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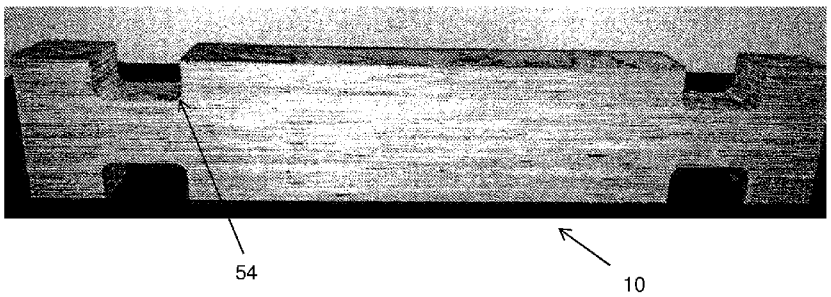


Figure 8A

(57) Abstract: A crib element comprising a unitary engineered wooden member having in a preferred embodiment at least a pair of notches in an upper edge and at least a pair of notches in a lower edge to form a central web therebetween, each notch spaced from an end of the member such that the notches have a portion with a depth sufficient to allow the upper edge of the member to abut a lower edge of a second, parallel member sandwiching the central web of at least a third member in respective, aligned notches of the first and second members to form a crib arrangement.

A CRIB ELEMENT AND CRIB ARRANGEMENTS THERETO

TECHNICAL FIELD

[0001] The present invention relates to a crib element and crib arrangements for forming supports in different situations including in underground mines.

BACKGROUND ART

[0002] Cribs are widely used in underground mines to provide yielding support for the hanging wall or roof of mine workings. They are usually constructed from lengths of timber, commonly referred to as chocks. The chocks are arranged in layers, with a series of parallel chocks in each layer and with the chocks in alternate layers being at right angles to the chocks in the layers above and below. The layers are assembled sequentially on the footwall or floor of the mine working, and a sufficient number of layers are assembled for the crib to extend to a level close to the roof. Any gap between the uppermost layer and the roof can be taken up by insertion of timber wedges.

[0003] Many different crib configurations are known. By way of example, in a typical " four-pointer" crib there are two chocks in each layer and a total of four points at which the chocks in one layer cross and bear upon the chocks in the layer beneath. This configuration is illustrated in Figure 1. In a "nine-pointer" crib, there are three chocks in each layer and hence a total of nine bearing points. Irrespective of the number of bearing points, it will be appreciated that in the simplest form of such cribs or packs the entire vertical load imposed by the roof must be transferred from one layer to the next via the bearing points, i.e. the points at which the chocks cross one another. The timber in each chock between the bearing points serves no real load-bearing function.

[0004] Attempts have been made to distribute the imposed loading by so-called "composite packs". Each chock in the pack has one or more bricks or blocks, typically cementitious or of timber, fixed to it at a predetermined position along its length. When the chocks are assembled to form, say, a four- or nine-pointer crib, the bricks are positioned between the chock-on-chock bearing points to transfer load to the chocks below.

[0005] Conventional cribs or packs consisting of superimposed layers of chocks, with or without bricks or blocks as described above, also have the disadvantage that the chocks in one

layer are prone to sideways slippage relative to the chocks in the layers above and below when the crib or pack is subjected to vertical loading.

[0006] In this connection it has been proposed, for instance in South African patent 93/4786, to notch the chocks at the positions where they cross one another, the notches to a certain extent interlocking with one another. However in the proposed arrangements the problem still remains that load must be transferred from one layer to the next only at the crossing or bearing points.

[0007] The system in United States Patent No. 5746547 provides a solution to this bearing issue by provision of a series of superimposed layers of elongate chocks with a plurality of parallel, spaced apart chocks in each layer with the chocks in one layer arranged transversely to the chocks in the adjacent layer or layers so that each chock in a superimposed layer crosses the chocks in a layer below at at least two crossing points which are located inwardly of the ends of the chocks, and wherein operative upper and lower surfaces of the chocks in superimposed layers are formed with notches at the at least two crossing points, the notches interlocking with one another to lock the chocks together, and the notches being of such depth that portions of the chocks which are located between and beyond the notches bear on corresponding portions of the chocks in the next layer but one below. Chocks of this type are illustrated in Figures 2 and 3 with the formed crib illustrated in Figure 4.

[0008] One problem with this arrangement is that the chocks themselves are formed from unitary wooden members which are heavy and the height to which the crib is to be formed creates safety issues both in assembly and disassembling the crib.

[0009] Further, natural sawn lumber is generally cut from different sections of a log in relation to different angles relative to the growth rings. This creates pieces of lumber with different strengths stemming from the different cut sections. Some of the cuts are known as half sawn, back sawn, quarter sawn and the like. These different cut scores substantially different strengths in timber pieces depending on how they are sawn from the natural log. Use of natural sawn lumber in cribbing therefore leads to substantially different strengths in the different cribbing elements depending upon how the grain in each cribbing element lies and to the orientation of the cribbing element.

[0010] Defects in the timber such as knots, splits, a regular grain and other defects also affect the strength of the timber considerably. Any one piece of natural sawn timber can have inherent weaknesses jeopardising the structure. In many cases, the defects are not visually evident and therefore, there is inherent unpredictability in the use of natural sawn timber.

[0011] United States Patent No. 7841805 endeavours to utilise the grain of wood to achieve an improved wooden crib. Wooden support elements of the crib consist of a centre elongate element wherein the wood grain runs transversely to the crib element loading direction and at least two outer plate elements wherein the wood grain runs axially within the crib element loading direction. Each outer plate element is attached to a surface of the centre elongate element using one or more fastening means, such as nails, screws, bolts and/or adhesive and the outer plate element wood grain direction is aligned transversely to the grain direction in the centre elongate element. Whilst the wooden support elements of United States Patent No. 7841805 are purported to be lightweight, the wooden support elements are still vulnerable to the aforementioned problem of defects. The cribs of United States Patent No. 7841805 also rely on the correct arrangement of the centre elongate element and the at least two outer plate elements in each layer. Since the centre elements and the outer elements have different wood grain directions, the centre elements and the outer elements are not interchangeable. Furthermore, the outer elements are required to be attached to the centre elements which adds to the assembly time of the crib.

[0012] It will be clearly understood that, if a prior art publication is referred to herein, this reference does not constitute an admission that the publication forms part of the common general knowledge in the art in Australia or in any other country.

SUMMARY OF INVENTION

[0013] The present invention is directed to a crib element and crib arrangements, which may at least partially overcome at least one of the abovementioned disadvantages and/or provide the consumer with a useful or commercial choice.

[0014] With the foregoing in view, the present invention in one form, resides broadly in a crib element comprising a unitary engineered wooden member having an upper edge and a lower edge.

[0015] In contrast to natural sawn timber, engineered wood, also called composite wood, man-made wood, or manufactured board, includes a range of derivative wood products which are manufactured by binding or fixing the strands, particles, fibres, or veneers or boards of wood, together with adhesives, or other methods of fixation to form composite materials. These products are engineered to precise design specifications which are tested to meet national or international standards.

[0016] In another form, the present invention resides in a crib element including a unitary

engineered wooden member having at least a pair of notches in an upper edge and at least a pair of notches in a lower edge to form a central web therebetween, each notch spaced from an end of the member such that the notches have a portion with a depth sufficient to allow the upper edge of the member to abut a lower edge of a second, parallel member sandwiching the central web of at least a third member in respective, aligned notches of the first and second members.

[0017] In another form, the present invention resides in a crib element including a unitary engineered wooden member having at least a pair of notches in an upper edge and at least a pair of notches in a lower edge to form a central web therebetween, each notch spaced from an end of the member such that the notches have a portion with a depth of at least one quarter of the dimension between the upper edge and the lower edge of the member.

[0018] In another form, the present invention resides in a crib arrangement including a number of unitary engineered wooden chock members, each chock member having at least a pair of notches in an upper edge and at least a pair of notches in a lower edge to form a central web therebetween, each notch spaced from an end of the member, the chock members provided in layers with two chock members to each layer, alternating layers being offset perpendicularly to one another such that the notches of the chock members in a first layer have a portion with a depth sufficient to allow the upper edge of the chock members in the first layer to abut a lower edge of the chock members in a third layer, parallel to the first layer sandwiching the central web of the chock members in a second layer in respective, aligned notches of the chock members of the first and third layers.

[0019] The present invention will preferably use a unitary, engineered wooden member, preferably a laminated wood. Laminated wood has a variety of different names, but "plywood" is used most frequently. "Plywood" is normally defined as an assemblage of wood veneers bonded together to produce a flat sheet. Typically the veneers in plywood are positioned with the grains of adjoining veneers at right angles to each other although this does not need to be the case.

[0020] The wood chosen for the manufacture of the laminated wooden member according to a preferred embodiment of the present invention will normally be a softwood as distinguished from a hardwood. However, some hardwoods which are on the soft end of the hardwood scale such as poplar may also be used. Preferred softwoods include conifer species such as fir and pine and radiata pine is particularly preferred.

[0021] The grade quality of plywood ranges from A to D with A being the highest quality having imperfections removed and D being the lowest quality with defects such as knots and

splits being acceptable in any one or more of the layers.

[0022] Four types of gluebonds are defined and specified in Australian Standard AS2754.1 Adhesives for Plywood Manufacture. The bond types are - A, B, C and D, in decreasing order of durability under conditions of full weather exposure.

[0023] Type A bond, is produced from a phenol formaldehyde (PF) resin, which preferably sets permanently under controlled heat and pressure. It forms a permanent bond that will not normally deteriorate under wet conditions, heat or cold. It is readily typically recognisable by its black colour.

[0024] The formaldehyde adhesives typically used in plywood or laminated wood manufacture are thermosetting and will preferably not replasticise under reheating as do thermoplastic adhesives such as elastomeric wall board adhesives and PVA.

[0025] Formaldehyde emission from plywood products is below the stringent E1 requirement of 0.1 ppm accepted internationally. Phenolic Type A bonds have particularly low formaldehyde emission, of between 0.00 to 0.03 ppm.

[0026] Although poplar can be used according to the present invention, the situations in which it is used are less common than those for the use of radiata pine. This is typically because of the particular structure of the wood. Poplar is less likely to form a satisfactory Type-A bond.

[0027] On the other hand radiata pine is very compatible with Phenyl Formaldehyde glue being a different species of timber. Without wishing to be limited by theory, radiata pine is a softwood which soaks up the glue better and quicker during the heat/pressing and curing process.

[0028] White poplar can be used but it has a different cell wall structure and using Phenyl Formaldehyde glue typically takes a lot longer under heat and pressure during the curing stage in the manufacturing process to impregnate the veneers used to form the laminated wood member therefore driving up processing costs considerably and being time consuming.

[0029] White poplar bonds easily with other known glues used in the manufacture of laminated veneer plywood and other engineered wood products, but these glues do not have water proof qualities like the phenolic glues used in Type-A bonding. Phenyl Formaldehyde resin or adhesive is the preferred adhesive used and also has little to no formaldehyde gas emissions after the resin curing process.

[0030] The remaining gasses from Phenyl Formaldehyde in the laminated wood member

that are released before and during the process dissipate into the environment several days after manufacture preferably creating a product with an E0 emission standard, E0 being the lowest, with no threat to humans and being suitable for indoors or confined spaces as well as underground.

[0031] Painting or sealing of the laminated wood member can be used to limit or stop emissions but it is preferred that a Type-A bond is formed with its attendant lower emissions.

[0032] Due to the large quantities of the crib (chock) elements required to form crib arrangements underground in possibly humid, wet conditions, a Type-A adhesive is best suited for these applications with E0 emissions.

[0033] Phenyl Formaldehyde adhesives are standard for exterior bonds, combined with visually inspected and manicured high grade whole veneers used giving the plywood its structural grade category.

[0034] With the Phenyl Formaldehyde adhesive properly formulated and suitably employed, no exposure conditions or laboratory tests are known which will degrade hot pressed phenolic glue bonds without destroying the adjacent wood layers.

[0035] All permanently exposed Type A bonded exterior plywood should be treated against fungal attack and the surface should be finished with paint or water repellents to minimise mechanical surface checking. This is not necessarily a consideration for underground application.

[0036] Structural Laminated Veneer Lumber (LVL) manufactured to AS/NZS 4357.0 Structural Laminated Veneer Lumber is an assembly of veneers laminated with a Type A phenolic resin. According to a particularly preferred embodiment of the present invention, the grain direction of the veneers is in the longitudinal direction. The process used to manufacture LVL is defined and explained in a number of references including the Australian Standard.

