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DANCER Building System

Direct Anchorage Non-strapped Cyclone & Earthquake Resistant

Building System for Wind, Earthquake and Tsunami Resistance

Five Police Houses constructed using the Partner Housing DANCER building system at Baiyer River for the Government of Papua New Guinea.

Contents

Partner Housing Australasia (Building) Incorporated

Partner Housing is an entirely voluntary organisation, which aims to transform the lives of people living in Asia-Pacific villages by improving the cyclone, earthquake and tsunami resistance of their houses, clinics, schools and community buildings; and by providing clean water supplies and hygienic sanitation.

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Partner Housing also acknowledges the generosity of David Mahaffey of Mahaffey Associates for providing laboratory space, equipment and staff during the second phase of the testing.

Partner Housing also recognises the dedication of the Board of Vision for Homes (PNG) and their commitment to this project.

Dedication

The members of Partner Housing remember with fondness our friend and colleague, Ron Albert, who passed away during the development of the **DANCER** Building System. Ron Albert volunteered his considerable CAD skills and building experience for the preparation of the **DANCER** 3D drawings and details. Ron's quiet commitment to "getting the job done" is an inspiration to all of us.

Scope of Handbook

The **DANCER** Building System handbook continues to be updated on an on-going basis .This handbook is not intended for routine construction, but serves as the source document from which working drawings, cutting lists, bills of quantities and specifications can be derived for specific projects.

Part 1 – DANCER Handbook

Part 1 provides the background and brief description of the **DANCER** Building System, together with guidance on the use of this handbook.

Introduction

Partner Housing and its consultants have long considered the practical problems associated ensuring the cyclone, earthquake and tsunami resistance of village houses, schools and clinics in locations where supervision is lacking, the builders are relatively unskilled and steel fittings are either unavailable or very expensive. This situation has led us to the development of the **DANCER** Building System.[1]

Background

The South Pacific region is home to a diverse range of people, many of whom live in small village houses that must withstand the ravages of cyclonic wind, earthquake and (in some cases) tsunamis. Previously these houses were often destroyed by natural disasters, but today there is an expectation that housing, no matter how humble, should remain intact when subjected to cyclone, earthquake or tsunami.

Unlike the cyclone resistant housing systems developed for Australia, the **DANCER** Building System does not require screwed steel anchor rods, steel brackets, steel nailing plates, extensive steel strapping or large quantities of concrete.

The **DANCER** Building System is a simple timber framed house building system incorporating sawn timber framing fixed by a handful of bolts and nuts, steel (or timber) posts, a small quantity of concrete for piers (if available), steel (or leaf) roof cladding, sawn timber flooring and local or imported wall cladding.

The cyclone/earthquake/tsunami resistance is economically achieved by orienting the timber purlins such as to maximize the truss or rafter spacing and ensure that the uplift loads are transmitted to the ground via bolted connections directly between rafter/truss, anchorage studs, double bearers and posts. The key is in the name:

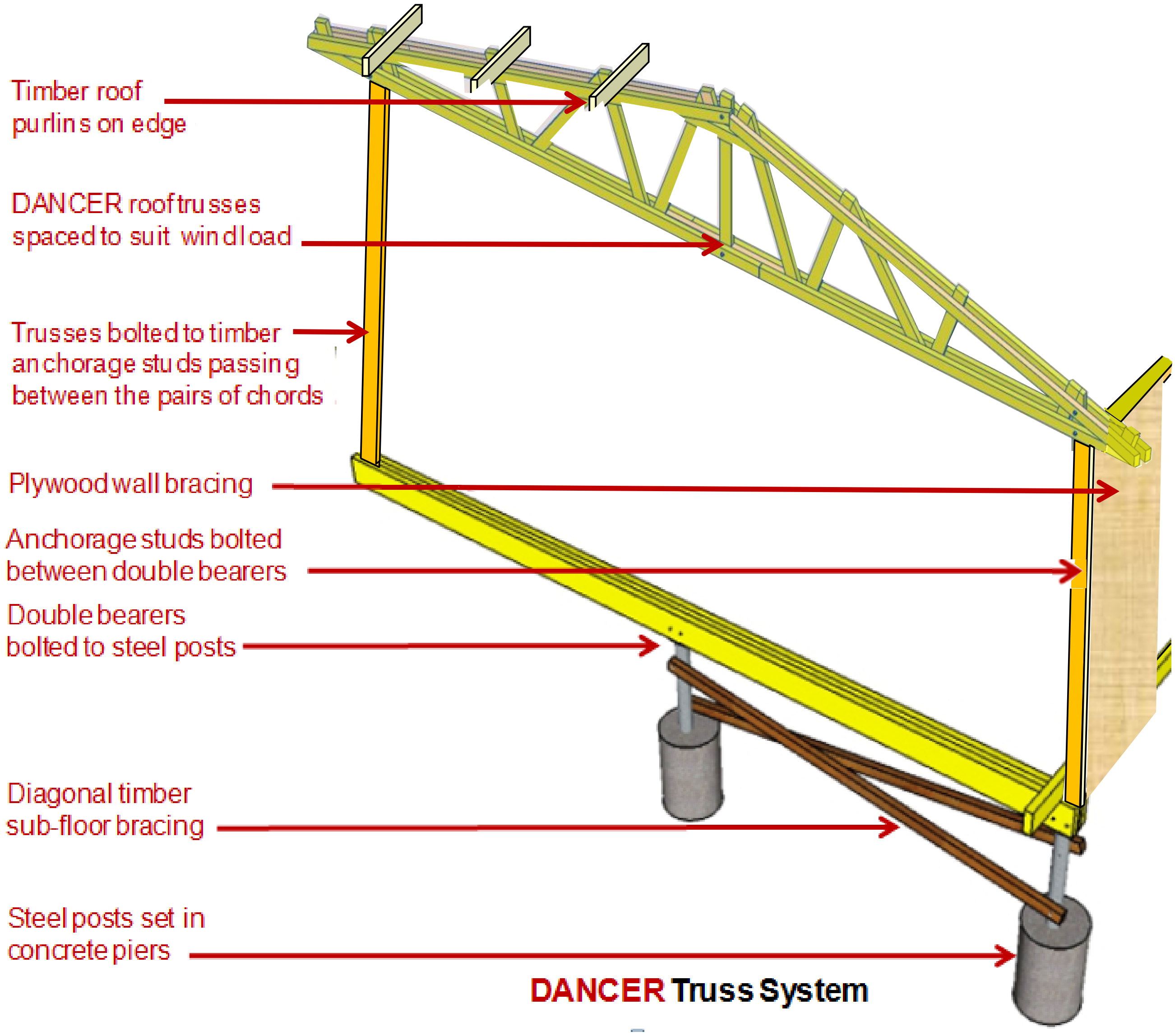
DANCER - Direct Anchorage Non-strapped Cyclone & Earthquake Resistant

The **DANCER** building system consists of the following:

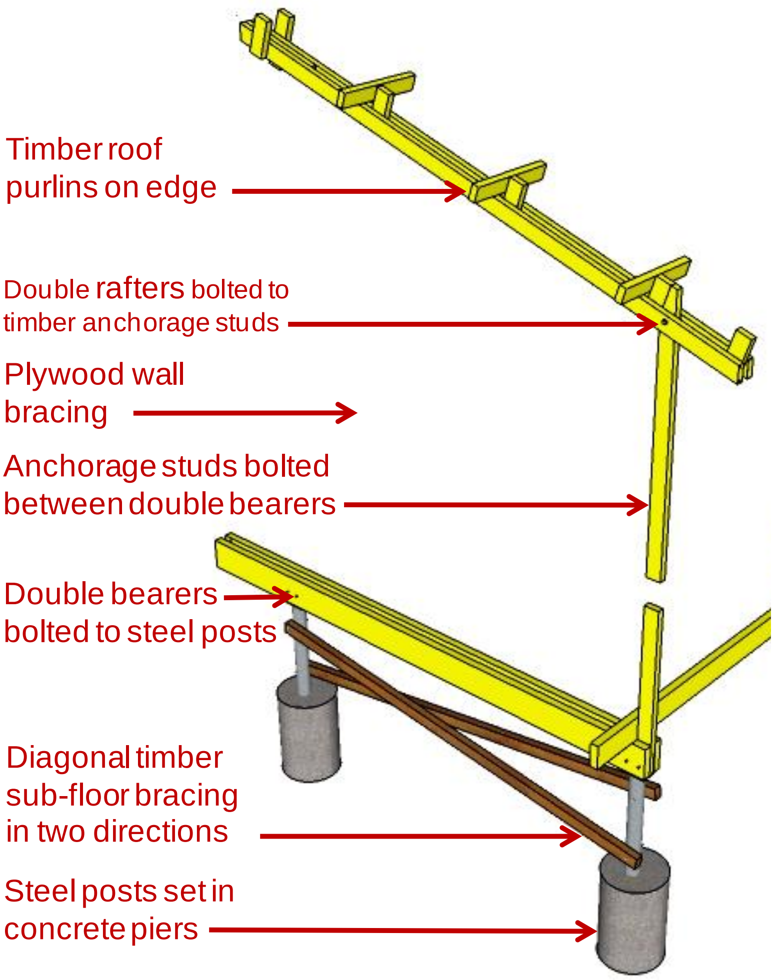
- Timber roof purlins, on edge (to maximize the span) are nailed horizontally to timber lacing members that are fixed between the double truss chords (or double rafters, as appropriate). They are fixed at 900 mm maximum centres to support corrugated steel roof sheeting.
- **DANCER** Trusses (or **DANCER** Rafters) consisting of double top chords and double bottom chords (enabling the lacing/purlin cleats to be nailed between from both sides and the anchorage studs bolted in double shear between).
- The **DANCER** Trusses (or **DANCER** Rafters) are bolted to timber Anchorage Studs between both pairs of chords.
- The timber Anchorage Studs are bolted in double shear between the Double Bearers, providing a direct load path from the roof system to the floor and subfloor
- Double Bearers are bolted to steel (or timber) posts, which are set in concrete piers.
- Plywood wall bracing and diagonal timber sub-floor bracing provide racking resistance.

[1] **DANCER - Direct Anchorage Non-strapped Cyclone & Earthquake Resistant**

DANCER Truss System



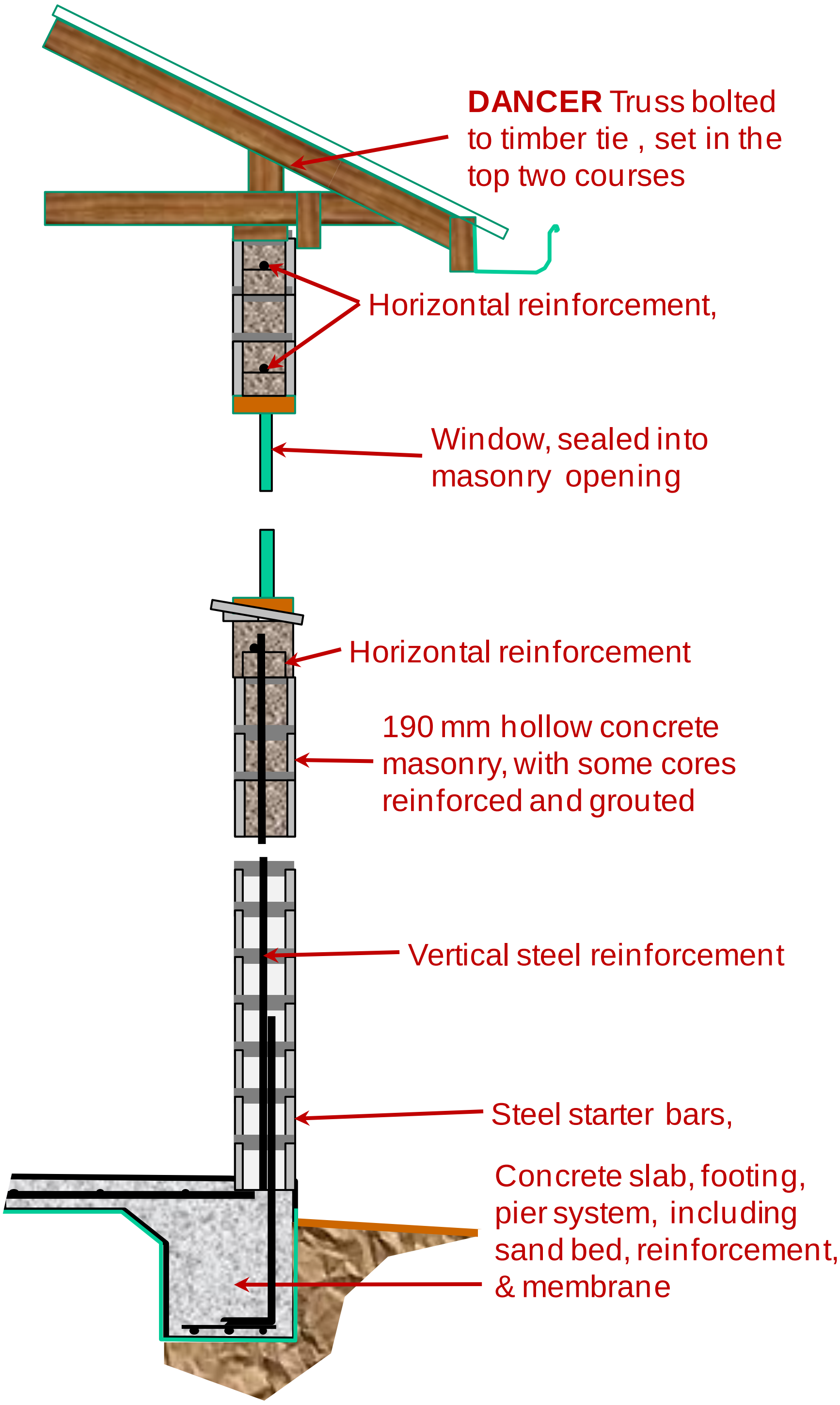
DANCER Rafter System



DANCER Rafter System

DANCER Reinforced Masonry System

DANCER roof systems may also be used with Partially Reinforced Concrete Blockwork walls on Concrete Slab-on-Ground construction. The **DANCER** Trusses (or **DANCER** Rafters) are bolted to short timber ties, which are set in the top two courses of reinforced concrete blockwork.



DANCER Reinforced Masonry System

Purpose and Structure of This Handbook

The purpose of this handbook is to provide a comprehensive reference on the background, design and detailing of the **DANCER** Building System, together with the records of its development and testing. The intention is to provide a single document in seven parts, from which other simpler or focused documentation can be extracted of developed.

Part 1 – **DANCER** Handbook

Part 1 provides the background and brief description of the **DANCER** Building System, together with guidance on the use of this handbook.

Part 2 – **DANCER** Design

Part 2 provides an introduction to the **DANCER** Design Package, consisting of a Microsoft Excel workbook, which may be used to customise the design of **DANCER** buildings for particular loads and specific applications. The same work book may be used for fabrication and construction quality assurance purposes.

Part 3 – **DANCER** Details

Part 3 provides member and connection details, material lists and timber cutting schedules for the principal components of the most common **DANCER** buildings. The **DANCER** Design Package may be used to prepare customised details, material lists and timber cutting schedules for other applications.

Part 4 – **DANCER** Specifications

Part 4 provides generic specifications for the principal components of **DANCER** buildings.

Part 5 – **DANCER** Bills of Quantities

Part 5 provides bills of quantities for the principal components of the most common **DANCER** buildings. The **DANCER** Design Package may be used to prepare customised Bills of Quantities for other applications.

Part 6 – **DANCER** Fabrication and Construction Guide

Part 6 provides guidelines on the factory prefabrication, including (when appropriate) trial erection of the system, and the construction process.

Part 7 – **DANCER** Development and Testing Program

Part 7 provides a record of the development of the system and the testing program use to refine and verify it.

Part 8 – **DANCER** Design Actions

Part 8 provides guidance on the determination of design actions for the countries of the South Pacific

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Part 2 – DANCER Design

Part 2 provides an introduction to the **DANCER** Design Package, consisting of a Microsoft Excel workbook, which may be used to customise the design of **DANCER** buildings for particular loads and specific applications. The same work book may be used for fabrication and construction quality assurance purposes.

For a copy of the **DANCER** Design Package and information regarding its condition of use, contact

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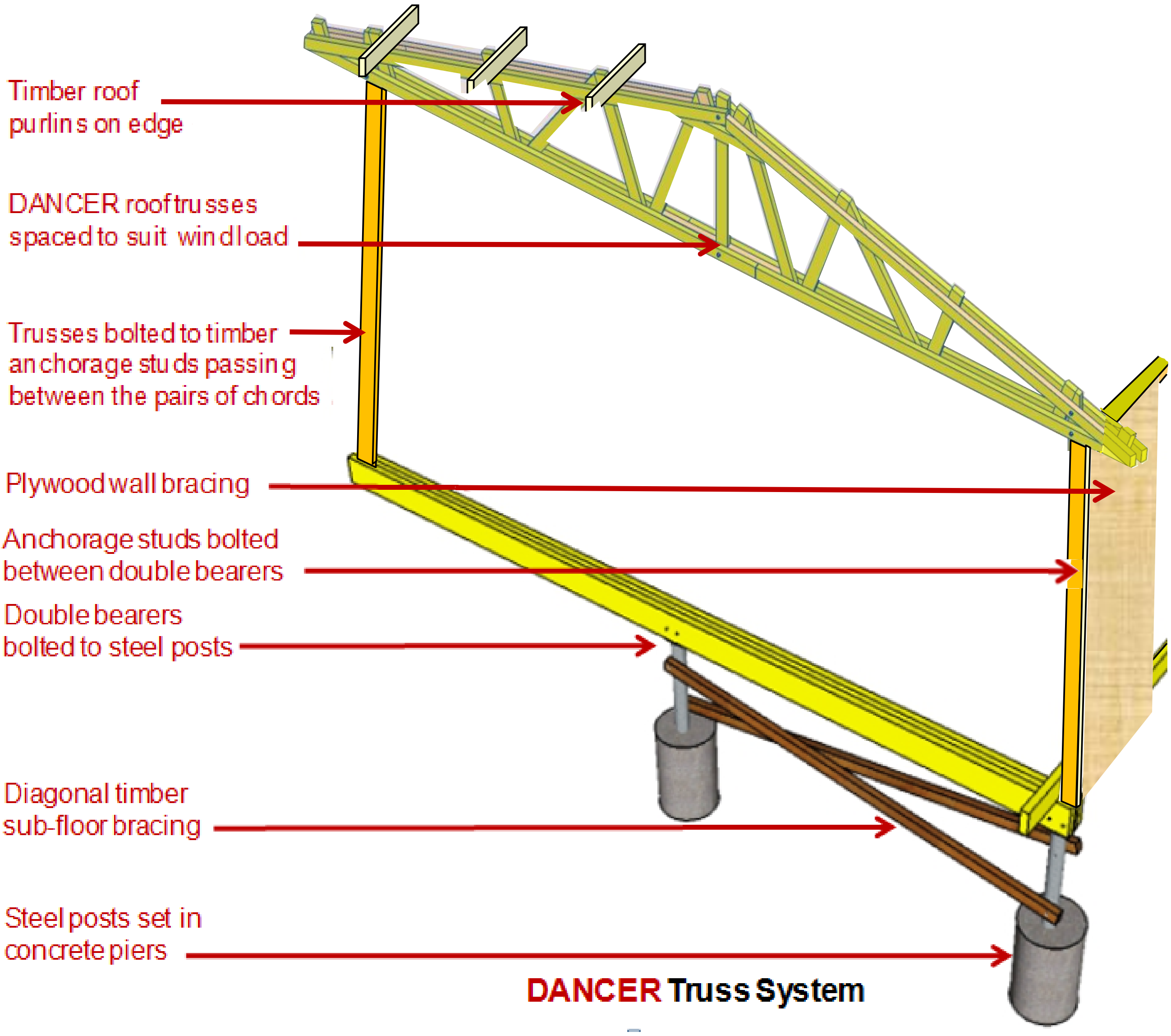
DANCER Truss System



Timber Specification

The **DANCER** Truss System is fabricated from the following timber:

- 90 x 35 seasoned softwood, MGP10, Joint Group JD4 (or better); or
- 100 x 38 unseasoned hardwood F11 or better, Joint Group JD2 (or better)

To facilitate prefabrication and transport to site, trusses are manufactured in two halves, and bolted together on site, with one bolt in the top chord at the apex and one bolt in the bottom chord. Each truss end is fixed to the Anchorage Studs by two bolts.

The following tables provide the timber type and the bolt size for each relevant combination of wind classification, truss span and truss spacing.

Design Actions

Part 8 of this handbook provides information on the appropriate design actions for the South Pacific region. This information may serve as design input when using the **DANCER** Design Package software.

Hardwood DANCER Trusses - Low to Medium Non-cyclonic Wind

Wind Class	Truss Spacing	Truss Span Outside Studs	Net Wind Suction + Pressure Perpendicualr to Roof	Vertical Roof Permanent Action	Tensile Force in Each Anchorage Stud	Bending Moment in Roofing Purlin	Shear connecting the purlin to the lacing	Horizontal Force at Top Chord Apex Splice & Bottom Chord Splice	Unseasoned Hardwood
	m	m	kPa	KN/m	kN	kN.m	kN	kN	J2
N2	0.45	4.80	0.95	0.379	0.06	0.02	0.38	0.10	M12
N2	0.45	5.70	0.95	0.379	0.07	0.02	0.38	0.12	M12
N2	0.45	6.60	0.95	0.379	0.09	0.02	0.38	0.14	M12
N2	0.45	7.50	0.95	0.379	0.10	0.02	0.38	0.16	M12
N2	0.45	8.40	0.95	0.379	0.11	0.02	0.38	0.18	M12
N2	0.90	4.80	0.95	0.342	1.10	0.07	0.77	1.71	M12
N2	0.90	5.70	0.95	0.342	1.31	0.07	0.77	2.08	M12
N2	0.90	6.60	0.95	0.342	1.52	0.07	0.77	2.46	M12
N2	0.90	7.50	0.95	0.342	1.73	0.07	0.77	2.84	M12
N2	0.90	8.40	0.95	0.342	1.95	0.07	0.77	3.21	M12
N2	1.35	4.80	0.95	0.341	2.06	0.16	1.15	3.19	M12
N2	1.35	5.70	0.95	0.341	2.45	0.16	1.15	3.89	M12
N2	1.35	6.60	0.95	0.341	2.85	0.16	1.15	4.59	M12
N2	1.35	7.50	0.95	0.341	3.24	0.16	1.15	5.30	M12
N2	1.35	8.40	0.95	0.341	3.64	0.16	1.15	6.01	M12
N2	**2.70**	**4.80**	**0.95**	**0.371**	**4.85**	**0.62**	**2.31**	**7.51**	**M12**
N2	**2.70**	**5.70**	**0.95**	**0.371**	**5.77**	**0.62**	**2.31**	**9.15**	**M12**
N2	**2.70**	**6.60**	**0.95**	**0.371**	**6.70**	**0.62**	**2.31**	**10.81**	**M16**
N3	0.45	4.80	1.49	0.379	0.60	0.03	0.60	0.93	M12
N3	0.45	5.70	1.49	0.379	0.71	0.03	0.60	1.13	M12
N3	0.45	6.60	1.49	0.379	0.83	0.03	0.60	1.34	M12
N3	0.45	7.50	1.49	0.379	0.94	0.03	0.60	1.54	M12
N3	0.45	8.40	1.49	0.379	1.06	0.03	0.60	1.75	M12
N3	0.90	4.80	1.49	0.342	2.18	0.11	1.20	3.37	M12
N3	0.90	5.70	1.49	0.342	2.59	0.11	1.20	4.11	M12
N3	0.90	6.60	1.49	0.342	3.01	0.11	1.20	4.85	M12
N3	0.90	7.50	1.49	0.342	3.42	0.11	1.20	5.60	M12
N3	0.90	8.40	1.49	0.342	3.84	0.11	1.20	6.35	M12
N3	1.35	4.80	1.49	0.341	3.67	0.24	1.80	5.68	M12
N3	1.35	5.70	1.49	0.341	4.37	0.24	1.80	6.93	M12
N3	1.35	6.60	1.49	0.341	5.07	0.24	1.80	8.18	M12
N3	1.35	7.50	1.49	0.341	5.78	0.24	1.80	9.44	M12
N3	1.35	8.40	1.49	0.341	6.48	0.24	1.80	10.70	M16
N3	2.70	4.80	1.49	0.371	8.07	0.97	3.61	12.49	M16

Hardwood DANCER Trusses - High Non-cyclonic Wind

Wind Class	Truss Spacing	Truss Span Outside Studs	Net Wind Suction + Pressure Perpendicualr to Roof	Vertical Roof Permanent Action	Tensile Force in Each Anchorage Stud	Bending Moment in Roofing Purlin	Shear connecting the purlin to the lacing	Horizontal Force at Top Chord Apex Splice & Bottom Chord Splice
	m	m	kPa	KN/m	kN	kN.m	kN	kN
N4	0.45	4.80	2.21	0.379	1.33	0.04	0.90	2.05
N4	0.45	5.70	2.21	0.379	1.58	0.04	0.90	2.51
N4	0.45	6.60	2.21	0.379	1.83	0.04	0.90	2.96
N4	0.45	7.50	2.21	0.379	2.09	0.04	0.90	3.41
N4	0.45	8.40	2.21	0.379	2.34	0.04	0.90	3.87
N4	0.90	4.80	2.21	0.342	3.63	0.16	1.79	5.62
N4	0.90	5.70	2.21	0.342	4.33	0.16	1.79	6.86
N4	0.90	6.60	2.21	0.342	5.02	0.16	1.79	8.10
N4	0.90	7.50	2.21	0.342	5.72	0.16	1.79	9.34
N4	0.90	8.40	2.21	0.342	6.41	0.16	1.79	10.59
N4	1.35	4.80	2.21	0.341	5.85	0.36	2.69	9.06
N4	1.35	5.70	2.21	0.341	6.97	0.36	2.69	11.05
N5	0.45	4.80	3.25	0.379	2.37	0.06	1.32	3.67
N5	0.45	5.70	3.25	0.379	2.83	0.06	1.32	4.48
N5	0.45	6.60	3.25	0.379	3.28	0.06	1.32	5.29
N5	0.45	7.50	3.25	0.379	3.74	0.06	1.32	6.11
N5	0.45	8.40	3.25	0.379	4.19	0.06	1.32	6.92
N5	0.90	4.80	3.25	0.342	5.72	0.24	2.63	8.86
N5	0.90	5.70	3.25	0.342	6.82	0.24	2.63	10.81
N5	0.90	6.60	3.25	0.342	7.91	0.24	2.63	12.76
N6	0.45	4.80	4.39	0.379	3.52	0.08	1.78	5.45
N6	0.45	5.70	4.39	0.379	4.19	0.08	1.78	6.64
N6	0.45	6.60	4.39	0.379	4.86	0.08	1.78	7.84
N6	0.45	7.50	4.39	0.379	5.54	0.08	1.78	9.05
N6	0.45	8.40	4.39	0.379	6.21	0.08	1.78	10.26
N6	0.90	4.80	4.39	0.342	8.01	0.32	3.56	12.41
N6	0.90	5.70	4.39	0.342	10.11	3.95		12.83

Hardwood DANCER Trusses - Cyclonic Wind

Wind Class	Truss Spacing	Truss Span Outside Studs	Net Wind Suction + Pressure Perpendicualr to Roof	Vertical Roof Permanent Action	Tensile Force in Each Anchorage Stud	Bending Moment in Roofing Purlin	Shear connecting the purlin to the lacing	Horizontal Force at Top Chord Apex Splice & Bottom Chord Splice	Unseasoned Hardwood
	m	m	kPa	KN/m	kN	kN.m	kN	kN	J2
C1	0.45	4.80	2.16	0.379	1.28	0.04	0.87	1.98	M12
C1	0.45	5.70	2.16	0.379	1.52	0.04	0.87	2.41	M12
C1	0.45	6.60	2.16	0.379	1.76	0.04	0.87	2.85	M12
C1	0.45	7.50	2.16	0.379	2.01	0.04	0.87	3.28	M12
C1	0.45	8.40	2.16	0.379	2.25	0.04	0.87	3.72	M12
C1	0.60	4.80	2.16	0.358	2.05	0.07	1.17	3.17	M12
C1	0.60	5.70	2.16	0.358	2.44	0.07	1.17	3.87	M12
C1	0.60	6.60	2.16	0.358	2.83	0.07	1.17	4.57	M12
C1	0.60	7.50	2.16	0.358	3.22	0.07	1.17	5.27	M12
C1	0.60	8.40	2.16	0.358	3.62	0.07	1.17	5.97	M12
C1	0.75	4.80	2.16	0.348	2.79	0.11	1.46	4.33	M12
C1	0.75	5.70	2.16	0.348	3.33	0.11	1.46	5.28	M12
C1	0.75	6.60	2.16	0.348	3.87	0.11	1.46	6.23	M12
C1	0.75	7.50	2.16	0.348	4.40	0.11	1.46	7.19	M12
C1	0.75	8.40	2.16	0.348	4.94	0.11	1.46	8.15	M12
C1	0.90	4.80	2.16	0.342	3.53	0.16	1.75	5.47	M12
C1	0.90	5.70	2.16	0.342	4.21	0.16	1.75	6.67	M12
C1	0.90	6.60	2.16	0.342	4.88	0.16	1.75	7.87	M12
C1	0.90	7.50	2.16	0.342	5.56	0.16	1.75	9.08	M12
C1	0.90	8.40	2.16	0.342	6.23	0.16	1.75	10.30	M16
C2	0.45	4.80	3.21	0.379	2.33	0.06	1.30	3.62	M12
C2	0.45	5.70	3.21	0.379	2.78	0.06	1.30	4.41	M12
C2	0.45	6.60	3.21	0.379	3.23	0.06	1.30	5.21	M12
C2	0.45	7.50	3.21	0.379	3.68	0.06	1.30	6.01	M12
C2	0.45	8.40	3.21	0.379	4.12	0.06	1.30	6.81	M12
C2	0.60	4.80	3.21	0.358	3.46	0.10	1.74	5.36	M12
C2	0.60	5.70	3.21	0.358	4.12	0.10	1.74	6.53	M12
C2	0.60	6.60	3.21	0.358	4.78	0.10	1.74	7.72	M12
C2	**0.60**	**7.50**	**3.21**	**0.358**	**5.45**	**0.10**	**1.74**	**8.90**	**M12**
C2	**0.60**	**8.40**	**3.21**	**0.358**	**6.11**	**0.10**	**1.74**	**10.09**	**M16**
C2	0.75	4.80	3.21	0.348	4.56	0.16	2.17	7.06	M12
C2	0.75	5.70	3.21	0.348	5.43	0.16	2.17	8.61	M12
C2	0.75	6.60	3.21	0.348	6.30	0.16	2.17	10.17	M16
C2	0.75	7.50	3.21	0.348	7.18	0.16	2.17	11.73	M16
C2	**0.90**	**4.80**	**3.21**	**0.342**	**5.65**	**0.23**	**2.60**	**8.74**	**M12**
C2	**0.90**	**5.70**	**3.21**	**0.342**	**6.73**	**0.23**	**2.60**	**10.66**	**M16**
C2	**0.90**	**6.60**	**3.21**	**0.342**	**7.81**	**0.23**	**2.60**	**12.59**	**M16**
C3	0.45	4.80	4.73	0.379	3.86	0.09	1.92	5.97	M12
C3	0.45	5.70	4.73	0.379	4.59	0.09	1.92	7.28	M12
C3	0.45	6.60	4.73	0.379	5.33	0.09	1.92	8.60	M12
C3	0.45	7.50	4.73	0.379	6.07	0.09	1.92	9.92	M16
C3	0.45	8.40	4.73	0.379	6.81	0.09	1.92	11.25	M16
C3	0.60	4.80	4.73	0.358	5.49	0.15	2.55	8.50	M12
C3	0.60	5.70	4.73	0.358	6.54	0.15	2.55	10.36	M16
C3	0.60	6.60	4.73	0.358	7.59	0.15	2.55	12.24	M16
C3	0.75	4.80	4.73	0.348	7.09	0.24	3.19	10.99	M16
C4	0.45	4.80	6.39	0.379	5.52	0.12	2.59	8.55	M12
C4	0.45	5.70	6.39	0.379	6.58	0.12	2.59	10.42	M16
C4	0.45	6.60	6.39	0.379	7.63	0.12	2.59	12.31	M16
C4	0.60	4.80	6.39	0.358	7.71	0.21	3.45	11.94	M16

Softwood DANCER Trusses - Low to Medium Non-cyclonic Wind

Wind Class	Truss Spacing	Truss Span Outside Studs	Net Wind Suction + Pressure Perpendicualr to Roof	Vertical Roof Permanent Action	Tensile Force in Each Anchorage Stud	Bending Moment in Roofing Purlin	Shear connecting the purlin to the lacing	Horizontal Force at Top Chord Apex Splice & Bottom Chord Splice	Seasoned Softwood
	m	m	kPa	KN/m	kN	kN.m	kN	kN	JD4
N2	0.45	4.80	0.95	0.160	0.58	0.02	0.38	0.89	M12
N2	0.45	5.70	0.95	0.160	0.69	0.02	0.38	1.09	M12
N2	0.45	6.60	0.95	0.160	0.80	0.02	0.38	1.29	M12
N2	0.45	7.50	0.95	0.160	0.91	0.02	0.38	1.49	M12
N2	0.45	8.40	0.95	0.160	1.02	0.02	0.38	1.68	M12
N2	0.90	4.80	0.95	0.155	1.54	0.07	0.77	2.39	M12
N2	0.90	5.70	0.95	0.155	1.84	0.07	0.77	2.91	M12
N2	0.90	6.60	0.95	0.155	2.13	0.07	0.77	3.44	M12
N2	0.90	7.50	0.95	0.155	2.43	0.07	0.77	3.97	M12
N2	0.90	8.40	0.95	0.155	2.72	0.07	0.77	4.50	M12
N2	**1.35**	**4.80**	**0.95**	**0.164**	**2.47**	**0.16**	**1.15**	**3.83**	**M12**
N2	**1.35**	**5.70**	**0.95**	**0.164**	**2.95**	**0.16**	**1.15**	**4.67**	**M12**
N2	**1.35**	**6.60**	**0.95**	**0.164**	**3.42**	**0.16**	**1.15**	**5.52**	**M12**
N2	**1.35**	**7.50**	**0.95**	**0.164**	**3.89**	**0.16**	**1.15**	**6.37**	**M12**
N2	**1.35**	**8.40**	**0.95**	**0.164**	**4.37**	**0.16**	**1.15**	**7.22**	**M12**
N2	2.70	4.80	0.95	0.205	5.24	0.62	2.31	8.11	M16
N3	0.45	4.80	1.49	0.160	1.11	0.03	0.60	1.72	M12
N3	0.45	5.70	1.49	0.160	1.33	0.03	0.60	2.10	M12
N3	0.45	6.60	1.49	0.160	1.54	0.03	0.60	2.48	M12
N3	0.45	7.50	1.49	0.160	1.75	0.03	0.60	2.87	M12
N3	0.45	8.40	1.49	0.160	1.97	0.03	0.60	3.25	M12
N3	0.90	4.80	1.49	0.155	2.62	0.11	1.20	4.05	M12
N3	0.90	5.70	1.49	0.155	3.12	0.11	1.20	4.94	M12
N3	0.90	6.60	1.49	0.155	3.62	0.11	1.20	5.83	M12
N3	0.90	7.50	1.49	0.155	4.12	0.11	1.20	6.73	M12
N3	0.90	8.40	1.49	0.155	4.62	0.11	1.20	7.63	M16
N3	1.35	4.80	1.49	0.164	4.08	0.24	1.80	6.32	M12
N3	1.35	5.70	1.49	0.164	4.87	0.24	1.80	7.71	M16
N3	1.35	6.60	1.49	0.164	5.65	0.24	1.80	9.11	M16

Softwood DANCER Trusses - High Non-cyclonic Wind

Wind Class	Truss Spacing	Truss Span Outside Studs	Net Wind Suction + Pressure Perpendicualr to Roof	Vertical Roof Permanent Action	Tensile Force in Each Anchorage Stud	Bending Moment in Roofing Purlin	Shear connecting the purlin to the lacing	Horizontal Force at Top Chord Apex Splice & Bottom Chord Splice	Seasoned Softwood
	m	m	kPa	KN/m	kN	kN.m	kN	kN	JD4
N4	0.45	4.80	2.21	0.160	1.84	0.04	0.90	2.85	M12
N4	0.45	5.70	2.21	0.160	2.19	0.04	0.90	3.48	M12
N4	0.45	6.60	2.21	0.160	2.55	0.04	0.90	4.11	M12
N4	0.45	7.50	2.21	0.160	2.90	0.04	0.90	4.74	M12
N4	0.45	8.40	2.21	0.160	3.25	0.04	0.90	5.37	M12
N4	0.90	4.80	2.21	0.155	4.07	0.16	1.79	6.30	M12
N4	0.90	5.70	2.21	0.155	4.85	0.16	1.79	7.69	M16
N4	0.90	6.60	2.21	0.155	5.63	0.16	1.79	9.08	M16
N5	0.45	4.80	3.25	0.160	2.89	0.06	1.32	4.47	M12
N5	0.45	5.70	3.25	0.160	3.44	0.06	1.32	5.45	M12
N5	0.45	6.60	3.25	0.160	3.99	0.06	1.32	6.44	M12
N5	0.45	7.50	3.25	0.160	4.55	0.06	1.32	7.43	M16
N5	0.45	8.40	3.25	0.160	5.10	0.06	1.32	8.42	M16
N5	0.90	4.80	3.25	0.155	6.16	0.24	2.63	9.54	M16
N6	0.45	4.80	4.39	0.160	4.03	0.08	1.78	6.24	M12
N6	0.45	5.70	4.39	0.160	4.80	0.08	1.78	7.61	M16
N6	0.45	6.60	4.39	0.160	5.58	0.08	1.78	8.99	M16

Softwood DANCER Trusses - Cyclonic Wind

Wind Class	Truss Spacing	Truss Span Outside Studs	Net Wind Suction + Pressure Perpendicualr to Roof	Vertical Roof Permanent Action	Tensile Force in Each Anchorage Stud	Bending Moment in Roofing Purlin	Shear connecting the purlin to the lacing	Horizontal Force at Top Chord Apex Splice & Bottom Chord Splice	Seasoned Softwood
	m	m	kPa	KN/m	kN	kN.m	kN	kN	JD4
C1	0.45	4.80	2.16	0.160	1.79	0.04	0.87	2.77	M12
C1	0.45	5.70	2.16	0.160	2.13	0.04	0.87	3.38	M12
C1	0.45	6.60	2.16	0.160	2.48	0.04	0.87	3.99	M12
C1	0.45	7.50	2.16	0.160	2.82	0.04	0.87	4.61	M12
C1	0.45	8.40	2.16	0.160	3.16	0.04	0.87	5.23	M12
C1	0.60	4.80	2.16	0.155	2.53	0.07	1.17	3.91	M12
C1	0.60	5.70	2.16	0.155	3.01	0.07	1.17	4.77	M12
C1	0.60	6.60	2.16	0.155	3.49	0.07	1.17	5.63	M12
C1	0.60	7.50	2.16	0.155	3.98	0.07	1.17	6.50	M12
C1	0.60	8.40	2.16	0.155	4.46	0.07	1.17	7.37	M16
C1	0.75	4.80	2.16	0.154	3.25	0.11	1.46	5.03	M12
C1	0.75	5.70	2.16	0.154	3.87	0.11	1.46	6.14	M12
C1	0.75	6.60	2.16	0.154	4.49	0.11	1.46	7.25	M12
C1	0.75	7.50	2.16	0.154	5.12	0.11	1.46	8.36	M16
C1	0.75	8.40	2.16	0.154	5.74	0.11	1.46	9.48	M16
C1	0.90	4.80	2.16	0.155	3.97	0.16	1.75	6.15	M12
C1	0.90	5.70	2.16	0.155	4.73	0.16	1.75	7.50	M16
C1	0.90	6.60	2.16	0.155	5.49	0.16	1.75	8.85	M16
C2	0.45	4.80	3.21	0.160	2.85	0.06	1.30	4.41	M12
C2	0.45	5.70	3.21	0.160	3.39	0.06	1.30	5.38	M12
C2	0.45	6.60	3.21	0.160	3.94	0.06	1.30	6.36	M12
C2	0.45	7.50	3.21	0.160	4.49	0.06	1.30	7.33	M16
C2	0.45	8.40	3.21	0.160	5.03	0.06	1.30	8.31	M16
C2	**0.60**	**4.80**	**3.21**	**0.155**	**3.94**	**0.10**	**1.74**	**6.10**	**M12**
C2	**0.60**	**5.70**	**3.21**	**0.155**	**4.69**	**0.10**	**1.74**	**7.43**	**M16**
C2	**0.60**	**6.60**	**3.21**	**0.155**	**5.44**	**0.10**	**1.74**	**8.78**	**M16**
C2	0.75	4.80	3.21	0.154	5.01	0.16	2.17	7.77	M16
C2	0.75	5.70	3.21	0.154	5.97	0.16	2.17	9.47	M16
C2	0.90	4.80	3.21	0.155	6.09	0.23	2.60	9.43	M16
C3	0.45	4.80	4.73	0.160	4.37	0.09	1.92	6.77	M12
C3	0.45	5.70	4.73	0.160	5.21	0.09	1.92	8.25	M16
C3	0.60	4.80	4.73	0.155	5.96	0.15	2.55	9.24	M16
C4	0.45	4.80	6.39	0.160	6.03	0.12	2.59	9.35	M16

End Connections for Lacing and Diagonals

The member forces in the lacing and diagonal members of the trusses vary considerably, and the members and connections should be designed to transmit these loads.

However, the maximum probable diagonal lacing load (from the preceding tables) is 6.27 kN.

Therefore it is recommended that the nailed connections be selected to resist this load.

Following are the design capacities of various nailed connections. Where 8 nails are specified, this is taken as 4 through each of the two chord members penetrating into the diagonal lacing member.

