

INFORMATION SHEET

STRUCTURAL MATERIALS

PLYWOOD APPLICATIONS

The information provided below has been taken from the New Zealand Timber Design Guide 2007, published by the Timber Industry Federation and edited by Professor A H Buchanan. To purchase a copy of the Timber Design Guide, visit www.nztif.co.nz

FLOORS ROOFS AND DECKING

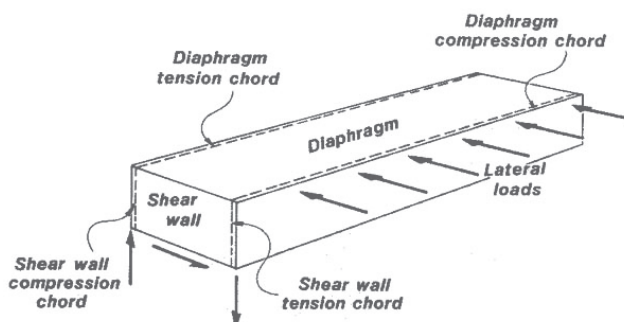
As plywood is available in a range of thicknesses and is stress graded it is suited to higher commercial floor loadings than particleboard panels, or where longer spans are required.

Plywood is a solid wood veneer panel made with highly durable adhesive and when preservative treated is especially suited to wet area flooring such as bathrooms, laundries, kitchens and adjacent to exterior doors where exposure to moisture would damage a particleboard floor.

DIAPHRAGMS AND SHEAR WALLS

Plywood sheathing on walls or flooring may be used “in plane” to resist earthquake or wind loads. The plywood sheathing resists the shear forces and the outer rows of joists (floor diaphragm) or studs (shear wall) act as chords in tension or compression. Floor diaphragms are effectively I-beams spanning between end walls, and shear walls are vertical cantilevers as shown in diagram 1 below. Chords should be detailed for continuity using splices or long-length LVL or glulam to transfer compression and tension forces. The thickness of the sheathing is usually determined by face loads such as wind (walls) or live load (floors).

Diagram 1: Diaphragm and shear wall construction



A key element of the design is the nailing between the plywood and the chords to transfer the shear. For the in-plane loads, standard nail patterns are often sufficient but a check calculation may require closer spacing in regions of high shear. Transfer of reactions to other elements needs careful detailing to avoid eccentricities and tension stresses perpendicular to grain in the timber. Deflection calculations need to include panel shear, panel rotation, nail slip and bending deflection. Design is similar to web beams below.

BEAMS AND FRAMES

Box-beams, I-beams and C-beams can be used as beams, joists, rafters or portal frames by nailing sheets of plywood to a timber frame. Longer spans require splicing of the sawn timber flanges, or alternatively, LVL or glued laminated full length flanges can be used.

The same C-beam and box-beam sections used in plywood web beams can be used as the rafter and column elements in portal frames. After determining moments, shears, and axial forces from structural analysis, each element can be designed using the procedures outlined for web beams. In addition, for the frame as a whole, attention must be given to stability and detailing of the joints in the frame, at the footing, the knee and the apex.

I sections are more difficult to nail, but are available as factory assembled items with glued flange web joints.

PLYWOOD WEB BEAMS

Plywood webs can be used with timber, glulam or LVL flanges to form box, I- or C-shaped beam cross sections as shown in diagrams 2 and 3.

Diagram 2: Types of plywood web beams in cross-sectional view

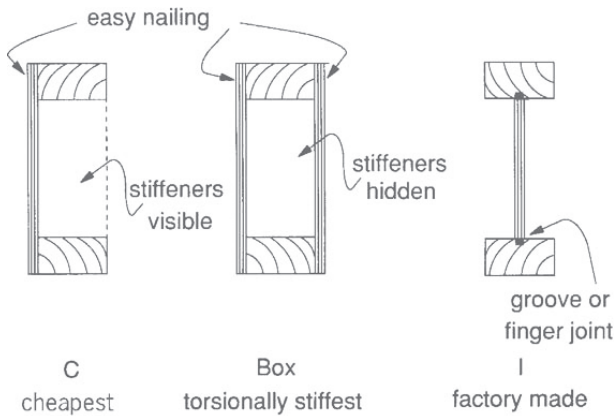
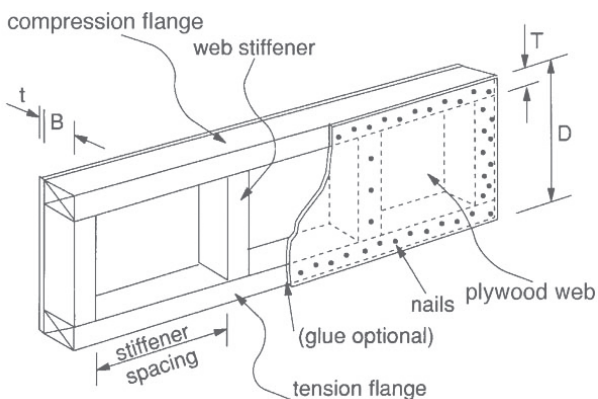


