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Prefabricated Timber Ground Floor Systems Final Summary Report

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Prefabricated Timber Ground Floor Systems
Final Summary Report

Prepared for

Forest & Wood Products Australia

by

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Executive summary

Builders currently prefer concrete slab-on-ground construction for new house construction. They have concerns with traditional built-on-site joist and bearer systems because of the multiple trades required and the longer construction periods compared to the slab-on-ground alternative.

This project has developed practical options for easy-to-install prefabricated lightweight timber ground floor systems that include both the prefabricated timber floor panels and the floor support to footings and provides a viable option that will deliver **one contract, to deliver a working platform, on a site, on a specific date, for a specific cost** with the additional benefits of a raised timber floor for:

- sloping sites
- highly reactive clay soils
- flood inundation areas
- homes for second and third buyers/owners where quality is the measure rather than minimum cost.

Prefabricated timber ground floors represents a significant opportunity to grow volumes of timber used in residential and light commercial construction through a new product and delivery model that meets market needs.

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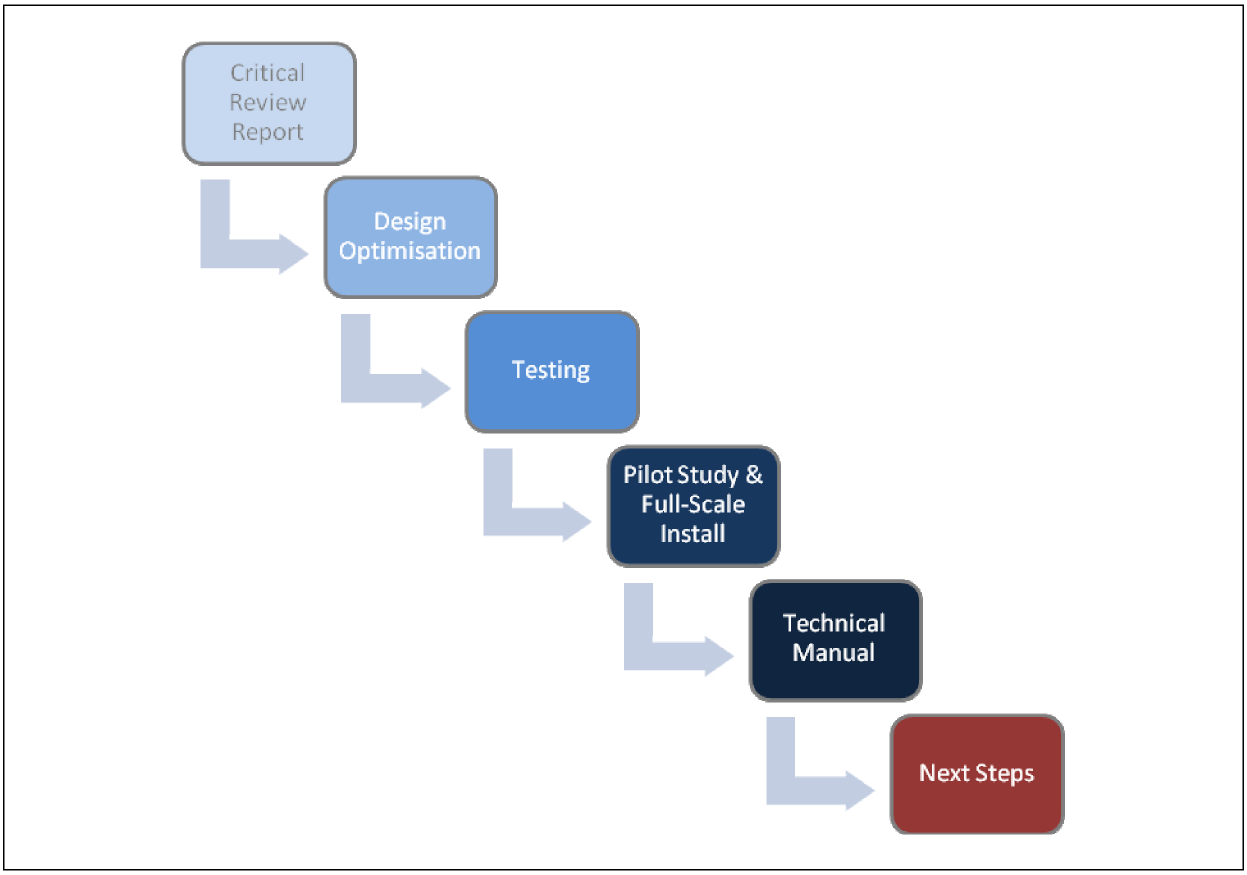
Project overview

The project followed a logical sequence of events and used a collaborative approach with project partners Bowens, Mitek and Holmesglen TAFE to develop a technical advisory manual that frame and truss manufacturers can use, which provides sufficient background and design information to offer prefabricated timber floors as an additional product offering.



Oversight of the project was provided by a Project Steering Committee comprising the project collaborative, Metricon and Panel Build.

A separate technical committee (including house builders, TAFE tutors and component and timber industry suppliers) provided advice to refine the development of practical prefabricated flooring solutions.

Critical review report

The review found:

- whilst the timber industry has attempted to win back ground-floor market share from concrete slab on ground, it has not been particularly successful
- despite some upper storey cassette floor activity internationally, no one in Australia or internationally was delivering a commercial prefabricated timber ground floor system approach.
- the importance of offering a total system solution that includes the prefabricated timber floor, the supporting system and a simple, effective and quick installation process.

Design optimisation

Prefabricated panelised flooring configuration options – these were optimised around structural performance, delivery and installation considerations and cost, while utilising the current range of commonly available structural flooring products and providing solutions for small sawn section and LVL floor joists, I-beam floor joists and floor trusses.

Prefabricated floor system support and footing methods – including general floor supporting requirements and external wall wind-load tie-down and overturning resisting requirements.

On-site installation requirements – determining techniques and procedures for between-panel jointing, addressing potential floor dimensional growth and crane lifting requirements.

Floor insulation options – that are cost effective, suitable for transport and easily installed – examining all the currently available products and methods.

Testing

A range of tests were carried out at BRANZ's research facilities, and individual test reports were provided for each stage. The initial elemental testing demonstrated that a connecting system comprising a simple metal top plate to the pier will cope with realistic site conditions and proved straightforward to construct and be satisfactory for most residential buildings in Australia, excluding cyclonic regions (see Appendix 1).

Connector plate

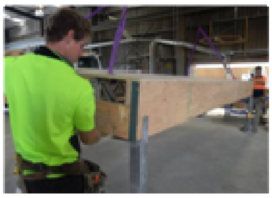
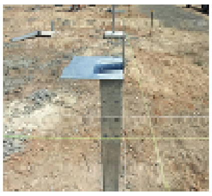
Three full-scale structural tests were undertaken on multiple connected floor panel elements constructed form engineered I-beams with a particleboard floor deck. This testing successfully demonstrated the serviceability and constructability of the flooring system, and the results were used to calibrate the computer simulation, which allows designs to be further refined (see Appendix 2).

Full-sized testing of floor insulation installation with polyester and with expanded polystyrene demonstrated that a tested prefabricated timber floor could be competitive with concrete slab and waffle pods' theoretical R-Values. Significantly, the test results gave a very close correlation, of the calculated system R-value, using HEAT2 finite element modelling (see Appendices 3 and 4).

Panel lowered into position

Pilot study and full-scale install

Prefabricated floor panels were manufactured by Bowens Timbertruss, and a trial installation was undertaken at Bowens Innovation Centre prior to their subsequent installation in a single-storey 116 m^2 lightweight clad home at Heathcote In Victoria. The pilot testing and trial full-home installation provided a wealth of valuable practical information and proved the efficiency of the new prefabricated floor system approach (see Appendices 5 and 6).

Technical manual

The technical advisory manual captures the project findings and provides truss and frame manufacturers with sufficient background and design information to offer prefabricated timber floors as an additional product offering. The manual will not be released publicly at this stage but will be utilised by a market implementation group facilitated by the Frame & Truss Manufacturers Association (FTMA) to provide a structured and strategic release to market (see Appendix 7).

Next steps

The opportunity exists for the frame and truss (F&T) sector to expand its product range and consequently increase the volume of sales for panel products, sawn timber and engineered wood products.

The F&T sector already has significant share of the roof truss, wall frame and second-storey floor joist products in the new residential timber framing market.

This means that there is limited opportunity for further market growth in the current product areas.

Conversely, the F&T sector has very little share of the residential ground-floor market share, thought to be less than 5%, in a market dominated by concrete, and consequently, this provides a significant market opportunity.

Timber ground floor construction is far from a new concept. What is new, original and innovative in this project is the delivery method and market offering that will provide **one contract, to deliver a working platform, on a site, on a specific date, for a specific cost** through the supply and installation of a prefabricated ground floor system that provides:

- the prefabricated timber floor
- the floor support system
- the footing system (with a number of options depending on soil conditions)
- a simple, effective and quick installation process.

Long-span prefabricated ground floor systems provide a fast and efficient construction method that a competent F&T plant can offer using their existing skill set and established timber products. Prefabricated floor panels can be constructed utilising a range of different configurations to suit all structural timber member types, including:

- small-section sawn timber floor joists, spanning across the panel and long-span bearers (S-type)
- I-beam floor joists, spanning along the panel and short-span bearers (I-type)
- floor truss joists, spanning along the panel and short-span bearers (T-type).

Who are the potential customers and what's in it for them?

Prefabricated ground floors provide an extension to the F&T product range that will appeal to both existing and new customers for a range of situations. They provide significant advantages for:

- sloping sites
- highly reactive clay soils
- flood inundation areas
- homes for second and third buyers/owners where quality is the measure rather than minimum cost.

What new skills will be needed?

The principal benefit of this opportunity is that it builds on existing technical skills and familiar materials to develop to provide a more comprehensive product offering.

The following skills will be critical to successful implementation.

Business development will help ensure that existing and new customers take advantage of the many benefits that prefabricated timber floors provide.

While prefabricated timber floors can be manufactured using existing plant and facilities, as with anything new, it will require an enthusiastic and **well informed workforce** that understands what it is doing and **effective quality management** to ensure minimum rework and satisfied customers.

Effective working relationships must continue to be developed with existing suppliers, including metal component and software suppliers and a range of new suppliers and service providers, from pier and concrete suppliers to geotechnical and structural engineers.

All states and territories have **licensing requirements** for when an individual or company wants to carry out or supervise building work. Requirements vary and will need to be verified for each state or territory.

How can the F&T sector take advantage?

To assist in ensuring a successful take-up to market following this R&D project, it is proposed that a restricted and strategic approach will be pursued. This will involve:

- working closely with the Frame & Truss Manufacturers Association
- identifying 2–3 innovative and quality F&T manufacturers in each state
- forming a small implementation group of these key companies
- assisting companies in understanding the concepts and touting for some jobs in their states
- assisting companies on each job, seeing what we can learn and updating this technical advisory manual
- working with MiTek, Pryda and Multinail to include design and fabrication details in their software
- once a number of new projects have been completed in each state, starting to share the information more broadly with the F&T sector.

Appendices: Reports from project stages

Appendix 1: BRANZ Test Report SR0968-1 Elemental tests on prefabricated floor support connection systems

Appendix 2: BRANZ Test Report SR0968-2 Construction and load testing of full scale prefabricated floor panels at BRANZ

Appendix 3: BRANZ Test Report SR0968-DU01 Thermal resistance of a prefabricated timber floor system insulated with EPS

Appendix 4: BRANZ Test Report SR0968-DU02 Thermal resistance of a prefabricated timber floor system insulated with polyester

Appendix 5: BRANZ Report Prefabricated Lightweight Ground Floor Systems – Trial Installation of Full Size Panels

Appendix 6: BRANZ Report Prefabricated Lightweight Ground Floor Systems – Full Size Home Installation, Heathcote, Victoria

Acknowledgements

This project – to develop a new prefabricated ground floor system solution – has been undertaken by BRANZ Ltd in conjunction with TPC Solutions (Aust) Pty Ltd and Bowens Timber & Building Supplies.

The project team kindly acknowledges the assistance of Forest & Wood Products Australia Ltd for its financial backing and support provided for this project.

The project team would also like to acknowledge the support provided by many individuals and organisations, including but not limited to the Frame & Truss Manufacturers Association, Timber Development Association of New South Wales, Timber Queensland, Wood Products Victoria, Bowens, GTS Industries, Carter Holt Harvey, Panel Build Qld, Tilling Timber, MiTek, Pryda, Multinail, Swenrick Construction, Metricon, Holmesglen Institute of TAFE, Housing Industry Association and Master Builders Australia.

BRANZ would particularly like to acknowledge the input of the Project Steering Committee:

Robert Tan – MiTek (Chair)
Charles Simpson – Holmesglen Institute of TAFE
Jeff Harvey – Bowens
Jarrod Gooden – FWPA
Olga Petinis – Metricon
Matthew Gaunson – Metricon
Doug Bartlett – Panel Build Qld
Mark Grouios – Carter Holt Harvey
George Dolezal – Carter Holt Harvey
Alastair Woodard – TPC Solutions
David Sharp – BRANZ
Roger Shelton – BRANZ

The project team would also particularly like to acknowledge and thank the contribution of the following.

Charles Simpson – Holmesglen Institute of TAFE, an exceptional and motivated building professional, creative and innovative conceptually, extremely knowledgeable and practical in building construction practices, highly skilled in plan and process development and totally committed to seeing this initiative become a reality.

Holmesglen Institute of TAFE – for providing Charles Simpson's time and for their support and encouragement and excellent meeting room resources for countless project meetings.

Bowens Timber & Building Supplies – for their extensive in-kind support and for their visionary approach of pursuing innovation to best service their customers and improve building practices. Thanks to all the staff who contributed, particularly John Bowen, Jeff Harvey, Mark Benson and the fabrication 'A-team'.

Particular recognition to **Steve Manion**, Bowens Innovation & Business Development Manager, whose passion for improving the level of prefabrication and panelised systems in Australia was the major driver for the project. Steve's enthusiasm was infectious and his commercial drive and understanding without peer. Despite his illness, he remained connected with and an on-going contributor to this project. His early passing rocked all those who knew him and who truly appreciated his genuine friendship and professional skill. A life cut too short.

Appendix 1
SR0968/1

Elemental tests on prefabricated floor support and connection systems

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Elemental tests on prefabricated floor support and connection systems

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2. INTRODUCTION

This test report represents the elemental testing undertaken as part of Milestone 3 Stage 1 of the laboratory testing as described in the project proposal for the FWPA sponsored project PNA244-1112 “Prefabricated lightweight timber ground floor systems”, to determine the structural adequacy of the floor support systems identified in Milestone 2 of the Design Phase.

3. OBJECTIVE OF ELEMENTAL TESTS

There were three objectives for the elemental series of tests.

- To develop a simple, buildable and economical support system for the prefabricated floor panel system as identified in the interim report to FWPA dated 28th February. Three support systems were derived, based on concrete stumps, metal supports and timber piles, each set into a concrete foundation.
- To determine an indicative resistance to wind uplift of the chosen support systems.
- To investigate between-panel jointing requirements and integrated panel performance.

4. DEVELOPMENT OF THE SYSTEM, AND CONSTRUCTION OF TEST SPECIMENS

To check practicality and buildability of the supporting systems and connections, nine test specimens were constructed, three each using concrete piles, metal anchors and timber stumps. These were selected as being representative of the wide variety of support systems that the floor system needs to be compatible with.

The general test arrangement is shown diagrammatically in Figure 1 with a photograph in Figure 11.

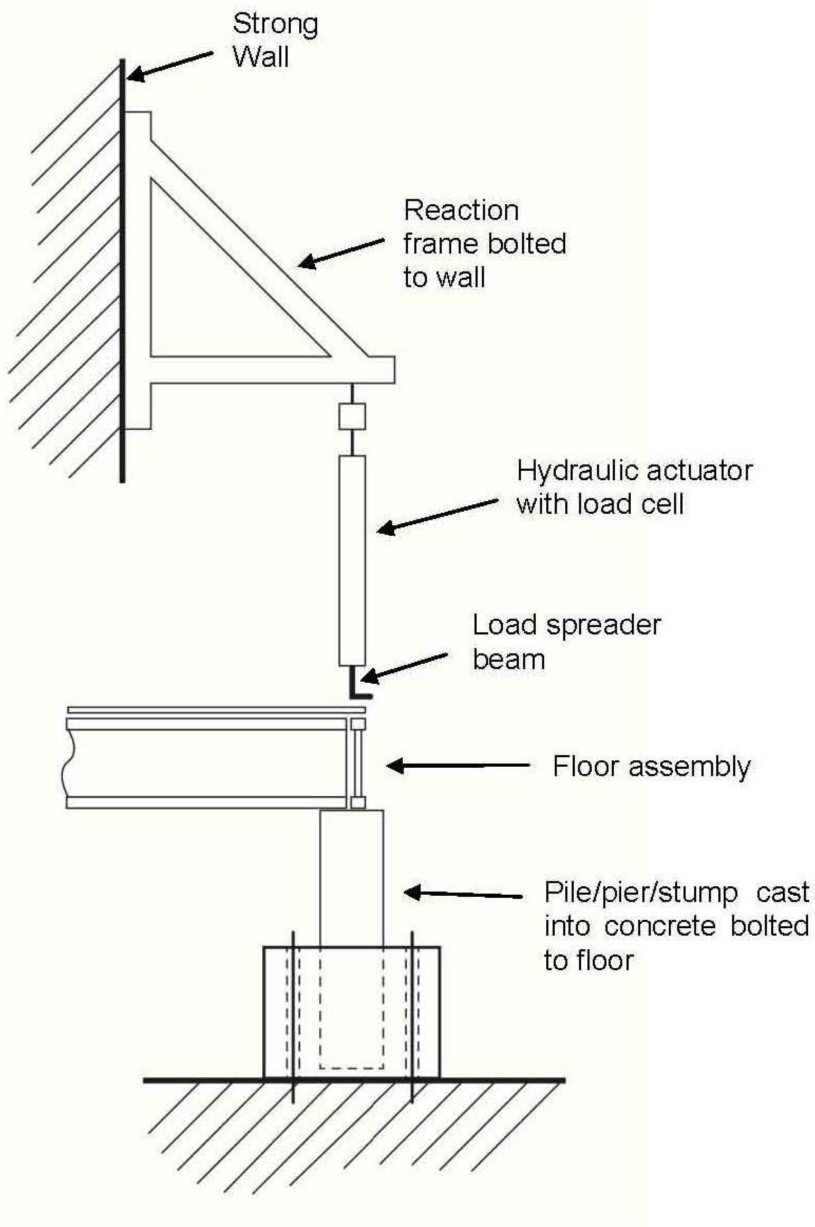

Figure 1. Test arrangement

Changes were made to the construction details and individual components as the work proceeded and detail problems were solved. A schedule of tests showing these changes is presented in Table 1.