[0037] The inventor has found that use of LVL or plywood formed from a softwood such as radiata pine even though classified as softwood or the less preferred poplar, provide the required strength and toughness characteristics as well as sought after emissions characteristics when a Type-A adhesive is used to make this particular type of LVL or plywood surprisingly useful in crib formation for use in underground mines.

[0038] The LVL or plywood member of the preferred embodiment will normally be

laminated first and then cut or routed to the finished shape.

[0039] As to the shape of the crib (chock) elements themselves, there are many different shapes that can be used. The shape of the chock elements will normally be substantially planar and rectangular in cross sectional shape with a number of notches. The notches can have any shape and/or location. It is preferred that a uniform shape is used for all notches. It is further preferred that the location of the notches be symmetrical (both longitudinally about a transverse midline of the member and transversely about a longitudinal midline of the member) and the same on all chock elements for ease of manufacture and assembly of the crib.

[0040] Whilst uniformity in shape is preferred, the joint formed between members in the system of the present invention can have any configuration and may involve the notches formed in one edge of the member differing in configuration from those in another, normally opposite edge. Normally, if provided in a non-uniform configuration, the notches formed in one edge of the member will preferably have notches of a corresponding configuration provided on the opposite edge. Alternatively, there may be two sets of members, each set of members to be used in alternating levels of the crib, one set with notches of a first configuration and the other set with notches of a second configuration corresponding to those of the first configuration to allow offset members to engage with one another.

[0041] In some embodiments, the unitary engineered wooden member of the crib element may further comprise strands, particles, fibres, veneers or layers of one or more of the following amongst the plurality of wood veneers or layers: one or more plants; one or more grasses, such as bamboo; metal, such as aluminium or steel; fibreglass; carbon fibre; other synthetic materials, such as plastics.

[0042] In some embodiments, the crib element may comprise a reinforcing layer on at least one outer surface of the crib element. The reinforcing layer can be selected from the following: fibreglass; carbon fibre; metal, such as aluminium. The reinforcing layer can provide additional strength and can assist in preventing buckling of the crib element.

[0043] In another form, the present invention resides in a kit comprising a plurality of the aforementioned crib elements for coupling together to form the crib arrangement.

[0044] Any of the features described herein can be combined in any combination with any one or more of the other features described herein within the scope of the invention.

BRIEF DESCRIPTION OF DRAWINGS

[0045] Preferred features, embodiments and variations of the invention may be discerned from the following Detailed Description which provides sufficient information for those skilled in the art to perform the invention. The Detailed Description is not to be regarded as limiting the scope of the preceding Summary of the Invention in any way. The Detailed Description will make reference to a number of drawings as follows:

[0046] Figure 1 is an isometric view of a prior art crib arrangement showing the forces on a four-pointer crib.

[0047] Figure 2 is an isometric view of a chock according to a prior art configuration which may be used according to a preferred embodiment of the present invention.

[0048] Figure 3 is a front elevation view of the chock illustrated in Figure 2.

[0049] Figure 4 is an isometric exploded view of a crib arrangement formed using the chocks illustrated in Figures 3 and 4.

[0050] Figure 5 is an isometric view of a cross lap joint which may be used according to a preferred embodiment of the present invention.

[0051] Figure 6 is an isometric view of the member designated “Y” in Figure 5.

[0052] Figure 7 is an isometric view of a cogged joint which may be used according to a preferred embodiment of the present invention.

[0053] Figure 8A is an elevation view of a chock according to a preferred embodiment of the present invention.

[0054] Figure 8B is an isometric view of the chock illustrated in Figure 8A.

[0055] Figure 9 is a photograph of a test rig used to test samples in a test program explained below.

[0056] Figure 10 is an isometric view from above of 6 test specimens sampled in the test program.

[0057] Figure 11 is a front elevation view of test sample LVL A after the testing.

[0058] Figure 12 shows a load displacement curve for test sample LVL A.

[0059] Figure 13 is a front elevation view of test sample LVL B after the testing.

[0060] Figure 14 shows a load displacement curve for test sample LVL B.

[0061] Figure 15 is a front elevation view of test sample LVL C after the testing.

[0062] Figure 16 shows a load displacement curve for test sample LVL C.

[0063] Figure 17 is a front elevation view of test sample LVL D after the testing.

[0064] Figure 18 shows a load displacement curve for test sample LVL D.

[0065] Figure 19 is a front elevation view of test sample Plywood 1 after the testing.

[0066] Figure 20 shows a load displacement curve for test sample Plywood 1.

[0067] Figure 21 is a front elevation view of test sample Plywood 2 after the testing.

[0068] Figure 22 shows a load displacement curve for test sample Plywood 2.

[0069] Figure 23 shows a load displacement curve for Test A – a plywood crib arrangement according to a preferred embodiment of the present invention.

[0070] Figure 24 shows a load displacement curve for Test B – a plywood crib arrangement according to a preferred embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0071] According to a particularly preferred embodiment of the present invention, a crib element (also referred to herein as a chock, or chock member) and crib arrangement using a plurality of crib elements (chock members) is provided.

[0072] As illustrated in Figure 2, the chock of the preferred embodiment comprises a unitary laminated wooden member 10 having at least a pair of notches 11 in an upper edge 12 and at least a pair of notches 13 in a lower edge 14 to form a central web 15 therebetween. Each notch 11, 13 is spaced from an end 17 of the member 10. The configuration of the embodiment illustrated in Figures 8A and 8B has generally the same shape and configuration as the member illustrated in Figures 2 and 3. In the embodiment illustrated in Figures 8A and 8B, the notches 11, 13 comprise curved wall portions 54 between vertical and horizontal wall portions of the notches. Curved wall portions 54 can facilitate interlocking of the unitary laminated wooden members 10 in the crib arrangement.

[0073] As illustrated in Figure 4, a plurality of chock members 10 are provided in layers with two chock members to each layer to form a crib arrangement. Alternating layers are offset perpendicularly to one another such that the notches 11, 13 of the chock members in a first layer A have a portion with a depth sufficient to allow the upper edge 12 of the chock members in the first layer A to abut a lower edge 14 of the chock members in a third layer C, parallel to the first layer A, sandwiching the central web 15 of the chock members in a second layer B in respective, aligned notches of the chock members of the first layer A and the third layer C.

[0074] According to some embodiments of the present invention, the laminated member 10 is manufactured of wood of the type having scientific name Pinus Radiata (common name radiata pine). Radiata pine is an abundant plantation timber, preferably sourced from sustainably managed forests compatible with Phenyl Formaldehyde adhesive for the creation of a structural plywood member.

[0075] The adhesive preferred is a Phenyl Formaldehyde adhesive or resin. The common Australian name is Type-A bond permanent glue which is a thermosetting adhesive with an E0 emissions standard. The Phenyl Formaldehyde adhesive or resin is water proof. Once cured, the molecule links cannot be reversed. Heat, water, and chemicals have no effect on the glue. The Phenyl Formaldehyde adhesive or resin is compatible with the radiata pine for the manufacture of engineered wood products.

[0076] The LVL or plywood member of the preferred embodiment will normally be laminated first and then cut or routed to the finished shape.

[0077] There are many different shapes that can be used for the shape of the chock 10 itself. The shape of the chock elements 10 will normally be substantially planar and rectangular in cross sectional shape with a number of notches. The notches can have any shape and/or location. It is preferred that a uniform shape is used for all notches as illustrated in Figures 2 and 3. It is further preferred that the location of the notches be symmetrical (both longitudinally about a transverse midline of the member and transversely about a longitudinal midline of the member) and the same on all chock elements for ease of manufacture and assembly of the crib.

[0078] Whilst uniformity in shape is preferred, the joint formed between members in the system of the present invention can have any configuration and may involve the notches formed in one edge of the member differing in configuration from those in another, normally opposite edge. Normally, if provided in a non-uniform configuration, the notches formed in one edge of the member will preferably have notches of a corresponding configuration provided on the

opposite edge. Alternatively, there may be two sets of members, each set of members to be used in alternating levels of the crib, one set with notches of a first configuration and the other set with notches of a second configuration corresponding to those of the first configuration to allow offset members to engage with one another.

[0079] Examples of joint configurations that may find use in the present invention are the cross lap joint illustrated in Figures 5 and 6 where the notch 16 is provided in both members X, Y and then positively locates the members X, Y relative to one another when the notches 16 in the respective members are aligned. A cogged joint pattern is another joint configuration, as illustrated in Figure 7, in which the notch 16 in member X is located over the portion identified as 50 in the adjacent member Y. This configuration requires that the notches 16 in the upper edge are either that depicted by reference numeral 16 or that identified by reference numeral 50 and the other of the two is provided on the adjacent member. Different combinations can be used on the chock 10 with the same or different notches used at either end of the member or in the upper and lower edge provided that the pattern is repeatable when assembling the crib.

[0080] The plies/veneers in the laminated member of the preferred embodiment are orientated so that the grain direction in one ply is rotated 90 degrees relevant to adjacent plies. Solid wood is 20 times stronger along the grain than across and generally breaks easily along the grain. By cross laminating the veneers, this greatly increases the strength, shear resistance and load sharing capabilities in both directions.

[0081] Solid wood shows significant changes in the transverse direction to grains, but contraction and swelling on the longitudinal plane are usually limited. A well-balanced manufacturing of plywood with direction of the grains of adjacent veneers at a right angle tends to balance tension and increases strength and dimensional stability when more layers are added. This makes the plywood of the present invention virtually split proof and it returns to original dimensions if wetting and drying occurs with no shrinkage. LVL usually has unidirectional veneers, that is all veneers are parallel to the beam length and there are no cross veneers.

[0082] Plywood (comprising differently oriented grain directions in adjacent veneers) is suited far better than LVL (aligned grain directions in adjacent veneers) for mine cribbing. The required strength characteristics in the way the plies are horizontal and cross laminated in plywood for the intended application of mine cribbing exceed LVL outright.

[0083] The structural plywood lumber for the chock element 10 in under ground mine cribbing manufactured as described above, is an engineered alternative to the current natural

sawn species used world wide in Longwall and under ground coal mining with particular advantages.

[0084] Costs are reduced using softwood, such as sustainably managed plantation radiata pine manufactured into engineered plywood for the invention and this material is the most preferred environmental product to date. Trees trap carbon forever, so it is environmentally suited to under ground applications as the timber is left behind during mining extraction of the coal seam. Engineered plywood uses the least amount of energy to manufacture than other engineered standing roof support systems like steel and concrete. The waste wood of plywood manufacture is also recycled into the plant for energy supply in the processing equipment. In comparison to steel and concrete, engineered plywood for the invention is the best environmental choice.

[0085] **Test Program**

[0086] The aim of the testing program was to obtain the maximum compression load carrying capacity of six different engineered composite timber specimens provided. The tests provide a comparison of compression load carrying capacity of different engineered composite timber loaded in different orientations of laminations, with or without distortion or deformation.

[0087] An MTS universal servo-controlled testing machine of 1 MN capacity was used for the compression testing (Figure 9). Load and displacements were measured for each specimen. Maximum displacement was set at 55mm for all the tests except for sample LVL A. The displacement limit for the MTS machine is 60mm. LVL A was the first specimen to be tested, and as the range of displacement was not known, the displacement limit was set to 25mm for LVL A. After testing LVL A, the displacement limit was increased to 55mm for all the remaining tests.

[0088] Specimen dimensions and mass are given in Table 1. Specimens for testing are shown in Figure 10. The species of the timber is pinus radiata (scientific name) – radiata pine (common name). The timber was grown in the southern hemisphere from sustainably managed plantation forests with Forestry Stewardship Council (FSC certification).

[0089] Table 1. Specimen dimensions

Spec. Name	**Height of specimen, *h* (mm)**	**width, *b* (mm)**	**length, *l* (mm)**	**Mass (kg)**	**Lamination Orientation**
LVL A	146	74	100	0.650	Horizontal lamination

					with grains along the length
LVL B	147	73	100	0.655	Horizontal lamination with grains along the width
LVL C	147	74	100	0.655	Vertical lamination with grains along the length
LVL D	147	74	100	0.655	Vertical lamination with grains along the height
Plywood 1	147	75	100	0.650	Horizontal lamination with cross grained veneers
Plywood 2	147	74	100	0.585	Vertical lamination with cross grained veneers

Compression Test Results

[0090] Specimen LVL A started yielding at the load of 47kN and corresponding displacement of 3.4mm. The maximum load attained was 79.4 kN at the maximum displacement of 24.7 mm. Specimen after the test is shown in Figure 11 and the load-displacement curve is shown in Figure 12. The test was stopped as the displacement limit was set at 25mm. For all the remaining tests, displacement limit was set at 55mm.

