Structural members, building structures, and methods for making them, are provided that are less prone to develop squeaks. The methods include, in one aspect, placing at least one panel on the flange surfaces of joists with an activatable adhesive provided between the panel and the flange surfaces to bond the flange surfaces to the panels in an effective long lasting manner. In another aspect, adhesive is introduced into a groove array in a joist flange surface to attach a panel pre-positioned on the grooved flange surface. Building frame structures, such as subflooring assemblies, made by the methods are also provided.
STRUCTURAL MEMBERS AND STRUCTURES USING THEM, AND METHODS

TECHNICAL FIELD

[0001] The present invention relates generally to structural members and structures assembled using them, for example, building structures using joists and panels, such as subflooring, and, to methods for constructing them.

BACKGROUND OF THE INVENTION

[0002] Flooring systems in typical residential and many commercial buildings include wood joists and a wooden overlayment, often referred to as subflooring. In flooring construction, wood joists typically are set on edge, and a subflooring is secured to the top edge or flange of the joist with nails, screws or staples. Subflooring commonly consists of particle board, oriented strand board (OSB), plywood sheets, or similar materials. Finished flooring material, such as carpet, tile, linoleum, laminate, hardwood, or the like, is typically then placed upon the subflooring, directly or indirectly as placed upon an intermediate layer arranged on the subflooring.

[0003] In the case of some flooring materials, such as hardwood stone, tile, granite, and so forth, it can be important that the floor be stiff and strong to eliminate and prevent problems such as cracks and crazing. In addition, avoidance of floor squeaks in flooring materials can be important. Wooden joist and subfloor construction can become prone to squeaks or other undesirable audible structural noise when walked upon. This squeaking problem can occur in new and old floors alike. Squeaks can have a number of causes. Squeaks, for instance, often develop where a gap between the joist and the subfloor panel permits the panel to flex and up as a person walks across the floor. During flexing, the subfloor can rub against the fasteners, such as a decking staple or nails, causing the squeaking noise. This squeaking noise can arise due to inadequate fastening of the flooring components during original assembly, or physical changes that occur in the structural components in use or over time. For instance, drying or dampness in the subfloor may cause it to warp or shrink with the result that the subfloor may pull or bend away from the top of a joist to which it is fastened.

[0004] It can be very costly or even impractical to repair a floor squeaking problem. The subflooring often is not easily accessible, if at all, from beneath the floor in a finished building structure. Conversely, to obtain access to the problem area of the subflooring from the top side, it is usually necessary to remove finished flooring materials, such as wood flooring, floor tiles or carpeting, that have been fastened over the subflooring. This also can be problematic or expensive.

[0005] As realized by the present investigators, the floor squeaking problem ideally needs to be addressed by effective long-term preventive measures that can be integrated in a practical and economical manner into the original construction process.

SUMMARY OF THE INVENTION

[0006] The present invention is directed to building structures, and structural members used in assembling the structures, that are less prone to making squeaks or other structural noise, and methods for making them wherein joists are joined with panels with adhesive in manners to create a more effective and longer-lasting bond therebetween.

[0007] In one embodiment, a method is provided for making a building structure that preserves structural members assembled into the structure in their original installed state, comprising placing at least one panel on a flange surface(s) of a joist(s) with an activatable adhesive pre-applied between the panel and the flange surfaces that, after activation, bonds the flange surface(s) to the panel. Fasteners, such as nails or staples, can also be driven through the panel and into the joist(s) to mechanically secure the panel to the joists. In a further embodiment, a plurality of generally planar panels are adhered and fastened to joists in this manner with side edges of the panels in approximate abutment with one another to provide substantially continuous paneling coverage of the joists. In this manner, a paneled building frame structure can be assembled that is less prone to develop squeaks or other audible noise associated with panels. An advantage of this embodiment of the present invention is that an activatable adhesive is applied in a dormant (un-cured) state until ready to use (activate), and thus can avoid problems associated with using adhesive in structural member assembly where the adhesive is dispensed from a dispenser in an active state of cure.

[0008] In another embodiment, a method is provided for constructing a subfloor assembly of a building so as to prevent squeaking of the floor, wherein an activatable adhesive is applied to the upper flange surfaces of floor joists and at least one floor panel is mounted on the upper flange surfaces of the joist with the adhesive pre-applied to the floor panel and the upper flange surfaces of the joists. The applied adhesive can be activated in place to more permanently and consistently bond the upper flange surfaces of the joists to the overlying panel or panels. Fasteners can also be driven through the floor deck panel and into the joists to mechanically secure the floor deck panel to the joists. The adhesive can be activated, for example, via chemical activation or energy activation, depending on the adhesive formulation.

[0009] In one embodiment, activatable adhesive is pre-applied on joist flange surfaces in a non-tacky state on the floor flange surface and then is activated in place with at least one panel member placed on the adhesive, to adhesively bond the joist and panel together. In one further embodiment, integral retention means, such as grooves, can be provided in the surface of the flange surface for pre-positioning activatable adhesive. In an alternative embodiment, grooves are provided in the joist flange surfaces to provide a channel network for flow of activator fluid to activatable adhesive pre-applied on the joist flange surfaces (grooved or non-grooved flange surface portions). In one embodiment, the activatable adhesive is essentially non-tacky at normal installation conditions. The activatable adhesive can be activated in place by contacting it with a chemical activator. In another embodiment, activation of the activatable adhesive on the joist surfaces can be induced by imparting activating energy to the adhesive, such as sonic energy, high frequency radiation energy, heat energy, or pressure (compression) energy, or any combinations of these.

[0010] In another embodiment, activatable adhesive can be contained in a non-tacky carrier film placed on the joist flange surfaces (grooved or non-grooved surface portions), before a panel is place on the joist. In one embodiment, the carrier film material and contained activatable adhesive can be essentially non-tacky at normal installation conditions. The activatable adhesive can be substantially uniformly dispersed or distributed in, or contained at discrete areas in/on, a carrier film. In
one embodiment, a carrier film can be placed on the upper
flange surface of a joist, and the adhesive is activated by
contacting the film with an activator fluid, wherein the joist
can be bonded to a panel placed on the opposite side of the
carrier film in contact with the contained adhesive. In an
alternative embodiment, the activatable adhesive in the car-
rier film can be activated by application of activating energy.

[0011] In a further embodiment, a method is provided for
constructing a subfloor assembly that comprises providing
joists having upper flange surfaces imparted with a groove
array, wherein an activatable adhesive can be introduced into
the grooves before the panels are mounted on the joists. In one
embodiment, the grooves define an array, such as a pattern,
grid, or series of grooves, for applying and positioning adhe-
usive on the upper flanges surfaces of the joist. The pre-applied
adhesive can be activated in place in the groove array by
spraying it with an activation fluid before the panel is
mounted thereon. In another embodiment, the groove pattern
provided on the joist upper flange surfaces can be used to
provide flow channels through which activated fluid can be
introduced before or after assembly of the joists and at least
one panel, whereby the activator fluid can flow along the
length of the joist surface away from a point of introduction to
substantially contact all the pre-positioned adhesive in the
groove pattern. In one further embodiment, at least one joist
hole is provided that extends from a side opposite the upper
flange surfaces to a groove of the groove pattern, wherein
activation of the adhesive comprises injecting an activator
fluid through the joist hole into the groove, where it can flow
throughout the groove pattern and reach the activatable adhe-
usive pre-positioned on the upper flange surfaces of the joist.
The activator fluid has a characteristic of allowing or initiat-
ing curing in the adhesive. The joists can further comprise a
drain hole at a different longitudinal location along the joists
different than the joist hole, such as at the opposite longitudi-
nal end of the joist. The drain hole also extends from a
groove of the groove pattern to a side opposite the upper
flange surfaces so that the installer can detect when the
amount of activator fluid injected through the joist hole is
sufficient to reach substantially all the groove pattern when it
drains from the drain hole. In another further embodiment,
the joists having grooved upper flange surfaces and at least one
panel are united by activating adhesive positioned therebe-
tween with application of activating energy relative to the
activatable adhesive. In particular embodiments, activation of
the adhesive applied to the joist surfaces is induced by soni-
cation energy, high frequency radiation energy, heat energy,
or pressure energy applied to the adhesive sufficient to induce
activation of the adhesive. The high frequency radiation
energy can be, for example, radio frequency energy or micro-
wave energy.