Test	Support	Fixing (plate to support)	Plate	Fixing (plate to floor)	Floor panels	Alignment
1	Timber	5/14g x 100 csk screws	Steel	6/14g x 50 Hex screws	Butted	Edge
2	Timber	8/14g x 100 csk screws	Steel	10/14g x 50 Hex screws	Butted	Edge
3	Timber	8/14g x 100 csk screws	Steel	10/14g x 50 Hex screws	Butted	Edge
4	Steel	6/14g x 50 Tek screws	Steel	8/14g x 50 Hex screws	Butted	Edge
5	Steel	6/14g x 50 Tek screws	Steel	8/14g x 50 Hex screws	Spaced	Edge
6	Steel	6/14g x 50 Tek screws	Ply	8/14g x 50 Hex screws	Spaced	Centred
7	Concrete	Screw bolt	Steel	8/14g x 50 Hex screws	Spaced	Centred
8	Concrete	Screw bolt	Steel	8/14g x 50 Hex screws	Spaced	Centred
9	Concrete	Screw bolt	Steel	8/14g x 50 Hex screws	Spaced	Centred

Table 1. Schedule of tests

4.1 Pile/pier/stump and concrete bases

Each floor support was cast into a concrete base to simulate being cast into an in-situ concrete footing. The bases were sized to allow bolting to the laboratory strong floor by threaded rods passing through sleeves. The height of the base allowed for 450 mm embedment as required by AS 1684.2.

4.1.1 Concrete piles

The precast concrete piles were used to simulate all types of concrete based support systems. They were obtained locally and can be seen in Figure 2. The top diameter was 150 mm, base diameter 200 mm, and the piles were 750 mm in length.

Connecting plates were attached with a single screw bolt, 150 mm long and 16 mm shank diameter (Figure 3).

Figure 2. Concrete pile with screw bolt

Figure 3 Concrete pile with connector plate attached

4.1.2 Metal anchors

The metal anchors were sourced from Advanta-Pier, Victoria, as being representative of steel support systems commonly available. They were of galvanised steel hollow square section, formed from nested channels, of 75 x 75 mm overall size and wall thickness of 2.4 mm. They featured a telescopic top section to allow in-situ height adjustment. The top and bottom sections were fixed together by 8 Tek screws 5.34 mm diameter and 25 mm long with drill points. The anchors were modified by cutting off the vertical cleat on the top section, but leaving the side tags intact, as can be seen in Figure 4.

Connecting plates were attached with 6 Tek screws, as described above, drilled and screwed into the anchor tags.

Figure 4. Telescopic metal anchor (note cleat cut off top section on left and tags folded in for attaching connector plate)

4.1.3 Timber stumps

Timber stumps were sourced locally, and an example can be seen in Figure 5. They were CCA treated Radiata Pine house piles, 125 x 125 mm in section, and were cut to length to suit the test set up. This size is representative of those in AS 1684.2.

Connecting plates were attached with 14g x 100 mm long self drilling countersunk head Type 17 screws. Five screws were used for test one, and a symmetrical arrangement of 8 for the remainder.

Figure 5. Timber stump with plate fixing screw

4.2 Floor assemblies

Sections of prefabricated floor panels were constructed to attach to the supports. The panels used were based on Option E1 as described in the preliminary report submitted on 28th February. Corners of two panels abutting at an outside wall were constructed using a single plywood flooring sheet to secure them together for test. A test floor assembly is shown diagrammatically in Figure 6.

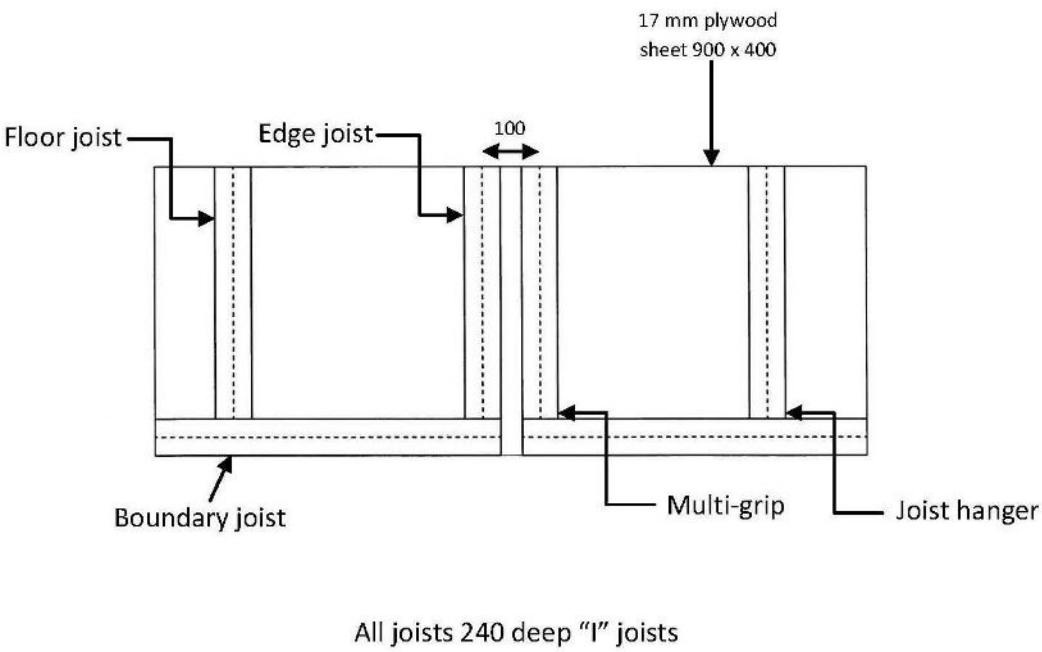

Figure 6. Floor assembly

RHS DPS

All specimens were initially made with the edge joists close butted together. However from Test 5 onwards they were altered by spacing them apart to allow for a 100 mm makeup flooring piece, as indicated in the figure.

4.3 Floor to support connections

Connection between floor and support was made with a connector plate attached to the support (as described in 4.1 above) and screwed to the floor assemblies (described in 4.2 above).

For all tests except 6 the plate was a steel plate similar to the one shown in Figure 7. For test 6 the steel plate was substituted by a 17 mm plywood plate to try and maximise the number of wood components in the system. The layout and holing were the same as the steel plates, and as shown in the figure.

The holes for the timber stump were countersunk to allow the floor assemblies to sit flat on the plate. The hole pattern was developed during the test series by trial and error. The intent was to allow one plate design to be used for all support types and all positions within the floor (edge situation with two panels landing – the arrangement as tested, or central situation with 4 panels landing).

The pattern of holes around the edge achieves this objective of a single plate design. It also provides clearance for post-fixing (from underneath) of the floor panels in any orientation without interference from any of the support systems. The 20 mm hole pitch allows sufficient flexibility for floor assemblies to attach with sufficient screws while allowing plenty of tolerance in the installation of the supports.

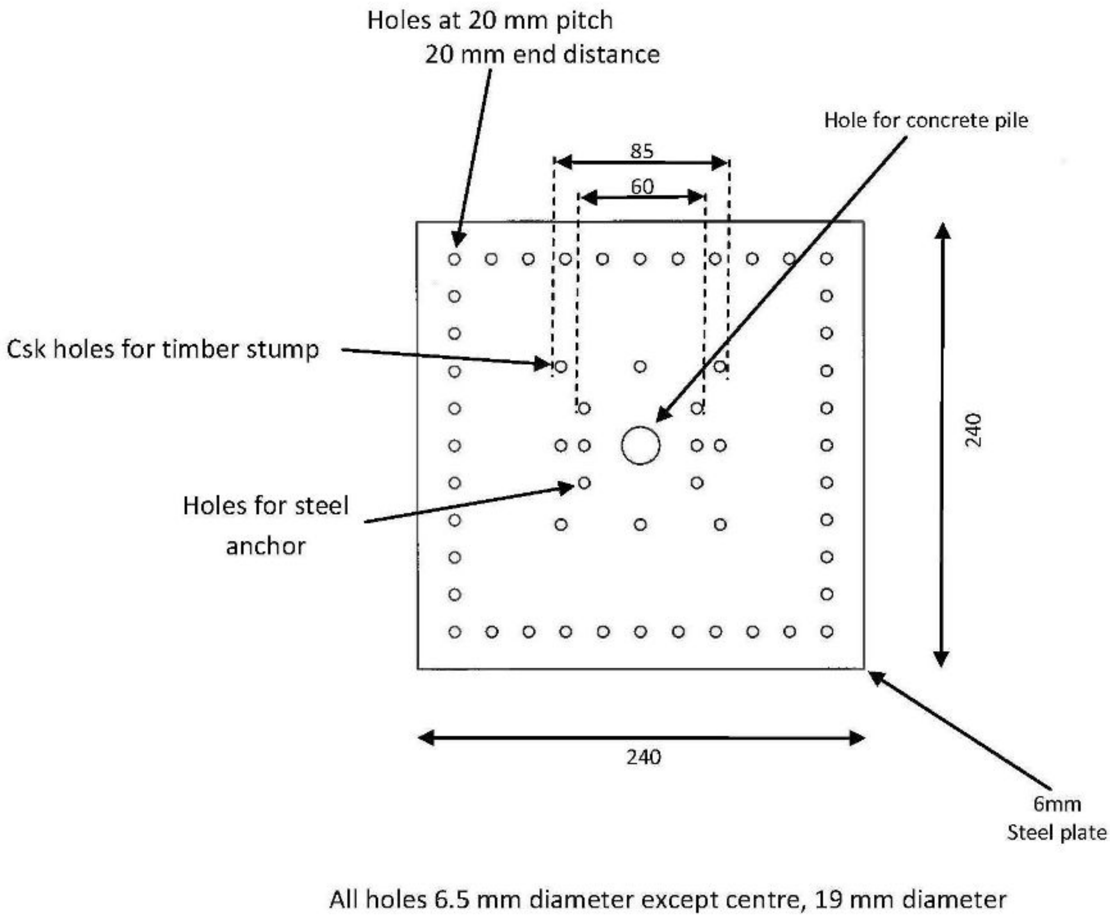

Figure 7. Connector plate layout (final version)

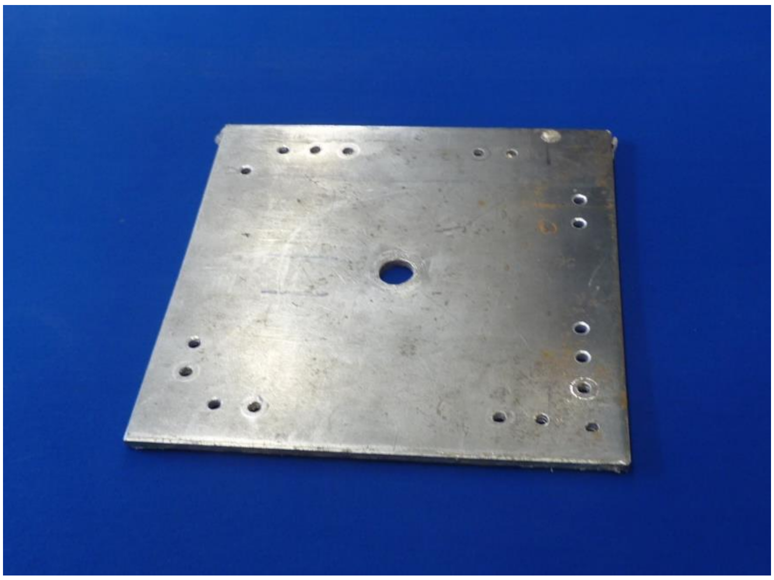

Figure 8. Steel connector plate during the course of development

RHS DPS

4.4 Construction of test specimens

Initially the floor assembly was positioned to allow concentric loading down through the line of the boundary joist (Figure 9). The connector plate was positioned offset so as not to interfere with wall or subfloor cladding or framing.

Figure 9. Initial floor/plate/support alignment

From test 6 onwards the connector plate was located central on the support, and the floor assembly moved forward to the edge of the plate (Figure 10). This produced eccentric loading on the specimen, but in practice this would be eliminated by the other three supports for each individual floor panel. The arrangement also has the advantage of allowing subfloor cladding to be positioned clear of the support, and permit alignment with the wall cladding above.

This arrangement was developed in conjunction with the plate holing design referred to in section 4.3.

RHS DPS

Figure 10. Connector plate central on support

5. DESCRIPTION OF THE TESTS

5.1 Date and Location

The testing was carried out during May 2012 at the Structures Testing Laboratory of BRANZ Ltd, Judgeford, Porirua City, New Zealand.

5.2 Test Setup and Equipment

A reaction frame bolted to the laboratory strong wall to permit vertical uplift load to be applied to each test specimen. Each foundation block was then bolted in turn to the laboratory strong floor as shown diagrammatically in Figure 1. The floor assembly was positioned over the support and connection was made using the connector system under development.

Tension load was applied through a load cell by a hydraulic ram operated by hand pump. Load was applied to the floor assembly through a 100 x 100 angle screwed to the joists to simulate the uplift load-path through an external wall and its various fixings.

The general arrangement can be seen in Figure 11.

Figure 11. General arrangement for test

Load was measured by a calibrated load cell within International Standard EN ISO 7500-1 1999 Grade 1 accuracy. The measurements were recorded using a data-logging system for subsequent analysis by spreadsheet.

5.3 Test Procedure

Load was applied to each specimen monotonically until failure. Observations were recorded manually and by video and still camera, and applied load was recorded electronically then analysed using an Excel spreadsheet. A video record was also made for distribution to other members of the project team.

RHS DPS

6. OBSERVATIONS

The support/connector/floor assemblies generally performed well, and in line with design expectations.

At low load levels the connector plates deformed by cupping upwards. At worst, this cupping distortion was estimated at about 5 mm corner to corner of the plate. Plate distortion was mostly elastic and largely recovered after load was removed.

Test one failed prematurely when two screws pulled out of the timber stump and the floor assembly tilted. The specimen became unstable and the load dropped off.

Test 6 also failed prematurely by rupture of the plywood connecting plate (Figure 12). The rupture was in a cross grain direction, which would have been weaker than longitudinal direction, but in practice there would be no control over ply grain/support orientation.

Figure 12. Plywood plate ruptured

The remainder of the specimens creaked distinctively as the increasing load stressed the floor components and eventually pulled the I joists apart. Most joists failed by the ply web parting from the LVL flanges (Figure 13) and some by delaminating the LVL flanges (Figure 14) and some by a combination of both.

Figure 13. Joist flange delamination

Figure 14. Joist web pulling out of flange

All floor assembly connections (joist hangers and multi-grips) remained intact throughout the test series.

All supports remained securely embedded in the concrete bases. No attempt was made to optimise the embedment length.

7. RESULTS

Peak applied loads and failure modes for each test are presented in Table 2.

Test	Peak load (kN)	Mode of failure
1	11.97	Screws pulled out of timber stump
2	25.51	Joists pulled apart
3	23.81	Joists pulled apart
4	24.02	Joists pulled apart
5	20.49	Joists pulled apart
6	9.84	Ply plate broke
7	19.82	Joists pulled apart
8	19.72	Joists pulled apart
9	19.94	Joists pulled apart

Table 2 Results and observations

It can be seen that generally the load limit was reached when the joists pulled apart. This failure mode is intrinsic to the floor joist system selected, and was not limited by the connecting or support system.

Tests 7, 8, 9 showed lower load values because the revised plate location caused eccentric loading on the test specimen which proved difficult to avoid without major alteration. In practice, resistance to the eccentricity would be provided by the other corner supports of the floor panels. Thus loads more in line with tests 2 to 5 could be expected. Two screws into each joist (8 in total for the support) were sufficient to resist the loads. The holing pattern was designed to achieve this.

The connecting system showed good tolerance to cope with expected realistic site conditions and proved straightforward to construct.

The results indicate that an uplift load of 19 to 20 kN could reasonably be expected from the flooring system as developed and tested. This is a value that would be satisfactory for most residential buildings in Australasia, excluding cyclonic regions. Its precise applicability with respect to site wind zones and building sizes will be the subject of further investigation later in this project.

8. LIMITATION

The results reported here relate only to the item/s tested.

Appendix 2
SR0968-2

Construction and load testing of full scale prefabricated floor panels at BRANZ.

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Construction and load testing of full scale prefabricated floor panels at BRANZ.

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2. INTRODUCTION

Four 5.4 x 2.7m floor panels were constructed by Pre-nail Frames and Trusses Ltd in accordance with the drawings shown in the Appendix. The design utilised 300 mm deep I Joists and LVL beams with 19mm particleboard flooring sheet deck.

The panels were subsequently erected on both lightweight concrete and cold formed adjustable metal supports (Advanta-Pier supplied by GTS Industries). The concrete supports were cut to size and adhesive fixed to the concrete foundations with a thin bed adhesive. The metal supports were fixed to the concrete foundations with screw bolts.

Perforated metal plates 280x280x2.5mm were fixed to the top of the supports to provide landing for and positive screw fixing to the floor panels.

The test panels were lifted into place by mobile crane using polypropylene straps inserted through cut outs immediately above the top flange and wrapped around the I-Joists at the four corners.

Initially the panels were placed with the long edges adjacent, incorporating two cantilevered connections and one 100 mm infill strip. After preliminary load testing, one panel was insulated with polystyrene sheets glued to the underside, and then two panels were moved so the four panels formed a rectangular floor plan 10.8 x 5.4m overall. Following further load testing, two of the panels were then shortened by a metre, and a final series of load tests was undertaken.

Load testing consisted of a 1 kN concentrated load in the centre of the panel and dynamic frequency testing. The test results were used to calibrate a computer simulation of the original and shortened floor panels.

3. LIMITATION

This test report describes the full scale floor testing undertaken as part of Milestone 4 Stage 4 of the laboratory testing as described in the project proposal for the FWPA sponsored project PNA244-1112 “Prefabricated lightweight timber ground floor systems”, to determine the structural adequacy of the floor support systems identified in Milestone 2 of the Design Phase.

There were three objectives for the full scale series of tests.

- To construct a trial floor system, using the prefabricated floor panels developed in the earlier phases of the development programme.
- To construct a floor consisting of 4 prefabricated panels as proof of concept and conduct basic load tests
- To develop a computer model of the test floor to pre-test critical floor parameters to help with adjusting the test floors as results came to hand.

4. DESIGN AND CONSTRUCTION OF THE TEST SPECIMENS

4.1 Design of panels

Panel design was based on Option E1 as described in the preliminary report submitted to FWPA on 28th February 2012. Drawings of the panels and the support structure are included in the Appendix to this report.

4.2 Construction of panels

Four 5.4 x 2.7 m floor panels were constructed by Pre-nail Frames and Trusses Ltd in accordance with detail sheets 2 and 3 of the drawings in the Appendix. The design utilised 300 mm deep I Joists and LVL beams with a 19 mm particleboard flooring sheet deck. A view of a panel ready for lifting into place can be seen in Photograph 1, and a detail of connections from the underneath in Photograph 2.

Photograph 1. Panel ready for erection. Lifting slings being inserted.

RHS DPS

Photograph 2. Connection detail beneath floor panel. Note joist hangers, nailplate connection between boundary joists, and screw connection to concrete support and plate.

Pre-nail Frames and Trusses Ltd had not previously manufactured prefabricated floor panels and fabrication was treated as a one off. Without the use of existing jigs the panels took longer to fabricate than estimated.

