foam to the top of the frame members the fixed/continuous panel supported 469 Pa, a 237% increase over the 139 Pa continuous panel's capacity. When bonded with an 128 kg/m³ polyurethane foam the panel supported the same load as the 32 kg/m³ foam indicating that the 32 kg/m³ foam's bond was sufficient to induce a fully fixed boundary condition on the panel and any additional bonding strength was of no benefit. Finally, a narrow, intermittent strip of 32 kg/m³ polyurethane foam was used to bond the continuous panel to the frame members and the panel was only able to support 139 Pa over the spans, the same as the unbonded continuous panel.

[0119] From the above tests, the 2.5 cm fixed/continuous panel's 469 Pa load capacity was a 709% increase over the same 2.5 cm simply supported panel's 58 Pa load capacity over the same span. This means that a fixed/continuous conditioned panel can have a higher load capacity increase than either a continuous panel with a maximum of a 141% increase, or a fixed

boundary conditioned panel with a maximum load capacity increase of 400%, or both combined at a 540% increase. This was an unexpected result, and even more so since it was attained with a 32 kg/m³ density polyurethane foam bonding itself to frame members.

[0120] In another embodiment a panel's continuous section is configured with a dropped section over the span to induce an increased load capacity on the panel. This new configuration is called a continuous/dropped condition and induces a substantial increase in the panel's load capacity without increasing the structural section's thickness and/or enables a thinner section without sacrificing load capacity. Fig. 2 shows the same panel as Fig. 1 except the polyurethane foam 7 has been thickened between the frame members 3 to add a dropped section 19 that is in the space 4 between the frame member's sides 25. As such, the composite panel 1 comprised of a cladding 23 and the foam 7 is both continuous over, as a continuous section 18, and dropped between the frame members 3, as a dropped section 19, to form a continuous/dropped panel condition. This results in a thickened polyurethane foam 7 while the thickness 5 of the structural section 10 remains the same. In addition, the polyurethane foam 7 has a much larger bonding area 14 by by the interface with the frame member's top edge 26 and sides 25. The dropped section can be any thickness, i.e. depth, and preferably of at least .2 cm thick, more preferably at least .6 cm thick, even more preferably at least 1.3 cm thick, even still more preferably at least 1.9 cm thick and still even more preferably at least 2.5 cm thick. The dropped section's maximum thickness is 45.65 cm which is the panel's maximum thickness of 45.7 cm less the .05 cm minimum continuous section thickness.

[0121] Assuming a sufficient bond between the panel 1 and frame members 3, the panel 1 in Fig. 2 is herein referred to as having a fixed/continuous/dropped condition which combines the continuous/dropped configuration with a fixed boundary condition on the panel 1. The panel 1 may be fixed to the top edge 26 and/or one or more sides 25 of the frame members 3 to induce a fixed/continuous/dropped condition. Such a condition induces a substantial increase in load capacity on the panel, enabling it to carry a greater load 11, and thereby the need for rotational resistance members 34 fastened 2 or otherwise attached to the frame member's bottom edge 27. While the continuous/dropped configuration exists with or without the frame members in place, the fixed/continuous/dropped condition is only induced on the panel when the frame members are fixed in place and influence the load carrying capacity of the panel. If the panel 1 in Fig. 2 was not fixed to the frame members 3, it would have a continuous/dropped condition.

[0122] In one test of a single spanned panel with a fixed/continuous/dropped condition, a 40.6 cm wide foam composite panel comprised of 4.8 cm thick polyurethane foam with a .08 cm plastic cover (cladding). The panel's continuous section comprised of 2.5 cm foam with the

plastic cover and fixed to the top edges of two frame members spaced 36.8 cm apart. The panel's dropped section comprised 2.3 cm of foam which was fixed to the sides of the two frame members facing each other. The 2.5 cm continuous section was predicted to carry 58 Pa when simply supported and a 4.8 cm thickened panel was predicted to carry 393 Pa simply supported and 1,965 Pa as a fully fixed boundary panel. However, when the 4.8 cm thick fixed/continuous/dropped panel was load tested it carried a 5,410 Pa load, a 175% increase over the 1,965 Pa predicted fully fixed boundary condition, a 1,277% increase over the 393 Pa thickened panel and a 9,228% increase over the 58 Pa continuous section.

[0123] Testing was also conducted on several 11.4 cm thick structural sections comprised of a 2.5 cm polyurethane foam panel over the top of 3.8 cm wide by 8.9 cm deep frame members for both single and multiple spans. One set of panels were simply supported or continuous panels comprised of a 2.5 cm thick section of foam supported by and/or continuous over the top edge of frame members. A second set of panels were continuous/dropped panels that had a 2.5 cm continuous section over the frame members and a 2.5 cm dropped section that thickened the panel to 5 cm between the frame members. The spans were all 36.8 cm and the frame members were supported by rotational resistance members to prevent frame member rotation.

[0124] The first test was of a 9.5 cm wide by 44.5 cm long, 2.5 cm thick simply supported panel over a single 36.8 cm span that carried 58 Pa before deflecting .15 cm. A second test was of a 44.5 cm long simply supported continuous/dropped panel over a 36.8 cm span with a 2.5 cm continuous section and a 2.5 cm dropped section. This panel carried 354 Pa or a 510% increase in load capacity over the 2.5 cm simply supported panel that carried 58 Pa. In another test, the 2.5 cm thick by 44.5 cm long panel was bonded to the top edges of the frame members with 32 kg/m³ polyurethane foam to induce a fixed/continuous condition on the panel. This panel carried 330 Pa, about a 469% increase from its 58 Pa simply supported.

[0125] The continuous/dropped panel was then fixed to both the top edge and the sides of the frame members facing each other to induce a fixed/continuous/dropped condition on the panel which supported 1,585 Pa. As such, the fixed/continuous/dropped conditioned panel over a single span produced an increased load capacity of 2,632% over the 58 Pa carried by the same simply supported panel and a 380% increase over the 330 Pa supported by the same panel in a fixed/continuous condition. The 1,585 Pa was also a 348% increase over the 354 Pa continuous/dropped panel and was 248% above the predicted load of 455 Pa for a simply supported 5 cm thickened section.

[0126] The same panels were then lengthened (spliced) with the same polyurethane foam to 88.9 cm long and positioned as continuous over two equal 36.8 cm spans. In these tests, the 2.5

cm thick, unbonded continuous panel carried 139 Pa, which was a 141% increase over the single span - as predicted. When the continuous panel was bonded to the top edges of the frame members with 32 kg/m³ foam to induce a fixed/continuous condition, it carried 469 Pa. Testing of the same lengthened continuous/dropped panel resulted in it carrying 838 Pa with the dropped section tightly against the frame member's sides and 570 Pa when a .3 cm gap existed between the dropped section and the frame member's sides. When the continuous/dropped panel was fixed to the top edge and sides of the frame members with a 32 kg/m³ polyurethane foam to induce a fixed/continuous/dropped condition on the panel, it was able to support 1,747 Pa over each span. As such, the fixed/continuous/dropped conditioned panel over two spans produced an increased load capacity of 1157% over the continuous panel's 139 Pa and 272% above the 469 Pa supported by the fixed/continuous panel. The 1,747 Pa was also a 206% increase over the 570 Pa of the continuous/dropped panel with the gap, indicating less than a fully fixed boundary condition. The 1,747 Pa capacity was also 60% above the predicted load capacity of 1,092 Pa for a simply supported 5 cm thickened section over two spans.

[0127] The dramatic increases in load capacities induced on panels by the fixed/continuous/dropped condition were unexpected because they are far above the 141% increases from a continuous condition, or the 400% increase from a fixed boundary condition or even the 272% increase over the fixed/continuous conditioned panel. The fixed/continuous/dropped conditioned panels also had significant increased load capacities over the fixed/continuous panel, the continuous/dropped panel and even over the continuous panel having its continuous section the same thickness of a continuous/dropped panel's thickened section. Not only does the dropped section increase the panel's load capacity, it also increases the interface which enables more bonding area to further increase the fixed boundary condition.

[0128] A .87 cm thick plywood panel was also tested with the fixed/continuous dropped condition over a 122 cm span. When simply supported the 20.3 cm wide panel carried 115 Pa and when bonded to frame members with a 315 N bonding strength it carried 340 Pa. This was a 196% increase for a fixed/continuous condition. When a 2.5 cm layer of polyurethane foam was bonded to the plywood as a dropped section, the fixed/continuous/dropped conditioned panel carried 402 Pa over the 122 cm span, a 250% increase in load capacity over the continuous section's 115 Pa .

[0129] As a result of this and other testing all of the low modulus of elasticity materials or panels having a low flexural stiffness had an increased load capacity induced on the panel with a fixed/continuous/dropped condition. This applied to all foams, plastic and wood tested and indicates the fixed/continuous/dropped condition applies to most rigid or semi-rigid materials.

[0130] As demonstrated above, a panel's load capacities from the various existing and new conditions can be compared to one another. While the existing simply supported, continuous and fixed boundary conditions all have mathematical relationships, the new conditions must be load tested until more definitive relationships are determined. Since the fixed boundary condition is variable, based upon bond strength, it is more meaningful to compare the increased load capacities induced on panels by the new conditions with the load capacities of simply supported or continuous conditioned panels.

[0131] A panel configured with a dropped section has a different flexural stiffness for the part of the panel that is over frame members and for part of the panel that is the thickened section over the span. Since the dropped section may or may not be bonded to the continuous section, a panel with a dropped section may have a different flexural stiffness for the continuous section, the dropped section and for the combined continuous and dropped sections, i.e. the thickened section. Additionally, a panel's load capacity over a span may also be separately determined for the continuous section only, the dropped section only or for the thickened section. This applies regardless of whether the panel is simply supported or continuous and whether or not the continuous and dropped sections are bonded together. Fillets are not included in determining flexural stiffness.

[0132] As such, a simply supported and a continuous conditioned panel both have a continuous section that has a load capacity over each span. This enables the increased load capacity of panels induced with the continuous/dropped or the fixed/continuous/dropped conditions to be compared to the same panel's continuous section. This comparison determines the amount of increased load capacity provided by inducing the new conditions on the panel. The increased load capacity induced over a panel's spans by the new conditions may be induced over the outside spans or over one or more spans, or preferably over two or more spans or more preferably over three or more spans or even more preferably over at least half of the spans and still more preferably over substantially all of the spans or even more preferably still over all of the panel's spans. The increased load capacity induced by a fixed/continuous/dropped condition may also be compared to the load capacity of the panel's unfixed thickened section.

[0133] In another embodiment a panel with the continuous/dropped condition can derive some or all of its increase in load capacity from rotational resistance members. For example, a continuous/dropped conditioned panel 1 is shown in Fig. 3 comprised of a continuous section 18 continuous over the frame member's top edge 26 and a dropped section 19 between the frame member's sides 25 and in contact with the continuous section 18. The continuous section 18 and the dropped section 19 may be of the same or different material and may or may not be bonded

to one another. Also shown is a rotational resistance member 34 that is fastened 2 or otherwise bonded to the frame members 3 and in contact with the dropped section 19. As a result of this configuration the panel 1 has a continuous/dropped condition that increases the load 11 it can carry by virtue of the support, i.e. bearing capacity, provided by the rotational resistance member 34 to the dropped section 19. The amount of increase in load capacity can be wholly or partially dependent upon the load capacity of the rotational resistance members 34. As an alternative, the continuous section 18 and/or the dropped section 19 of Fig. 3 may be fixed to the frame members 3 to induce a fixed/continuous/dropped condition on the panel 1.

[0134] Another embodiment is based upon the discovery that the panel's dropped section may be shaped to further or more efficiently increase the panel's load capacity. For example, Fig. 4 shows an XPS foam board 9, tested as a panel 1 supported by two frame members 3 spaced 61 cm apart and load tested to carry 12 Pa before deflecting .25 cm ($L/240$ [Math 1]). However, when a buildup 13 of polyurethane foam 7 was bonded to each frame member 3 and the foam board 9, the same XPS foam board 9 carried a 215 Pa load 11 over the 61 cm span 6. This is a 1,692% increase in load capacity above the 12 Pa simply supported load and required a rotational resistance member 34. A similar test was done with .87 cm plywood and the same buildups. In that test a simply supported plywood panel over an 45.7 cm span supported 1,915 Pa and when 8.9 cm fillets were added as a fixed dropped section, the fixed/continuous/dropped plywood panel supported 7,038 Pa over the same span, a 268% increased load capacity.

[0135] Such a substantial load capacity increase was caused by two factors. First, the polyurethane foam provided a sufficient bond to induce a fixed boundary condition that increased the foam board's load capacity. Second, the buildup was of a sufficiently strong material to function like a ledge attached to the frame member that effectively shortened the span between frame members. This is validated by the beam theory formulas where the calculated load for a fully fixed boundary condition for this XPS foam board over a 40 cm span is 215 Pa, the same as obtained from the tested panel. Although, while the polyurethane foam fillets maximized shortening the span and inducing a fully fixed boundary condition on the XPS foam board, the same fillets were less effective on the .87 cm thick plywood in that a fully fixed boundary condition over an 27.9 cm span should have carried a 8,618 Pa load.

[0136] The buildups 13 of Fig. 4 are basically large fillets that can be placed on one or both sides of the frame members. Fig. 5 shows a continuous panel 1 comprised of a cladding 23 with fillets 12 bonded to the bottom of the cladding 23 to create a fixed/continuous/dropped panel. The fillets 12 are also bonded to both sides 25 of the frame members 3 to effectively shorten the span 6 between frame members 3 and thereby increase the panel's 1 load 11 capacity

even more. In addition, when fillets 12 are bonded to both the panel 1 and the side 25 of the frame members, they increase the bonding area 14 which increases the bonding strength and thereby induces a greater fixed boundary condition to further increases the panel's load capacity.

[0137] As such, both a simply supported and a continuous panel can be converted into a fixed/continuous/dropped conditioned panel by the addition of fillets 12 bonded to the sides 25 of frame members and optionally bonded to the bottom of the simply supported or continuous panel 1. When this occurs, the panel 1 is then comprised of a continuous section 18 and a dropped section 19 with the dropped section consisting of fillets 12. A rotational resistance member 34 will be required to prevent frame member 3 rotation from the increased load 11. Therefore, a panel may have a single dropped section, when over a single span, or multiple dropped sections when a panel is continuous over several spans and/or multiple dropped sections such as two fillets within each span or the continuous section having a corrugated shaped bottom that extends into the dropped section area. As a result, a panel may have one or more dropped sections between said frame members.

[0138] Fillets are herein defined as a distinguishable strip or intermittent strips of any material capable of bonding to the sides of frame members in order to support a continuous panel. Distinguishable means the fillet can be distinguished from the frame member. For example welds are considered to be distinguishable whereas molded or integral cast fillets on a frame member are not. Fillets may have a self bonding or self-adhesive capability such as polyurethane foam or otherwise adhered to frame members and optionally adhered to the panels. When not adhered to the panels the fillets can effectively shorten the span between frame members. As such, in order to support a continuous panel, fillets must be of such material or composition, i.e. material appropriate, capable of effectively shortening the span and optionally of sufficiently bonding the panel to the frame members to induce a fixed boundary condition on the panel. Since the fillets are bonded to the sides of frame members, they are considered a dropped section in and of themselves as shown in Fig. 4 or they may extend the dropped section as shown in Fig. 6. In foam backed panels fillets may be bonded to the continuous section's foam and thereby add a dropped section, or bonded to the dropped section's foam and thereby extend the dropped section, or they may be unbonded to the continuous section and simply provide a support structure on which the continuous section bears.