[0012] In one particular embodiment, a method is provided
for constructing a subfloor assembly, which includes the
application of a foamy adhesive to upper flange surfaces of
the joists, wherein the foamy adhesive can be activated to
foam in place and wet both the upper flange surfaces and the
panels to provide an enhanced flange-to-panel bond. The
activation of the adhesive in this embodiment also can be
accomplished by using a chemical activator or energy activa-
tor, depending on the selected formulation of activatable adhe-
sive.

[0013] In another embodiment, a method is provided for
constructing a subfloor assembly with reduced squeaking that
comprises providing at least one joist having an upper flange
surface including a groove array, wherein flowable adhesive
is introduced into the groove array after pre-positioning a
panel or panels on the joists. In one further embodiment, a
panel is provided having at least one panel hole extending
through the panel. Adhesive is injected into the panel hole at
the top side of the panel, flows through the panel through-
hole, and discharges from the panel hole at the bottom side of
the panel to be deposited into an underlying groove of a
groove pattern provided in the upper flange surface of the
joists, effective to provide an intermediately-located adhesive
used to bond the joists and panels. In one additional embodi-
ment, the panel comprises a plurality of panel holes extending
through the panel through which the adhesive can be injected
into a groove of the groove pattern. In an alternate further
embodiment, the joists further comprise at least one joist hole
extending from a side opposite the upper flange surfaces to a
groove of the groove pattern, and the adhesive is injected
through the joist hole into a groove of the groove pattern. The
adhesive also can be injected into the space between the
panels and joists. The adhesive can be introduced, for
example, via holes provided through the panels, the joists, or
both. In particular embodiments, the adhesive used in this
embodiment can be self-hardening or activatable, such as
where grooves are used to carry adhesive.

[0014] In another embodiment, a building structure is pro-
vided which can be made with these methods. The building
structure can be, for example, a building frame structure. The
building frame structure can be selected, for example, from a
floor, a wall, a ceiling, or a roof. These types of building frame
structures use a structural element or combination of struc-
tural elements to which a panel is mounted. These structural
elements also have a surface that mates or joins to a portion of
the panel material (subflooring, roof and wall sheathing, dry-
wall, etc.) covering the structural elements. Buildings incor-
porating one or more of these frame structures are also pro-
vided. In a particular embodiment, a joist-supported floor of a
building, such as made in accordance with these methods is
provided, as well as a building incorporating the joist-sup-
ported floor structure. In addition, the methods of the present
invention can be applied to assembly of building frames on-
site in building construction or to assembly of prefabricated
building frames fabricated off-site and transported on-site for
use in building construction.

[0015] Other features and advantages of the present inven-
tion will become readily apparent from the following detailed
description, the accompanying drawings, and the appended
claims. It is to be understood that both the foregoing general
description and the following detailed description are exem-
porary and explanatory only and are only intended to provide
a further explanation of the present invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. 1 is a partial schematical view of a subfloor
assembly according to an embodiment of the present inven-
tion.

[0017] FIG. 2 is a partial fragmentary view of the subfloor
assembly of FIG. 1 with the panel partially removed to show
hidden structural details.

[0018] FIGS. 3A-3F are illustrations showing steps of a
method for subfloor assembly using joists and a pre-applied
adhesive gluing method according to an embodiment of the
present invention.
FIG. 4 is a top view of a grooved upper flange surface of a joist including hole through the flange for introducing adhesive activating fluid therethrough.

FIG. 5 is a bottom perspective of the upper flange of the joist of FIG. 4 showing introduction of activating fluid to a joist hole from the bottom side of the flange.

FIG. 6 is a top view of a floor joist having a grooved upper flange surface having an array of dots of activatable adhesive placed on or over non-grooved portions of the flange surface, wherein activating solution is introduced into the groove array in the joist flange surface via a joist hole according to another embodiment of the invention.

FIG. 7 is a top view of upper flange surface of a joist having a groove pattern into which adhesive is introduced via a hole provided through an overlaying panel according to an embodiment of the invention.

FIGS. 8, 9, and 10 show examples of adhesive arrays that can be used in various embodiments according to the invention.

FIG. 11 is a perspective view of the use of a carrier film/layer containing activatable adhesive to bond I-joists and subfloor panels together according to another embodiment of the present invention.

FIG. 12 is a perspective view of the use of a viscoelastic carrier film containing activatable dots of adhesive to bond I-joists and subfloor panels together according to another embodiment of the present invention.

**DETAILED DESCRIPTION**

The present invention relates to methods of constructing floors and other building structures with structural members that are joined at least in part with enhanced adhesive bonding designs and techniques. These methods and structures can effectively eliminate squeaks and are economical, convenient to practice, and can be used in a wide range of construction conditions.

Referring to the drawings and in particular FIG. 1, in various exemplary and non-limiting embodiments, a subfloor assembly 101 is constructed, which is made of several structural members 103, 105, 107, and 109 that connect the assembly 101 to a generally conventional foundation 111 and form the flat surface for completing the structure. For example, in platform construction the basic structural components of a floor system can include joists 103, subfloor panels 105, rim board 107, and sill plate 109. These components are shown in their installed locations in FIG. 1 according to one non-limiting illustration. The longitudinal direction 102 of the joists 103 is indicated by the arrow in FIG. 1. A panel 105 is installed on top of the joists 103 at upper flange surfaces 113 thereof using adhesive 117 located therebetween. Additional details on example adhesive 117 are provided in the several embodiments illustrated herein. The panel 105 can also be mechanically fastened to the upper flange surfaces 113 of joists 103 with mechanical fasteners 115, such as nails, screws, or staples, or any combinations thereof. Portions of these joists and joist components (flanges and web) can be made, for example, of solid sawn lumber, while others can be formed from engineered wood products, without limitation. A sill plate 109 is usually pressure-treated solid sawn lumber, but can be an engineered wood composite material. The sill plate functions as a transition from the foundation 111 (typically concrete block or poured concrete wall) to the rest of the frame structure 101. A sill plate 109 is usually treated to resist rot and insects, and, thus, pressure-treated lumber can be a preferred material for this component. The joists 103 are used to span the distance between two of the outer foundation walls or from one foundation wall to a central beam (not shown).

Referring to FIG. 2, when the joists 103 are installed, their longitudinal ends 114 typically rest on the sill plate 109. The sill plate 109 can directly rest on an upper end 112 of the foundation 111, or, optionally, the sill plate can rest on an intervening gasket or mortar 116. The joists 103 can be evenly spaced at specific intervals (usually 12 inches, 16 inches, 19.2 inches or 24 inches on-center) so that subfloor panels 105 can be set on top of this array of joists 103 to create a flat surface. A rim board 107 is not necessarily needed or used in all instances. If rim board 107 is used, it is placed parallel to the sill plate 109 around the outer perimeter of the subfloor system 101 with a lower edge 118 resting on the sill plate 109. The face 119 of the rim board 107 is typically perpendicular to the joists 103, such as in a rectangular shaped room, with the ends 114 of the array of joists 103 flush against the face 119 of the rim board 107. The rim board orientation to the joists may not necessarily be perpendicular for rooms with other shapes, but the concepts of the present invention, such as illustrated herein, can still be applied.