[0091] Specimen LVL B started yielding at the load of 49kN and corresponding displacement of 4mm. The maximum load attained was 131 kN at the maximum displacement of 55mm. The loading was stopped at the displacement of 55mm. Specimen after the test is shown in Figure 13 and the load-displacement curve is shown in Figure 14.

[0092] Specimen LVL C started yielding at the load of 77kN and corresponding displacement of 6.5mm. The specimen crushed at 101 kN at the maximum displacement of 16.5 mm. Specimen after the test is shown in Figure 15 and the load-displacement curve is shown in Figure 16.

[0093] Specimen LVL D crushed at 323 kN at the maximum displacement of 3.5 mm. Specimen after the test is shown in Figure 17 and the load-displacement curve is shown in Figure 18.

[0094] Specimen Plywood 1 started yielding at the load of 48kN and corresponding displacement of 3.3mm. The maximum load attained was 157 kN at corresponding displacement

of 55 mm. The loading was stopped at the displacement of 55mm. Specimen after the test is shown in Figure 19 and the load-displacement curve is shown in Figure 20.

[0095] Specimen Plywood 2 crushed at 171 kN at the maximum displacement of 3.1 mm. Specimen after the test is shown in Figure 21 and the load-displacement curve is shown in Figure 22.

[0096] Tests A and B were subsequently conducted by the National Institute for Occupational Safety and Health (NIOSH) in the United States on full size crib elements and crib arrangements according to embodiments of the present invention using a Mine Roof Simulator (MRS).

[0097] **Test A**

[0098] Test A was conducted on a crib arrangement comprising preformed plywood crib elements having dimensions 1000mm x 150mm x 75mm and a mass of approximately 5.44kg (12lbs). The plywood crib elements comprise notches 11, 13 towards the ends of the crib elements as described herein to allow for full contact between the crib elements in adjacent layers. The notched plywood crib elements improve crib stability by completely interlocking the crib elements and the full contact greatly improves support capacity. In Test A the resulting crib arrangement had a height of 2,945 mm. The MRS utilised displacement control with a vertical displacement rate of 12.7-mm/min (0.5-in/min).

[0099] In Test A, the plywood crib arrangement is placed in the centre of the MRS. The lower platen is raised to establish a full roof and floor contact creating a uniform loading on the crib arrangement. A controlled vertical displacement at a rate of 0.5-in/min (12.7-mm/min) is applied to the crib arrangement by the MRS to simulate convergence of the mine roof and floor. The applied loading is measured as a function of time and vertical displacement to determine the performance of the crib arrangement. Convergence continues until the crib arrangement becomes unstable, sheds load until the support load is inadequate, or the full 24-in (609.6-mm) stroke of the MRS is reached.

[00100] **Test A Results:**

[00101] A load-displacement curve for Test A is shown in Figure 23. A yield load capacity at 171kips (77.6t) at 1.97-inches (50mm) and peak capacity load of 410-kips (186t) over 16.21 inches (412mm) was observed.

[00102] The plywood crib arrangement provided a fairly stiff initial response. After yielding, the plywood crib arrangement continued to increase its support load capacity. There was no

significant loss of stability or capacity during the yielding process. Failure mode was due to shear failure of the plywood crib elements. At approximately 16 inches (406mm) of displacement a crack developed on one of the plywood crib elements ¼ of the distance up the height of the crib arrangement on the left side of the crib arrangement. The crack increased in size until the plywood crib element snapped in half. Due to the broken crib element, the surrounding plywood crib elements started to break from a shear failure and the crib arrangement collapsed.

[00103] The plywood crib arrangement performed well and the arrangement was able to support a large load for over 16 inches (406mm) of displacement at a high load capacity of over 400kips (181t). The crib arrangement was observed to have a minor crack in one of the crib elements at 16 inches of displacement, but failed quickly at 17 inches (432mm) of displacement. Nonetheless, the plywood crib arrangement of Test A exceeds industry standards. The yielding of the plywood crib arrangement of Test A also provides a "telltale" sign well in advance of failure of the crib arrangement.

[00104] **Test B**

[00105] Test B was conducted on a crib arrangement comprising the same type of preformed plywood crib elements as used in Test A and having the same dimensions of 1000mm x 150mm x 75mm and the same mass of approximately 5.44kg (12lbs). In Test B the crib arrangement had a height of 2,941 mm. The same MRS machine was used as in Test A and utilised the same displacement control with a vertical displacement rate of 12.7-mm/min (0.5-in/min). In Test B however, a 2:1 vertical:horizontal convergence test was conducted.

[00106] **Test B Results:**

[00107] A load-displacement curve for Test B is shown in Figure 24. A yield load capacity at 166kips (75.3t) at 2.01 inches (51mm) and peak capacity load of 394kips (179t) over 13.8 inches (351mm) was observed.

[00108] The plywood crib arrangement provided a fairly stiff initial response. After yielding, the plywood crib continued to increase its support load capacity. There was no significant loss of stability or capacity during the yielding process. Failure mode was due to shear failure of the plywood crib elements. At approximately 13.6 inches (345mm) of displacement a crack developed on one of the plywood crib elements ¼ of the distance down the height of the crib arrangement on the rear of the crib arrangement. The crack continued to increase in size until the test was stopped to prevent the crib arrangement from collapsing. This failure behaviour was similar to the failure of the crib arrangement in Test A.

[00109] The plywood crib arrangement performed well and it was able to support a large load for over 16 inches (406mm) of displacement at a high load capacity of over 394kips (179t). The

crib arrangement was observed to have a minor crack in one of the crib elements at 16 inches of displacement but failed quickly at 17 inches (432mm) of displacement. Nonetheless, the plywood crib arrangement of Test B exceeds industry standards and demonstrates the plywood crib arrangement of the present invention can withstand horizontal as well as vertical loads. The yielding of the plywood crib arrangement of Test B also provides a "telltale" sign well in advance of failure of the crib arrangement.

[00110] According to some embodiments of the present invention, the unitary engineered wooden member 10 of the crib element can further comprise strands, particles, fibres, veneers or layers of one or more other materials amongst the plurality of wood veneers or layers. Examples of other materials that can be included are one or more other plants, one or more grasses, such as bamboo, due to its high tensile strength, one or more metals, such as aluminium or steel, fibreglass, carbon fibre and/or other synthetic materials, such as plastics. The mode of inclusion of the one or more other materials in the unitary engineered wooden member 10 of the crib element will depend on the type and number of different other materials.

[00111] In some embodiments of the present invention, the unitary engineered wooden member 10 of crib element can comprise a reinforcing layer 52 on at least one outer surface of the crib element, as shown in Figure 7. The reinforcing layer 52 can be selected from the following: fibreglass; carbon fibre; metal, such as aluminium. The crib elements comprising the at least one reinforcing layer are arranged in the crib arrangement such that the reinforcing layer is on the outside of the crib arrangement. The reinforcing layer can provide additional strength and can assist in preventing buckling and/or shearing of the crib element when under load in the crib arrangement. For example, in some embodiments the crib element can be coated in a layer of fibreglass on one or more outer surfaces. In another example, the reinforcing layer 52 can be in the form of a metal sheet affixed by any suitable means to an outer surface of the crib element. In some embodiments of the present invention, the reinforcing layer 52 is provided on more than one outer surface of the crib element.

[00112] Hence, the crib elements and crib arrangements according to embodiments of the present invention address or at least ameliorate one or more of the aforementioned problems of the prior art. The unitary engineered wooden crib elements and crib arrangements constructed therefrom according to embodiments of the present invention are lightweight compared with, for example, natural sawn timber elements and therefore are easier to manoeuvre, thus minimising safety issues when assembling and disassembling the crib, particularly to the heights typically required for crib arrangements. For example, some conventional hardwood crib elements are 30-

40% heavier than the unitary engineered wooden crib elements according to some embodiments of the present invention. The uniformity of shape and composition of the crib elements allows the crib elements to be interchangeable, thus avoiding the need to selectively arrange crib elements having different shapes and/or compositions and thus facilitating the ease and efficiency of construction of crib arrangements according to the present invention. The provision of notches in the crib elements prevents sideways slippage of crib elements in adjacent layers. The provision of notches also avoids the need for the crib elements to be fastened together, which further facilitates the ease and efficiency of assembly and disassembly of crib arrangements using the present invention. The unitary engineered wooden crib elements also avoid the aforementioned drawbacks associated with defects in timber and the natural variations and different strengths of natural sawn timber. The crib elements and crib arrangements according to embodiments of the present invention exceed industry standards in terms of the loads that they can support. The yielding of the plywood crib arrangement under load provides an early warning sign well in advance of failure of the crib arrangement thus providing time for personnel to vacate the surrounding area. The inclusion of a reinforcing layer on at least one outer surface of the crib element can further assist in preventing buckling and shearing of the crib element.

[00113] In the present specification and claims, the word 'comprising' and its derivatives including 'comprises' and 'comprise' include each of the stated integers, but does not exclude the inclusion of one or more further integers.

[00114] Reference throughout this specification to 'one embodiment' or 'an embodiment' means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, the appearance of the phrases 'in one embodiment' or 'in an embodiment' in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more combinations.

CLAIMS

1. A crib element comprising a unitary engineered wooden member having an upper edge and a lower edge.

2. The crib element as claimed in claim 1, comprising at least a pair of notches in the upper edge and at least a pair of notches in the lower edge to form a central web therebetween.

3. The crib element as claimed in claim 2, wherein each notch is spaced from an end of the member such that the notches have a portion with a depth sufficient to allow the upper edge of the member to abut a lower edge of a second, parallel member sandwiching the central web of at least a third member in respective, aligned notches of the first and second members.

4. The crib element as claimed in claim 2, wherein each notch is spaced from an end of the member such that the notches have a portion with a depth of at least one quarter of the dimension between the upper edge and the lower edge of the member.

5. The crib element as claimed in any preceding claim, wherein the engineered wooden member comprises a composite of materials formed by binding or fixing strands, particles, fibres, veneers or boards of wood, together with one or more adhesives, or other methods of fixation.

6. The crib element as claimed in any preceding claim, wherein the unitary engineered wooden member is formed from laminated wood comprising a plurality of wood veneers or layers.

7. The crib element as claimed in claim 6, wherein the plurality of wood veneers or layers are positioned with the grains of adjoining veneers or layers at right angles to each other.

8. The crib element as claimed in any preceding claim, wherein the unitary engineered wooden member is made from a plurality of veneers or layers of softwood or hardwood.

9. The crib element as claimed in any preceding claim, wherein the unitary engineered wooden member is made from a plurality of veneers or layers of one or more of the following: poplar; conifer species; fir; pine; radiata pine.

10. The crib element as claimed in any one of claims 6 to 9, wherein a grade quality of the

laminated wood ranges from A to D with A being the highest quality having imperfections removed and D being the lowest quality with defects such as knots and splits being acceptable in any one or more of the layers.

11. The crib element as claimed in any one of claims 5 to 10, wherein the one or more adhesives comprise bond types ranging from A to D in decreasing order of durability under conditions of full weather exposure as defined in Australian Standard AS2754.1.

12. The crib element as claimed in any one of claims 5 to 11, wherein at least one of the one or more adhesives is produced from a phenol formaldehyde (PF) resin.

13. The crib element as claimed in any one of claims 5 to 12, further comprising one or more of the following: a fungal resistant coating/treatment; paint; a water repellent.

14. The crib element as claimed in any one of claims 1 to 6, wherein the unitary engineered wooden member is in the form of structural Laminated Veneer Lumber (LVL) manufactured to AS/NZS 4357.0.

15. The crib element as claimed in claim 14, wherein the structural LVL is an assembly of veneers laminated with a Type A phenolic resin wherein the grain direction of the veneers is in the longitudinal direction.

16. The crib element as claimed in any preceding claim, wherein the crib element is substantially rectangular in cross sectional shape.

17. The crib element as claimed in any one of claims 2 to 16, wherein all of the notches have a uniform shape.

18. The crib element as claimed in any one of claims 2 to 17, wherein a location of the notches is symmetrical according to one or both of the following: longitudinally about a transverse midline of the crib element; transversely about a longitudinal midline of the crib element.

19. The crib element as claimed in any one of claims 6 to 18, wherein the unitary engineered wooden member further comprises strands, particles, fibres, veneers or layers of one or more of the following amongst the plurality of wood veneers or layers: one or more plants; one or more grasses, such as bamboo; metal, such as aluminium or steel; fibreglass; carbon fibre; other synthetic materials, such as plastics.

20. The crib element as claimed in any preceding claim, comprising a reinforcing layer on at least one outer surface of the crib element.

21. The crib element as claimed in claim 20, wherein the reinforcing layer is selected from the following: fibreglass; carbon fibre; metal, such as aluminium.