4.3 Foundations and support structure

The floor support structure is described on detail sheet 6 of the drawings in the Appendix.

The rectangular pad footings were sized to accommodate adjustments of up to a metre in floor spans and pier locations. The round ones were sized to provide adequate bearing on the foundation soil. They were all cast to a level consistent with the surrounding ground level which varied approximately 600 mm across the site.

The concrete supports were pre-cast aerated concrete blocks supplied to BRANZ by the local agent of Litebuilt Building Products, Melbourne. They were 200 x 200 mm in section and their lengths were cut to measure using a tungsten saw-blade to form a level top surface. Their measured density was 1,465 kg/m^3. They were fixed to the pads using Hebel thin bed adhesive.

The metal supports were Advanta-piers supplied by GTS Industries, Melbourne. They were fixed to the concrete foundations with screw bolts and adjusted to height as required. They are described in more detail in BRANZ Report ST0968/1.

RHS DPS

Perforated steel connector plates, of size 280 x 280 x 2.5 mm, were fabricated and fixed to the top of the supports to provide landing for, and positive screw fixing to the floor panels. They were similar to the connector plates described in more detail in BRANZ Report ST0968/1. They were fixed to the concrete supports by 4/90 x 10 countersunk head screw bolts (Photograph 3), and to the steel supports by 4/6mm self drilling Tek screws (Photograph 4).

Photograph 3. Concrete support pier with connector plate

Photograph 4. Steel support pier. Note upper telescoping section screwed to connector plate

4.4 Erection of the floors

The floor panels were lifted into place by mobile crane using 4 x 1 tonne Safe Working Load round, endless polyester slings inserted through circular cut outs in the particle board wrapped around the floor joists near the four corners of the panel (Photograph 5). The crane chains were attached to the slings.

Photograph 5. Lifting sling positioned through hole in particleboard

Panels were attached to the plates by 6 mm Type 17 self drilling screws, using a minimum of two screws per joist.

The trial floors were erected in three crane visits to the site:

- Panel 1 only was positioned on two concrete and two metal supports for preliminary investigations.
- All 4 panels were placed with the long edges adjacent in layout for test 2, as shown on detail sheet 1 of the drawings in the Appendix. The panel/panel joints incorporated two cantilevered connections and one 100 mm infill strip.
- After preliminary load testing, one panel was insulated with 40 mm thick polystyrene sheets glued to the underside of the flooring between the joists. This is described in more detail in BRANZ Report DUxxxx. Then panels 1 and 2 were moved, so the four panels formed a rectangular floor plan 10.8 x 5.4m overall (Panel layout 3 on drawing sheet 1).

The flat steel plates proved very easy to land the panels on and provided room for final position adjustment (if required) using a bar. Lifting and placing was quick and straightforward once initial teething problems were overcome, and the actual panel placing operation took less than 10 minutes of crane time. A general view of a panel being positioned can be seen in Photograph 6.

Photograph 6. Panel being lifted into position.

A video record of the floor erection operation was made for distribution to other members of the project team. A time lapse photographic record was created from a fixed camera overlooking the site and was also distributed to the project team.

On completion of testing, while the crane was still present, a panel was weighed to confirm the calculated weight (Photograph 7).

5. DESCRIPTION OF THE TESTS

5.1 Date and Location

The testing was carried out during August 2012, at the yard of BRANZ Ltd, Judgeford, Porirua City, New Zealand.

5.2 Subjective tests

Following placement of the first floor panel on its supports, members of the project team assessed the floor for bounce while walking and working on it. Opinion was fairly unanimous that it felt quite lively and needed to be firmer under walking and working conditions. In practice, many real floors would have additional stiffening in the form of walls and fitments, but there may well be instances where a 5 x 3 metre internal living space would have similar support conditions.

To create a record of this behaviour, a potentiometer was set up under the centre of the floor while the author (approximately 85 kg) walked across the diagonal of the panel and return. This measurement is reproduced as Figure 1.

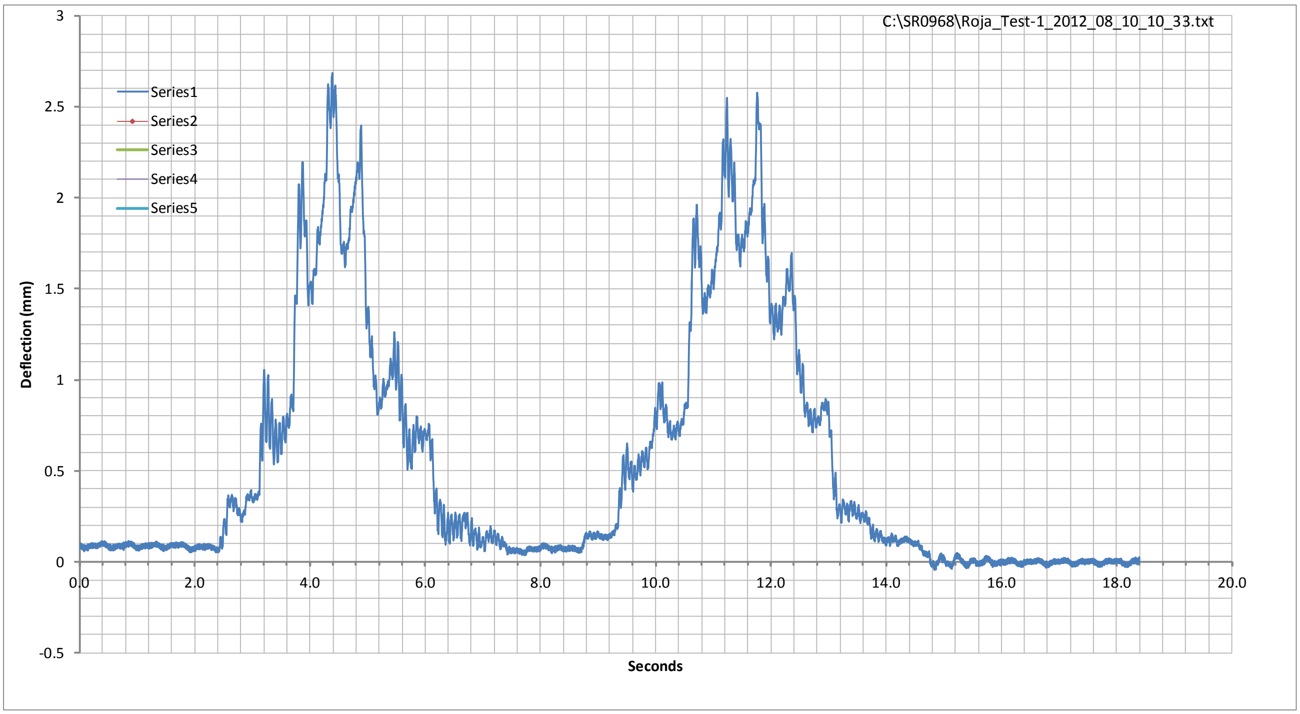


Figure 1. Deflection plot of a person walking across a floor panel.

5.3 Concentrated load tests

A number of authorities (for example National Building Code of Canada) suggest that a "rule of thumb" criteria to guard against problems with "lively" floors is that a floor system should deflect less than 1 to 2 mm under a concentrated load of 1 kN applied anywhere.

A 100 kg mass (equivalent to 1 kN) was applied by calibrated steel weights placed at the centre of floor panel 1. Deflection was measured by a potentiometer gauge mounted beneath the panel and reading through an in-house developed data acquisition system recording the data as text files for subsequent spreadsheet processing.

An example plot of the deflection record is shown in Figure 2. Note that the peaks are recording the weight of the two people lifting the weights into position so are not relevant. The recorded deflection for this test is 0.73 mm.

The results are summarised in Table 2.

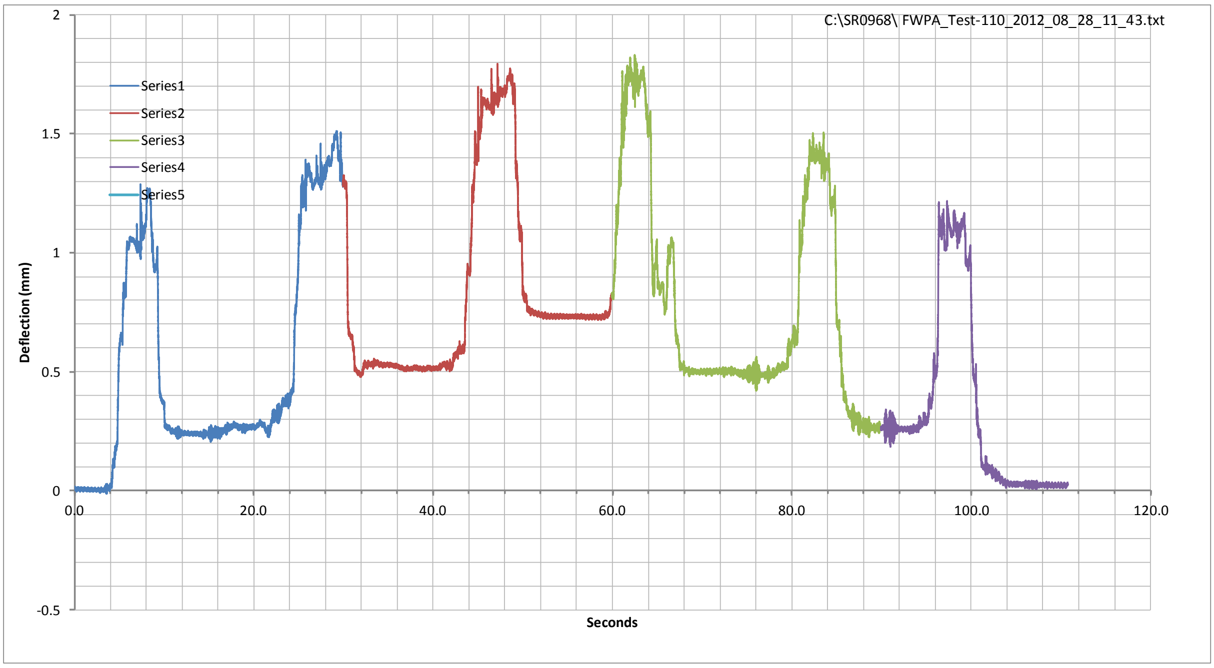


Figure 2. Deflection under a 1 kN weight at centre of panel (shortened panel)

Test number	Description	Deflection (mm)
3	Panel 1, 5.4 m span	1.22
110	Panel 2, 4.4 m span	0.73
115	Panel 1, 4.4 m span	0.85

Table 1. Results of concentrated load tests

5.4 Dynamic frequency tests

Serviceability performance relating to dynamic behaviour of a floor system is notoriously difficult to quantify or predict. Numerous studies (few relating specifically to timber framed floors) have suggested limits on minimum flexural rigidity, or ensuring that resonant frequencies are away from the human body's discomfort range of 1 to 6 Hz. Two commonly used criteria intended to provide a filter against human discomfort are a static deflection under a 1 kN load which has been referred to above, and a natural frequency above the range 8 Hz. There is no clear consensus that these criteria are effective and prediction methods are not particularly successful.

A recent study on timber floors (FWPA, PN04.2011 "Improving dynamic behaviour in lightweight engineered timber floors") suggests that lack of damping is a more effective performance criterion and an effective indicator of the number of complaints likely to be received relating to unsatisfactory floor behaviour. Methods of improving damping were suggested in the study but an investigation of these are beyond the scope of this section of the project. Surrounding construction, soft furnishings, presence of humans are all relevant, but are not a feature of the current study. However the presence of underfloor insulation was seen as a possible avenue to increase damping, and the thrust of the full scale floor tests was directed towards investigating that possibility.

An accelerometer was placed at the centre of floor panels 1 (after the insulation was applied, see 4.4 above) and 2 (bare floor), and readings were amplified and recorded through the data acquisition system for subsequent spreadsheet analysis. The panels were excited by a number of heel-drops from an 85 kg person and by striking lightly with a 700g hammer. The tests were carried out before and after the panels were shortened by one metre.

Damping was assessed by superimposing a damping decay curve onto a plot of the measured floor response as shown in Figure 3, and fitting it by adjusting the damping ratio and frequency.

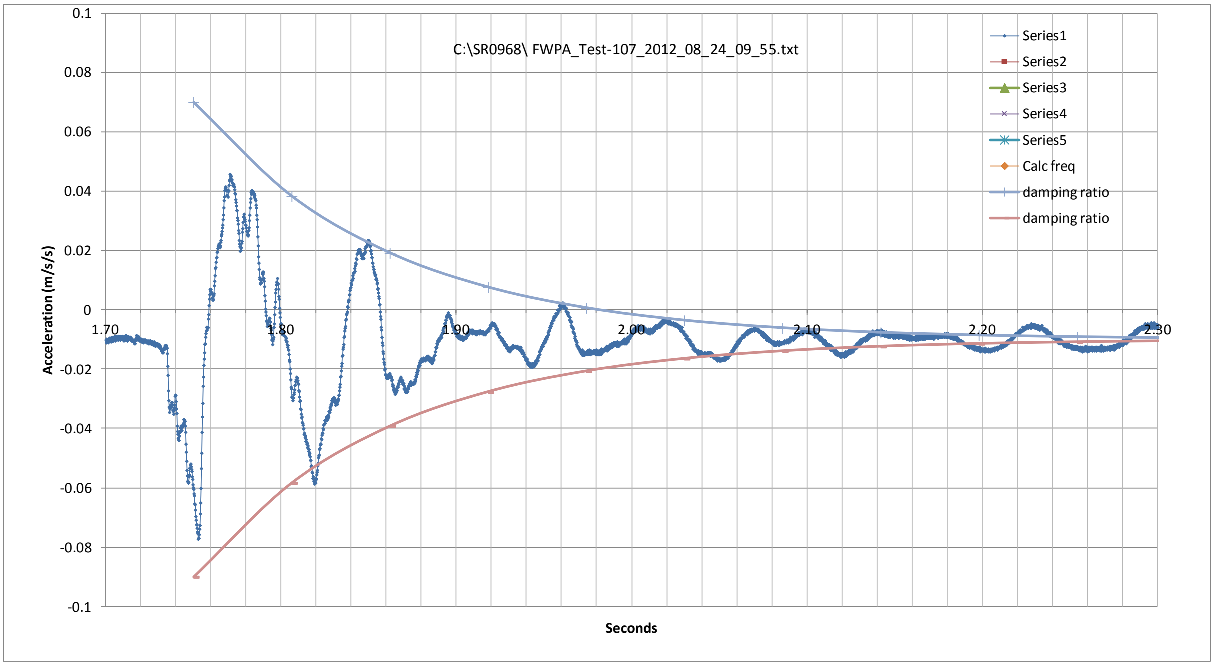
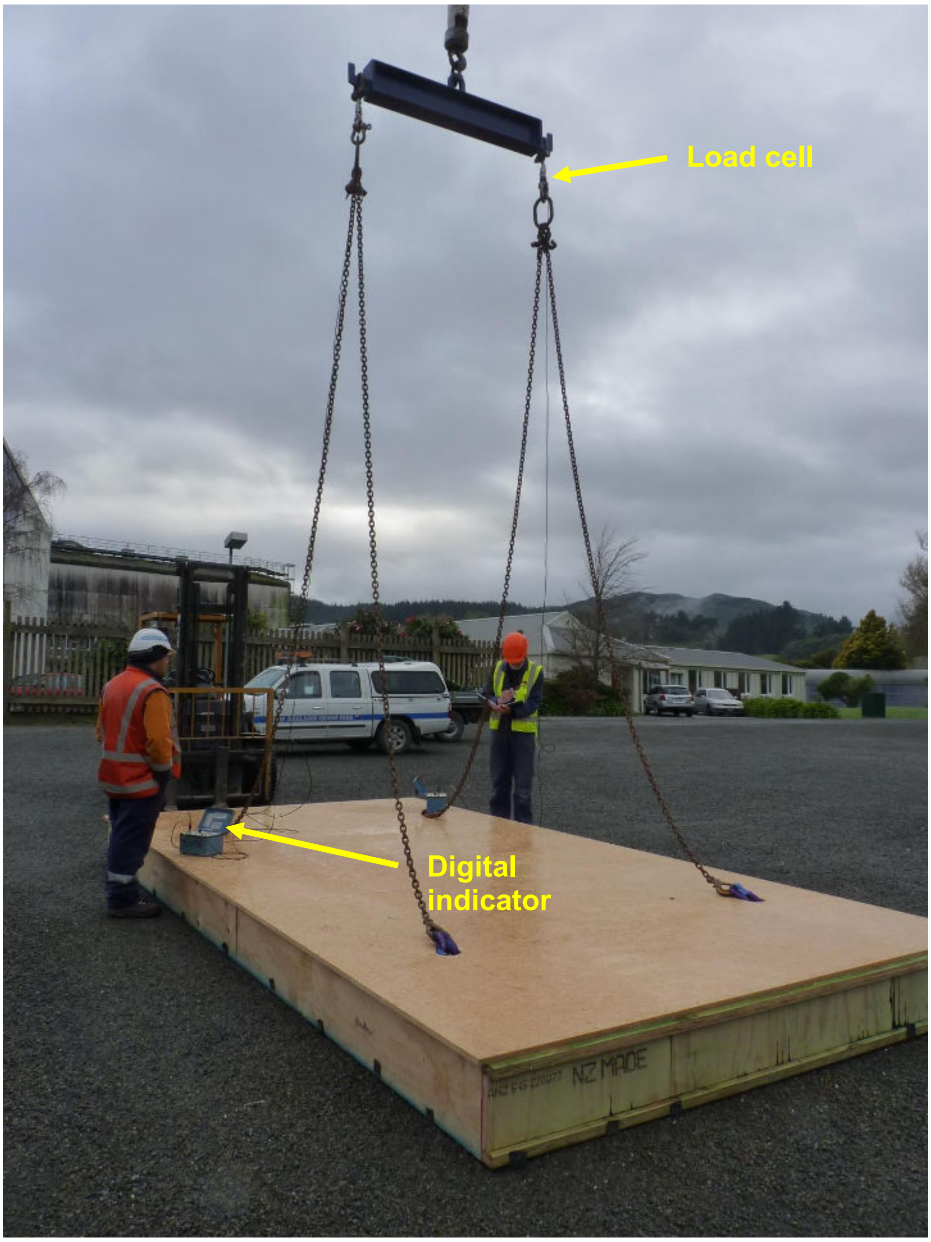


Figure 3. Damping decay curve superimposed on vibration record

Results were highly variable, but did show that the presence of the insulation increased the damping by up to 30% over the bare floor. It is suggested that these measurements could be repeated on the proposed trial house construction to be undertaken in Melbourne.

5.5 Panel weight

During the floor re-arrangement process, panel 1 was weighed by suspending it from the crane with a spreader beam and two load cells, reading through a pair of strain bridge circuits with digital readout indicators (see Photograph 7).



Photograph 7. Floor panel being weighed

The results are tabulated below.