The rim board 107 can be made, for example, from engineered strand lumber (ESL), oriented strand lumber (OSL), parallel strand lumber (PSL), laminated veneer lumber (LVL), or solid sawn lumber. Once the joists are in place, subfloor panels are installed over the joists to create a uniform, flat surface that will become the floor of the interior space of the building. Each of these members can be mechanically fastened to the other. For instance, the sill plate is usually bolted to the foundation or held down by straps. The other members of the system can be fastened to their adjoining members with mechanical fasteners, such as nails, staples, or screws.

The subfloor assembly serves many important functions. One important function of the subfloor assembly is to carry the load of the walls, roof, interior walls, and any furniture, appliances, people, etc. into the foundation; in this sense, it serves as a foundation for the rest of the house or other building structure (e.g., office building, apartment building, storage building, hotel building, etc.). For example, FIG. 2 partially shows a wall structure 121 being formed on the subfloor assembly 101. Therefore, it should be strong, stiff, and durable and resist the effects of weather, use and time during years of use. The subfloor is also the substrate for the finished floor materials, cabinets, HVAC, plumbing and other subsystems desirable to make a home comfortable and safe. The subfloor assembly preferably has strong, durable and has consistent performance. The methods for constructing a subfloor assembly in accordance with embodiments of the present invention meet or exceed at least some of these needs and requirements.

Subfloor panels 105 are typically plywood or OSB. Subfloor panels can be any practical size, such as with respect to width, length and thickness. In general, the panels will have planar dimensions sufficient to span between the flange surfaces of at least two joists. For example, and not by limitation, some subfloor panels can be approximately 4 feet by 8 feet and have thicknesses of approximately 3/8 inches to 1.25 inches. Panels of other sizes can be used. Subfloor panels can also include a tongue and groove along the edges, or other edge features, which allows individual panels to transfer loads placed on the floor to adjacent panels between the span of the joists.
The upper and lower flange dimensions (width, thickness, etc.) of the joist can vary, and, for example, can be between 1.5 inches x 1.5 inch up to 3.5 inches x 2 inch, or other dimensions, and the flange material can be solid-sawn lumber or engineered lumber, such as laminated veneer lumber (LVL), parallel strand lumber (PSL), engineered strand lumber (ESL) or other similar material. The web material is usually plywood or oriented strand board (OSB). In addition to I-joists, other joist configurations also can be used in the practice of the present invention, such as, for example, open web trusses, solid sawn lumber configurations, or other joist configurations.

The use of adhesive can add strength and stiffness to a floor system and can improve the experience of the occupants of the building. Some benefits of a stronger and stiffer subfloor assembly include longer life and durability. Further, the extra stiffness and strength is desirable if some types of finished floor materials, such as hardwood, ceramic tile, stone, etc., are installed over the subfloor. The use of construction adhesive also improves the environment by reducing squeaks and reducing the amount of vibration transmitted through the floor. In an unglued or poorly glued floor, squeaks are noticed in a floor system when an occupant steps on the floor and the subfloor panels and joists flex, usually rubbing against a nail. Homeowners or other building occupants can also notice an unglued or poorly glued floor when they walk across one part of a room and, for example, hear the dishes in their china cabinet across the room rattle as they move. In order to achieve the above benefits, the present inventors have discovered that it is desirable that the adhesive be applied uniformly and sufficiently along the joist to more permanently create a strong bond. Insufficient adhesive along the joist can create defects that lead to poor performance.

Gluing problems can be associated with a subfloor construction that is installed with adhesive applied in a non-uniform, non-permanent manner to joist flange surfaces, which problems are avoided by the present invention. Construction adhesive is known that is supplied in large tubes (generally 23 oz-28 Oz) that can be dispensed from a caulk gun onto joist surfaces. Construction adhesives have been commercially marketed, and include, for example, Liquid Nails® 1.N.602 or Low VOC L.N-902 (Liquid Nails, Strongsville, Ohio USA), OSI GreenSeries™ Subfloor & Deck High Performance Adhesives, and PL Premium (Henkel Corporation, Avon, Ohio USA). These adhesives are commercially available in large tubes that typically need a caulk gun for application. Problems can occur if these adhesives are dispensed with caulk guns to bond the top surface of the upper flange of the joists to the bottom surface of subfloor panels. For instance, after joists are installed, the framer could load the caulk gun with a tube of these types of adhesive. If so, the framer then would cut off a portion of the conical tip on the adhesive tube to set the size of the adhesive bead. The framer then would measure several feet (such as four feet to match the typical subfloor panel’s width) from the edge of the floor and reach over the open floor and lay down a bead of adhesive on each joist where the subfloor panel is to be installed. The panel then would be dropped onto the joists, slid into place, positioned, then mechanically fastened with nails or screws. The framer then would move to the next section of subfloor and repeats the process until the subfloor assembly is completed.

Still referring to the above comparative construction scenario in which caulk guns are used by a framer to dispense construction adhesives on joists, application of the adhesive across the floor system is difficult and prone to application problems that can lead to defects that affect strength, stiffness, and performance. Gaps are prone to be created at panel edges where the framer does not go out four feet or when the framer is in between squeezes on the caulk gun. The size of the bead extruded depends on where and how the conical tip of the adhesive is cut and how the installer operates the caulk gun (e.g., how fast or slow the operator moves the tip, how often the caulk gun is squeezed, etc.). These difficulties will mean that too much or too little adhesive is applied to the joist, or that there is a gap in the glue bead. In addition, because such caulk glues set up within a limited period of time, construction workers need to place the panels on the joists almost immediately after the glue has been dispensed, which interfere with flexibility in managing the construction tasks of the projects. If a panel is not applied over the adhesive in a timely fashion, the adhesive dries and must be removed prior to installing the subfloor panel. Furthermore, in very hot or cold climates, the caulk glue will set up quickly, which aggravates this problem. These conditions can be expected to lead to a floor system that squeaks, is not flat and does not have the expected stiffness and strength needed to meet the demanding conditions. Safety is a concern also since the framer will need to lean out over the open part of the subfloor or walk out onto the narrow edges of the joists to apply the glue to the joists prior to laying a subfloor panel in place. The framer applying the adhesive will also be constantly running out of adhesive and having to reload the caulk gun because even large 28 oz. tubes of adhesive will only provide enough adhesive for about two to four panels depending on the amount applied. This makes gluing the slow or rate determining step of the assembly process and significantly reduces the speed and efficiency of the crew laying the floor. Panels may be laid down without glue or with insufficient glue under the panel, creating a defect and potential squeak source and lower assembly performance. In addition, the conical tips of the glue tubes can be cut off at random places by the person applying the glue, so the bead sizes can vary with each tube and affect how the glue is applied. The differences in the amount of glue applied along the joist create variation in performance across the entire floor system. The framer applying the adhesive will also tend to experience hand fatigue since the person will be squeezing the caulk gun constantly while trying to extrude the thick, high viscosity adhesive from large 28 oz. tubes using a manual caulk gun. This situation is aggravated in colder weather conditions since the adhesive’s viscosity increases dramatically with decreasing temperature, making it even harder to extrude from the tubes (unless the tubes are warmed until used so that the adhesive can be squeezed out of the tubes more easily). In addition, when the panels are slid into place along the tops of the joists the glue is often scraped off, leaving bare spots where too little no glue is left to form a bond, making this conventional technique even less effective. In addition, applying the adhesive with caulk guns tends to be untidy and messy. Adhesive gets on equipment and clothes. Adhesives also gets on floors and other surfaces which need to be cleaned up before other steps in the construction process can begin. For instance, deposited adhesive that misses the joists may fall onto a basement floor below that will need to be scraped off that floor before putting down finish floor materials thereon.