[0139] Since fillets are included as a panel's dropped section and used to increase the load capacity of the panel's continuous section, a continuous section may span as much as 254 cm and still have its continuous section's load capacity increased by 100% or more by adding fillets. For example, a 15.2 cm polyurethane foam board with a 8.3 MPa modulus of elasticity can carry

48 Pa over a 254 cm span with a 1.06 cm deflection as simply supported. Bonding the panel to frame members and adding 20.3 cm fillets to both ends effectively shortens the span to 213.4 cm and enables the panel to carry 96 Pa, a 100% increase in load capacity. Or, if 30.5 cm fillets are used, the span is effectively shortened to 193 cm and the panel can carry 144 Pa with the same 1.06 cm deflection, which is a 200% increase in load capacity above that of the continuous section. In both cases the panel is 45.7 cm or less thick, which is the maximum panel thickness.

[0140] Fig. 6 shows a structural section 10 having a fixed/continuous/dropped panel configuration with a continuous section 18 over the top edge 26 and comprised of a cladding 23 bonded to foam 7. The panel's dropped section 19 is comprised of foam 7 extending from the continuous section 18. The foam 7 is fixed to the frame members 3 and thereby a fixed/continuous/dropped condition is induced on the panel 1. Fillets 12 extend the dropped section 19 along the sides 25 of the frame members 3. The fillets 12 increase the panel to frame interface and bonding area 14 and effectively shorten the span 6, both of which further increase the panel's load 11 capacity. The structural section 10 is comprised of the panel 1, frame members 3 and the rotational resistance member 34.

[0141] A test comparing a 5 cm thick continuous panel with a fixed/continuous/dropped panel having a 5 cm thickened section was conducted. The predicted load capacity for a 5 cm thick polyurethane foam panel over 36.8 cm spans is 450 Pa when simply supported, 2,700 Pa for a continuous conditioned inside span (6 multiplied by 450) and 2,250 Pa for a fixed boundary condition (5 multiplied by 450). These predicted loads were compared to the actual loads carried by the inside span of a continuous/dropped and a fixed/continuous/dropped panel with a 5 cm thickened section comprised of a 2.5 cm thick continuous section and a 2.5 cm thick dropped section of polyurethane foam. When tested, the continuous/dropped panel carried 2,030 Pa on its inside span, which is less than the 2,700 Pa for the 5 cm thick continuous panel over the same span. However, the fixed/continuous/dropped panel's inside span was able to support 3,615 Pa, a 34% increase over the 5 cm thick continuous panel. This demonstrates that both inside spans can be increased by the new conditions and that sufficiently bonding, i.e. fixing a continuous/dropped panel substantially increases its load bearing capacity.

[0142] A panel is defined as a generally rigid surface, having some amount of flexural stiffness, such as a sheathing that covers a frame or frame members. The panel's outside surface, i.e. its face, may be flat or shaped and the inside surface, i.e. its backside, may have protrusions or indentations. A panel may be of any material or combination of materials not herein excluded and be of any size. Some examples of panels are: plywood or plastic sheets, sandwich panels, wood or foam boards, siding and roof panels, rib and similar protrusion

backed panels, claddings, molded and corrugated or any combination hereof to name a few. A panel may be a composite panel, which is defined as a panel comprised of two or more materials adhesively bonded together. A foam panel has foam as its sole material and a foam backed panel is comprised of a material with foam backing.

[0143] Due to the interrelationship of compressive and tensile strength in a panel's rotation, it is important that a panel's compressive and tensile strengths be relatively similar for purposes of this disclosure. Therefore any panel comprised of 20% or more, preferably 30% or more, still more preferably 40% or more and even still more preferably 50% or more in volume of a material that has a five times or greater difference between its compressive and tensile strength, both as measured perpendicular to the face or grain, is specifically excluded as a panel. Some of the excluded materials include concrete, ceramics and glass, all with about ten times more compressive strength than tensile strength. Other materials such as glass fiber epoxy composites, tend to have higher tensile strengths than compressive strengths.

[0144] One objective of the inventive subject matter is to increase the load capacity of weaker, lighter and thinner panels which are panels comprised of materials having a low modulus of elasticity or panels with a continuous section having a low flexural stiffness. As herein disclosed in several examples, panels comprised of low modulus of elasticity materials such as foam, can have significant increases in load capacity when induced with one the the new conditions. Panels with a continuous section having a low flexural stiffness, may be comprised of almost any material, although materials having a high modulus of elasticity, such as wood or metals which are generally flat, need to be much thinner to have a low flexural stiffness.

[0145] For panels with a flat continuous section a low flexural stiffness of the continuous section is herein defined as less than 225,000 N-cm², preferably less than 130,000 N-cm², more preferably less than 98,000 N-cm², even more preferably less than 50,000 N-cm² and still even more preferably less than 27,000 N-cm². Examples of flexural stiffness for wood having a 11,700 MPa modulus of elasticity are about: 1.3 cm thick wood has a flexural stiffness of 215,000 N-cm²; 1.1 cm thick has a 130,000 N-cm²; 1.0 cm thick an 98,000 N-cm²; .8 cm thick a 50,000 N-cm² and .66 cm thick a 27,000 N-cm² flexural stiffness. The thinner the flat wood or other material becomes, the greater the influence that a low modulus of elasticity material dropped section, bonded to the wood, will have on increasing the resulting composite panel's load capacity. All other continuous section shapes other than flat, may have unlimited flexural stiffness, although the higher the continuous section's flexural stiffness, the more difficult it is to increase the panel's load capacity with a dropped section and/or a fixed boundary condition.

[0146] Flat panels are defined as those whose moment of inertia can be determined by the formula $I = bh^3/12$ [Math 9] where I is the moment of inertia, b is the base and h is the height, and with or without composite material transformation. As such, flat panels have two generally flat, parallel faces with no exposed or embedded protrusions. For example, sheets of plywood, foam boards, slabs, boards, metal plates, rib-less sandwich panels are flat panels. Ribbed panels are defined as a single skinned panel having protrusions such as ribs extending at an angle from the skin, regardless of whether the protrusions are molded or otherwise bonded to the skin or are bent, corrugated or otherwise shaped from the skin and results in panel with an increased moment of inertia resulting from such non-flat shape.

[0147] Those skilled in the art will recognize that there may be economical considerations in combining weaker and lighter materials that have desirable properties with structural materials that have a much higher flexural stiffness. At some point it become economically unfeasible to increase the thickness of the dropped section with a non-structural material or to increase the bonding strength simply to increase the panel's load capacity. At this point it is usually preferable from a cost perspective to add or to increase the thickness of a structural material in a panel's continuous section.

[0148] For example, increasing load capacity for foam composite, insulated wood panels by 25% or more using the new conditions becomes economically unfeasible when the wood is about 1.0 cm to 1.3 cm or more thick. A 1.0 cm thick plywood panel 20.3 cm wide over a 61 cm span can carry about 1,360 Pa before deflection .25 cm. A 25% increased load capacity means adding at least 340 Pa through the new conditions, and especially the fixed/continuous/dropped condition. This can be done by adding about 7.5 cm of 32 kg/m³ polyurethane foam as a dropped section in a fixed/continuous/dropped condition. Since 7.5 cm of polyurethane foam is a sufficient amount of insulation in many building wall applications adding any thicker foam to attain an increase in load capacity is economically unfeasible. Beyond the 7.5 cm, it is much more economically efficient to use thicker wood for the increased load capacity since less than a 10% increase in wood thickness achieves the 25% increase in load capacity.

[0149] In order to demonstrate that the new conditions clearly provide an increased load capacity over a simply supported, a continuous panel, a continuous section or over a thickened section is for the increase to be large enough to be easily distinguished and/or structurally sufficient for an application. As such, a panel with one of the four new conditions must have an increased load capacity at least 25% greater, preferably 50% greater, more preferably 100% greater, even more preferably 150% greater, still more preferably 200% greater, even still more preferably 300% greater and even more preferably still 400% greater than (above) the simply

supported, continuous panel, continuous section or thickened section to which the increased load capacity is compared. This means that a panel's increased load capacity of at least 25% greater than the panel's continuous section's load capacity must result in an increased load capacity of at least 125% of the continuous section's load capacity. For example if a panel's continuous section has a 2,873 Pa load capacity, a load capacity of at least 25% greater is at least 3,591 Pa. The amount of increased load capacity may be predetermined.

[0150] The technical relationship between increasing a panel's load capacity with one of the new conditions and the degree to which it may be increased is inversely related to the flexural stiffness of the panel's continuous section. The lower the continuous section's flexural stiffness the greater the potential increased load capacity may be. A panel with a continuous section that has a very low flexural stiffness has the potential for an increased load capacity of up to a 500,000% increase or more, depending upon the dropped section and bonding strength. However, the potential increase is not indefinite due to the dropped section's maximum thickness or depth.

[0151] Given the wide variety of materials and applications for which this inventive matter can be used, some experimentation will be necessary. However, since the objective of this inventive matter is to only increase as opposed to maximize a panel's load bearing capacity, there is no need for undue experimentation. Given this disclosure and the availability of material properties such as bonding capacity and modulus of elasticity as well as the existence of flexural stiffness and deflection formulas, some indication of the degree of increased load capacity can be easily estimated and then confirmed with experimentation. It will be recognized by those skilled in the art that as a continuous section's flexural stiffness increases or the span increases, the percentage increase in a panel's load capacity created by the new conditions will decrease, until at some point the new condition's increase in load capacity fails to reach its minimum required increase and is thereby ineffective.

[0152] The following example demonstrates how the maximum increased load capacity of a fixed/continuous/dropped conditioned panel may be determined and the magnitude of the increase over the panel's continuous section. Beginning with a panel's continuous section comprised of a 1.3 cm thick EPS foam board having a .83 MPa modulus of elasticity resulting in a 15 N-cm² flexural stiffness. When simply supported over a uniformly loaded single 36.8 cm span this panel can support about 1 Pa. When continuous over two 36.8 cm spans, as a continuous section, it can support about 2.3 Pa before deflecting more than .15 cm ($L/240$ [Math 1]). The EPS panel is induced with a fixed/continuous/dropped condition by bonding it to the top of frame members and bonding a 5.1 cm thick polyurethane foam dropped section, with a

6.9 MPa modulus of elasticity, to its backside. The dropped section is also bonded to frame member's sides to enable the fixed/continuous/dropped panel to carry about 2,394 Pa over each 36.8 cm span. Adding 5 cm fillets effectively reduces the span to 26.8 cm and thereby the panel can support about 8,500 Pa before deflecting more than .15 cm. This 8,500 Pa load equals .85 N/cm², which over a 36.8 cm span equals a 31.3 N load per centimeter of the panel to frame member interface.

[0153] Testing has shown that a 5.1 cm thick polyurethane foam panel over 36.8 cm span has about a 46 bond to load factor to induce a fully fixed boundary condition on the foam panel. Adding a 2.5 safety factor increases this to a 115 bond to load factor and multiplying it times 31.3 N equals 3,600 N. Since the 5.1 cm thick dropped section plus the 5 cm fillets provide 10.1 cm² of bonding area per interface centimeter, a bonding material with a 356 N/cm² bonding capacity is needed to support the 3,600 N per interface centimeter. Presently, bonding materials with higher bond capacities applicable to polyurethane foam ranges up to about a 690 N/cm² bonding capacity with a 1,200 kg/m³ density polyurethane foam. Any material appropriate bonding material having a 356 N/cm² or greater bonding capacity may be used to bond the panel to the frame members. As such, the 8,500 Pa increased load capacity induced on the panel by the fixed/continuous/dropped condition is a 369,565% increase over the continuous section's 2.3 Pa load capacity.

[0154] However, in the event a bonding material with a bonding capacity of only 330 N/cm², for example, is preferred, it is possible to work backwards from the selection of bonding capacity. A material with a 330 N/cm² bonding capacity applied to the 10.1 cm² interface has a 3,333 N bonding strength and when divided by the 115 bond to load factor results in a 29 N interface load. Dividing this by the 36.8 cm span equals a .788 N/cm² or 7,880 Pa load, which is the maximum load possible for this bonding capacity under these conditions and results in the fixed/continuous/dropped panel having a 342,608% increased load capacity over the 2.3 Pa load capacity of the panel's continuous section.

[0155] A frame member is any structure that supports at least part of a panel over a span and has at least a top edge, a bottom edge and two sides. Frame members may be of any type, material, size or shape and used for any application and the top or bottom edges may be a tip or an apex. There may also be a multitude of edges such as a channel and a multitude of sides such as a circle or polygon. Frame members include any frame member used in any type of structure including all building frame members such as studs, rafters, purlins, battens, beams, columns, plates, ledger boards and similar members. Frame members include attachments or extensions such as flanges, mountings and supports and may also include cladding extensions that are

molded, bent or otherwise shaped into ribs, perimeter returns or other rib-like configurations generally perpendicular to the cladding and that functions like a frame member. Frame members also include ribs when the ribs are acting as frame members in a configuration that induces a fixed/continuous and/or a continuous/dropped condition on a foam composite panel.

[0156] A frame or framework is comprised of a single or a multitude of spaced apart frame members, attached or unattached to one another. A single or a multitude of frame members shall mean that either a single frame member by itself or optionally any number of more than one frame members may be used to support a panel. A single frame member may be spaced apart from itself such as a circular shaped frame member as shown in Figs. 7 and 8. Fig. 7 is a section view of a structural section 10 comprised of a panel 1 supported by a single frame member 3. The panel 1 is comprised of a continuous section 18, that is over the top edge 26 of the single frame member 3, and a dropped section 19 which is a fillet 12 bonded to the panel 1 and to the sides 25 of the single frame member 3. Fig. 8 is a bottom view of Fig. 7 showing structural section 10 with a circular panel 1 continuous over a single, spaced apart frame member 3 with the fillet 12 bonded to both the frame member 3 and the panel 1 to induce a fixed/continuous/dropped condition on the panel 1. Since the panel 1 is continuous over and extends beyond the outside perimeter of the frame member 3 any load on the span will be resisted by the cantilever and the panel has a continuous condition. Rotational resistance is provided by the curvature of the frame member 3 which prevents it from rotating.

[0157] As such, in another embodiment of the inventive subject matter, Figs. 7 and 8 shows that a panel may be continuous over and supported by, i.e. bears on, one spaced apart frame member that creates a single span and is in a continuous condition that has an increased load capacity over that span. When this embodiment is combined with the continuous conditioned panels over two or more spans it may be said that a panel may be continuous over and supported by one or more spaced apart frame members to create one or more spans between said frame members and the panel has a load capacity over the spans.

