A Plywood House in Australia

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Abstract
This paper describes the design and construction of a house based upon the structural properties of plywood. Three particular features incorporated in the design are; the use of a diaphragm floor system; deep plywood box beams; and verandah joists suspended from handrail trusses.

The purpose of the design and construction methodology was the provision of a well designed, low cost, simply built system capable of being constructed by low-skilled sweat equity occupants.

Background
The principle of constructing a gravity load carrying house frame of 'sticks' which is then clad to keep the elements seems inefficient. There seemed to be advantage in using the envelope to do much of the load carrying to supplement a frame comprising of fewer – or smaller – 'sticks'. An obvious choice of cladding material for achieving this is plywood.

The Prototype
Prior to committing to the construction of the house a 2.4x3.6m workshop was built to test the construction method. This was based upon 100x100mm corner posts on galvanised sockets cast into concrete pads. 75x50mm studs at 0.6 m centres on three walls and 1.2 centres on the fourth, with a 15mm plywood floor. A monopitch metal roof with breathing paper and R2.2 insulation on fibrous cement internal lining sheets over the rafters formed the roof.

Three thicknesses of plywood[1] were tried as an external surface: 6, 10, and 12mm. It was found that the 6mm ply drummed and distorted on studs at 0.6m centres. 12mm spans 1.2m between studs without distortion, but drums and fails to attenuate air-borne noise. The plywood was nailed[1] at 50mm centres.

The Building Design
A site was purchased on Macleay Island in Queensland, Australia. It is about 30 x 18m, oriented roughly 30 degrees north of east, and facing Moreton Bay. The site is bordered by tall eucalypts that provide shade to the north, and the eastern aspect affords excellent views over the water only 100m away. The site is 11m above high water line.

The design problem was set as a project for second year students in the School of Architecture, the University of Auckland. The ideas demonstrated in one student's proposal (Yun Yung Do 98) was developed into the project design.

The building is oriented with its long side facing about 30 degrees north of east to make best use of the view. These eastern facing windows are protected by a 2.4m deep verandah. The few windows facing west are protected by the Eucalypts on the northern boundary. The western glazing to the laundry and downstairs bathroom is protected by a small roof over the back door: that to the dining area and the second bedroom are not.

The building's structural design is based upon plywood panel modules. It has a 2.4m planning grid and stump plan. A plywood diaphragm floor (PAA 91) deck was used instead of conventional bearers and joists. This system uses 120x45mm Cypress F7 timbers site-glued and nailed at 15cm centres. Two timbers are fixed into an inverted 'T' between which 120x45mm joists span. 17mm structural plywood is glued and nailed over the top, forming a very wide flange to the resulting 'I' beam. The advantage of the diaphragm floor is the use of smaller structural timbers than would otherwise be needed, ie. The equivalent of 140x70mm bearers with 140x45mm joists (F7) at 60cm centres. The disadvantage is the greater labour required to cut and place the joists between bearers. For sweat-equity projects where availability of labour is not a problem, the system has advantages.

The building plan is shown in Figure.1. It is seen to consist of a high-set single storey structure, with the master bedroom suite on the second level.

The structural system transfers the roof loads to the external walls by a 0.6m deep[1] plywood box beam ridge. The ridge beam is faced both sides with 10mm ply, and nailed with 30 x 2.5mm clouts at 50mm centres. This ridge then spans between the two second storey sidewalls. These sidewalls are themselves 2.1m deep plywood box beams spanning between the front and back walls.

The ridge box beam continues down in the form of a diaphragm wall. The floor joists are supported on the foot of the diaphragm wall hence they are effectively suspended from the ridge beam so that no load is transferred to the mid-span of the diaphragm floor deck. Box beams are faced with ply both sides nailed at 50mm centres having 100x50mm F7 Cypress internal framing.