The methods of assembly of building frames according to embodiments of the present invention can be
used to address many of the problems identified above and provide improved adhesive bonding in building frame assembly during building construction or preparations therefor. These methods make it easier to apply an effective amount of adhesive over the bonding surface area available between the joists and subfloor panels. Facilitating the application of adhesive over the bonding surface between the joists and subfloor also improves the floor performance and provide an improved experience for builders, framers and owners.

[0037] In particular embodiments of the present invention, methods are provided for assembly of structural sheathing, such as floors, walls, and roof panels with adhesive bonding of structural elements and decks or panels with adhesive applied in an amount sufficient to create a strong, longer-lasting bond between these building components. With respect to floors, for example, methods are provided which can reduce or prevent squeaks from developing in the flooring. In one method according to an embodiment of the present invention, an activatable adhesive is pre-applied to upper flange surfaces of flooring joists. The adhesive is activated before or after floor decking panels are mounted thereon. The pre-applied adhesive can be activated during assembly by the framing crew such that a strong, longer-lasting adhesive bond is created between the joists and adjoining subfloor panels. In one method, the framing crew activates a specific portion of adhesive on the joist, such as by spraying an activating solution to the surface of the joist where pre-applied adhesive is present, prior to installing individual subfloor panels thereon. In another method, the framing crew first completes the installation of the whole subfloor, including mounting or positioning panels on top of the upper flange surfaces of the joists, and then activates the pre-applied adhesive. Activation of the adhesive can be accomplished, for example, via a chemical activator or energy activator, depending on the type of adhesive being used. For example, chemical activatable adhesives can be activated by pumping an activator fluid into to the adjoining surface of the joists and subfloor panels sufficient to contact the activatable adhesive. In an alternative embodiment, activatable adhesive in the joist and subfloor areas of the subfloor assembly can be heated directly or indirectly via exposure to high frequency radiation or vibratory energy, such as radio frequency, microwave, sonication, etc., or using another suitable means of activation. For example, the adhesive can be formulated to be susceptible to dielectric heating via exposure to high frequency radiation energy such as radio frequency (RF) energy or microwave energy. The adhesive also can be formulated to be susceptible to heating via sonication. The induced heating of the adhesive can render the adhesive flowable/ fusible if it is thermoplastic and, thus, it wets surfaces to be bonded, and/or can initiate/promote curing of the adhesive as it wets surfaces to be bonded if it is thermosettable. The heating can be used to initiate a chemical reaction, for example, such as in the case of a radical initiator and acrylic adhesives. In other embodiments, the activatable adhesive also can be pressure activatable.

[0038] In another method of the present invention, the upper flange surfaces of the joist component of the subfloor assembly are provided with grooves formed therein, for example, as an array. The groove array can be, for example, a grid or crosshatch pattern or a series of parallel extending grooves, and so forth. The grid pattern, for example, can include a pattern of intersecting grooves formed across the surface of the upper flange of the joists, such as in a diamond pattern. The grid pattern can also incorporate one or more parallel extending grooves that extend in the longitudinal direction of the joist. These grooves can be used to position pre-applied adhesive before joist and panel assembly.

[0039] Adhesive can be pre-applied in a grooved grid pattern provided in the upper flange surfaces of joists, and the pre-applied adhesive can be activated during assembly by the framing crew, by spraying an activating solution to the surface of the joist where pre-applied adhesive is present, and prior to installing individual subfloor panels thereon. For example, a flooring joist can used which has pre-applied adhesive filling a grooved grid pattern or other array formed in the upper flange surface of the joist. The adhesive is activated by the spraying of an activator fluid or solution on the top of the flange, wherein the activator solution comes into contact with the pre-applied adhesive. This method also could be implemented by depositing the adhesive in a grid pattern or as a continuous coat on a non-grooved smooth upper flange surface of the joists.

[0040] As illustrated, for example, in FIGS. 3A-3F, which is described in more detail in the examples provided below, in one embodiment of the present invention, the adhesive is pre-applied in grooves in the flange surface of the joists. In general, the framing crew first completes the installation of part of or the whole subfloor, including mounting or positioning panels on top of the upper flange surfaces of the joists, and then activates the pre-applied adhesive by introducing activating solution into the groove pattern. More particularly, and as shown in FIGS. 3A-3F, this method performed in a series of six steps or stages 301-306, and which are performed in that order. In stage 301, glue can be pre-applied in small grooves onto the 1 joist as well as in the panel tongue and groove. In stage 302, the panel can be dropped in place on top of the dry joist. In stage 303, positioning is easy and safe because the work area is dry and not tacky. In stage 304, the floor can be nailed down. In stage 305, the glue installer activates the glue with an activating fluid 129, such as solvent. Predrilled holes in the exposed bottom side of the joist flange serve as injection points. In stage 306, the solvent travels through the groove in the flange surface and ultimately emerges at an opposite end of the joist. As indicated, a drain hole 71 can be provided on the joist 103 bearing the pre-applied adhesive on its upper surface. For example, a drain hole can be located near an opposite longitudinal end of the same joist or elsewhere along the joist relative to the activator injection hole(s), which will visually inform the framer that sufficient adhesive activator fluid has been injected into the groove array when activator fluid 129 drains out of the drain hole 71. In an alternative embodiment, the activating solution can be introduced into or onto the joists as the subfloor panels are installed, and the benefits of pre-application of adhesive can still be realized.

[0041] As shown in further detail in FIGS. 4 and 5, the adhesive 117 is activated by introducing the activating solution into a central groove 1251 on the top surface of the upper flange from underneath via a hole 123 drilled completely through the thickness of the upper flange 127. Access to the central groove 1251 is gained via a channel intersecting, and thus which can fluidly communicate with, hole 123 on the bottom side 128 of the upper flange 127 of joist 103 (shown in FIG. 5). An activating solution injector device 130 can be used to pump an activator solution through hole 123 into the central groove 1251 and, from there, the activator can flow onto the pre-applied adhesive 117 positioned in a groove pattern 1252, a diamond grid here, that interconnected with the central groove 1251. The injector device can be a pipette or
other fluid storing, pumping, and dispensing means. FIG. 4 also shows the widthwise direction 108 of the joist surface, which is referenced herein, and is oriented orthogonally to the longitudinal direction 102 of the joist 103. As also shown, joist 103 has opposite lateral edges 1031 and 1032.

[0042] Referring to FIG. 6, in another embodiment of the present invention, activatable adhesive 1170 is arranged as discrete dots on non-grooved portions (flats) of the joist flange surface 113 of the joist 103 adjacent grooves 1254 of the groove pattern or array 1255. In this illustration, a groove pattern 1255 is repeated along the length of the upper flange 113. Activator solution is pumped into the pattern 1255 via access hole 123 (such as discussed with respect to FIGS. 4-5) to activate the adhesive dots 1170 and bond to a subfloor panel (not shown) and the joist together. In another embodiment, fluid adhesive is pumped into the groove pattern 1255 via access hole 123 of the joist 103 to bond the subfloor panel and adhesive together. The activatable adhesive 1170 can be arranged as separate discrete dots that are deposited directly on the flange surface. Alternatively, the discrete areas of activatable adhesive 1170 can be contained in a carrier film (such as described in greater detail with respect to FIGS. 11-12 infra), which is placed on the flange surface.