Diagram 3: Basic elements of a plywood web beam



These beams are very efficient because they concentrate most material at the outer edges where the highest stresses occur. Longer beams with sawn timber will require splices in flanges, which could be nail plates, finger joints, or nailed or glued lap joints. However, site made end joints are difficult to control, and a better option is to use continuous length factory controlled chords like LVL. The webs are usually cut from standard sheets of plywood, but continuous slabs of cross banded LVL can be used for special situations.

Sawn timber flanges are only suitable for smaller one-off beams, and standard details and spans are given for house lintels in NZS 3604. The simplest plywood web beam is a nailed C-section, with one plywood web nailed to sawn timber chords. All components of the beam are visible and accessible for jointing. Adding a second web to form a box section covers web stiffeners from view. Nailed web beams are easy to fabricate on site but are labour intensive in large quantities. A system using a box beam with boxed columns provides portal action to resist wind and seismic loads.

For site-made or non standard plywood web beams, depths should be an integral fraction of the sheet width of 1200 mm to avoid waste (e.g. two 600 mm or three 400 mm depths can be cut out of a sheet, but 800 mm leaves 400 mm waste unless other beams in the project are that depth). The same cross sections can be used to fabricate portal frames. The combination of plywood web beams as purlins with portals is very effective, since the deep purlins provide the necessary lateral stability to portal frame members.

Larger deeper I-beams or box beams designed and fabricated for engineered buildings may utilise the full depth of a 1200 wide sheet, or even the full length of a 2400 mm long plywood sheet. To get more beam depth for a limited size of plywood sheet, the top chords may be extended above the web to make an even deeper beam, providing a groove for services. Webs may be jointed or spliced depending on the design requirements.

Even stronger beams can be made using full-length webs of cross-banded LVL. Cross banded LVL is effectively plywood, but has most of the veneers parallel to the face to deliver very strong members in one direction. While the crossbands provide stability for the wider panels, the higher number of parallel veneers contribute to bending stiffness and strength as well as shear strength in these types of buildings. Careful detailing using continuous slabs of cross banded LVL for webs can result in very impressive timber buildings. In comparison, the contribution to bending of thin plywood webs is limited, as the web is primarily used to take the shear stresses. Thin webbed beams also need to be protected from fire with rated ceiling linings.

One of the largest beams in New Zealand has a 44 m span, and is 2.4 m deep with webs glue-nailed to the glulam flanges.

Proprietary I joists are readily available, and are manufactured in a controlled factory environment. Refer to manufacturer's literature for span tables and specific design information.

I-beams or I-joists from 200 mm to 400 mm deep are made at speed in special forming machines to groove and glue the flange material at the same time as feeding in profiled plywood (or oriented strandboard) web sections. Factory made joists are optimised to minimise material use and reduce on-site labour costs and end jointing risk. Design is provided through proprietary software for residential construction.

VIBRATION OF LIGHTWEIGHT FLOOR BEAMS

When using web beams for floors, the dynamic performance of the floor becomes a design factor. Designs should be restricted to spans with natural frequencies above 8 Hz and with RMS accelerations below 0.375 m/s² when subjected to footfall impact. Most human sensitivity is outside these limits.

Vibration problems can be quite complex and the science of vibration control becomes an art. It is possible to improve performance using a strong-back across the floor somewhere in the middle third of the span. This changes the mode of vibration from one over the whole span to a secondary mode constrained by the strong-back. Partition walls above the floor make a significant difference for the same reason. While intuitively adding the extra load of a wall might be expected to increase the problem, the extra stiffness of the wall can fix it. Likewise, judicious placement of mass can alter the vibration mode.