8 / 75 x 3.75φ galvanized nails , shear, side grain, in hardwood J2	12.02 kN
8 / 75 x 3.75φ galvanized nails , shear, side grain, in softwood JD4	8.60 kN
8 / 75 x 3.75φ galvanized nails , shear, side grain, in softwood JD5	7.09 kN
8 / 75 x 3.15φ galvanized nails , shear, side grain, in hardwood J2	8.80 kN
8 / 75 x 3.15φ galvanized nails , shear, side grain, in softwood JD4	4.46 kN
8 / 75 x 3.15φ galvanized nails , shear, side grain, in softwood JD5	3.45 kN

The following nailing of lacing and diagonal members between pairs of chords is recommended:

8 / 75 x 3.75φ galvanized nails , shear, side grain, in softwood

8 / 75 x 3.15φ galvanized nails , shear, side grain, in hardwood

Part 3 – DANCER Details

Part 3 provides member and connection details, material lists and timber cutting schedules for the principal components of the most common **DANCER** buildings. The **DANCER** R Design Package may be used to prepare customised details, material lists and timber cutting schedules for other applications.

Standard **DANCER** Floor Plans

The **DANCER** Building System can be safely and economically used for rectangular buildings, either elevated timber or reinforced concrete masonry construction, with gable, hip or skillion roofs up to approximately 9.0 x 9.0 m.

The standard designs typically employ piers and posts on grids of:

- 2.7 x 2.7 m grid for buildings in low to medium non-cyclonic wind areas (N1, N2 and N3)
- 1.8 x 1.8 m grid for buildings in low to high non-cyclonic wind areas (N4, N5 and N6) and in cyclonic wind areas (C1, C2, C3 and C4).

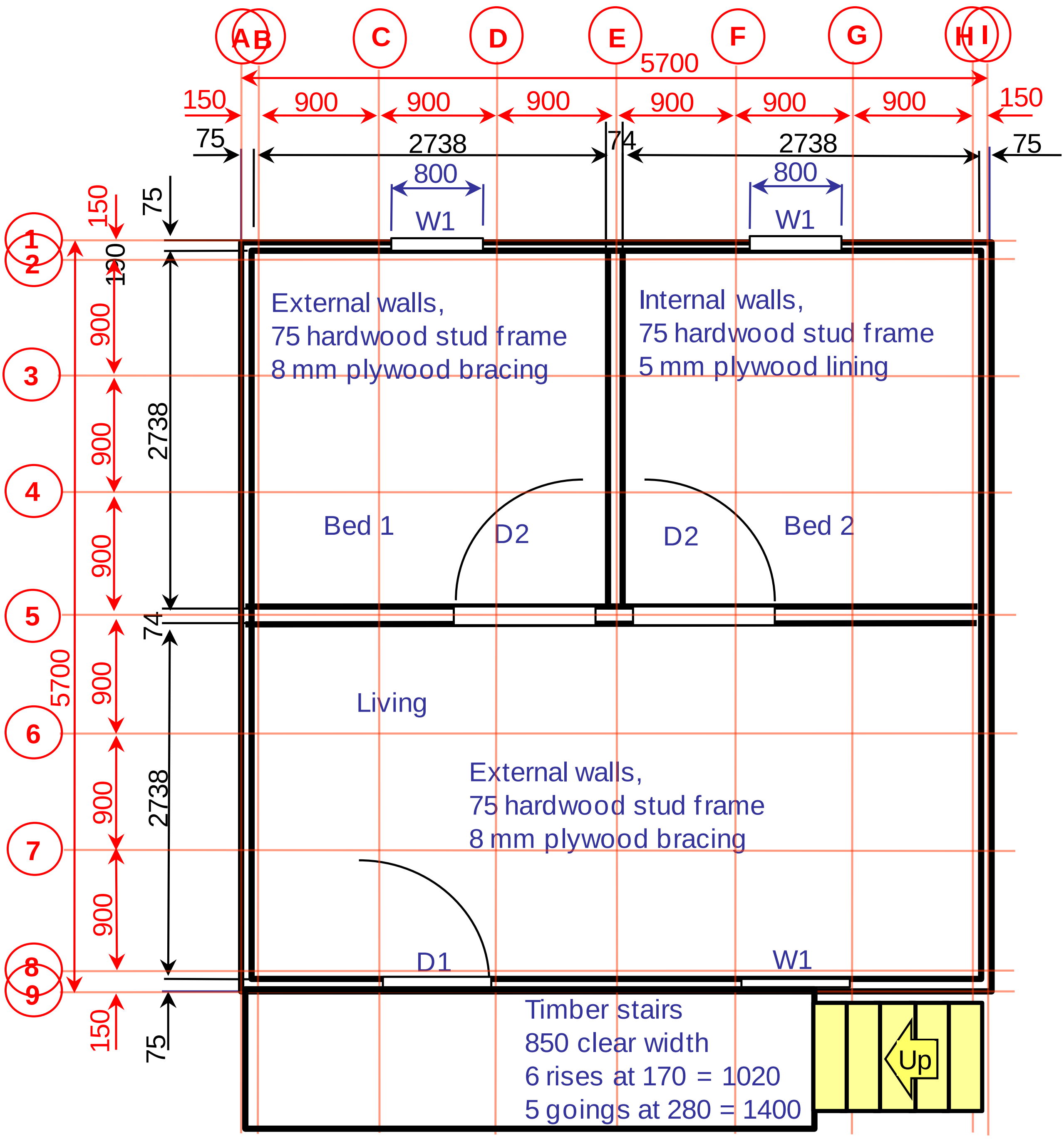
In both applications, the standard **DANCER** buildings incorporate an additional 150 mm at each side and at each end (to the outside of the wall framing), although non-standards building can be achieved by varying this dimension.

These grids facilitate a roof purlin (batten) spacing of 900 mm.

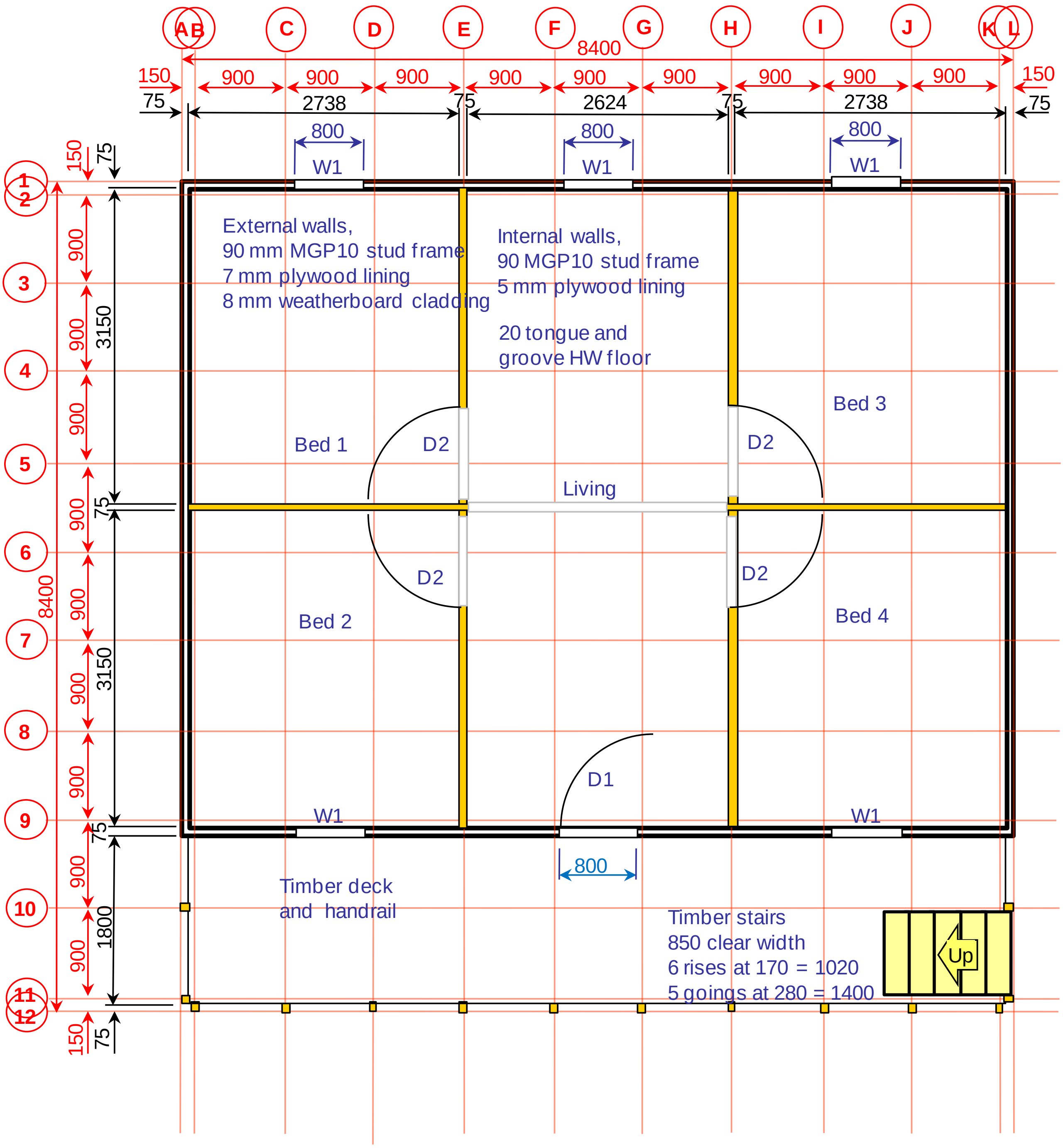
This Handbook includes details for a range of Standard **DANCER** buildings, as listed below and in the following pages.

No	Use	Dimensions	Storeys	Construction
1	House	5.700 x 5.700	One	Clad timber frame + elevated timber floor
2	House	8.400 x 6.525 + 1.875 veranda	One	Clad timber frame + elevated timber floor
3	House	5.700 x 5.700	One	Reinforced blockwork + concrete slab
4	House	8.400 x 6.525 + 1.875 veranda	One	Reinforced blockwork + concrete slab
5	House	8.400 x 6.525 + 1.875 veranda	Two	Reinforced blockwork + concrete slab + timber floor
6	Transition House	6.000 x 3.500	One	Clad timber frame + elevated timber floor

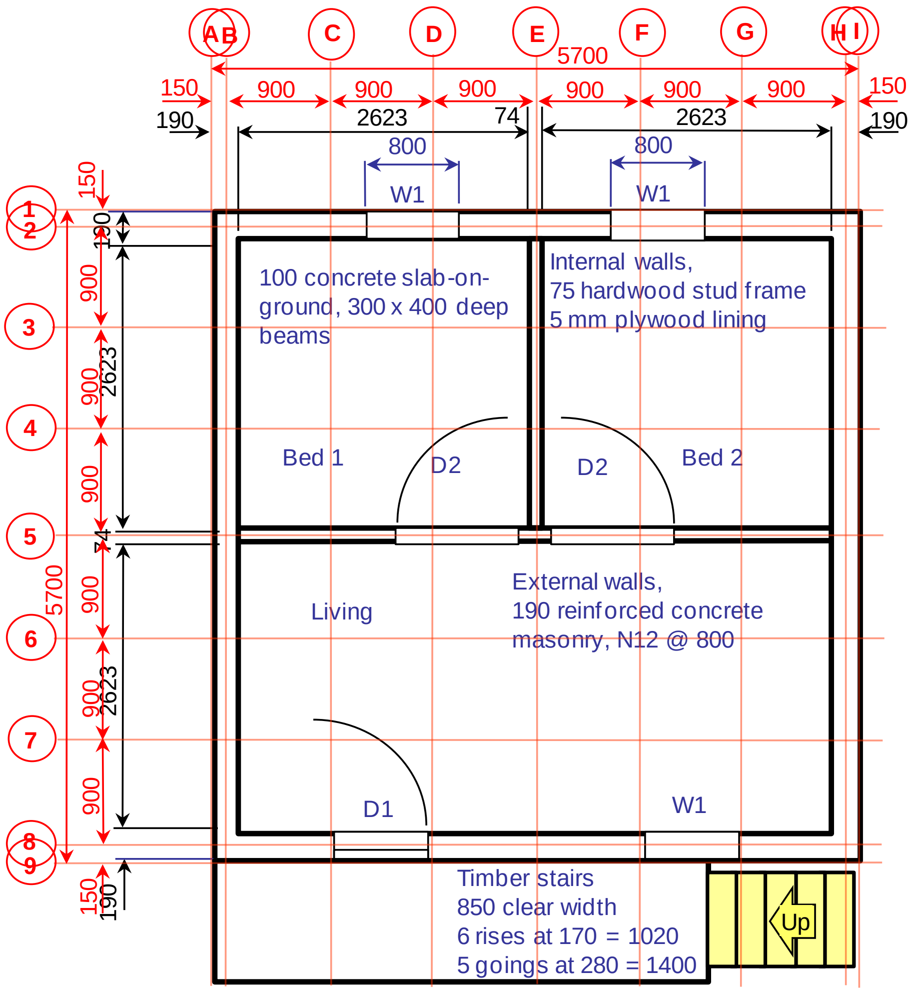
1 – House, 5.700 x 5.700, one storey, timber



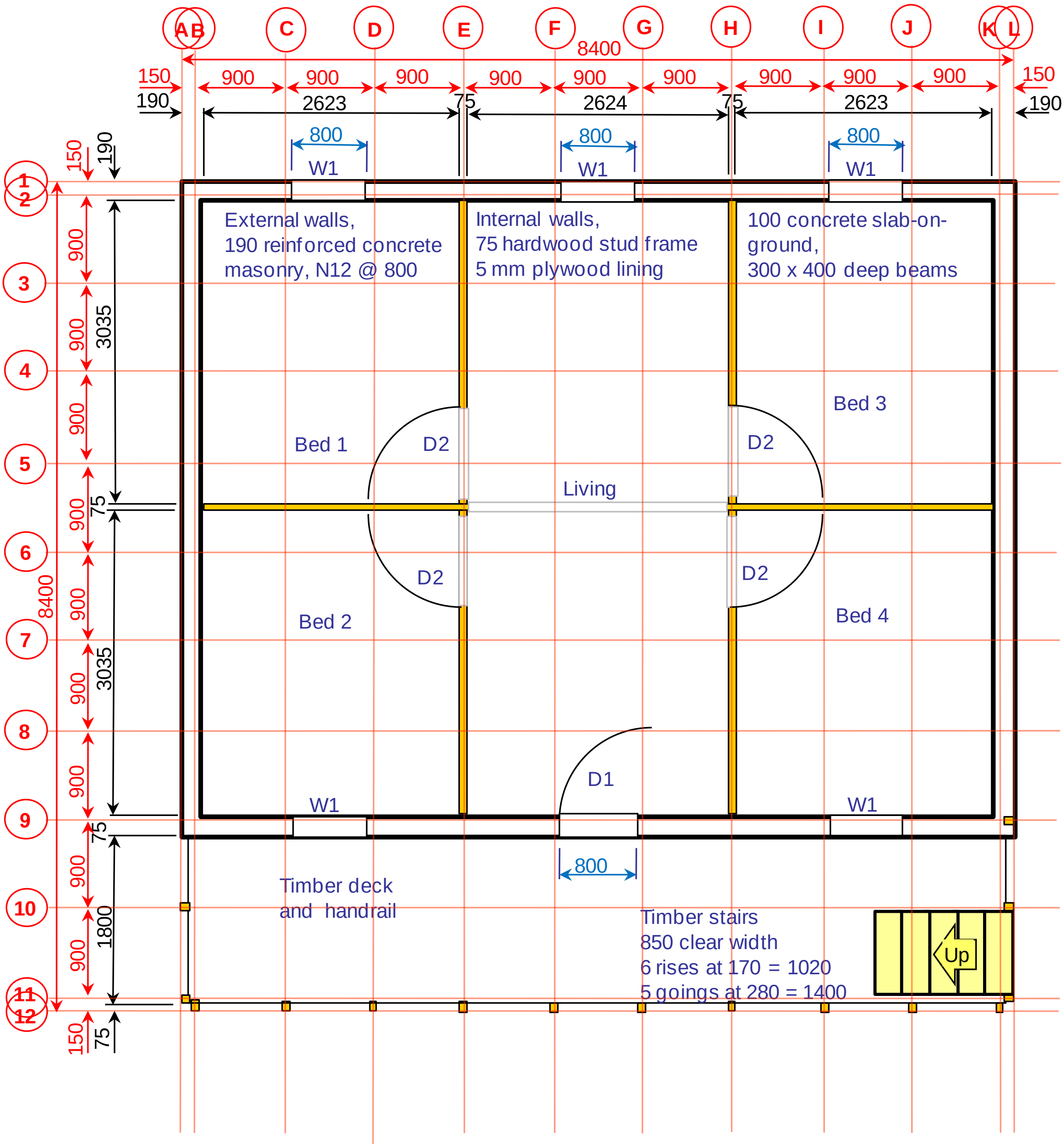
2 – House, 8.400 x 6.525 + 1.875 veranda, one storey, timber



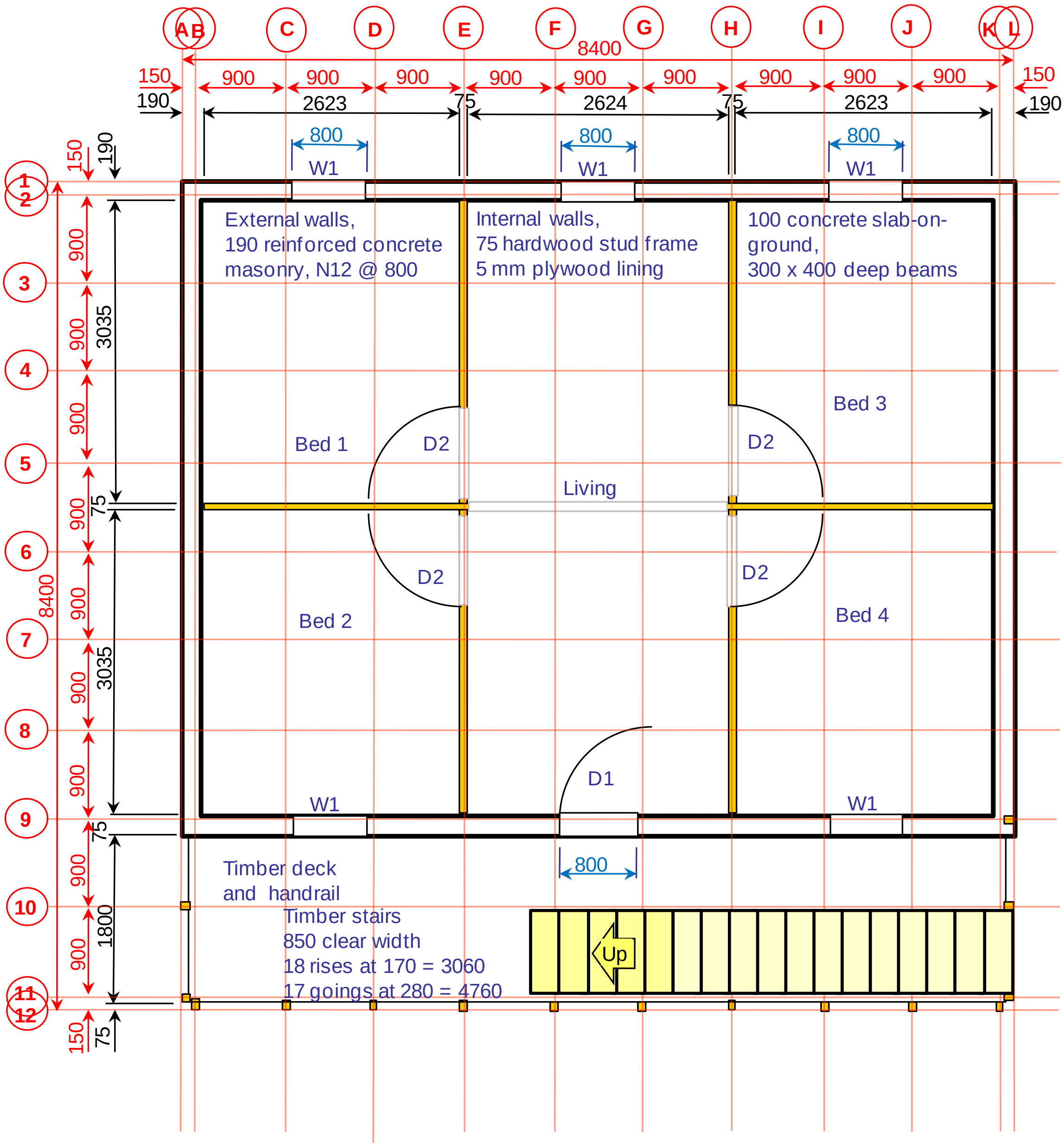
3 – House, 5.700 x 5.700, one storey, masonry



4 – House, 8.400 x 6.525 + 1.875 veranda, one storey, masonry



5 – House, 8.400 x 6.525 + 1.875 veranda, two storeys, masonry

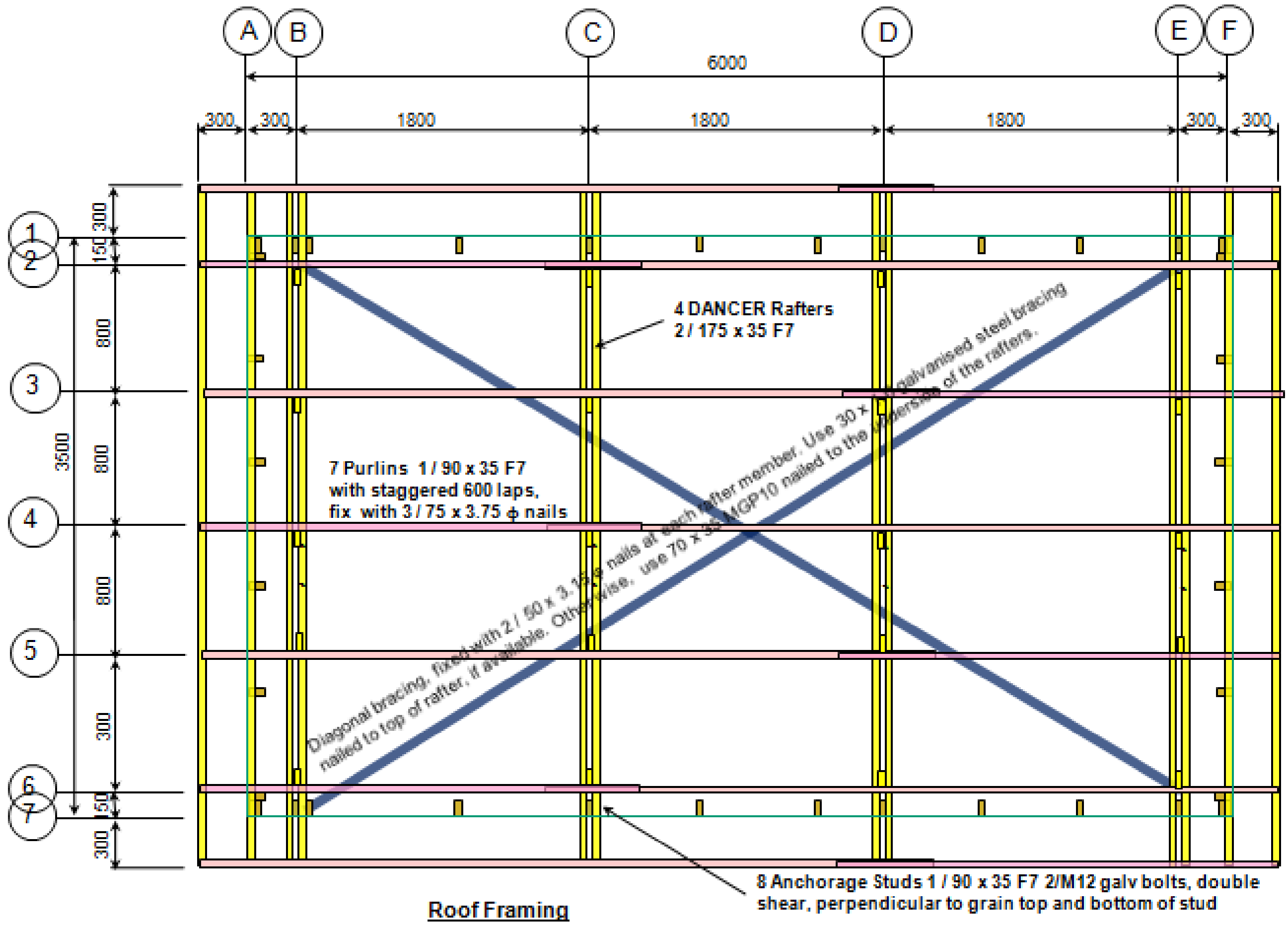


Non-standard DANCER Floor Plans

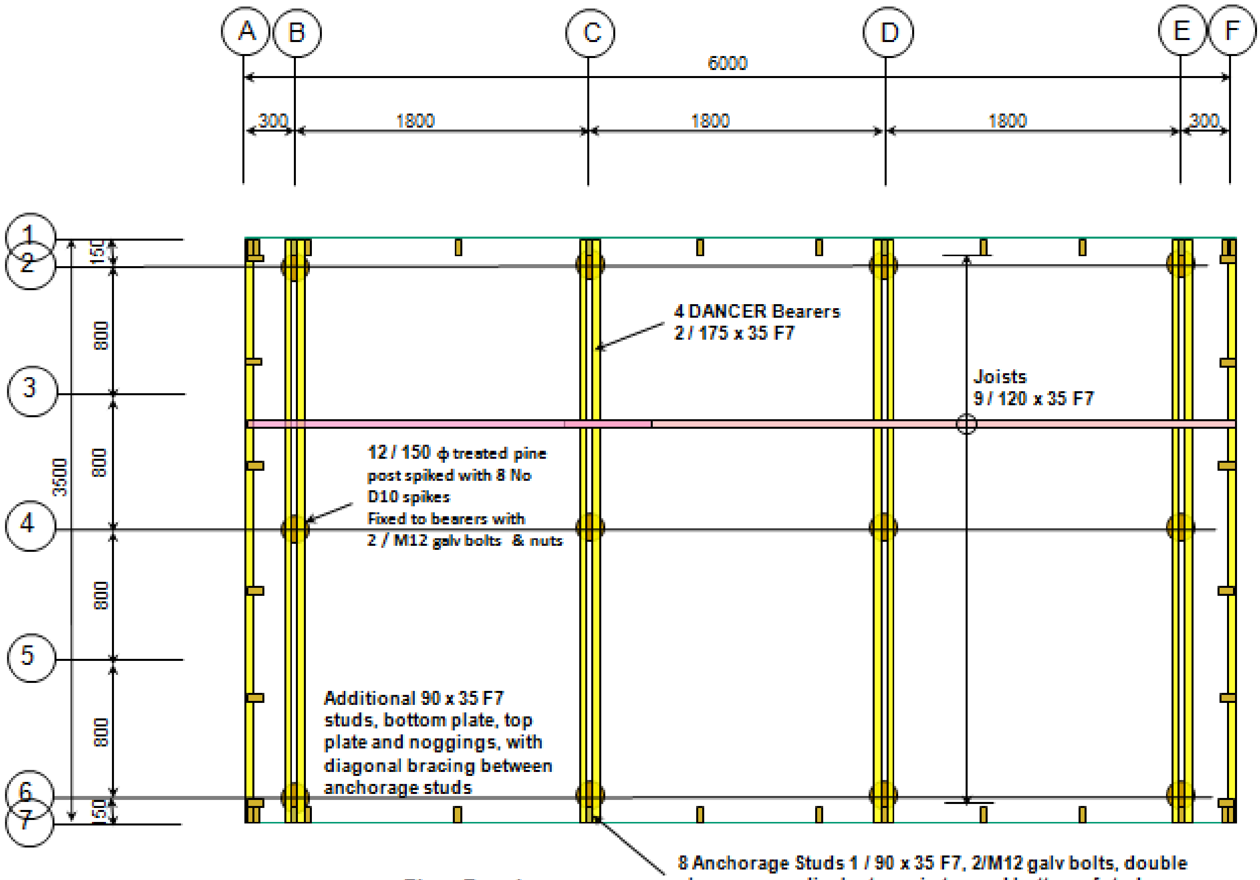
The **DANCER** Building System can be safely and economically used for rectangular buildings, either elevated timber or reinforced concrete masonry, with gable, hip or skillion roofs up to approximately 9.0 x 9.0 m.

This Handbook includes details of customised **DANCER** designs which have been prepared on an ad-hoc basis for particular projects.

DANCER Transition House



Roof Framing

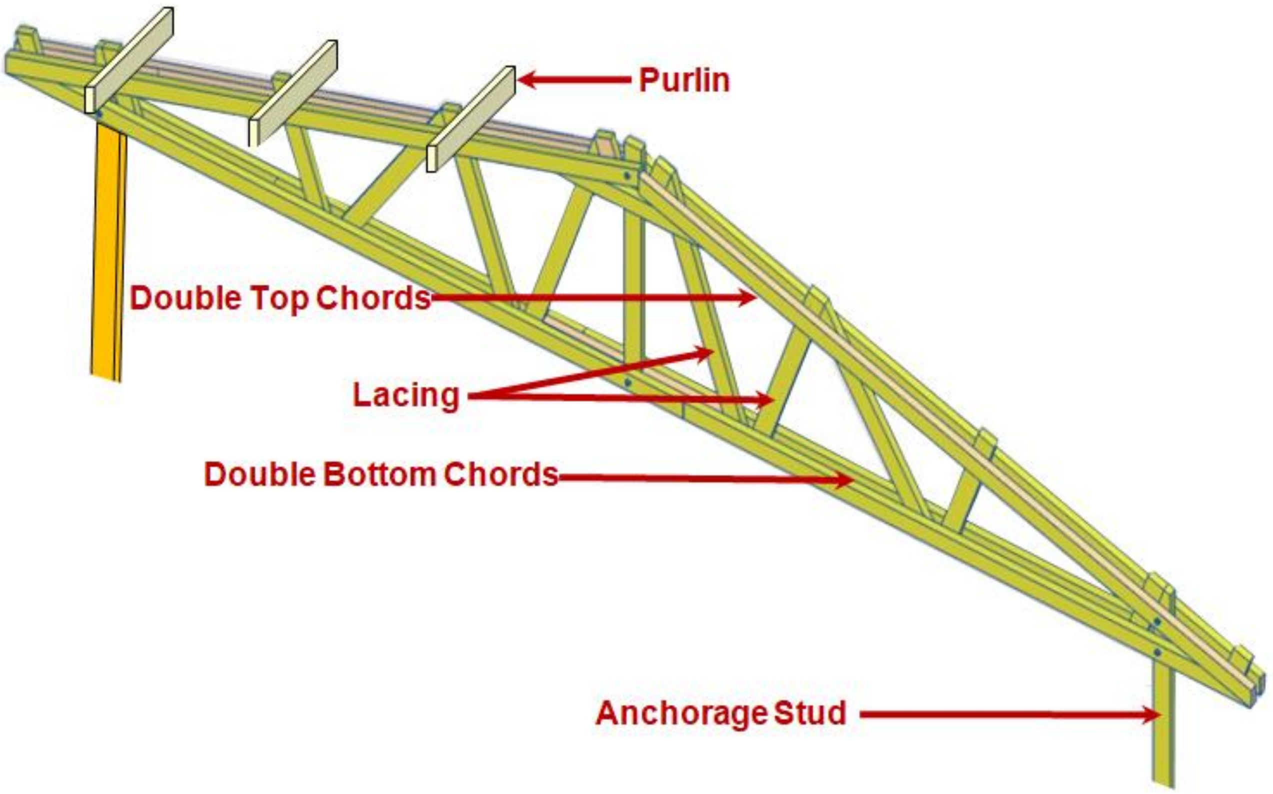


Floor Framing

DANCER Truss

The following details are typical for **DANCER** Trusses.

.



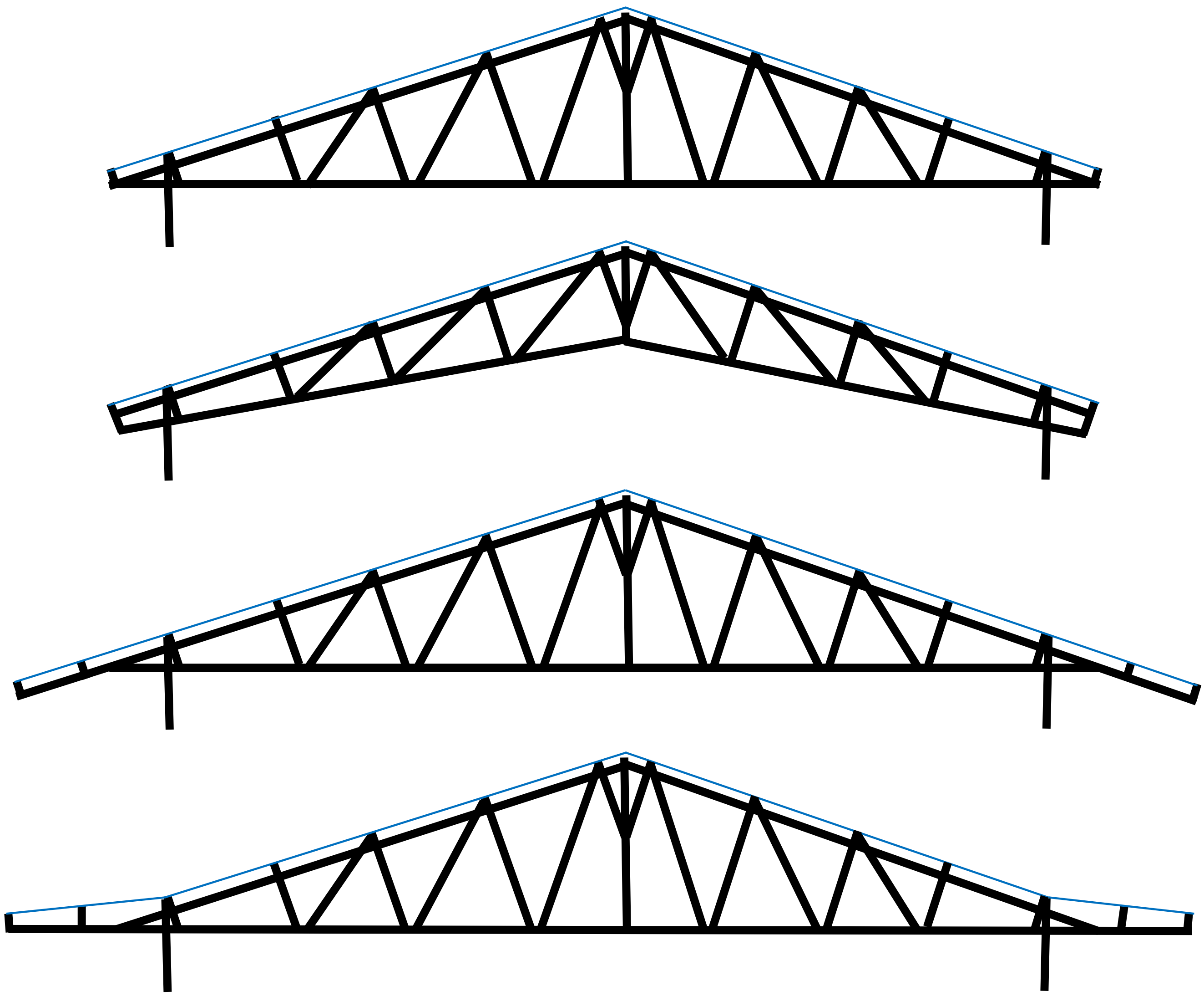
Typical details of standard **DANCER** Trusses of varying width, spacing and wind exposure are set out in the following tables, which are based on 90 x 35 MGP10 (JD4) seasoned softwood and 100 x 38 F11 (JD2) unseasoned hardwood.

Analysis indicates that the design is governed by the joint strengths, JD4 and J2.

Software is available for determining the details for other applications and timber specifications, including other timber stress grades and joint types.

Variations of DANCER Truss Arrangements

The following diagrams show some of the many variations of roof truss shape that are possible with the **DANCER** system. This includes raked bottom chords, extended eaves and variable rake roofs.



Hardwood DANCER Trusses - Low to Medium Non-cyclonic Wind

Wind Class	Truss Spacing	Truss Span Outside Studs	Unseasoned Hardwood	Pier Spacing
	m	m	J2	m
N2	0.45	4.80	M12	2.700
N2	0.45	5.70	M12	2.700
N2	0.45	6.60	M12	2.700
N2	0.45	7.50	M12	2.700
N2	0.45	8.40	M12	2.700
N2	0.90	4.80	M12	2.700
N2	0.90	5.70	M12	2.700
N2	0.90	6.60	M12	2.700
N2	0.90	7.50	M12	2.700
N2	0.90	8.40	M12	2.700
N2	1.35	4.80	M12	2.700
N2	1.35	5.70	M12	2.700
N2	1.35	6.60	M12	2.700
N2	1.35	7.50	M12	2.700
N2	1.35	8.40	M12	2.700
N2	**2.70**	**4.80**	**M12**	**2.700**
N2	**2.70**	**5.70**	**M12**	**2.700**
N2	**2.70**	**6.60**	**M16**	**2.700**
N3	0.45	4.80	M12	2.700
N3	0.45	5.70	M12	2.700
N3	0.45	6.60	M12	2.700
N3	0.45	7.50	M12	2.700
N3	0.45	8.40	M12	2.700
N3	0.90	4.80	M12	2.700
N3	0.90	5.70	M12	2.700
N3	0.90	6.60	M12	2.700
N3	0.90	7.50	M12	2.700
N3	0.90	8.40	M12	2.700
N3	1.35	4.80	M12	2.700
N3	1.35	5.70	M12	2.700
N3	1.35	6.60	M12	2.700
N3	1.35	7.50	M12	2.700
N3	1.35	8.40	M16	2.700
N3	2.70	4.80	M16	2.700

Hardwood DANCER Trusses - High Non-cyclonic Wind

Wind Class	Truss Spacing	Truss Span Outside Studs	Unseasoned Hardwood	Pier Spacing
	m	m	J2	m
N4	0.45	4.80	M12	1.800
N4	0.45	5.70	M12	1.800
N4	0.45	6.60	M12	1.800
N4	0.45	7.50	M12	1.800
N4	0.45	8.40	M12	1.800
N4	0.90	4.80	M12	1.800
N4	0.90	5.70	M12	1.800
N4	0.90	6.60	M12	1.800
N4	0.90	7.50	M12	1.800
N4	0.90	8.40	M16	1.800
N4	1.35	4.80	M12	1.800
N4	1.35	5.70	M16	1.800
N5	0.45	4.80	M12	1.800
N5	0.45	5.70	M12	1.800
N5	0.45	6.60	M12	1.800
N5	0.45	7.50	M12	1.800
N5	0.45	8.40	M12	1.800
N5	0.90	4.80	M12	1.800
N5	0.90	5.70	M16	1.800
N5	0.90	6.60	M16	1.800
N6	0.45	4.80	M12	1.800
N6	0.45	5.70	M12	1.800
N6	0.45	6.60	M12	1.800
N6	0.45	7.50	M12	1.800
N6	0.45	8.40	M16	1.800
N6	0.90	4.80	M16	1.800
N6	0.90	5.70	M16	1.800

Hardwood DANCER Trusses - Cyclonic Wind

Wind Class	Truss Spacing	Truss Span Outside Studs	Unseasoned Hardwood	Pier Spacing
	m	m	J2	m
C1	0.45	4.80	M12	1.800
C1	0.45	5.70	M12	1.800
C1	0.45	6.60	M12	1.800
C1	0.45	7.50	M12	1.800
C1	0.45	8.40	M12	1.800
C1	0.60	4.80	M12	1.800
C1	0.60	5.70	M12	1.800
C1	0.60	6.60	M12	1.800
C1	0.60	7.50	M12	1.800
C1	0.60	8.40	M12	1.800
C1	0.75	4.80	M12	1.800
C1	0.75	5.70	M12	1.800
C1	0.75	6.60	M12	1.800
C1	0.75	7.50	M12	1.800
C1	0.75	8.40	M12	1.800
C1	0.90	4.80	M12	1.800
C1	0.90	5.70	M12	1.800
C1	0.90	6.60	M12	1.800
C1	0.90	7.50	M12	1.800
C1	0.90	8.40	M16	1.800
C2	0.45	4.80	M12	1.800
C2	0.45	5.70	M12	1.800
C2	0.45	6.60	M12	1.800
C2	0.45	7.50	M12	1.800
C2	0.45	8.40	M12	1.800
C2	0.60	4.80	M12	1.800
C2	0.60	5.70	M12	1.800
C2	0.60	6.60	M12	1.800
C2	**0.60**	**7.50**	**M12**	**1.800**
C2	**0.60**	**8.40**	**M16**	**1.800**
C2	0.75	4.80	M12	1.800
C2	0.75	5.70	M12	1.800
C2	0.75	6.60	M16	1.800
C2	0.75	7.50	M16	1.800
C2	**0.90**	**4.80**	**M12**	**1.800**
C2	**0.90**	**5.70**	**M16**	**1.800**
C2	**0.90**	**6.60**	**M16**	**1.800**
C3	0.45	4.80	M12	1.800
C3	0.45	5.70	M12	1.800
C3	0.45	6.60	M12	1.800
C3	0.45	7.50	M16	1.800
C3	0.45	8.40	M16	1.800
C3	0.60	4.80	M12	1.800
C3	0.60	5.70	M16	1.800
C3	0.60	6.60	M16	1.800
C3	0.75	4.80	M16	1.800
C4	0.45	4.80	M12	1.800
C4	0.45	5.70	M16	1.800
C4	0.45	6.60	M16	1.800
C4	0.60	4.80	M16	1.800

Softwood DANCER Trusses - Low to Medium Non-cyclonic Wind

Wind Class	Truss Spacing	Truss Span Outside Studs	Seasoned Softwood	Pier Spacing
	m	m	JD4	m
N2	0.45	4.80	M12	2.700
N2	0.45	5.70	M12	2.700
N2	0.45	6.60	M12	2.700
N2	0.45	7.50	M12	2.700
N2	0.45	8.40	M12	2.700
N2	0.90	4.80	M12	2.700
N2	0.90	5.70	M12	2.700
N2	0.90	6.60	M12	2.700
N2	0.90	7.50	M12	2.700
N2	0.90	8.40	M12	2.700
N2	**1.35**	**4.80**	**M12**	**2.700**
N2	**1.35**	**5.70**	**M12**	**2.700**
N2	**1.35**	**6.60**	**M12**	**2.700**
N2	**1.35**	**7.50**	**M12**	**2.700**
N2	**1.35**	**8.40**	**M12**	**2.700**
N2	2.70	4.80	M16	2.700
N3	0.45	4.80	M12	2.700
N3	0.45	5.70	M12	2.700
N3	0.45	6.60	M12	2.700
N3	0.45	7.50	M12	2.700
N3	0.45	8.40	M12	2.700
N3	0.90	4.80	M12	2.700
N3	0.90	5.70	M12	2.700
N3	0.90	6.60	M12	2.700
N3	0.90	7.50	M12	2.700
N3	0.90	8.40	M16	2.700
N3	1.35	4.80	M12	2.700
N3	1.35	5.70	M16	2.700
N3	1.35	6.60	M16	2.700

Softwood DANCER Trusses - High Non-cyclonic Wind

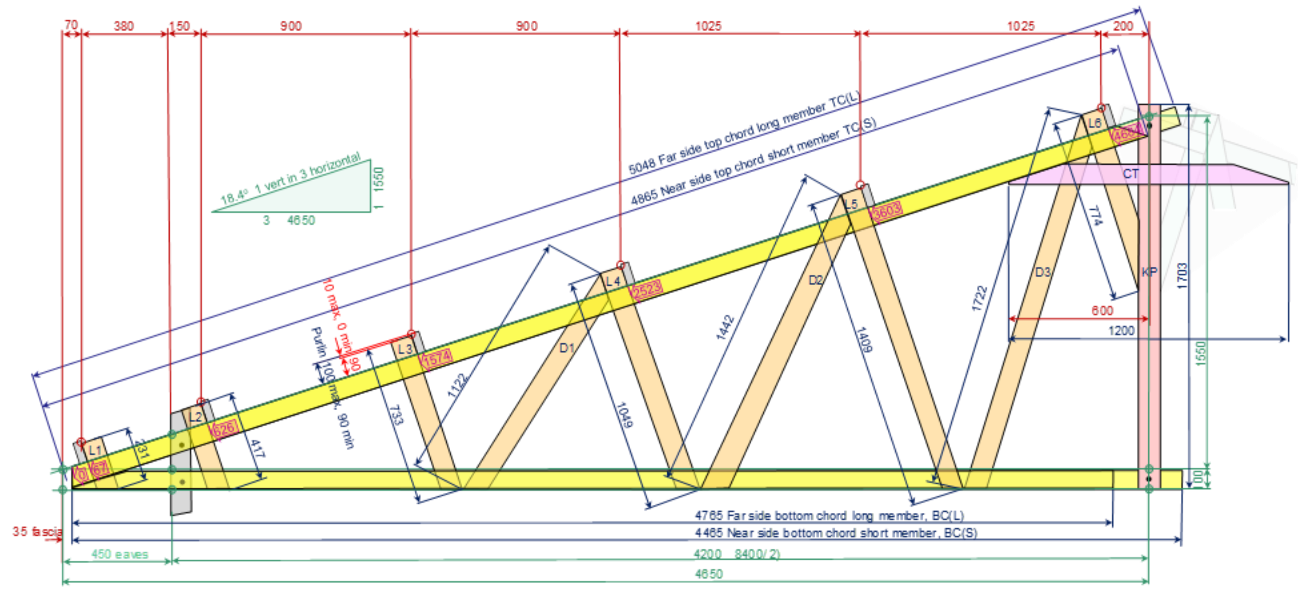
Wind Class	Truss Spacing	Truss Span Outside Studs	Seasoned Softwood	Pier Spacing
	m	m	JD4	m
N4	0.45	4.80	M12	1.800
N4	0.45	5.70	M12	1.800
N4	0.45	6.60	M12	1.800
N4	0.45	7.50	M12	1.800
N4	0.45	8.40	M12	1.800
N4	0.90	4.80	M12	1.800
N4	0.90	5.70	M16	1.800
N4	0.90	6.60	M16	1.800
N5	0.45	4.80	M12	1.800
N5	0.45	5.70	M12	1.800
N5	0.45	6.60	M12	1.800
N5	0.45	7.50	M16	1.800
N5	0.45	8.40	M16	1.800
N5	0.90	4.80	M16	1.800
N6	0.45	4.80	M12	1.800
N6	0.45	5.70	M16	1.800
N6	0.45	6.60	M16	1.800

Softwood DANCER Trusses - Cyclonic Wind

Wind Class	Truss Spacing	Truss Span Outside Studs	Seasoned Softwood	Pier Spacing
	m	m	JD4	m
C1	0.45	4.80	M12	1.800
C1	0.45	5.70	M12	1.800
C1	0.45	6.60	M12	1.800
C1	0.45	7.50	M12	1.800
C1	0.45	8.40	M12	1.800
C1	0.60	4.80	M12	1.800
C1	0.60	5.70	M12	1.800
C1	0.60	6.60	M12	1.800
C1	0.60	7.50	M12	1.800
C1	0.60	8.40	M16	1.800
C1	0.75	4.80	M12	1.800
C1	0.75	5.70	M12	1.800
C1	0.75	6.60	M12	1.800
C1	0.75	7.50	M16	1.800
C1	0.75	8.40	M16	1.800
C1	0.90	4.80	M12	1.800
C1	0.90	5.70	M16	1.800
C1	0.90	6.60	M16	1.800
C2	0.45	4.80	M12	1.800
C2	0.45	5.70	M12	1.800
C2	0.45	6.60	M12	1.800
C2	0.45	7.50	M16	1.800
C2	0.45	8.40	M16	1.800
C2	**0.60**	**4.80**	**M12**	**1.800**
C2	**0.60**	**5.70**	**M16**	**1.800**
C2	**0.60**	**6.60**	**M16**	**1.800**
C2	0.75	4.80	M16	1.800
C2	0.75	5.70	M16	1.800
C2	0.90	4.80	M16	1.800
C3	0.45	4.80	M12	1.800
C3	0.45	5.70	M16	1.800
C3	0.60	4.80	M16	1.800
C4	0.45	4.80	M16	1.800

Details of DANCER Trusses

The following dimensions are for the Standard **DANCER** 8.4 Truss, which is the largest standard truss in the range.