Component	**Reading (kN)**	**Mass (kg)**
Floor panel (LC 1)	2.9	296
Floor panel (LC 2)	2.3	234
Lifting chains		50
Net weight of panel		480

The 480 kg compares with a weight calculated from manufacturer's literature of about 466 kg. The difference is likely to be due to the moisture content of the test panel (particularly the particleboard which had been exposed to rain for some time - although its surface was sealed).

6. COMPUTER SIMULATION

Computer models of panels 1 and 2 were constructed using Space Gass proprietary structural analysis software. The model is shown in stick format in Figure 4. Member section properties were taken from manufacturer's datasheets. For the purposes of these tests a central concentrated load of 1 kN was applied to the centre of the panels, although normal dead and imposed loads from domestic occupancy or walls etc, could be applied in future. This latter process would be essential when floors are designed to fit into actual buildings whose configurations differed from the test panels.

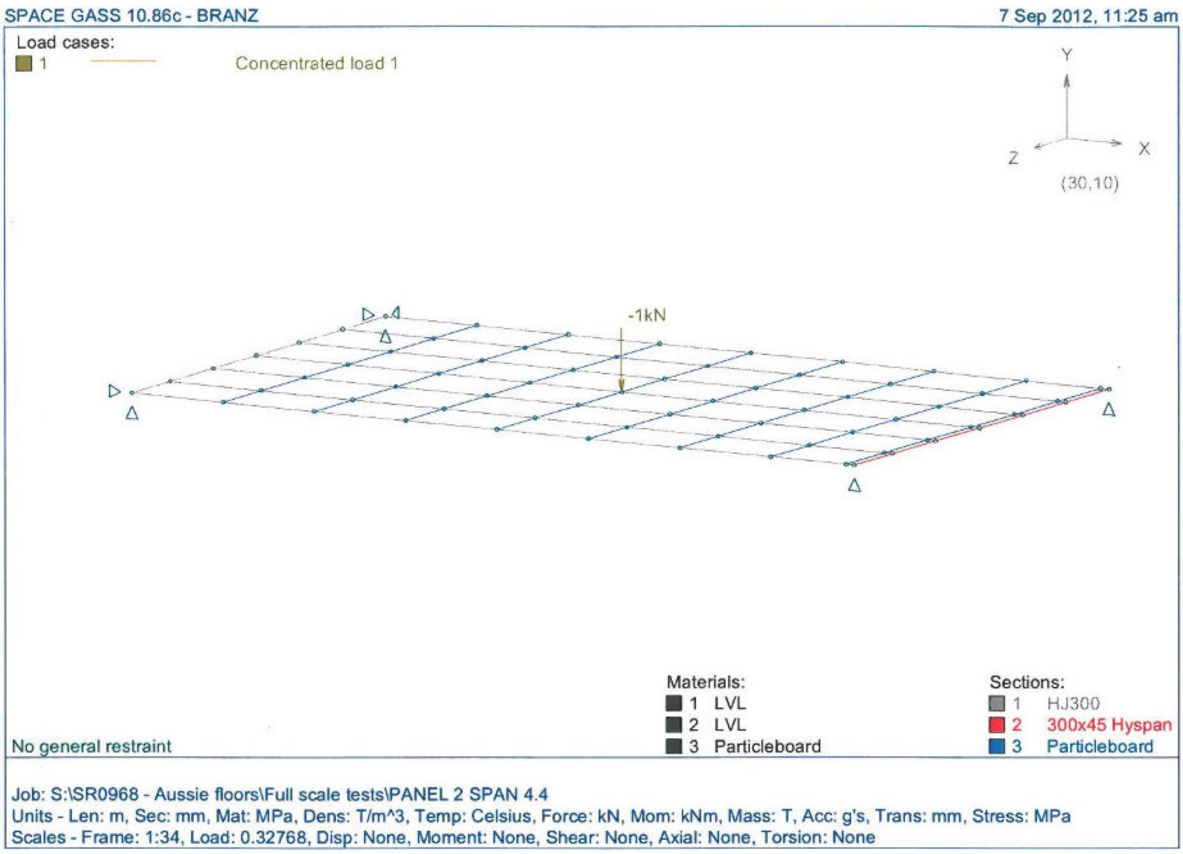


Figure 4 Analysis model

Once the load test results became available, the models were calibrated by adjusting the modulus of elasticity of the materials so the deflection agreed with the measured deflection. The values finally used were 15,000 MPa for the LVL components and 3,600 MPa for the particleboard.

Both models were then modified by shortening, to the same extent that the full scale specimens were, and the analyses were re-run.

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Dynamic frequency analyses were also run to determine the frequencies and mode-shapes of the first 6 modes of vibration. A summary of the analysis results (after calibration), and a comparison with the measured test values are presented in Table 2.

Floor panel	Test deflection (mm)	Calculated deflection (mm)	Calculated frequency (Hz)	
			1st mode	2nd mode
Panel 1 (5.4m)	1.22	1.2	14.2	16.4
Panel 2 (5.4m)	-	1.2	14.1	16.0
Panel 1 (4.4m)	0.85	0.84	19.2	23.9
Panel 2 (4.4m)	0.73	0.84	18.9	23.5

Table 2. Analysis results summary

7. CONCLUSION

The floor panels proved straightforward to construct and erect, putting aside teething problems associated with an untried system. Full scale testing reproduced analysis results in general, and a floor span was determined which is unlikely to be too vibration prone under normal pedestrian traffic.

8. LIMITATION

The results reported here relate only to the item/s tested.

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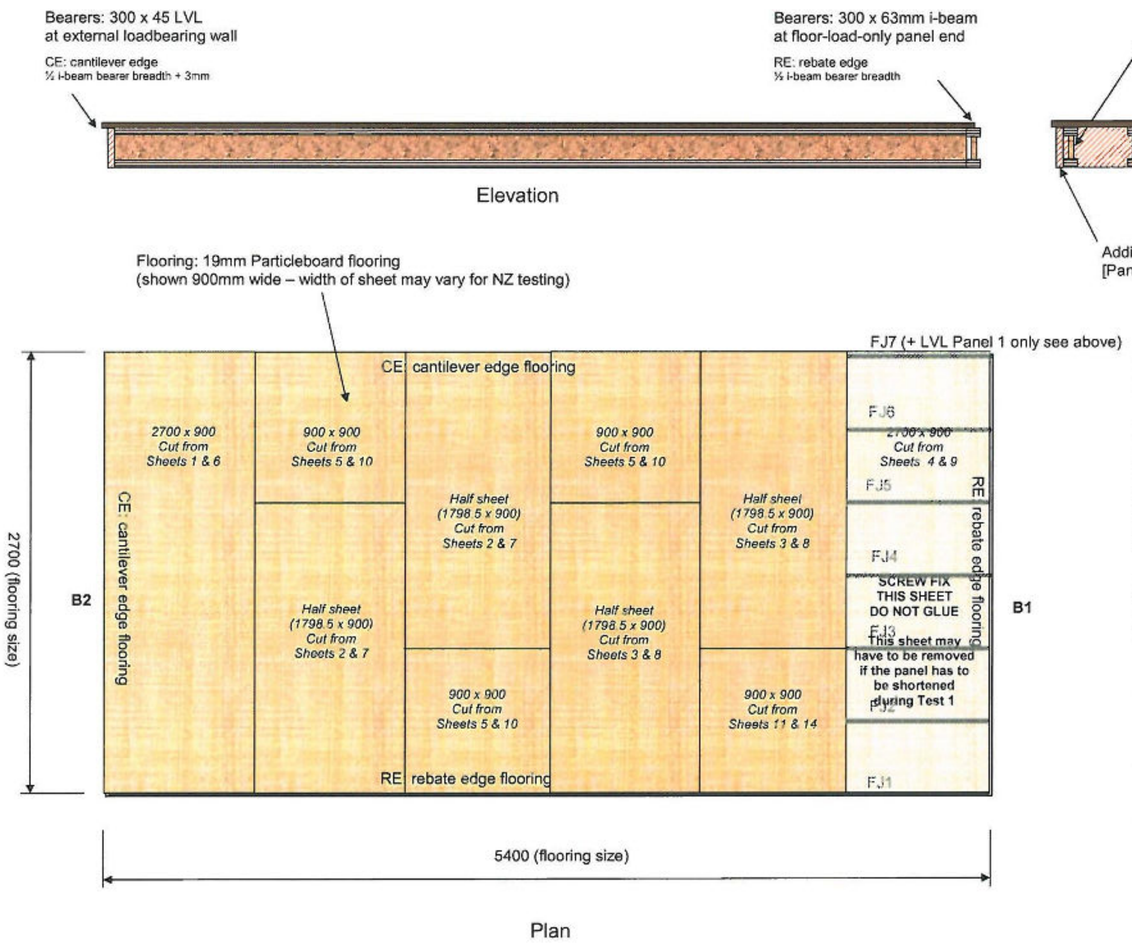
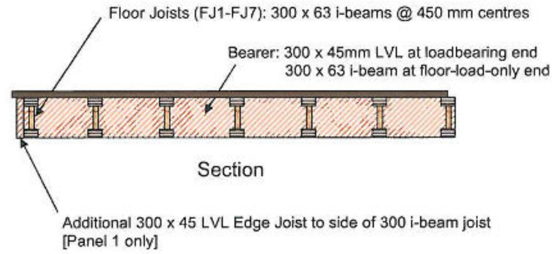
9. APPENDIX

RHS DPS





Floor Joists (FJ1-FJ7):
Nelson Pine: 300 x 63 i-beams @450mm centres

Face Fix Joist Hangers:
Use only face fix joist hangers and block between the flanges of the i-beam bearer where fixing is required.
Fix joist hangers generally using 30 x 3.15 galv bracket nails (LVL end), but screw the boots on at the end of the panel with the removable floor sheet (i-beam end), as shown, using 35 x 8 gauge bugle head screws or similar.

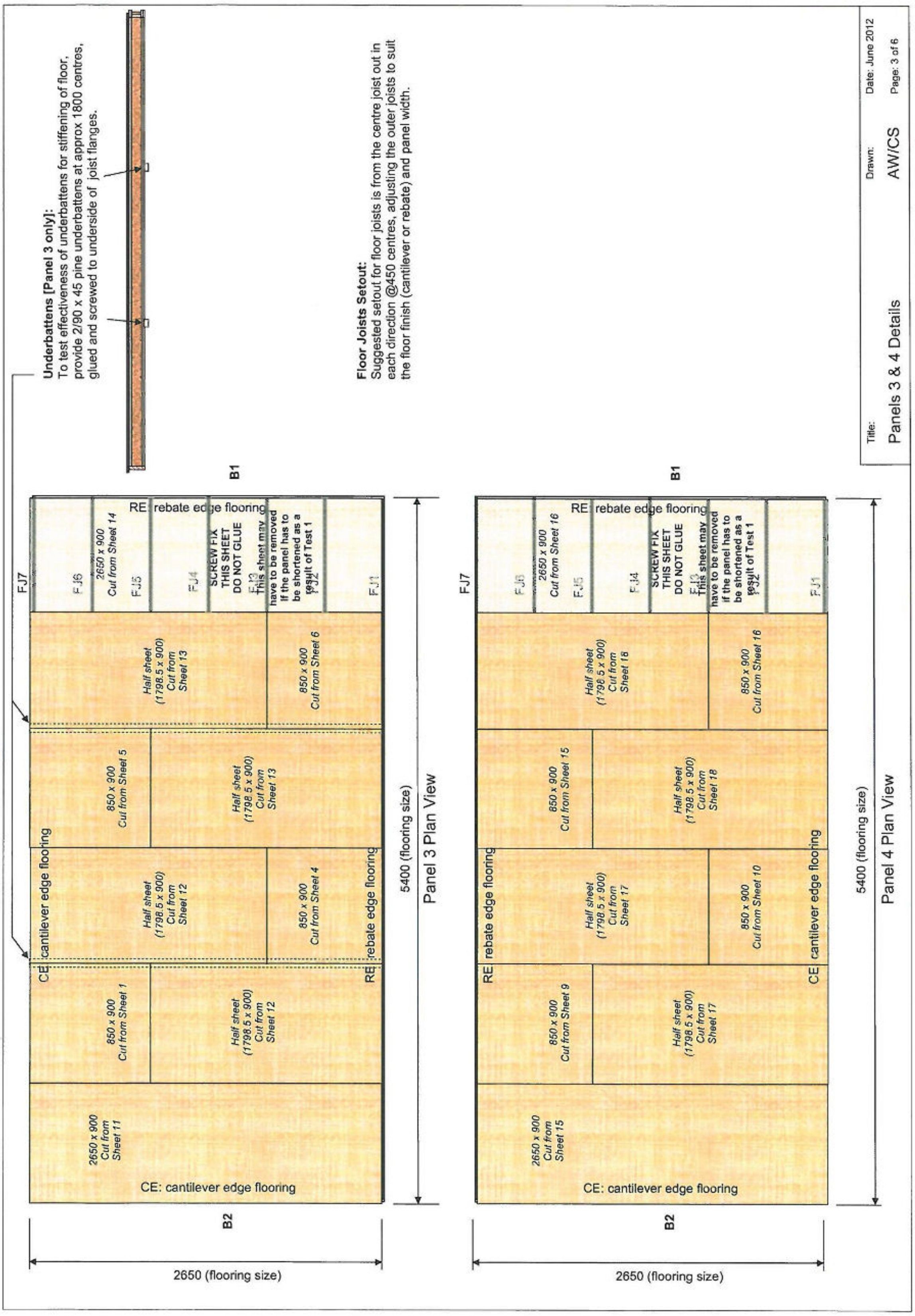
Floor Joists Setout:
Suggested setout for floor joists is from the centre joist out in each direction @450 centres, adjusting the outer joists to suit the floor finish (cantilever or rebate) and panel width.

Bearers:
B1: 300 x 63 i-beam; B2: 300 x 45 LVL

Flooring:
19mm particleboard flooring generally glued and nailed using construction adhesive and 65mm nails @ 150 cts along ends of sheets and @ 200 cts through the rest of the sheet.
Screw fix last sheet on each panel as shown using 50 x 8 gauge type 17 screws at similar spacings.

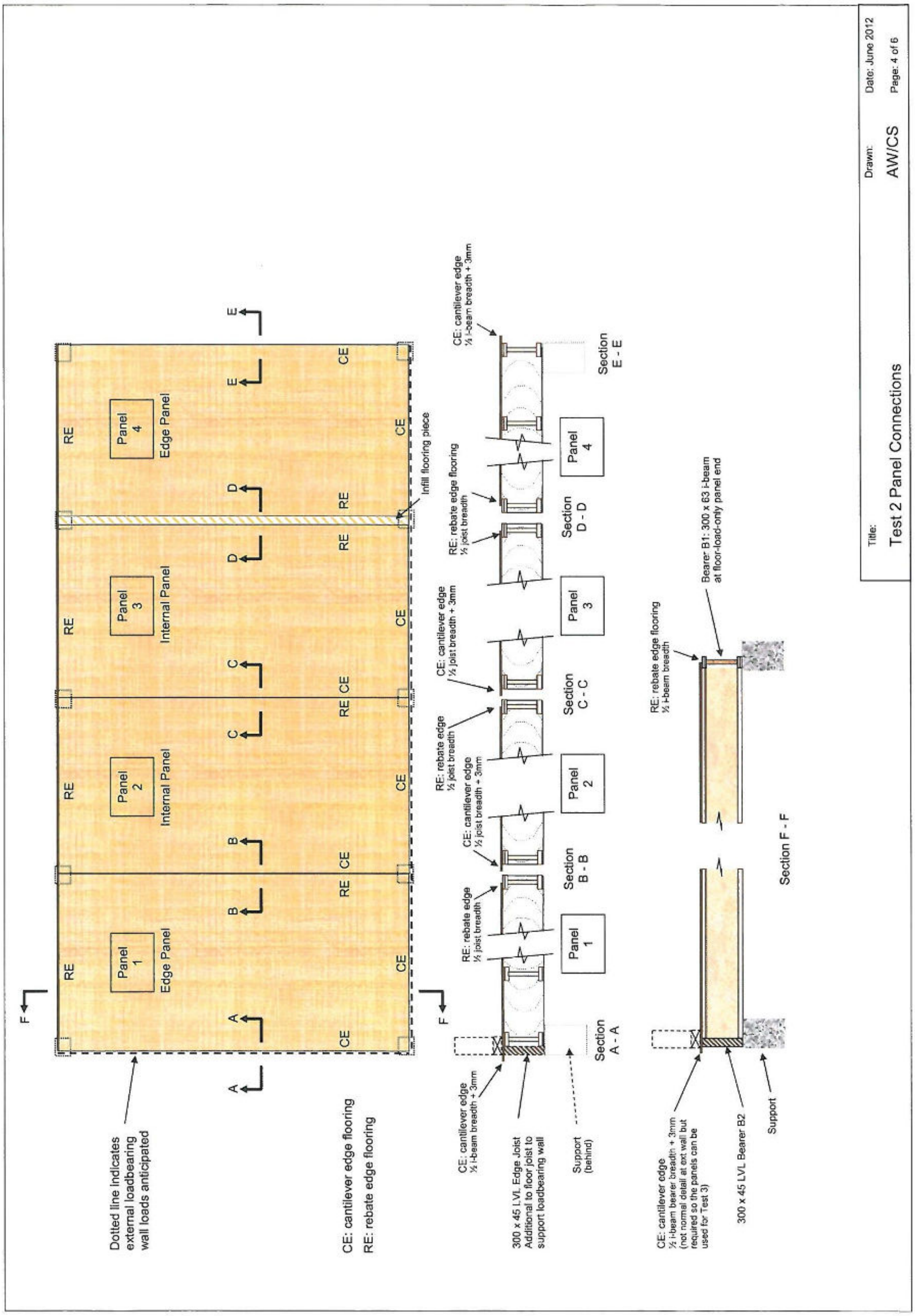
Title:	Drawn:	Date: June 2012
Panels 1 & 2 Detail	AW/CS	Page: 2 of 6