[0043] Examples of adhesives that can be used in various embodiments of this invention include, for example, epoxies, acrylics, cyanoacrylates, hot melts (ethylene vinyl acetate, LD polyethylene, alkyl succinic anhydride, etc.), asphaltic, oleoresinous, butyl, butyl rubber, polyurethane, neoprene, nitrile rubber, silicones (with and without silanes or other coupling agents including organo-functional silanes, Permapol® family, Hypalon®, Caesin and other protein adhesive, starch-based, natural rubber and polyisobutylenes, amino resin, phenolic resin polyvinyl acetate emulsions, polyvinyl alcohol emulsions, polyvinyl acetal, polyester and polyamide hot melts. These adhesives can also be blended or combined to produce useful combinations. Categories of use of these and other types of adhesives for embodiments of the present invention are illustrated below. These various types of adhesives can be used singly or in combinations within the same type or of different types thereof.

[0044] Pre-Applied Activatable Adhesives and Corresponding Activator Fluids

[0045] This type of adhesive and activator combination can include, for example, the following:

[0046] 1. Hot melts (ethylene vinyl acetate, LD polyethylene, alkyl succinic anhydride, etc.), activated with organic solvents such as acetone, ethanol, methanol, ethyl acetate, methylene chloride, etc.

[0047] 2. MDI/polyurethane, activated with water (can have catalytic amounts of amines) or organic solvents listed above.

[0048] 3. Polyvinyl acetate emulsions, polyvinyl alcohol emulsions activated with water and some milder organic solvents, like methanol, ethanol, etc.

[0049] 4. Epoxies where the epoxide component of the adhesive is preapplied and the hardener component is applied to the adhesive in a solvent such as ethyl acetate, or alternatively hardener component can be preapplied and the epoxide component can be applied in the solvent.


[0051] 6. Acrylics activatable with a chemical radical initiator.

[0052] Energy Activated Adhesives

[0053] This adhesive type essentially can be any adhesive that can be formulated to cure in response to heat conditions. Example include, for example, epoxies, acrylics, anaerobics, cyanoacrylates, hot melts (e.g., ethylene vinyl acetate, LD polyethylene, alkyl succinic anhydride, etc.), asphaltic, oleoresinous, butyl, butyl rubber, polyurethane, neoprene, nitrile rubber, silicones (with and without silanes or other coupling agents including organo-functional silanes, Permapol® family, Hypalon®, Caesin and other protein adhesive, starch-based, natural rubber and polyisobutylenes, amino resin, phenolic resin polyvinyl acetate emulsions, polyvinyl alcohol emulsions, polyvinyl acetal, polyester and polyamide hot melts.

[0054] Self-Hardening Adhesives (Activation Not Required)

[0055] Examples of this type of adhesive, include, for example, polyvinyl acetate emulsions, polyvinyl alcohol emulsions, polyvinyl, polyurethanes, acrylics, anaerobics, cyanoacrylates, hot melts (ethylene vinyl acetate, LD polyethylene, alkyl succinic anhydride, etc. (these can be pumped hot into the space between joist and panel and allowed to cool), asphaltic, oleoresinous, butyl, butyl rubber, polyurethane, neoprene, nitrile rubber, silicones (with and without silanes or other coupling agents including organo-functional silanes, Permapol® family, Hypalon®, Caesin and other protein adhesive, starch-based, natural rubber and polyisobutylenes, acetal, polyester and polyamide hot melts.

[0056] In other embodiments of the present invention, adhesive is introduced into a groove array provided in the joist flange surface after pre-positioning a panel or panels on a joist or joists, and the joist(s) and panel(s) are bonded together using the introduced adhesive Grooves provided in the upper flange surface of the joist can be used to directly distribute introduced adhesive along and across the joist flange surface between the upper flange surface of a joist and the bottom surface of an overlying panel that is already placed thereon. For example, after a framing crew completes the installation of the joists and subfloor panels, they can inject construction adhesive into the area between the joists and panels using the groove pattern to facilitate flow of adhesive along the length of the joist. Several methods can be used to add or introduce adhesive to the area between the joist and subfloor panel.

[0057] In one method applicable to a grooved flange surface, the framing crew fills the grooves between the joists and subfloor panels with adhesive introduced from underneath the subfloor assembly using one hole or a set of spaced holes that extend from the bottom of the top flange to a central groove machined or otherwise formed into the top surface of the upper flange. Adhesive can be injected into the port or hole, which can be similar to that shown as hole 123 in FIGS. 4 and 5 used for introduction of activator solution in that above-discussed embodiment. The adhesive can be pumped into the hole, such as via a pressurized container (not shown), and into the central groove 1251 on the top surface 113 of the joist 103. The adhesive fills the grooves on the top of the joist and creates a bond to an adjoining subfloor panel.

[0058] Referring to FIG. 7, in an alternate method, the adhesive 117 is applied from above through a hole or holes provided in a panel or panels overlying the grooves in the upper flange surface of a joist. In this embodiment, a panel (not shown) is positioned over the joist and adhesive is introduced via at least one through-hole provided through the overlying panel such adhesive can flow into and fill the series...
of parallel longitudinally-extending grooves 1253 provided in the underlying upper flange surface 113 of the joist 103 in an amount effective to bond the joist and panel together (not shown). These holes are located over the joists and spaced so that when adhesive is pumped into the panel holes, the adhesive fills and follows the series of grooves provided in the top surface of the joist to completely wet and bond the whole area between the joist and subfloor panel. In an alternative case of the pre-applied adhesive being provided on the upper flange surface of the joist, the right amount of adhesive is already on the joists, the glue bond is continuous and there are no gaps in the adhesive bead.

[0059] In this embodiment, the addition of adhesive after assembly of the subfloor panels means that gaps between the joists and subfloor panels are filled. In these above methods using either pre-applied adhesive or adhesive injected between the joist surface and pre-mounted panel, the mating surfaces available between the joists and subfloors panels can be effectively used for bonding the subfloor assembly together creating a stronger, stiffer subfloor assembly with uniform, consistent performance. The stronger, more consistent bond means the subfloor will be more durable and perform better. In addition, framers avoid the tedious steps related to applying construction adhesive with caulks guns, such as running out, cleaning messy adhesives, avoiding loss of time, and cleaning clothes and equipment. Builders will benefit from fewer “call-backs” because of the improved reliability of installation resulting in fewer installation mistakes that need to be corrected after the owner occupies the structure. The present invention can be a more cost effective means of applying glue in assembly of building frame structures and can facilitate greater use by builders of adhesive in assembly and installation of building beam structures.

[0060] The grooves in the joist flange surface, which carry the activator fluid or adhesive, depending on the embodiment, to bond the joist and subfloor panels together, can, for example, be machined, cut, milled, molded, or otherwise formed into the top surface of the upper flange. The grooves can be arranged so that they extend substantially over the flange surface. The groove size and shape is determined by the means used to join the joist and subfloor panel. The size and number of grooves will depend on the intended function. For example, the grooves are to hold adhesive to be filled later, such as after panel placement on the joists, a central groove may be larger with smaller grooves extending outward to the edges of the upper flange of the joist. If the grooves are to hold activatable glue, in one embodiment some of the grooves can be filled with activatable adhesive and the other grooves are left unfilled with adhesive to route activator fluid introduced to the grooves partly filled with activatable adhesive. Grooves that are formed or machined into the top surface of the upper flange of a flooring joist such that they run parallel to the major axis (length), can be cut, for example, 1/16 inch to 1/2 inch deep and spaced, for example, 1/16 inch to 1.5 inch apart. The spacing of grooves can depend on the adhesive and how easily the adhesive flows and wets the adjoining surfaces between the joist and panel. The grooves can be spaced along an axis perpendicular to the length of the flange. The grooves can be straight, at a desired angle to the major axis of the joist, or be curved or wavy. There may also be a second set of grooves that run across the first set of grooves to interconnect all the grooves and allow the adhesive to flow over the entire surface of the joist. Their shape, number and dimensions are selected to provide enough volume to hold the adhesive while keeping enough surface on the upper flange so that there is sufficient surface area to bond the panel to the joist without compromising floor system performance (while allowing the adhesive to flow without too much back pressure).