The following table provides the member lengths of the components of the complete range of Standard **DANCER** Trusses, from 4.8 m to 8.4 m span.

Note: Dimensions allow for 450 mm eaves

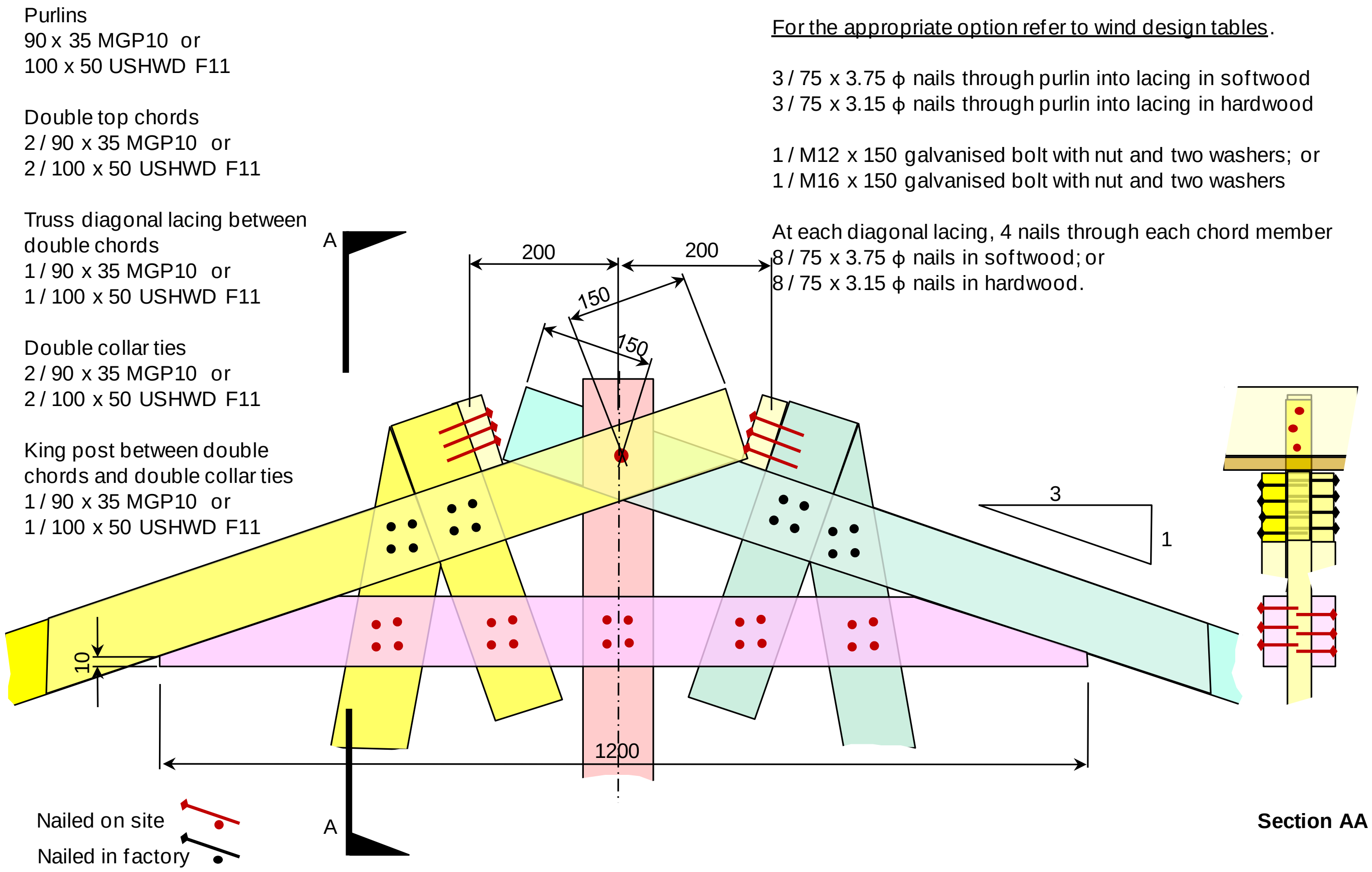
		4.800	5.100	5.400	5.700	6.000	6.300	6.600	6.900	7.200	7.500	7.800	8.100	8.400
Item	Component	Length mm	Length mm	Length mm	Length mm	Length mm	Length mm	Length mm	Length mm	Length mm	Length mm	Length mm	Length mm	Length mm
TC(L)	Truss Top Chord	3,151	3,309	3,467	3,625	3,784	3,942	4,100	4,258	4,416	4,574	4,732	4,890	5,048
TC(S)	Truss Top Chord	2,968	3,126	3,284	3,442	3,600	3,758	3,916	4,075	4,233	4,391	4,549	4,707	4,865
BC(L)	Truss Bottom Chord	2,965	3,115	3,265	3,415	3,565	3,715	3,865	4,015	4,165	4,315	4,465	4,615	4,765
BC(S)	Truss Bottom Chord	2,665	2,815	2,965	3,115	3,265	3,415	3,565	3,715	3,865	4,015	4,165	4,315	4,465
CT	Collar Tie	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
KP	King Post	1,103	1,153	1,203	1,253	1,303	1,353	1,403	1,453	1,503	1,553	1,603	1,653	1,703
L1	Lacing at eaves	231	231	231	231	231	231	231	231	231	231	231	231	231
L2	Lacing at anchorage	417	417	417	417	417	417	417	417	417	417	417	417	417
L3	Lacing	733	733	733	733	733	733	733	733	733	733	733	733	733
L4	Lacing	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049
L5	Lacing	0	0	0	0	0	0	0	1,278	1,304	1,330	1,357	1,383	1,409
L6	Lacing	774	774	774	774	774	774	774	774	774	774	774	774	774
D1	Diagonal	1,122	1,122	1,122	1,122	1,122	1,122	1,122	1,122	1,122	1,122	1,122	1,122	1,122
D2	Diagonal	0	0	1,275	1,389	1,511	1,640	1,169	1,206	1,247	1,291	1,339	1,389	1,442
D3	Diagonal	0	0	0	0	0	0	1,436	1,409	1,467	1,528	1,591	1,656	1,722

DANCER Truss Bolted Apex Splice

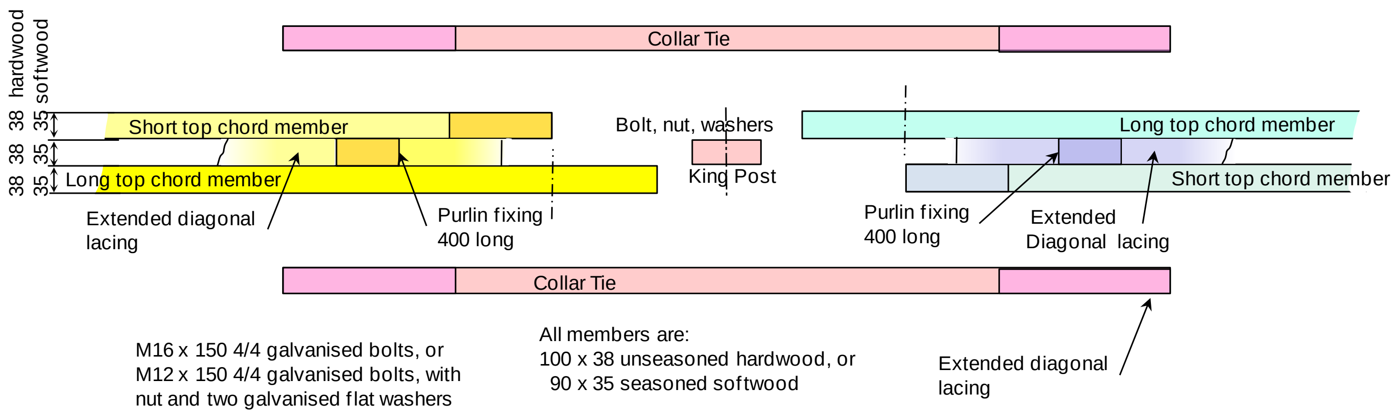
Trusses longer than 3.5 metres cannot be easily transported over significant distances.

They must be fabricated in two sections and joined on site. In this case the top chords must be joined with a bolted connection, and the bottom chords must be joined by a bolted connection.

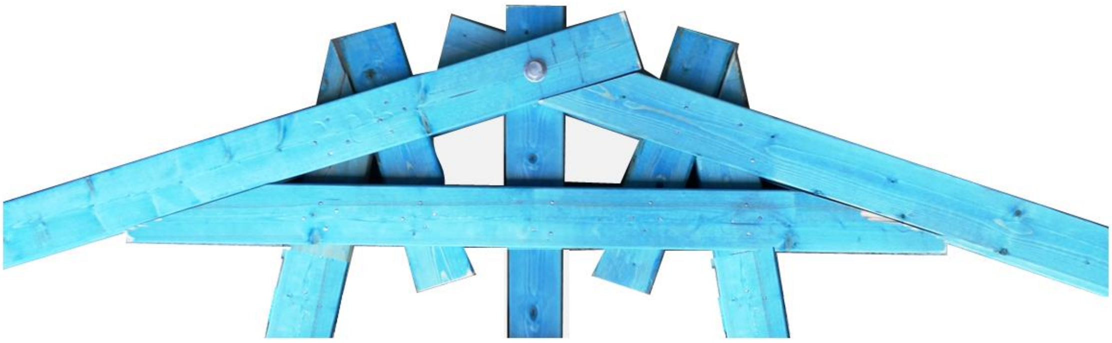
Bolted connections must not incorporate nails, since the premature failure of the nails could disrupt the timber and destroy the bolted connection before it has time to be effective.

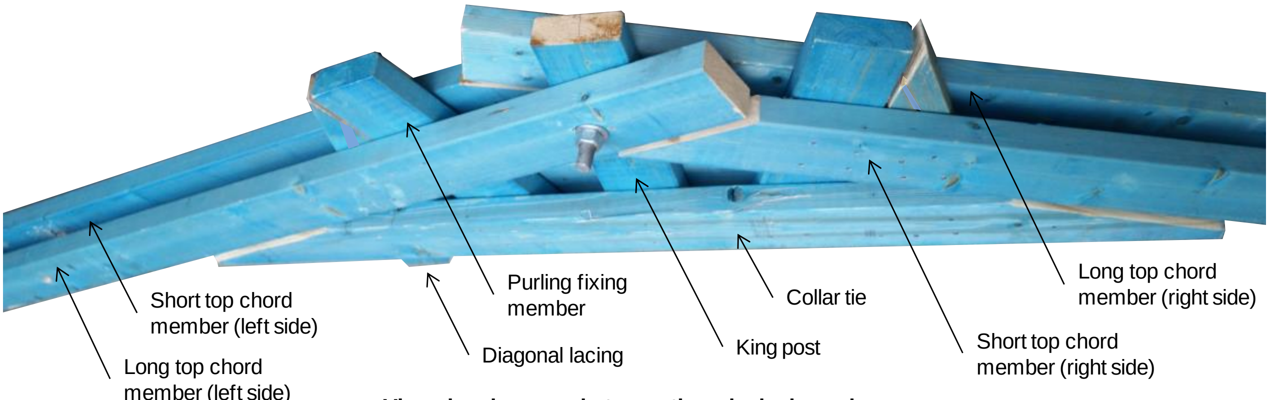


Connection Lacing to Truss Top Chord
Connection Truss Top Chord Apex Splice



Exploded Plan View Purlins omitted for clarity)

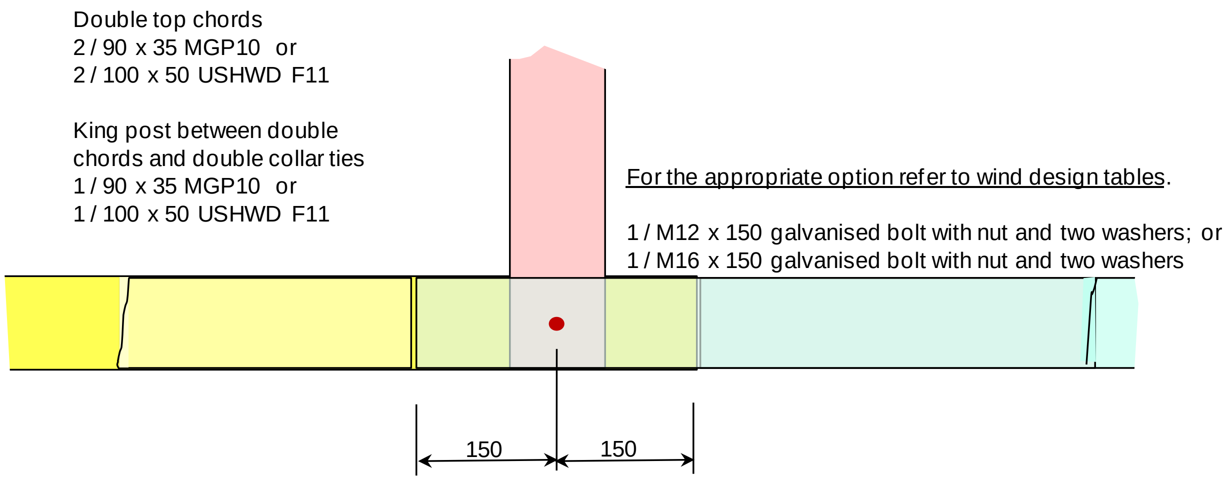




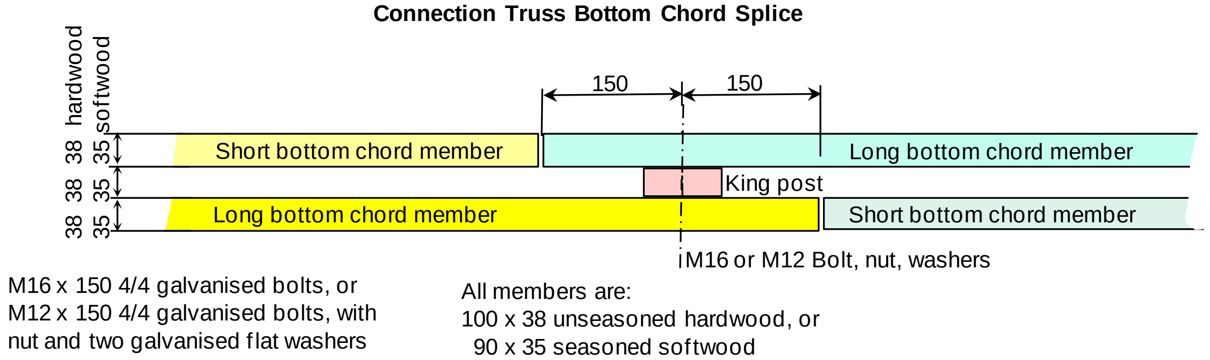
<u>**View showing gaps between the principal members**</u>

DANCER Truss Bolted Bottom Chord Splice

The Bottom Chords shall be spliced in a lapped double chord arrangement (similar to the top chord).

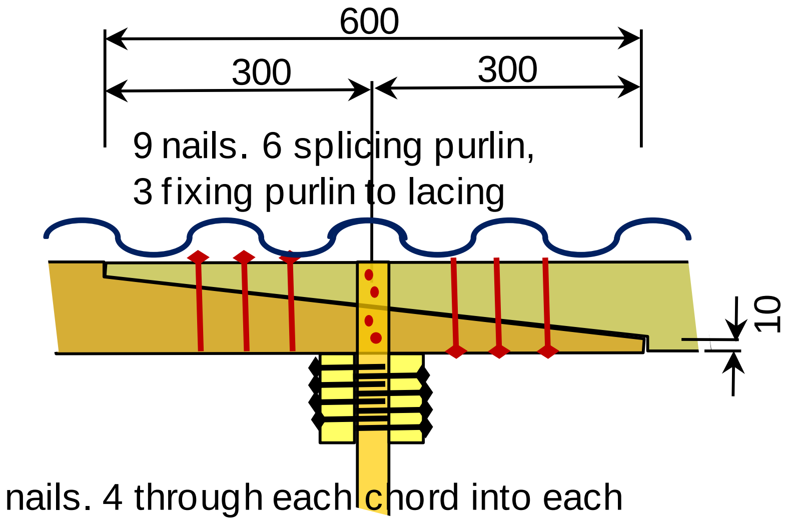


Connection Truss Bottom Chord Splice

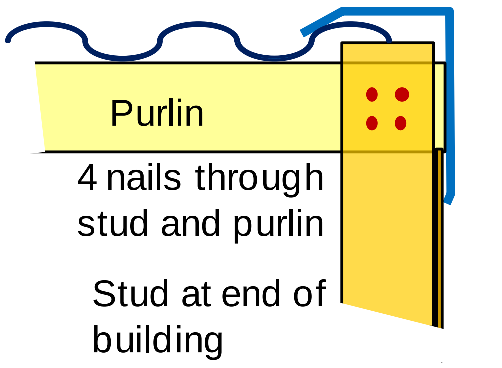


Plan View

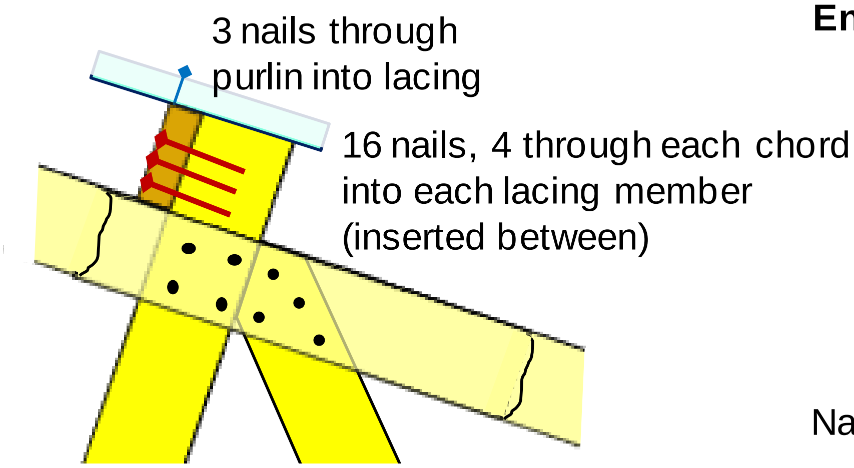
Purlin, Diagonal Lacing and Double Top Chord Connections



Purlin Splice



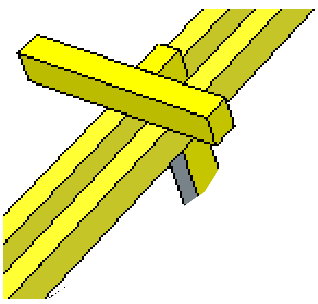
Connection Purlin to End Wall Stud

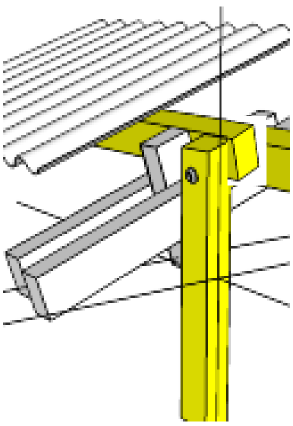


Connection Purlin to Double Top Chord
Connection Lacing to Double Top Chord

75 x 3.75 ϕ nails in softwood
75 x 3.15 ϕ n hardwood

Purlins, double chords and truss diagonal lacing between double chords
90 x 35 MGP10 or
100 x 50 USHWD F11

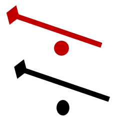


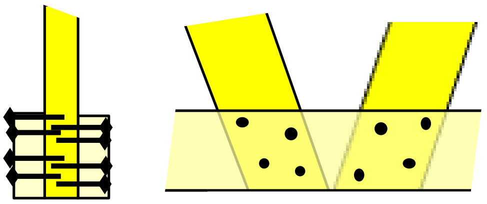


Double Bottom Chord, Anchorage Stud and Eaves Connections

Nailed on site

Nailed in factory



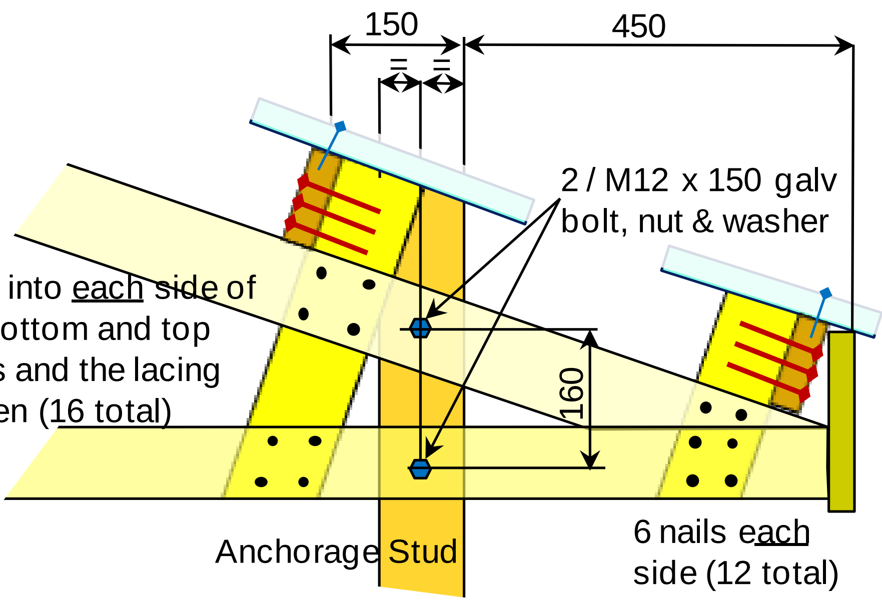


4 nails through <u>each</u> side of <u>both</u> bottom chords into lacing at <u>both lacing</u> (16 total)

Connection Lacing to Bottom Chords

75 x 3.75 ϕ nails in softwood
75 x 3.15 ϕ n hardwood

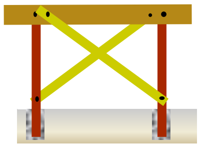
Purlins, double chords and truss diagonal lacing between double chords
90 x 35 MGP10 or
100 x 50 USHWD F11



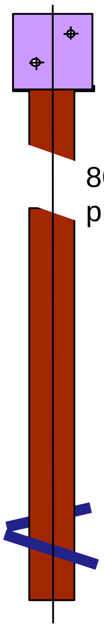
Top Chord to Bottom Chord
Top Chord to Anchorage Stud

Diagonal Sub-floor Bracing

Direct Anchorage Detail
Fix diagonal braces at the top directly to the bearers or joists (as appropriate), to provide a direct load path to the ground

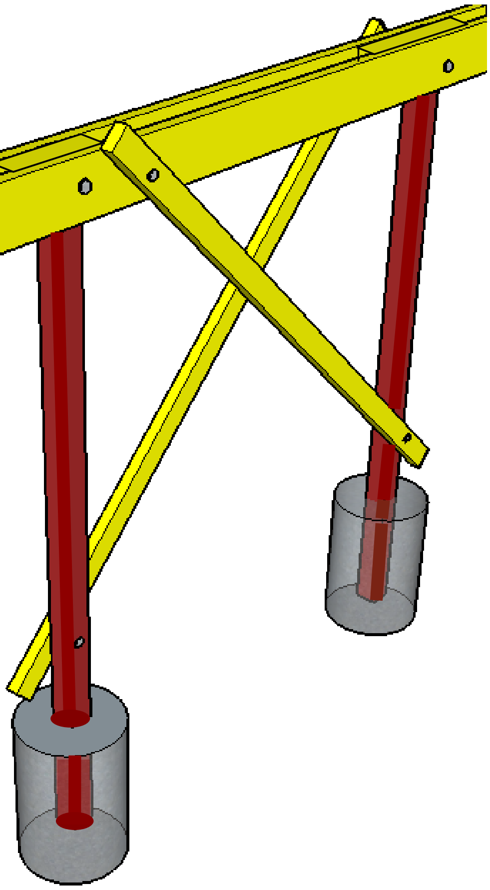


125 x 75 x 6 L drilled
with 2-14 mm holes

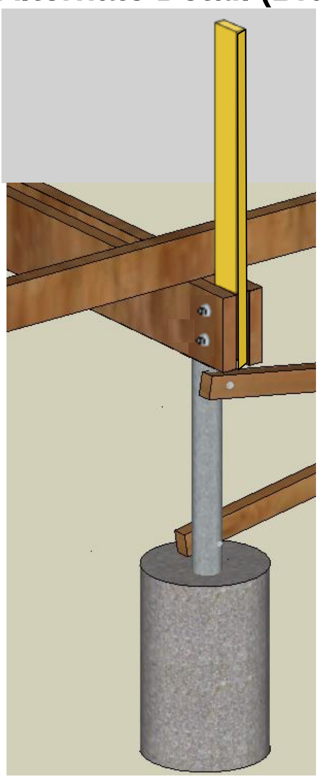


80 NB x 6.5 galvanized
pipe x 1200 long

Steel Posts (ex stock)



Alternate Detail (Braces bolted to top of posts)



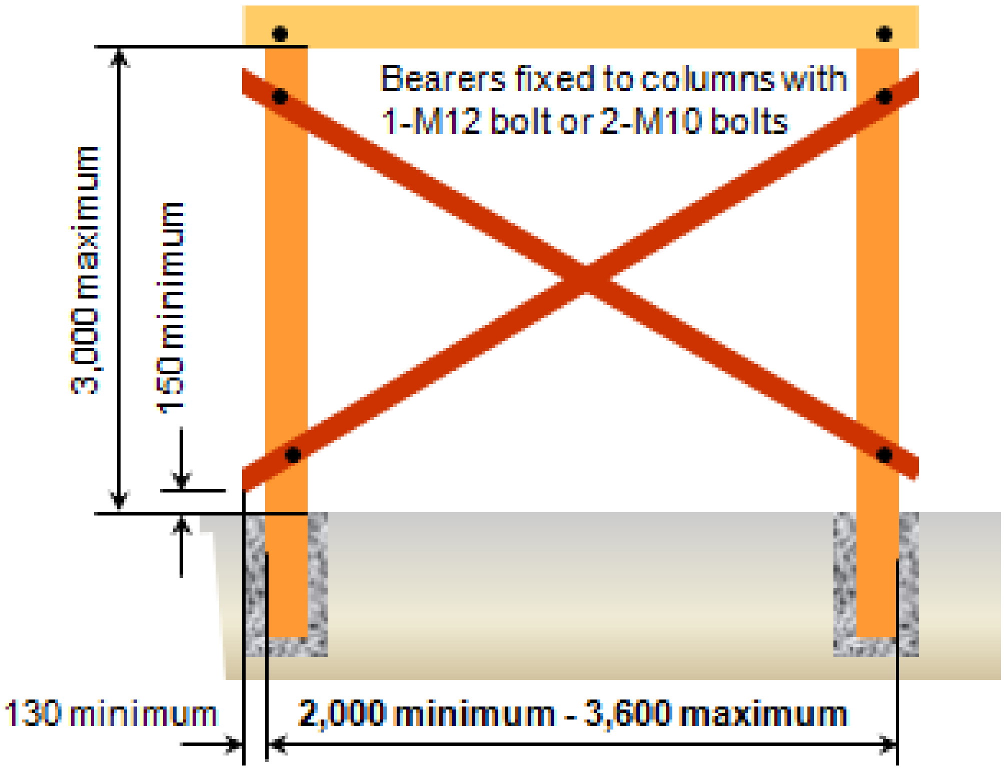
Sub-floor Tension Bracing

Capacity 15 kN
Based on AS 1684.3 Table 8.9

Columns, of dimensions not less than:

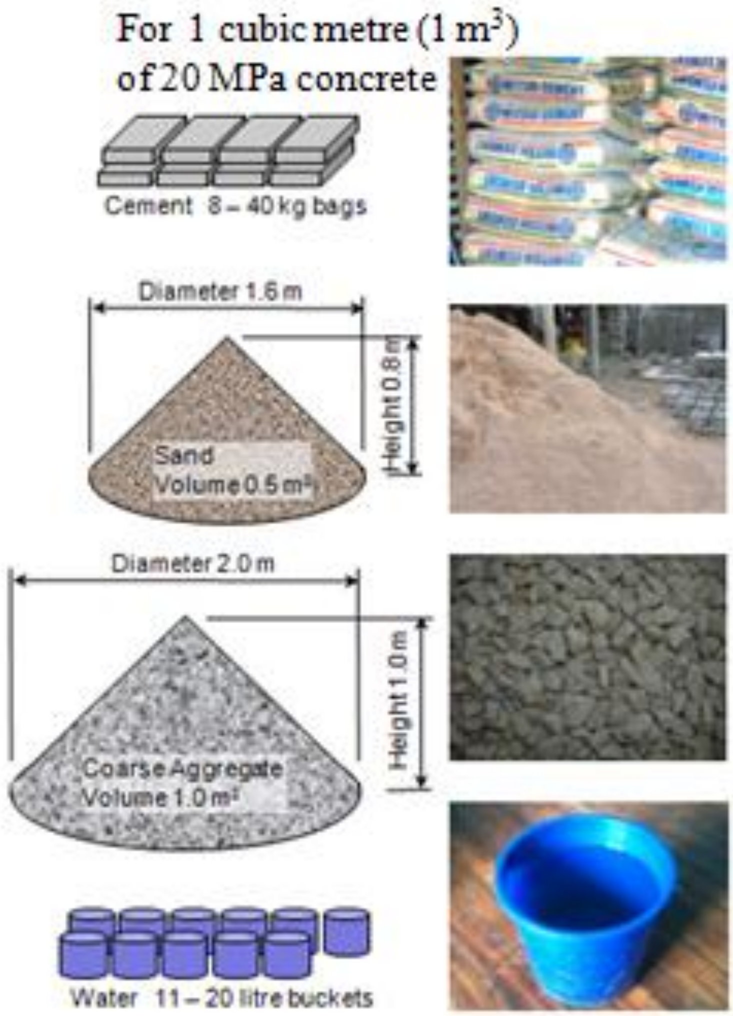
- 90 x 90 mm F11 (or stronger) hardwood
- 90 x 90 mm N20 (or stronger) concrete with 1 N12 reinforcing bar
- 190 x 190 mm 15 MPa reinforced concrete masonry with 1 N12 reinforcing bar
- 90 OD x 3 mm CHS galvanised steel hollow section

Two diagonal braces, 90 x 45 mm F11 (or stronger) hardwood, fixed to columns at the bottom and to the bearer (preferred) or column at the top by 1-M16 bolt (or stronger). Angle of braces from horizontal between 30° and 60°.



Concrete Piers

20 MPa mix (by volume) 1 : 2 : 4		
Volume of concrete	m^3	1.0
Wastage included	%	
GP or GB cement	40 kg bags	8
Clean sharp sand	m^3	0.5
20 mm rock aggregate	m^3	1.0



Braced Post in Concrete Backfill

Braced Post in Concrete Backfill
Capacity 16 kN

Based on AS 1684.3 Table 8.7. For other diameters, depths and corresponding capacities, refer to the standard.

Application:

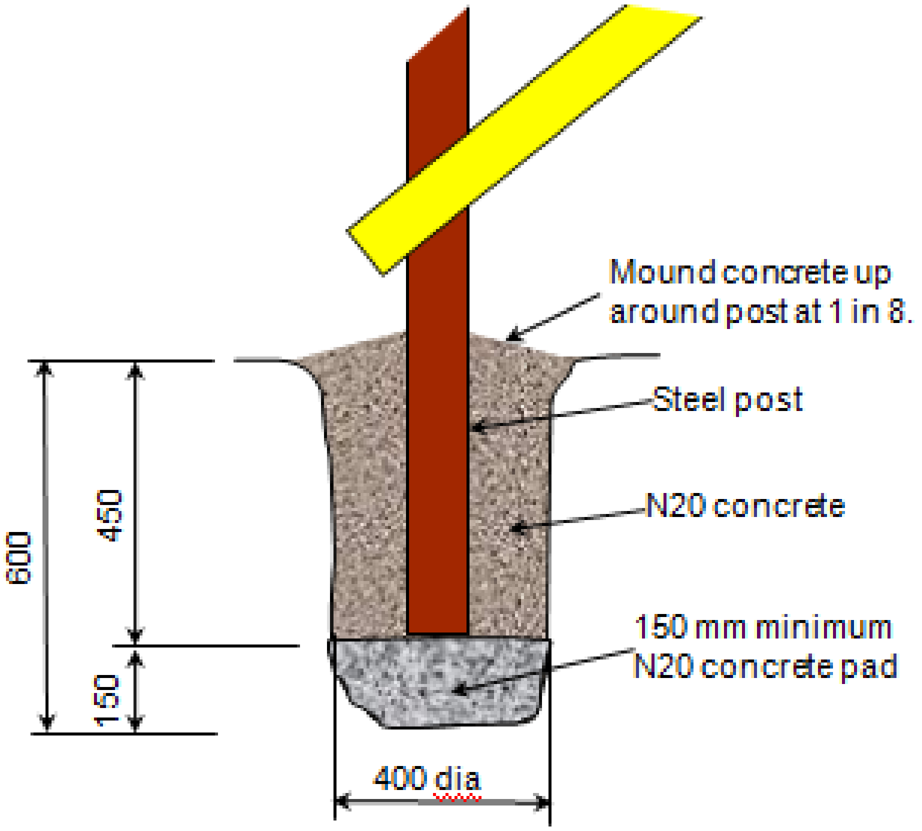
Wind classification up to AS 4055 "cyclonic" C1.

For stronger winds, reduced capacities must be calculated using AS 2870.

Soil classification to AS 2870

- A – sand and rock sites
- S – slightly reactive clay sites
- M – moderately reactive clay sites

Preferred Detail



Braced Post in Compacted Soil Backfill

Braced Post in Compacted Soil Backfill
Capacity 9.5 kN

Based on AS 1684.3 Table 8.8. For other dimensions, depths and corresponding capacities, refer to the standard.

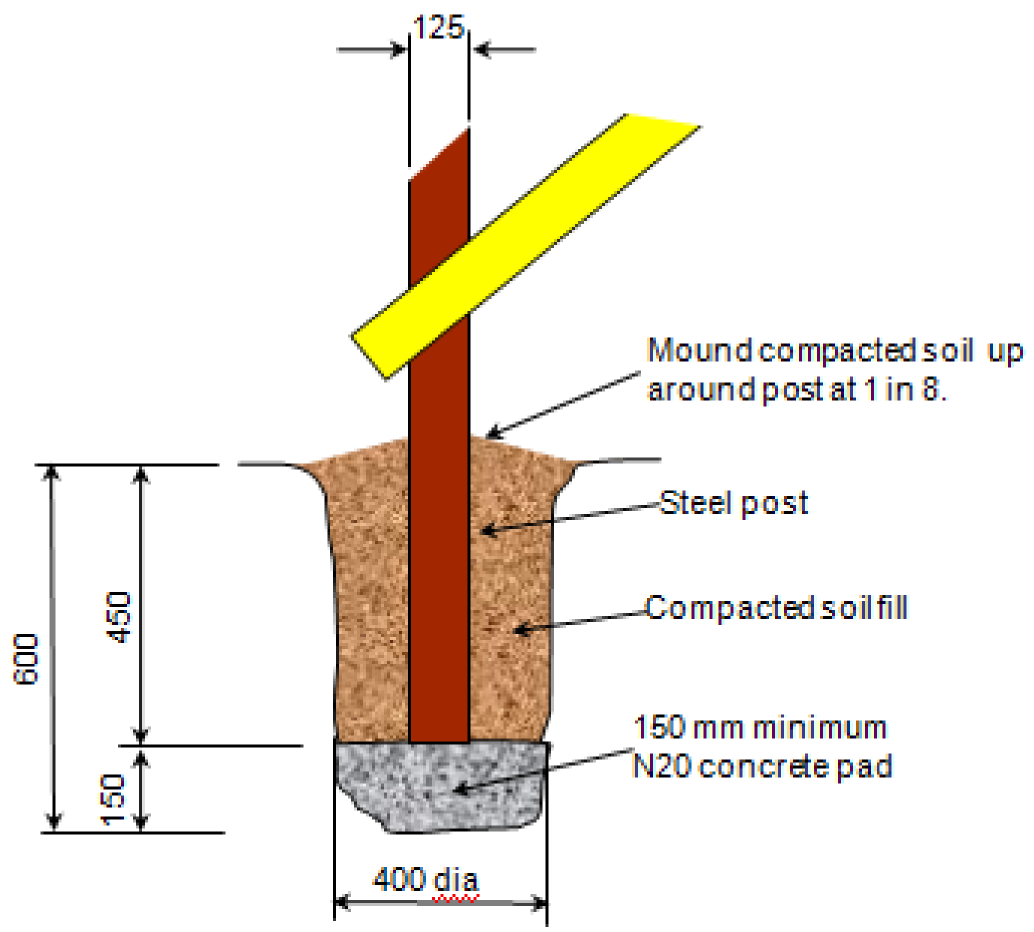
<u>Application:</u>

Wind classification up to AS 4055 "cyclonic" C1.