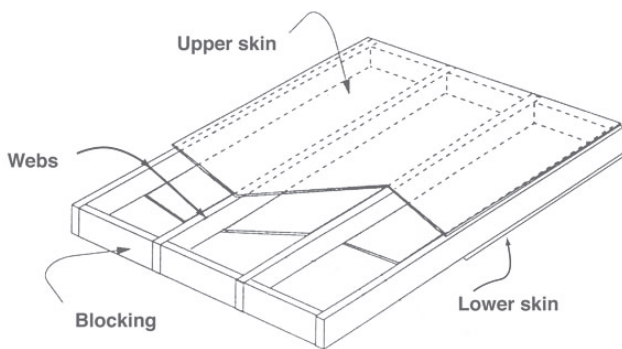
PLYWOOD FOR STRUCTURAL CONNECTIONS

Plywood is extremely useful in joining very large timber components together such as in gusset plates for portal frames or for trusses. (refer to Connections / Other Structural Connectors / Ply and steel plate Gussets). Box beam ends can be efficiently joined to other members using plywood plates and cleats. Plywood can be fastened with, nails, screws, power-driven nails, other mechanical fasteners, and with high quality controlled adhesives.

STRESSED SKIN PANELS

Stressed skin panels are structural flat plates (sandwich panels) which rely on composite action. The flexural strength is provided by the skins and the shear resistance is provided by the filling or webs between the skins. For a simply supported structure, the top skin is in compression and the lower skin is in tension, similar to the behaviour of an I-beam. Full composite action can only be achieved by gluing the joints between the skins and web joists with a rigid adhesive (not elastomeric adhesive). Partial composite action with nailed connections is more difficult to analyse, because of nail slip and creep effects, and it is usual to ignore composite action in floors where the sheathing is only nailed to the joists. Stressed skin panels can also be made as T-beams, where the top skin acts compositely with the floor joists. While they can be designed with conventional calculations for structural loading and deflection control, their light weight means that dynamic and acoustic response becomes important requiring specialist consideration.

Diagram 4: Stressed skin panel construction



Stressed skin panels are moment-resisting floor panels, or roof or wall panels, made by nail-gluing plywood to joist rib members as shown in Diagram 4. Single skin or double skin panels are possible, analogous to T- or I-beam sections. Because composite action is achieved, floor depths can be as little as half the depth of conventional construction. In panels used for floors, for a given joist depth, calculated spans of double skin panels are twice the spans tabled in NZS 3604 for floors with no composite action. For single skin panels, the span capacity is increased to at least that of a joist of the next biggest standard size, and adding the lower skin increases spans one further size (one skin one size, two skins two sizes). However, their light weight means dynamic performance needs to be evaluated.

Face grain of plywood may run along the ribs or across the ribs. Fewer structural connections are required if the face grain runs along the ribs but the performance of the plywood spanning between ribs needs to be checked for face loads because of the reduced section properties perpendicular to the face grain.