[0158] In another embodiment a single skinned ribbed panel is comprised of a single skin, i.e. cladding, and may be a frame supported ribbed panel and/or a ribbed structural section depending upon how the panel is used. The frame supported ribbed panel is one where the ribs are supported by frame members, whereas the ribbed structural section is one where the ribs are frame members. As such, a panel, used as a ribbed structural section, is defined as excluding the ribs while a panel, used as a frame supported ribbed panel, is defined as including the ribs. For purposes of this disclosure all ribbed panels are limited to composite panels that have both the ribs and a second material bonded to the skin's backside and the second material is also bonded

to at least some of the rib's sides. In most cases the second material is a foam. As used herein, the words skin and cladding are synonymous.

[0159] Testing was undertaken to determine whether the fixed boundary condition and the continuous/fixed condition can induce an increase in load capacity on a frame supported ribbed panel since such panels have a relatively high flexural stiffness. Two 15.2 cm wide ribbed panels were tested and were comprised of a twin "T" shape with a .13 cm thick vinyl cladding (the skin) and two .13 cm wide by 2.5 cm tall ribs spaced 7.6 cm apart and 3.8 cm from each edge and perpendicular to the cladding. The vinyl had a modulus of elasticity of about 2,400 MPa and the ribbed panel had a flexural stiffness of about 146,000 N-cm². The ribbed panels were foam composite panels since the polyurethane foam was bonded to the cladding's backside and to the ribs and thereby bonding the ribs to the cladding.

[0160] The first ribbed panel was a continuous panel comprised of 2.5 cm thick polyurethane foam 7 bonded to the backside 8 of a vinyl cladding 23, and to the ribs 31 and supported by spaced apart frame members 3 as shown in Fig. 9. A rotational resistance member 34 prevented the frame members 3 from rotating. The second ribbed panel (not shown) was a fixed/continuous/dropped panel with the same continuous section as the continuous panel and a 2.5 cm thick polyurethane foam dropped section and was fixed to the frame member's top edge and sides. In both cases the ribs were bonded to the cladding with the polyurethane foam as opposed to being molded to the cladding. The polyurethane foam was 32 kg/m³ density with a modulus of elasticity of about 6.5 MPa.

[0161] The continuous panels were tested first as simply supported over different single spans of 36.8, 57.2 and 87.6 cm respectively, with uniform loads until deflection reached $L/240$ [Math 1]. The load test results were 1,341 Pa, 335 Pa and 100 Pa respectively, which was consistent with calculated loads with the bonded ribs performing as though they were molded to the cladding. The continuous panels were then induced with a fixed/continuous condition by being fixed to the top edges of the frame members using an 128 kg/m³ density polyurethane foam having a 83 N/cm² bonding capacity. When tested the ribbed, fixed/continuous panels all had substantial increases in load capacity and in some cases greater than a 400% increase. For example, the continuous panel over 87.6 cm span carried 100 Pa unfixed and 531 Pa fixed, 431% increase in load capacity. Moreover, adding 2.5 cm fillets to the 2.5 cm thick fixed/continuous panels further increased their load capacity. For example, over the 57.2 cm span, the continuous panel carried 335 Pa, and when fixed it carried 1,226 Pa, a 266% increase, and when fixed and with fillets it carried 1,532 Pa, a 357% increase.

[0162] The fixed/continuous/dropped panels were also tested and carried 8,140 Pa, 2,250 Pa and 622 Pa respectively over the same 36.8, 57.2 and 87.6 cm spans. As such, the fixed/continuous/dropped panels each carried over a 500% increase in load capacity above the ribbed continuous conditioned panel. In all cases the frame supported ribbed panels performed similar to rib-less panels with comparable degree of increases in load capacity for a fixed/continuous condition and a fixed/continuous/dropped condition. This demonstrates that the same percentage increase induced on a foam panel can be induced on a frame supported ribbed panel and a foam composite panel, despite the ribbed panels having a higher flexural stiffness. This finding was unexpected because the increases were easily induced on ribbed panels having a relatively high flexural stiffness and the foam was sufficient to prevent the thin ribs from buckling despite up to 8,140 Pa loads. The 87.6 cm fixed/continuous/dropped panel was also tested over two 39.4 cm spans and found to exhibit the same increases in load capacity as the non-ribbed panels over two or more spans.

[0163] In another embodiment the ribbed panel is a ribbed structural section with a composite cladding. During testing it was discovered that ribs may function as frame members in inducing the fixed/continuous and the fixed/continuous/dropped conditions on a ribbed panel's skin. Basically the skin is continuous over and bonded to spaced apart ribs and, assuming a sufficient bond, a fixed/continuous condition is induced upon the skin. As such the ribbed panel's skin, whether or not a composite, has an increased load capacity.

[0164] As previously stated, both the frame supported ribbed panel and the ribbed structural section are limited to having a composite cladding comprised of a second material, such as foam and preferably polyurethane foam, adhesively bonded to the cladding's backside and to the sides of the ribs. Therefore, a ribbed structural section has a composite cladding with an increased load capacity induced by a fixed/continuous/dropped condition. It is important that the dropped section be distinguishable from the frame members for a fixed/continuous/dropped condition. Otherwise, the dropped section may be a thickened continuous section.

[0165] Fig. 10 shows a ribbed structural section 10 comprised of a panel 1, ribs 31 as frame members and a rotational resistance member 34. The panel 1 is a composite panel comprised of polyurethane foam 7 (or another foam) bonded to the backside 8 of a cladding 23 and at least the cladding 23 is continuous over spaced apart ribs 31 acting as frame members. The cladding 23 is bonded to the ribs 31 and the ribs 31 may be integrally molded to the cladding 23 or the polyurethane foam 7 or other bonding material may be used to bond the ribs 31 to the cladding 23. The cladding 23 comprises the continuous section 18 and the polyurethane foam 7

comprises the dropped section 19 of the composite panel 1 and therefore a fixed/continuous/dropped condition is induced upon the composite panel 1.

[0166] This condition increases the load capacity of the cladding 23 and polyurethane foam 7 composite panel 1 over the span between the ribs 31. While the increase in the cladding's 23 load capacity occurs perpendicular to the ribs 31, the increased load capacity functions in all directions. In addition, the foam 7 bonded to the sides of the ribs 31 may stiffen the ribs 31 from buckling. Flanges 16 are also shown which increases the rib's 31 flexural stiffness. Finally, a rotational resistance member 34 is attached to the flanges 16 and may also be bonded to the polyurethane foam 7. In the event the rotational resistance member 34 provides a second face bonded to and covering substantially all of the polyurethane foam 7, the structural section becomes a sandwich panel and is not a structural section of this disclosure. The structural section 10 of this disclosure specifically excludes a sandwich panel structure which requires both skins to cover substantially all of the structure's front and back sides and the skins adhesively bonded to a core material that is different than that of the skins.

[0167] Fig. 11 shows a perspective of the backside of a frame supported ribbed composite panel 1 in a fixed/continuous/dropped condition. The composite ribbed panel 1 is comprised of a cladding 23 with ribs 31 molded or otherwise bonded to the cladding 23 and polyurethane foam bonded to the cladding's backside 8. The cladding 23, part of the foam 7 and the ribs 31 are continuous over the frame members 3 to comprise the panel's 1 continuous section 18. The panel's dropped section 19 consists of polyurethane foam 7 between the frame members 3, and the foam 7 also bonds the panel 1 to both the frame member's top edge 26 and the sides 25. Rotational resistance members are not shown, although rotational resistance may be provided by the dropped section 19 if it is deep enough to prevent the frame members 3 from rotating.

[0168] In another embodiment a ribbed panel may be both a frame supported ribbed panel and a ribbed structural section. Fig. 12 shows a perspective wall section with a frame supported ribbed panel 1 comprised of polyurethane foam 7 bonded to the backside 8 of a cladding 23 and to the sides of ribs 31, thereby also bonding the ribs 31 to the cladding 23. The ribbed panel 1 is supported by and bonded to a top plate 28 and a bottom plate 29, which are frame members. The ribs 31 may be fully or partially bonded to the top or sides of the top plate 28 and bottom plate 29. The ribs 31 also have flanges 16 on the ends for additional strengthening. Therefore, assuming a sufficient bond, the ribbed panel is in a fixed/continuous/dropped condition relative to the two plates which are frame members and the panel's increased load capacity is induced on the panel 1 parallel to the ribs 31. As such, the ribbed panel's increase in load capacity is compared to the same ribbed panel as simply supported since the ribbed panel is not continuous

over two or more spans. The rotational resistance for such a the ribbed panel is provided by the foundation, slab, floor, joists, rafters, etc. (not shown) to which the plates are bonded to and prevent the plates from rotating.

[0169] In addition, a ribbed structural section 10 is also shown in Fig. 12, where the panel 1 is a foam composite panel 1 comprised of cladding 23 as the continuous section 18 and foam 7, as the dropped section 19, bonded to the cladding 23. In this configuration the ribs 31 are not part of the panel 1 but rather function as frame members 3 supporting the continuous/dropped panel. Assuming a sufficient bond, a fixed/continuous/dropped condition is induced on the foam composite panel 1 based on the panel's continuous/dropped configuration to the ribs 31, acting as frame members 3. While this increase in load capacity was caused perpendicular to the ribs 31, it still results in an increased load capacity of the panel in any direction. The ribbed structural section's rotational resistance is provided by the top 28 plate and the bottom plate 29, although intermediate rotational resistance members (not shown) may also be needed.

[0170] In order to achieve increased load capacity, it is necessary to provide frame members with sufficient rotational resistance. Panels induced with the new conditions use frame members to increase their load capacity. Both the fixed/continuous and the fixed/continuous/dropped conditions sufficiently bond the panel to the frame members making the frame members an extension of the panel and thereby subject to rotational forces from loads applied to the panel. This differs from both a simply supported panel and a continuous panel which are both free to rotate without forcing the frame members to do likewise. Load testing has shown that rotational resistance is necessary with a fixed/continuous or a fixed/continuous/dropped conditioned panel to attain an increased load capacity.

[0171] Figs. 1 and 2 show a rotational resistance member 34 attached to the bottom edges 27 of the frame members 3 to prevent the frame members from rotating when a load 11 is applied to the panel 1. For example gypsum board fastened 2 to the bottom edges 27 of frame members 3 in Figs. 1 and 2 can provide sufficient rotational resistance for most building panel load situations. Rotational resistance can also be achieved with blocking 35 between the sides 25 of frame members 3 that are supporting the panel 1 as shown in Fig. 13. The blocking 35 may be for the entire depth of the frame member 3 or only at or near the bottom edge 27. Other types of rotational resistant members include purlins, tops of trusses, beams, floors, foundations, joists, etc. Basically any element that can be attached to the frame members and resist the degree of rotation for a particular load for a particular application may be a rotational resistance member. This includes a fixed/continuous/dropped panel's dropped section which extends in depth along

the frame members sides. The deeper the dropped section and/or the bond between the dropped section and the frame members, the greater the rotational resistance.

[0172] The rotational resistance members may cover a small section or the entire backside of the composite panel and include fiberglass or other thickened or reinforced spray material capable of resisting frame member rotation. Regardless of the type or amount of rotational resistance members, it is important frame members have sufficient rotational resistance to at least facilitate, i.e. be capable of handling any predetermined or other stated amount of an increased load capacity.

[0173] Cladding is defined as any panel, material or combination of materials used to provide a cover for a framed structure. Cladding may be of any size and shape and of any material including panels, panel skins, siding, tiles, bricks, stones, shingles, aggregates, stucco, fiberglass, coatings, paint and other materials and even a foam's integral skin if the skin has a modulus of elasticity different than the foam's core. The cladding may be a panel itself, such as plywood or a foam board or may it be a part of a panel such as a coating applied to a foam board. The cladding has a face, i.e. front side or exposed side, and a backside that is generally unexposed and may be bonded to another material.

[0174] Testing was conducted on foam composite panels comprised of 32 kg/m³ polyurethane foam bonded to the backside of several different claddings including a .1 cm vinyl panel, .87 cm plywood and a XPS board. A variety of load tests were performed on the panels with both a fixed/continuous and a fixed/continuous/dropped condition. In all cases there was an increased load capacity over that of a simply supported or a continuous panel over the same spans. In the case of the .1 cm vinyl cladding, the polyurethane foam provided substantially all of the load capacity. As such this results in the ability to use thin (around .3 cm) and even ultra thin (around .01 to .13 cm) claddings that have little or no influence on a composite panel's flexural stiffness and the foam providing the load capacity.

[0175] This is contrary to present construction practices where foam is used solely as an insulation applied to structural sheathing with little or no influence on the panel's flexural stiffness. For example, when 5 cm thick, 32 kg/m³ polyurethane foam, with a modulus of elasticity of about 6.9 MPa, is bonded to 1.9 cm of wood sheathing, with a modulus of elasticity of about 11,700 MPa, the foam provides only 1% of the panel's flexural stiffness. However, if the same 5 cm of polyurethane foam is bonded to .6 cm thick wood, the foam provides about 24% of the composite panel's flexural stiffness. The polyurethane foam's influence is even more dramatic when the cladding is a coating and the foam provides 100% of the flexural stiffness.

[0176] Another way to ensure using weaker panels or the use of material with a low modulus of elasticity is to require that the foam provide some meaningful amount of a panel's flexural stiffness. For example, 2.5 cm of EPS foam bonded to the backside of .3 cm vinyl cladding will provide about 33% of the resulting composite panel's flexural stiffness. Or, 2.5 cm of polyurethane foam bonded to the backside of a ribbed vinyl panel with .2 cm wide by 2.5 cm tall ribs will provide about 5% of the the composite panel's flexural stiffness. Therefore in another embodiment of the inventive subject matter, foam must provide at least 5%, preferably at least 10%, more preferably at least 20% and more preferably at least 30% of the flexural stiffness of a thickened section of a foam composite or a foamed backed panel over at least half of the panel's spans.

[0177] Due to the importance of the foam in providing part of a foam backed panel's flexural stiffness, the foam must have a minimal modulus of elasticity. As such, the minimum modulus of elasticity of a foam in this disclosure is .7 MPa. Beyond this, the foam used herein may be any type of foam capable of being formed into a rigid or semi-rigid foam board and capable of providing at least .35 RSI insulation value per 2.5 cm of thickness. In a foam backed panel, the foam may be adhesively or otherwise bonded or unbonded to the cladding and frame members and the foam may provide a backing or otherwise support all or part of the cladding. The foam may have a self bonding or self-adhesive bonding capability such as polyurethane foam or the foam may be bonded to the cladding and frame members with another bonding technique. In some cases it may be desirable to use an adhesive foam in conjunction with a separate bonding technique or material. The foam may also be of two or more types, for example an EPS foam board used as the continuous section 18 and a polyurethane foam used as the dropped section 19 in a continuous/dropped configuration as shown in Fig. 3. The foam may also be optionally bonded to frame members, optionally fixed to frame members or optionally free of an adhesive bond to frame members.