For stronger winds, reduced capacities must be calculated using AS 2870.

Soil classification to AS 2870

- A – sand and rock sites
- S – slightly reactive clay sites
- M – moderately reactive clay sites



Unbraced Post in Concrete Backfill

Unbraced Post in Concrete Backfill

Capacity 2.4 kN Underside of bearers 1.2 m above ground

Capacity 1.7 kN Underside of bearers 1.8 m above ground

Based on AS 1684.3 Table 8.10. For other diameters, depths and corresponding capacities, refer to the standard.

Application:

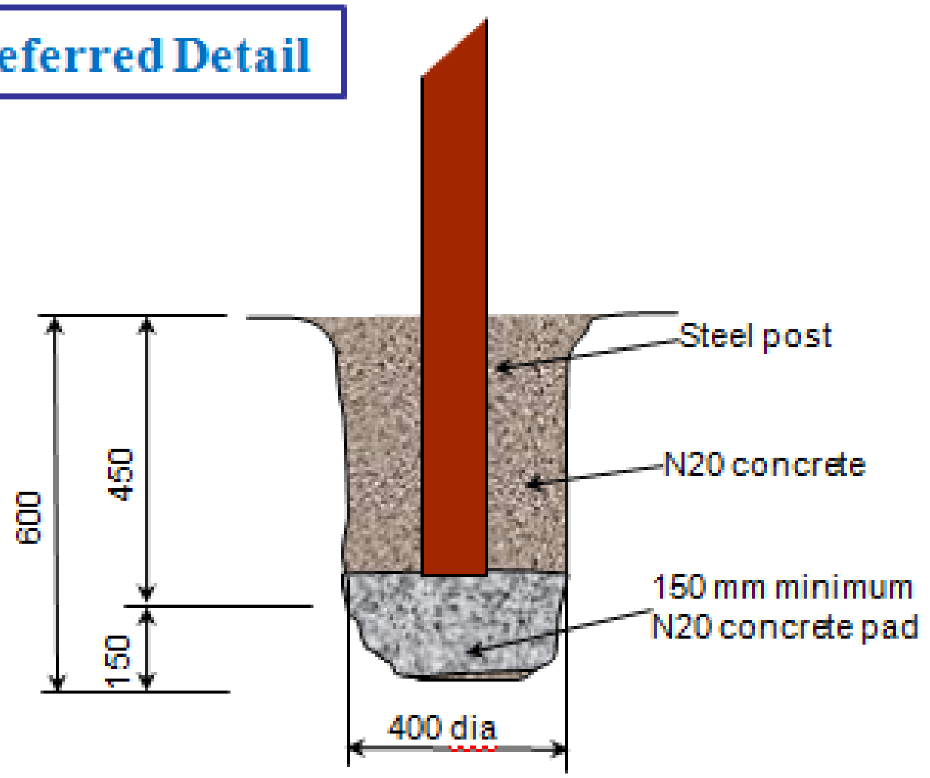
Wind classification up to AS 4055 "cyclonic" C1.

For stronger winds, reduced capacities must be calculated using AS 2870.

Soil classification to AS 2870

- A – sand and rock sites
- S – slightly reactive clay sites
- M – moderately reactive clay sites

Preferred Detail



Unbraced Post in Compacted Soil Backfill

Unbraced Post in Compacted Soil Backfill

Capacity 0.7 kN Underside of bearers 1.2 m above ground

Capacity 0.5 kN Underside of bearers 1.8 m above ground

Based on AS 1684.3 Table 8.#. For other dimensions, depths and corresponding capacities, refer to the standard.

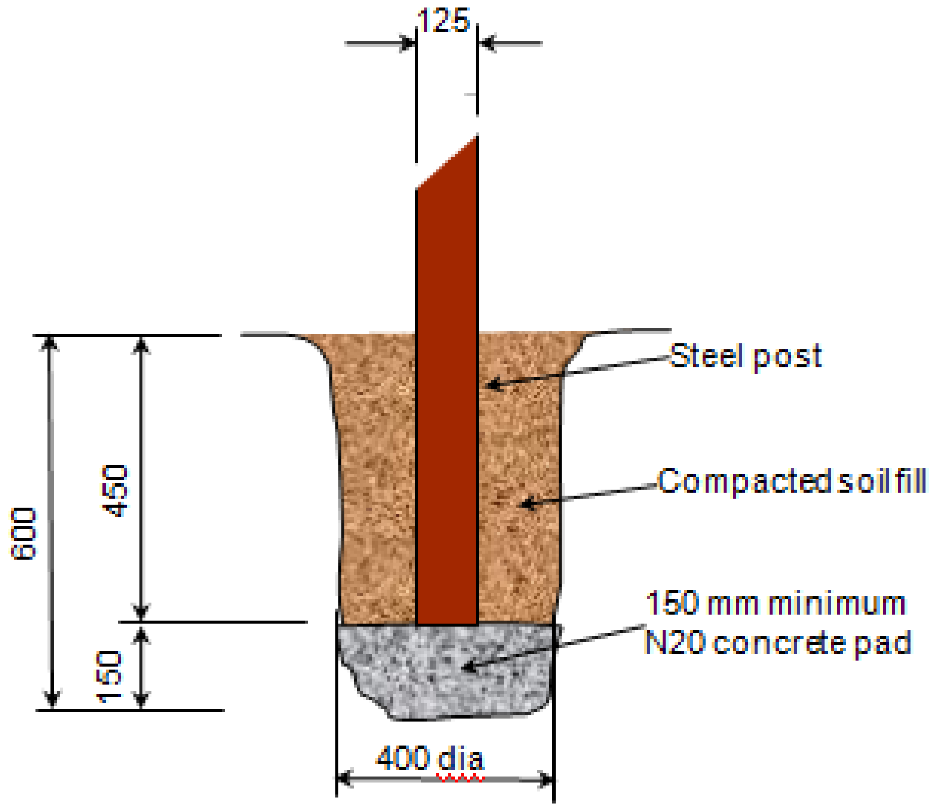
Application:

Wind classification up to AS 4055 "cyclonic" C1.

For stronger winds, reduced capacities must be calculated using AS 2870.

Soil classification to AS 2870

- A – sand and rock sites
- S – slightly reactive clay sites
- M – moderately reactive clay sites



Wall Bracing – Plywood Sheeting Without Additional Connections

This is the preferred method of bracing buildings incorporating the **DANCER** Building System.

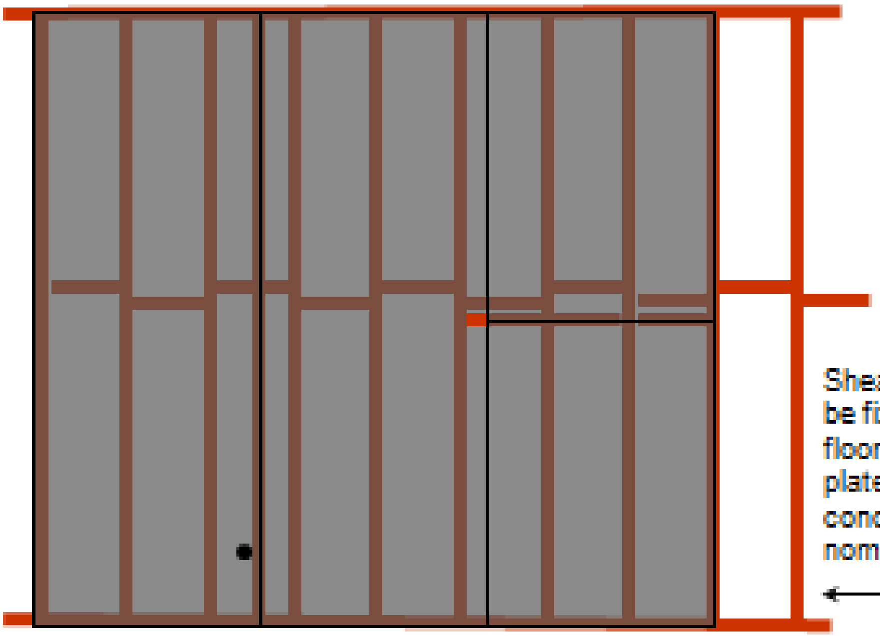
Capacity 3.4 kN/m length
Based on AS 1684.3 Table 8.18 (g)

Minimum Plywood Thickness				
Stud Spacing	450 mm	600 mm	450 mm	600 mm
Stress Grade	No nogging (except at horizontal butt joints)		One row of nogging	
F8	7 mm	9 mm	7 mm	7 mm
F11	4.5 mm	7 mm	4.5 mm	4.5 mm
F14	4 mm	6 mm	4 mm	4 mm
F27	3 mm	4.5 mm	3 mm	3 mm

Plywood sheets fixed:

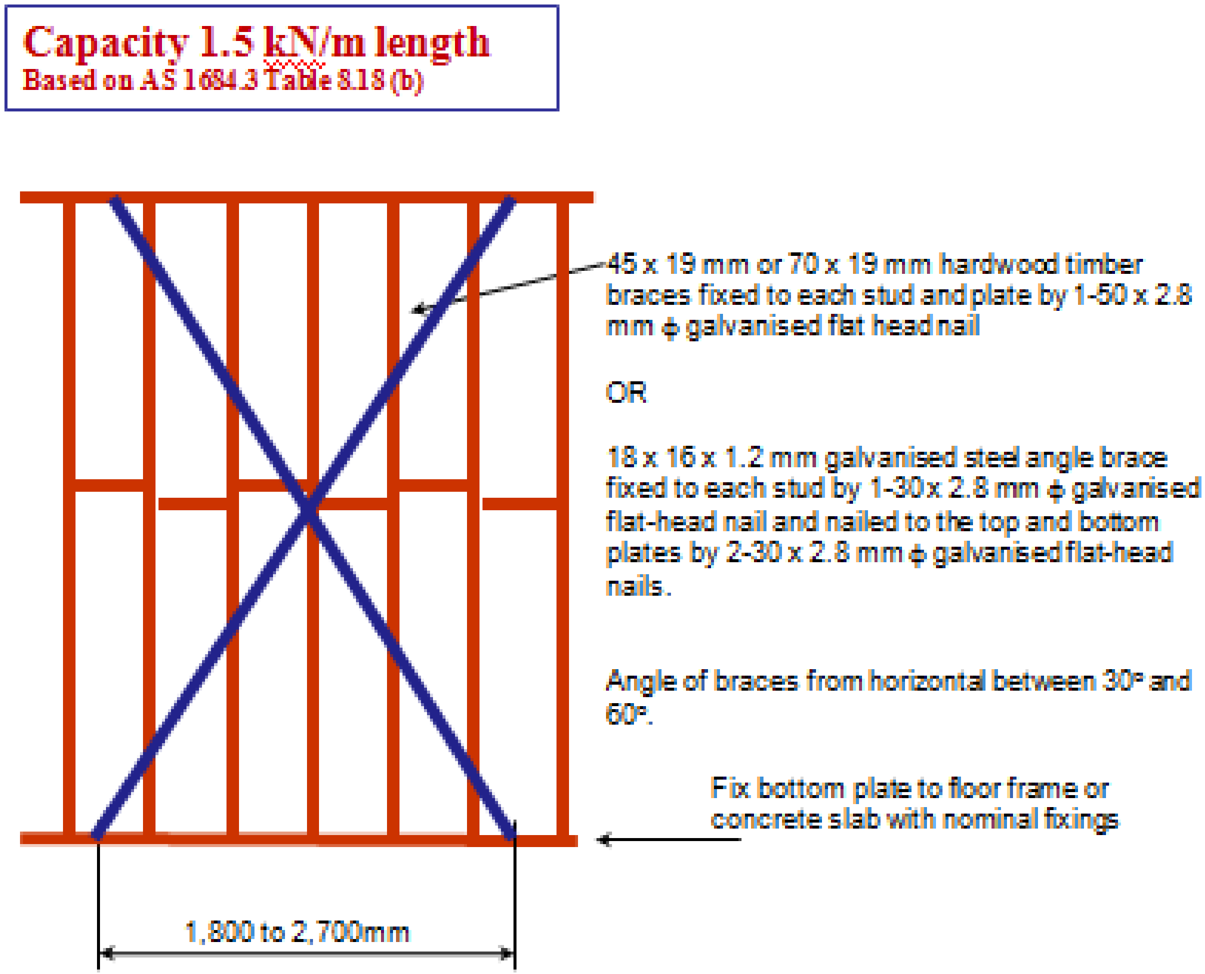
- Around perimeter to top plate, bottom plate and end studs at 150 mm centres by 30 x 2.8 mm ϕ galvanised flat head nails; and
- To internal studs (and noggings where required) at 300 mm centres by 30 x 2.8 mm ϕ galvanised flat head nails.

Sheets may be butt jointed horizontally, provided they are fixed horizontally at the edges to noggings. Provide an additional row of nogging at half height of the wall, if required.



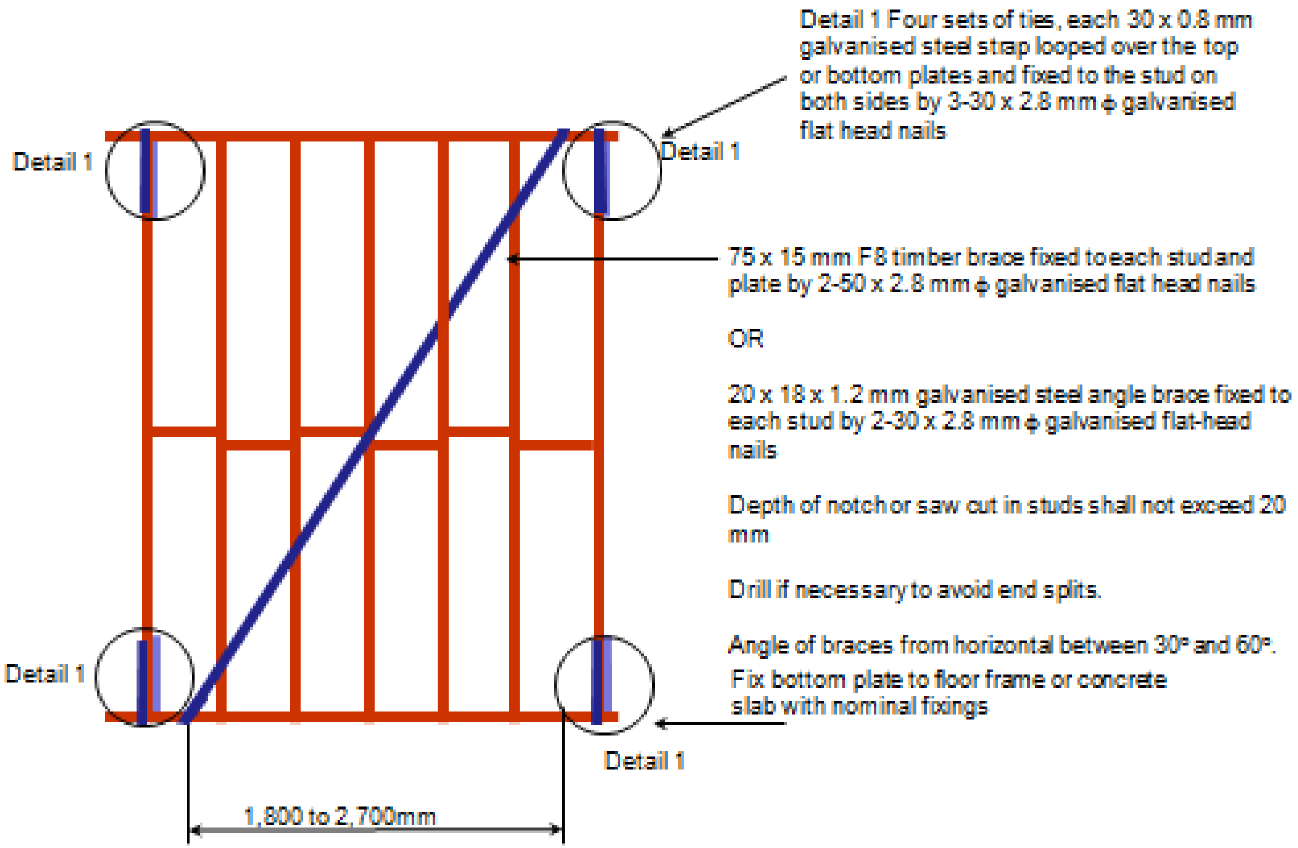
Sheathed panels shall be fixed to the sub-floor. Fix the bottom plate to floor frame or concrete slab with nominal fixings.

Wall Bracing – Pairs of Tensioned Metal Straps



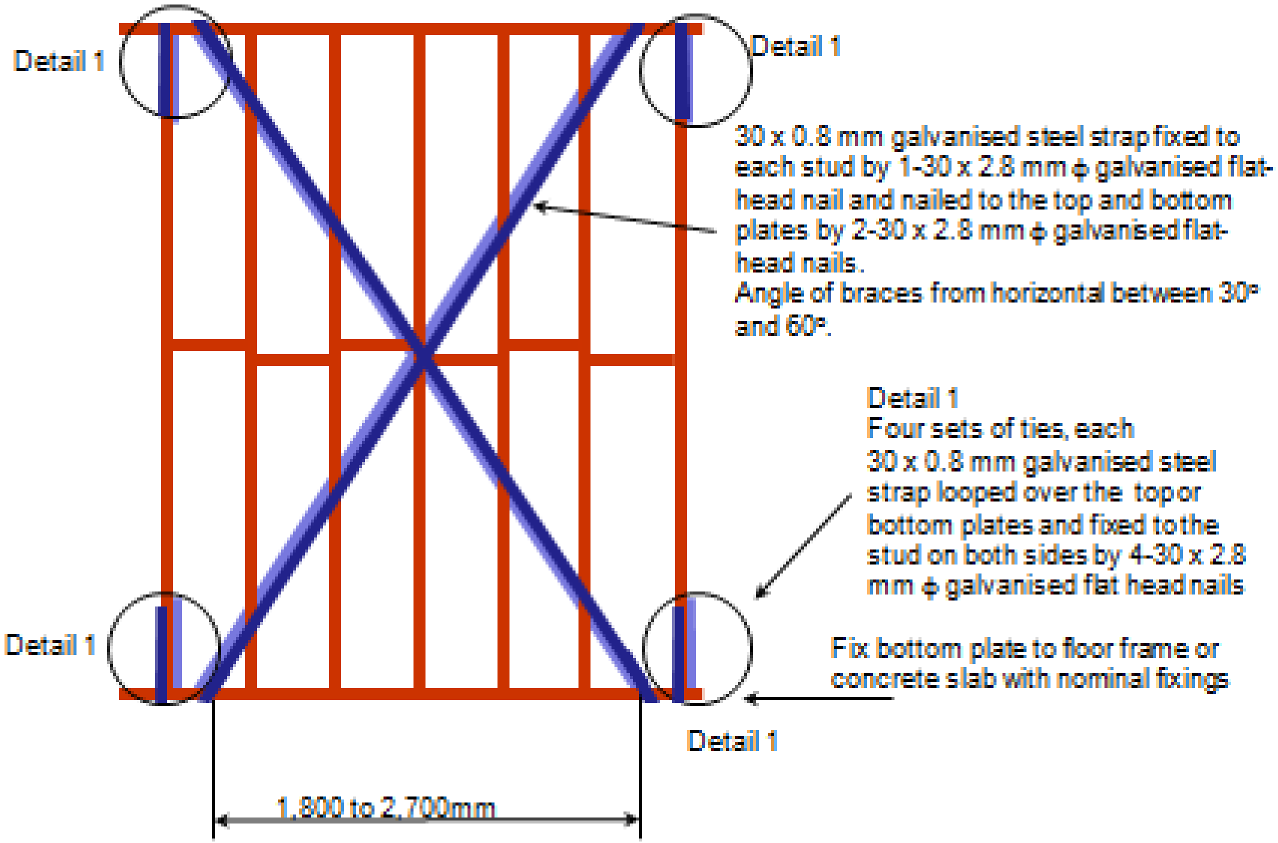
Wall Bracing – Timber or Metal Angle Braces

Capacity 1.5 kN/m length
Based on AS 1684.3 Table 8.18 (c)



Wall Bracing – Tensioned Metal Straps with Stud Straps

Capacity 3.0 kN/m length
Based on AS 1684.3 Table 8.18 (d)



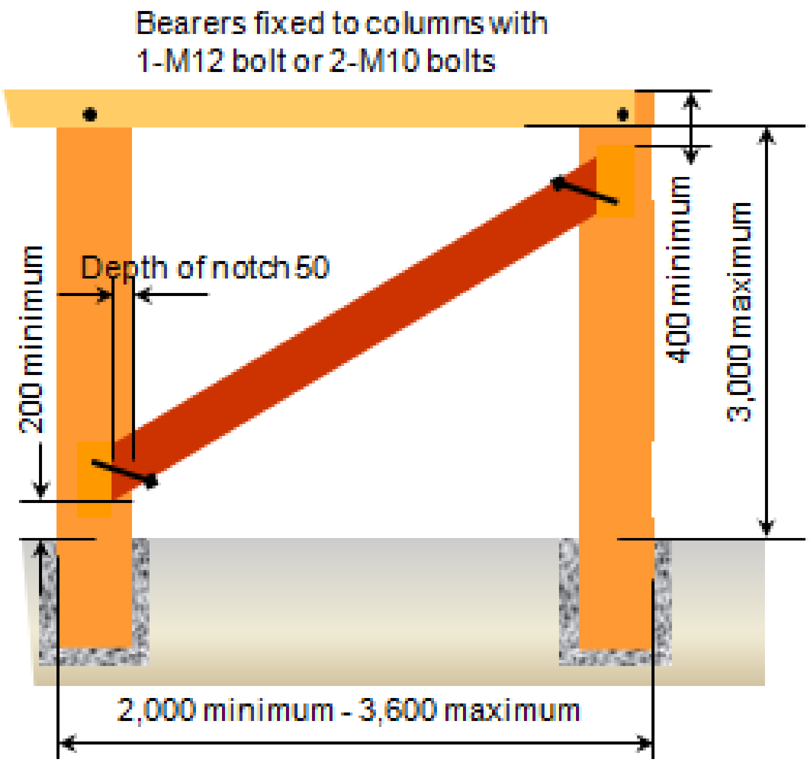
Sub-floor Compression Bracing

Capacity 15 kN (Nominal)

Columns, of dimensions not less than:

- 200 x 200 mm or 250 mm diameter F11 (or stronger) hardwood, or
- 150 x 150 mm or 200 mm diameter N20 (or stronger) concrete with 1 N12 reinforcing bar

Two diagonal braces in opposing directions in two bays on each side of building, at least 90 x 90 mm or 150 mm diameter F11 (or stronger) hardwood, notched into the columns to a depth of 50 mm and fixed at the top and bottom by at least 2 – 150 x 3.15 mm ϕ galvanised flat head nails (or stronger) . Angle of braces from horizontal between 30° and 60°.

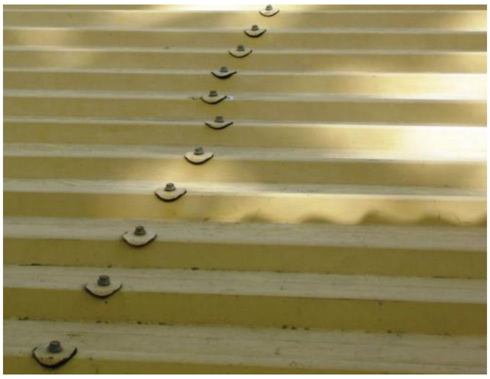


Roof Fixings and Cyclone Washers

Cyclonic wind can suck roof sheeting (and wall sheeting) off the framing if there is an insufficient number of appropriate roofing screws, or if the screws have been installed without cyclone washers.

Roof sheets should be fixed through the high point of the ribs using long screws, not valley fixed. Roof sheets shall be laid in continuous lengths where practical, with the upper end turned up using the correct tool.

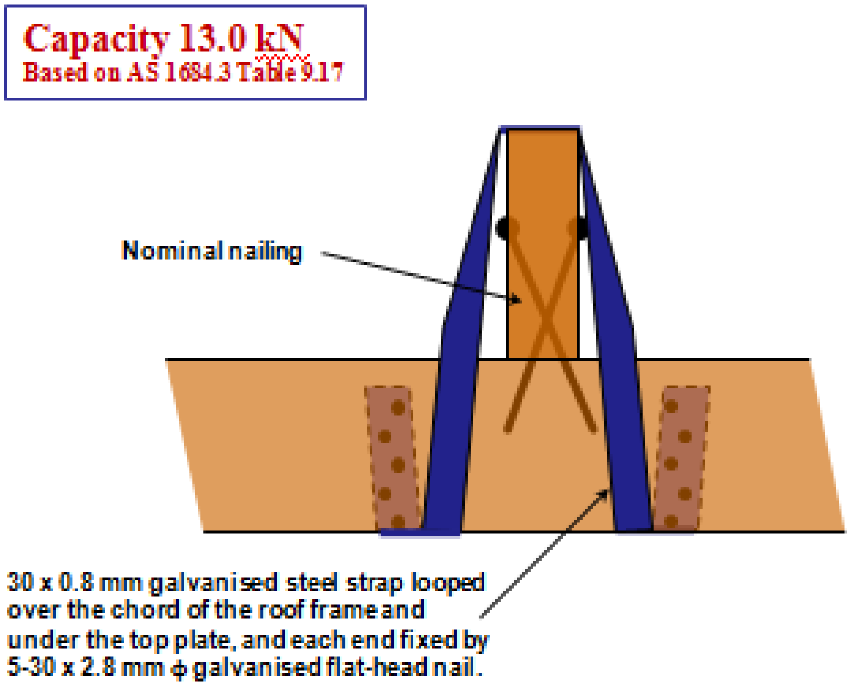
In very high wind areas, turn the sheets down into the eaves gutter at the lower end.



Suitable Spans and Fixing Arrangemetns of Corrugated Steel Sheeting (0.42 mm BMT)					
AS 4055 Wind Classification	**N1 N2 N3**	**N4 C1**	**N5 C2**	**N6 C3**	**C4**
Maximum end span without cyclone washers	950	900	750	Not suitable	Not suitable
Maximum end span with cyclone washers		1,200	900	Not suitable	Not suitable
Number of ribs to be fixed	Every second rib	Every rib	Every rib	Not suitable	Not suitable
Maximum internal span without cyclone washers	1,200	900	750	Not suitable	Not suitable
Maximum internal span with cyclone washers		1,200	900	Not suitable	Not suitable
Number of ribs to be fixed	Every third rib	Every rib	Every rib	Not suitable	Not suitable

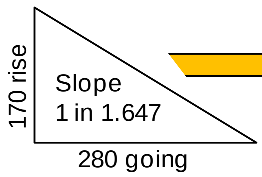
Notes:
1. In some cirmstances, engineering analysis of test results may give improved spans.
2. Refer to roofing manufacturer's technical manuals for specification of fixing screws, details and material compatibility.
3. References include: Lysaghts "Cyclonic Area Design Manual". http://www.lysaght.com/roofing

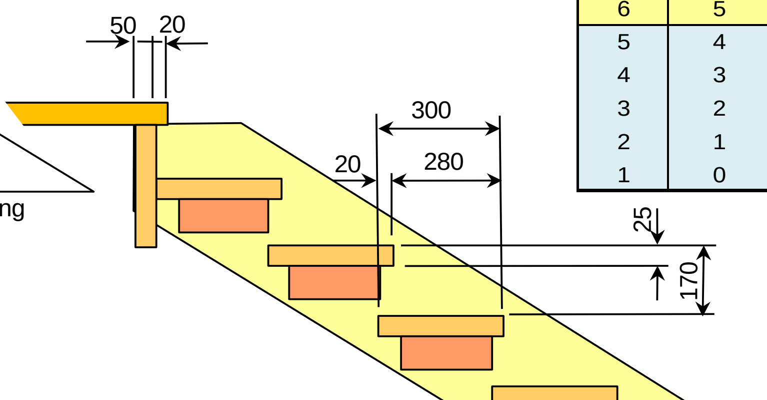
Anchorage of Members Not Secured by the "Direct Anchorage" Method

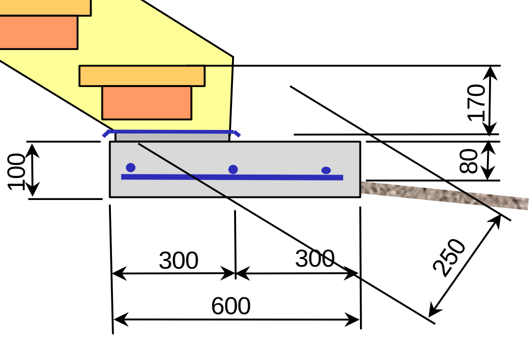


Stairs

Stair Dimensions				
Stair going			280	mm
Stair rise			170	mm
Grout thickness			0	mm
Height of slab above ground			80	mm
No of Rises	No of Goings	Stair Rise	Stair Going	Veranda Height
18	17	3060	4760	3140
17	16	2890	4480	2970
16	15	2720	4200	2800
15	14	2550	3920	2630
14	13	2380	3640	2460
13	12	2210	3360	2290
12	11	2040	3080	2120
11	10	1870	2800	1950
10	9	1700	2520	1780
9	8	1530	2240	1610
8	7	1360	1960	1440
7	6	1190	1680	1270
6	5	1020	1400	1100
5	4	850	1120	930
4	3	680	840	760
3	2	510	560	590
2	1	340	280	420
1	0	170	0	250







Section Through Typical Stair

Top support 1 No
300 x 25 F11 hardwood x 910 long.
Slot the treads into rebates, 5 mm deep in the stringers.
At each stinger, 4 / 90 x 3.05φ galvanized nails driven horizontally through stringer into support and 4 / 90 x 3.05φ galvanized nails driven horizontally through support into top tread. Bolt top support to the structure with 2/ M12 x 125 galvanized bolts, nuts & washers

Stringers 2 No 250 x 50 F11 hardwood
Length of stringers to suit the length of stair.

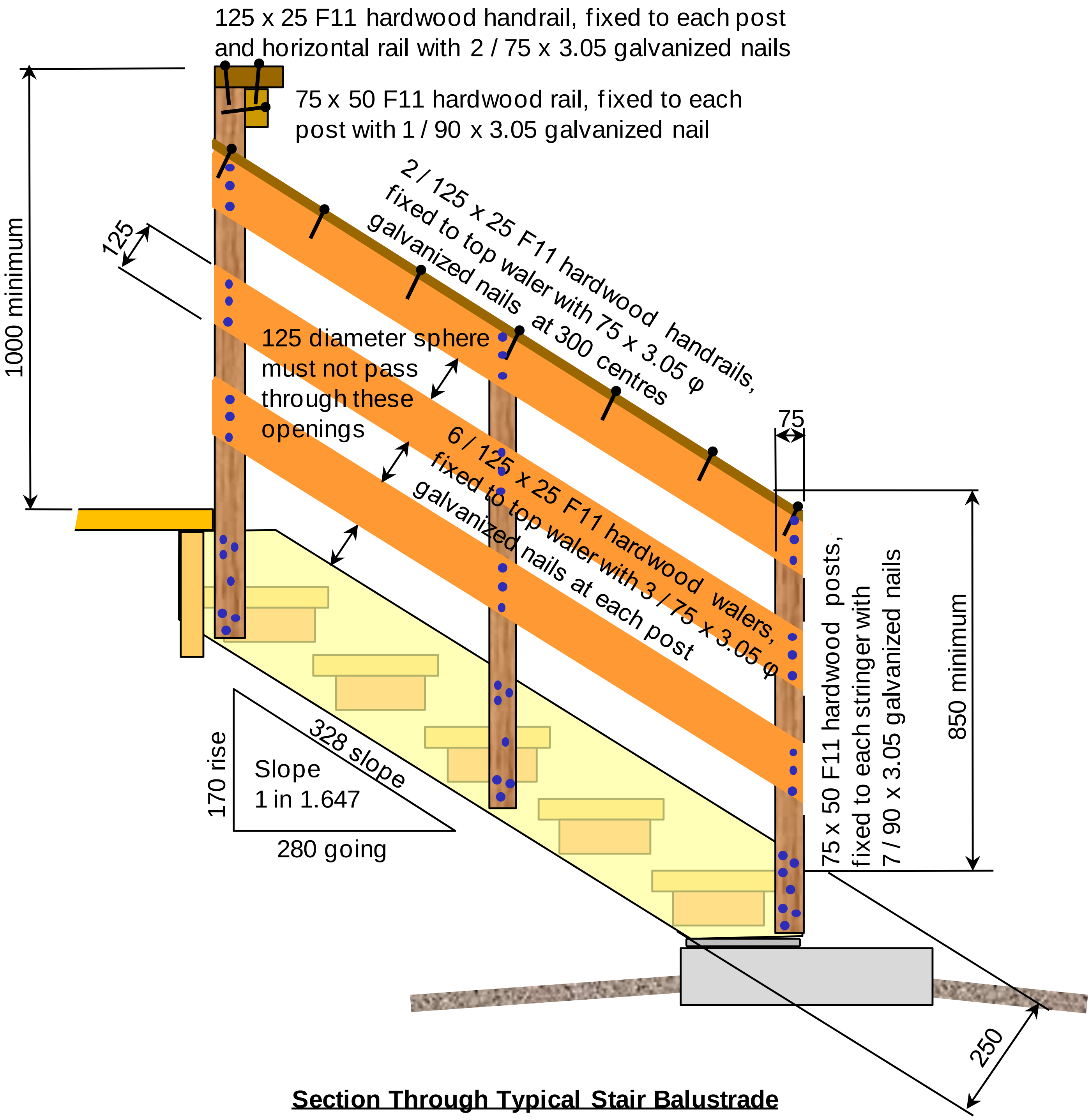
Treads – Number of treads to suit length of stair
300 x 25 F11 hardwood x 910 long. Slot the treads into rebates,
5 mm deep in the stringers. At each stinger,
2 / 90 x 3.05φ galvanized nails driven horizontally through stringer into tread and 2 / 90 x 3.05φ galvanized nails
driven vertically through stringer into support

Tread supports –
2 per tread. 75 x 50 F11 hardwood x 260 long
3 / 90 x 3.05φ galvanized nails driven horizontally through support into stringer

Termite shield – 2 / 100 x 3 x 350 galvanized steel strips, folded down 20 mm around edges, nailed to the underside of the stair stringer and kept clear of debris.

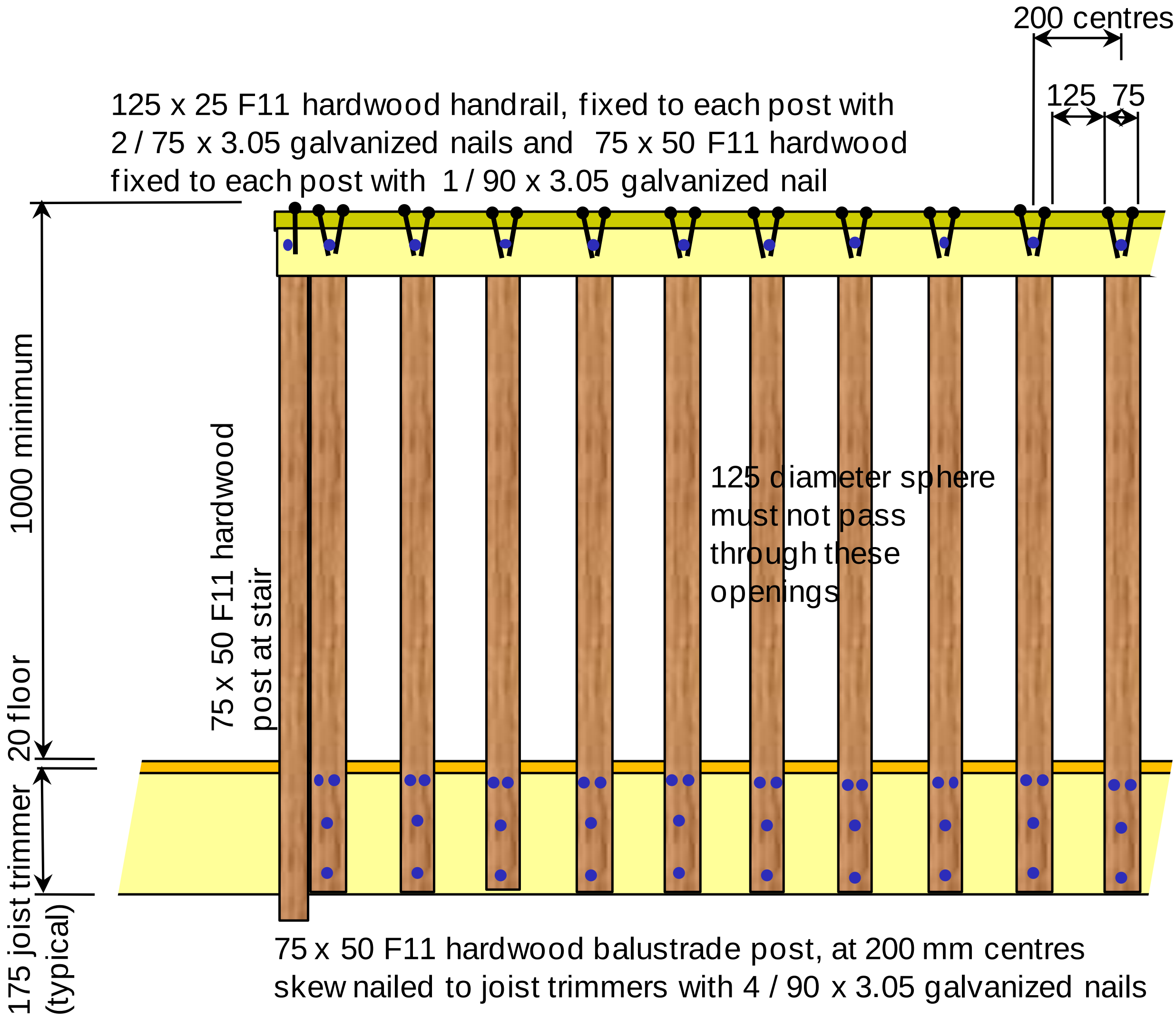
Concrete Pad – 1,200 x 600 x 100 mm thick
3 / N10 x 550 reinforcing bars and
3 / N10 x 950 reinforcing bars
Top surface of slab nominally 80 mm above ground level. If the slab surface is low, grout (up to a maximum thickness of 10 mm) under both stringers to make up required height. If the slab surface is high, trim the bottom surface of the stringers.