RHS DPS

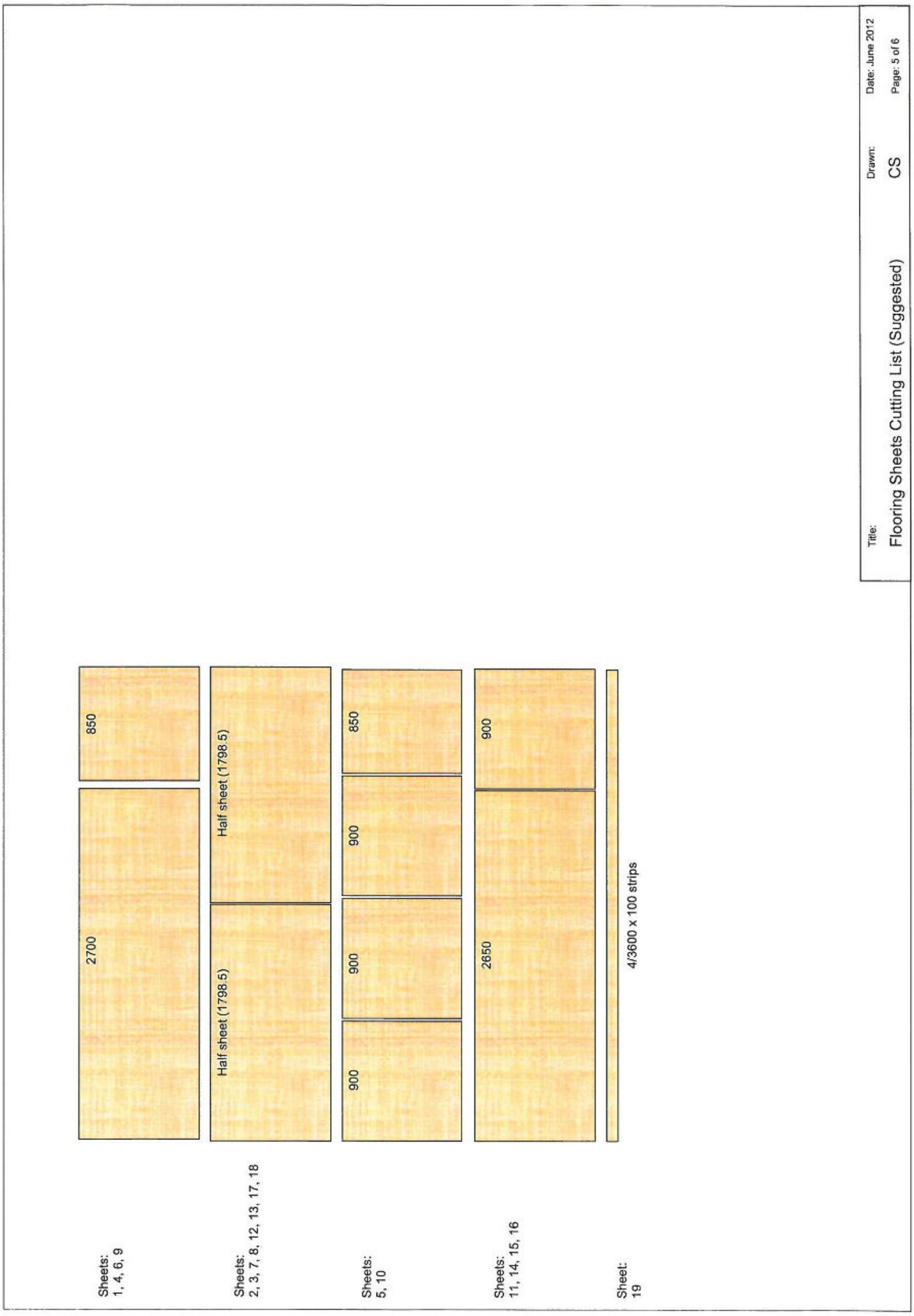

Underbattens [Panel 3 only]:
To test effectiveness of underbattens for stiffening of floor, provide 2/90 x 45 pine underbattens at approx 1800 centres, glued and screwed to underside of joist flanges.
Floor Joists Setout:
Suggested setout for floor joists is from the centre joist out in each direction @450 centres, adjusting the outer joists to suit the floor finish (cantilever or rebate) and panel width.
B1
B2
FJ7
FJ6
FJ5
FJ4
FJ3
FJ2
FJ1
RE: rebate edge flooring
CE: cantilever edge flooring
CE cantilever edge flooring
RE rebate edge flooring
2650 x 900 Cut from Sheet 14
2650 x 900 Cut from Sheet 16
SCREW FIX THIS SHEET DO NOT GLUE
This sheet may have to be removed if the panel has to be shortened as a result of Test 1
Half sheet (1798.5 x 900) Cut from Sheet 13
Half sheet (1798.5 x 900) Cut from Sheet 12
Half sheet (1798.5 x 900) Cut from Sheet 18
Half sheet (1798.5 x 900) Cut from Sheet 17
850 x 900 Cut from Sheet 6
850 x 900 Cut from Sheet 5
850 x 900 Cut from Sheet 4
850 x 900 Cut from Sheet 1
850 x 900 Cut from Sheet 16
850 x 900 Cut from Sheet 15
850 x 900 Cut from Sheet 10
850 x 900 Cut from Sheet 9
2650 x 900 Cut from Sheet 11
2650 x 900 Cut from Sheet 15
5400 (flooring size)
2650 (flooring size)
Panel 3 Plan View
Panel 4 Plan View
Title:
Panels 3 & 4 Details
Drawn:
AW/CS
Date: June 2012
Page: 3 of 6

RHS

DPS

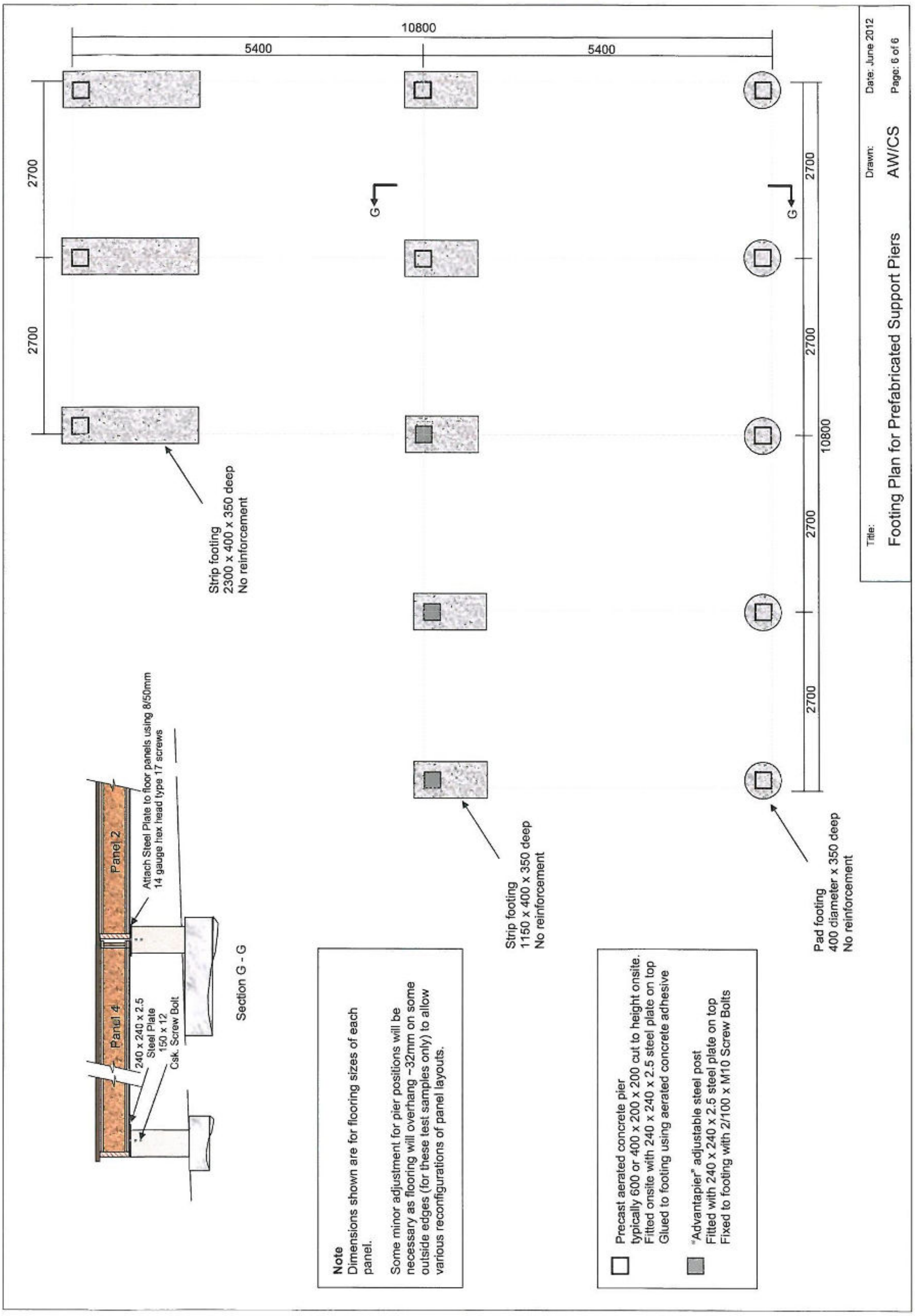

Panel 1
Edge Panel
Panel 2
Internal Panel
Panel 3
Internal Panel
Panel 4
Edge Panel
RE
CE
Infill flooring piece
Dotted line indicates external loadbearing wall loads anticipated
CE: cantilever edge flooring
RE: rebate edge flooring
Section A - A
Section B - B
Section C - C
Section D - D
Section E - E
Section F - F
CE: cantilever edge ½ I-beam breadth + 3mm
300 x 45 LVL Edge Joist Additional to floor joist to support loadbearing wall
Support (behind)
RE: rebate edge ½ joist breadth
CE: cantilever edge ½ joist breadth + 3mm
RE: rebate edge flooring ½ joist breadth
RE: rebate edge flooring ½ I-beam breadth
Bearer B1: 300 x 63 I-beam at floor-load-only panel end
CE: cantilever edge ½ I-beam bearer breadth + 3mm (not normal detail at ext wall but required so the panels can be used for Test 3)
300 x 45 LVL Bearer B2
Support
Title:
Test 2 Panel Connections
Drawn:
AW/CS
Date: June 2012
Page: 4 of 6

RHS DPS


Sheets:
1, 4, 6, 9
2700
850
Sheets:
2, 3, 7, 8, 12, 13, 17, 18
Half sheet (1798.5)
Half sheet (1798.5)
Sheets:
5, 10
900
900
900
850
Sheets:
11, 14, 15, 16
2650
900
Sheet:
19
4/3600 x 100 strips
Title:
Flooring Sheets Cutting List (Suggested)
Drawn:
CS
Date: June 2012
Page: 5 of 6

RHS

DPS



10800
5400
5400
2700
2700
2700
2700
2700
2700
10800
G
G
Strip footing
2300 x 400 x 350 deep
No reinforcement
Strip footing
1150 x 400 x 350 deep
No reinforcement
Pad footing
400 diameter x 350 deep
No reinforcement
Panel 4
Panel 2
240 x 240 x 2.5
Steel Plate
150 x 12
Csk. Screw Bolt
Attach Steel Plate to floor panels using 8/50mm
14 gauge hex head type 17 screws
Section G - G
Note
Dimensions shown are for flooring sizes of each panel.
Some minor adjustment for pier positions will be necessary as flooring will overhang ~32mm on some outside edges (for these test samples only) to allow various reconfigurations of panel layouts.
Precast aerated concrete pier
typically 600 or 400 x 200 x 200 cut to height onsite.
Fitted onsite with 240 x 240 x 2.5 steel plate on top
Glued to footing using aerated concrete adhesive
"Advantapier" adjustable steel post
Fitted with 240 x 240 x 2.5 steel plate on top
Fixed to footing with 2/100 x M10 Screw Bolts
Title:
Footing Plan for Prefabricated Support Piers
Drawn:
AW/CS
Date: June 2012
Page: 6 of 6

RHS

DPS

Appendix 3
SR0968-DU01

Thermal resistance of a prefabricated timber floor system insulated with EPS

Author: Ian Cox-Smith
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Reviewer: Roger Stanford
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   iii. BRANZ is neither an insurer nor a guarantor and disclaims all liability in such capacity. Clients seeking a guarantee against loss or damage should obtain appropriate insurance.
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   vii. BRANZ shall have no liability for any indirect or consequential loss (including loss of profits).
   viii. In the event of any claim the Client must give written notice to BRANZ within 30 days of discovery of the facts alleged to justify such claim and, in any case, BRANZ shall be discharged from all liability for all claims for loss, damage or expense unless legal proceedings are commenced in respect of the claim within one year from:
      - The date of performance by BRANZ of the service which gives rise to the claim; or
      - The date when the service should have been completed in the event of any alleged non-performance.

b. Indemnification: The Client shall guarantee, hold harmless and indemnify BRANZ and its officers, employees, agents or subcontractors against all claims (actual or threatened) by any third party for loss, damage or expense of whatsoever nature including all legal expenses and related costs and howsoever arising relating to the performance, purported performance or non-performance, of any Services.

c. Without limiting clause b above, the Client shall guarantee, hold harmless and indemnify BRANZ and its officers, employees, agents or subcontractors against all claims (actual or threatened) by any party for loss, damage or expense of whatsoever nature including all legal expenses and related costs arising out of:
   i. any failure by the Client to provide accurate and sufficient information to BRANZ to perform the Services;
   ii. any misstatement or misrepresentation of the Outputs, including Public Outputs;
   iii. any defects in the Products the subject of the Services; or
   iv. any changes, modifications or alterations to the Products the subject of the Services.

Thermal resistance of a prefabricated timber floor system insulated with EPS

1. CLIENT

Forest and Wood Products Australia
Level 4, 10-16 Queen Street
Melbourne VIC 3000

2. LIMITATION

The results reported here relate only to the item/s tested.

3. TEST SPECIMEN

The test panel was constructed at BRANZ Judgeford laboratories and insulated by BRANZ staff using expanded polystyrene (eps) insulation products sourced by BRANZ.

The test specimen consisted of a fully horizontal floor frame of 19mm particle board supported on 300mm deep engineered I-joists wtih LVL flange and a plywood web,. The support beams were spaced at 450 mm centres. The underside of the panel was un-lined and insulated with a combination of 40 & 60 mm expanded polystyrene sheets. .. The upper 40 mm layer of insulation was cut to fit between the support beam flanges and the lower 60 mm layer of insulation was cut to fit between the support beam webs. The combination was held in place using brackets attached to the side of the support beam webs.

4. APPARATUS

See Figure 2.

- Two insulated, open faced, temperature controlled chambers plus associated external heating and cooling equipment
- A large diameter, slow rotation, mixing fan in each chamber
- Insulated heat flow metering box (meter box) including DC electrical heating elements and circulation fans
- Precision programmable power supply for driving of metering box fans and measurement of their power consumption
- Precision programmable power supply for heating the metering box and measurement of the heating power
- 25 element thermopile imbedded into the interior and exterior surfaces of the walls and back face of the meter box
- 16 pairs of type 'T' thermocouples for measuring the air-to-air temperature difference between the two chambers

- 2 sets of 16 pairs of type 'T' thermocouples for measuring the air-to-surface temperature difference on the faces of the test specimen. Because the underside of the floor was unlined it was not possible to measure the surface temperatures on the underside (cold side) so the air-to-surface temperature difference was only measured for the top surface (warm side) of the floor panel.
- PC based data acquisition and control system with sampling every 5 seconds and data recording at 1 minute intervals

Figure 1. Guarded Hot Box with floor panel installed.

4.1 Chambers

The test apparatus was the BRANZ Guarded Hot Box which consists of two insulated chambers of approximate face area 2.4 m x 2.2 m, with an internal depth of 1.2 m. The four sides and one face of the chambers include 100 mm of rigid foam insulation (R 2.6 m^2K/W). The open faces of the chambers are held against the faces of the test specimen. The test specimen was sandwiched between the faces of the two chambers. The temperature of the air in the two chambers is controlled independently using heating and cooling equipment which is connected to the chambers using 300 mm diameter supply and extract ducts on opposite sides of each chamber. There is also a large diameter, slow rotation, mixing fan in each chamber.

4.2 Metering Box

One chamber is kept warmer than the other so that there is a constant temperature difference across the test specimen, generating a constant heat flow, which is measured using a 1.2 m x 1.2 m face area metering box. The 2.4 m x 2.2 m

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dimensions of the test specimens allows for a so called 'guard' area of at least 500 mm between the edges of the metering box and the perimeter of the specimen. The guard area minimizes lateral heat flow in the test specimen near the metering area. The metering box has a depth of 240 mm including 50 mm of rigid foam insulation (R 2.0 m^2K/W) on all four sides and the back face. The front face is open and is kept against the face of the specimen under test.

Inside the metering box there are DC electrical heating elements and mixing fans. Fans and baffles within the metering box produce air movement in one direction against the face of the sample. Imbedded into the surfaces of the four sides and one face of the metering box is a 25 element thermopile, which gives a null output when the resistive heating power plus fan power supplied to the inside of the metering box is such that the inside surfaces are being maintained at exactly the same temperature as the outside surfaces. There is then no heat flow through the walls and back face of the metering box and all of the heating energy is therefore being transferred by air movement through the open front face, and then by conduction through the specimen.

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Figure 2. Schematics of Guarded Hot Box Apparatus

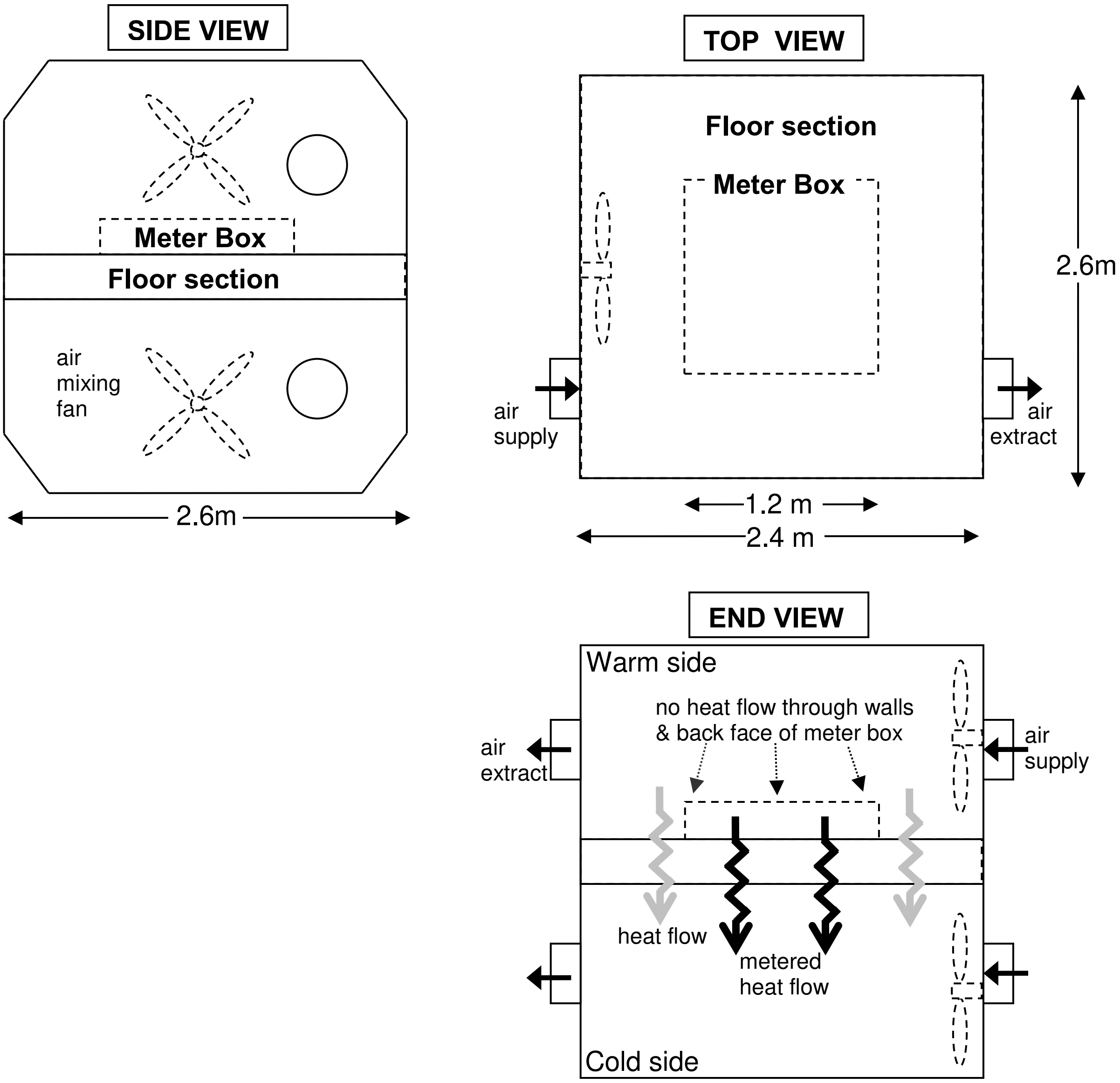

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Figure 3. Floor frame from below with combined 40mm & 60mm EPS

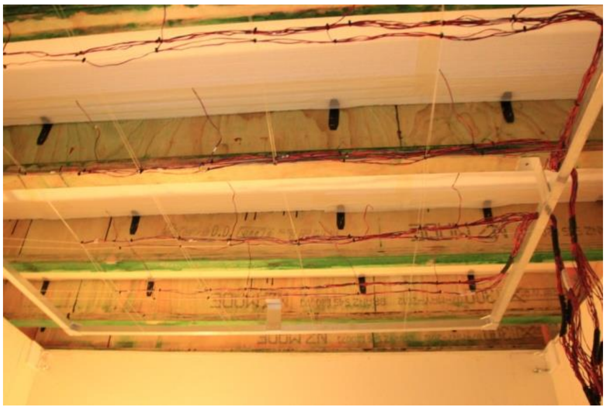


Figure 4. Metering box in upper chamber

4.3 Thermocouples

The air-to-air temperature difference between the two chambers is measured using 16 pairs of type 'T' thermocouples. Air-to-surface temperature difference on the top face of the sample was measured using a set of 16 thermocouple pairs. Because the thermocouples form differential pairs, there is no need to measure and include a junction temperature into the determination of temperature difference, leading to increased accuracy and precision above what is normally expected from thermocouple based temperature measurement. All of the thermocouple wire used in association with the apparatus comes from a single batch of wire for which the particular temperature characteristic has been determined.