[0178] A foam backed panel may be a composite panel with materials adhesively bonded together or an unbonded panel wherein the materials are not bonded together but merely stacked, or a combination of the two panels. In all three cases, a foam backed panel has a flexural stiffness for the continuous section and for the thickened section over a span. A foam may provide a direct or indirect backing to a cladding material by being in direct contact or indirectly by having one or more other materials between the foam and the cladding's backside. The foam may cover all of part of the cladding's backside and the cladding may be directly or indirectly in contact with frame members. For example the cladding may be in the continuous section over the frame members while the foam is in a dropped section. Although when the

cladding is in direct contact with the frame members, it has to be more substantial than a coating or a foil paper, for example. As such claddings, when used as the sole material in the continuous section or the continuous section itself must be at least .05 cm thick, preferably at least .08 cm thick, more preferably at least .1 cm thick and even more preferably at least .13 cm thick. Foam adhesively bonded to a cladding shall also mean a cladding adhesively bonded to the foam. For example, foam may be bonded to the backside of a cladding or a coating or other cladding may be applied to the foam, both of which creates a foam composite panel.

[0179] Regardless of whether the cladding is a panel or part of a panel, the panel's continuous section should not be more than 15.2 cm thick. This will allow for all types of claddings to be used as a composite panel 1, including brick 43 that can be bonded to frame members 3 with continuous polyurethane foam 7 as shown in Fig. 14. Rotational resistance members 34 can be used to prevent the frame members 3 from rotating. As such, the continuous section 18 must be from .05 cm to 15.2 cm in thickness. It should be noted that when a break or seam exists in the cladding over a span, such as with bricks, the cladding provides little or no load capacity to the panel. In Fig. 14 while the bricks 43 and the foam 7 comprise the panel 1 in a fixed/continuous/dropped condition, only the foam 7 is induced since the bricks are not continuous over a span 6. Although, in some cases a cladding that is not continuous may impact the panel's load capacity, which can be determined by load testing. The maximum thickness of a panel is 45.7 cm since the continuous section can be 15.2 cm thick and it is common for foam cavity insulation to be as much as 30.5 cm thick.

[0180] In another embodiment some foams such as polyurethane foam can be applied in a continuous manner and be extended or spliced together with newly applied foam while retaining its structural continuity. Structural continuity means that polyurethane foam's structural properties, such as bonding capacity, load carrying capacity, tensile strength, etc., are continuous from the old or previously applied foam to the newly applied foam as though all the foam was applied at the same time. This assumes the new foam has the same or higher properties than the old foam. This has several important ramifications when applied to the inventive matter.

[0181] Structural continuity enables polyurethane foam or foam composite panels to be continuous over an unlimited number of spans. This is important to load capacity since a continuous panel over three or more spans has an inherent load capacity over its inside or center spans that is much greater than the outside span's load capacity. This is because a panel over the inside span is continuous over adjacent spans that react to a load on the inside span, whereas the outside spans only have a span on one side reacting to a load. As such an inside span has spans on both sides whereas an outside span is either a single span or has a span on only one side.

[0182] According to continuous beam analysis, a continuous panel over four equal spans will support about a 100% increase in load on its outside spans and about a 212% increase in load capacity on its inside spans above the panel's simply supported load capacity. A continuous panel over three spans will support about a 89% increase in load capacity over its outside spans as compared to a simply supported panel and about a 285% increase in load capacity on its inside (center) span. However, in both cases the increased load capacity of a panel over the inside spans is wasted or unrecognized since the weaker section of the panel, i.e. over the outside spans, determines the panel's effective load carrying capacity or rating. Until now, this waste of inherent load capacity was an unrecognized problem.

[0183] One novel solution to this problem is to enlarge the panel size so that there are a multitude of inside spans with only two outside spans. While not practical with most materials, it is practical with materials like polyurethane foam that can be sprayed or otherwise applied as a continuous panel over an entire wall or roof section. Moreover, by applying the continuous/dropped condition to the two outside spans or shorting the outside spans, the load capacity of the outside spans can be inexpensively increased to correspond to that of the inside spans. This has the effect of more than doubling the load capacity of a typical continuous panel.

[0184] For example, Fig. 15 shows a continuous panel 1 over four equal spans 6 created by spaced apart frame members 3 secured by a rotational resistance member 34. The outside spans 36 have a much thicker dropped section 19 than the inside spans 37 and thereby have a greater increased load capacity induced by its continuous/dropped condition while the inside spans 37 have a lower amount of increased load capacity induced from its fixed/continuous/dropped condition. As such, the increased load capacity induced on the outside spans 36 by a thicker dropped section 19 as shown in Fig. 15, corresponds to the increased load capacity on the inside spans 37 that is induced by the existence of continuous spans on both sides.

[0185] Testing of a polyurethane foam panel continuous over three spans showed that when one or both of the outside spans were given an increase in load capacity by inducing or further increasing a continuous/dropped condition, the outside spans were able to carry the same or even a greater load than the inside span. The same occurred when the outside spans were effectively shortened to have the same or more increased load capacity as the inside span. Testing also showed that it did not matter as to whether the inside spans were in a continuous condition, a fixed/continuous condition or a continuous/dropped condition. In all cases it was possible to increase the load capacity of the outside spans to correspond to the inside spans.

[0186] For example testing showed that a 5 cm thick 32 kg/m³ polyurethane foam panel with a 2.5 cm continuous section and a 2.5 cm dropped section, supported 354 Pa over a single span

when simply supported. The same longer panel over two 36.8 cm spans supported 838 Pa about a 137% increase in load capacity and consistent with the beam theory formulas. However, the same longer, unfixed panel over three 36.8 cm spans was able to support 2,030 Pa over its inside (center) span which was 473% above the simply supported load and even higher than the 285% predicted increase for an inside span. The load capacity was easily increased on both outside spans of the three span panel to support 2,030 Pa or more to correspond with the inside span. When the continuous/dropped panels were bonded with 32 kg/m³ polyurethane foam to induce a fixed/continuous/dropped condition, the inside span's load capacity increased to 2,916 Pa, a 248% increase over the 838 Pa when continuous over two spans. When bonded with 128 kg/m³ foam the inside span's load capacity increased to 3,615 Pa, a 331% increase over the 838 Pa. In all cases the load capacity of the panel over the outside spans was increased to that of the panel over the inside span.

[0187] When the increased in load capacity from the enhanced continuous condition are compared to a continuous section, the increases are even greater. For example a 2.5 cm thick polyurethane foam continuous panel can support 58 Pa over a single 36.8 cm span and 220 Pa over the inside span of three 36.8 cm spans. However, when the above fixed/continuous/dropped condition is induced on the panel to increase its inside span's load capacity to 3,615 Pa, the increased load capacity is 1,543% above the 220 Pa of the inside span in a three span continuous condition.

[0188] Testing was also conducted on panels continuous over six spans to ensure the same load capacity increases from the new conditions are applicable to inside spans that are inside other inside spans such as the middle two spans of a panel continuous over six spans. A .56 cm thick by 20.3 cm wide by 243.8 cm long plywood panel was divided into four 36.8 cm inside spans and two 34.9 cm outside spans by 3.8 cm frame members. The plywood has a flexural stiffness of 1,050 N-cm² and its predicted and actual simply supported load capacity was 1,100 Pa. Therefore the predicted inside span over five or more spans was up to a 230% increase or 3,630 Pa. The plywood was bonded to the top of each frame member with 315 N bonding strength. The fourth span from one end was the tested inside span with the two adjacent spans having uniform loads. The tested inside span carried 4,022 Pa before deflecting .15 cm. As such, the fixed/continuous inside span carried 392 Pa or 11% more than the same continuous conditioned inside span, which shows that the fixed/continuous condition is applicable to any number of a continuous panel's inside spans.

[0189] A 2.5 cm dropped section of polyurethane foam was then added to the .56 cm thick plywood panel continuous over six spans and bonded to the spaced apart frame members. The

same inside span was tested as above and carried 4,285 Pa or slightly more than the same spans without the dropped section. As such, the fixed/continuous/dropped condition is also applicable to any number of a continuous panel's inside spans. Although, in this case the 4,285 Pa was only a 18% increase above the continuous section's 3,630 Pa over the same span, consistent with the difficulty in increasing load capacities of panels with a higher flexural stiffness.

[0190] For purposes of this disclosure, increasing the load capacity of the outside spans to correspond with, i.e. be about the same as the load capacity of the inside spans, is called an enhanced continuous condition. The enhanced continuous condition is a panel supported by multiple spaced apart frame members with a continuous section that is continuous over and fixed to the top edges and/or the sides of the frame members and the spaced apart frame members create multiple inside spans of 2 or more, preferably 3 or more, more preferably 4 or more, even more preferably 5 or more and even still more preferably 6 or more spans with the outside spans having an increased load capacity to correspond to that of the inside spans. Increasing the load capacity of the outside spans may be accomplished by inducing or increasing a fixed boundary condition and/or by adding or increasing the depth or size of a dropped section, and/or by shortening the outside spans. Since increasing the load capacity of the outside spans enables the acknowledgment and utilization of the higher amounts of load capacity in the inside spans, the enhanced continuous condition may be said to increase the load capacity over two or more spans or more preferably over three or more spans or even more preferably over at least half of the spans and still more preferably over substantially all of the spans or even more preferably still over all of the panel's spans.

[0191] In another embodiment regarding polyurethane foam's structural continuity, two or more individual foam or foam composite panels may be spliced together to form a single, structurally continuous panel simply by applying polyurethane foam to the seams between the individual panels. Testing has shown that pouring or spraying polyurethane foam, of the same or greater density of the panels to be united, into a gap between the polyurethane foam of the respective panels, binds the panels together as though the foam on both panels and the foam in the gap were all applied at the same time. The polyurethane foam expands to fill the seam gap and bonds to each panel's polyurethane foam and cladding with the same degree of bonding capacity that the panels were originally formed with. This means, for example, that a seam over a span can be eliminated by filling in the seam at a latter time with the same polyurethane foam.

[0192] Several tests were conducted whereby a polyurethane foam panel made in a single casting had its load capacity compared to a polyurethane foam panel comprised of two separate, cured pieces spliced together by the same polyurethane foam. In all cases the load capacities

were the same. For example, Fig. 16 shows the backside of two adjacent foam backed panels 1a and 1b each comprised of a cladding 23a and 23b bonded to polyurethane foam 7 which also bonds each panel 1a and 1b to frame members 3. The panels 1a and 1b also have continuous sections 18 over the frame members 3 and a dropped section 19 between the frame members 3. The panels 1a and 1b in Fig. 16 are separate and have a seam 42 between them as can be seen by the respective backsides 8a and 8b of the claddings 23a and 23b showing a break in the foam 7 with a seam 42 between the two panels. Depending upon the type of cladding 23a and 23b and installation process, the cladding 23a and 23b may or may not be continuous over the seam 42. A “seam” as herein used, is a break in previously applied foam, either within a panel or between panels and may be subsequently spliced with another foam to provide structural continuity of the foam. A splice is a seam filled with a foam that provide structural continuity between the foams on both sides of the seam.

[0193] In Fig. 16 the claddings 23a and 23b are butted, overlapped or otherwise closed together, although the seam 42 is created by the absence of or a break in the polyurethane foam 7. In Fig. 17, the polyurethane foam 7 is poured or sprayed on the two cladding's backsides 8a and 8b, at the seam 42 and expands to fill the area surrounding the seam 42, while bonding to the backsides 8a and 8b and to the existing polyurethane foam 7 on both sides of the seam 42. As such, the polyurethane foam 7 structurally bonds the two panels 1a and 1b together. A seam 42 may exist in the continuous section 18 and, if needed, rotational resistance members can be attached to the frame members. Assuming the panels 1a and 1b are fixed to frame members 3 a fixed/continuous/dropped condition is induced over all spans.

[0194] The result is that the polyurethane foam effectively spliced the panels together as though there was never a seam between two panel's foam. In other words, the polyurethane foam 7 spliced area between the two frame members 3 has the same load carrying capacity as non-spliced polyurethane foam over the same span length. This of course excludes any load capacity provided by the cladding, since it remains discontinuous at the seam 42 in Fig. 17.

[0195] The implication is that adjacent wall or roof foam composite panels may be bonded together for structural continuity by simply spraying polyurethane foam onto the seamed area. The polyurethane foam not only bonds the panels together and seals the seam with an air, vapor and moisture barrier, but it also transforms two or more individual panels into a single panel spanning any number of frame members. The polyurethane foam between the frame members bonds together such that the resulting foam board between the two frame members is in a fixed/continuous/dropped condition with a load capacity. In other words, the polyurethane foam

splice and the polyurethane foam on both sides of the splice becomes a single foam with structural continuity as if all three sections were simultaneously sprayed as one panel.

[0196] This is important in those cases where the cladding's load capacity is inconsequential and the foam providing much or virtually all of the panel's load capacity. This process enables an exceptionally simple method of joining panels together during installation. It also points out that a single foam composite panel can be created to enclose an entire building. As long as the primary material(s) that provide the majority of the load capacity to a composite panel is continuous, the panel is considered to be continuous.

[0197] The foam's structural continuity also applies to the ability to thicken polyurethane foam at any time and achieve structural continuity through the foam's entire thickness. As such, structural continuity thickness is obtained by adding polyurethane foam to thicken a polyurethane foam composite panel at a later time that is more than five minutes after the initial application of polyurethane foam to the cladding. Regardless of when the additional polyurethane foam is added and the foam is thickened and has structural continuity over the entire thickness as if the foam was applied at the same time. For example, a polyurethane foam composite panel may be manufactured with a 2.5 cm continuous section of foam and then installed by positioning the panel against frame members or cladding spacers and then spraying polyurethane foam against the continuous section's foam backside to add a dropped section. As a result, the panel has structural continuity from the continuous section to the dropped section as though the foam was applied to both sections at the same time.

[0198] In another embodiment, a panel having a continuous/dropped configuration may be prefabricated with slots for insertion of frame members. Upon inserting the frame members into the slots, a continuous/dropped condition is induced and if fixed to the frame members, a fixed/continuous/dropped condition is induced on the slotted panel. Fig. 18 shows a perspective of a slotted panel 1 having a continuous section 18, a dropped section 19 and slots 30 into which frame members are to be inserted. A roof tile designed cladding 23 is also shown bonded to the continuous section 18, although the panel 1 may be without a cladding. The slots may be sized for tight fitting frame members or enlarged with side and possibly top gaps between the panel and the frame members to allow for insertion of a bonding material, such as polyurethane foam, to be injected into the gap and bond the panel to the frame members.

[0199] The slotted panel in Fig. 18 also shows ribs 31a and 31b embedded in the continuous section 18, and the dropped section 19 respectively. The ribs 31a in the continuous section 18 are perpendicular to and continuous over the slots 30 so as to be supported by the inserted frame members. The ribs 31b in the dropped section 19 are parallel to the slots 30 so as to stiffen the

panel 1 during handling. The slotted panel 1 may also be without ribs. The slotted panel may be made of any material and may or may not be bonded to the frame members although sufficiently bonding the panel to frame members will induce a fixed/continuous/dropped condition on the panel.

[0200] Fig. 19 shows a single material panel 1 with a continuous/dropped condition created by a slot 30 such as a dado notched out of the backside 8 of the panel 1. This enables the panel 1 to have a continuous section 18 over the frame members 3 while also having a dropped section 19 between the frame members 3 that may be bonded to the frame member's sides 25. Assuming the panel 1 is fixed to the frame members, a fixed/continuous/dropped condition is induced on the panel 1. A rabbet 38 is also shown at the corner intersection of two panels 1. Rotational resistance members 34 are used as needed.