22. A crib arrangement comprising a plurality of the crib elements as claimed in any one of claims 1 to 21 coupled together.

23. The crib arrangement as claimed in claim 22, wherein each of the plurality of the crib elements is the same.

24. The crib arrangement as claimed in claim 22, wherein a pair of notches formed in the upper edge of a first type of the members differ in configuration from a pair of notches formed in the lower, normally opposite edge of a second type of the members.

25. The crib arrangement as claimed in claim 23, wherein the notches formed in the upper edge of the first type of the members are of a corresponding configuration to the pair of notches formed in the lower, normally opposite edge of the second type of the members.

26. The crib arrangement as claimed in claim 21, comprising two sets of crib elements, each set of crib elements to be used in alternating levels of the crib arrangement, one set of crib elements comprising notches of a first configuration and the other set of crib elements comprising notches of a second configuration corresponding to those of the first configuration to allow offset crib elements to engage with one another.

27. A crib arrangement comprising a plurality of unitary engineered wooden chock members, each chock member having at least a pair of notches in an upper edge and at least a pair of notches in a lower edge to form a central web therebetween, each notch spaced from an end of the respective chock member, the chock members provided in layers with at least two chock members to each layer, alternating layers being offset perpendicularly to one another such that the notches of the chock members in a first layer have a portion with a depth sufficient to allow the upper edge of the chock members in the first layer to abut a lower edge of the chock members in a third layer, parallel to the first layer sandwiching the central web of the chock members in a second layer in respective, aligned notches of the chock members of the first and third layers.

28. A kit comprising a plurality of the crib elements as claimed in any one of claims 1 to 21 for coupling together to form a crib arrangement.