[0061] As described above, the grooves can be machined or otherwise formed into the top surface of the flange of the joist. Machining can be accomplished, for example, with a CNC machine programmed with the appropriate pattern to rout the grooves using a cutter head of desired shape and size or in a more labor-intensive manner by using a hand-held router and template attached to the flange to be machined. Forming the grooves into the upper flange can be achieved by changing the manufacturing process such that the grooves are pressed into the surface of the flange material. For example, a press used to manufacture OSB can be modified with caul plates which have the negative image of the desired grooves formed thereon. Therefore, when the OSB mat is pressed and consolidated into a final product, the grooves are present. It is also possible that the grooves could be pressed into the surface using a pressure roller or platen that has the negative image of the desired grooves. The grooved upper flange can be used to manufacture engineered I-joists or open-web trusses using the grooved flange material. The adhesive can be applied before or after manufacturing the joists, whichever is most convenient.

[0062] Referring to FIGS. 8, 9 and 10, alternative glue line arrays 1171, 1172, and 1173 are illustrated that can be used in embodiments of the present invention. The glue line does not need to be a continuous film or bead. The pre-applied adhesive preferably is arranged in an array. The adhesive array can take advantage of the total surface area between the upper flange surface 113 of the joist 103 on the subfloor panel (not shown) and generates a strong bond between the two adjoining surfaces. The adhesive array can also correspond to a groove array formed in the joist flange surface. The adhesive can fill part or all of the grooves of such a groove array, depending on the embodiment. As indicated above, for activatable adhesives, one embodiment has grooves of a groove array only partly filled with pre-applied adhesive so that the unfilled grooves remain to support flow and distribution of activator fluid introduced into the groove array. On the other hand, where flowable adhesive is introduced into the groove array, it can be introduced in an amount filling part or the entire grooved array in the flange surface.

[0063] In various embodiments, it is desirable that the adhesive is not tacky until it is activated. The construction site can be very dirty and dusty. A tacky or sticky adhesive film would collect dirt and sawdust that would then lead to lower bond performance or unbonded areas in the subfloor assembly. In some embodiments of the present invention, an activatable adhesive system is used to provide sufficient “open-time” (i.e., working time, assembly time) after being activated to allow framers to perform assembly activities after activation, such as placement of the panels on the joists, allowing the panel to be shifted on top of the joists (e.g., to fit the tongue and groove (“T&G”)), and allowing movement of the panel into final position before, optionally, fastening into place with nails or screws. A release liner could be optionally added to the adhesive film on top of the joist. The release liner has the advan-
tage that it keeps the adhesive film clean and the removal of the liner could be used as a means of activating the adhesive film.

[0064] In another embodiment of the present invention, a process is provided for applying a film of activatable adhesive or a carrier holding activatable adhesive to a joist, such as an l-joist, for example, which can include having the joist run under a dispenser that applies the right amount of adhesive to the top flange of the joist followed by a drying step. A drying process allows the film to become non-tacky for transportation and handling. The use of a carrier holding activatable adhesive in this manner can be used with appropriate modifications made to an existing process for l-joist or open web truss manufacture, or other joist manufacture.

[0065] Referring to FIG. 11, for example, if it is desirable to use an engineered l-joist with the adhesive film on a carrier, the application of an activatable adhesive carrier 140 could be integrated into a continuous manufacturing process for l-joists, such as l-joists comprising an upper flange 133 and l-joist web 135. The carrier film can comprise, for example, a polyvinyl acetate film (PVAc film), a synthetic elastomer/thermoplastic/thermosetting blend film, or other activatable adhesive film materials. An example of an activatable bonding film that can be used as the carrier film, is Scotch-Weld™ 583 activatable bonding film (3M, Saint Paul, Minn., USA), which is heat and/or solvent (e.g., ethyl acetate) activatable. After the l-joists are assembled, the continuous joist has the carrier adhesive applied to the upper flange before going into a drying room. To apply the adhesive-carrier to the upper flange, the carrier could be unwound from large rolls and run through a dip tank and squeeze rolls to work the adhesive into and throughout the thickness of the carrier. Then, the adhesive-carrier could be applied to the surface of the joist in a continuous manner that is not disruptive to the current process. After the adhesive-carrier is applied to the top surface, the joists can be cut into lengths then go into the drying room, per the normal process. It is also possible that the adhesive-carrier can be supplied as a separate item that is applied at the construction site. The strips of carrier could be tacked or otherwise physically attached to the top flange of the joists prior to joist installation and then activated as needed to adhesively bond the joist and panel and complete the subfloor assembly.

[0066] Referring to FIG. 12, in this embodiment a viscoelastic carrier 1400 with discrete areas of adhesive 1110 is placed on the joist surface. In this example, the carrier 1400 has discrete areas of activatable adhesive 1110 that can be activated by spraying the activator solution over the top of the joist just prior to setting the panel (not shown). In an alternative, the adhesive dots 1110 can be activated by activator solution introduced from underneath the joist by pumping an activator solution via an access hole (such as described with respect to FIG. 6) into a series of grooves or channels 1256 formed in the flange surface 113 underneath the carrier layer 1400. Grooves can be used under any carrier or film.

[0067] Other enhancements or embodiments also can be optionally applied. The activating solution used with an activatable adhesive in embodiments of the present invention can, for example, have a catalyst, co-reactant, or other ingredients that improve bonding performance and weather resistance. For instance, a cross-linking agent can be added to the aqueous solution used to activate polyvinyl acetate (PVAc) adhesives making the bond more resistant to water and rewetting/debonding. One example of a cross-linking agent is formaldehyde or other aldehydic agent.

[0068] Another enhancement is to add materials that make the adhesive film more sensitive to activation methods. For example, such adhesives may include use of metallic particles to aid in heating the adhesive film with microwaves, for example, so that it will flow and bond. Another means of providing a cross-linking agent or sensitizing agent is to incorporate filled microcapsules or microballoons into the adhesive film. The microcapsules can contain the above-mentioned metallic particles to increase heating. The microcapsules can also contain a solvent or activating ingredient that is released once the film is dosed with microwaves, radio frequency energy, or sonication. The microcapsules burst releasing their contents and activating the adhesive film on the joist, thereby creating a durable bond. The microcapsules can also be sensitive to an ingredient in the activating solution so that they dissolve and release their contents into the adhesive film to increase activation and improve bonding performance. One benefit of using remote vibration or radiation such as sonication or microwaves, etc. is that repairing squeaks in floors may be more easily accomplished and with less mess. For example, if an adhesive film is used that is activated by sonication, the loose area or unbonded area of a subfloor panel can be set in place by placing a weight over the spot with the squeak and using a hand-held sonicator to heat up the adhesive in that spot reactivating the adhesive and rebonding the panel. To accomplish the same repair conventionally requires the use of screws that go through existing finished floor materials. Another previous used method to repair floor squeaks is to force more subfloor adhesive into the gap between the joist and subfloor panel which requires access to the squeaky spot in the floor from underneath the subfloor assembly. In contrast, sonication could be accomplished from either underneath or through the finished floor without disturbing the existing finished materials. A device that can be used or adapted to apply sonic energy to the activatable adhesives responsive to sonic energy in the desired manner can be, for example, an Ultrasonic Hand Welder, manufactured by Abbeon. A device that can be used or adapted to apply microwave frequency energy to the activatable adhesives that are responsive to microwave frequency energy in the desired manner can be, for example, MPG-4 or MPG-4M, manufactured by Ophthos Instruments, Inc. In addition, RF instruments are available, such as from Megadyne, which could be modified or adapted based on the current teachings for use in methods of the present invention. It is also possible to make the adhesive films heat up when activated to improve bonding performance. For instance, adding calcium oxide to the adhesive film and then wetting it with water will produce an exothermic reaction. The excess heat from the reaction will heat the adhesive aiding flow and improving bond performance. Other example materials that may be useful in such self-heating adhesive formulations could be magnesium-iron oxide or cobalt ferrite nanoparticles. Each of the materials will react with water or other activator, and produce excess heat that could be useful to activate adhesives. These methods may be especially useful if hot melt adhesives are used on the joist. Typical hot melt adhesives are blends of a polymer, e.g., polyethylene—polyacrylate, a tackifying resin, and a petroleum wax. The formulation and the components of hot melt adhesives can be modified to yield the optimal performance, such as desired melting range and final bond strength.
The adhesive also can be formulated to provide a compressible material which can also compensate for or "smooth out" irregularities and discontinuities between the flange surfaces of the joists and the bottom surface of the panels so as to eliminate any gaps which would permit the subfloor panel to work up and down and cause squeaks. Secondly, the adhesive serves a shock-absorbing function which helps prevent the transmission of sound vertically through the floor. For example, formable adhesives can be used which provide these benefits.