[0201] In another embodiment, sandwich and double faced ribbed panels are panels of this disclosure if the panel is in a fixed/continuous/dropped configuration with the frame members such that the panel's outside is a continuous section and the panel's inside is slotted to be a dropped section between frame members. Fig. 20 shows a foam composite panel configured as a foam core slotted sandwich panel 1 having a polyurethane foam 7 core bonded to the outside skin 32a which is a cladding 23 to comprise the foam composite panel. The panel 1 has a continuous section 18 over the frame member's top edge 26 and a dropped section 19 between the frame member's sides 25 for a continuous/dropped condition, which becomes a fixed/continuous/dropped condition if the slotted sandwich panel 1 is fixed to the frame members 3. The inside skin 32b is also bonded to the foam 7 and may be a cladding, a penetration barrier or some other type of barrier between the frame member's sides 25. The inside skin 32b may provide some degree of rotational resistance separately or in conjunction with a rotational resistance member 34, as well as substantially strengthen the structural section 10 by bracing the inside of the frame members 3. In another configuration, a typical sandwich panel may provide the panel's continuous section while fillets bonding the sandwich panel to the frame members are the dropped section.

[0202] In another embodiment a panel's continuous conditioned section is structurally insufficient, i.e. unable to carry at least a minimum load for an application, and is made to be structurally sufficient for that application by inducing one of the herein disclosed new conditions on the panel. Structurally sufficient means that a panel has a sufficient load capacity to enable it to be used in a certain application and the new conditions can increase a panel's load capacity to make it structurally sufficient. This requires the presence of sufficient rotational

resistance to facilitate at least the increased load capacity that enabled the panel to become structurally sufficient.

[0203] The determination as to whether a panel is structurally sufficient or structurally insufficient, is based upon a given deflection, load and span as prescribed by a code, rule, specification, directive or other requirement or desire concerning the particular structure to which the panel is being attached. For example, a building code or an engineer may specify that a building panel not deflect more than $L/240$ [Math 1] when a 1,915 Pa lateral load is applied. If L equals 40.6 cm, the maximum allowable deflection for this 1,915 Pa load is .17 cm. This allowable deflection is then used to determine the minimum amount of load capacity necessary for a building panel to support this load and be structurally sufficient. Typically, a load capacity greater than the minimum amount is specified in order to provide a safety or other factor that ensures the panel meets or exceeds its load carrying requirement. As such, in most cases it is necessary to identify and thereby predetermine some degree of a panel's increased load capacity to ensure it is structurally sufficient for an application.

[0204] In many cases the amount of increased load capacity can be predetermined based on the knowledge of the panel's load capacity before conditions are applied. In addition, load testing can be used to determine the amounts of increased load capacity expected with different variables such as condition applied, panel material and thickness, bonding capacity, span, bonding area, etc., and the appropriate combination applied to attain at least a predetermined amount. Knowledge that a certain combination results in attaining at least some minimum amount of increased load capacity, means that amount was predetermined. Such load testing also enables the ability to regulate and rate the structural sufficiency of a panel by providing parameters that results in known increases in load capacity induced on a panel by a fixed/continuous condition and/or a continuous/dropped condition.

[0205] In another embodiment a foam composite panel bonded to frame members may be prefabricated or fabricated in place and the foam may be applied to the cladding or the cladding applied to the foam. The foam composite panel bonded to frame members may be jobsite fabricated by positioning a cladding adjacent to an erected frame or frame members and then applying foam to the backside of the cladding and bonding the foam to the frame members. Bonding to the frame members may be accomplished by using polyurethane foam or by using a separate adhesive between the foam and the frame members.

[0206] As shown in Fig. 21, cladding 23, comprised of a ribbed 31 siding panel 24 is attached to erected frame members 3 with fasteners 2 or other bonding. In this configuration the ribs 31 provide a spacing 44 between the cladding 23 and the frame member 3 to enable the

polyurethane foam to fill in the spacing 44 and provide a continuous condition over the frame members 3. Fig. 22 shows the siding panels 24 fully attached to the frame members 3 and polyurethane foam 7 filled into the spacing 44 and bonding to the side 25 of the frame member to bond the siding panel 24 to the frame members 3. Assuming a sufficient bond, the panel 1 is induced with a fixed/continuous/dropped condition.

[0207] In another configuration of the panel being fabricated in place, cladding spacers are situated between the panel and the frame members to provide a space into which foam may be applied. A cladding spacer is a structure that creates open space between the frame members and a cladding or a composite panel. Fig. 23 is a section view of a framed wall comprised of frame members 3 attached to a bottom plate 29 which is attached to a foundation 46 or floor structure. Also shown is a temporary brace 33 fastened 2 to the foundation 46 and preferably secured at its top (not shown) and used to support siding panels 24 while being bonding to the frame members 3. The siding panels 24, which are a cladding, are positioned against the brace 33 and secured by a cladding spacer 39 wedged between the siding panel 24 and the frame member 3. As a result, a spacing 44 is created between the siding panel 24 and the frame members 3. The cladding spacers 39 may be any material although a small foam block is preferred so as to prevent a thermal bridge. Once the siding panels 24 have been positioned, they may be further secured by a clump of polyurethane foam (not shown) sprayed between the siding panel 24 and the frame members 3.

[0208] Fig. 24 shows the same framed wall of Fig. 23, with a panel 1 comprised of polyurethane foam 7 applied to the backside 8 of the siding panels 24, which represents the cladding 23 of this panel 1. The polyurethane foam 7 filled in and occupies the spacing 44, to sufficiently bond the siding panels 24 to the frame members 3. A continuous section 18 is comprised of the siding panels 24 and the polyurethane foam 7 in the spacing 44. The polyurethane foam 7 is also the dropped section 19 bonded to the frame member's sides 25. As such, the panel 1 is continuous over, dropped between and fixed to the frame members 3 to induce a fixed/continuous/dropped condition on the panel 1. The polyurethane foam 7 may also seal the siding panel 24 to the bottom plate 29 and the foundation 46. The purpose of the cladding spacers is to provide a spacing between the cladding and the frame members that can be filled with an insulating material such as foam. As such the cladding spacers may be individual spacers or an elongated member fastened to the frame members and/or the cladding.

[0209] A foam composite panel bonded to frame members may also be prefabricated, which includes using the spray-up manufacturing process. Prefabrication begins with preparing a surface such as a platform, worktable, backstop or form and positioning the cladding material on

the surface. Fig. 25 shows a surface 40 onto which a cladding 23 is positioned with its backside 8 up, i.e. exposed. The surface 40 may be horizontal, vertical or at some angle. The cladding 23 may be positioned in a number of ways depending upon the type of material. For example a coating material may be sprayed against a prepared form surface 40, or an aggregate cladding may be spread over a horizontal surface 40, or siding panels, tiles, thin bricks or similar types of cladding 23 may be laid-out on a worktable. The cladding 23 may also be a composite comprised of two or more different materials or materials with different properties. For example a polyurea may be sprayed onto a form surface 40 followed by a resin mixture poured or sprayed on top of the polyurea to comprise a composite cladding 23.

[0210] After the cladding 23 has been positioned, a frame 41 or individual frame members 3 are positioned above the cladding 23 as shown in Fig. 26. The frame 41 may be suspended or spacers used to create a spacing 44 between the backside 8 of the cladding 23 and the frame 41. Polyurethane foam 7 is bonded to the backside 8 to create a foam composite panel 1 as shown in Fig. 27. The polyurethane foam 7 may be poured or sprayed onto the backside 8 and as it expands it bonds the cladding to the frame 41 and individual frame members 3. Fig. 27 shows that both a continuous section 18 and a dropped section 19 are present and if fixed to frame members 3, a fixed/continuous/dropped condition is induced on the panel 1. Fillets may be added to further increase the panel's 1 load capacity. There are several alternatives to the spray-up process although the preferred method is spraying a polyurea or similar coating on a form, followed by applying a liquid polyurethane foam on the backside of the coating. Arranging a frame or frame members above the coating's backside and letting the polyurethane foam expand and bond the coating to the frame members.

[0211] In another embodiment both the fixed/continuous condition and the fixed/continuous/dropped condition, when bonded to frame members, increases a panel's uplift resistance simply due to the bond between the panel and the frame members. The uplift resistance is even more pronounced with ribbed panels since the ribs provide additional bonding area as well as introducing a shear bond between the foam and the rib's sides. Moreover, when the ribs are perpendicular to the frame members, the bonding is extended along the ribs.

[0212] In another embodiment the continuous/dropped conditions can minimize the effects of thermal expansion or contraction on cladding materials. Fig. 28 shows polyurethane foam 7 bonded to the backside 8 of a cladding 23 to create a foam composite panel 1 that is fixed to the frame members 3 to induce a fixed/continuous/dropped condition on the panel 1. As such, the panel's 1 continuous section 18 is bonded to the frame member's top edge 26 and more importantly is thoroughly bonded to the dropped section 19 which in turn is both bonded to and

constrained between the sides 25 of frame members 3. Since the dropped section's 19 span is relatively small, the change in linear dimension is so small that the frame member's 3 physical presence prevents the foam 7 in the dropped section 19 from expanding. In addition, if the foam 7 is sufficiently bonded to the frame member's sides 25, the foam 7 in the dropped section 19 is prevented from contracting. As a result, since the foam 7 in the dropped section 19 cannot expand or contract, neither can the foam 7 in the continuous section 19 nor can the entire panel 1. Fig. 28 also shows a rotational resistance member 34.

[0213] In another embodiment, a mesh is bonded to the frame members to provide an anti-penetration layer to the panel. As shown in Fig. 29, a mesh 45 is stapled to the top edge 26 of frame members 3 and is continuous over two or more frame members 3. Polyurethane foam 7 is applied to the backside 8 of the cladding 23 and as it expands into a continuous/dropped configuration, the polyurethane foam 7 engulfs the mesh 45 resulting in mesh 45 being an embedded layer in the polyurethane foam 7. The mesh 45 provides an anti-penetration layer to the panel 1 by its attachment to the frame member's top edge 26 which absorbs a shear force from any projectile penetrating the panel 1. A rotational resistance member 34 is needed to prevent frame member 3 rotation. The mesh 45 may be bonded or otherwise attached to the frame members 3 in any fashion. The panel 1 is induced with a fixed/continuous/dropped condition if it is fixed to the frame members 3.

[0214] In another embodiment the continuous/dropped condition enables thinner frame members since the dropped section's bond to the frame member's sides can provide practically all of the necessary panel support. In addition, the dropped section supports the thinner frame member from buckling and can be used to prevent the frame from racking and may provide some or all of the rotational resistance. The dropped section can be of the same or a different material than the continuous section.

[0215] Fig. 30 shows a perspective of a structural section 10 comprised of a thin skin, i.e. cladding 23, on the front side that is continuous over and bonded to thin frame members 3. Also shown is a dropped section 19, of another material, bonded to the backside 8 of the cladding 23 to comprise a composite panel 1. The dropped section 19 is fixed to the sides of frame members 3 to induce a fixed/continuous/dropped condition on the composite panel 1. The dropped section 19 also reinforces the frame members 3 from buckling. Rotational resistance members 34 are shown bonded to the bottom edge 27 of the frame members 3 and optionally bonded to the dropped section 19. Since the rotational resistance members 34 are individual, spaced apart members the composite panel 1 is not a sandwich panel. A sandwich panel's increased load capacity derives from the interaction between the two skins bonded to a core material.

[0216] From the description above, a number of advantages of some embodiments of the stiffened, frame supported panel become evident:

[0217] (a) This invention enables weaker, thinner, lighter, more versatile and less expensive materials to have increased load capacities up to several thousand percent increase to enable them to be used as structural panels.

[0218] (c) This invention enables polyurethane foam bonded to a cladding and frame members to become a multi-functional structural panel providing a finished exterior, continuous and cavity insulation as well as an air, moisture and vapor barrier, increased uplift resistance and the elimination of condensation and of thermal expansion/contraction.

[0219] (d) This invention enables fillets to increase a panel's load capacity by several thousand percent above that of the same simply supported or continuous panel.

[0220] (e) This invention enables panels to have substantial increased load capacity without thickening their structural section.

[0221] (f) This invention enables panels to be sliced together with structural continuity to create very large panels to utilize the inherent increased load capacity of inside spans which is presently wasted.

[0222] (g) This invention enables the utilization of a low cost spray-up process to manufacture comprehensive building panels.

[0223] (h) This invention enables the utilization of thinner frame members since panels can be bonded to frame member's sides to support the panel and thinner frame members can be supported by the panel's dropped section.

[0224] (i) This invention enables prefabricated slotted panels to have it's load capacity increased multiple times by simply being sufficiently bonded to frame members.

[0225] (j) This invention enables thin ribbed panels to have a substantial increase in load capacity by being filled with and bonded to frame members with polyurethane foam that also prevents the ribs from buckling.

[0226] (l) This invention enables a fixed/continuous/dropped condition to greatly reduce thermal expansion and contraction on susceptible claddings.

[0227] Although the description above contains many specifications, these should not be construed as limiting the scope of the embodiments but as merely providing illustrations of some of several embodiments. Thus the scope of the embodiments should be determined by the appended claims and their legal equivalents, rather than by the examples given.

CLAIMS

I claim,

- Claim 1. A frame supported panel with a load capacity, wherein the improvement comprises:
a single or a multitude of frame members having a top edge, a bottom edge and two sides and said frame members are spaced a distance apart with one or more spans between said frame members;
a panel with a continuous section and one or more dropped sections to comprise one or more thickened sections; and
said continuous section supported by said frame members and continuous over said top edges and said continuous section has a thickness of .05 centimeter to 15.2 centimeters and has a continuous conditioned load capacity over each said span; and
said dropped sections situated between said sides; and
said thickened sections have a flexural stiffness; and
said panel fixed to said top edges and/or to one or more said sides with a bonding technique and said bonding technique has a bonding capacity of at least 7 N/cm²; and
said panel has a fixed/continuous/dropped condition with an increased load capacity over at least half of said spans that is at least 25% greater than said continuous conditioned load capacity; and
said frame members have sufficient rotational resistance to facilitate at least said 25% greater load capacity; whereby said panel has an increased load capacity.
- Claim 2. A frame supported panel of claim 1 wherein said increased load capacity is predetermined.
- Claim 3. A frame supported panel of claim 1 wherein said increased load capacity is at least 50% greater and said increased load capacity is predetermined.
- Claim 4. A frame supported panel of claim 1 wherein said increased load capacity is at least 100% greater.
- Claim 5. A frame supported panel of claim 1 wherein said dropped sections comprise fillets and said fillets are fixed to said frame members and are optionally bonded to said panel and said increased load capacity is at least 100% greater and said increased load capacity is predetermined.
- Claim 6. A frame supported panel of claim 1 wherein said panel is a foam backed panel comprising a continuous/dropped configuration with slots for the insertion of said frame members.