The on site constructed external walls are composed of oil-stained 7.5mm untreated bracing ply nailed at 15cm centres, over radiative foil insulation, and internally by 10mm five veneer plywood. Whilst all the plywood used was generally CD, the interior finish was generally very good. The great advantages of plywood over plasterboard for internal lining are the ability to fix shelves, light fittings, curtain rails etc. to it directly, its relative robustness, as well as its contribution to bracing.

Large sliding doors are installed into the walls. Box beams 0.9m deep form the lintels over them on the front wall, and 0.3m beams on the back. The widest lintel has a 3.6m span.

The verandah balustrade is constructed as a double corded truss spanning between the verandah posts. The verandah joists are suspended from these trusses at the outer edge, and sit on shoes at the inner. 50mm square welded wire mesh is built into the trusses to meet the 'childproofing' requirements of the Australian Building Code.

All of the water services are concentrated into a short length of the rear wall. The pipework is concealed within the wall and floor. The en suite bathroom in the master bedroom is stacked over the laundry on the level below. The laundry is between the downstairs bathroom and the kitchen. Thus all services have short runs to taps and drains.

The roof to the second storey has a shallow (20m radius) curve, of standard rafter construction using graded size roof battens to achieve the curve. The rounded roof was used in order to keep the ridge height low compared to the front and back walls. The corrugated iron roofing overhangs by 40cm.

The roofs contain a reflective barrier and R3.3 fibreglass insulation and the internal surface is T&G pine boarding. The roof to the single storey has an 8^{o} pitch.

The construction of the envelope was carried out by a single person. Assistance was required to manhandle the roof sheeting up to the second storey roof, to install the 250x50mm hard wood roof rafters at the lower storey, and to manoeuvre and fit one of the sliding doors.

Discussion

Conventional timber house building in Australasia relies upon the construction of a gravity-bearing frame of 'sticks' that is then clad with an exterior surface. The use of plywood reduces reliance upon the sticks and utilises the engineering properties of the ply to carry loads as well as act as bracing.

Plywood construction requires less material by volume than conventional construction, and if designed on plywood modules, minimises wastage. These assumptions will be measured and in due course once the data has been analysed.

The cost of the house of $120m^2$ covered area, and $29m^2$ of verandah was around A$40,000 (NZ$50,000). This excludes builders labour costs, site purchase cost, internal finishes, and electricians labour. It does include foundations, kitchen whiteware, plumbing subcontract and materials including the septic tank system. It is not yet clear how this will compare to traditional construction techniques.

A great advantage of using plywood in construction is that it enforces the discipline of right angles, an advantage for owner builders, as it makes inaccuracies evident whilst there is still time to correct them.

It was originally intended to use 7.5mm three veneer bracing ply inside and out. Advice from Boral Handcock Pty Ltd. suggested that there would be unacceptable 'rippling' of the surface, and the cost penalty of using

10mm five ply was not excessive. Fixing internal fittings to 10mm ply would, moreover, be more robust than fixings to 7.5mm.

Experience suggests that the optimum construction might prove to be studs at 0.9m centres using 10mm plywood sheets. This construction appears to be quite rigid and eliminates buckling. 0.9m wide plywood sheets would be more easily man-handled on site.

A plywood stressed skin floor is not necessary unless minimising floor to floor heights is important. It involves a great deal of additional work over conventional constructions.

The Plywood Association of Australia have made a A$10,000 research grant to the Environmental Design and Technology Program at the University of Queensland in which the School of Architecture at the University of Auckland will collaborate. The grant is for a comparison of a number of advanced timber house building techniques, including this, developed by researchers.

References

PAA 98 Plywood Association of Australia, LP91 Low Profile Stressed Skin Plywood Floor System, 1998

Do, Yun Yung 98 Yo Yu, 2nd Year, 2nd Semester Design Project, School of Architecture, University of Auckland,1998

Figure.1 Plans and Elevations of House Design

A Plywood Box-Beam House

Low profile floor - 125x50 Cypress pine F7 framing.

Two storey framing

Interior - kitchen and dining area. T&G ceilings