Stair Balustrades



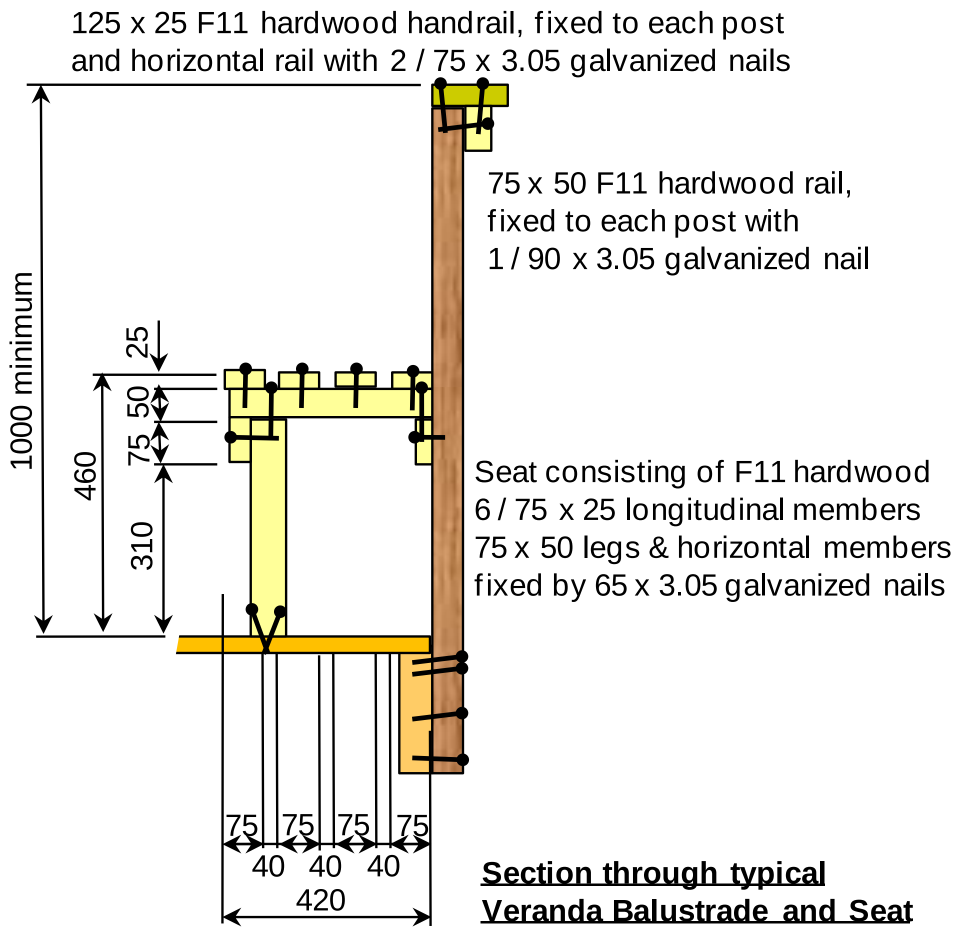
Section Through Typical Stair Balustrade

Veranda Balustrades



Elevation of typical Veranda Balustrade

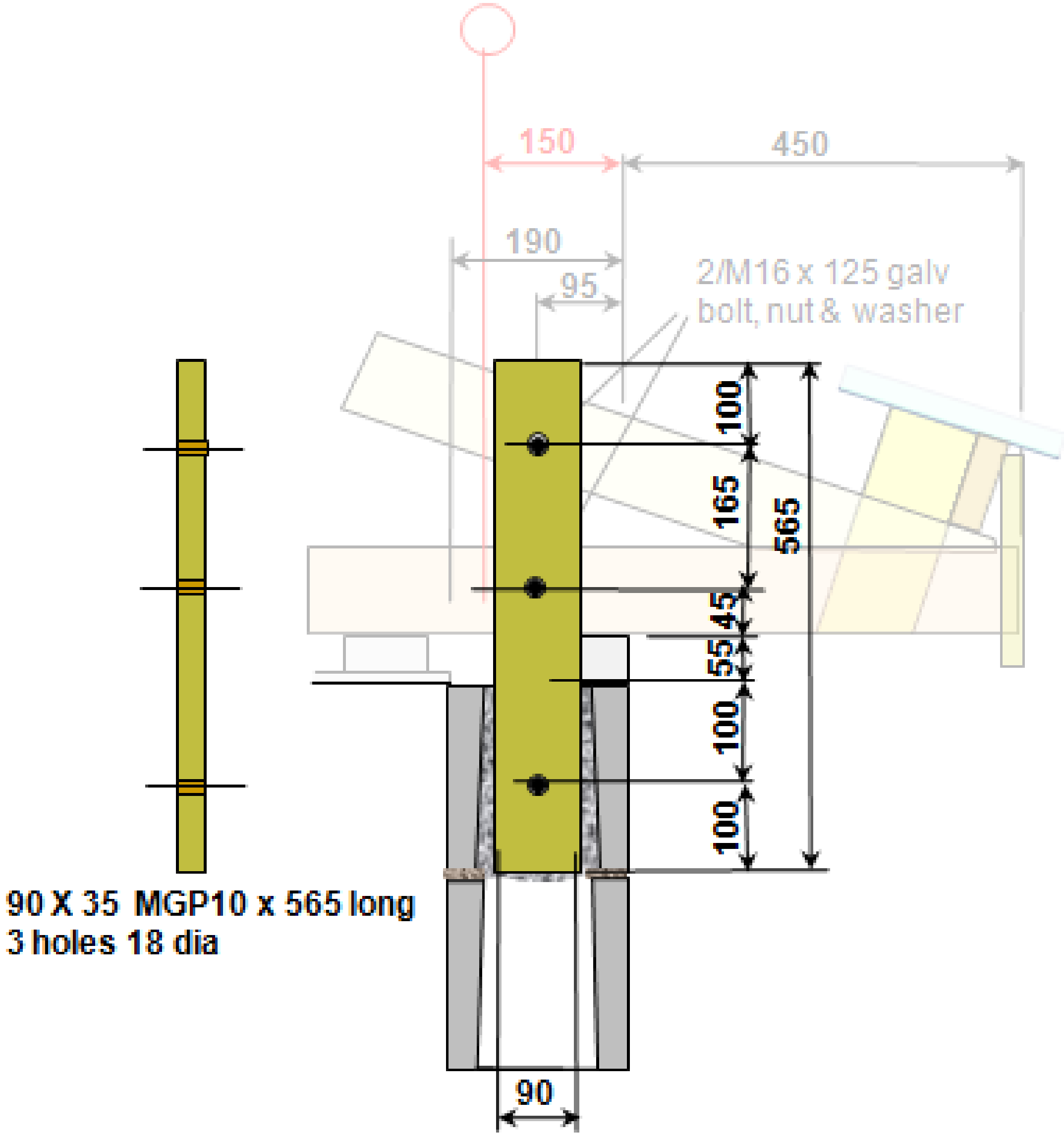
Veranda Balustrades with Seats



Section through typical Veranda Balustrade and Seat

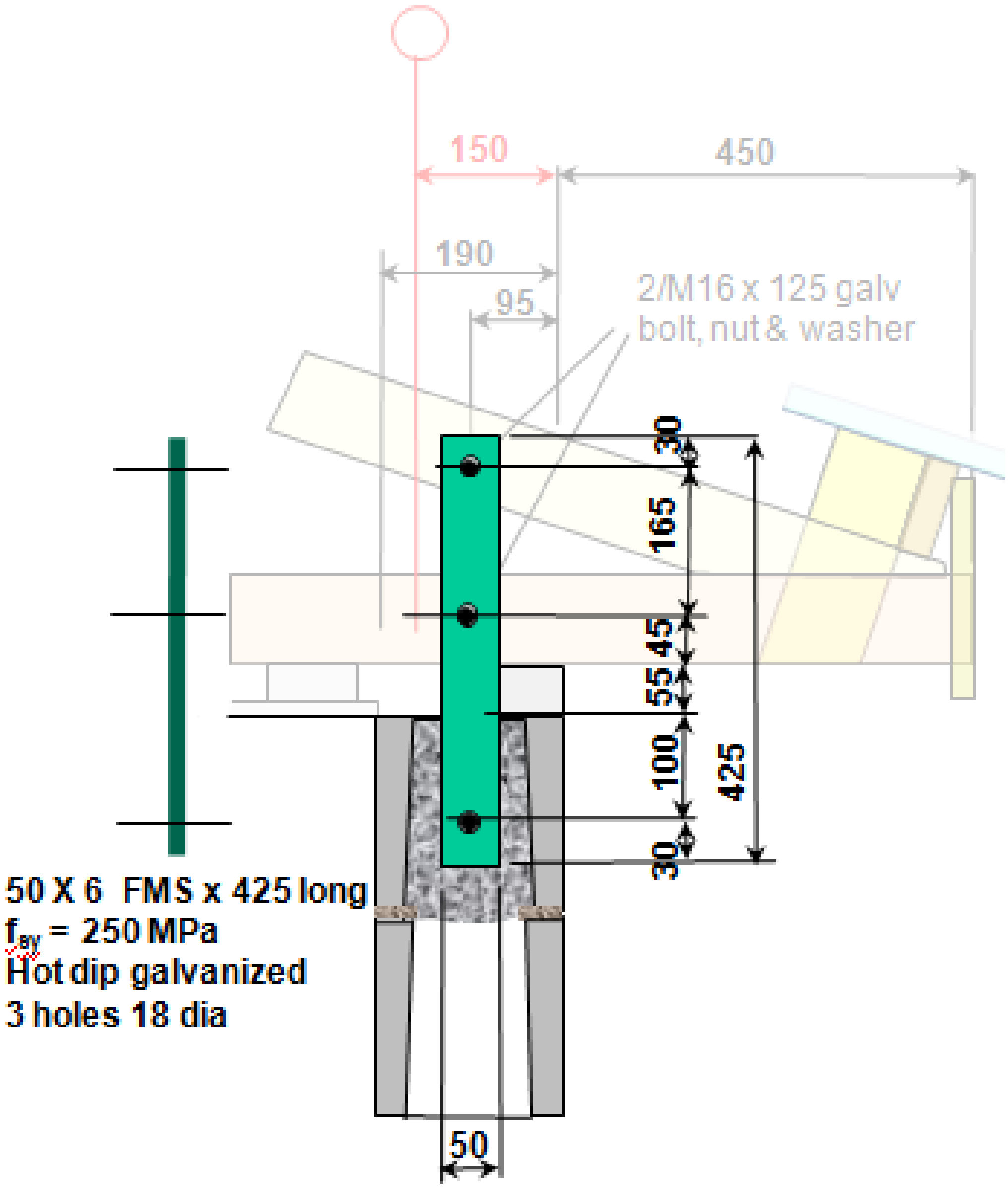
Timber Roof Anchors for Single Bond Beam

Capacity
190 mm reinforced masonry 13.1 kN



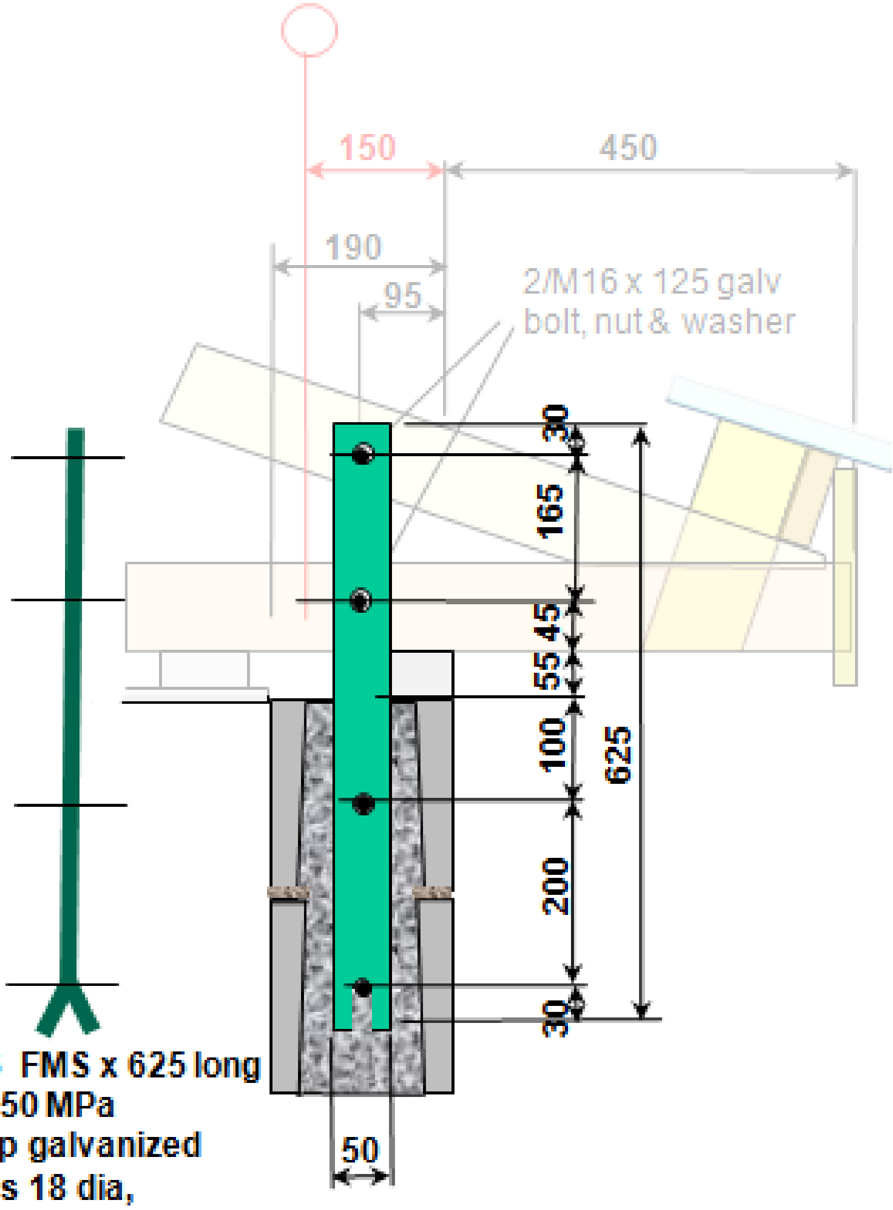
Steel Roof Anchors for Single Bond Beam

Capacity
190 mm reinforced masonry 13.1 kN



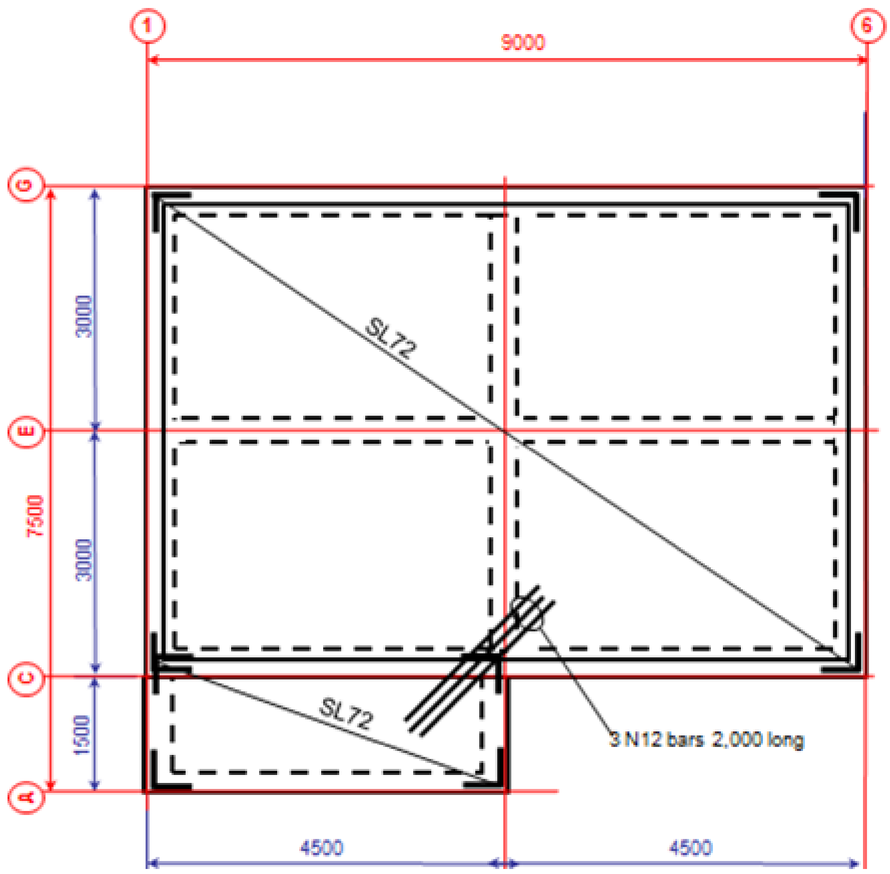
Steel Roof Anchors for Double Bond Beam

Capacity
190 mm reinforced masonry 30.7 kN



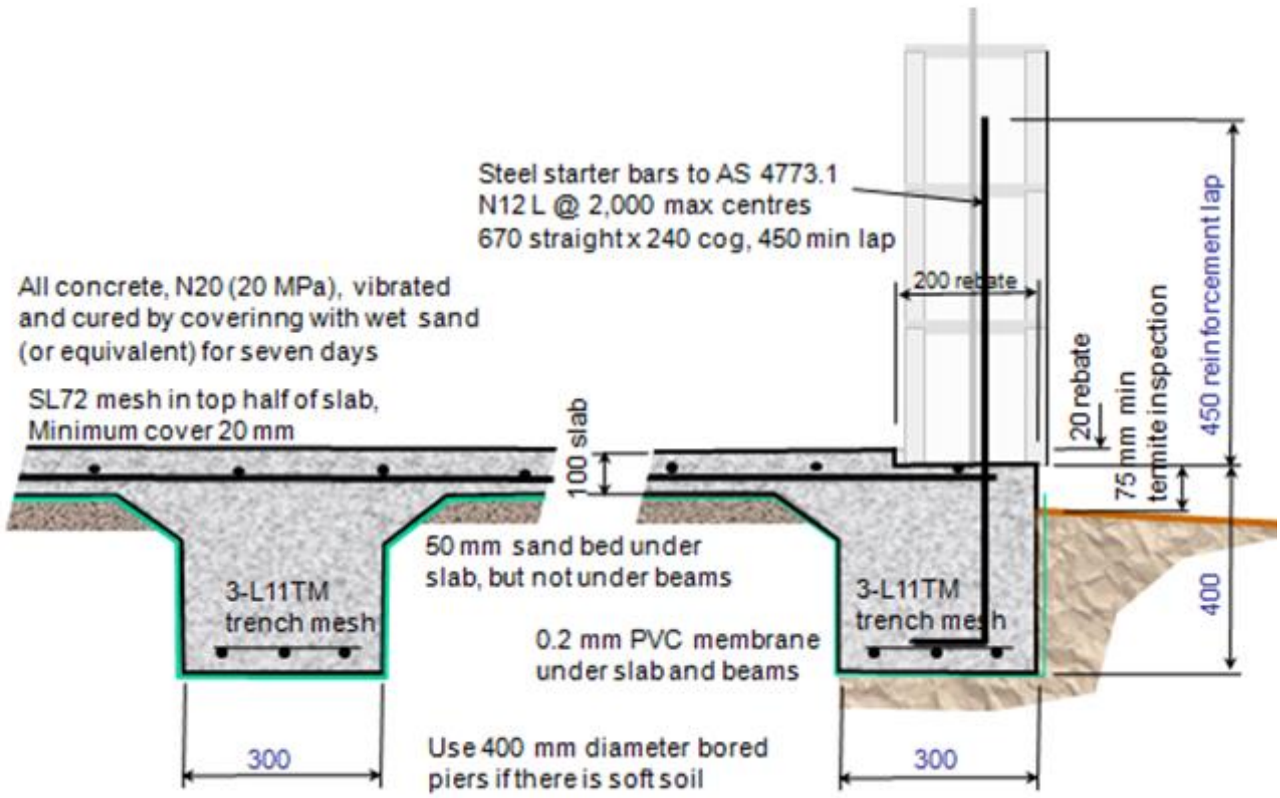
50 X 6 FMS x 625 long
f_{sy} = 250 MPa
Hot dip galvanized
3 holes 18 dia,
slot 18 dia x 40 long
Form a fishtail by bending
each side through 30°

Concrete Slab-on-Ground

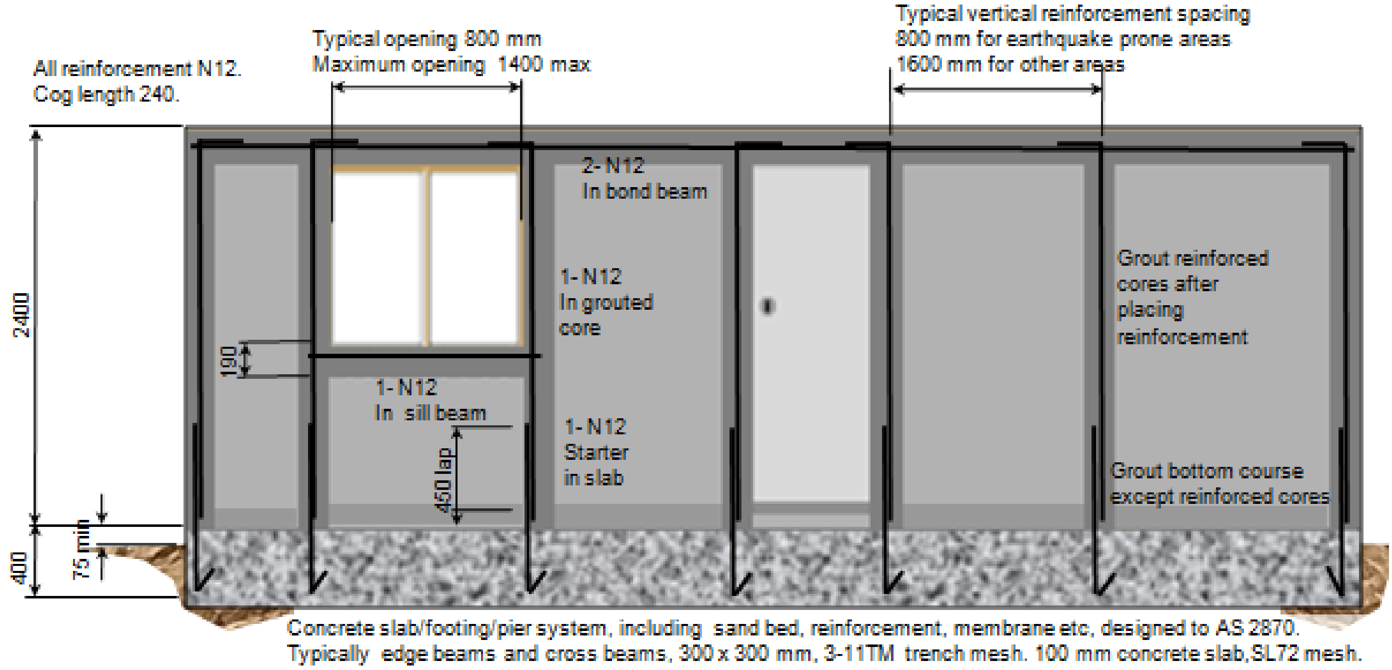


Typical Arrangement

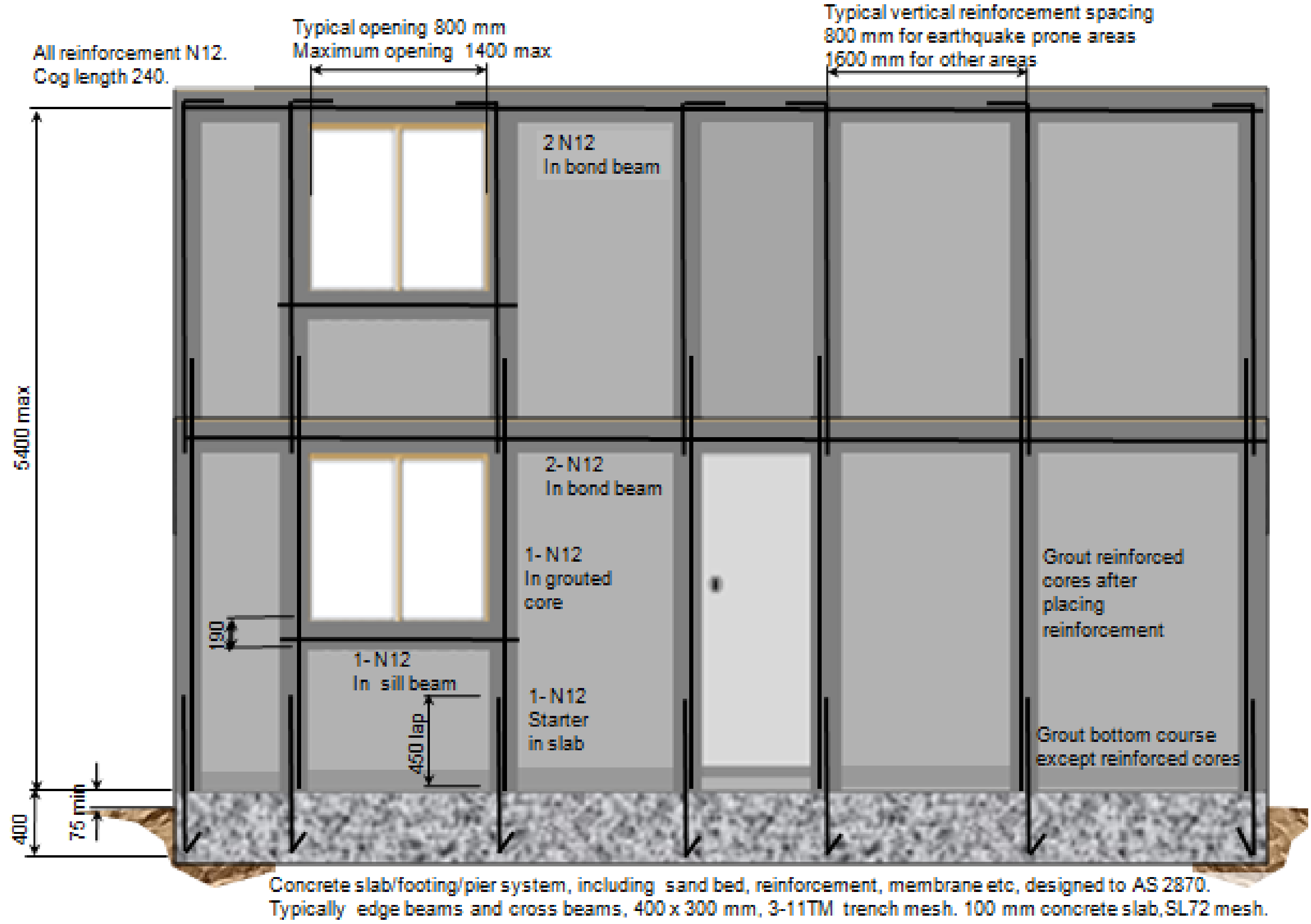
Vary to suit each particular building



Reinforced Concrete Masonry Walls (Elevation)

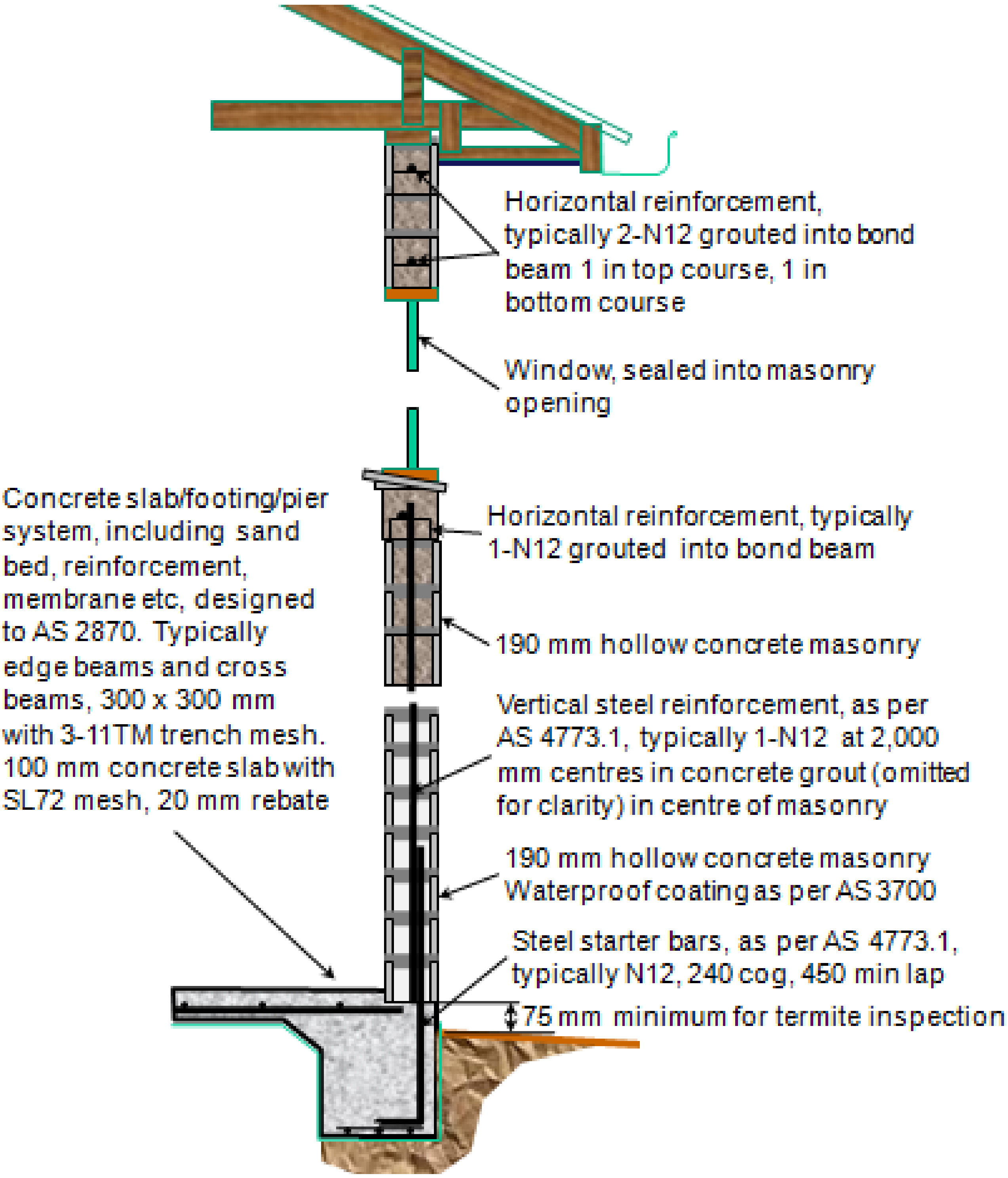


<u>Typical Arrangement of Reinforcement</u>



<u>Typical Arrangement of Reinforcement</u>

Reinforced Concrete Masonry Walls (Section)



Part 4 – DANCER Specifications

Part 4 provides generic specifications for the principal components of **DANCER** buildings.

These specifications are limited to timber, concrete and masonry. If required, a comprehensive specification for other aspects of building is available.

All materials and construction shall comply with the most recent version of:

- the relevant parts of the Building Regulations;
- the Standards referred to therein;
- other Standards nominated in this specification; and
- other relevant Regulations.

Timber

Scope

This section covers timber framing, such as columns, posts, beams, battens, rafters, trusses and the like, consisting of sawn timber and plywood.

Relevant Standards

AS 1684.1 Residential Timber Framed Construction – Design Criteria

AS 1684.2 Residential Timber Framed Construction – Non – cyclonic areas

AS 1684.3 Residential Timber Framed Construction – Cyclonic areas

AS 1720.1 Timber structures - Part 1 Design methods

AS 1720.2 Timber structures - Part 2 Timber properties

AS 1604 Timber – Preservative treated – Sawn and round

AS 2209 Timber – Poles for overhead lines

AS 2082 Visually stress-graded hardwood for structural purposes

AS 2858 Visually stress-graded softwood for structural purposes

AS 2878 Timbers – Classification into strength groups

AS 3519 Timber – Machine proof grading

Levels, Dimensions, Square and Setting Out

The structure upon which the framing is to be constructed shall be within the specified tolerances, with particular attention given to levels, dimensions, square and setting out.

Bracing

All buildings shall be adequately supported against lateral wind loads, as specified in the relevant Standard (AS 1170.2 or AS 4055). In some cases, lateral earthquake loads may be a design criterion. The bracing requirements shall be determined for the appropriate Region, Terrain Category, Topography and Shielding and recorded on the drawings by the design engineer.

Tie Down

All buildings shall be adequately tied down to resist overturning due to wind loads, as specified in the relevant Standard (AS 1170.2 or AS 4055). The tie-down requirements should be determined for the appropriate Region, Terrain Category, Topography and Shielding and recorded on the drawings by the design engineer. Ensure that all tie-down systems are continuous to the footings or to the specified location on the structure.

Timber Shrinkage

Provision shall be made for timber shrinkage. Gaps that result from timber splitting shall be repaired, filled with wood filler and sanded smooth before completion.

Preservatives

Timber in exposed applications shall be treated with pyrethroid-and metal-based light organic solvent preservatives (LOSPs) to minimize fungal decay and attack by insects.

Health Warnings and Precautions

Precautions shall be in accordance with the requirements of the relevant Regulations and, where applicable, the recommendations of the following reference *RIC Good Wood Project & the Good Wood Advisory Centre, Victoria, Preservatives.*

Light Organic Solvent Preservative (LOSP)

- LOSP is a solvent-based treatment, which inhibits fungal invasion of timber. It contains copper naphthenate, zinc naphthenate, tri-butyl tin oxide (TBTO) or pentachlorophenol (PCP), with resin or wax to improve its retention and to increase its ability to repel water.
- LOSP will release, to the atmosphere, 30-40 litres of hydrocarbon solvent per cubic metre of treated timber.
- LOSP is suitable for above-ground applications where dimensional-stability is important, is used principally in external applications (e.g. fences, decks and outdoor furniture).
- LOSP is not suitable for in-ground applications because it does not chemically fix in the wood and will leach into the soil.
- LOSP must not be used for food storage, except where LOSP formulation is of very low toxicity.
- Where LOSP treated timber is exposed, cut or drilled, the exposed surface should be coated with a post-protection treatment.

Although previously in use, the following timber preservatives shall not be used.

(a) *Creosote*: Creosote gives off a vapour that irritates the eyes and skin; and is therefore not recommended.

(b) Pigment Emulsified Creosote (PEC): PEC is a combination of coal tar, with a heavy metal pigment used to stabilize it. PEC is not suitable for normal building applications.

(c) Pentachlorophenol (PCP): PCP (derived from sodium pentachlorophenate) is an organochlorine family, of the same chemical group as DDT and Agent Orange. PCP can cause fatigue, fever, weight loss and nausea. PCP dioxins can also cause birth defects, allergies or cancer. PCPs can be passed on to successive generations through sperm and breast milk. PCP must be disposed of without special technology and facilities. It is recommended that PCPs should not be used.

(d) *Copper Chrome Arsenate (CCA)*: CCA consists of heavy metals, copper, chromium and arsenic, which may leach from the timber and pose a health risk. CCA shall not be used; and when timber treatment is required, one of the alternatives listed above may be used.

If CCA-treated timber is already in use, the following precautions should be taken:

- Wear protective equipment when handling CCA treated timber.
- Wash hands thoroughly after handling CCA treated timber.
- Do not allow food to come into contact with CCA treated timber.
- Do not burn CCA treated timber in open fires, stoves, fireplaces or the like.

(e) Ammoniacal copper quaternary (ACQ)

(f) Copper azole

(g) Boron

Design and Construction

Timber structures shall comply with the Drawings, Building Regulations and relevant Standard (AS 1684 [residential applications], AS 1720 [general applications]).

Minimum Strength Grade

Timber used for structural framing purposes shall have a strength grade not less than F11 or MGP10 as applicable.

Timber Type, Properties, Preservation and Application

Timber and timber products shall comply with the Drawings, Building Regulations and relevant Standard (AS 1684 [residential applications], AS 1720 [non-residential applications]), and shall be of the nominated stress grade (or strength group), durability class, and (where appropriate) lyctid susceptibility, shrinkage and ignitability.

1. The following tables are based on AS 1684.2 & 3 Table H1. For additional properties and definitions refer to source document.
2. Preservative requirement: P = Should be preservative treated, S = Should be seasoned ,O = Commonly used untreated
3. Availability: R = Readily available, L = Limited Availability
4. Durability Class: 1 = Highest natural durability to 4 = Lowest natural durability.
5. Where required to achieve particular resistance to termite and/or borer attack, the species listed herein shall be treated to achieve the hazard levels listed in AS 1684.2 & 3 Table C1.
6. Lyctid Susceptible: S = Susceptible, N = Not susceptible, R = Rarely susceptible

Timber and Timber Products for Use Below Found Level

Timber and timber products shall not be used in direct contact with the ground.

If timber is required to be embedded below ground level, it shall be encased in Grade N20 concrete (20 MPa) of sufficient thickness to provide not less than 50 mm cover to all parts of the timber.

Timber and Timber Products for Above-ground External Exposed Framing

Standard Trade Name	Preservative Requirement	Available	Strength Group Seasoned	Durability Class	Lyctid Susceptible	Tangential Shrinkage %	Early Fire Hazard Ignitability
Group (Mixed Queensland & North NSW Hardwoods)	O	R	SD3	3	S		
Jarrah	O	R	SD4	2	S	7.4	13
Hoop Pine	P	R	SD5	4	N	3.8	14
Slash Pine	P	R	SD5	4	N	4.2	
Radiata Pine	P	R	SD6	4	N	5.1	14
Kwila (Merbau)	O	L	SD3	2	S	2.5	
Red Mahogany	O	L	SD3	2	N	6.3	
Keruing	P	L	SD3	4	S	9.5	

Timber and Timber Products for Above-ground Internal Protected Framing

Standard Trade Name	Preservative Requirement	Available	Strength Group Seasoned	Durability Class	Lyctid Susceptible	Tangential Shrinkage %	Early Fire Hazard Ignitability
Group (Mixed Queensland &	O	R	SD3	3	S		

North NSW Hardwoods)							
Douglas Fir (Oregon)	O	R	SD5	4	N	4.0	14
Hoop Pine	S	R	SD5	4	N	3.8	14
Slash Pine	S	R	SD5	4	N	4.2	
Radiata Pine	S	R	SD6	4	N	5.1	14
Group (Hemfir)	O	R	SD7	4	N		
Group (Australian mixed softwoods)	O	R	SD7	4	N		
Group (Spruce Pine Fir [SPF])	O	R	SD7	4	N		
Group (Unidentified imported softwoods)	O	R	SD8	4	N		
Kwila (Merbau)	O	L	SD3	2	S	2.5	
Keruing	O	L	SD3	4	S	9.5	

Concrete

Scope

This section covers the construction of the following concrete members for small to medium sized buildings:

- Concrete footings
- Concrete ground beams
- Concrete slab-on-ground
- Concrete piers.

Building Regulations and Standards

All materials and construction shall comply with the most recent version of:

- the relevant parts of the Building Regulations;
- the Standards referred to therein;
- other Standards nominated in this specification; and
- other relevant Regulations.

Relevant Standards

AS 3600 Concrete Structures

AS 3610 Formwork for concrete

AS 3660.1 Termite management – New Building work

AS 3660.2 Termite management – In and around existing buildings and structures – Guidelines

AS 3660.3 Termite management – Assessment criteria for termite management systems

AS 1379 Specification and supply of concrete

AS 1478.2 Chemical admixtures for concrete, mortar and grout

AS 2870 Residential slabs and footings - Construction

AS 3799 Liquid membrane-forming curing compounds for concrete

AS 4200.1 Pliable building membranes and underlays - Materials

AS/NZS 4671 Steel reinforcing materials

Definitions

Site Classifications (based on AS 2870)

Class A – Most sand and rock sites with little or no ground movement from moisture changes

Class S – Slightly reactive clay sites with only slight ground movement from moisture changes

Class M – Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes

Class H – Highly reactive clay sites, which can experience high ground movement from moisture changes

Class E – Extremely reactive sites, which can experience extreme ground movement from moisture changes

Class P – Filled sites including soft or unstable foundation, soils, such as soft clay or silt or loose sands, landslip, mine subsidence, collapsing soils, soils subject to erosion, reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise.

Note: For deep-seated movements, typical of dry climates and corresponding to a design depth of suction change equal to or greater than 3 metres, the classification Classes M, H and E shall be modified to M-D, H-D or E-D.

Sand Bedding

A bedding sand layer 50 to 100 mm in thickness shall be placed over the compacted soil base to the level of the underside of the slab.

Vapour Barrier

The vapour barrier shall be installed immediately beneath the concrete slab-on-ground and footings. The vapour barrier shall not be punctured. Laps shall be 200 mm at joints. Plumbing penetrations shall be taped or sealed with a close-fitting sleeve. Where shallow bulk piers are used, the vapour barrier shall line the pier hole to enable the piers and footings to be poured integrally.

Reinforcement

Reinforcement shall be placed in accordance with the drawings such that the following laps and cover are achieved. Three N12 corner bars 2.0 metre long shall be placed at all re-entrant corners.

Reinforcement	Minimum Required Laps
Bars	500 mm
Fabric	2 cross wires overlapping
Trench mesh	500 mm

Bar chairs shall be placed at one metre centres both ways. Bar chairs shall incorporate wide bases and be placed on metal bases that do not puncture the vapour barrier. Where fabric with 7 mm bars at 200 mm centres (SL72), or lighter, is used, the bar chair spacing shall be reduced to 800 mm. Bar chairs shall be placed to give the following clear cover.

- 40 mm in concrete in contact with unprotected ground
- 40 mm in concrete exposed externally
- 30 mm to a sealed vapour barrier
- 20 mm to the internal surface

Placing Concrete

Trenches and footing excavations shall be dewatered and cleaned prior to concrete placement so that no softened or loosened material remains.

All concrete shall be compacted by mechanical immersion vibrator.

Notes

1. Formwork - Edge forms for suspended concrete slabs are often difficult to secure and keep straight. When permanent steel sheet formwork is used, preformed metal edge forms may also be screwed to the sheeting by short metal straps.
2. Reinforcement Cover - The lapping of welded fabric reinforcement in the top face of a slab will significantly increase the thickness of reinforcement and reduce the cover. The slab thickness shall be such as to provide both sufficient cover and sufficient effective depth.

Finishing Concrete

Concrete surfaces shall be finished as noted below unless specified otherwise.

- Floor slabs - Steel float.
- External paths, driveways and parking areas at less than 10% slope - Fine broomed steel float.

- External paths, driveways and parking areas at greater than 10% slope - Coarse broomed steel float.
- Vertical surfaces exposed in the completed building - Rubbed back to fill all voids and provide smooth surface.
- Vertical surfaces not exposed in the completed building - Off form finish.

Curing Concrete

All concrete shall be cured using a sprayed curing compound. Wax-based compounds shall not be used in areas requiring the subsequent application of curing adhesives.

Notes

1. The Builder shall apply and maintain the curing system; or ensure that the Contractor correctly applies and maintains the curing system.
2. Sprayed emulsions require less attention than moistening and covering the slab.

Stripping Formwork

Unless adverse weather or the use of retarders delays the hardening of concrete, the minimum stripping time for formwork shall be 3 days.

Maintenance

The building owner is responsible for the building and site maintenance as detailed in the CSIRO Pamphlet 10-19 *Guide to Home Owners on Foundation Maintenance and Footing Performance*.

Bedding Sand Bedding

Bedding sand shall comply with the Drawings, Building Regulations and relevant Standard (AS 2758.1). Unless stated otherwise, sand shall be clean, free from salts, vegetable matter and impurities, and with the following grading:

Sieve	**Percent Passing**
4.75 mm	90 to 100
2.36 mm	60 to 100
1.18 mm	30 to 85
0.600 mm	15 to 60
0.300 mm	5 to 30
0.150 mm	0 to 15
0.075 mm	0 to 10

Vapour Barrier

Vapour barriers shall comply with the Drawings, Building Regulations and relevant Standard (AS 4200). Unless stated otherwise, vapour barriers shall be not less than medium impact resistance polyethylene vapour barrier 0.2 mm thick.

In areas of known salt damp, a damp-proofing membrane with high impact resistance is required.

Adhesive tape shall be PVC for normal applications, or polyethylene tape for fixing to higher strength or thicker membranes.

Bar Chairs

Bar chairs shall comply with the Drawings, Building Regulations and relevant Standard. Unless stated otherwise, properties shall such that:

- Reinforcement is positioned in the top half of the concrete slab

- Reinforcement in footings has 40 mm in concrete in contact with unprotected ground and 30 mm to a sealed vapour barrier

Reinforcement

Reinforcement shall comply with the Drawings, Building Regulations and relevant Standard (AS 4671, AS 2870). Unless stated otherwise, properties shall be not less than:

- Deformed bars - 500 MPa, normal ductility (N)
- Square fabric, rectangular fabric and trench mesh - 500 MPa, low (L) or normal (N) ductility ribbed wires
- Fitments -500 MPa, low (L) or normal (N) ductility ribbed wires
- Round bar (e.g. R250 N10 for dowels) - 250 MPa round

Concrete

Concrete shall comply with the Drawings, Building Regulations and relevant Standard (AS 3600 or AS 2870). Unless stated otherwise, properties shall be not less than:

- Characteristic compressive strength of 20 MPa (Strength grade N20) for residential ground slabs and footings to AS 2870
- Characteristic compressive strength of 25 MPa (Strength grade N25) for other structures to AS 3600
- Maximum aggregate size of 20 mm
- Of sufficient slump to facilitate the nominated means of placement
- Subject to plant control testing.