- Claim 7. A frame supported panel of claim 1 wherein said panel is a foam composite panel comprised of a cladding with foam adhesively bonded to at least part of said cladding's backside and said foam has a modulus of elasticity of at least .7 MPa and provides at least 5% of said flexural stiffness over at least half of said spans.
- Claim 8. A frame supported panel of claim 7 wherein said increased load capacity is at least 100% greater and said increased load capacity is predetermined.
- Claim 9. A frame supported panel of claim 7 wherein said dropped section comprise fillets and said fillets are fixed to said frame members and said fillets are optionally bonded to said panel and said increased load capacity is at least 100% greater and said increased load capacity is predetermined.
- Claim 10. A frame supported panel of claim 7 wherein said panel is a frame supported ribbed panel.
- Claim 11. A frame supported panel of claim 7 wherein said panel is a ribbed structural section.
- Claim 12. A frame supported panel of claim 7 wherein a mesh is continuous over and bonded to said frame members and embedded in said foam as an anti-penetration layer.
- Claim 13. A frame supported panel of claim 7 wherein cladding spacers situated between said cladding and said frame members provide a spacing and said foam occupies at least part of said spacing.
- Claim 14. A frame supported panel of claim 7 wherein said panel is a foam core slotted sandwich panel having an outside as said continuous section and a slotted inside as said dropped section.
- Claim 15. A frame supported panel of claim 7 wherein said panel was manufactured and fixed to said frame members with a spray-up process.
- Claim 16. A frame supported panel of claim 7 wherein said foam provides at least 20% of said flexural stiffness.
- Claim 17. A frame supported panel of claim 7 wherein two or more said panels are spliced together by polyurethane foam to form a single panel with structural continuity.
- Claim 18. A frame supported panel of claim 7 wherein said foam is a polyurethane foam and said foam is thickened at a later time with additional polyurethane foam whereby said foam has structural continuity thickness.
- Claim 19. A frame supported panel of claim 7 wherein an enhanced continuous condition is induced on said panel and said panel has 2 or more inside spans and an increased load capacity of outside spans to correspond to the load capacity of said inside spans.

Fig. 1

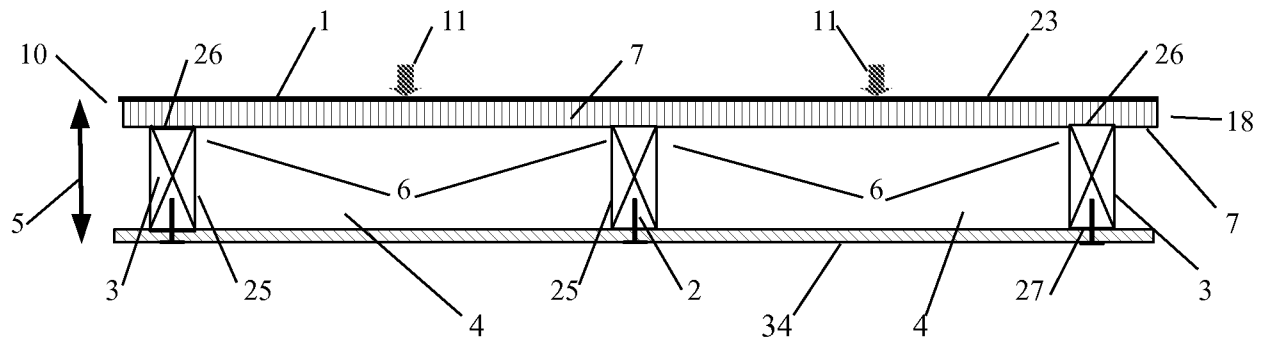


Fig. 2

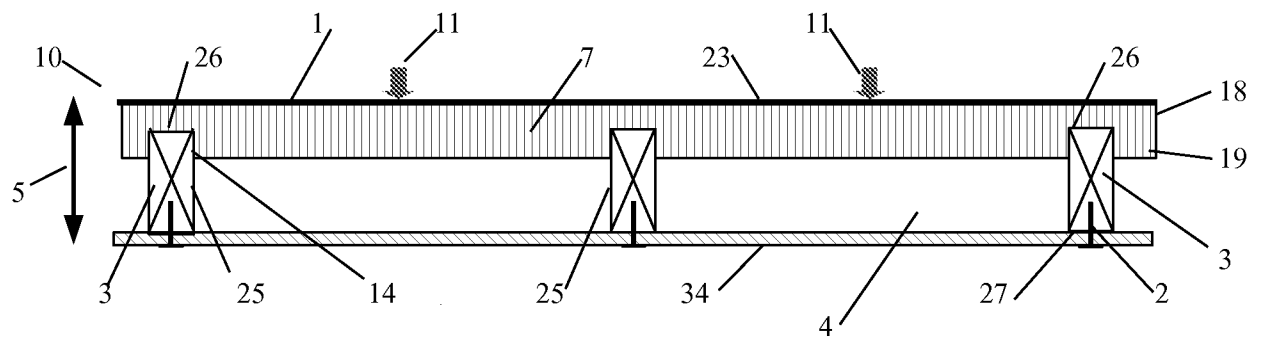
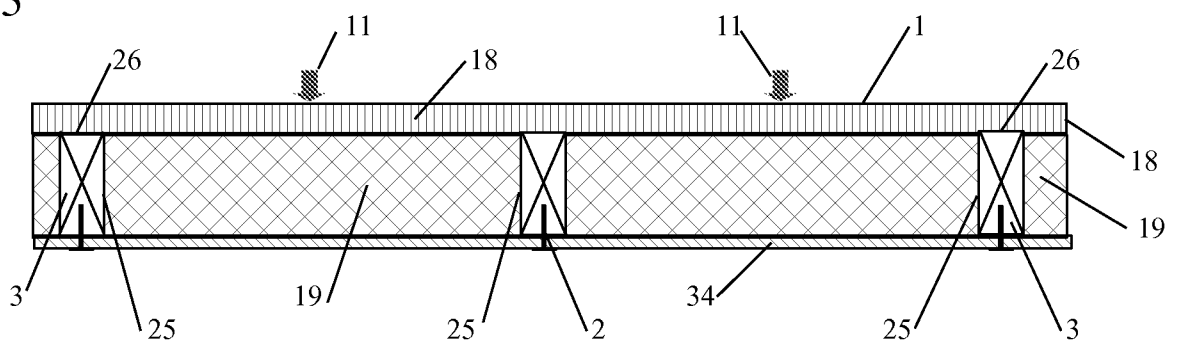


Fig. 3



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Fig. 4

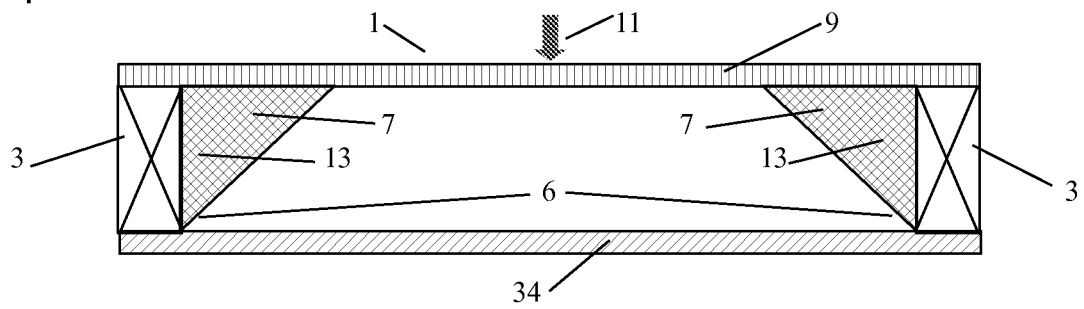


Fig. 5

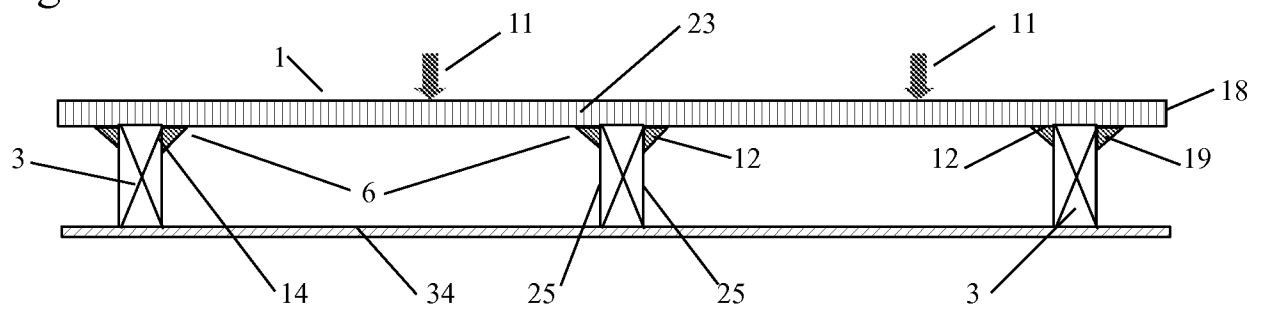
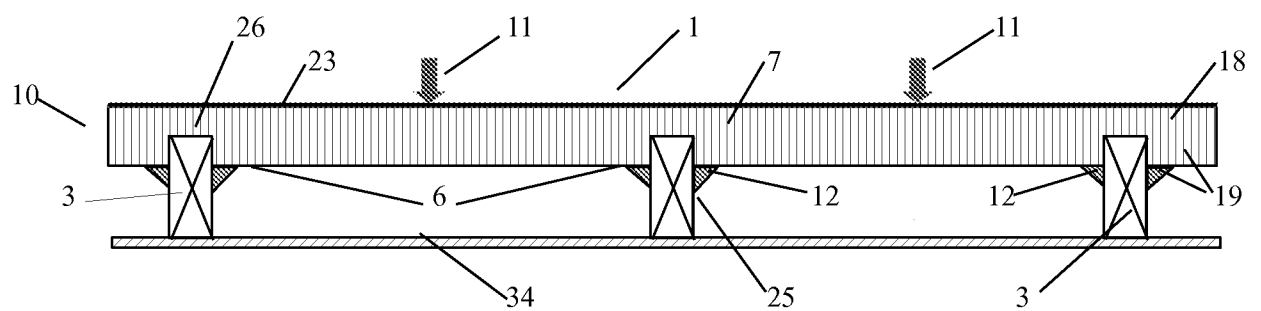


Fig. 6



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Fig. 7

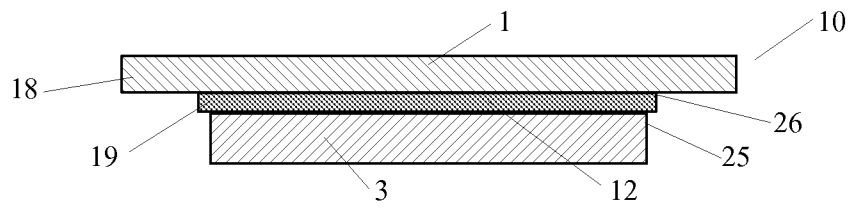


Fig. 8

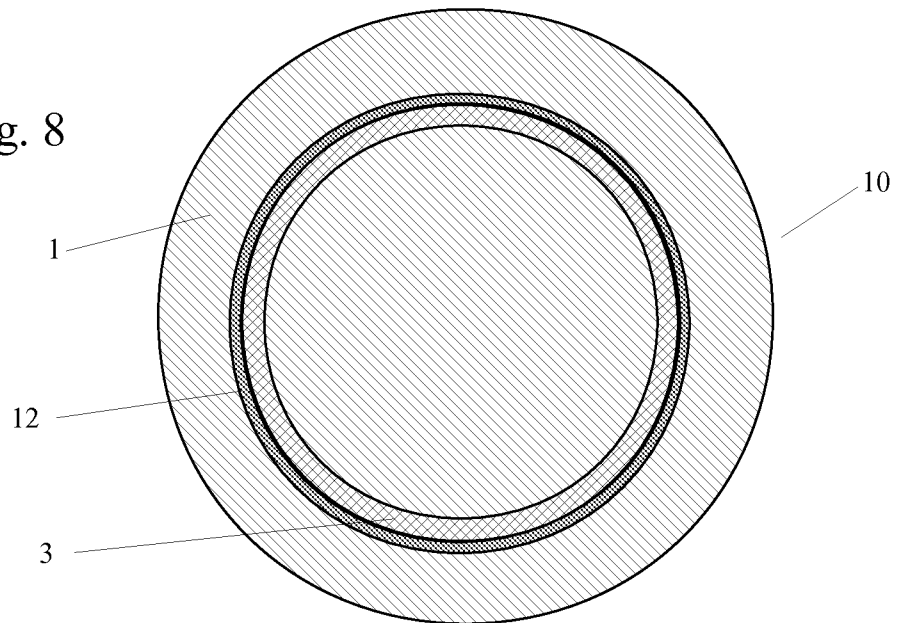


Fig. 9

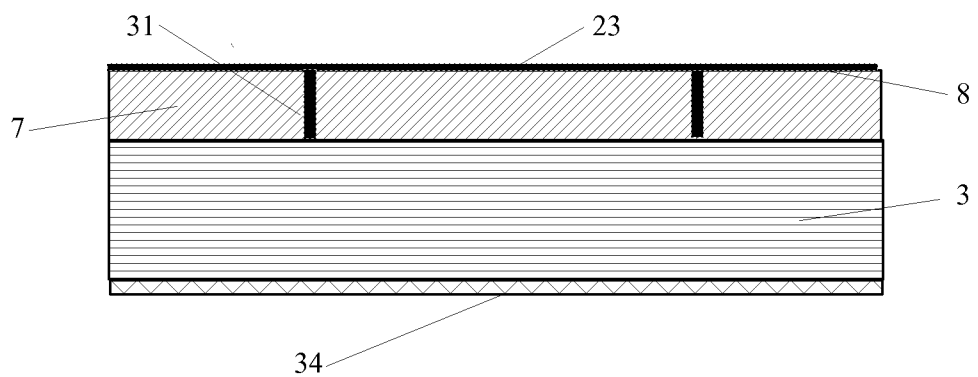


Fig. 10

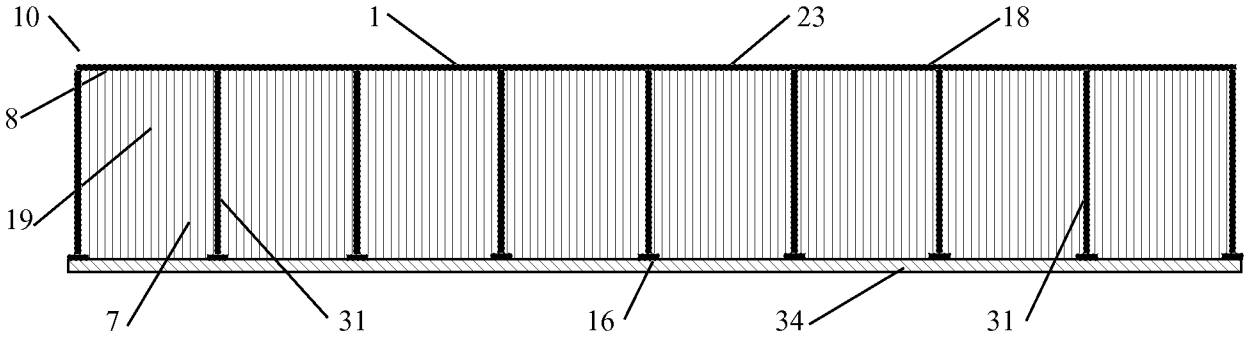
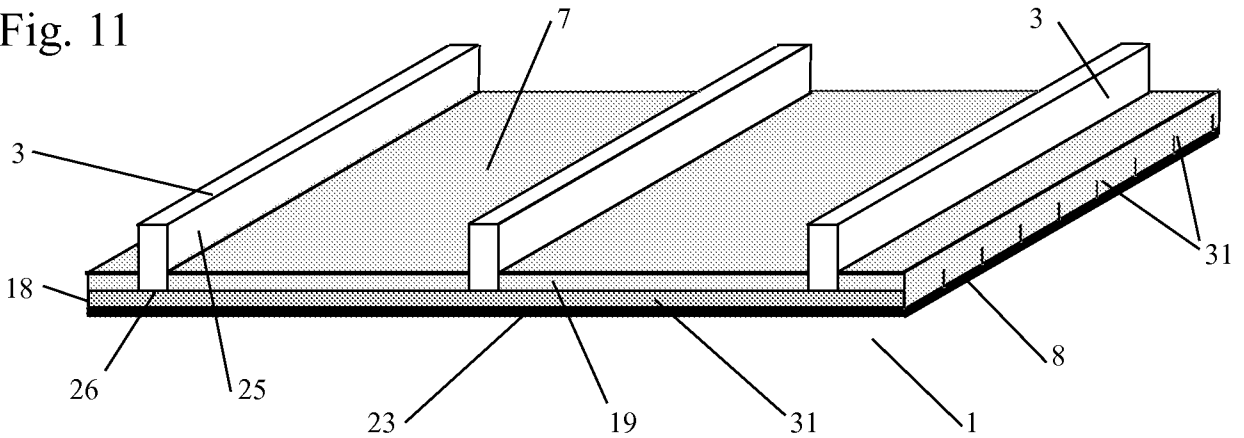