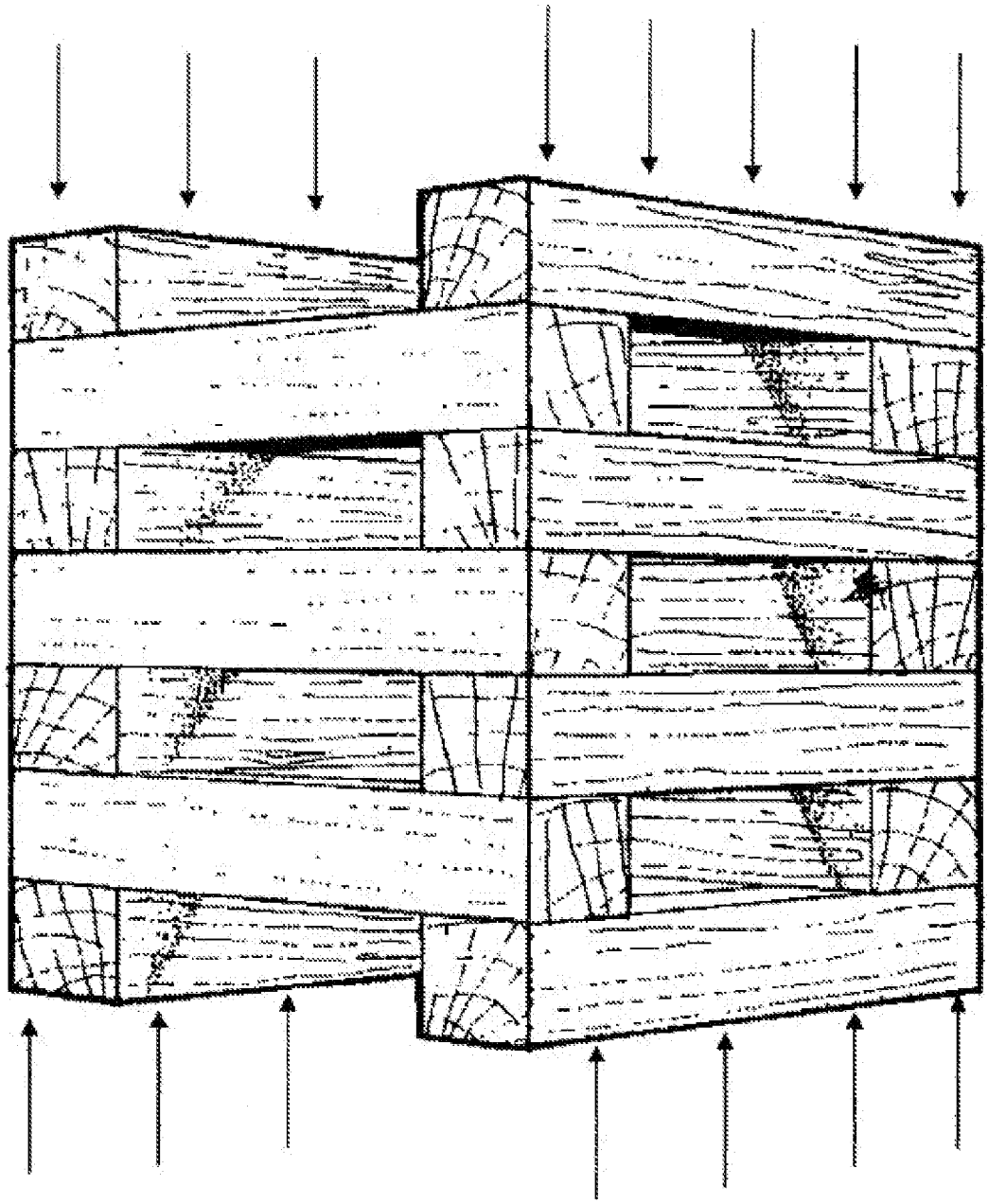


Figure 1

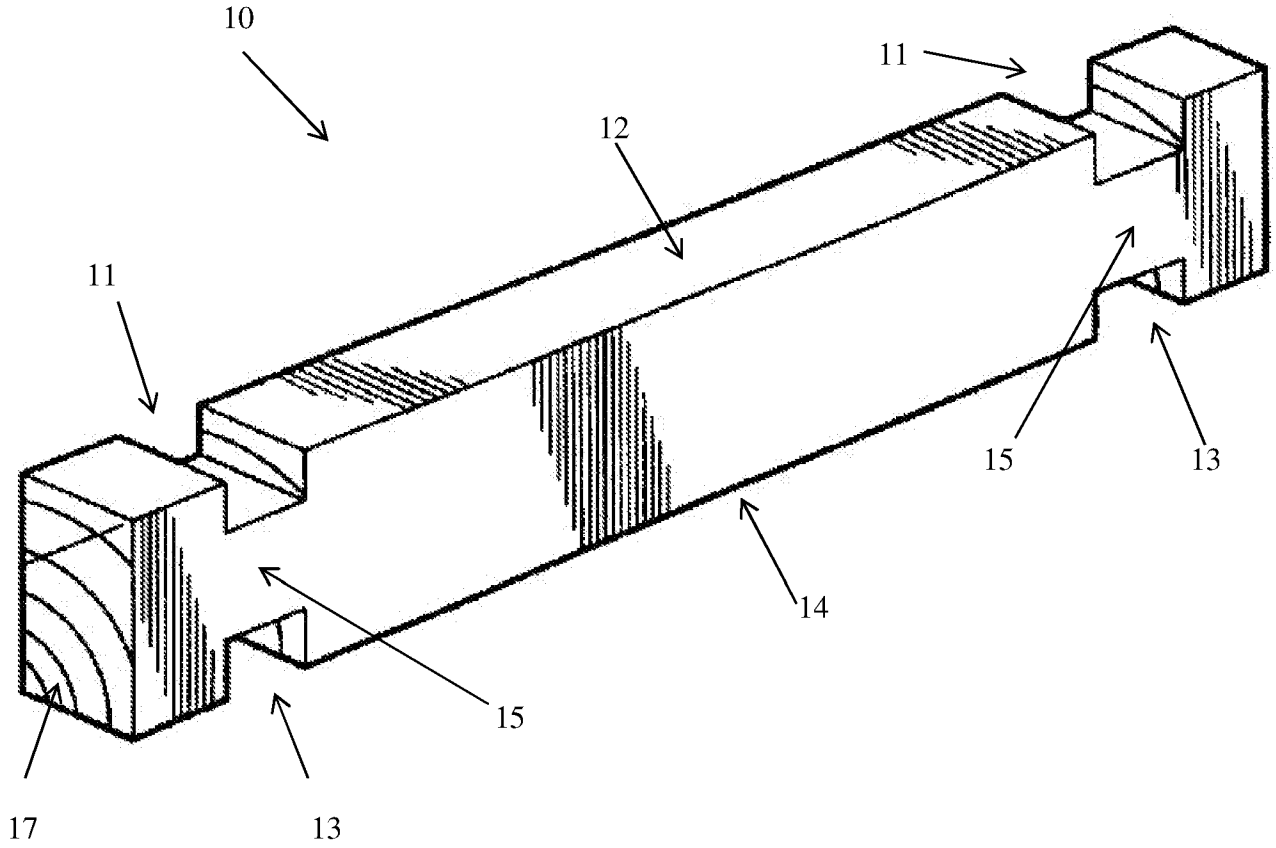


Figure 2

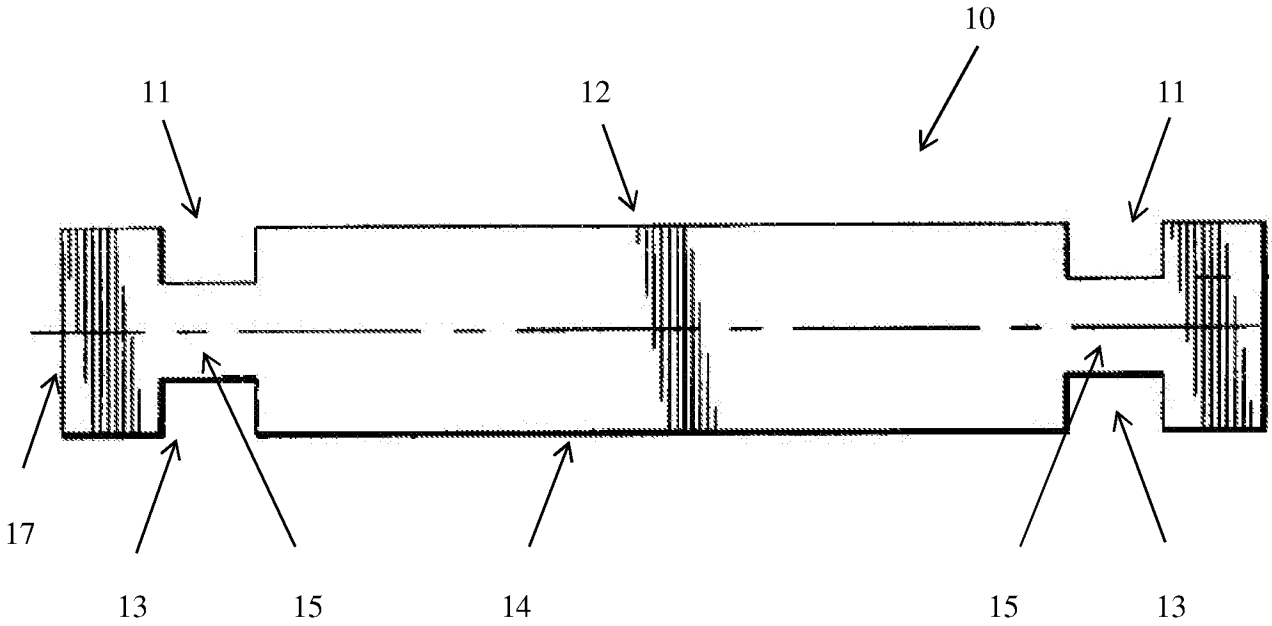


Figure 3

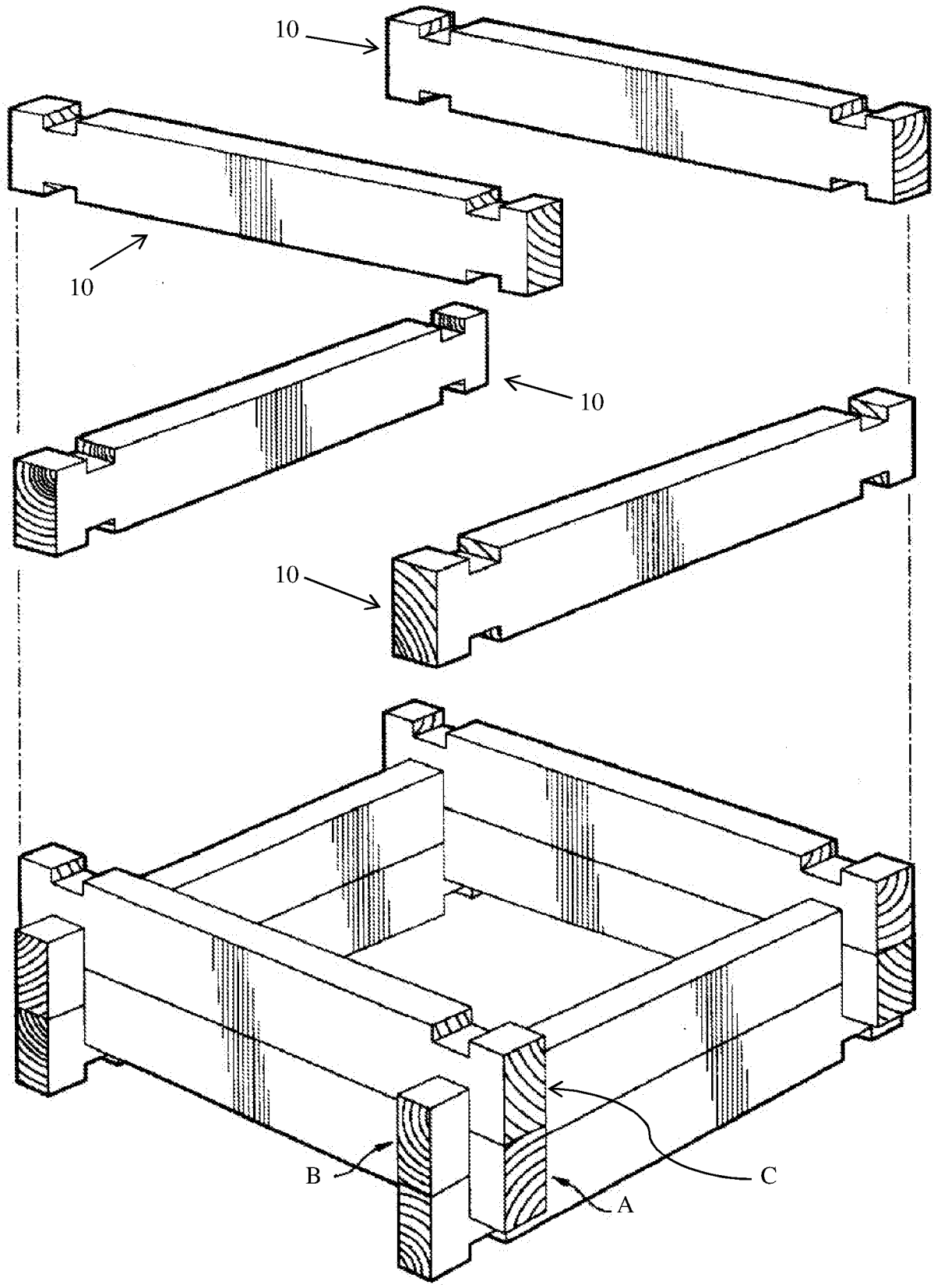


Figure 4

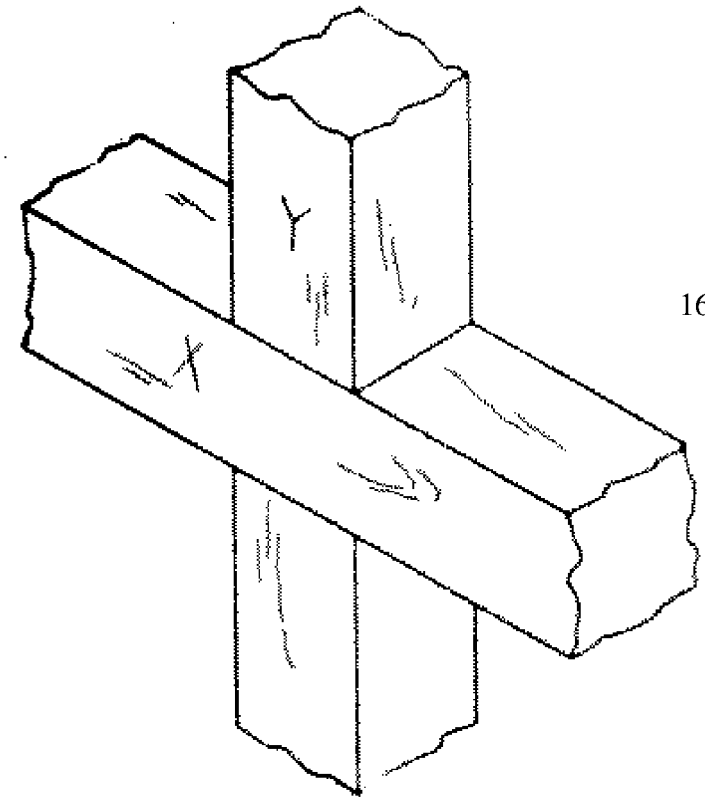


Figure 5

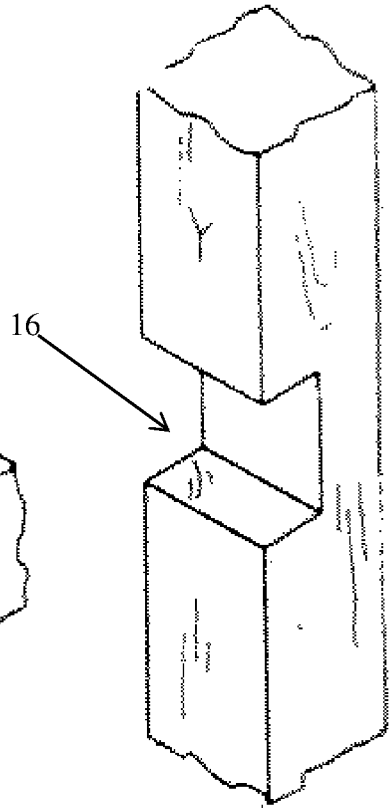


Figure 6

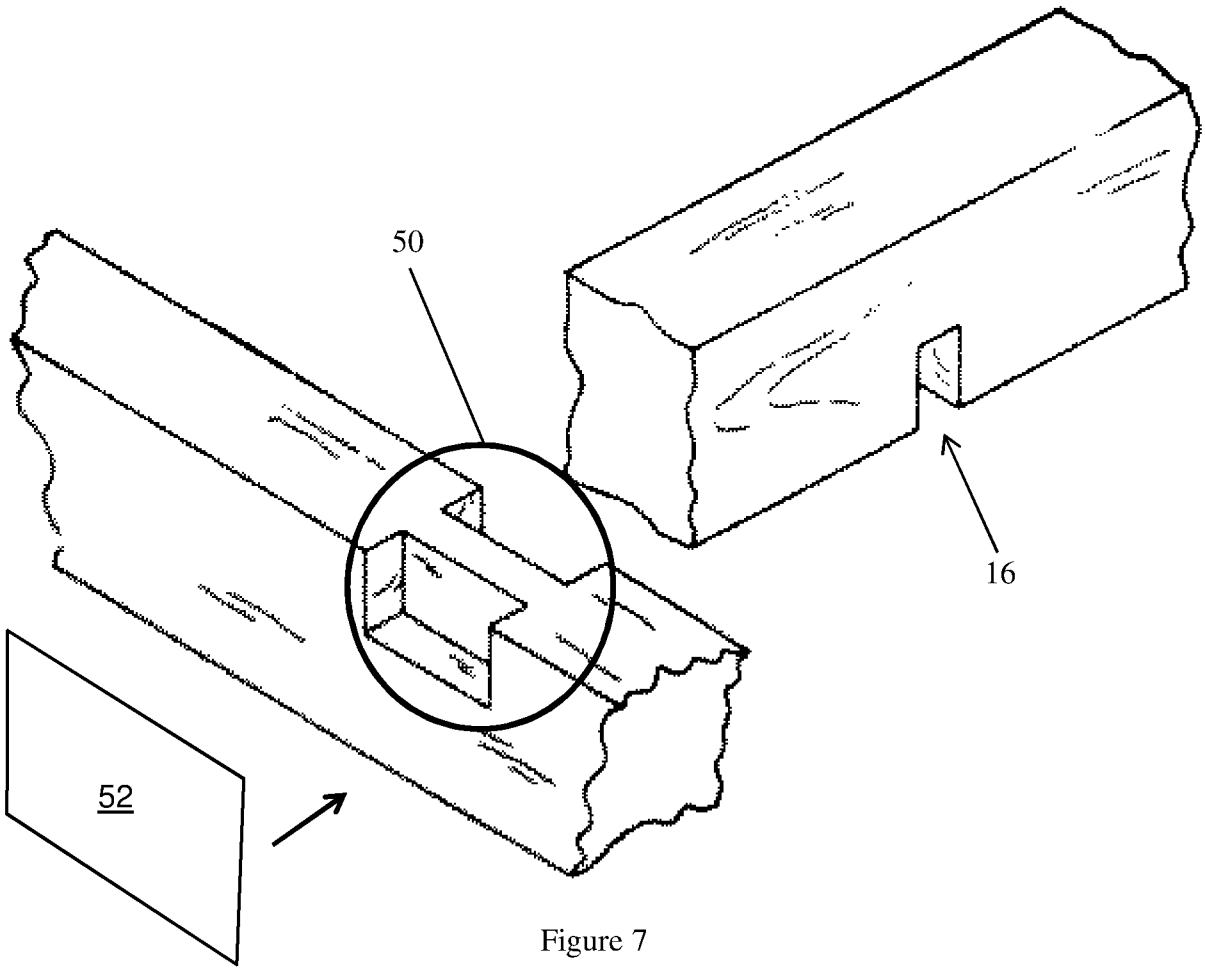


Figure 7

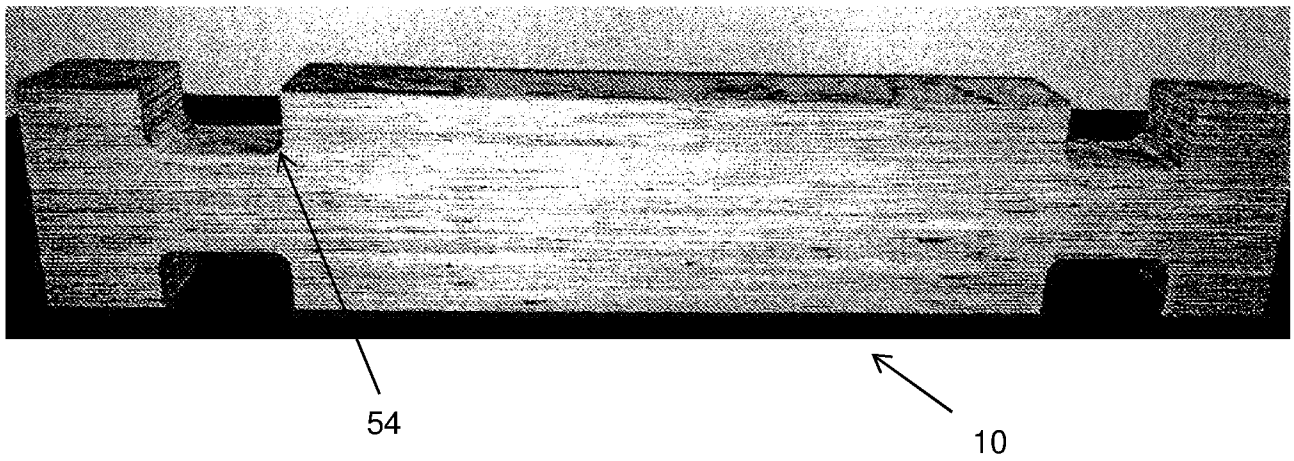


Figure 8A

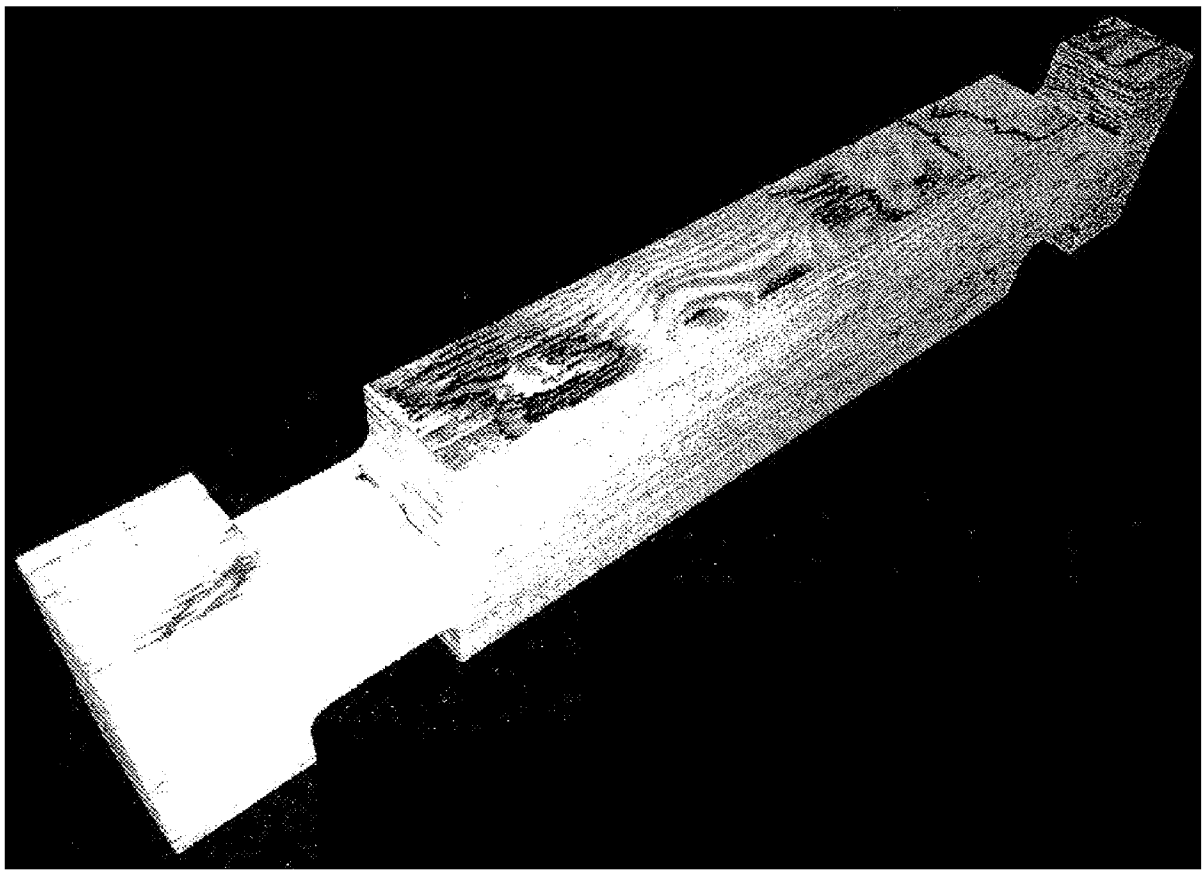


Figure 8B



Figure 9



Figure 10

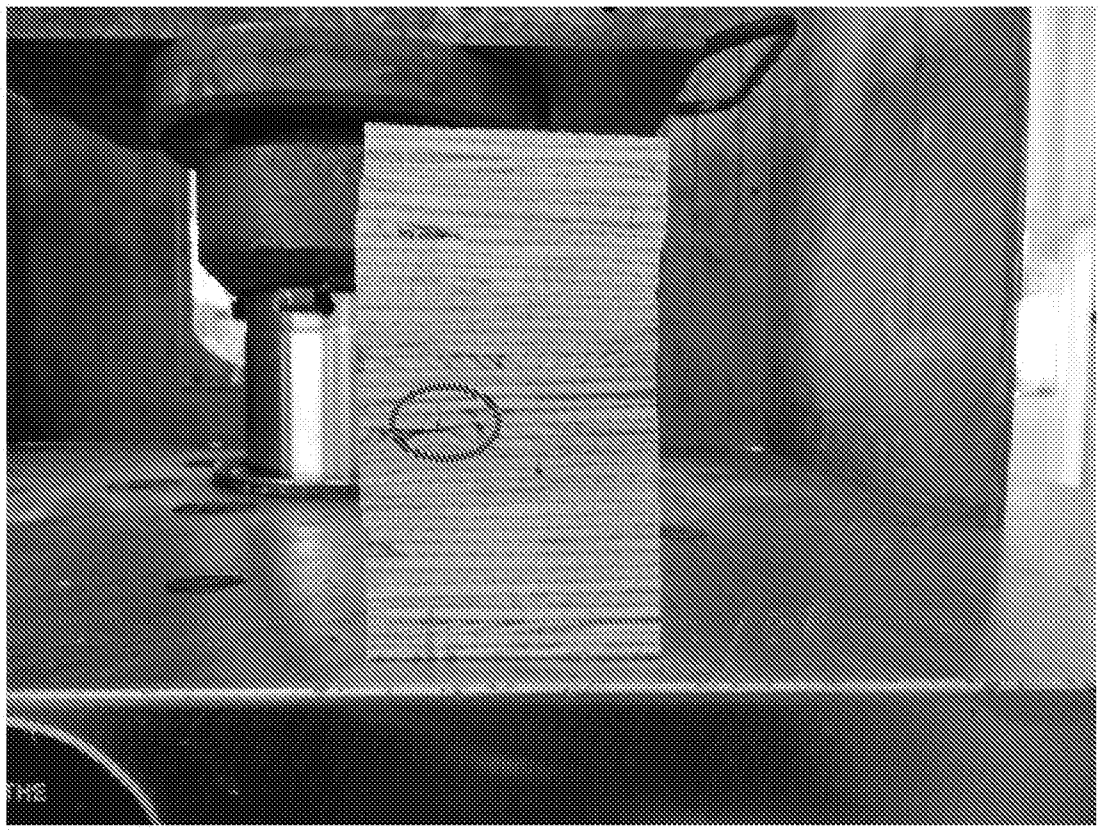


Figure 11

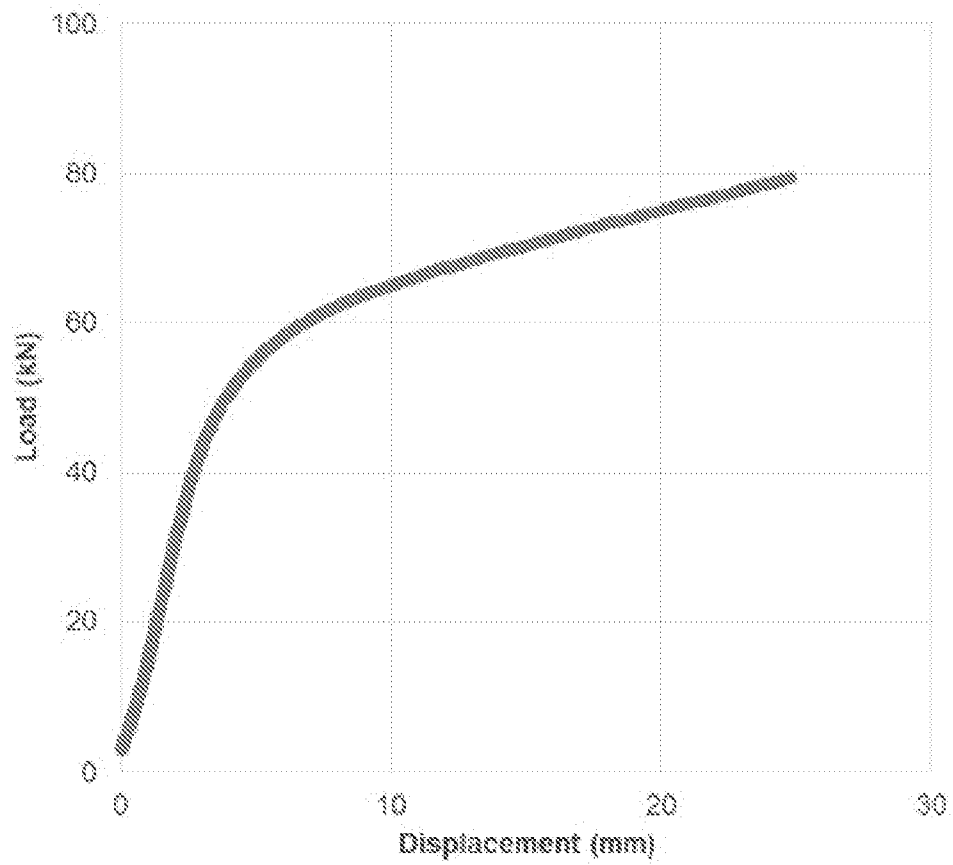


Figure 12

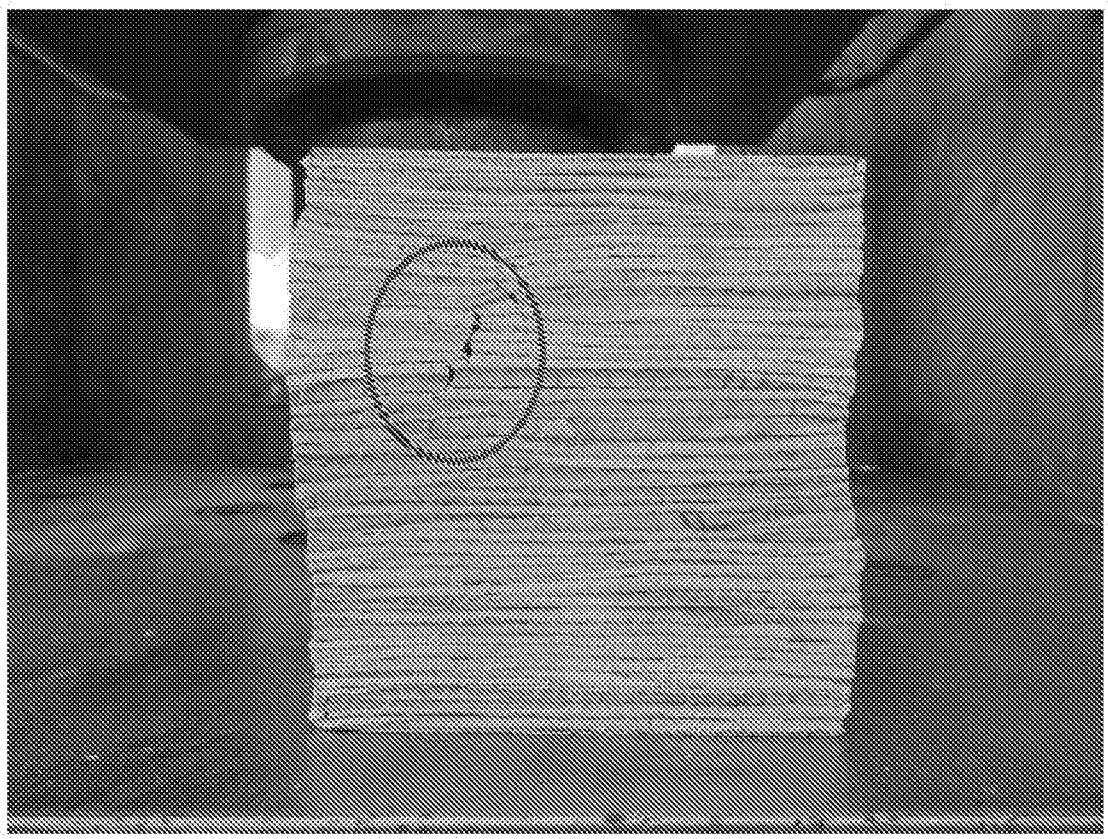


Figure 13

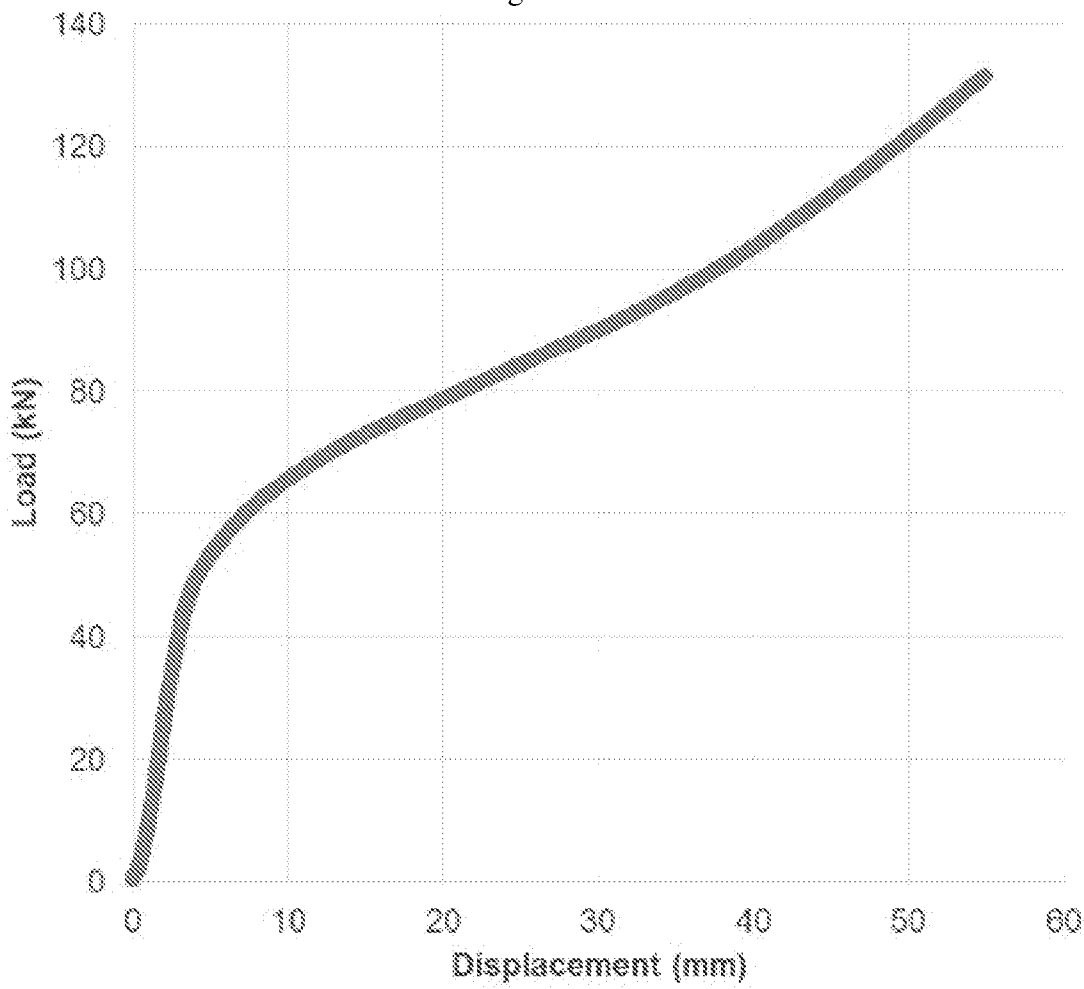


Figure 14



Figure 15

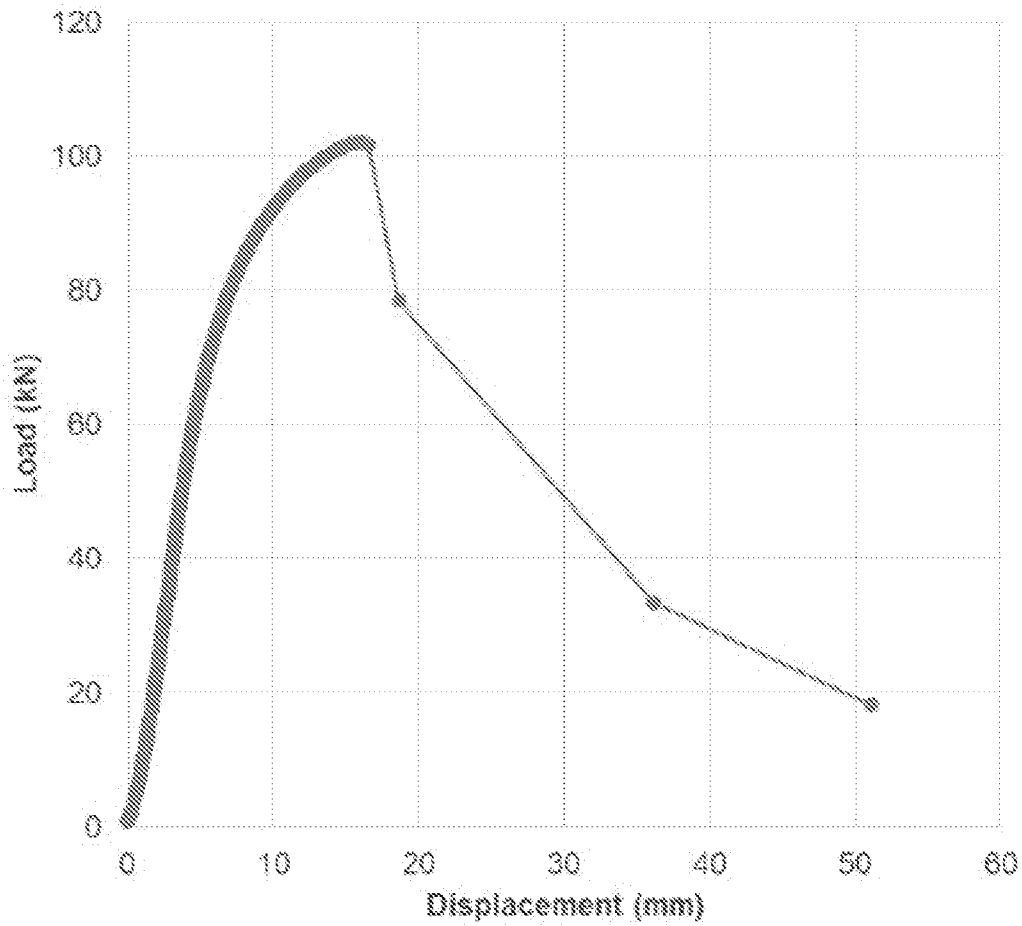


Figure 16



Figure 17

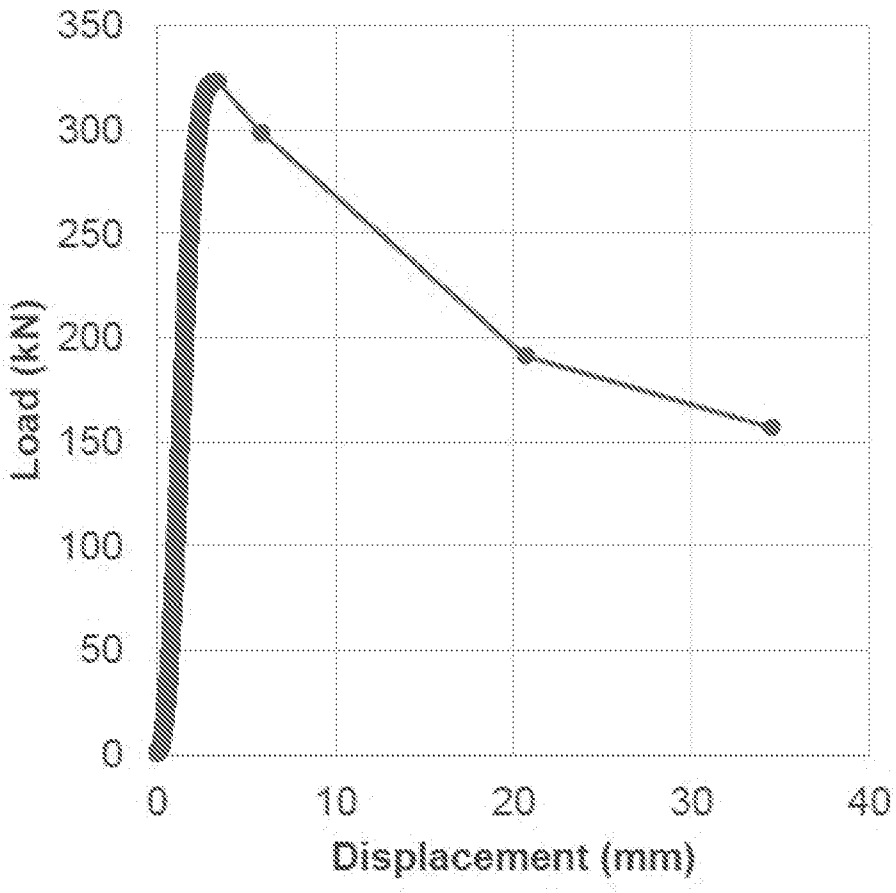


Figure 18

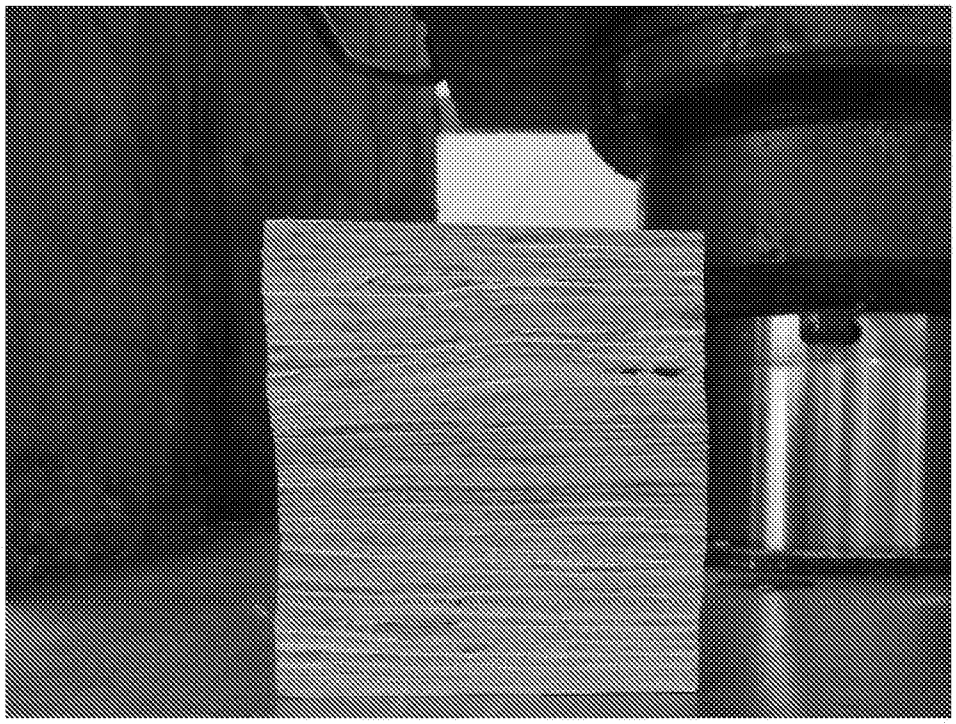