5. METHOD

The apparatus is constructed and operated according to ASTM C1363-97. The test method requires steady-state conditions and therefore does not simulate such effects as the combination of climatic variation and thermal mass. In fact the measurement takes at least three days to allow one day for the initial response to the change in temperature and two days to determine that there were no slow changes in behaviour due to moisture movement in the specimen or exterior environmental effects on the test chambers. The final R-value is determined by averaging the measurements over at least 24 hours.

The measured total input power to the meter box, including fans, divided by the meter box face area of 1.44 m^2 gives the heat flux in Watts per square metre. The measured temperature difference between the air in the two chambers, divided by the heat flux, gives the air-to-air R-value of the test specimen. The air-to-air R-value includes two air-to-surface resistances, one of which was determined by measuring the difference between the temperature of the air near the top surface of the flooring and the surface temperature of the floor. The air-to-surface resistance of the underside of the floor panel was not measured.

The area measured by the meter box includes three I-joists. Because the metering box width of 1200 mm is not an exact multiple of the three beams spaced at 450 mm centres, the measured R-value was biased low. The measured results were then theoretically adjusted, using two dimensional finite element modelling, to the correct area weighting of I-joists.

The thermal conductivity of a specimen of the insulation was measured using test method ASTM C518 in the BRANZ heat flow meter instrument (LaserComp Fox 600).

6. DEVIATIONS FROM STANDARD TEST METHOD

This test did not fully comply with the following provision of Test Method C1363:

- Surface air velocities were not measured
- The moisture content of the individual materials has not been measured
- The actual densities of the materials have not been measured
- The surface heat transfer coefficient was only measured for the upper surface of the floor frame but not for the lower surface (the surface of the fibrous insulation)

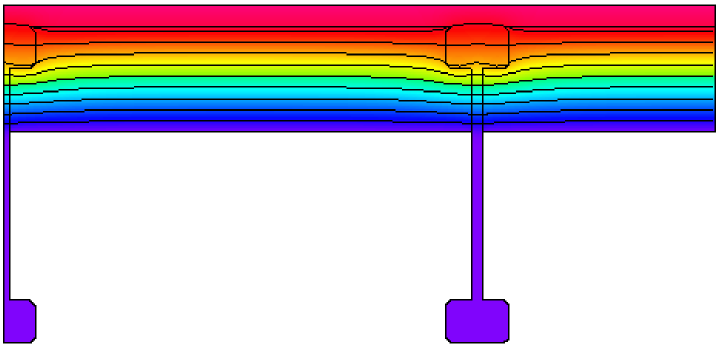
Although surface air velocities were not measured, the surface-to-air temperature difference and hence surface thermal resistance value of the top surface has been measured. The surface thermal resistance on the cold side is measured when the test sample has a solid surface on which to attach the thermocouples and is typically about 0.02 m^2K/W.

7. RESULTS

Table 1. Floor panel test results

Insulation System	40 mm + 60 mm EPS
ASTM C518 measured R-value at 20°C for 100 mm of the EPS insulation	2.46 m^2K/W
Test period	3rd to 10th Sept 2012
Temperature stabilisation	4 days
Test interval after temperature stability achieved	3 days
Approx. mean sample temperature	20°C
Approx. cold side air temperature	12°C
Approx. warm side air temperature	28°C
Air-to-air temp. difference	15.39 K
Total heating power over 1.44 m^2 metering area	9.89 W
Heat flux	6.87 W/m^2
Warm side air-to-surface temperature difference	0.11 K
Warm side surface resistance	0.02 m^2K/W
Assumed cold side surface resistance	0.02 m^2K/W
Measured system air-to-air thermal resistance (R-value) ± 10%	**2.24 ± 0.22 m^2K/W**
Calculated system R-value for metering area and actual mean temperature of 20 °C using HEAT2 finite element modelling	2.35 m^2K/W
Difference of measured R-value from calculated (m^2K/W)	**-5%** (-0.11)
ASTM C518 measured R-value at 23°C for 100 mm of the EPS insulation	2.44 m^2K/W
standard surface resistances – combined hot & cold surfaces (m^2K/W)	0.15 m^2K/W
Calculated system R-value for 450 mm I-joist spacing, mean temperature of 23°C, and standard surface resistances (m^2K/W)	2.47 m^2K/W
Measured system R-value adjusted to same conditions (m^2K/W)	**2.35 ± 0.24 m^2K/W**

Figure 5. Example of HEAT2 finite element modelling results



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8. MODELLING

Figure 6. Options for modelling:

layer 1 either 40 mm EPS or airspace (either reflective or not)
layer 2 60 mm EPS
layer 3 additional 40 mm EPS

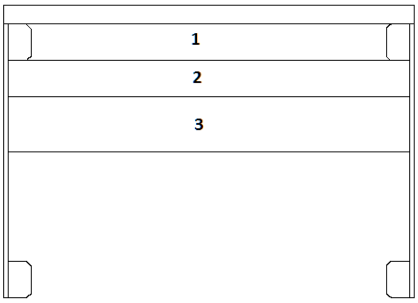

Table 1. Modelling results

Layer			R-value (m^2K/W)	
1 40 mm	**2** 60 mm	**3** 40 mm	Winter downward heatflow	Summer upward heatflow
EPS	EPS	----	2.47	2.47
non-reflective airspace	EPS	----	1.86	1.83
non-reflective airspace	EPS	EPS	2.78	2.75
reflective airspace	EPS	-----	2.48	2.05
reflective airspace	EPS	EPS	3.40	2.97

If the downward facing surface of layer 3 is non-reflective then enclosing the subfloor space with a perimeter wall will add an additional R-value of between 0.2 and 0.5 m^2K/W depending on the wind exposure of the subfloor space.

If the downward facing surface of layer 3 is reflective then enclosing the subfloor space with a perimeter wall will add an additional R-value of between 0.2 & 0.4 in summer and between 0.4 & 1.0 m^2K/W in winter, depending on the wind exposure of the subfloor space.

9. CONCLUSION

The measured thermal resistance of the floor system is in close agreement with the performance calculated using two dimensional finite element modelling. The modelling

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has then been used to estimate the system thermal resistance for various combinations of insulation layers with either a non-reflective or reflective air space.

10. REFERENCES

ASTM 1363-97. *Standard Test Method for the Thermal Performance of Building Assemblies by Means of a Hot Box Apparatus*.
American Society for Testing and Materials, Philadelphia, PA, 1997.

HEAT2 Versions 8.03 (8.0.3.0.A) Aug 1, 2011 *Developers*: Dr Thomas Blomberg, Blocon
Prof. Johan Claesson, Dept of Building Physics, Chalmers Institute of Technology / Dept. of Building Physics, Lund University.

Appendix 4
SR0968-DU02

Thermal resistance of a prefabricated timber floor system insulated with Polyester

Author: Ian Cox-Smith
Building Physicist

Reviewer: Roger Stanford
Senior Technician Materials

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Thermal resistance of a prefabricated timber floor system insulated with Polyester

1. CLIENT

Forest and Wood Products Australia Ltd
Level 4
10-16 Queen Street
Melbourne
VIC
Australia

2. LIMITATION

The results reported here relate only to the item/s tested.

3. TEST SPECIMEN

The test panel was constructed at BRANZ Judgeford laboratories and insulated by BRANZ staff using a fibrous polyester insulation product sourced by BRANZ.

The test specimen consisted of a fully horizontal floor frame of 19mm particle board supported on 300mm deep engineered I-joists wtih LVL flange and a plywood web. The support beams were spaced at 450 mm centres. The underside of the panel was un-lined and insulated with friction fitted 2.4 m lengths of a 100 mm thick fibrous polyester insulation product with a density of 31.5 kg/m^3 and a nominal R-value of 2.5 m^{2}K/W.

4. APPARATUS

See Figure 2.

- Two insulated, open faced, temperature controlled chambers plus associated external heating and cooling equipment
- A large diameter, slow rotation, mixing fan in each chamber
- Insulated heat flow metering box (meter box) including DC electrical heating elements and circulation fans
- Precision programmable power supply for driving of metering box fans and measurement of their power consumption
- Precision programmable power supply for heating the metering box and measurement of the heating power
- 25 element thermopile imbedded into the interior and exterior surfaces of the walls and back face of the meter box
- 16 pairs of type 'T' thermocouples for measuring the air-to-air temperature difference between the two chambers

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- 2 sets of 16 pairs of type 'T' thermocouples for measuring the air-to-surface temperature difference on the faces of the test specimen. Because the underside of the floor was unlined it was not possible to measure the surface temperatures on the underside (cold side) so the air-to-surface temperature difference was only measured for the top surface (warm side) of the floor panel.
- PC based data acquisition and control system with sampling every 5 seconds and data recording at 1 minute intervals

Figure 1. Guarded Hot Box with floor panel installed.

4.1 Chambers

The test apparatus was the BRANZ Guarded Hot Box which consists of two insulated chambers of approximate face area 2.4 m x 2.2 m, with an internal depth of 1.2 m. The four sides and one face of the chambers include 100 mm of rigid foam insulation (R 2.6 m^2K/W). The open faces of the chambers are held against the faces of the test specimen. The temperature of the air in the two chambers is controlled independently using heating and cooling equipment which is connected to the chambers using 300 mm diameter supply and extract ducts on opposite sides of each chamber. There is also a large diameter, slow rotation, mixing fan in each chamber.

4.2 Metering Box

One chamber is kept warmer than the other so that there is a constant temperature difference across the test specimen, generating a constant heat flow, which is measured using a 1.2 m x 1.2 m face area metering box. The 2.4 m x 2.2 m dimensions of the test specimens allows for a so called 'guard' area of at least 500 mm

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between the edges of the metering box and the perimeter of the specimen. The guard area minimizes lateral heat flow in the test specimen near the metering area. The metering box has a depth of 240 mm including 50 mm of rigid foam insulation (R 2.0 m^2K/W) on all four sides and the back face. The front face is open and is kept against the face of the specimen under test.

Inside the metering box there are DC electrical heating elements and mixing fans. Fans and baffles within the metering box produce air movement in one direction against the face of the sample. Imbedded into the surfaces of the four sides and one face of the metering box is a 25 element thermopile, which gives a null output when the resistive heating power plus fan power supplied to the inside of the metering box is such that the inside surfaces are being maintained at exactly the same temperature as the outside surfaces. There is then no heat flow through the walls and back face of the metering box and all of the heating energy is therefore being transferred by air movement through the open front face, and then by conduction through the specimen.

Figure 2. Schematics of Guarded Hot Box Apparatus

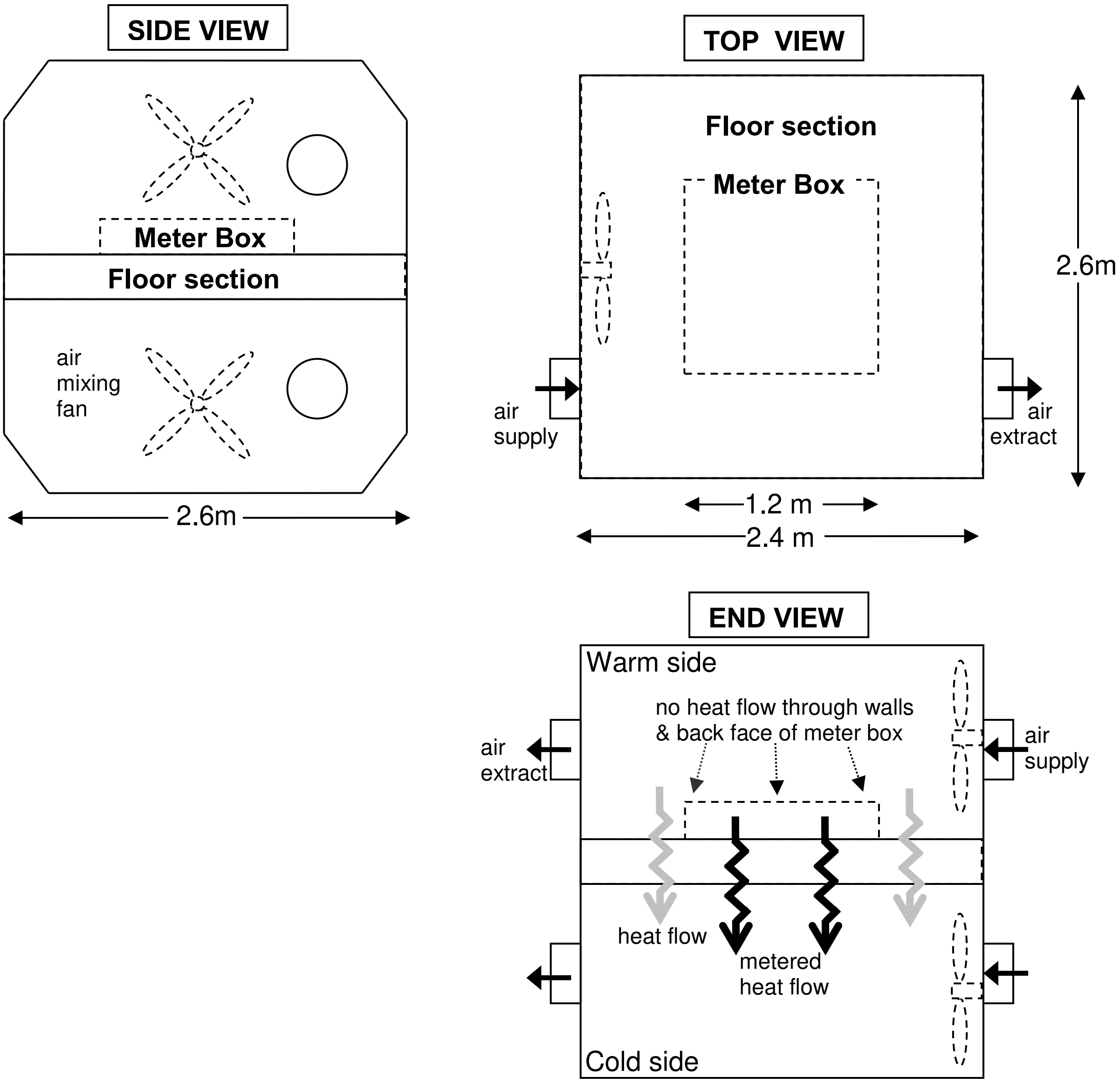

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Figure 3. Floor frame from below with polyester insulation installed

Figure 4. Metering box in upper chamber

4.3 Thermocouples

The air-to-air temperature difference between the two chambers is measured using 16 pairs of type 'T' thermocouples. Air-to-surface temperature difference on the top face of the sample was measured using a set of 16 thermocouple pairs. Because the thermocouples form differential pairs, there is no need to measure and include a junction temperature into the determination of temperature difference, leading to increased accuracy and precision above what is normally expected from thermocouple based temperature measurement. All of the thermocouple wire used in association with the apparatus comes from a single batch of wire for which the particular temperature characteristic has been determined.

5. METHOD

The apparatus is constructed and operated according to ASTM C1363-97. The test method requires steady-state conditions and therefore does not simulate such effects as the combination of climatic variation and thermal mass. In fact the measurement takes at least three days to allow one day for the initial response to the change in temperature and two days to determine that there were no slow changes in behaviour due to moisture movement in the specimen or exterior environmental effects on the test chambers. The final R-value is determined by averaging the measurements over at least 24 hours.

The measured total input power to the meter box, including fans, divided by the meter box face area of 1.44 m^2 gives the heat flux in Watts per square metre. The measured temperature difference between the air in the two chambers, divided by the heat flux, gives the air-to-air R-value of the test specimen. The air-to-air R-value includes two air-to-surface resistances, one of which was determined by measuring the difference between the temperature of the air near the top surface of the flooring and the surface temperature of the floor. The air-to-surface resistance of the underside of the floor panel was not measured.

The area measured by the meter box includes three I-joists. Because the metering box width of 1200 mm is not an exact multiple of the three beams spaced at 450 mm centres, the measured R-value was biased low. The measured results were then theoretically adjusted, using two dimensional finite element modelling, to the correct area weighting of I-joists.

The thermal conductivity of a specimen of the insulation was measured using test method ASTM C518 in the BRANZ heat flow meter instrument (LaserComp Fox 600).

6. DEVIATIONS FROM STANDARD TEST METHOD

This test did not fully comply with the following provision of Test Method C1363:

- Surface air velocities were not measured
- The moisture content of the individual materials has not been measured
- The actual densities of the materials have not been measured
- The surface heat transfer coefficient was only measured for the upper surface of the floor frame but not for the lower surface (the surface of the fibrous insulation)

Although surface air velocities were not measured, the surface-to-air temperature difference and hence surface thermal resistance value of the top surface has been measured. The surface thermal resistance on the cold side is measured when the test sample has a solid surface on which to attach the thermocouples and is typically about 0.02 m^2K/W.