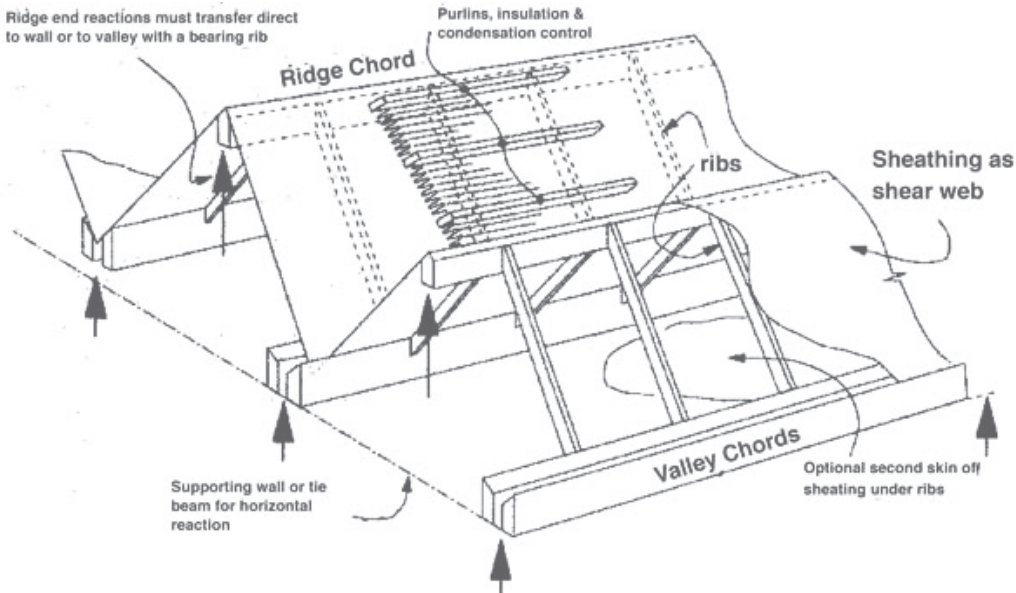
To obtain a structural glued joint between the plywood and the joist material, it is necessary to use dry framing timber or LVL, adequate quality control of the gluing process and the correct glue. Melamine urea or resorcinol formaldehyde adhesives have low creep characteristics and resorcinol is recognised as one of the most durable structural adhesives for wood. Elastomeric construction adhesives may creep excessively so they are not recommended. Also, their longevity after years of service has not been proven. Many of these factors introduce fabrication costs that can offset the savings in material depth.

Stressed skin panel systems have been used extensively in North America where mass production in factories has resulted in economies. Insulation and services can be incorporated into the panels, and one side may be exterior cladding and the other interior cladding. Sandwich panels are similar to stressed skin panels but contain no framing. The core (often foamed plastic insulation) acts as the ribs of the panel supporting the skins over the whole panel area. These panels are known as structural insulated panels (SIPs).

FOLDED PLATES

Folded plate structures use the curved or folded geometry of the structure to make lightweight roof components, where ridge and valley chords act in compression and tension, with panel product sheathing acting in shear. Valley and ridge connections, need to be detailed for shear, axial and splitting forces, and site erection needs to provide support for framing before the elements are joined together.

Diagram 5: Elements of folded plate construction



By tilting roof diaphragms to form folded plates, large spaces can be covered with relatively small framing members. Ridge chords act in compression and are tied together or are common to each diaphragm or plate element. Likewise valley chords are in tension. Plywood sheathing acts in shear. Folded plate action can be achieved with site fabrication, with or without gluing. Chords must be continuous for the full span to take the axial forces, so for longer spans, the chords need to be spliced or made from LVL or glulam timber. Detailing must allow for the transfer of shear and splitting forces between plates.

Loads on folded plates are resolved into forces in the plane of and normal to the plates. From these forces and reactions, moments and shears can be calculated for the in-plane element that will be designed as a web beam, and for out of plane forces the roof may be designed as stressed skin panels or conventional decking over the ribs spanning from ridge to valley. Once the material strengths and deflections have been checked, splitting loads and thrusts at valleys and chords can be calculated and details designed. If the roof also resists horizontal loads from wind or earthquake the shear must be transferred at the valley chords to generate diaphragm action along and across the building.

FORMWORK

Plywood has a proven record as concrete formwork.

It has high strength and stiffness, adequate creep and impact resistance, provides an acceptable surface finish and is able to withstand cleaning, vibrator contact and the rigours of construction site handling. Plywood is stable, with minimal edge swelling, capable of minor repairs and is able to be sealed water tight to contain concrete under high pressure, for as many re-uses as possible.

Plywood for formwork is usually coated with an impregnated paper overlay to give a smooth durable surface. Sometimes special effects can be achieved on the concrete surface, for example, using bandsawn faced plywood, with or without grooves.

NON-STRUCTURAL USES

Plywood is used for many non-structural uses. Plywood is used extensively for furniture, joinery and other fitments such as shelving, boatbuilding, interior or decorative linings, as well as external claddings.

There are also specialty products such as Signboard plywood for signage.

MARINE PLYWOOD

Marine plywood for boat manufacture has high visual-quality face veneers made from species that have high resistance to moisture permeability. Marine plywood also has the same durable adhesive as structural plywood, but because of its high cost it should not be specified for building construction when a stress graded application is required.