Fig. 11



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Fig. 12

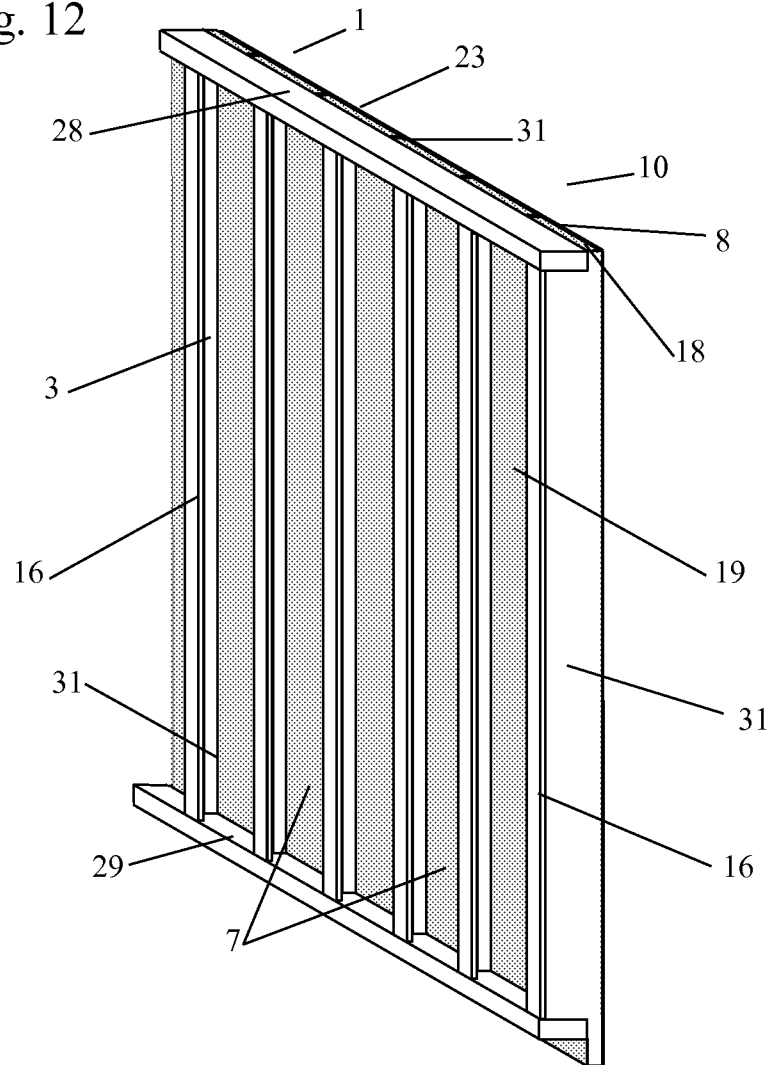


Fig. 13

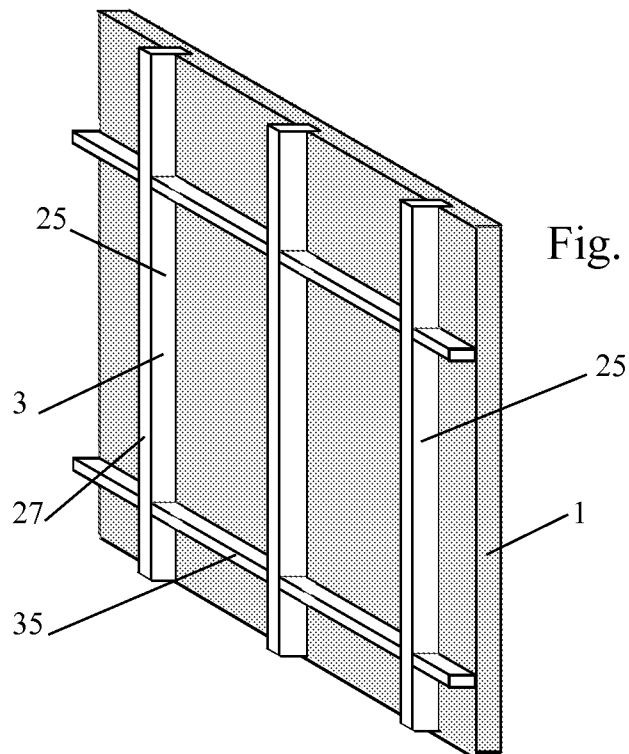


Fig. 14

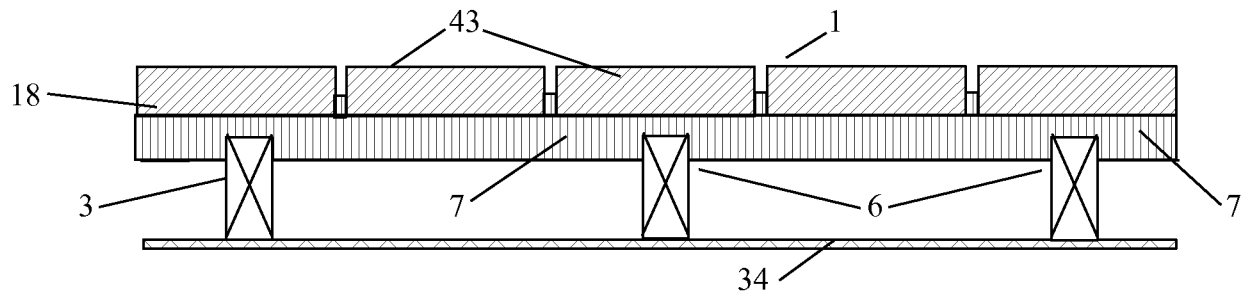


Fig. 15

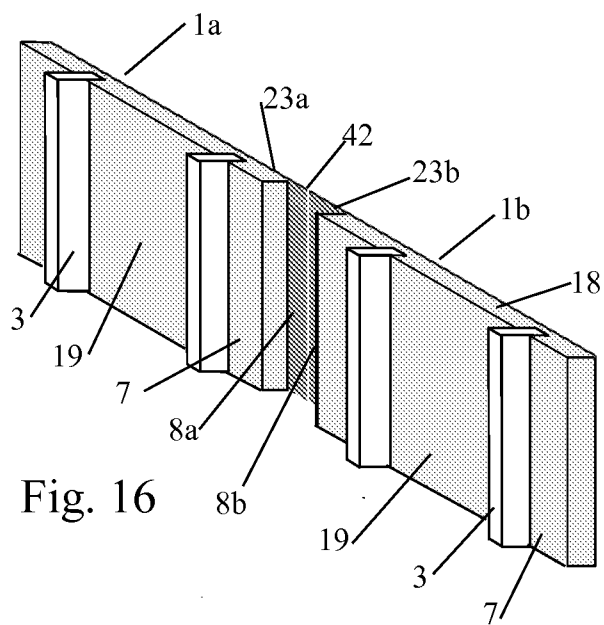
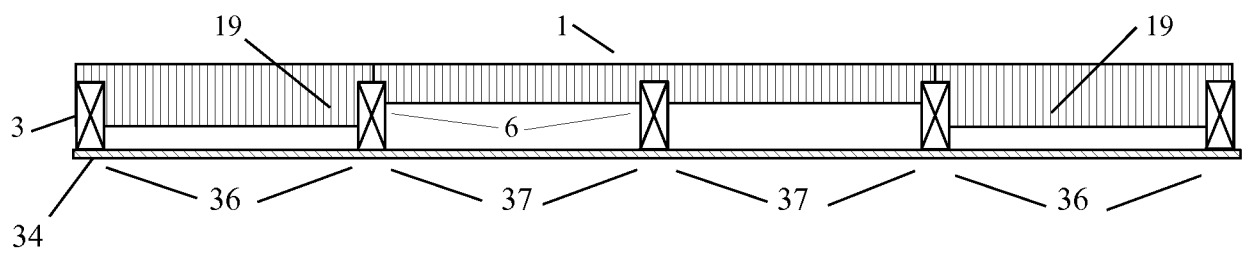