Figure 19

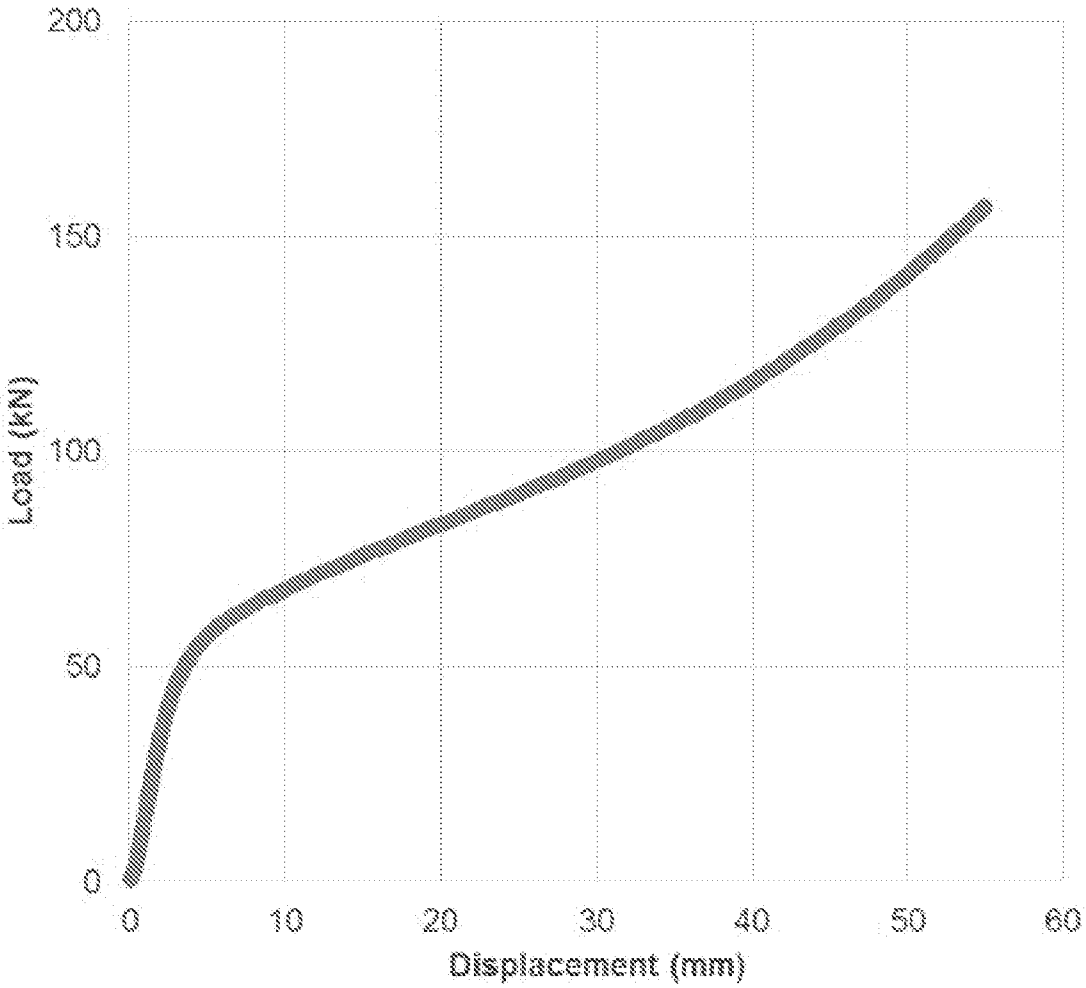


Figure 20



Figure 21

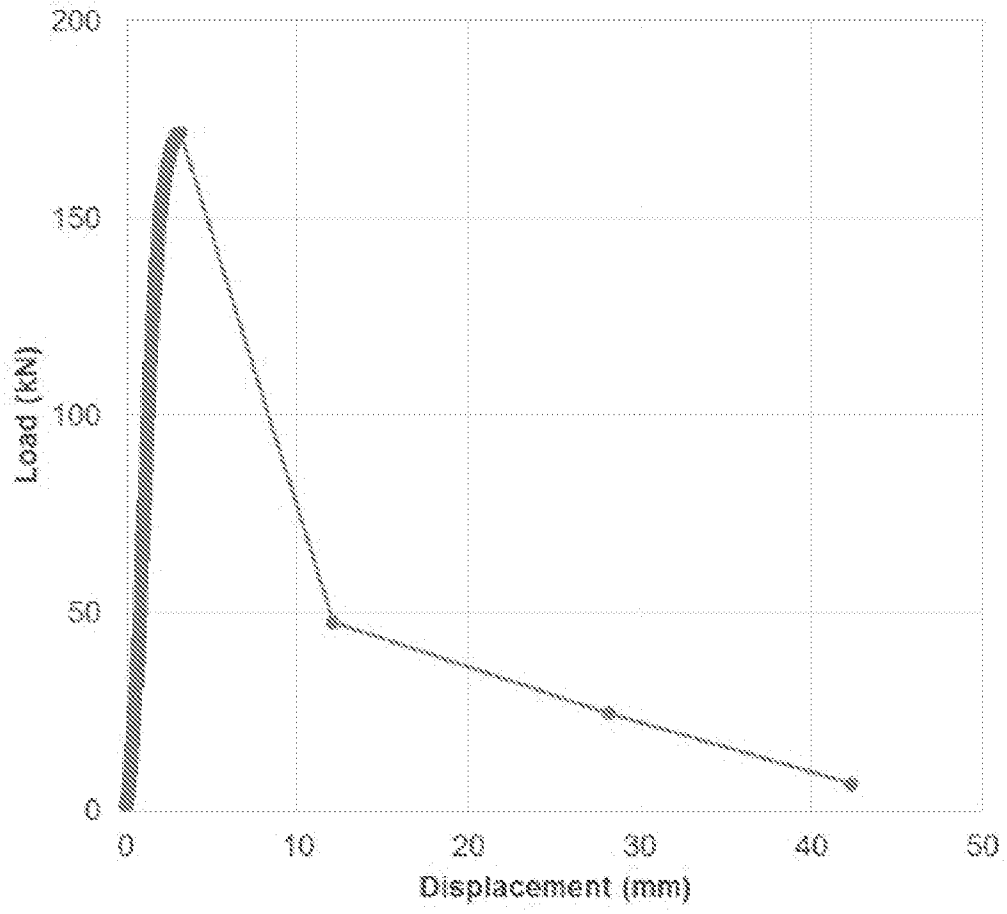


Figure 22

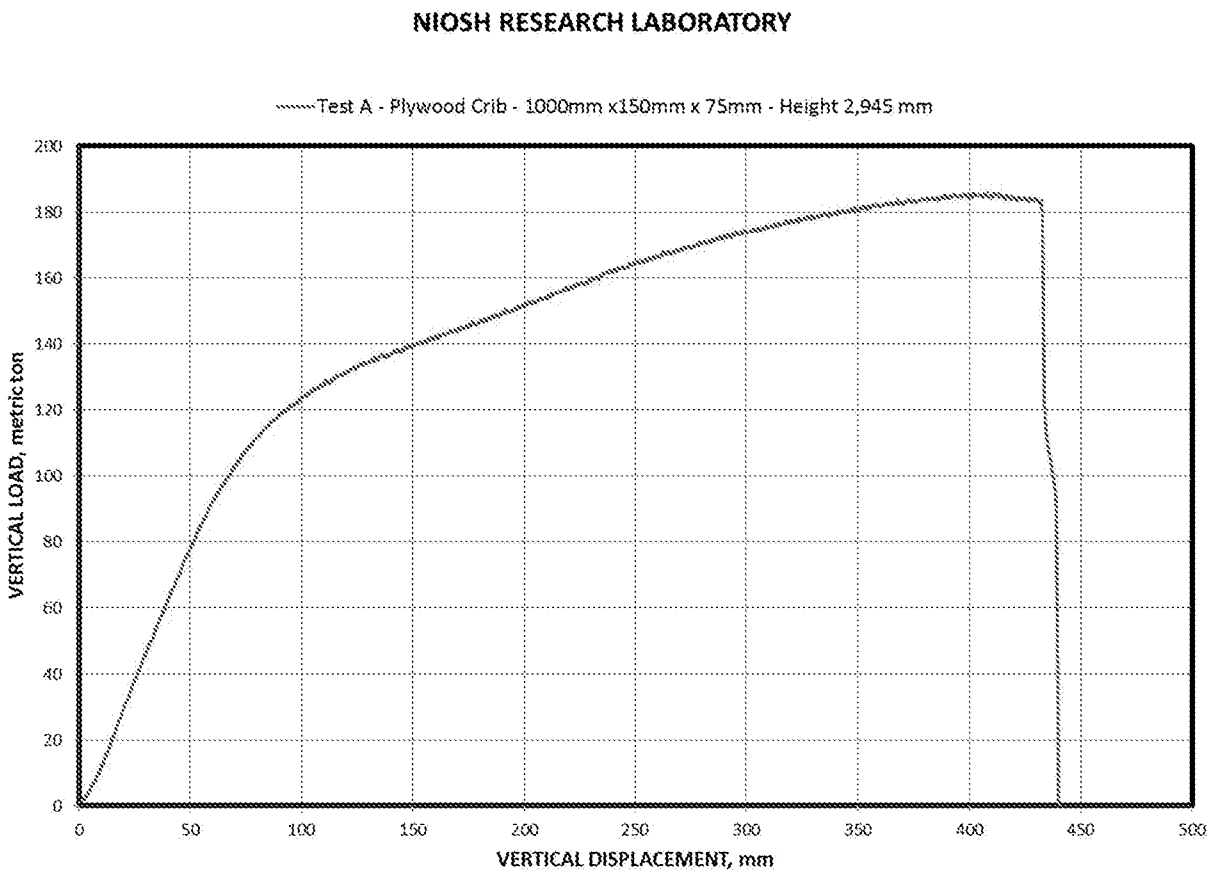


Figure 23

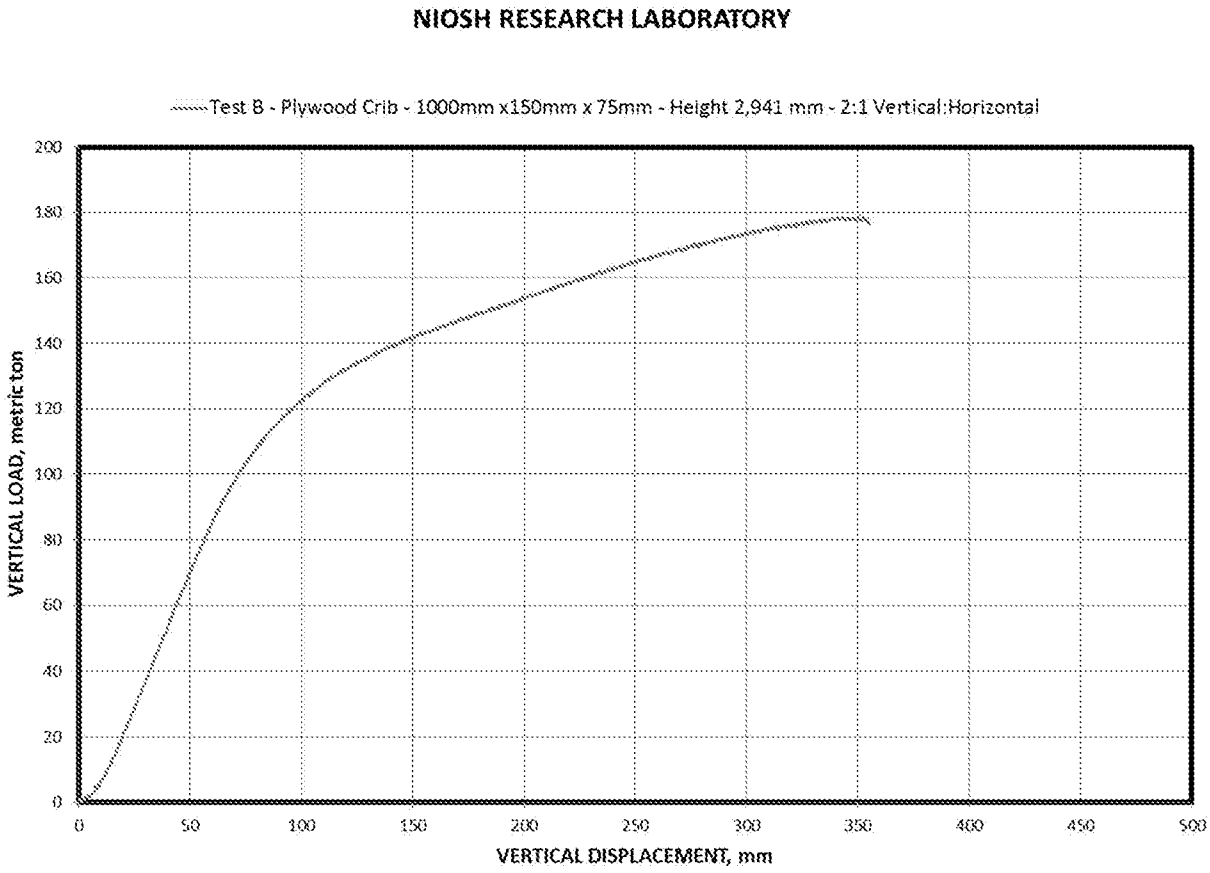


Figure 24

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2017/050076

A. CLASSIFICATION OF SUBJECT MATTER

E21D 15/48 (2006.01)

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)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPIAP & TXTE: /IC/CC E21D15/48, E21D15, E02D29/0216, E04G1/10, E04G21/26, E04G23/04, E04G25/00 & KW(Engineer, Laminate, Composite, Veneer, Wood, Timber, Lumber, Poplar, Plywood, Chock, Block, Crib, Member and similar terms). **Espacenet:** CPC E21D15, E04G25, E02D29/0216, E04G1/10, E04G21/26, E04G23/04 & KW (Timber, Wood, Laminate, Composite, Veneer and similar terms), Applicant/Inventor name search, Citing & Cited of all relevant documents. **Other:** Applicant/Inventor name searched in internal databases provided by IP Australia.