Site-mixed 20 MPa concrete shall comply with the following specification. For each cubic metre of concrete, mix

- 320 kg of portland or blended cement (8 No 40 kg bags or 16 No 20 kg bags);
- 0.5 cubic metres of clean sharp sand;
- 1.0 metre of coarse 20 mm rock aggregate; and
- 220 litres (11 No 20 litre buckets) of drinkable water.

Formwork

Formwork shall comply with the Drawings, Building Regulations and relevant Standard (AS 3610).

Curing Compounds

Curing compounds shall comply with the Drawings, Building Regulations and relevant Standard (AS 3799). Unless stated otherwise, curing compounds shall be hydrocarbon, solvent-based acrylic, water-based acrylic or wax-based acrylic. Wax-based compounds shall not be used in areas requiring the subsequent application of curing adhesives.

Joint Material

Joint material shall comply with the Drawings, Building Regulations and relevant Standard (AS 2870). Unless stated otherwise:

- Backing rod for control joints, expansion joints and articulation joints shall be expanded polystyrene tube or bead or, rigid steel backing profile with closed cell foam adhered to the metal profile face.
- Joint sealant shall be gun grade multi-purpose polyurethane sealant.

Concrete Jointing Accessories

Concrete jointing accessories shall comply with the Drawings, Building Regulations and relevant Standard (AS 2870). Unless stated otherwise, concrete jointing accessories shall have appropriate properties to ensure they fulfil their intended function and can be accurately installed.

Dowel Cradles shall provide accurate horizontal and vertical alignment of dowels.

Crack Inducers shall provide an adequate crack to relieve contraction stresses.

Rebate Moulds shall be constructed of a rigid PVC material and form a true square or rectangular rebate.

Dowel Sleeves shall include provision for longitudinal expansion in the ends of all sleeves, stiffening ribs to minimise distortion, end clips to ensure correct alignment during pour and end closures to prevent entering of slurry.

Expansion Caps shall fit a variety of dowel sizes and provide internal compression pins for longitudinal expansion.

Permanent Flexible Plastic Capping shall be UV treated PVC material and provide a bevelled edge to the joint.

Removable Capping shall be PVC material and provide a bevelled edge to the joint.

Foam Filler compression strips shall be closed cell polyethylene foam.

Key Joint Joiners shall provide accurate alignment of key joints in both horizontal and vertical directions without interrupting the capping line.

Masonry

Scope

This section covers the construction of partially reinforced hollow concrete blockwork used as the walls of buildings constructed on concrete slab-on-ground..

Relevant Standards

AS 3700 Masonry structures

AS 3700 Supplement 1 Masonry Structures – Commentary

AS 4773.1 Masonry in small buildings – Design

AS 4773.2 Masonry in small buildings – Construction

AS/NZS 4455 Masonry units and segmental pavers

AS/NZS 4456 Masonry units and segmental pavers - Methods of test

AS/NZS 2904 Damp-proof courses and flashings

AS/NZS 2699.1 Built-in components for masonry construction - Wall ties

AS/NZS 2699.2 Built-in components for masonry construction - Connectors and accessories

AS/NZS 2699.3 Built-in components for masonry construction - Lintels and shelf angles (durability requirements)

AS 3972 Portland and blended cements

AS 2758.1 Aggregates and rock for engineering purposes - Concrete aggregates

AS 3660.1 Termite management – New Building work

AS 3660.2 Termite management – In and around existing buildings and structures - Guidelines

AS/NZS 4671 Steel reinforcing materials

AS 3600 Concrete structures

AS 2870 Residential slabs and footings – Construction

Mortar

For general applications (except as listed for M4 or M2), Type M3 mortar shall be used, and shall consist by volume of:

- 1 part GP or GB cement, 1 part lime, 6 parts sand (water thickener optional)
- 1 part GP or GB cement, 5 parts sand plus water thickener

For the applications listed below, Type M4 mortar shall be used, and shall consist by volume of:

- 1 part GP or GB cement, 0.5 part lime, 4.5 parts sand (water thickener optional)
- 1 part GP or GB cement, 4 parts sand plus water thickener
- 1 part GP or GB cement, 0-0.25 parts lime, 3 parts sand (water thickener optional)

This applies to:

- Elements in interior environments subject to saline wetting and drying
- Elements below a damp-proof course or in contact with ground in aggressive soils
- Elements in severe marine environments
- Elements in saline or contaminated water including tidal splash zones
- Elements within 1 km of an industry producing chemical pollutants.

Damp-Proof Course

Damp-proof-courses shall be built into the masonry in accordance with the Drawings, Building Regulations and relevant Standard (AS 3700). Unless stated otherwise, damp-proof-courses shall be:

- Placed under walls to provide a continuous damp-proof barrier around the building
- Lapped not less than 150 mm at joints
- Projecting through the entire width of the masonry and project beyond the external face of the masonry
- Stepped at changes of floor level
- Positioned (if applicable) under the coping of any parapet more than 300 mm above adjoining roof cladding
- Positioned (if applicable) in chimney stacks, 150 mm to 300 mm above the highest junction of roof and chimney
- At least 75 mm above finished surface level of adjacent paved, concreted or landscaped areas that slope away from the wall
- At least 50 mm above finished paved or concreted areas sloping at least 50 mm over the first 1 m from the building and protected from the direct effects of the weather by a carport, verandah or similar
- At least 150 mm above the adjacent finished ground in all other cases.

Flashings

- Flashings shall be built into the masonry in accordance with the Drawings, Building Regulations and relevant Standard (AS 3700). Unless stated otherwise, flashings shall be:
- Fixed with clouts to timber studs or built into an inner leaf of masonry as applicable
- Built into the external leaf of walls exposed to weather, extending across the cavity,
- Turned up 150 mm and nailed to the frame or built 30 mm into an inner leaf of masonry,
- Positioned at openings (unless they are protected by an overhang), where they shall extend 100 mm past the end of opening and be turned up to prevent leakage.

Termite Protection

Masonry walls in buildings shall incorporate termite protection. Refer to the separate specification on Termite Protection in “Concrete”.

Mortar Joints

Mortar joints shall comply with the Drawings, Building Regulations and relevant Standard (AS 3700). Unless stated otherwise, mortar joints shall comply with the following:

- Mortar joint shall be 10 mm thick.
- Mortar joints in hollow blockwork, shall be face shell bedded and shall be ironed, unless a flush joint is specified for aesthetic reasons.

Provision for Timber Shrinkage

In masonry veneer construction, a gap in accordance with schedule below shall be left between the timber frame and the top of the masonry, and at window sills, to accommodate timber shrinkage.

Location in timber framed buildings	Minimum Clearances (mm)	
	Unseasoned hardwood frame	Other timber frame
Sills of lower or single storey windows	10 mm	5 mm
Roof overhangs of single storey buildings	16 mm	8 mm
Sills of second storey windows	20 mm	10 mm
Roof overhangs of two storey buildings	24 mm	12 mm

Reinforced Masonry Construction (Excluding Retaining Walls)

All construction of reinforced concrete masonry shall comply with the Drawings, Building Regulations and relevant Standard (AS 3700). Unless stated otherwise, the following shall apply:

Vertical steel reinforcement shall be tied using tie wire to steel starter bars through clean-out holes in each reinforced core and fixed in position at the top of the wall by plastic clips or template. Starter bars shall be tied into position to provide the specified lap above the top surface of the footing. The starter bars shall be held in position on the centre line of a reinforced blockwork wall by a timber member or template and controlled within a tolerance of +,- 5 mm through the wall and +,- 50 mm along the wall.

Horizontal steel may be laid in contact with rebated webs of Double U or H blocks. It shall be held in position by steel ties or plastic clips. Cover to horizontal steel in lintel blocks shall be maintained by the use of wheel type plastic clips.

The minimum cover (from the edge of the steel reinforcement to the inside face of the block core) shall be 20 mm, except where specified otherwise. In severe marine environments, saline or contaminated water including tidal and splash zones, and within 1 km of an industry in which chemical pollutants are produced, the minimum cover to the inside face of the block core shall be 30 mm.

For houses (and similar buildings) consisting of partially reinforced concrete masonry on concrete slab-on-ground, control joints shall not be built in.

For other reinforced concrete masonry applications, control joints shall be built into reinforced concrete masonry at all points of potential cracking and at the locations shown on the drawings. The spacing of control joints should not exceed 8.0 metres, except that the spacing of control joints may be increased in reinforced masonry walls meeting the following criteria:

- Consisting of at least 190 mm hollow concrete units,
- Built less than 3.0 metres high,
- Incorporating a top reinforced bond beam,
- Incorporating N16 horizontal reinforcement at not greater than 400 mm centres,
- On a site with rock or slightly reactive foundations,
- With a reinforced concrete footing of adequate stiffness.

Hollow Concrete Masonry Units

Hollow concrete masonry units shall comply with the Drawings, Building Regulations and relevant Standard (AS/NZS 4455.1) and the following properties:

- Dimensional Category DW4;

- General Purpose Salt Attack Resistance Grade (except for applications requiring Exposure Grade including saline wetting or drying, aggressive soils, severe marine environments, saline or contaminated water including tidal or splash zones, or within 1 km of a industry producing chemical pollutants);
- Characteristic Compressive Strength not less than a value specified by the Engineer or 15 MPa (measured using face shell bedding), whichever is the lesser;
- Characteristic Lateral Modulus of Rupture not less than 0.8 MPa;
- Mean Coefficient of Residual Drying Contraction not more than 0.6 mm/m.
- When intended for face applications and exposed to the weather:
    - Permeability not more than 2 mm/minute
    - Efflorescence Potential of Nil or Slight
    - Colour and texture within an agreed range.
- If units are intended to incorporate both horizontal and vertical reinforcement and are not protected both sides by a waterproof membrane, they shall be “H” or “Double U” configuration such that:
- Units may be fully grouted and may be reinforced both vertically and horizontally;
- Cores such that concrete grout may flow easily around and enclose the reinforcement in all cores; and provide cover is consistent with the requirements for durability, strength and fire resistance as appropriate.

Cement

Cement shall be Type GP portland cement or GB blended cement complying with the relevant Standard.(AS 3972).

Water Thickener

Water thickener shall be methyl-cellulose based.

Sand

Sand shall be well graded and free from salts, vegetable matter and impurities. Sand shall not contain more than 10% of the material passing the 75 micron sieve. Sand within the following grading limits complies with this requirement and is deemed suitable for concrete masonry.

Sieve	Percent Passing
4.76 mm	100
2.36 mm	95–100
1.18 mm	60–100
600 µm	30–100
300 µm	10–50
150 µm	0–10
75 µm	0–4

Concrete Grout

Concrete grout shall comply with the Drawings, Building Regulations and relevant Standard (AS 3700). Unless stated otherwise, properties shall be:

- a minimum portland cement content of 300 kg/cubic metre;
- a maximum aggregate size of 10 mm;

- sufficient slump to completely fill the cores; and
- a minimum compressive cylinder strength of 20 MPa.

Flashings

Flashings shall comply with the Drawings, Building Regulations and relevant Standard (AS 3700, AS/NZS 2904).

Metal and metal-cored flashings shall not be used in locations that expose them to saline ground water or rising salt damp.

Metal flashings shall be compatible with the materials with which they are in contact, and shall not give rise to electrolytic action. If there is potential for electrolytic action to occur, flashings shall be isolated by inert materials.

Flashings intended to hold their shape shall be manufactured from rigid material. (e.g. metal cored material)

Unless stated otherwise flashings shall consist of one of the following options:

- Flashing in Concealed Locations (e.g. cavity flashings) shall be one of the following:
- Uncoated annealed lead having a mass not less than 10 kg/m^2 in lengths not exceeding 1.5 m, but shall not be used on any roof that is used to catch potable water;
- Uncoated copper having a mass not less than 2.8 kg/m^2 and having a thickness of 0.3 to 0.5 mm;
- Bitumen coated metal (normally aluminium) with a total coated thickness of 0.6 mm to 1.0 mm;
- Zinc coated steel with a thickness not less than 0.6 mm;
- Embossed/quilted polyethylene sheet with an average thickness not less than 0.5 mm

Flashings in Exposed Locations (e.g. flashings from the roof to masonry wall) shall be one of the following:

- Uncoated annealed lead having a mass not less than 20 kg/m^2 in lengths not exceeding 1.5 m, but shall not be used on any roof that is used to catch potable water;
- Uncoated copper having a mass not less than 2.8 kg/m^2 and having a thickness of 0.3 to 0.5 mm;
- Bitumen coated metal (normally aluminium) with a total coated thickness of 0.6 mm to 1.0 mm;

Zinc coated steel of thickness not less than 0.6 mm

Damp Proof Course

Damp-proof courses (DPCs) shall comply with the Drawings, Building Regulations and relevant Standard (AS 3700, AS/NZS 2904). Unless stated otherwise damp-proof courses (DPCs) shall consist of one of the following options.

- A material complying with the Standard AS/NZS 2904;
- Embossed black polyethylene film of high impact resistance and low slip, with a nominal thickness of 0.5 mm prior to embossing, and meeting the requirements of the relevant Standard (Clause 7.6 of AS/NZS 2904);
- Polyethylene coated metal damp proof courses with an aluminium core not less than 0.1 mm thick, shall be coated both sides with bitumen adhesive enclosed in polyethylene film not less than 0.1 mm thick on each face, and has a nominal total thickness of not less than 0.5 mm prior to embossing;
- Termite shields (with no penetrations) continuous throughout the wall or pier.

Notes:

Metal and metal-cored damp-proof courses and termite shields shall not be used in locations with saline ground water or subject to rising salt damp.

Termite Barriers Consisting of Woven Stainless Steel Mesh

Woven stainless steel mesh acting as a termite barrier shall comply with the Drawings, Building Regulations and relevant Standard (AS 3660.1). Unless stated otherwise, properties shall be not less than the following:

- Mesh shall be woven wire from a fine wire loom.
- Wire shall be stainless steel grade 304 or 316 (AS 1449).
- Wire diameter shall be not less than 0.18 mm.
- Aperture size shall be not greater than 0.66 mm × 0.45 mm, except in those locations where a very small species of heterotermes vagus is present (e.g. parts of northern Australia), the aperture shall be reduced to a maximum of 0.40 × 0.40 mm

Pipe collars, manufactured from woven stainless steel mesh with a 50 mm annulus, shall be attached to any penetrating service by a stainless steel clamp. Such collars shall be:

- Embedded in concrete; or
- Clamped and parged to the top surface of the slab and protected from damage by covering with a tile mortar bed or false floors of cupboards or vanities. The clamp shall be sealed with the parging mix.

Termite Barrier Parging Material for Woven Stainless Steel Mesh

Parging material, for woven stainless steel mesh acting as a termite barrier, shall comply with the Drawings, Building Regulations and relevant Standard (AS 3660.1). Unless stated otherwise, parging material shall be a highly modified cementitious grout of a water-dispersed copolymer with a dry mixture of Type GP portland cement and sieved aggregate of a size that passes readily through the woven stainless steel mesh.

Hardened parging material shall provide:

- Termite resistance, when in contact with soil and termite workings;
- Bond strength (mesh to substrate) of not less than 1 kN/m at 28 days for a temperature range of 10°C to 30°C at a relative humidity range of 10%RH to 70%RH; and for at least 60 freeze-thaw cycles in saline solution between −15°C and 18°C.

Termite Barriers Consisting of Composite Fibre Blanket and Plastic Membrane with Termiticide Impregnation

Termite barriers, consisting of composite fibre blanket and plastic membrane with termiticide impregnation, shall comply with the Drawings, Building Regulations and relevant Standard (AS 3660.1).

Unless stated otherwise, properties shall be not less than:

- Internal non-woven fibre blanket, not less than 200 grams per square metre,
- Impregnated with termiticide of pyrethroid deltametherin crystals to a loading of not less than 1 gram per square metre (low toxicity to warm blooded animals which both strongly repels and kills termites),
- Bonded to a top moisture vapour barrier of low density polyethylene (LDPE), not less than 200 microns thick,
- Bonded to a bottom membrane of low density polyethylene (LDPE) not less than 50 microns thick, to prevent the termiticide leaching into soil.

Part 5 – DANCER Cost Comparisons and Bills of Quantities

Part 5 provides bills of quantities for the principal components of the most common **DANCER** buildings. The **DANCER** Design Package may be used to prepare customised Bills of Quantities for other applications.

DANCER Cost Comparisons

Background

The **DANCER** building System provides structural framing in which the uplift and racking forces due to wind, earthquake and tsunami are efficiently transmitted to the foundations via the timber frame itself, rather than through separate steel anchors and ties.

In this way, **DANCER** differs from a conventional timer house framing (designed to AS 1684), which relies on steel anchors and ties to secure the roof structure through the walls and floor system to the sub-floor.

Notwithstanding any cost differences, the advantages of the **DANCER** system are that it has a simple site construction method that does not rely on tensioning straps and it does not use steel components that are difficult to source in remote areas.

Scope of Cost Comparisons

1. The cost comparisons in this section deal only with the cost differences between the **DANCER** framing above the sub-floor and conventional timber house framing above the sub-floor.
2. The roof cladding, wall cladding, flooring, subfloor, windows, doors, internal walls, ceiling, internal lining and fit-out can be (and in most cases would be) identical in both systems and are therefore not included in the cost comparisons below.

Assumptions

1. Designs complying with AS 1684 can utilize a number of solutions, depending on the sub-floor post and pier spacing. So too, the **DANCER** system could adopt different arrangements for sub-floor post and pier spacing. To enable reasonable cost comparisons to the made, both systems have been based on the same sub-floor arrangement.
2. The roof systems described in AS 1684 is consists of rafters, ridge beams, collar ties, struts, underpurlins, hanging beams ceiling joists and the like, sometimes referred to as a “cut roof”. This system relies on load bearing walls for support at various intermediate points and is not favored in modern design.
3. Most modern building would incorporate a trussed roof (designed to AS 1720.5) in preference to the cut roof described in AS 1684. Therefore, the costs are based on a truss system.
4. The designs of both systems vary depending on the building geometry, wind exposure, earthquake risk and availability of structural timber.
5. The following combinations are assumed for both systems for the cost comparisons.
    (a) In non-cyclonic regions (such as Papua New Guinea Highlands), a wind classification of N2 and an availability of unseasoned hardwood of stress grade F11 and joint type J2 are assumed. For this combination, a post and pier grid of 2.7 x 2.7 m has been used.
    (b) In cyclonic regions (such as Solomon Islands, Vanuatu, Fiji and Tonga), a wind classification of C2 and an availability of seasoned softwood of stress grade MGP10 and joint type JD4 are assumed. For this combination, a post and pier grid of 1.8 x 1.8 m has been used.
6. Notwithstanding the assumption listed above, the design of individual structures will depend on availability of local materials and the local exposures.

Cost Comparison 5.7 x 5.7 Building, Cyclonic Wind C2, Timber MGP 10

Building: 5.7 x 5.7 m with a small porch

Subfloor: Steel posts arranged on a 1.8 m x1.8 m grid

Timber: Seasoned pine, MGP10, Joint Type JD4

DANCER Trusses, Purlins and External Wall Frames									
No of trusses	10								
Bolts, nuts and washers									
M12 x 150 gal bolt nuts	80	M12	x	150	$	2.07	each	$	165
M12 galv flat washers	160	M12			$	0.20	each	$	31
M16 x 150 gal bolt nuts	20	M16	x	150	$	3.41	each	$	34
M16 galv nuts	40	M16			$	0.33	each	$	13
								$	244
Timber									
Studs, Plates, Noggings	1.501	m^3			$	1,022	m^3	$	1,535
Roof trusses	1.443	m^3			$	1,022	m^3	$	1,475
Roof Purlin (or Roofing B	0.299	m^3			$	1,022	m^3	$	306
Other timber	1.355	m^3			$	1,022	m^3	$	1,386
Total timber	4.599	m^3						$	4,702
Total costs								**$**	**4,946**
Conventional Trusses. Battens and External Wall Frames									
No of trusses	10								
Bolts, nuts and washers									
M10 screwed galv rod	14	M10	x	2700	$	9.20	each	$	129
M10 galv nuts	28	M10			$	0.20	each	$	6
M10 galv flat washers	56	M10	x	3.0	$	0.15	each	$	8
								$	143
Truss components									
Galvanised knuckle plate	320				$	1.20	each	$	384
Galvanised knuckle plate	40				$	2.14	each	$	86
								$	470
Strapping for tie-downs									
30 x 1.0 mm steel strap	120	30	x 1.0 x	0.545 m	$	1.07	m	$	121
Timber									
Studs, Plates, Noggings	1.626	m^3			$	1,022	m^3	$	1,662
Roof trusses	1.271	m^3			$	1,022	m^3	$	1,299
Roof Purlin (or Roofing B	0.233	m^3			$	1,022	m^3	$	238
Other timber	1.355	m^3			$	1,022	m^3	$	1,386
Total timber	4.484	m^3						$	4,585
Total costs								**$**	**5,054**
Difference								**$**	**109**

1 – House, 5.700 x 5.700, one storey, timber

Bill of Quantities

Project		
Partners	Generic	
Use	Generic	
Nominal plan dimensions (allowing for exte	5.7 m x 5.7 m overall 5.7 m x 5.7 m habitable	
External elevation	One habitable storey,	
Internal arrangment	Two bedrooms,	
	Steel posts,	
	Cyclonic wind or high earthquake hazard	
Details		
Building designation	Generic	
Importance Level	2	
Ground floor type	Elevated	
Roof (skillion/gable/hip)	g	
Roof pitch	18.4	o
Shape (R = Rectangle)	Input	
No of habitable storeys	1	
Length (O/A ext studs	5.700	m
Width (O/A ext studs)	5.700	m
Total width incl verandas	5.700	m
Thickness of ext walls	0.090	m
Thickness of int walls	0.070	m
Area (inc walls, excl veranda)	32.49	m2
Area of habitable rooms	29.891	m2
Ext wall height w/o subfloor	2.585	m
Top storey height FFL to ceiling	0.000	m
Bottom storey height FFL to ceiling	2.400	m
Minimum sub-floor FFL	1.100	m
Eaves overhang (length)	0.450	m
Eaves overhang (width)	0.450	m
Does roof extend over verandas?	Yes	
Plan length of roof	6.600	m
Plan width of roof	6.600	m
Is there a ceiling?	Yes	0
Is there eaves lining?	Yes	0
Bottom bolt to top bolt	0.165	m
Bottom truss bolt to u/s chord	0.045	m
Ceiling joist depth	0.035	m
Ceiling depth	0.010	m
Roof rise ceiling to purlins top	1.332	m
External wall height	3.685	m
Total height to ridge	5.017	m

U/S Ceiling to FFL above		1.100	m							
Front veranda length (incl posts)		0.000	m							
Front veranda width (incl posts)		0.000	m							
Back veranda length (incl posts)		0.000	m							
Back veranda width (incl posts)		0.000	m							
Rise of stairs		1.100	m							
Number of external doors		1								
Number of internal doors		2								
Number of windows		7								
Area of windows		6.72	m2							
Length of internal walls		8.28	m							
Roof sheeting		Steel sheet								
Roof structure		Direct Anchorage Timber								
External walls		Clad timber frame								
Internal walls		Timber frame								
Footings for building		Concrete piers								
Footings for steps		Concrete pad footings								
Subfloor post type		Steel								
Is subfloor post embedded?		No								
Floor		Elevated timber								
Site Establishment										
Item	1 No	Lump sum for all partts of site establishment								
Earthworks & Site Drainage										
Clear site	1 No	12	x	12				**136.9**	m2	0%
		Clear the site of vegetation for a distance of 3.0 m around the building.								
Construct site drainage	1 No	12						**11.7**	m	0%
		Construct a drain and bund (200 mm high) around top side of site if necess								
Excavate for concrete piers	9 No	.								0%
Concrete										
N20 concrete in piers	9 No	600	x	400	dia			**0.7**	m3	10%
Components of concrete										
Cement in concrete								**239**	**kg**	
Sand in concrete								**0.4**	**m^3**	
Gravel in concrete								**0.7**	**m^3**	
N20 concretein stair pad	1 No	1,200	x	600	x		100	**0.1**	m	10%
Components of concrete										
Cement in concrete								**25**	**kg**	
Sand in concrete								**0.0**	**m^3**	
Gravel in concrete								**0.1**	**m^3**	
Reinforcement in Stair Pad	6 No	N10						**5.6**	m	10%
Windows & Glazing										
600 high x 600 long windows	2 No	.								0%
1200 high x 1200 long windc	2									

1200 high x 1800 long windc	1									
Shutters for louvre windows	0	No	.							0%

Steel Posts

Steel Post Specification 9 No 80NB galvanised medium wall pipe,125 x 75 x 6 L x 130, 2 holes 13 dia

Posts and brackets cosisting of:

	No of		Depth	x	Width	x	Length	Total		Wasteage
	No		mm		mm		mm	m		%
Steel Post	9	No	80 NB		galv med wall p		940	**9.3**	m	10%
	9	No	x 125 x 6 L			x	130	**1.3**	m	10%
	9	No	N12			x	300	**3.0**	m	10%

Timber Framing

Timber Specification	Radiata Pine	MGP10	Volume	**4.599**	m^3

Number of Fabricated Posts 0 Fabricated posts consist of four members separated and secured by space

Number of Trusses 10 Trussess consist of double top chords, single bottom chords and lacing.

	No of		Depth	x	Width	x	Length	Total		Wasteage
	No		mm		mm		mm	m		%
Bracing for Steel Posts	8	No	90	x	45	x	2,199	**19.4**	m	10%
Fabricated Timber Anchorag	0	No	0	x	0	x	0	**0.0**	m	10%
Fabricated Timber Anchorag	0	No	0	x	0	x	0	**0.0**	m	10%
Bracing for fabricated timber	0	No	0	x	0	x	0	**0.0**	m	10%
Solid Timber Posts	0	No	0	x	0	x	0	**0.0**	m	10%
Bracing for Solid Timber Pos	0	No	0	x	0	x	0	**0.0**	m	10%
Floor Bearer	12	No	120	x	35	x	3,050	**40.3**	m	10%
Floor Joist	28	No	120	x	35	x	3,000	**92.4**	m	10%
Floor Trimmer Joist	4	No	120	x	35	x	2,850	**12.5**	m	10%
Floor Joist Blocking	0	No	0	x	0	x	0	**0.0**	m	10%
Studs, Plates, Noggings	132	No	90	x	35			**476.6**	m	10%
Roof trusses	250	No	90	x	35			**458.0**	m	10%
Ceiling Batten	28	No	35	x	90	x	2,700	**75.6**	m	0%
Veranda Beam	0	No	230	x	35	x	200	**0.0**	m	10%
Roof Bracing	4	No	90	x	35	x	3,926	**17.3**	m	10%
Fascia Board	4	No	230	x	35	x	3,300	**14.5**	m	10%
Barge Board	4	No	230	x	35	x	3,531	**15.5**	m	10%
Roof Purlin (or Roofing Batte	24	No	90	x	35	x	3,600	**95.0**	m	10%
Stair Stringer	2	No	230	x	45	x	1,782	**3.9**	m	10%
Stair Tread	5	No	280	x	22	x	910	**5.0**	m	10%
Tread support	10	No	75	x	50	x	260	**2.9**	m	10%
Stair stringer support	1	No	280	x	22	x	910	**1.0**	m	10%
Stair post	2	No	90	x	35	x	975	**2.1**	m	10%
Stair walers	6	No	125	x	25	x	1,782	**11.8**	m	10%
Stair hand rail	2	No	125	x	25	x	1,782	**3.9**	m	10%
Veranda Balustrade Post	-3	No	90	x	35	x	1,095	**-3.6**	m	10%
Veranda Balustrades									m	
Veranda Stringers	0	No	75	x	50	x	0	**0.0**	m	10%
Seat components	0	No	0	x	0			**0.0**		

Bolts, Nuts, Washers, Screws and Nails								
All bolts and nuts are Grade 4.6/S, with one flat washer and galvanized.								
Bolts fixing bearers to posts	20	No	Input	x	150			10%
Bolts fixing subfloor bracing	9	No	Input	x	175			10%
Bolts fixing subfloor bracing	4	No	Input	x	125			10%
Bolts fixing subfloor bracing	4	No	Input	x	125			10%
Bolts fixing top chord to anc	22	No	M16	x	150			10%
Bolts fixing stairs to joist	2	No	Input	x	125			10%
Bolts fixing purlins to trusse:	0							10%
Screws								
Nails								
Carpentry & Joinery								
Timber floor	192	No	90	x	20	**401.3**	m	10%
Timber external wall claddin(	450	No	90	x	20	**906.8**	m	10%
Timber gable louvres	28	No	90	x	20	**55.4**	m	10%
Louvre area 2.0 m2. Two fabricated gable end fixed louvres, 10 fixed 90 x 20 HW blades x 1,800 mm								
Timber cornice	22	No	25	x	25	**58.6**	m	10%
Timber skirting	22	No	50	x	20	**52.6**	m	10%
Internal doors	2	No	.					0%
External doors	1	No	.					0%
Cupboards with sink over	3	No	.					0%
Adhesives								
Nails								
Roof Cladding								
Total area	45.9	m2						
Corrugated steel roof sheeting, 0.42 BMT, zincalume					762 mm coverage	**62.6**	m	0%
14-10x50 T17 HH Class 3	Top-lock hex galv roofing screws & plastic washe					**1,195**	No	20%
Roof Plumbing								
Eaves gutter	Zincalume 100 quad gutter					**15.0**	m	10%
Eaves gutter stop-ends	Zincalume 100 quad stop ends					**5**	No	10%
Eaves gutter brackets	Zincalume 100 quad brackets					**25**	No	10%
Eaves gutter screws	14-10x50 T17 HH Class 3					**106**	No	20%
Rainwater downpipes	DN80 PVC RWDP					**10.0**	m	10%
Rainwater downpipe inlets	DN80 PVC inlet					**3**	No	10%
Rainwater downpipe bends	DN80 PVC 45 bend					**5**	No	10%
Rainwater downpipe bracket	Zincalume DN80 brackets					**7**	No	10%
Rainwater downpipe bracket	14-10x50 T17 HH Class 3					**15**	No	0%
Ridge flashing	Zinc-coated steel 0.6 mm thick					**8.0**	m	0%
Gable flashing	Zinc-coated steel 0.6 mm thick					**16.0**	m	0%
Flashing screws	14-10x50 T17 HH Class 3					**166**	No	20%

Part 6 – DANCER Fabrication and Construction Guide

Part 6 provides guidelines on the factory prefabrication, including (when appropriate) trial erection of the system, and the construction process.

DANCER Prefabrication Procedure

1. A set of permanent steel posts in concrete piers, set out accurately to the 2.7 x 2.7 m gridlines (in noncyclonic regions) or 1.8 x 1.8 m gridlines (in cyclonic regions) shall be constructed at the prefabrication workshop. It is recommended that sufficient posts and piers by installed for buildings up to 8.4 x 8.4 m (allowing for and 150 mm at each side and each end).
2. One jig for each type of frame, truss, pier and floor member shall be manufactured and stored permanently at the at the prefabrication workshop. Initially these jigs will be manufactured from timber. As they prove to be accurate, the timber jigs may be replaced by steel jigs. Refer to Part 3 of this Handbook.
3. Once the permanent posts and the jigs are complete, fabrication of all timber components may commence.
4. All timber shall be ordered from the Material Lists and cut in accordance with the Cutting Lists. The Cutting Lists make provision for wastage due to cutting 10% oversize.
5. Once fabrication is complete, the building shall be erected in the prefabrication workshop on the permanent posts and bolted together. Any nailing should only be temporary.
6. All items shall be marked (by Grid Location and Item Number).
7. The structure shall be disassembled, packed and transported to the construction site.
8. The structure shall be reassembled, bolted and permanently nailed. All bracing, sheeting, cladding and the like shall be permanently fixed.

DANCER Trusses – Setting Out Assumptions

1. Because the dressing of timber affects the depth and thickness, the design is based on only one set of dimensions for the jig (template). i.e. the undressed dimensions …. 100 x 38.
2. The critical surfaces for fabrication will be:
    - the top surface of the top chords,
    - the bottom surface of the bottom chords, and
    - the interfaces between the lacing and the purlins at position of the roof sheeting
3. The fascia is assumed to be 35 thick.
4. This means that one jig will be used for all sizes of timber, provided the timbers are positioned hard against the critical surfaces. 100 x 38 will be suitable for 100 x 38, 90 x 35, 75 x 50, 70 x 45 and so on.
5. Purlins of depth less than 100 mm may need to be packed up from the critical surface (top surface of the top chord). Alternatively the top end of the lacing could be trimmed.
6. For fascias thicker than 35, the dimension over the eaves will be very slightly oversized (6 mm overall), but this is not a problem.

DANCER – Jig for Prefabrication of Standard Trusses

Principle

Production trusses may be prefabricated in a factory rather than on site where it is difficult to control the accuracy and the effectiveness of connections.

To facilitate factory-based prefabrication, the member of production trusses should be cut to length and the ends trimmed to the appropriate angles using templates, before being assembled in a jig.

Definitions

Production Truss – The roof trusses intended to be used in particular projects. The span and eaves length may vary depending on the project, but for standard **DANCER** projects the roof slope should be kept constant at 1 (vertical) to 3 (horizontal)

Production Half Truss – Half of a Production Truss. The **DANCER** Truss system is used for spans in the range 4.8 m to 8.4 m. Allowing for at least a 450 mm eaves overhang, the range of overall dimensions effectively becomes 5.7 to 9.3 m (or more). It is impractical to handle and transport full trusses in this range. Therefore, trusses are fabricated and transported to site in two halves, which are bolted together on site during erection. A feature of the **DANCER** Truss System is that both half trusses are usually identical. i.e. There is no requirement for a left-hand and a right-hand half (often called “As drawn” and “Opposite Hand”). Therefore, the Jig need only cater for a single half of a full truss, called a Production Half Truss.

Template – A timber or steel member, the exact shape as the members of the production trusses. The templates may (if required) be fitted with guides.

Jig – A timber or steel template, essentially the same plan shape as a Production Half Truss, fitted with guides and stops to enable the Production Truss members (chords and lacing) to be accurately positioned before being permanently connected with nails or screws.

Top Chord – The sloping top member of a roof truss. Each half truss of the **DANCER** system has a double top chord, consisting of one long top chord member, TC(L), and one short top chord member TC(S).

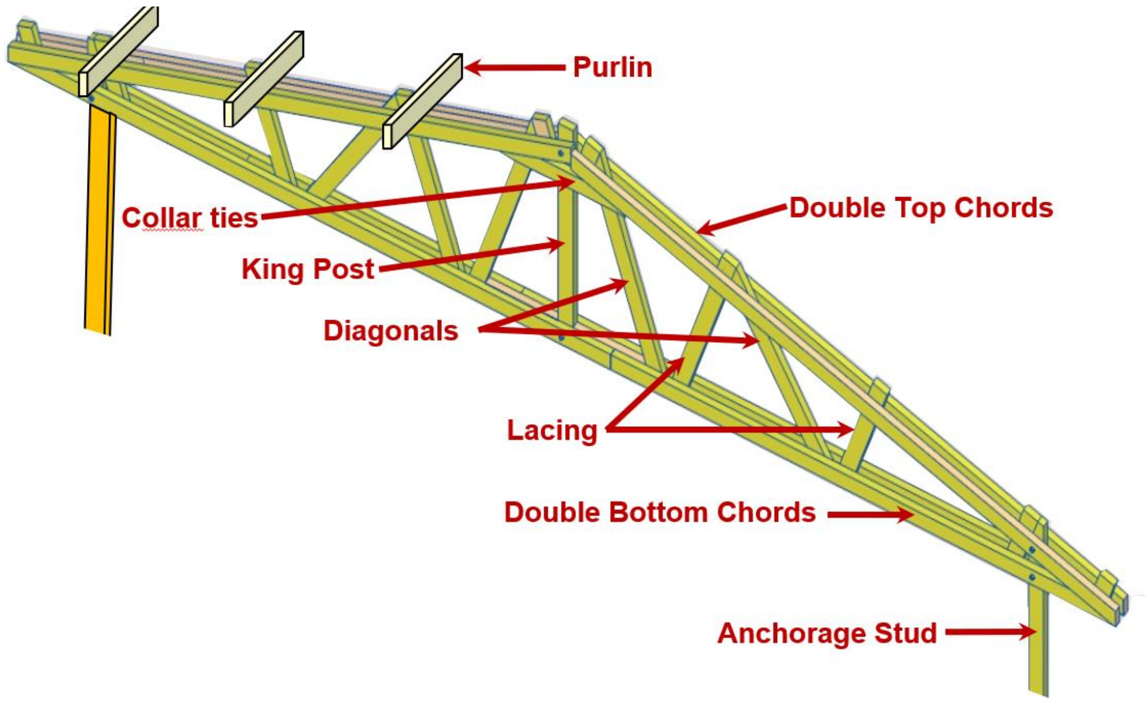
Bottom Chord – The bottom member of a roof truss. The bottom chord is usually horizontal, but in some systems it can be sloping. Each half truss of the **DANCER** system has a double bottom chord, consisting of one long bottom chord, BC(L), and one short bottom chord member BC(S). The bottom chords of the standard **DANCER** trusses are horizontal, although non-standard sloping bottom chords of various configurations may also be designed.

Lacing – The diagonal members of a roof truss that join the top and bottom chords. Lacing members (L1 to L6) are sometimes called webbing. In the **DANCER** system, lacing members are fixed between the double top chords and the double bottom chords, are perpendicular to the top chord, and protrude above the top surface of the top chord so that the purlins can be fixed to them.

Diagonals – The diagonal members of a roof truss that join the top and bottom chords. Diagonals (D1 to D3) are also sometimes called webbing. In the **DANCER** system, diagonal members are fixed between the double top chords and the double bottom chords, but in a diagonal direction that connects the bottom on one lacing member to the top of the next lacing member. They also protrude above the top surface of the top chord to maximise the end clearance of fixings.

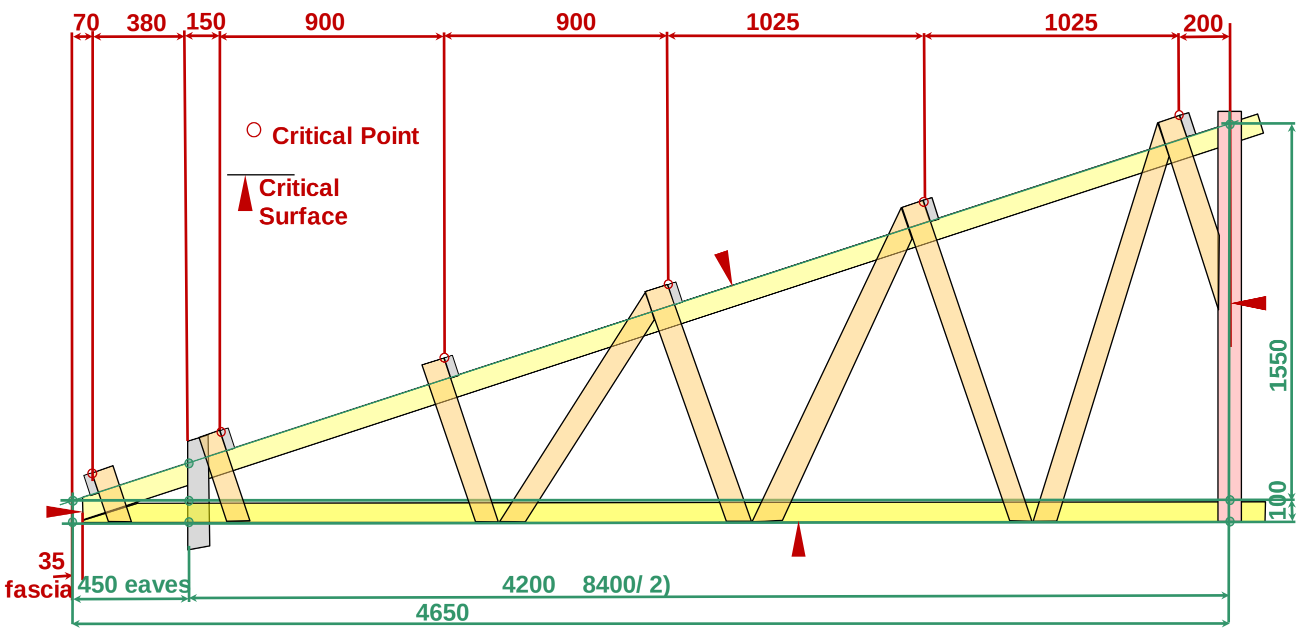
Purlin – The horizontal member to which the roof sheeting is fixed. Purlins are sometimes called battens. In timber “cut” roof systems, the term “purlin” may refer to different members.

Anchorage Stud – A vertical post to which the **DANCER** trusses are bolted, which transmit roof uplift forces down to the lower parts of the structure. For describing the **DANCER** system, the span is measured to the outside of the studs.



Critical Surfaces for a Multipurpose Jig

1. Adherence to the following principles will enable the standard jig to be used to manufacture trusses employing members of several different cross sections within the range 100 x 38 to 90 x 35 mm. Thicker members may also be used if non-standard trusses are required.
2. Because the dressing of timber affects the depth and thickness, the design is based on only one set of dimensions for the jig and templates. i.e. the undressed dimensions …. 100 x 38.
3. The critical surfaces (shown below) for fabrication will be:
    - the top surface of the top chords,
    - the bottom surface of the bottom chords, and
    - the inside face of the fascia, which is assumed to be 35 thick
    - the centreline of the truss
    - the interfaces between the lacing and the purlins at position of the roof sheeting.



4. This means that one jig will be used for all sizes of timber, provided the timbers are positioned hard against the critical surfaces. 100 x 38 will be suitable for 100 x 38, 90 x 35, 75 x 50, 70 x 45 and so on.
5. Purlins of depth less than 100 mm may need to be packed up from the critical surface (top surface of the top chord). Alternatively, the top end of the lacing could be trimmed.
6. For fascias thicker than 35, the dimension over the eaves will be very slightly oversized (6 mm overall), but this is not a problem.