7. RESULTS

Table 1. Floor panel test results

Insulation System	100 mm 32 kg/m^3 fibrous polyester
ASTM C518 measured R-value at 20°C for 100 mm fibrous polyerster insulation	2.53 m^{2}K/W
Test period	13th to 21st Sept 2012
Temperature stabilisation	5 days
Test interval after temperature stability achieved	3 days
Approx. mean sample temperature	20°C
Approx. cold side air temperature	12°C
Approx. warm side air temperature	28°C
Air-to-air temp. difference	15.43 K
Total heating power over 1.44 m^2 metering area	9.86 W
Heat flux	6.85 W/m^2
Warm side air-to-surface temperature difference	0.62 K
Warm side surface resistance	0.09 m^{2}K/W
Assumed cold side surface resistance	0.02 m^{2}K/W
Measured system air-to-air thermal resistance (R-value) ± 10%	**2.27 ± 0.23 m^{2}K/W**
Calculated system R-value for metering area and actual mean temperature of 20 °C using HEAT2 finite element modelling	2.38 m^{2}K/W
Difference of measured R-value from calculated (m^{2}K/W)	**-5%** (-0.11)
ASTM C518 measured R-value at 23°C for 100 mm of the fibrous polyester insulation	2.50 m^{2}K/W
standard surface resistances – combined hot & cold surfaces (m^{2}K/W)	0.15 m^{2}K/W
Calculated system R-value for 450 mm I-joist spacing, mean temperature of 23°C, and standard surface resistances (m^{2}K/W)	2.50 m^{2}K/W
Measured system R-value adjusted to same conditions (m^{2}K/W)	**2.38 ± 0.24 m^{2}K/W**

Figure 5. Example of HEAT2 finite element modelling results

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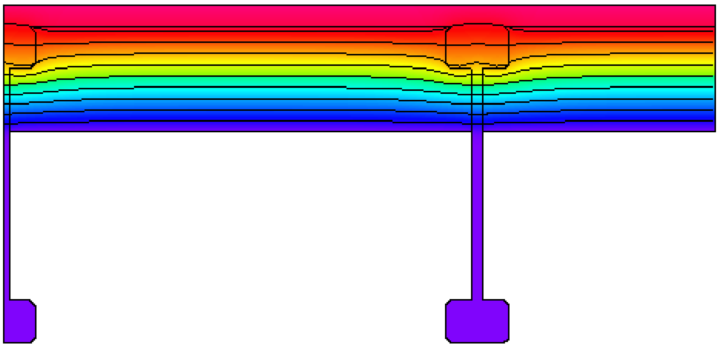

8. CONCLUSION

The measured thermal resistance of the floor system is in close agreement with the performance calculated using two dimensional finite element modelling.

9. REFERENCES

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HEAT2 Versions 8.03 (8.0.3.0.A) Aug 1, 2011 *Developers*: Dr Thomas Blomberg, Blocon Prof. Johan Claesson, Dept of Building Physics, Chalmers Institute of Technology / Dept. of Building Physics, Lund University.

Appendix 5

BRANZ

Prefabricated Lightweight Timber Ground Floor Systems

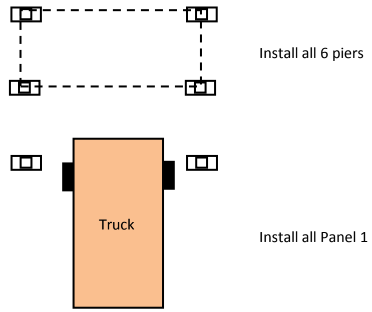
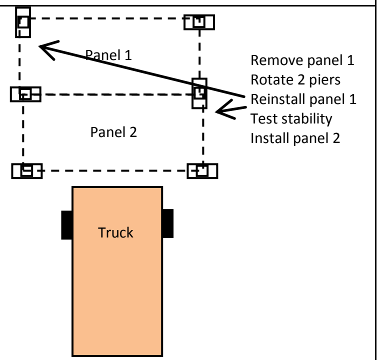
Trial Installation of Full Size Panels

17 January 2013

Appendix 5

Testing Plan - Bowen's Hastings Facility: Thursday 17th January 3013

Aim of Testing: to undertake a 'controlled' installation to familiarise installation contractors with specific installation activities, tools required & time taken and identify possible glitches or issues *(we need to be confident in all practices before heading to Heathcote for Swenrick installation)*

Test, Process and Aims	Tools / Materials needed	Comments
1. <u>Practice pier & floor set-out</u> • Discuss & practice setting out of construction hurdles • Setting out stringlines for floor/house • Setting out stringlines for footings & piers	• Timber for hurdles • Stringlines & chalk lines • Ramset (or Hilti) gun	Need to be very clear as to set out: steel pier installation lines and installed floor lines
2. <u>Practice steel pier installation 1 (baseplates arranged same direction)</u> • **Practice Screw anchor fixing installation** – investigate tools needed, time taken/pier, ease of installation • **Practice levelling top plates & screwing off** – investigate tools needed, time taken/pier, ease of installation • '**Investigate initial wobbliness of the piers at installation'** – we need to come up with a practical approach here that does not involve pier embedment, maybe some temporary reusable bracing jigs (probably only required for the first panel).	• 6 steel piers • Screw anchors (RT) • Hammer drill • Automatic level • Masonry bit (to suit anchors) • Cordless drill • Tool for installing screw anchors (air wrench? – socket & ratchet?)	
3. <u>Practice crane install – Panel 1.</u> • **'Panel Slinging &Lifting'** – practice loading/unloading panel 1 from truck • **'Lowering into accurate place '** –practice accurate placement of first panel (this is critical as this provides the reference for all other panels) • **Investigate wobbliness of installed panel (baseplates same direction)**	• Panel 1 • Slings • Crane truck	
4. <u>Practice steel pier installation 2 (2 base-plates arranged 90°)</u> • **'Investigate wobbliness of the piers with alternative baseplate arrangement'** – remove panel 1, rotate diagonally opposite piers 90° and re-anchor, reinstall panel 1 only - investigate if alternating baseplate direction improves stability.	• As per 2	
5. <u>Practice crane install Panel 2 fitted to Panel 1.</u> • **''Fitting one panel against another'** - crane lift panel 2 to fit against panel 1, investigate ease of doing this, particularly fine adjustment, accuracy of placement, cantilever floor fixing	• Panel 1 & 2 • Slings • Crane truck	

Testing at Hastings, Thursday 17th January 2013 – Pier and Panel Installation

In attendance:

- Jeff Harvey (Bowens)
- Paul (Timbertruss – Overseer)
- Craig (Timbertruss – Labourer)
- Peter (Bowens – Truck/crane operator)
- Charles Simpson (Holmesglen TAFE)
- Robert Tan (MiTek)
- Alastair Woodard (TPC Solutions Pty Ltd)

___

Test Observations

1. **<u>Practice pier & floor set-out</u>**
   - Pier set-out explained by CS to Paul
   - Went relatively well – two piers however ended up being misaligned
   - Confirmed that:
     - need to be very careful with on-site set-out alignment, and
     - with pier cap-plates need to standardise centralised welding to make installation set-out more uniform – redraft current AdvantaPier Top plate position detail.

2. **<u>Practice steel pier installation 1 (baseplates arranged same direction)</u>**
   - **Practice Screw anchor fixing installation** –
     - All went very smoothly once set-out
     - Only took around 5 minutes per pier
     - Drilling of concrete quite easy
     - Air wrench for installation of screw anchors very effective
     - The slots in the foot provide a degree of adjustment which is also helpful
     - With flat surface piers were quite plumb once anchor screws tightened



   - **Practice levelling top plates & screwing off** –
     - Didn't level top plates as done on concrete slab and Paul didn't have a level with him **(need to ensure that he does when he goes to Heathcote for actual installation)**

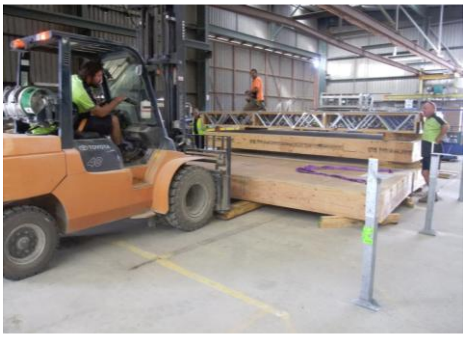
   - **'Investigate initial wobbliness of the piers at installation'** –
     - Piers when initially installed (before panel installation in fact quite stable) – maybe because slab surface was very smooth and flat).
     - **Need though to confirm with Swenrick – that top of footing should be levelled smooth and flat using a steel trowel**

3. **Practice crane install – Panel 1.**

- **'Panel Slinging &Lifting'** –
  - Installation of slings – hole-sawing the flooring and inserting around the top chord of the floor truss really proved to be quite slow and messy and generated some detailed discussions on alternative options particularly surface mounted lifting brackets (RT to investigate a screw-on steel channel option).



  - Once installed however the slings worked quite effectively
  - Panels were moved around easily within the plant and for loading on to truck using a forklift (though tines on the forklift here were overly thick and long, requiring deeper spacing blocks than preferred).



  - Crane Lifting Panels from truck: went very smoothly (panels approx 450kg, crane has a capacity of 675kg at 12m reach).

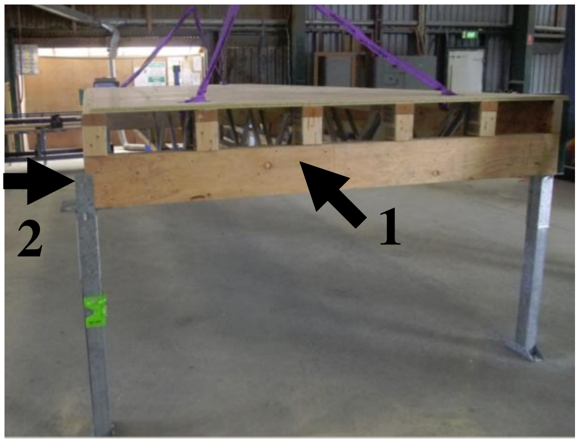


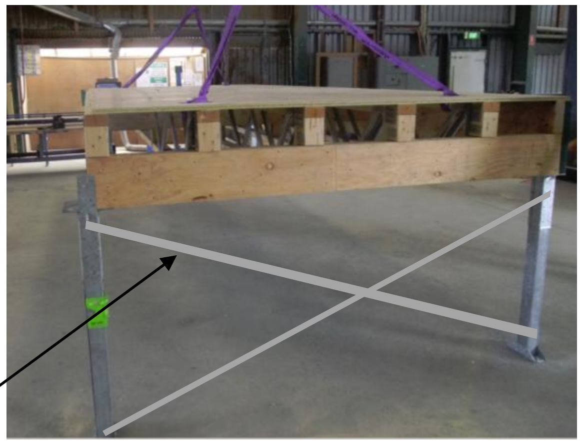
Accuracy of crane placement –

- Practice was undertaken utilising the truck mounted crane lifting and placing the panels. The crane operator demonstrated that the panels could be very accurately moved and placed (despite the fact that the crane cannot directly lower the panel vertically).
- The operator commented that placement would be easier to manoeuvre if the lifting points were closer to the middle.



- **Investigate wobbliness of installed panel (baseplates same direction)**
  - The lateral stability of the installed panel (without any bracing) was investigated by wobbling the panels by hand. The system appeared very stable in the long direction (1) parallel to the pier foot plates. In the short direction (2) perpendicular to the pier foot plates wobbliness increased but stability was still relatively good (1m high piers).
  - The general feeling was in terms of installation advice that:
    - Up to 1.2m high no temporary bracing was needed of the panel piers
    - Over 1.2m, temporary bracing should be provided to the piers before installation of the first panel to be installed to assist in preventing lateral collapse.
    - For all pier heights, as soon as the first panel is placed and screwed off to the piers, then the permanent bracing needs to be installed before the next panel is placed.





4. **<u>Practice steel pier installation 2 (2 base-plates arranged 90°)</u>**
   - **'Investigate wobbliness of the piers with alternative baseplate arrangement'** –
     - Panel 1 was then removed and two diagonally opposite pier footplates rotated 90° and re-anchored, then panel 1 was reinstalled
     - Alternating the baseplate foot direction certainly improved stability in the previous direction 1 (short side loaded). Though it did not make an overly dramatic difference – it was agreed that the installation advice should be to **'alternate baseplate directions to maximise pier stability'**
     - It is preferable not to have the feet protruding on external walls, so a foot layout plan might help the installers.

5. **<u>Practice crane install Panel 2 fitted to Panel 1.</u>**
   - **''Fitting one panel against another'** -
     - Panel 2 was then crane lifted into palace to fit against panel 1 tp investigate the ease of doing this, the need for particularly fine adjustment, and the accuracy of placement for the cantilever floor fixing.
     - The process went extremely smoothly due to the skill of the crane operator and the cantilever floor panel fitted extremely accurately and smoothly against the receiving rebated edge.

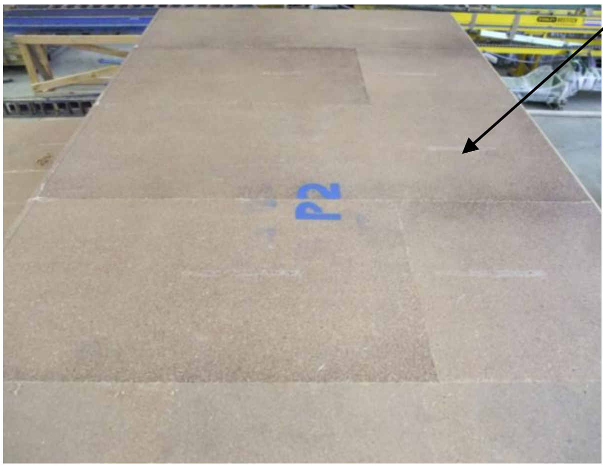



     - Despite the floor size measuring as per plan, the 10mm gap on the bearers was slightly reduced. Over any more than 2 joins this may become an issue for how central under the join the piers are. Larger floor may still require a 100mm make up strip in the floor. The dimensional accuracy of the floor in each panel is critical and is why the overall floor measured what it was meant to.
     - A step in floor level was noted at one end of the join. This was due to the bearer not being fitted tight up against the support block in the end of the trusses. The jig design is not helping this and it was again noted and corrected as a panel was being fabricated in front of us.
     - The dimensions of the fitted panels was precise on one side and 2mm over on the other. This was caused by the lack of straightness of rebate edge and probably easily closed up using a ratchet strap. (Improvement of this is discussed above)
     - A new top design was also discussed using a 200 x 200 folded into a 100 x 100 angle iron 200 long for edges of the building so that better side fixing is provided.

Other Observations

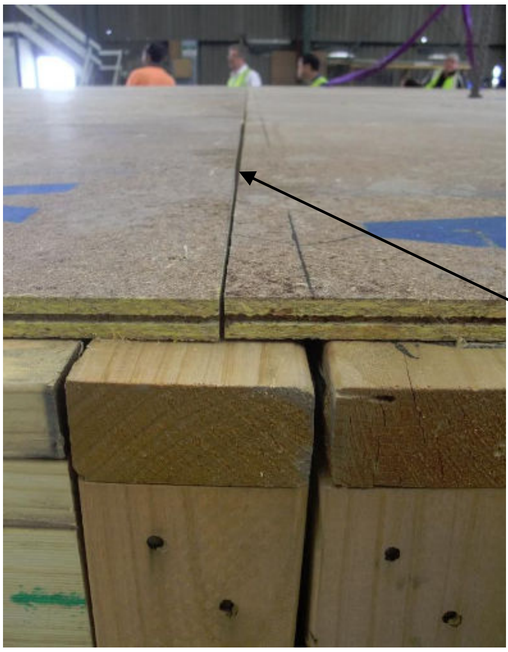
Gap between joists to stop potential squeaking

Bearing on cap top plates – worked

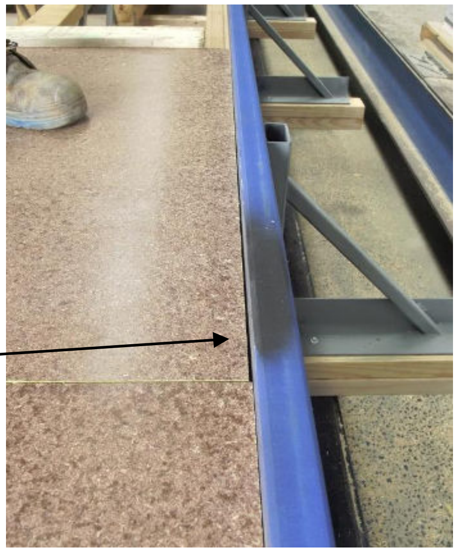


Optimising sheet flooring layout seemed to work well

Gluing T&G gluing produced excess lines that then needed to be chiselled off – need to add into installation advice about cleaning glue off excess glue during installation

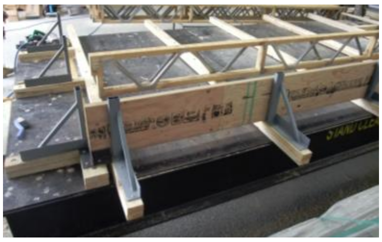
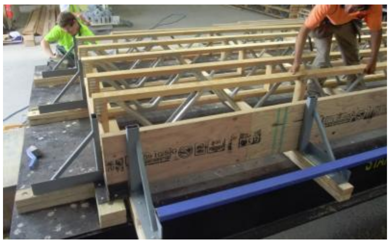


Factory cut edges of Yellow Tongue flooring did not appear to be square. Did not look particularly good when panels were installed against one another (photo at left shows factory cut edge laid against steel straight edge illustrating out of square issue.)



Construction of panels using jig

- Observed and photographed a panel being built in the jig.
- Once all components are pre-cut it takes only 20-25 minutes to shoot each panel's frame together (no floor). Floor sheet cutting by hand is quite slow and tedious (needs better capacity to accurately cut multiple sheets. Actual floor installation with gluing & nailing also comparatively quite slow.

- As mentioned above the squareness of the floor sheet ends is causing problems.
- Improvements?
  - Bearer kept tight up to truss (mentioned above). This could be improved by not having any supports in the jig under the trusses and letting them sit directly onto the bearers.
  - Use steel 35mm straight edge spacer (may also need to do a hand cut along both long edges.
  - Width of sheets – previously measured as 901.5, now 900mm, causing problems because the truss lengths wherever possible are based on 6 sheet widths, so as to avoid another cut edge on each panel. This has been overcome on this job but may be a problem on larger jobs.
  - The floor sheet cutting list works if it is stuck to.
- Speed of fabrication, currently 3 per day (2 men) + insulation still to be fitted. Ways to improve this?

Insulation fitting

- Much easier installing between floor insulation with the panel on edge instead of trying to work overhead.
- Would be simpler if wide rolls were used and applied straight to the underside of the trusses, but this might also be easily damaged by the forklift tynes during handling.

- It was agreed that Foilboard applied from the top prior to fitting the floor would be easier and also requires less panel handling.