As can be appreciated from the foregoing teachings, there are a number of benefits and advantages that can be derived from the present invention, which include, for example, the following:

1. The application of adhesive is simplified and can be completed at a convenient time after installation of the subfloor panels;
2. The bond between the subfloor panel and upper flange of the joist utilizes the full surface creating a stronger, higher performing floor system;
3. Subfloor assembly is more efficient since the crew only needs to activate the adhesive or that step is conducted at a later time;
4. Safety is increased since the framer applying glue does not have to lean out over the open part of the subfloor to apply glue to joists prior to subfloor panel installation;
5. Framers do not experience hand fatigue or need to take measures to warm-up tubes of construction adhesive in order to apply it easily;
6. More effective glue usage, minimizing waste, and reduction of glue costs.

Although this invention is described and illustrated herein in more detail with respect to a subfloor assembly, it will be understood that the invention has wider application and can also be applied to other building structures, such as walls, ceilings, and roofs.

The present invention will be further clarified by the following examples, which are intended to be exemplary of the present invention. Unless indicated otherwise, all amounts, percentages, ratios and the like used herein are by weight.

EXAMPLES

Example 1

Pre-filled grooves: In this example, a series of grooves were machined into the upper flange of an I-joist at an angle of 32.47° to the left and right of the centerline of the top flange of the joist. The grooves were ¼ inch wide and ⅛ inch deep, and spaced nominally 1 inch apart as measured between the centers of adjoining grooves. These grooves were filled with 1.4 grains per linear foot of Gorilla Glue® (The Gorilla Glue Company, Cincinnati, Ohio USA) adhesive. The adhesive was allowed to sit for at least 2 hours. Then, the adhesive was activated by spraying water over the surface of the upper flange so that the water spread across the surface of the flange. A subfloor panel (type: AdvanTech® (Huber Engineered Woods L.I.C. (Commerce, Ga. USA), dimensions: 6 inch x 8 inch) was placed over the joist, and the joists and panels were mechanically fastened using clamps. The adhesive was allowed to cure at room temperature and pressure, and a bond between the subfloor panel and joist was formed. In this example, the water allowed the PVA to flow and bond the two surfaces together.

In a modification to the above procedure, a hole (diameter: ¼ inch) was drilled at an angle of approximately 45 degrees relative to the longitudinal axis of the joist and then 45 degrees relative to the vertical axis of the joist, from the underside of the upper flange such that it opened into one of the grooves milled into the upper flange's top surface. A subfloor panel (type: AdvanTech®, dimensions: 4 feet x 4 feet) was placed on top and mechanically fastened to the joist using nails. Then, solvent (type: water activator was injected in an amount of ~250 ml) into the hole described above such that it flowed into the central groove of the joist and filled the other grooves. When the adhesive dried, a bond was created between the joist and subfloor panels. These examples are generally shown in FIGS. 4 and 5.

Example 2

Adhesive applied through subfloor panel: In this example, the adhesive was applied after the subfloor panels were placed over the joists (type: flanges were fabricated from two layers of commercially available OSB, the web was also constructed of commercially available OSB, both had a nominal thickness of ~½ inch). A series of grooves was machined into the upper flange of a joist (type: fabricated joist described above) before floor assembly. The grooves were ¼ inch wide, ⅛ inch deep, and ⅛ inch apart; this series of grooves was centered in the 3.5 inch wide flange. A subfloor panel (in this instance, a sheet of Plexiglas was used to observe adhesive flow) with a set of pre-drilled holes arranged in a line perpendicular to the longitudinal axis of the joist was placed over the joist such that the holes aligned with the grooves in the joist, and the panel was attached to the joist using screws. The set of holes were approximately ¼ inch in diameter and each set was formed at about 6-12 inch intervals along the centerline of the panel. Enough adhesive was added through a hole drilled into the surface of the subfloor panel to fill the grooves, which was determined by estimating the volume of adhesive needed to fill the volume of the grooves and previous experiments using Plexiglas as a substitute subfloor material to view flow. The adhesive flowed through the grooves and cured to form a bond between the joist and subfloor panel. These holes were spaced such that adhesive would flow between the panels and joists and create a uniform bond. The joists may or may not have grooves cut into the surface of the upper flange to aid flow of the adhesive along the length and across the width of the upper flange of the joists. Gorilla Glue® adhesive was added by filling the grooves with a bead of glue through each set of these holes, and then allowed to stand at room temperature and pressure for a time period sufficient to form a bond between the subfloor and joist. It was found that it was desirable to make sure the glue flowed through all or substantially all the grooves of the groove array. Therefore, adding a solvent, such as acetone at a ratio of 1:8-1:1 (acetone to adhesive), improved flow and reduced the number of holes required in the subfloor panel. For example, adding a solvent (such as acetone) to Gorilla Glue® adhesive allowed the adhesive to flow a longer distance along the grooves; the exact ratio of solvent to adhesive would desirably be optimized. In an alternative, the top surface of the upper flange can have two sets of grooves; the first set running parallel to the long axis of the joist with a second
set of grooves cut generally perpendicular or at an angle to the first set of grooves so that the grooves interconnect.

Example 3

[0082] Activatable Adhesive Film: A film of polyvinyl acetate (PVAc) adhesive (Titebond® Original Wood Glue, Franklin International, Columbus Ohio USA) was applied to the top surface of a joist at a rate of 10 g/liner foot (1 linear foot = an area 1.5 inch wide x 12 inch long) and allowed to dry overnight. The film was then activated with water at a rate of 6 g/liner foot (1 linear foot = an area 1.5 inch wide x 12 inch long). After standing for 0.5 to 3 minutes, the subfloor panel (type: AdvanTech®) was placed over the joist (type: SPF lumber dimensions: approx. 1.5 inch wide, 1.5 inch deep and 8 inch long to simulate a joist flange) with the activated glue film and mechanically fastened by clamping into place. After drying overnight at room temperature and pressure, a bond sufficient to hold the panel and joist together was formed. Further enhancements to the above method can be achieved by increasing the transfer of the activated adhesive from the joist surface, where it was pre-applied, to the bottom of the subfloor panel. This increased transfer of adhesive can be achieved in several ways, and two were tested. The first approach was the addition of a blowing agent to the adhesive. The blowing agent acts to expand the thickness of the adhesive film once the adhesive has been activated. In the second approach, a carrier was used.