Manufacturing a Jig

1. Types: The Jig may be manufactured of timber (easy to make) or hollow steel sections (long lasting).
2. Materials: Use either 100 x 38 milled timber; or 100 x 38 (or 100 x 50) RHS hollow steel sections.
3. Manufacture a Production Half Truss to the following plan dimensions. Include a collar tie (CT), a King Post (KP) and a short piece of Anchorage Stud. The dimensions below are for a **DANCER** Half Truss, overall span 5.7 m, slope of 1:3, and 450 mm eaves.

Cutting Members

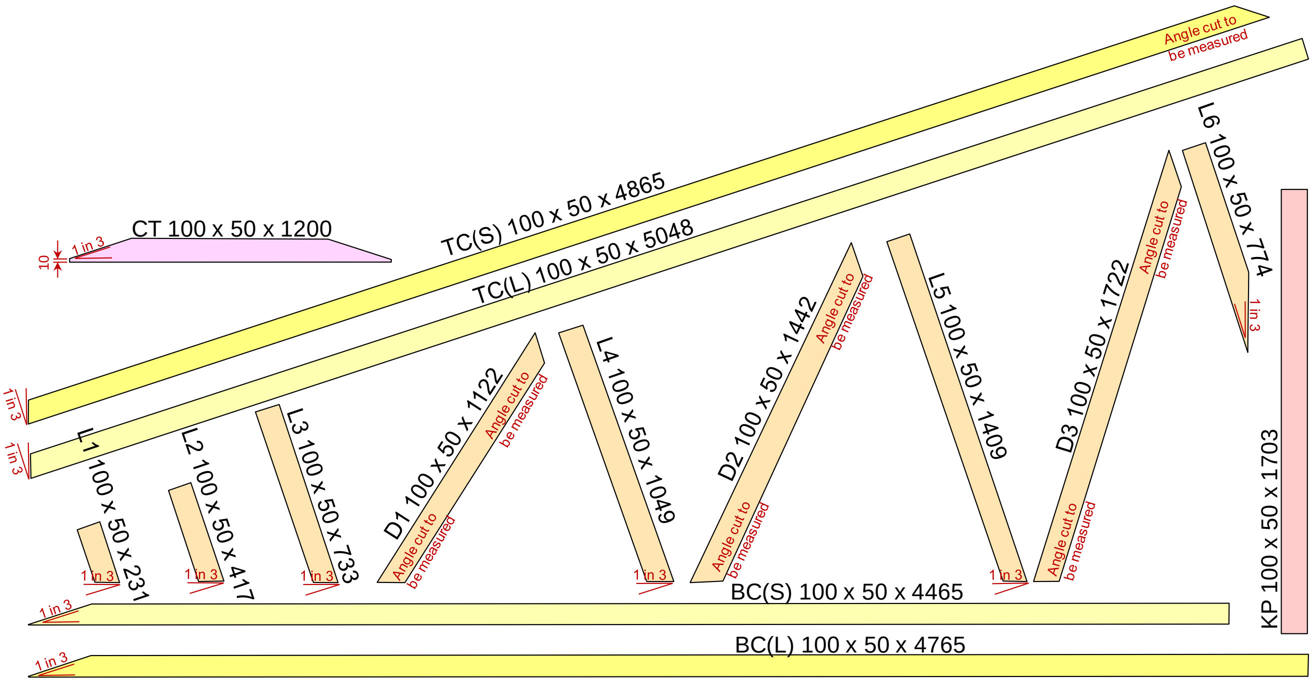
Cut two sets of the members for one half truss.

(a) One set of members will be used as templates for cutting the members of the production truss.

(b) The second set of members will be assembled to for the jig.

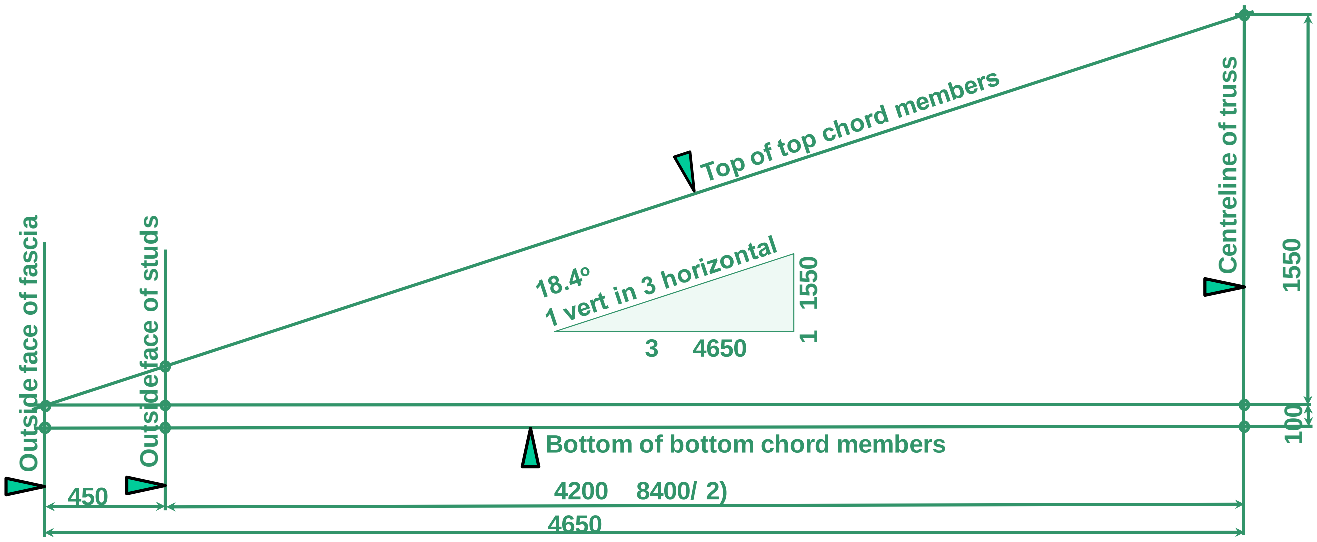
(c) Members TC(S), BC(S) and CT are not required for the jig.

(d) The following dimensions are for a standard **DANCER** Truss, width 8.4 m outside the studs, 1 in 3 slope and 450 mm eaves.



Setting Out

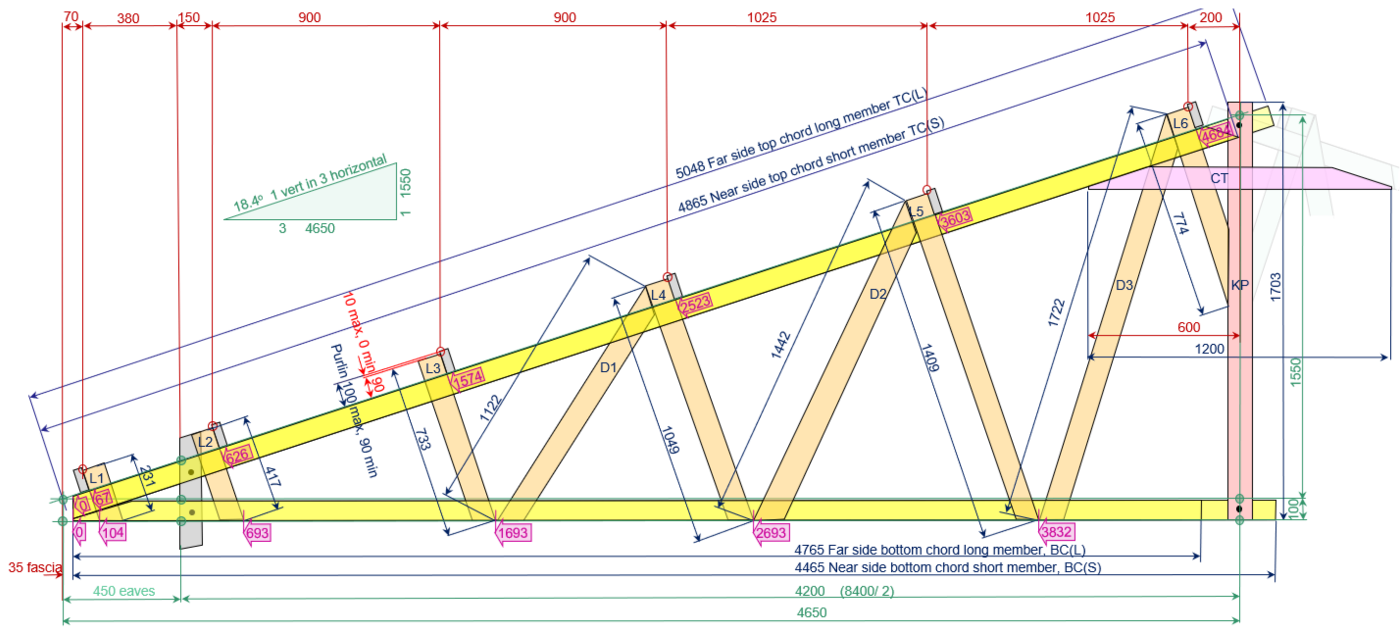
1. Prepare a flat level clean surface on which to set out the half truss.
2. Using a chalk line, mark the truss panel points and the setting out lines on the surface
   (a) Panel points are the points that control the overall truss dimensions.
   (b) The following setting out dimensions are for a standards **DANCER** Truss, width 8.4 m outside the studs, 1 in 3 slope and 450 mm eaves.



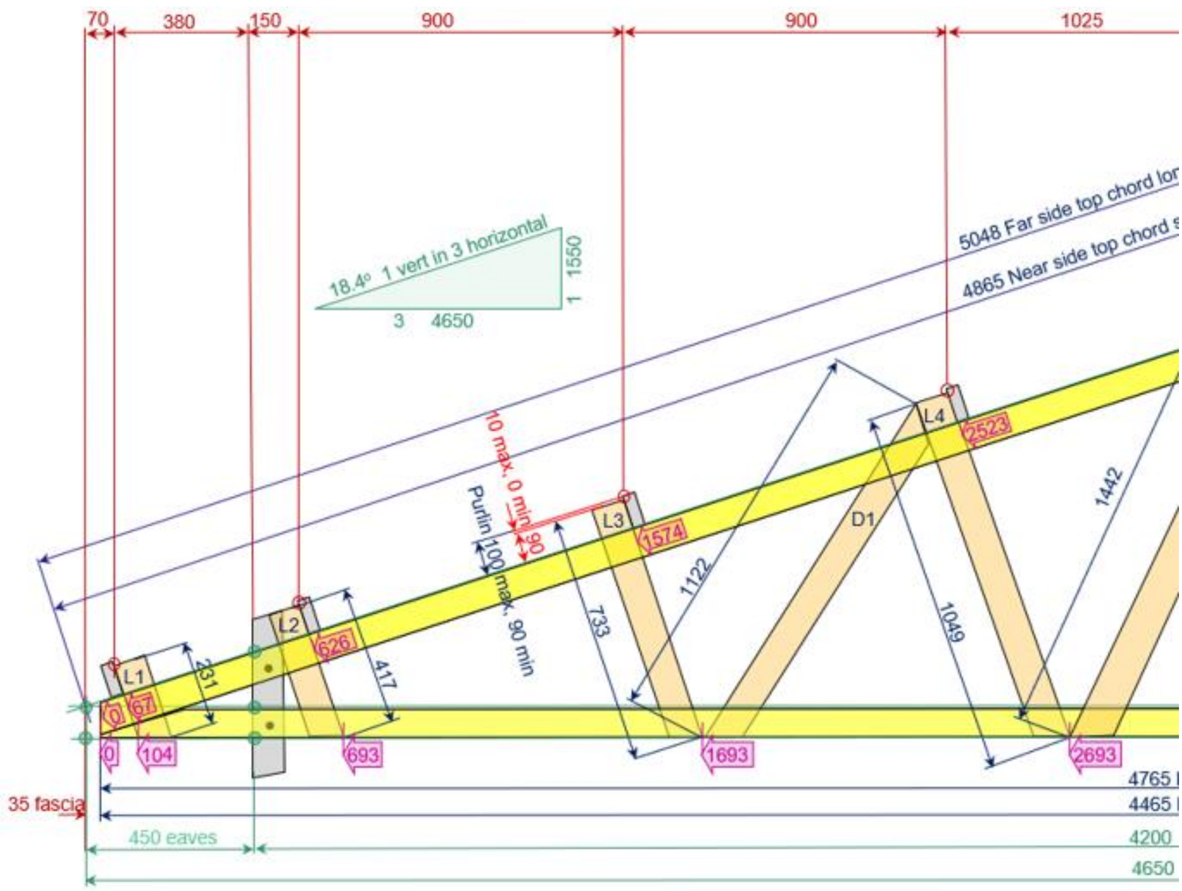
Assemble a Half Truss as a Jig

1. Assemble a half truss to serve as a jig, using the previously cut second set of members and the setting out surface.

   The purple numbers in the arrows are the distances along the top and bottom chords at their critical surfaces, allowing for a 35 mm fascia.



See enlarged views on the following pages


70
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5048 Far side top chord lon
4865 Near side top chord s
18.4° 1 vert in 3 horizontal
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3 4650
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90
Purlin
100 max, 90 min
L1
L2
L3
L4
D1
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67
626
1574
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104
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35 fascia
450 eaves
4765 l
4465 l
4200
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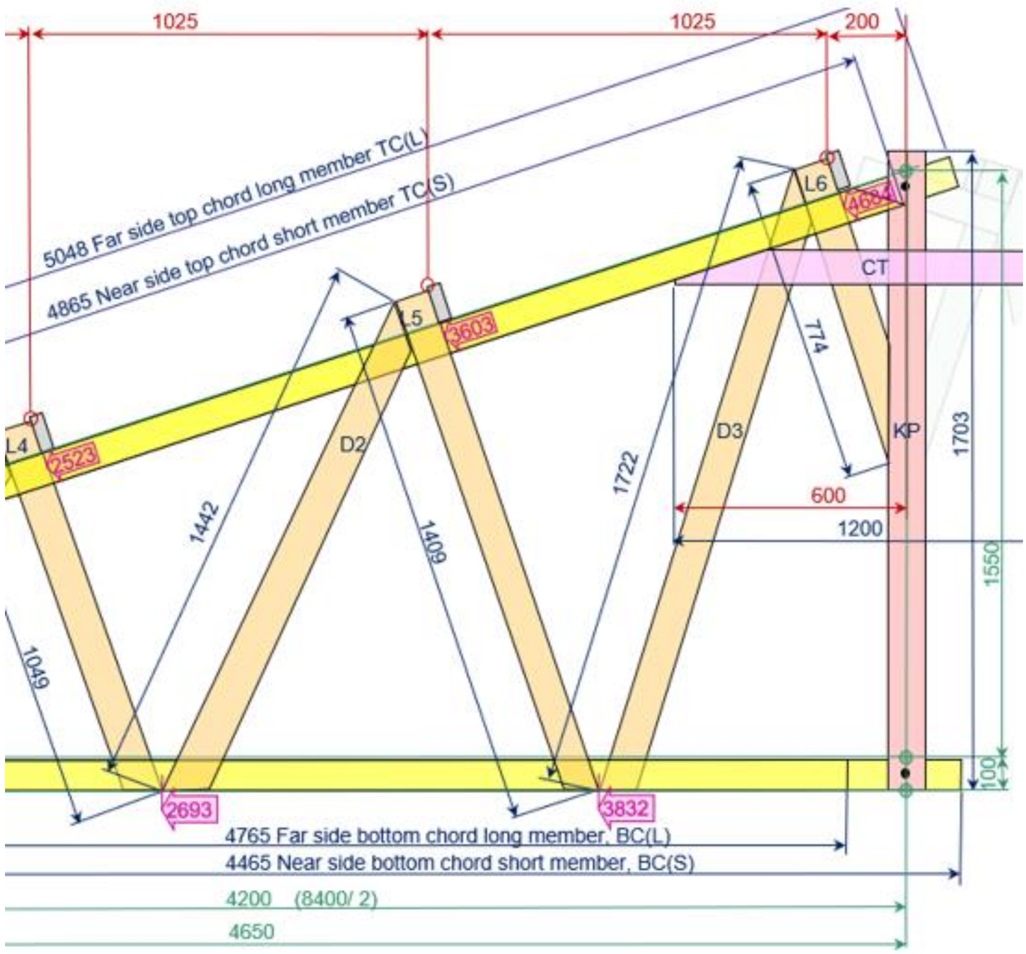
1025
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5048 Far side top chord long member TC(L)
4865 Near side top chord short member TC(S)
L4
L5
L6
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D3
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4765 Far side bottom chord long member, BC(L)
4465 Near side bottom chord short member, BC(S)
4200 (8400/ 2)
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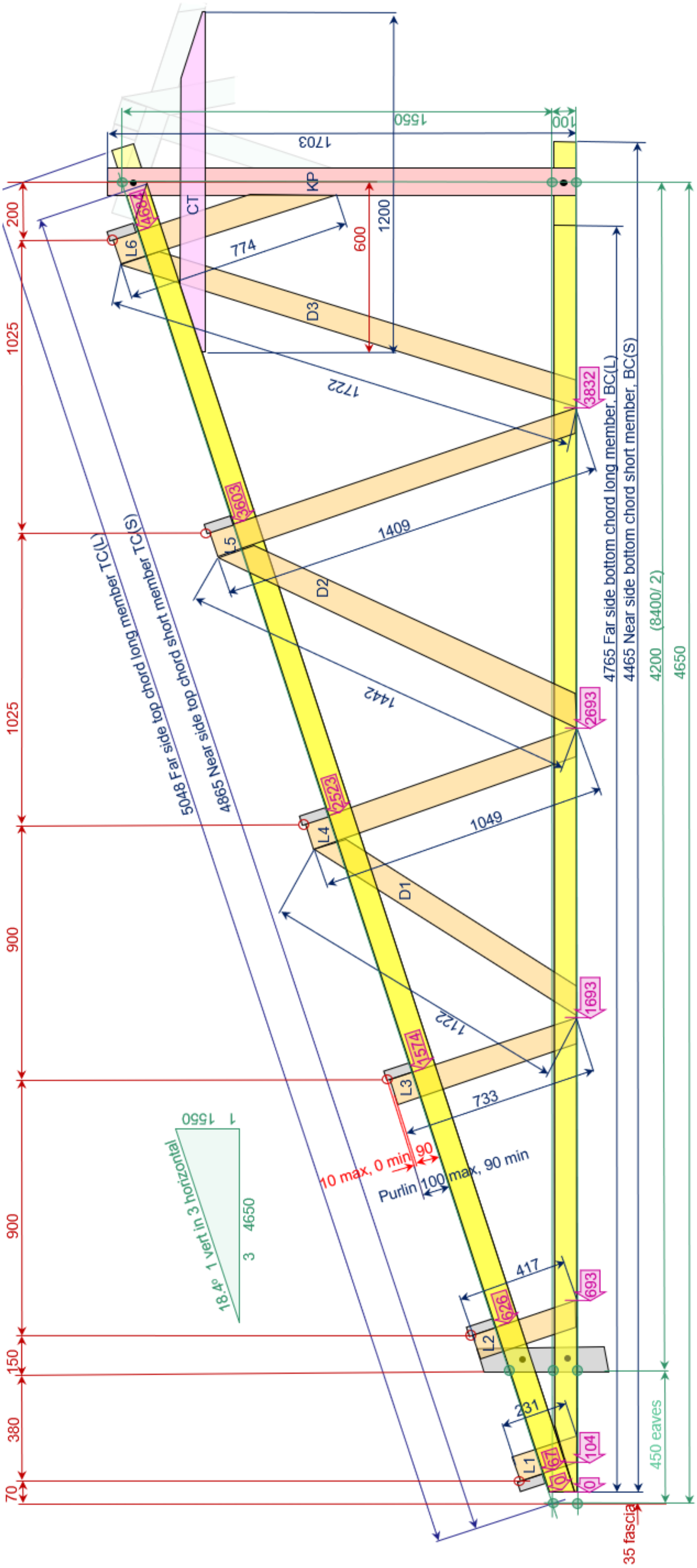
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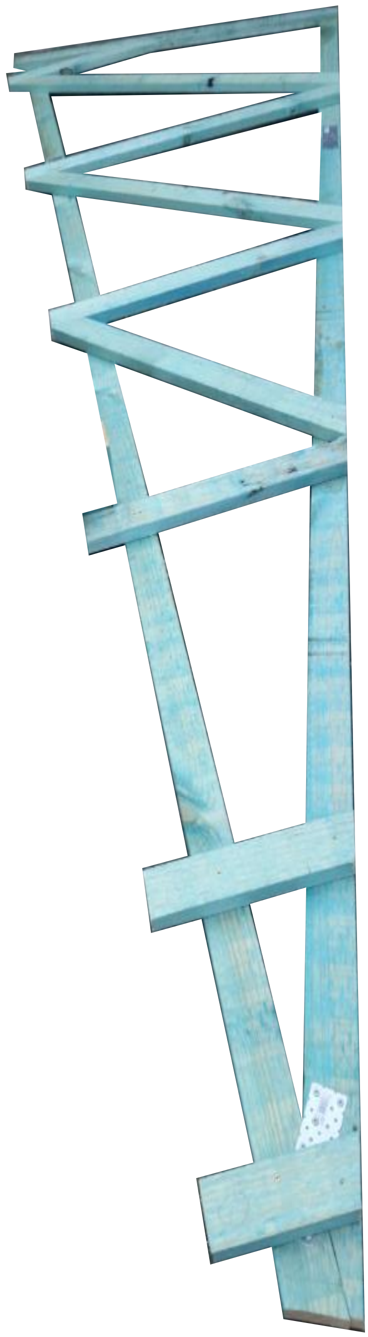
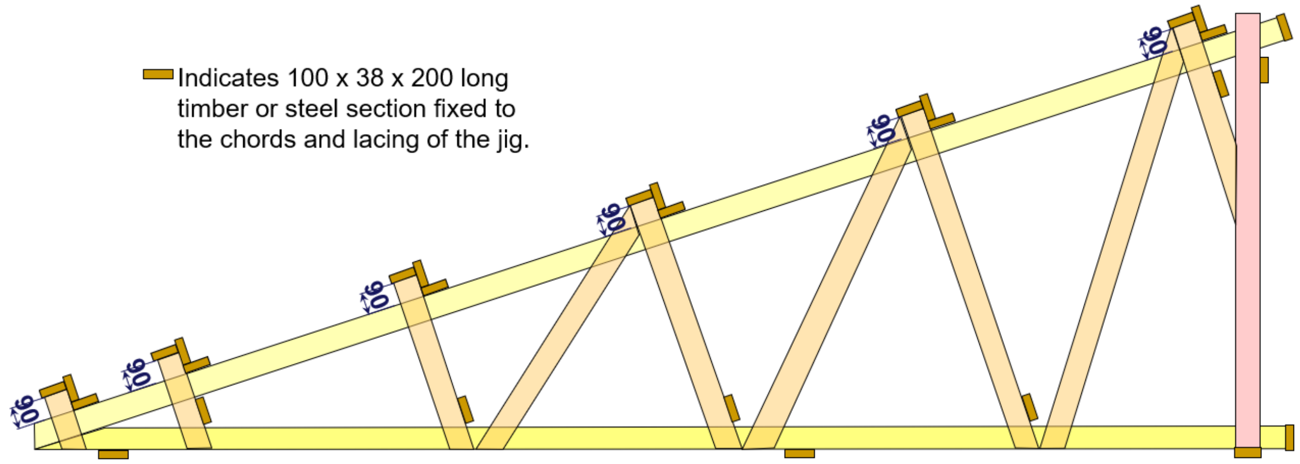
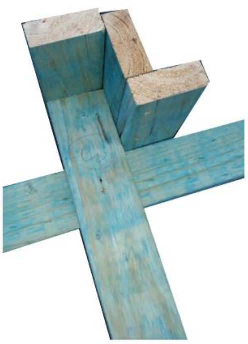
5048 Far side top chord long member TC(L)
4865 Near side top chord short member TC(S)
4765 Far side bottom chord long member, BC(L)
4465 Near side bottom chord short member, BC(S)
4200 (8400/ 2)
4650
1 1550
18.4° 1 vert in 3 horizontal
4650
3
900
417
693
626
L2
150
231
380
450 eaves
104
L1
67
0
0
70
35 fascia



2. Fit 100 x 38 x 200 mm timber or steel guides as shown to form a Standard **DANCER** 8.4 Half Truss Jig.
    a) By positioning the guides as shown in the drawing, it is easy to slide the cut members into position against the critical dimensions.
    b) Lacing protrudes only 90 mm above the top chord top surface, thus enabling the use of purlins of depth 90 mm or more.
    c) By leaving the left-hand end of the jig open (no guide), longer top chord members can be used to accommodate extended eaves.





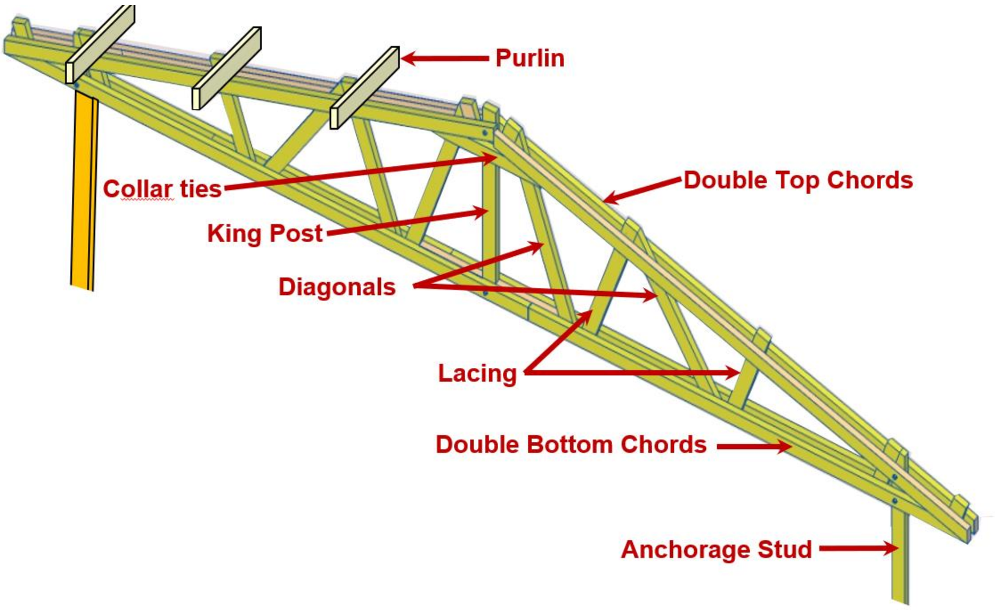
3. Mount the jig on a table or on legs of convenient height. The top surface of the jig should be approximately 800 mm above the ground.
4. The jig described above is suitable to the **DANCER** 8.4 Standard Half Truss.
    a) The left-hand end of the jig (up to and including lacing member L4) remains unchanged for shorter spans, but the right-hand end is modified by inserting new end guides at the appropriate distance from the left-hand end.
    b) The following shall be fixed to the top and bottom chords at the appropriate positions:
        - New King Post and King Post Guides;
        - New Lacing L6 and Lacing L6 Guides.
    c) Lacing L5 is only required in trusses of span greater than 6.6 m (outside studs)
    d) Diagonal D3 is only required in trusses of span greater than 6.3 m (outside studs)

DANCER – Manufacture of Production Trusses

Principle

1. Production trusses may be prefabricated in a factory rather than on site where it is difficult to control the accuracy and the effectiveness of connections.
2. A number of prefabricated production trusses may be trial erected and part of the quality assurance process before being sent to site.

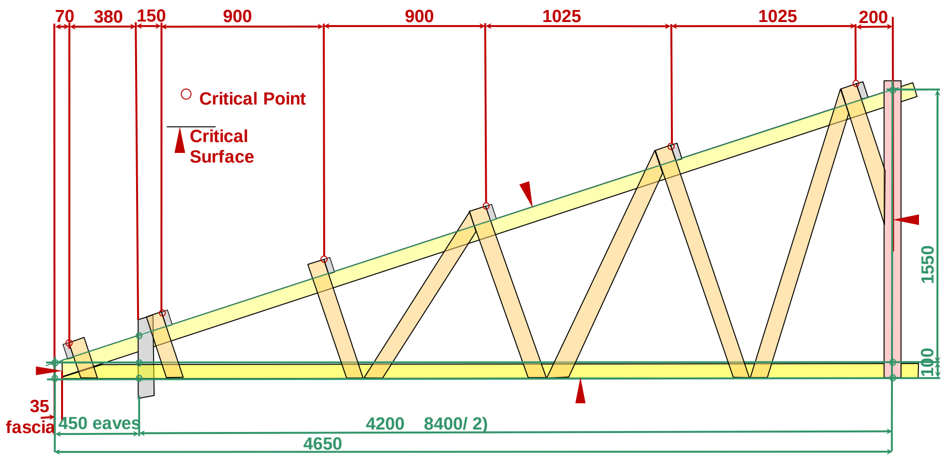
Both practices minimise inaccuracies and confusion on site regarding the dimensions.



Critical Surfaces for a Multipurpose Jig

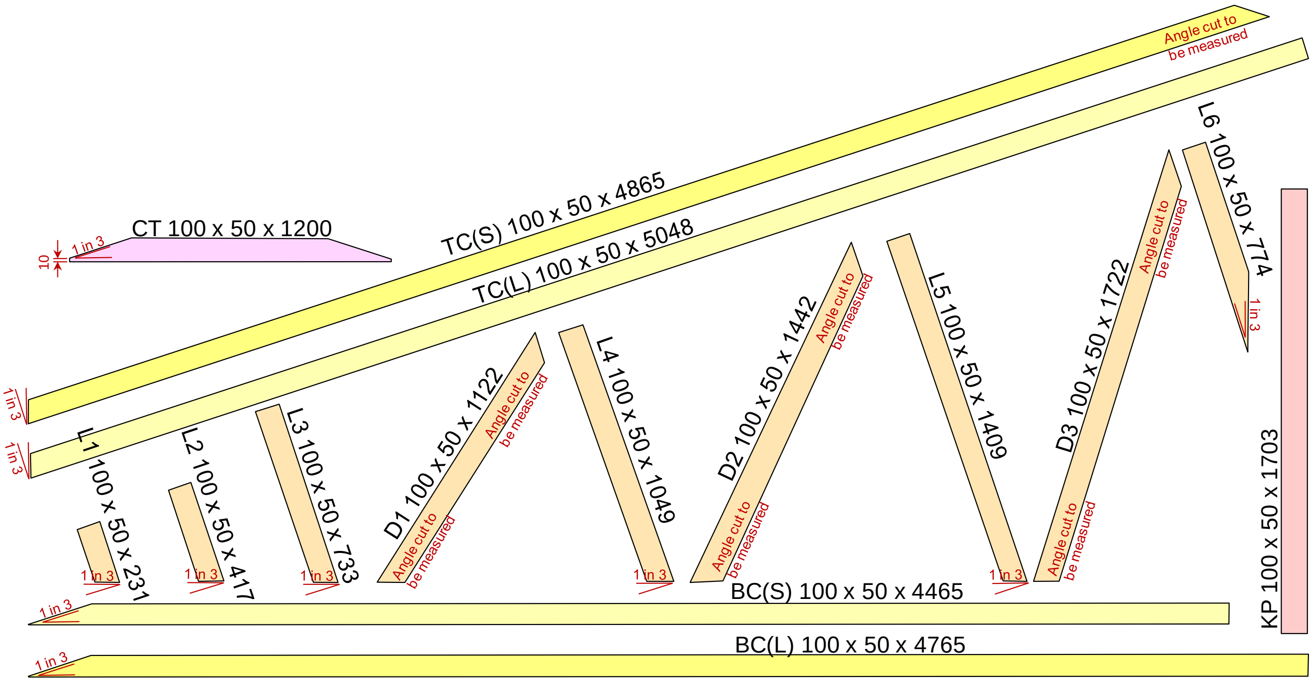
Adherence to the following principles will enable the standard jig to be used to manufacture trusses employing members of several different cross sections within the range 100 x 38 to 90 x 35 mm. Other members (75 x 50, 70 x 45 etc.) may also be accommodated if non-standard trusses are required. The critical surfaces (shown below) for fabrication will be:

- the top surface of the top chords,
- the bottom surface of the bottom chords, and
- the inside face of the fascia, which is assumed to be 35 thick
- the centreline of the truss
- the interfaces between the lacing and the purlins at position of the roof sheeting.



Cutting Members

Cut the members using the templates. The following dimensions are for a standard **DANCER** 8.4Truss, width 8.4 m outside the studs, 1 in 3 slope and 450 mm eaves.



The following dimensions are for all standard **DANCER** Trusses in the range 4.8 m to 8.4 m outside the studs, 1 in 3 slope and 450 mm eaves.

Note: Dimensions allow for 450 mm eaves

		4.800	5.100	5.400	5.700	6.000	6.300	6.600	6.900	7.200	7.500	7.800	8.100	8.400
Item	Component	Length mm	Length mm	Length mm	Length mm	Length mm	Length mm	Length mm	Length mm	Length mm	Length mm	Length mm	Length mm	Length mm
TC(L)	Truss Top Chord	3,151	3,309	3,467	3,625	3,784	3,942	4,100	4,258	4,416	4,574	4,732	4,890	5,048
TC(S)	Truss Top Chord	2,968	3,126	3,284	3,442	3,600	3,758	3,916	4,075	4,233	4,391	4,549	4,707	4,865
BC(L)	Truss Bottom Chord	2,965	3,115	3,265	3,415	3,565	3,715	3,865	4,015	4,165	4,315	4,465	4,615	4,765
BC(S)	Truss Bottom Chord	2,665	2,815	2,965	3,115	3,265	3,415	3,565	3,715	3,865	4,015	4,165	4,315	4,465
CT	Collar Tie	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
KP	King Post	1,103	1,153	1,203	1,253	1,303	1,353	1,403	1,453	1,503	1,553	1,603	1,653	1,703
L1	Lacing at eaves	231	231	231	231	231	231	231	231	231	231	231	231	231
L2	Lacing at anchorage	417	417	417	417	417	417	417	417	417	417	417	417	417
L3	Lacing	733	733	733	733	733	733	733	733	733	733	733	733	733
L4	Lacing	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049	1,049
L5	Lacing	0	0	0	0	0	0	0	1,278	1,304	1,330	1,357	1,383	1,409
L6	Lacing	774	774	774	774	774	774	774	774	774	774	774	774	774
D1	Diagonal	1,122	1,122	1,122	1,122	1,122	1,122	1,122	1,122	1,122	1,122	1,122	1,122	1,122
D2	Diagonal	0	0	1,275	1,389	1,511	1,640	1,169	1,206	1,247	1,291	1,339	1,389	1,442
D3	Diagonal	0	0	0	0	0	0	1,436	1,409	1,467	1,528	1,591	1,656	1,722

Assembly of Truss

1. Ensure that production truss members <u>are positioned hard against the critical surfaces</u>.
2. Position the lacing and the diagonals first.
3. Position the long top and bottom chord members, TC(L) and BC(L) over the lacing and diagonals; and fix with the specified number of nail or screws.
4. Remove the truss from the jig, turn it over so that the lacing and diagonals are on top and place it on a flat surface.
5. Position the short top and bottom chord members, TC(S) and BC(S) over the lacing and diagonals; and fix with the specified number of nail or screws.

Part 7 – DANCER Development and Testing Program

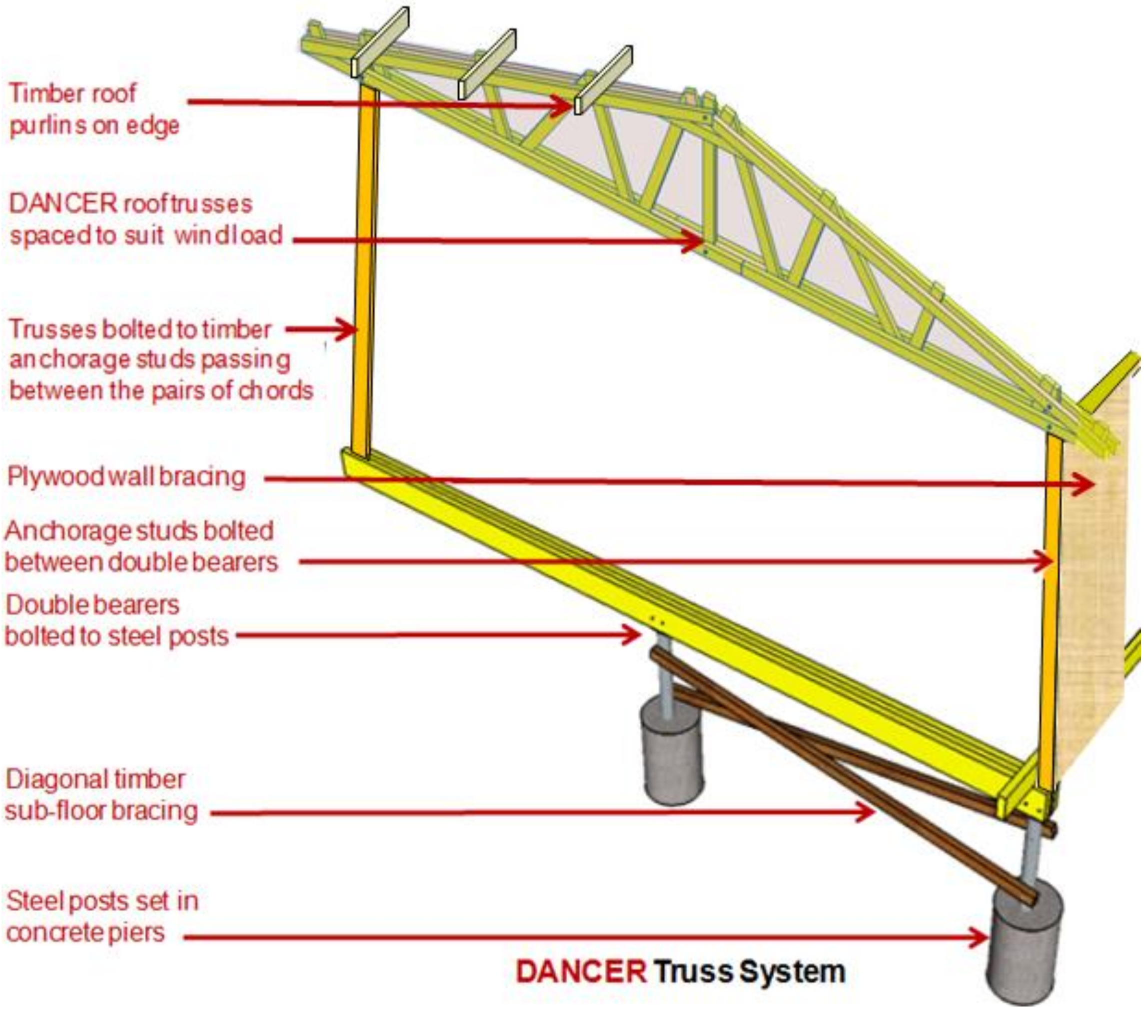
Part 7 provides a record of the development of the system and the testing program use to refine and verify it.

Background

The **DANCER** Building System is a simple timber framed house building system, for South Pacific village applications, incorporating sawn timber framing fixed by bolts and nuts, steel (or timber) posts, a small quantity of concrete for piers (if available), steel (or leaf) roof cladding, sawn timber flooring and local or imported wall cladding. The cyclone/earthquake/tsunami resistance is economically achieved by orienting the timber purlins such as to maximize the truss or rafter spacing and ensure that the uplift loads are transmitted to the ground via bolted connections directly between rafter/truss, anchorage studs, double bearers and posts.

The **DANCER** building system consists of the following:

- Timber roof purlins, on edge (to maximize the span) are nailed horizontally to timber lacing members that are fixed between the double truss chords (or double rafters, as appropriate). They are fixed at 900 mm maximum centres to support corrugated steel roof sheeting.
- **DANCER** Trusses (or **DANCER** Rafters) consisting of double top chords and double bottom chords (enabling the lacing/purlin cleats to be nailed between from both sides and the anchorage studs bolted in double shear between).
- The **DANCER** Trusses (or **DANCER** Rafters) are bolted to timber Anchorage Studs between both pairs of chords.
- The timber Anchorage Studs are bolted in double shear between the Double Bearers, providing a direct load path from the roof system to the floor and subfloor
- Double Bearers are bolted to steel (or timber) posts, which are set in concrete piers.
- Plywood wall bracing and diagonal timber sub-floor bracing provide racking resistance.



Purpose

The product development and testing program described in this report deal with:

(a) the principles underlying the **DANCER** Building System,

(b) the determination (by test and by structural analysis) of the ultimate strength capacities of key components of the **DANCER** Building System under simulated wind uplift,

(c) the practical issues associated detailing and constructing the system, and

(d) the suitability of using AS 1720.1 for designing the **DANCER** Building System in real buildings.

Summary of Principal Conclusions

Although the conclusions and recommendations are located throughout this report, the principal conclusions and recommendations are summarised below.

1. The combined results of the tests indicate that the ultimate capacities of the **DANCER** Building System components can be confidently predicted using AS 1720.1.
2. Therefore, the design of particular **DANCER** buildings and their components may be based on AS 1720.1, rather than design based on prototype testing.
3. In other words, the testing program should not be considered as "prototype" testing (as described in AS/NZS 1170.0 Appendix B). Rather, it should be considered as a "reality check" and for "product development" and used to refine the system. The capacities are measured means (best estimates), to be used with assumed variability. Used for this purpose, the results do not need to be modified to reflect the number of tests. This point is further explained in the section where the results are analyzed.
4. It is acknowledged that a more comprehensive testing program could be undertaken. However, if practical building design is carried out in accordance with Point 2 (i.e. design to AS 1720.1) and the current tests are used for the purpose stated in Point 3 (i.e. as a "reality check" and for "product development), the testing program is considered to be adequate.

Exclusions

The following must be carried out by a suitably qualified and experienced civil/structural engineers, architects and builders with the authority and responsibility for the design and construction of particular buildings. These activities are specifically excluded from the scope of this report.

- Architectural design;
- Determination of building importance and the corresponding probabilities of exceedance for the design actions listed herein;
- Determination of permanent design actions;
- Determination of imposed design actions;
- Determination of wind design actions, including (but not limited to) basic velocity, building height, terrain category, shielding, topography, ultimate wind design gust velocity, free-stream gust pressure and other factors listed in AS/NZS 1170.2 and AS 4055;
- Determination of seismic actions, including (but not limited to) hazard factor, soil classification and other factors listed in AS 1170.4;
- Determination of site classification (for soil properties);
- Drainage assessment;
- Structural design and specification of specific structures based on the points listed above; and

- Construction supervision, inspection and certification of particular buildings.