Fig. 16

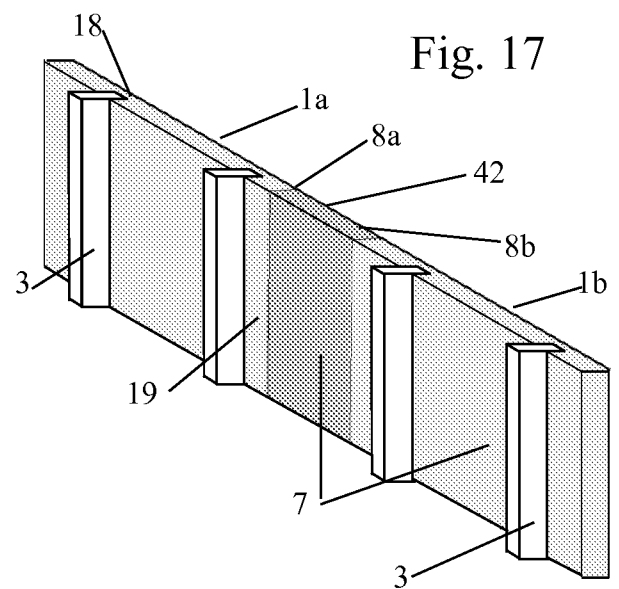


Fig. 17

Fig. 18

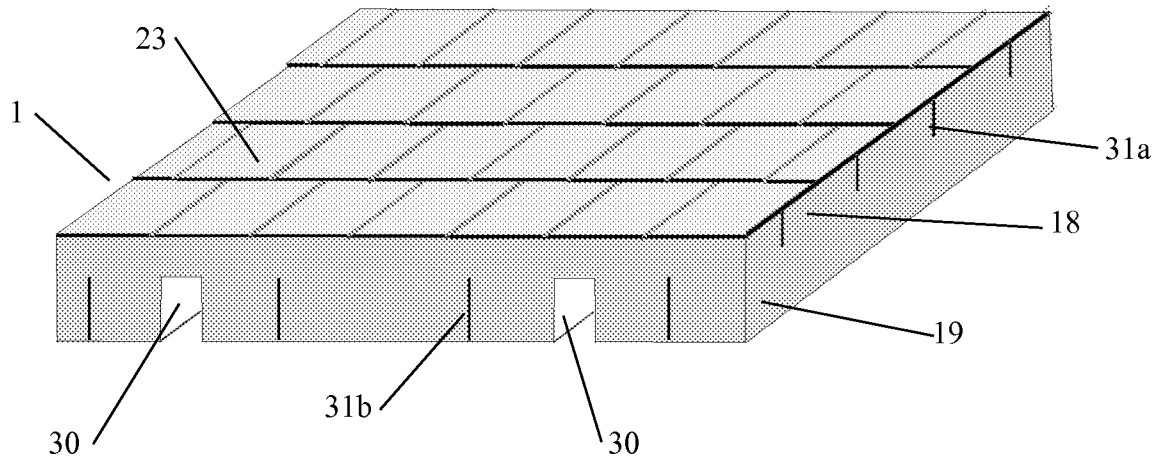


Fig. 19

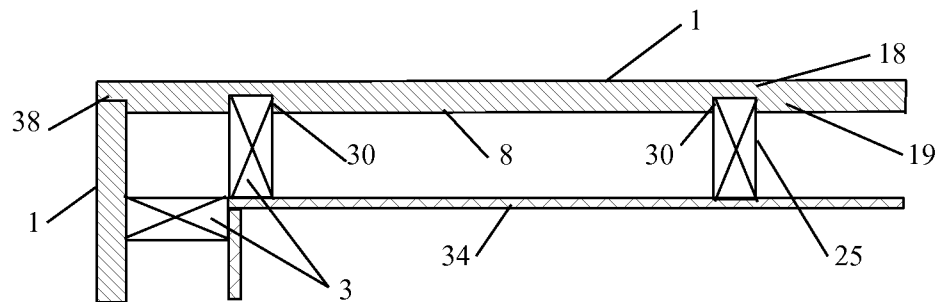


Fig. 20

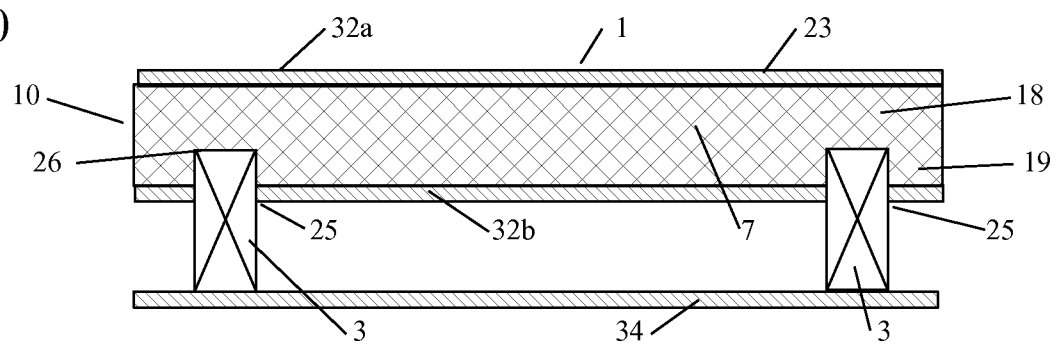


Fig. 21

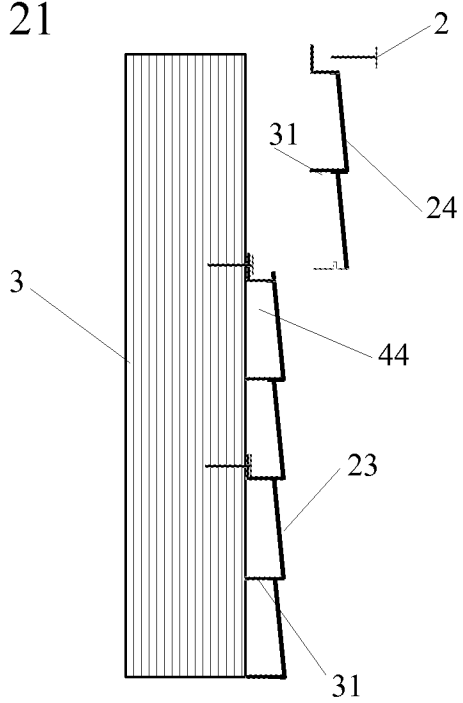


Fig. 22

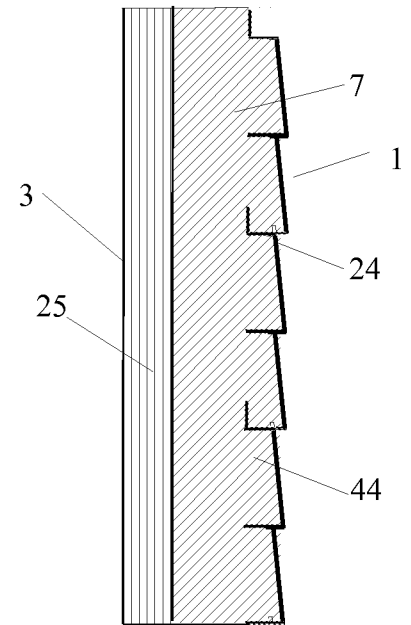


Fig. 23

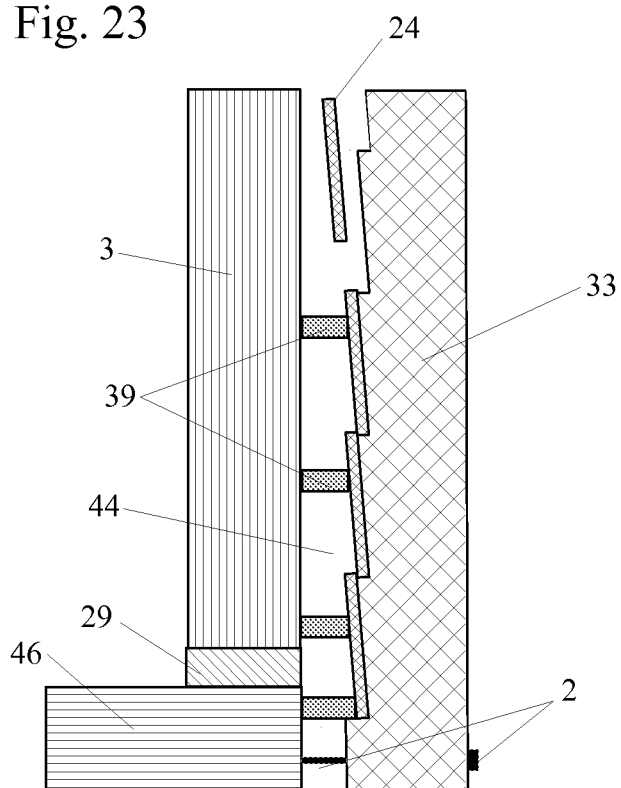


Fig. 24

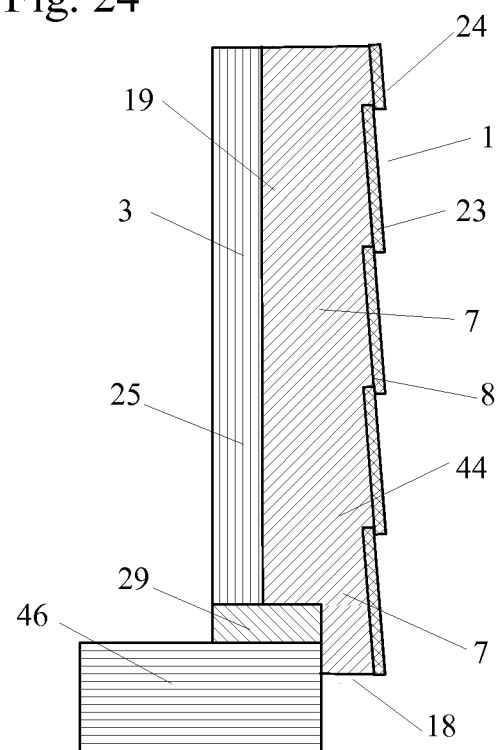


Fig. 25

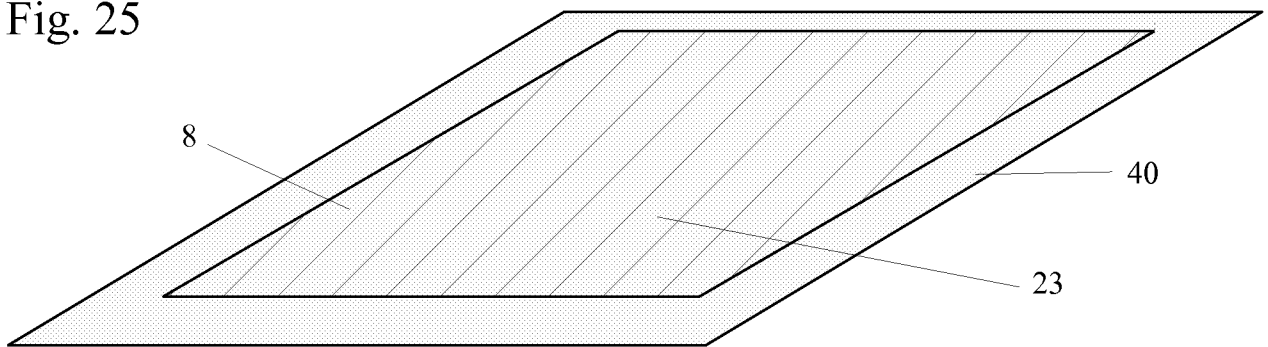


Fig. 26

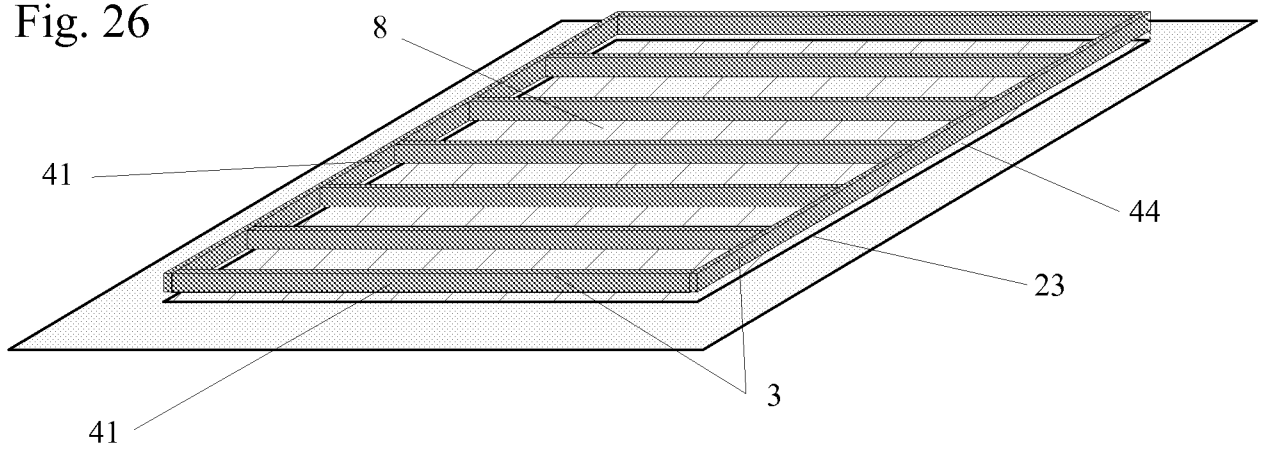
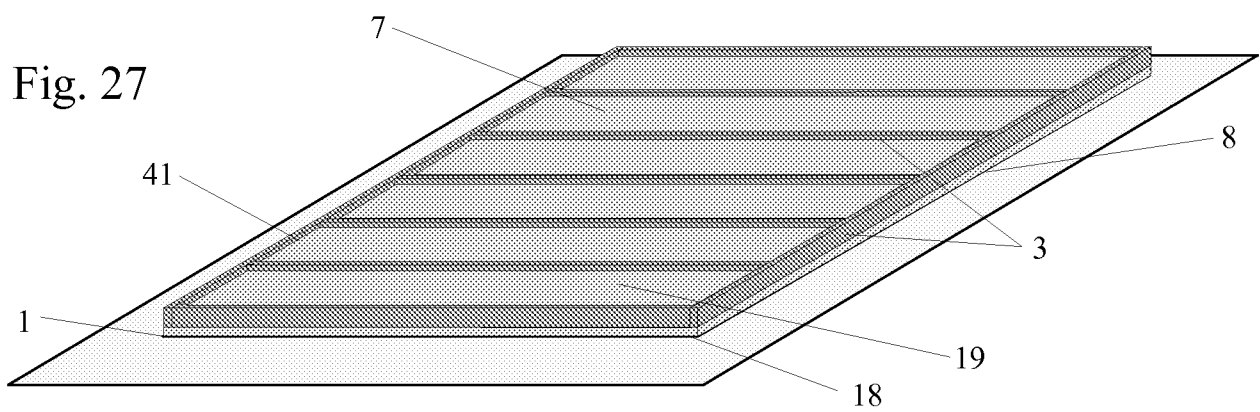


Fig. 27



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Fig. 28

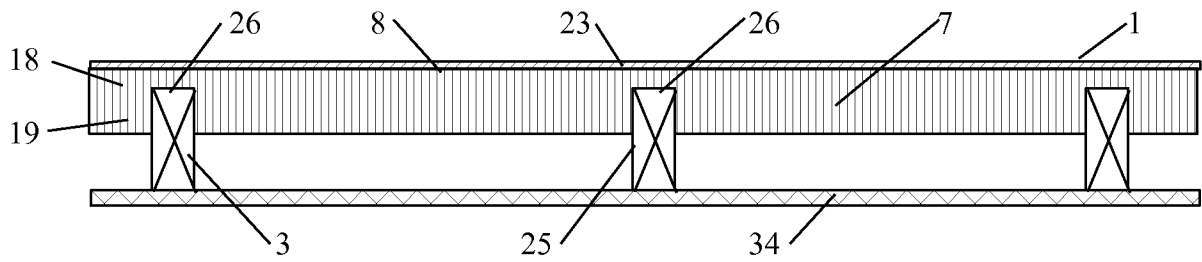


Fig. 29

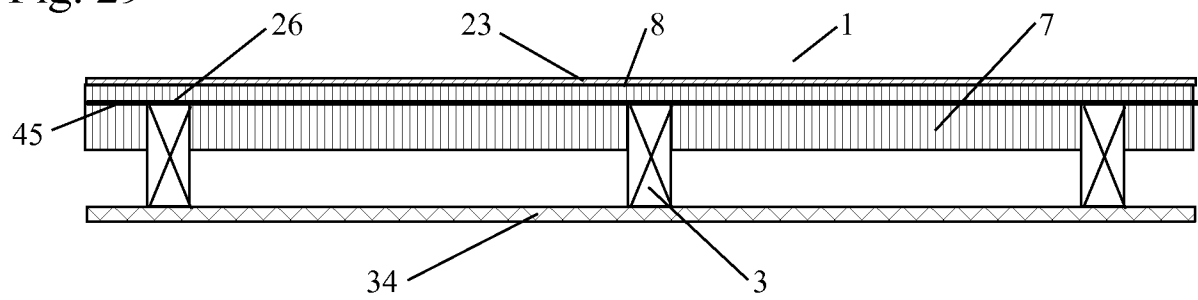
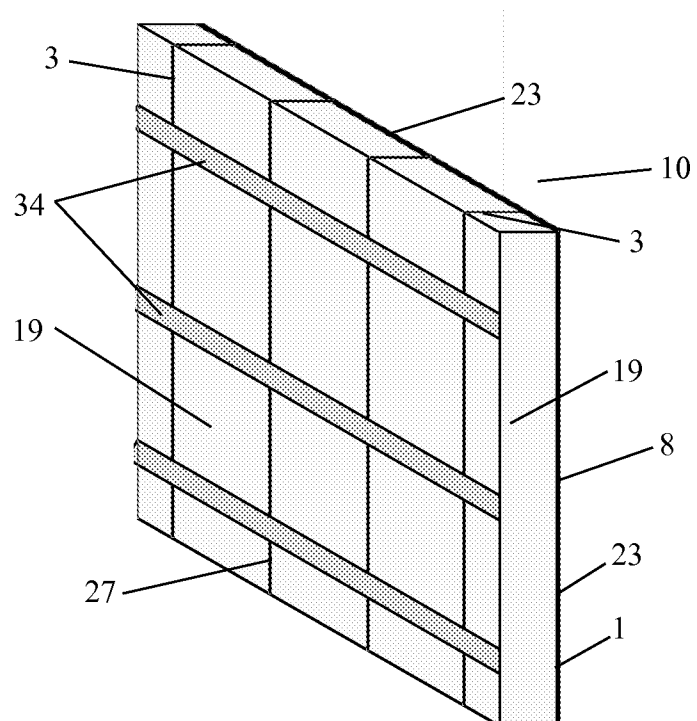


Fig. 30



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 15/37568

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - C09J 175/00, E04C 2/34 (2015.01)

CPC - C09J 175/00, E04C 2/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC (8) - C09J 175/00, E04C 2/34 (2015.01)

CPC - C09J 175/00, E04C 2/34

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - E04C 2/36, 2/205, 2/06, 2/24, 2/234, 2/246, B32B 2307/00Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Google (Schoalrs, Patents); PatBase (All); Search terms: frame structure backbone perimeter support rib panel wall floor cover layer composite compound foam continuous dropped fixed section part group increased load bearing taking supporting holding polyurethane cladding protect bond connect mate mix sandwich between middle enclose encase bonding

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 3,528,889 A (BUTCHER) 16 April 1962 (16.04.1962) entire document, especially col 1-2	1-19
A	US 2008/0295450 A1 (YOGEV) 04 December 2008 (04.12.2008) entire document especially col 1-2	1-19
A	US 6,308,491 B1 (PORTER) 30 October 2001 (30.10.2001) entire document	1-19
A	US 3,886,706 A (BAKER) 03 June 1975 (03.06.1975) entire document	1-19
A	US 8,539,721 B2 (ANTAL) 24 September 2013 (24.09.2013) entire document	1-19

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

04 Septemebr 2015 (04.09.2015)

Date of mailing of the international search report

30 SEP 2015

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
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