Example 4

[0084] Activatable Adhesive Film with Blowing Agent: Three (3.0) g sodium bicarbonate (Church & Dwight Co., Inc., Princeton, N.J. USA) was added to 20 g of PVAc emulsion adhesive (Titebond® Original Wood Glue, Franklin International, Columbus Ohio USA) and thoroughly blended with stirring. This mixture was applied by spreading the mixture to the top surface of a joist (type: SPF lumber dimensions: approx. 1.5 inch wide, 1.5 inch deep and 8 inch long to simulate a joist flange) at a rate of 8 g/liner foot (1 linear foot = an area 1.5 inch wide x 12 inch long) and allowed to dry overnight at room temperature and pressure. An activator solution of aqueous acetic acid (5% acidity) was applied to the film at a rate of 2 g activator solution/gram sodium bicarbonate in the adhesive film. After the adhesive film was wetted with the activator solution, the film began foaming, and the subfloor panel (type: AdvanTech® dimensions: nominally 1/4 inch thick, 6 inch wide x 8 inch long) was placed over the join with the activated, foaming glue film and also mechanically fastened into place. After drying overnight, a bond sufficient to hold the panel and joist together was formed.

[0085] A joist with pre-applied adhesive can also be manufactured by applying a carrier containing or filled with an activatable adhesive to the top surface of the upper flange of a joist. The carrier material can be compressible material, like foam or thick cloth. The activatable solution is used to contact the carrier which preferably wets the carrier, and activates the adhesive. Use of a carrier also allows for other benefits and features to be added to the floor system. As two examples, if a thicker compressible carrier is used, the carrier could fill gaps between the joist and subfloor panel, thus reducing floor flex and potential rattles and squeaks when the floor is walked on. Alternatively, a visco-elastic foam can be used as a carrier that reduces sound transmission.

Example 5

[0086] Activatable Adhesive on Carrier: Two compressible carrier materials were tested. The first was cotton batting (Holms Heirloom Natural, obtained from Michaels Stores, Inc.). Sixty-four g of PVAc emulsion was used to saturate a 1/4 inch thick x 2 inch wide x 4 foot long piece of batting which was then applied to the test joist flange (type: Trus Joist) and allowed to dry at room temperature and pressure. To test the bonding performance, the cotton batting filled with adhesive as described above and was applied to a joist (type: SPF lumber dimensions: approx. 1.5 inch wide, 1.5 inch deep and 8 inch long to simulate a joist flange). After drying, the batting carrier/adsorptive combination was bonded to the top surface of the joist. The batting was wetted with water at a rate of 5 g/liner foot (1 linear foot = an area 2 inch wide x 12 inch long) and allowed to stand for 0.5 to 3 minutes. Then, a subfloor panel (type: AdvanTech®, dimensions: 6 inch x 8 inch) was placed over the joist with the activated glue film and mechanically fastened into place. After drying overnight, a bond sufficient to hold the panel and joist together was formed.

[0087] In another example of using a carrier, a piece of foam (similar to that used in disposable foam paint brushes), which was 1/4 inch thick x 1.5 inch wide x 1 foot long, was filled with 5 g of PVAc emulsion, applied to the top of the test joist (type: SPF lumber dimensions: approx. 1.5 inch wide, 1.5 inch deep and 8 inch long to simulate a joist flange), and allowed to dry. After drying, the foam carrier/adsorptive combination was bonded to the top surface of the joist. After drying overnight, water was applied to the foam at a rate of 7 g/liner foot (1 linear foot = an area 1.75 inch wide x 12 inch long) to activate the adhesive-containing foam. After standing for 0.5 to 3 minutes, the subfloor panel (type: AdvanTech®, dimensions: 6 inch x 8 inch) was placed over the joist with the activated glue and mechanically fastened into place. After drying overnight, a bond sufficient to hold the panel and joist together was formed.

[0088] The features of the above examples can be combined. For instance, it may be advantageous to create a joist that uses one of the carriers described above where the adhesive applied to the carrier also contains a blowing agent. In addition, it may be desirable to combine the use of formed or machined grooves into the top surface of the upper flange on a joist with the adhesive-treated carrier. The grooves or channel could be filled with activating solution and could help provide better and more thorough activation after the subfloor panels have been installed over the joists.

[0089] Installation of a structural assembly using the modified joist and gluing methods, such as exemplified above, adds strength and prevents and limits movement (or causes members to move together). In the case of flooring, it also limits and prevent squeaks.

[0090] From the foregoing, it will be observed that modifications and variations can be affected without departing from the true spirit and scope of the novel concepts of the present invention. It is to be understood that no specific limitation with respect to the specific embodiments illustrated herein is intended or should be inferred. This invention can, however, be embodied in different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure...
will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

What is claimed is:

1. A method of making a building structure, comprising: placing at least one panel on a flange surface of a plurality of joists wherein a flange surface of a joist proximate to said panel comprises an effective amount of an activatable adhesive, and activating said activatable adhesive thereby bonding the panel and proximate flange surface.

2. The method of claim 1 further comprising securing said panel to said joists with fasteners to mechanically secure said panel to said joists.

3. The method of claim 1, wherein said building structure is selected from a floor, a wall, a ceiling, or a roof.

4. The method of claim 1, wherein said activating comprises contacting said adhesive with an activation fluid.

5. The method of claim 1, wherein said activating comprises spraying an activation solution on said adhesive on said upper flange surface before said placing of said panel on said upper flange surface.

6. The method of claim 1, wherein said adhesive comprises a foambale adhesive.

7. The method of claim 1, wherein said upper flange surface further comprises a groove array adapted to receive activatable adhesive, activating fluid, or both.

8. The method of claim 7, wherein said groove array comprises at least one groove positioning said activatable adhesive on the upper flanges surfaces of the joist.

9. The method of claim 7, wherein said joist further comprises at least one joist hole extending from a side opposite the upper flange surface to said groove array, and said activating of said adhesive comprises introducing an activator fluid through said joist hole into said groove array.

10. The method of claim 9, wherein said joist further comprising a drain hole at a different longitudinal location along the joist than the joist hole which extends from said groove of said array to said opposite the upper flange surface, wherein said activating of said adhesive comprises said introducing of said activator solution through said joist hole into said groove array at least until at least a portion of said activator fluid drains from drain hole.

11. The method of claim 1, further comprising a carrier film containing said activatable adhesive.

12. The method of claim 1, wherein said activating comprises imparting adhesive activation energy to said adhesive sufficient to induce activation of said adhesive to bond the upper joist surface and said panel thereto, wherein said activation energy is selected from sonication energy, radio frequency energy, microwave energy, heat energy, or pressure energy.

13. A method of making a building structure, comprising placing at least one panel on a flange surface of at least one joist wherein a flange surface of said joist proximate to said panel comprises a groove array adapted to receive flowable adhesive, introducing flowable adhesive into said groove array in an effective amount for bonding the panel and flange surface.

14. The method of claim 13, wherein said panel comprises at least one panel hole extending through said panel, and said adhesive being injected through said panel hole into said groove array of said joist.

15. The method of claim 13, wherein said joist further comprises at least one joist hole extending from a side opposite the upper flange surface to said groove array, and said adhesive being injected through said joist hole into said groove array.

16. A structural member comprising an activatable adhesive on a surface of a joist.

17. The structural member of claim 16, wherein said activatable adhesive comprises a foambale adhesive, and said joist comprises a grooved surface adapted for positioning said adhesive before activation of said adhesive.

18. The structural member of claim 16, further comprising a carrier film on said joist surface, said carrier film containing said activatable adhesive.

19. A building structure comprising a plurality of joists having flange surfaces and at least one panel attached on said flange surfaces comprising an effective amount of an activated adhesive attaching said joists to said at least one panel.

20. The building structure of claim 19, wherein said building structure is selected from a floor, a wall, a ceiling, or a roof.

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