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

* 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	Date of mailing of the international search report
9 May 2017	09 May 2017
Name and mailing address of the ISA/AU	**Authorised officer**
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustralia.gov.au	Pascar Chitsaka AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. 0262832130

INTERNATIONAL SEARCH REPORT C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		International application No. **PCT/AU2017/050076**
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2335678 A (SHARP et al.) 29 September 1999 Figs 3-4, Page 8 line 24, Page 9 lines 10-11, Page 13 lines 5-6, Page 14 lines 2-6, Page 15 lines 1-6,	1-28
X	WO 2003/031773 A2 (STRATA PRODUCTS (USA), INC.) 17 April 2003 Fig 1, 3 , 11, Page 6 line 3 & Page 8 lines 13-14,	1-3, 5, 8-9, 16-19, 22-23 & 25-28
X	US 6352392 B1 (McCARTNEY) 05 March 2002 Figs 16, 18-19, Col 4 lines 1-7	1-3, 5, 16-22 & 25-28
X	US 5746547 A (REINMANN et al.) 05 May 1998 Abstract, Fig 1 & 3	1 & 27
X	US 7841805 B2 (CHUGH) 30 November 2010 Fig 7, Col 7 lines 15-20 & Col 6 lines 57-58	1, 5, 12, 16, 22-23 & 28

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2017/050076**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		**Patent Family Member/s**	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
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		GB 2335678 B	01 Mar 2000
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US 7841805 B2	30 November 2010	US 2010221073 A1	02 Sep 2010
		US 7841805 B2	30 Nov 2010

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.