Summary of Key Issues Learnt

Set-out

Observation	Approx time for activity
• Need to be very careful and take appropriate time with the on-site set-out alignment and • Need to ensure piers are in the correct position dependant on pier cap-plate type and orientation	

Pier Installation

Observation	Approx time for activity
• Process is very efficient and quick	
• Need to ensure footing contractor provides a level and smooth footing surface (use a final steel trowel finish)	Approx 5min/pier baseplate install
• Need to ensure pier installer has an automatic level to accurately set final pier cap plate levels.	Not sure (didn't do)
• Advise in installation procedure to **'alternate baseplate directions to maximise pier stability'**	
• Advise in installation procedure that: ▪ *Up to 1.2m high no temporary bracing was needed of the panel piers* ▪ *Over 1.2m, temporary bracing should be provided to the piers before installation of the first panel to be installed to assist in preventing lateral collapse.* ▪ *For all pier heights, as soon as the first panel is placed and screwed off to the piers, then the permanent bracing needs to be installed before the next panel is placed.*	

Panel Slinging and Lifting

Observation	Approx time for activity
• Investigate a face mounted screw-on reusable steel channel lifting bracket option (will dramatically speed up install time and overcome unwanted boreholes/plugs in flooring)	
• Installation using truck mounted crane with a skilled operator is very efficient	Approx 15 min/panel

Other

Observation	Approx time for activity
• Panel frame is quickly assembled, slowest process is hand cutting flooring and installing • Contact needs to be made with CHH reps regarding squareness of flooring panels & factory cutting	20-25 minutes to shoot each panel's frame together. (no floor)
• Excess glue squeezed from T&G joints needs to be cleaned off as flooring installed (scraper & rag dampened with mineral turps – otherwise time consuming using a chisel to remove) • Look at foilboard insulation applied from the top rather than between joist insulation	Speed of fabrication, currently 3 panels per day (2 men) – need to improve this

Appendix 6

Prefabricated Lightweight Timber Ground Floor Systems

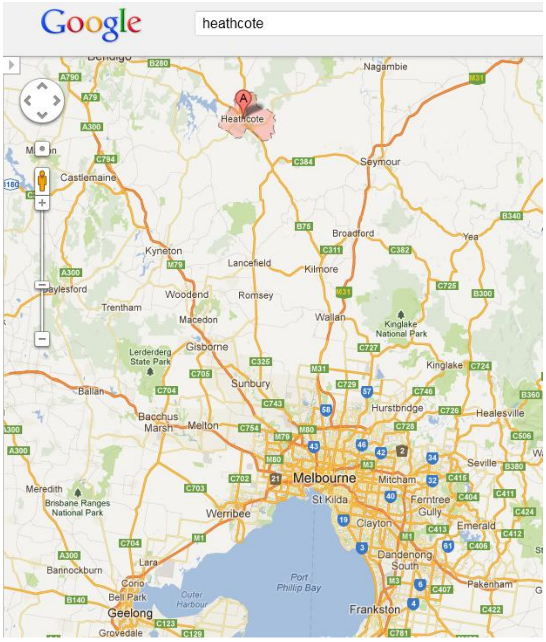
Full Size Home Installation Heathcote, Victoria

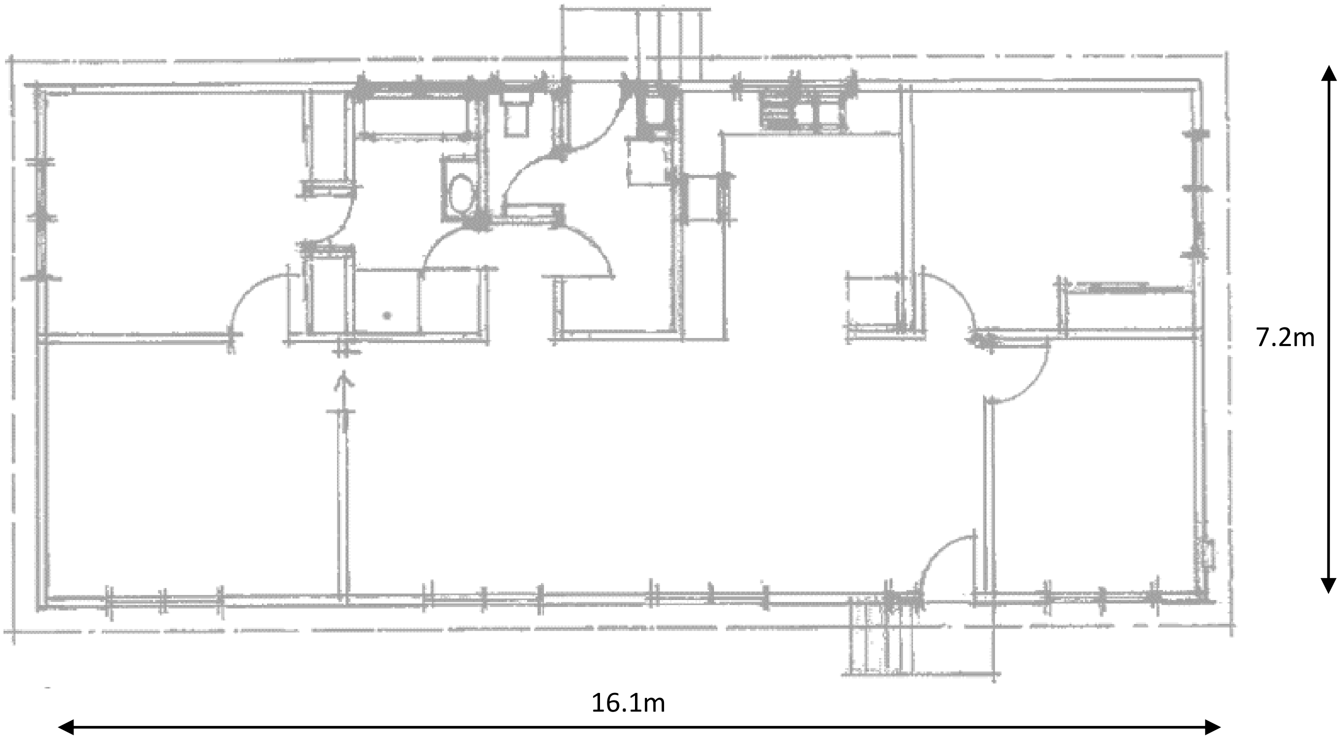
20th February 2013

Trail Home: Swenrick Homes – Haven (116m^2)

Constructed at 35 Kilroy St, Heathcote, Victoria

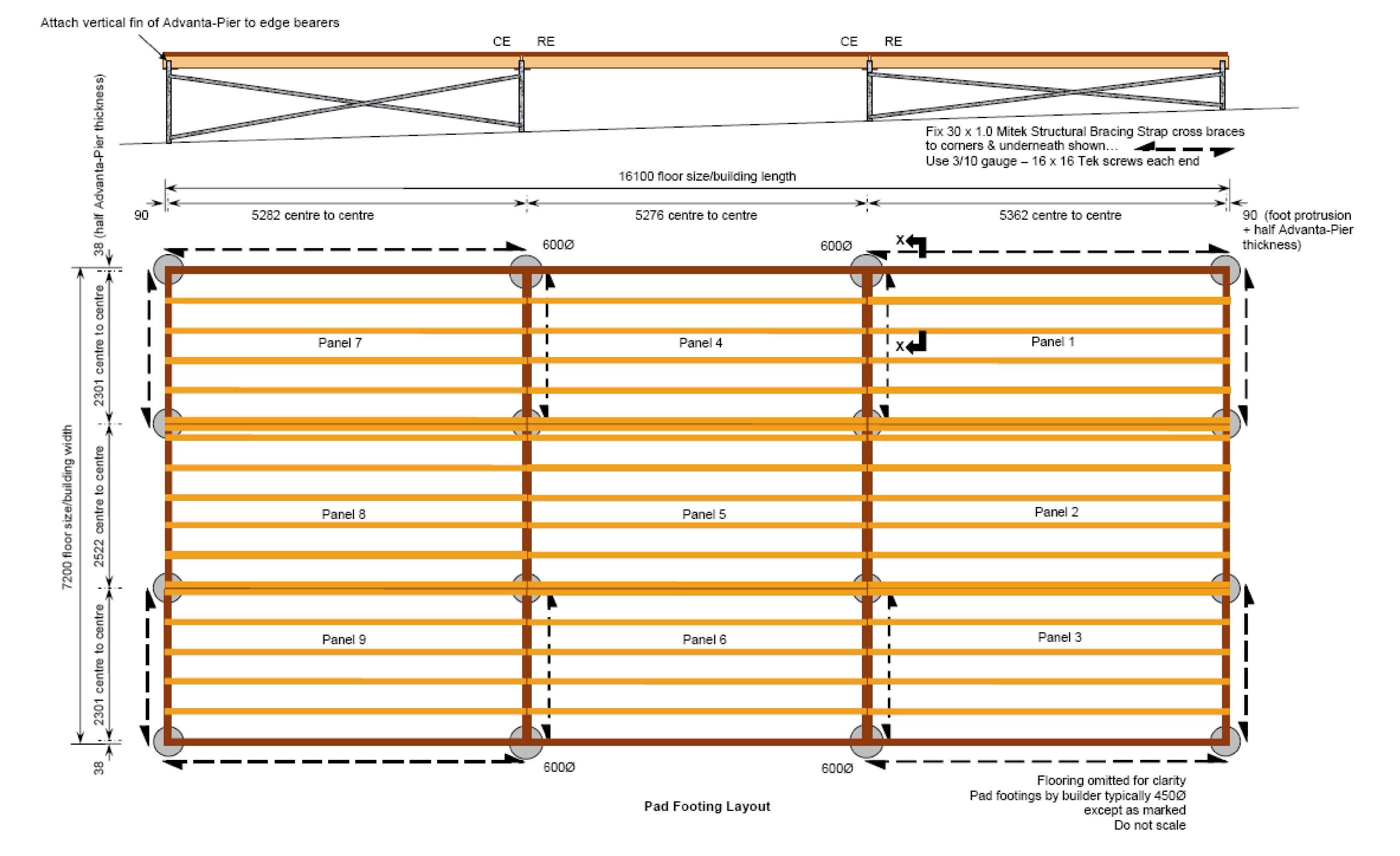
- Piers installed Monday 19th February 2012
- Floor Panels installed Tuesday 20th February 2013





Appendix 6

Full Size Home Installation, Heathcote, 19-20 Februray 201



Title: Prefab Floor System Construction Details	Project: Swenrick Constructions "Harris@Heathcote"	Detail: Pad Footing Layout & Sub-floor Bracing Detail	Drawn: CS Checked: RT & RS	Date: Nov 2012 Version: 2e Page: 4 of 4

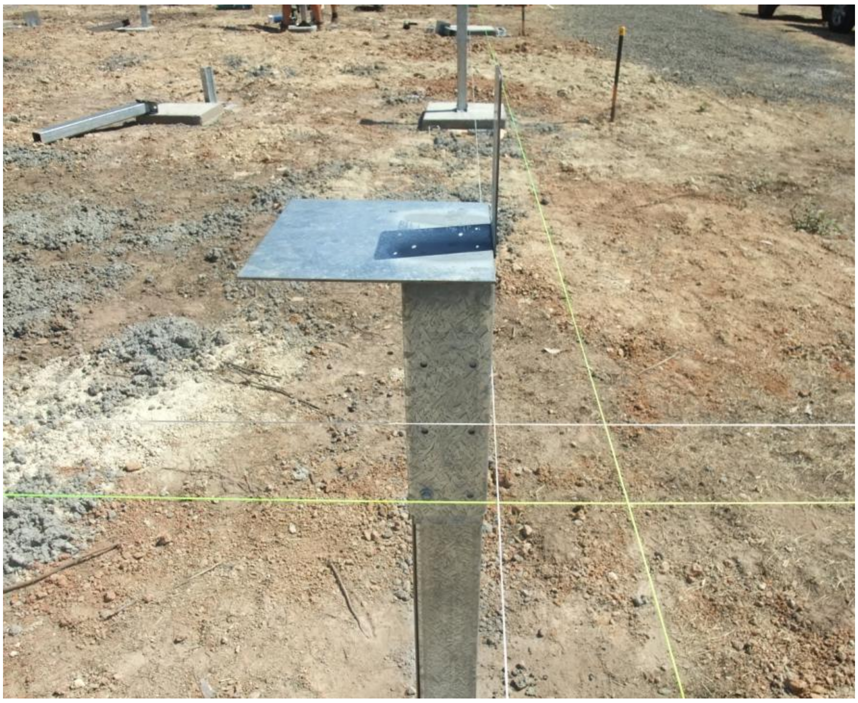
Photos and notes from Swenrick Homes Heathcote Floor Installation

Monday 19th and Tuesday 20th February 2013

View across site showing footings and piers laid out

Steel pier placement determining set out lines – this was done slowly and carefully to ensure all piers were accurately positioned

Wide hurdles at each corner established the building line and also a 100mm offset line

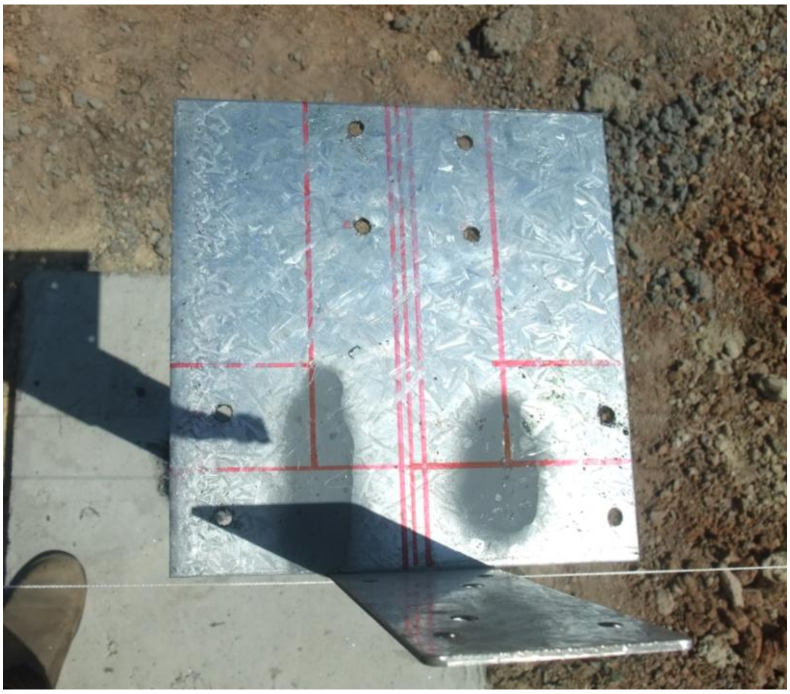


100mm edge of floor offset set out line used (yellow stringline), made it very easy to check line during installation.

Galvanised plated steel pier bases painted for additional protection with bituminous paint

Base plate hold down screw anchor holes drilled and screw anchors installed (process really quite quick)

Steel pier top plates then levelled using an automatic level – tapped into position, clamped off and then positioning screws installed (with the use of a rotating laser level this could be a one man task).



Expected position of floor panels marked on top plates (this was very useful to have during installation confirming position and accuracy) and hold down screw holes drilled (drilling these holes was quite slow – need to have these plates pre-punched.

Final steel pier installation – ready for floor panel installation

Tuesday 20th February 2012 – Floor Panel Installation

Truck arrival at site

First panel installation

First panel landed – great care then taken to ensure it was accurately aligned to house set-out lines before fixing in place

First panel - permanent bracing was fully installed prior to landing second panel

Second panel installation (actually panel 4 rather than panel 2
because truck not loaded to sequence plan)

Detail of panel joint – illustrating cantilevered flooring joint and 10mm between panel gap.

Detail of internal pier with three panels installed

Detail of external pier with screw fixings

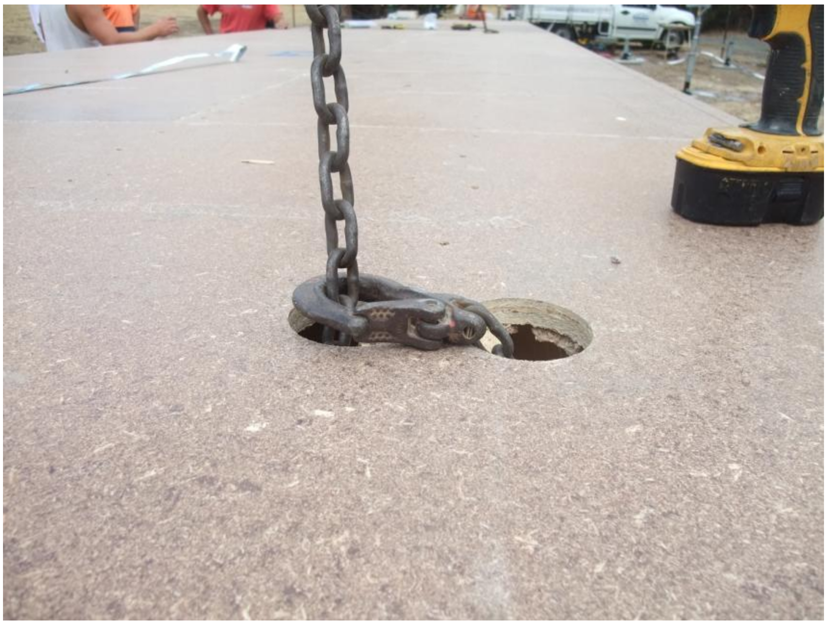
Panel 8 installation

Installation of final panel (9)

Floor with panels fully installed

Elevation – finished floor

A happy man



Lifting chains fitted directly around floor joist flange (rather than using lifting straps).

Lifting hole plugs fitted

Lessons Learnt

F&T manufacturer needs to establish from builder how power enters building and exactly where. If power riser to be used then floor panels need to be manufactured to allow the passage of the bearer (or joist) and to fit around riser.

In this instance the two LVL bearers were cut (approx 30mm of timber remains).

Bearer will be strengthened probably using a steel or ply fishplate.

With Panel 7 the edge Posijoist had an approx 10mm ‘bow’ not picked up in manufacture (installation of flooring & strongbacks then held this in place). This then meant a large gap between floor sheets on installing panel 8. To rectify - the floor nails were removed, the glue cracked, the strongback nails cut and the posijoist levered back in line before the flooring and strongbacks were re-nailed. Whilst rectification on site was possible it took time and increased the holding cost of the crane.

The experience reinforces the fact that adequate in-factory quality and tolerance control is critical for floor panels – key tolerances include:

- verticality and plumbness of side members,
- accuracy of overall panel dimensions including squareness,
- straightness of edge trusses,
- proper clamping of floor truss top/bottom chords to remove twist before adding nail plates and
- checking depth of LVL beams that will end up side by side at a panel join.

Also, need to consider doing away with the surplus edge truss on the cantilever edge of the panels – will save money and solve some of the installation issues and tight tolerances. (but will need to look at how to protect and support during load tying on the truck.)

Larger floor gaps needed to be filled with infill floor strips and planed flush. In-factory manufacturing tolerances need to ensure tight gaps between flooring panels.