Basis of Testing and Analysis

The testing program, analysis and recommendations described herein are consistent with:

- The principles of structural mechanics for strength, stability and serviceability;
- Current versions of Australian Standards listed in the herein.

Product Development Process

The development of the **DANCER** Building System involved the following iterative process over several years.

1. Concept development, project initiation and preliminary design.
2. Development (and on-going refinement) of comprehensive software for design, material lists, cutting schedules and bills of quantities.
3. Preparation (and on-going refinement) of standardised component and connection details.
4. Establishment of a prefabrication facility in Papua New Guinea by Vision for Homes, with assistance from Partner Housing.
5. Design and construction of Kalolo Clinic using an early version of what later evolved into the **DANCER** building system.
6. Refinement of the design; and construction of a demonstration house at Mt Hagen and five houses at Mul-Baiyer.
7. Testing program investigating a number of design options:
    - Testing to failure full- scale purlin/truss/stud/bearer assemblies, observing the progressing failure of various components.
    - Testing to failure five different apex connections.
    - Testing to failure a sample of typical nailed connections.
8. Design and construction of Kumbereta High School house.
9. Based on the lessons learned at each of these stages, final refinement of the design, design software, and details.
10. Preparation of a comprehensive handbook and training material.

Description of Test Program

The testing program consisted of:

1. Testing to failure five Nailed Joint Connections.
2. Testing to failure four full-scale Purlin/Truss/Stud/Bearer Assemblies (two different timber sections), observing the progressing failure of various components.
3. Testing to failure five types of apex connections.

Materials use for Test Specimens

Materials Source

All principal materials were purchased from Bunnings Warehouse, West Gosford.

Sourcing from one large supplier was done intentionally to minimise (to a significant degree) the variability that could result from sourcing from several smaller suppliers. Although not a valid practice in prototype testing program, this is an important consideration in a product development program.

Additional variability in materials properties, which results from sourcing materials for particular buildings from various suppliers, is accounted for in the capacity reduction factors (φ) specified in AS 1720.1.

Because of unplanned extensions to the testing program, three separate purchases were made. Although they were supposed to be identical, the second and third purchases appeared (anecdotally) to be a little more brittle than the first.

a) The first purchase covered the four trusses T70-1, T90-1, T90-2 and T90-3 (together with the associated, purlins, studs, double bearers), Apex Connection B and the nailed specimens, N1 to N5.

b) The second purchase covered Apex Connections A1, A2, A3, B and C.

c) The third purchase covered Apex Connection D.

Timber Specification

To minimise variability in the tests, all materials were MGP10 treated pine from a single source.

MGP10 was chosen because it is at the lower end of the strength and joint group spectra that are likely to be present in real buildings. For example, MGP10, with a characteristic bending capacity 17 MPa, approximates F7 with a characteristic bending capacity 18 MPa.

In other words, the timber for testing was selected to be at the lower end of the strength spectrum, but with the minimum variability.

Considering the points above, the selection of MGP10 treated pine for the testing program should not be interpreted as a recommendation that it necessarily be used for the design of particular buildings.

Bolt Specification

Bolts were M12 x 150 mm, 4/4 galvanised with galvanised flat washers under both the bolt head and the nut, except in Apex Connection D, where the bolt was M16 x 150 mm.

Nail Specification

Nails for Trusses T70-1, T90-1, T90-2, T90-3 and Apex Connection B were 75 x 3.75φ bright nails.

Nails for Nailed Connections N1 to N5 and Apex Connections B, A1, A2, A3, C and D were 75 x 3.75φ galvanized nails.

Timber Member Dimensions

With the exception truss T70-1 and the double bearers (which provide bottom anchorage), all tested components were fabricated from 90 x 35 MGP10.

One truss (T70-1) was fabricated from 70 x 45 MGP10.

The double bearers were manufactured from 190 x 45 MGP10.

Nailed Joint Connection Tests

Details

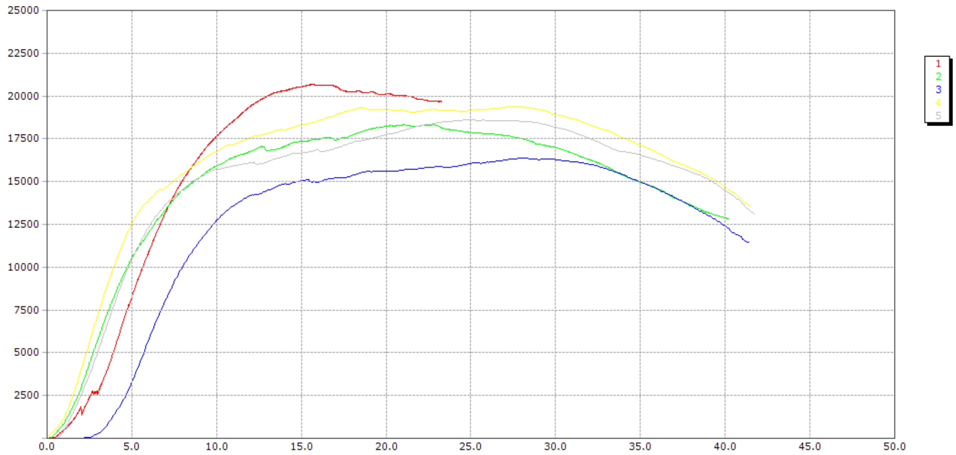
Five 10-nail Tee Joint shear specimens, each consisting of 3 / 90 x 35 MGP10 members, one sandwiched between the other two and secured with 5 / 75 x 3.75φ galvanized nails from each side, were tested with the nails in shear.

Fabrication and Testing

Fabricated 14/6/17 and tested 16/6/17 at Smithfield.

Failure

The mean ultimate capacity of the nails in single shear was 1.87 kN per nail.



Tests of 10-Nail Joints

Date	16/06/2017				
Location	Mahaffey Associates, Unit 8, 108-110 Percivale Street, Smithfield NSW 2164				

Tee-shaped triplets from 3 / 90 x 35 MGP10.

10 / 75 x 3.76 galvanized nails in single longitudinal and transverse shear (5 on each side)

1. Ultimate cacacities are at very high deflections.
2. Ultimate capacities are for uniform shear across 10 nails (5 nails from each side).

Ultimate Shear Capacities	Test No	Ultimate shear capacity 10 nails		Deflection at Ultimate	
	N1	20.7	kN	16	mm
	N2	18.3	kN	21	mm
	N3	16.4	kN	23	mm
	N4	19.4	kN	27	mm
	N5	18.6	kN	25	mm
Mean ultimate shear capacity of 10 nails	Mean	18.67	kN		
Number of nails in shear		10	kN		
Mean ultimate shear capacity of each nail		1.87	kN		

Full-scale Purlin/Truss/Stud/Bearer Assembly Tests

Details

Pairs of **DANCER** Purlin/Truss/Stud/Bearer systems were positions side-by-side 2.7 metres apart and connected by timber purlins (on edge). They were then loaded in the upwards direction load through a loading truss by.

Fabrication and Testing

Fabricated 5/4/17 and tested 7/4/17 at Wamberal.

Details

Four full-scale Purlin/Truss/Stud/Bearer specimens were constructed and tested as follows:

- Truss T70-1 consisted of 70 x 45 MGP10 **DANCER** Trusses and Anchorage Studs, bolted to Double Bearers by 2 M12 bolts at each truss/stud connection and each stud/bearer connection. The truss halves were connected at top and bottom chords by nailed splices;
- Truss T90-1 consisted of 90 x 45 MGP10 **DANCER** Trusses and Anchorage Studs, bolted to Double Bearers by 2 M12 bolts at each truss/stud connection and each stud/bearer connection. The truss halves were connected at top and bottom chords by nailed splices.
- The two trusses were positioned 2.7 m apart and connected by 90 x 35 MGP10 purlins-on-edge, nailed to each truss by 4 / 75 x 3.75φ bright nails to the extended diagonal lacing members.
- A loading truss was positioned midway between the two loaded trusses on two jacks (at the stud positioned) to push upwards against the purlins. The loading truss was significantly strengthened by sheet bracing to minimize its deflection.

Exploded View of the Typical Apex of Trusses 90-1, 90-2, 90-3 Before Assembly

Two Test Trusses Pushed Up By Loading Truss

Equipment

The following equipment was used:

a. Two 5 tonne hydraulic jacks, connected in parallel to a hand pump.

b. One load cell.

c. Data logger.

d. Two timber jack supports.

e. One central "strong" loading truss

f. Support framing

Loading Runs

Run 1: In the purlin nearest to the stud (P2) and the eaves purlin (P1), the four nails securing one end of the purlins began to loosen at a total load of 12 KN and pulled out of the extended stud at a total load of 22 KN.

Run 2: The failed purlins were then secured and Trusses T70-1 and T90-1 were both loaded. The run was terminated at a total load of 14 KN.

Run 3: Trusses T70-1 and T90-1 were both subject to loading at the apex, and T70-1 failed at 9.9 kN.

Run 4: Trusses T90-1 was subject to loading at the apex, and had not failed when the test was terminated at 12 kN total load (at the apex).

Deflection and Loads for Load Runs 1 to 4 for T70-1 and T90-1

Deflection at centreline of truss							
	Run 1		Run 2		Run 3		Run 4
Load Truss	Truss 70-1	Truss 90-1	Truss 70-1	Truss 90-1	Truss 70-1	Truss 90-1	Truss 90-1
kN	mm	mm	mm	mm	mm	mm	mm
1.0							
2.0							
3.0	0.8		1.2	1.2	7.0	3.2	4.6
4.0	1.3	1.3	2.0	1.9	10.4	5.3	6.5
5.0	2.0	1.7	2.7	2.3	12.1	6.1	6.6
6.0	2.6	2.1	3.5	2.6	13.9	6.9	11.0
7.0	3.8	2.4	4.3	2.9	18.2	9.3	13.1
8.0	4.5	2.8	5.2	3.3	22.1	11.3	15.1
9.0	5.2	3.2	5.8	3.4	30.2	12.7	17.1
10.0	5.9	3.7	6.5	4.8	**61.0**	18.5	19.5
11.0	6.6	4.4	7.4	5.3			23.0
12.0	7.4	4.8	8.2				28.0
13.0	8.3	5.4	9.1				
14.0	8.2	6.3	10.1				
15.0	10.2	6.9					
16.0	10.9	7.5					
17.0	11.8	8.4					
18.0	12.9	9.0					
19.0	14.8	10.4					
20.0	16.8	11.5					
21.0	20.9	13.1					

The deflection of Truss T70-1(70 x 45 MGP10 members) was at all times significantly greater than the deflection of Truss T90-1 (90 x 35 MGP10 members).

Effects of Truss Deflection During Test

During the loading of the central loading truss, initially a uniform vertical uplift was applied through the purlins to the two loaded trusses, as was intended.

However, as the test progressed and the load increased, the two loaded trusses deflected significantly at the centre (relative to the very small deflections at the stud supports). This had the effect of causing the applied load to shed towards the studs.

Visual evidence of this phenomenon was provided by the purlins closest to the studs exhibiting the greatest deflection, the next closest purlins exhibiting the next greatest deflection, and so on until the purlins closest to the apex exhibited the least deflection.

This infers that the purlins closest to the studs experienced the greatest load, the next closest purlins experienced the next greatest load, and so on until the purlins closest to the apex experienced the least load.

For the following analysis, it is assumed that 80% of the loading truss stud reaction is applied through the first purlins and each side for total loads in excess of 10 kN (5 kN reaction per stud)

Nailed Purlin Connection

Failure of the nails connecting the purlin closest to the stud to the extended lacing occurred at:

- a total applied load of 15.0 kN at each end of the loading truss;
- corresponding to 12.0 kN point load at the centre of the first purlin;
- corresponding to 6.0 kN at nailed at each end of the purlin, where it fixed to the and the lacing.

Each nailed connection consisted of 4 / 75 x 3.75φ bright nails.

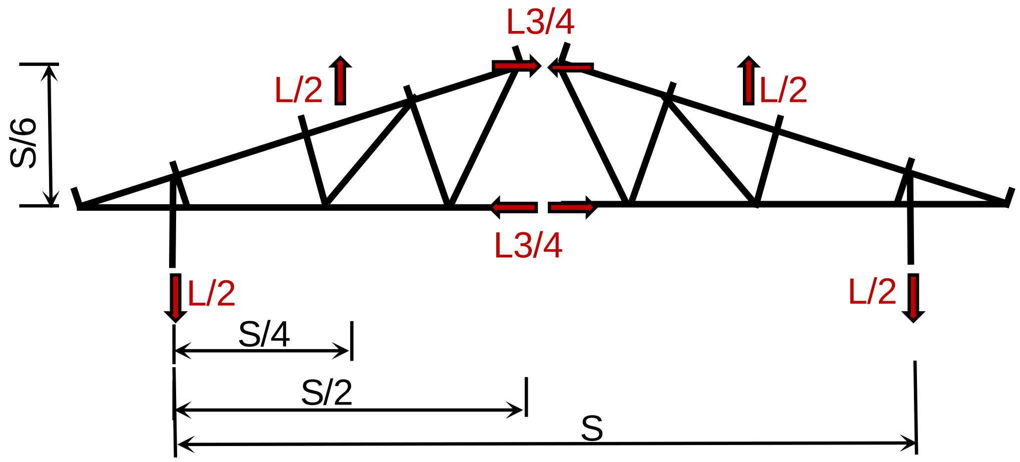
Apex Connection Tests

Based on the outcome of the full-scale truss tests, it was determined that improvement of the apex connection was required.

Five possible arrangements were tested.

- Trusses 90-1, 90-2 and 90-3 (with nailed apexes) were joined successively back-to-back in a horizontal position (joined at the studs) and pushed apart by a ram at the apex .These tests were performed in the Wamberal workshop.
- Isolated Apex Connections, A (three specimens), B (one specimen), C (one specimen) and D (one specimen) were constructed and the tested in the Smithfield laboratory.

The tension in the top chord at the apex splice (and compression in the bottom chord splice) approximately equal 0.75 times the total uplift load. i.e. 1.5 times the reaction in the studs.



A more accurate analysis of the standard 5.7 m **DANCER** Building System geometry (accounting for the distance between the top and bottom chord bolts at the studs) indicates that the tension in the top chord apex connection (and compression in the bottom chord splice connection) is 0.70 (not 0.75) times the total uplift load. i.e. 1.4 times the reaction in the studs. This is the basis to the loading in the apex tests.

Trusses 90-1, 90-2, 90-3 Loaded at the Apex

Do not use this detail

Details

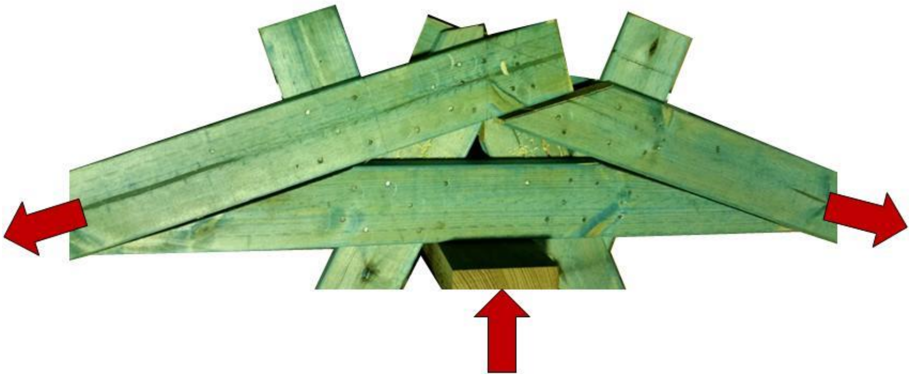
For Runs 5, 6 and 7, Trusses 90-1, 90-2, 90-3 were each laid in pairs in a horizontal position, joined at the ends by common studs and loaded by jacking apart at the apexes. Although tested under different conditions form the other apex connection tests (reported below) the test is essentially similar, and the results may be considered together with the apex connection tests. Trusses 90-1, 90-2, 90-3 consisted of 90 x 35 MGP10 members, joined as shown at the apex by lapping the chords and nailing as shown. Apex joint, 2 x 5 / 75 x 3.75φ galvanized nails in each lapped top chord with spacer. Two nailed collar ties, 4 / 75 x 3.75φ galvanized nails in each tie at each lacing and purlin cleat.

Failure

Vertical Load Capacity:	Truss 90-1	7/4/17 Run 7	12.51	kN
	Truss 90-2	7/4/17 Run 6	12.50	kN
	Truss 90-3	7/4/17 Run 5	12.48	kN
	Mean		12.5	kN

Fabrication and Testing:

Fabricated 5/4/17 Tested 7/4/17 at Wamberal.



Apex of Trusses 90-1, 90-2, 90-3 Arrangement Showing Directions of Loads (Runs 5, 6, 7)

Exploded View of the Typical Apex of Trusses 90-1, 90-2, 90-3 Before Assembly

Two Test Trusses Being Pushed Apart

Apex Connection A

Do not use this detail

Details

90 x 35 MGP10

Apex joint, 3 / 75 x 3.75φ galvanized nails in each lapped top chord with king post.

One bolted and nailed collar tie, 1 / M12 and 2 x 4 / 75 x 3.75φ galvanized nails in each end of each tie plus at 2 x 4 / 75 x 3.75φ galvanized nails in each lacing.

Fabrication and Testing

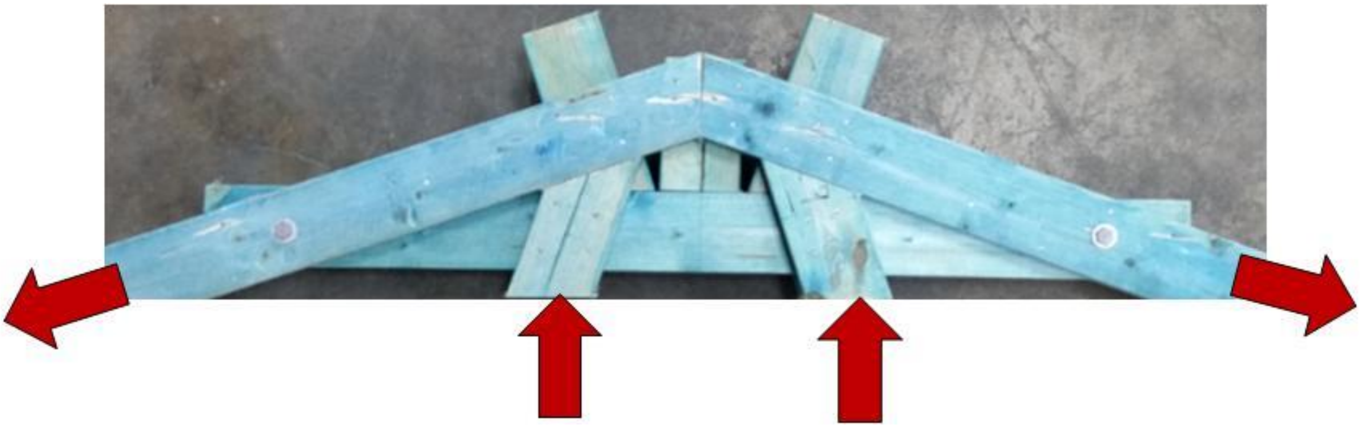
Fabricated 14/6/17 and tested 16/6/17 at Smithfield.

Failure

Ultimate failure was assumed when the collar tie timber failed at the nails due to in-plane moment. This then caused timber failure at the bolts. This occurred in all three specimens at approximately the same load (12 kN) and at similar deflections (41 to 54 mm).

Vertical Load Capacity:

A1	13.40 kN at a deflection of 45.1 mm
A2	10.90 kN at a deflection of 54.2 mm
A3	11.60 kN at a deflection of 41.1 mm
Mean	12.0 kN



Apex Connection B

Do not use this detail

Details

90 x 35 MGP10

Apex joint, M12 bolt, lapped top chords with king post. Two nailed collar ties, 4 / 75 x 3.75φ galvanized nails in each tie at each lacing and purlin cleat.

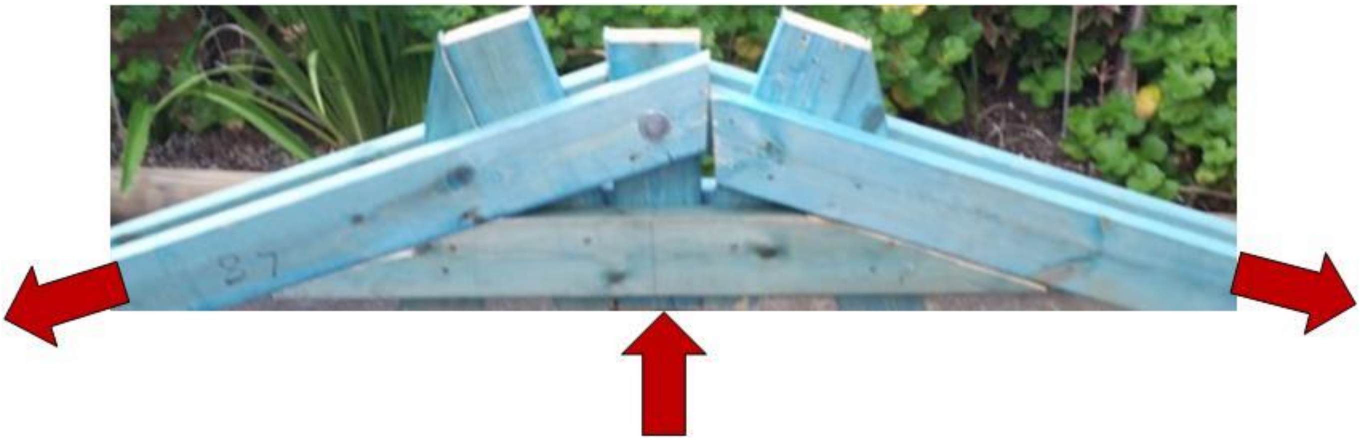
Fabrication and Testing

Fabricated 5/6/17 and tested 16/6/17 at Smithfield.

Failure

There had been no significant failure when the test terminated due to the ram reaching its limit of movement. This provides reasonable capacity, although the detail is complicated.

Vertical Load Capacity in excess of 21.1 kN



Apex Connection C

Do not use this detail

Details

90 x 35 MGP10

Apex joint consisted of one M12 bolt, tongue and clevis joint. No collar tie.

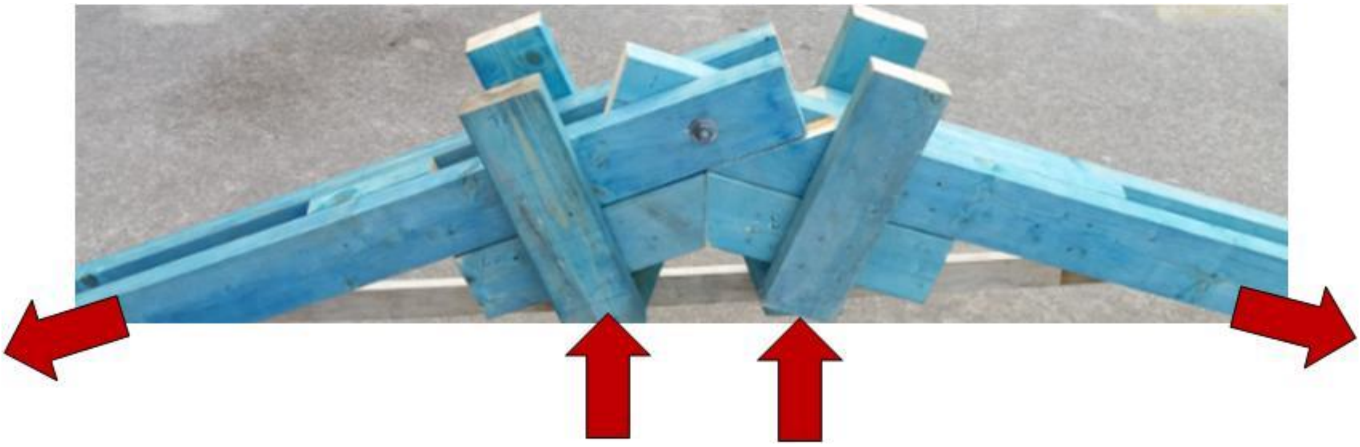
Fabrication and Testing

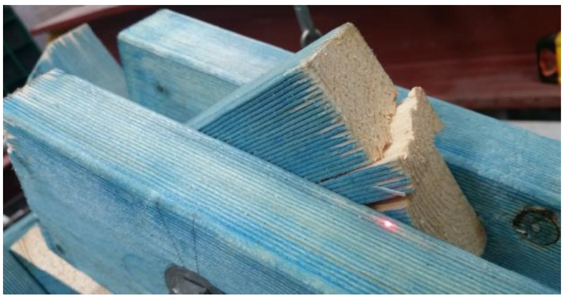
Fabricated 21/6/17 and tested 16/6/17 at Smithfield.

Failure

Timber longitudinal double shear failure at bolt. This is the simplest detail, although the fixing of the first purlin is complicated.

Vertical Load Capacity 14.0 kN when the timber in front of bolt failed in longitudinal shear.





Apex Connection D

This is the detail that is recommended for the DANCER Truss System

Details

90 x 35 MGP10

The apex joint consisted of 1 / M16 bolt, lapped top chords with a king post.

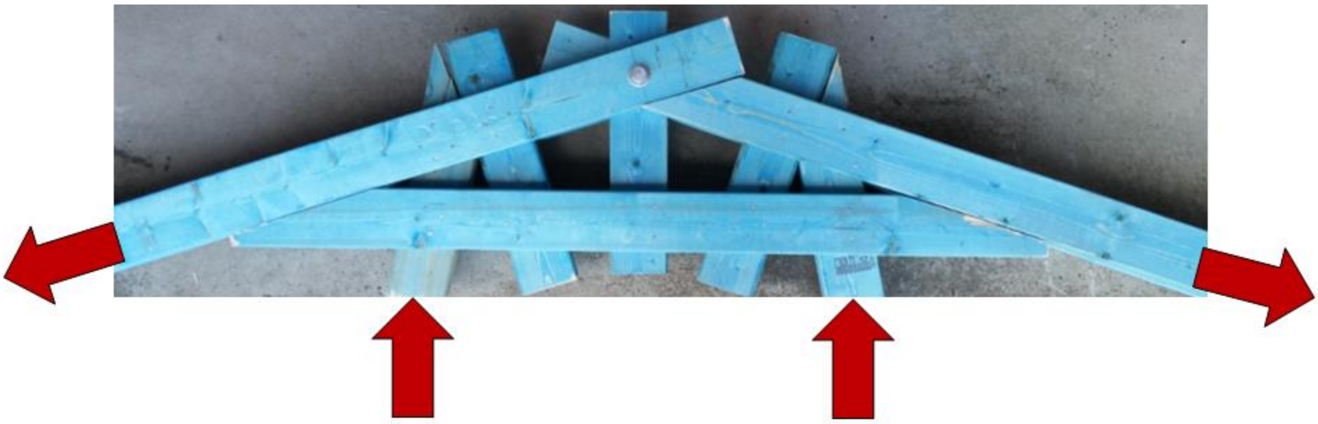
Two nailed collar ties, each fixed by 4 / 75 x 3.75φ galvanized nails in each tie at each loaded lacing member and unloaded and purlin cleat.

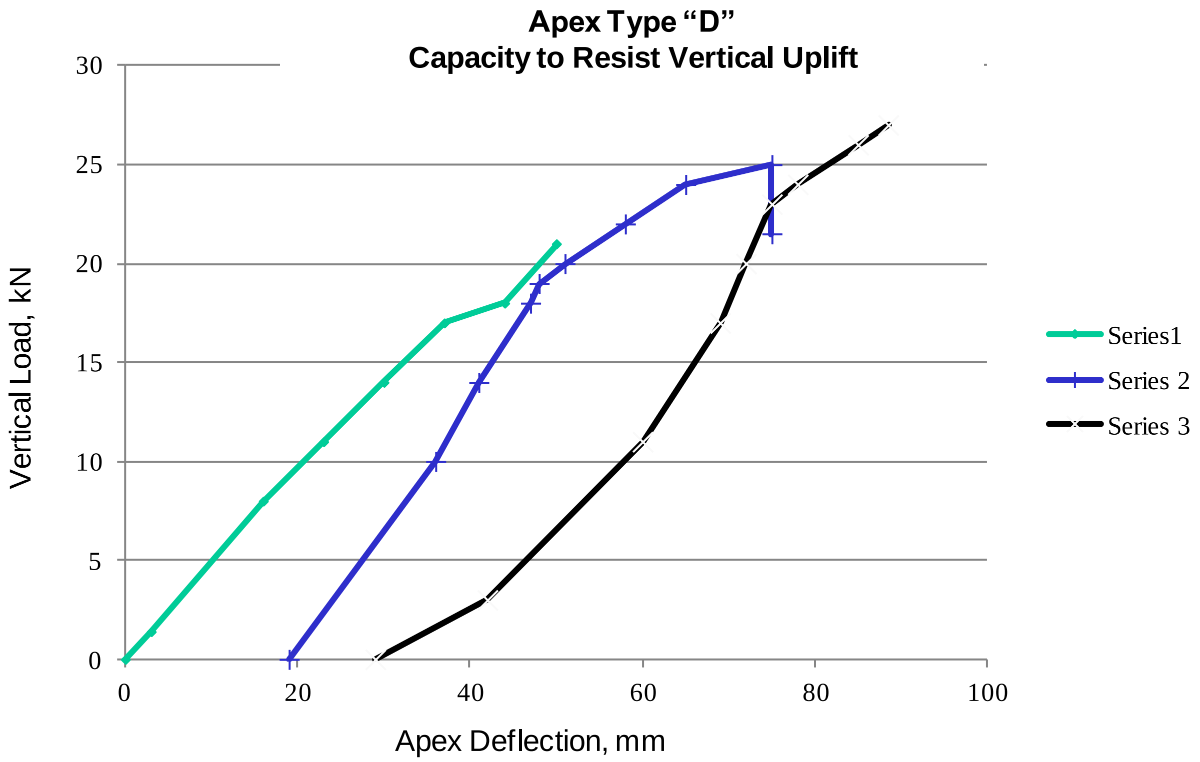
Fabrication and Testing

Fabricated 14/9/17 and tested 18/9/17 at Smithfield.

Failure

Ultimate failure occurred when the far-side collar tie bending failure. The ear-side collar tie split but still transmitted load. The M16 bolted connection rotated a little, with the washer compressing the timber, but was still transmitting load. Refer to the following detailed description.





1. Loads were applied evenly to the two diagonal lacing member stubs in the vertical direction, upwards positive.
2. Deflection of the apex was measured vertically, upwards positive.
3. Due to limited travel of the ram, load was applied in three separate series, the ram packing being adjusted twice, (between Series 1 and 2, and between Series 2 and 3)
4. In Load Series 1, no failure had occurred at 21 kN, when the ram reached its limit of travel. When the load was reduced to zero, a permanent deflection of 19 mm remained. This is probably due to the closing of some gaps between mating timber surfaces and bending of the bolts at the chord supports.
5. In Load Series 2, no failure had occurred at 25 kN when the ram reached its limit of travel. At a load 24 kN, horizontal cracking in the near-side collar tie was initiated and at 25 kN the cracking became more severe, although the load carrying ability remained. The load was maintained for a period in excess of 5 minutes. During this time, a further small creep deflection caused the applied load to reduce and stabilise at 21.5 kN. When the load was finally reduced to zero, there remained a permanent deflection of 29 mm, i.e. an additional 10 mm had occurred during Load Series 2 and the during period when the load was maintained at 21.5 kN.
6. In Load Series 3, bending rupture of the far-side collar tie occurred at 27 kN, causing resistance to diminish significantly. This was considered to be the ultimate failure capacity of the connection.
7. When the tested were terminate, the far-side collar tie had ruptured in bending (ultimate failure), the near-side collar tie had cracked significantly but still transmitted load (serviceability failure), the M16 bolted connection has rotated noticeably due to the washer compressing the timber (serviceability failure). One of the loaded lacing member stubs had split before the commencement of the test, but remained intact and transmitting load throughout the test.

Summary of Apex Connection Tests

Test detail, timber type and description of apex connection and collar tie connection	Specimen	Test	Measured vertical capacity kN	Vertical Deflection mm	Notes
70 x 45 MGP10. Full truss test. Apex joint, 2 x 4 / 75 x 3.75ϕ galv nails in each lapped top chord with spacer. Two nailed collar ties, 4 / 75 x 3.75ϕ galv nails in each tie at each lacing and purlin cleat.	Truss 70-1	7/4/17 #1, #2	**9.9**	Not recorded	Premature failure of trusses fabricated from 70 x 45 MGP10.
90 x 35 MGP10. Full truss test. Apex joint, 2 x 5 / 75 x 3.75ϕ galv nails in each lapped top chord with spacer. Two nailed collar ties, 4 / 75 x 3.75ϕ galv nails in each tie at each lacing and purlin cleat.	Truss 90-1	7/4/17	12.51	Not recorded	Nailed apex connection failure.
	Truss 90-2	7/4/17	12.50		
	Truss 90-3	7/4/17	12.48		
	Mean 90		**12.5**		
90 x 35 MGP10. Apex joint, 3 / 75 x 3.75ϕ galv nails in each lapped top chord with king post. One bolted and nailed collar tie, 1 / M12 and 2 x 4 / 75 x 3.75ϕ galv nails in each end of each tie plus at 2 x 4 / 75 x 3.75ϕ galv nails in each lacing.	A1		13.40	45.1	Ultimate failure was assumed when the collar tie timber failed at the nails due to in-plane moment. This then caused timber failure at the bolts.
	A2		10.90	54.2	
	A3		11.60	41.1	
	Mean A		**12.0**		
90 x 35 MGP10. Apex joint, M12 bolt, lapped top chords with king post. Two nailed collar ties, 4 / 75 x 3.75ϕ galv nails in each tie at each lacing and purlin cleat.	B		**21.8**	35.4	No significant failure when the test terminated. This provides the best resistance, although the detail is complicated.
90 x 35 MGP10. Apex joint, M12 bolt, tongue and clevis joint. No collar tie.	C		**14.0**	48.9	Timber longitudinal double shear failure at bolt. This is the simplest detail, although the fixing of the first purlin is complicated.
90 x 35 MGP10. Apex joint, 1/M16 bolt , lapped top chords with king post. Two nailed collar ties, 4 / 75 x 3.75ϕ galv nails in each tie at each lacing and purlin cleat.	D		**27.0**	89.0	Far-side collar tie bending failure, near-side collar tie cracked but still transmitted load, M16 bolted connection rotated (washer compressing the timber).

Recommendations Based on Interpretation of Tests

1. 90 x 35 members and 70 x 45 members have the same cross-sectional areas.

   100 x 38 members and 75 x 50 members have similar cross-sectional areas.

   Justification

90 x 35 mm = 3,150 mm^2	70 x 45 mm = 3,150 mm^2
100 x 38 mm = 3,800 mm^2	75 x 50 mm = 3,750 mm^2

2. 90 x 35 members have 29% higher bending resistance than 70 x 45 members.

   100 x 38 members have 35% higher bending resistance than 75 x 50 members.

   Justification

Section modulus	$35 \times 90^2 / 6 = 47{,}250$ mm^3	$70 \times 45^2 / 6 = 36{,}750$ mm^3
Section modulus	$100 \times 38^2 / 6 = 63{,}333$ mm^3	$75 \times 50^2 / 6 = 46{,}875$ mm^3

3. **DANCER** Trusses fabricated from 90 x 35 Softwood or 100 x 38 Hardwood have approximately 26% greater potential resistance to uplift than **DANCER** Trusses fabricated from 70 x 45 Softwood or 75 x 50 Hardwood.

   Justification

   The mean resistance of Truss Tests T90-1, T90-2 and T90-3 (12.5 kN) is 26% higher than the recorded resistance of Truss Test 70.1 (9.9 kN).

4. The **DANCER** Building System (incorporating purlins, trusses and studs) will be based on 90 x 35 Softwood and 100 x 38 Hardwood members, depending on application and availability.

   Justification

   Points 1, 2 and 3 above provide the basis.

5. It is inadvisable to provide additional nails in bolted joints, particularly those subject to rotation due to applied bending moment. Therefore Apex Connection "A" will not be used.

   Justification

   Apex Connection Tests A1, A2 and A3 consisted of 90 x 35 MGP10 members, one collar tie (with M12 bolt and 2 x 4 / 75 x 3.75φ galvanized nails) in each end of each tie plus at 2 x 4 / 75 x 3.75φ galvanized nails in each lacing. In addition, the apex joint was nailed with 3 / 75 x 3.75φ galvanized nails in each lapped top chord with king post. Ultimate failure occurred when the collar tie timber failed at the nails due to in-plane moment. This then caused timber failure at the bolts.

   .

6. Apex Connection "B" will not be used.

   Justification

   Apex Connection Tests B consisted of 90 x 35 MGP10 members, apex joint of one M12 bolt, lapped top chords with king post. Two nailed collar ties, 4 / 75 x 3.75φ galvanized nails in each tie at each lacing and purlin cleat.

   Apex Connection Test B did not fail, although the test was terminated at a vertical load of 21.8 kN and a deflection of 35 mm, when the ram reached its limit of travel.

Although the connection did not fail, the bolt clearance parallel to the grain did not meet the detailing requirements of AS 1720.1.

7. Apex Connection “C” will not be used.

   Justification

   Apex Connection Tests C consisted of 90 x 35 MGP10 members, apex joint of 1 / M12 bolt, tongue and clevis joint, with no collar tie. The timber of the tongue failed in longitudinal double shear failure at bolt.

   Although this is a simple apex detail, the fixing of the first purlin is necessarily complicated.

8. **Apex Connection “D” will be used**.

   Justification

   Apex Connection Tests C consisted of 90 x 35 MGP10 members, apex joint with1 / M16 and a double collar tie nailed at the lacing stub and at the purlin cleat member.

   The far-side collar tie failed in bending, while the near-side collar tie split, but still transmitted load. The M16 bolted connection twisted a little (with the washer compressing the softwood).

   For high wind uplift, the use of hardwood will improve the bending capacity of the collar ties (the members that failed in the test).

   For high wind uplift, the use of hardwood together with an M16 apex bolt, nut and washers will also improve the resistance to twisting.

9. **AS 1720.1 will be used** for the design and detailing of the **DANCER** Building System.

   Justification

   Based on the following analysis, the test results are consistent with design based on AS 1720.1.

   (a) The tests have been used for product development and to provide a “reality check” of designs that are based on AS 1720.1.

   (b) The tests have not been used for design based on prototype testing. Therefore the method set out in AS/NZS 1170.0 Appendix B is not applicable.

   (c) Based on Points (a) and (b), the mean of the test results that are available results will be considered to be the “best estimate”. This infers a 50% confidence limit, not the 75% confidence limit implicit in the reduction factors set out in AS/NZS 1170.0 Table B1.

   (d) It is assumed that:

   - the coefficient of variation of joints in timber approximates 30%
   - the joint capacities follow a log-normal (or normal) distribution
   - the capacity reduction factor from AS 1720.1 is 0.85
   - a “load duration on laterally loaded joints” factor, k_1, of 1.14 is applicable.

(e) The relationship between mean strength and the design value for connections in timber is as follows:

$$\varphi Q = \varphi k_1 Q [1 - 1.65 V)]$$
$$= 0.85 \times 1.14 Q [1 - 1.65 \times 0.3)]$$
$$= 0. 49 Q$$

i.e. the factored design capacity would be approximately half the mean of the tested strengths.

(f) In trusses with a top chord slope of 1 in 3 subject to a vertical load (applied through purlins), the horizontal load in the top chord (at the apex connection) and in the bottom chord (at the splice) is 3 times the vertical load at each stud. i.e. .1.4 times the total vertical load applied to the truss.

(See previous explanation)

(g) In the Apex Connection test with a top chord slope of 1 in 3 subject to a vertical load (applied through the lacing members), the horizontal load in the top chord (at the apex connection) is 1.5 times the total vertical load applied on both lacing member stubs..

(h) The following analysis applies to in M12 bolt in 90 x 35 MGP10 timber in Apex Connection C.

(i) The total vertical test load of 14 kN, corresponds to a load in the connection of 21 kN. A mean strength (one specimen) of 21 kN corresponds to a factored design load of 10.5 kN.

(ii) Based on AS 1720.1, the capacity of a single M12 bolt, parallel to the grain in 35 mm MGP10 seasoned softwood is:

- 5.72 kN for Joint Group JD5 (55% of the value the test suggests); or
- 7.27 kN for Joint Group JD4 (69% of the value the test suggests).

(iii) The timber used in the test is more likely to be JD4 than JD5.

(i) The following analysis applies to 10 / 75 x 3.75φ galvanized nails , shear, side grain in 90 x 35 MGP10 timber Tee pieces in Nailed Joint Connection Tests.

(i) A mean strength (five specimens) of 18.67 kN corresponds to a factored design load of 9.33 kN.

(ii) Based on AS 1720.1, the capacity of 10 / 75 x 3.75φ galvanized nails , shear, side grain in 90 x 35 MGP10 timber is:

- 8.87 kN in Joint Group JD5 (95% of the value the test suggests); or
- 10.76 kN in Joint Group JD4 (116% of the value the test suggests).

The timber used in the test could be either JD4 or JD5

(j) The following analysis applies to 4 / 75 x 3.75φ bright nails, shear, side grain in 90 x 35 MGP10 timber purlins and extended lacing.

(i) Failure of the nails connecting the purlin closest to the stud to the extended lacing occurred at a total applied load of 15.0 kN at each end of the loading truss, corresponding to 12.0 kN point load at the centre of the first purlin and 6.0 kN at the nailed connection. A test strength of 6.0 kN corresponds to a factored design load of 3.0 kN.

(ii) Based on AS 1720.1, the design capacity of 4 / 75 x 3.75φ galvanized nails , shear, side grain in 90 x 35 MGP10 timber is:

- 3.55 kN in Joint Group JD5 (18% of the value the test suggests); or
- 4.30 kN in Joint Group JD4 (143% of the value the test suggests).

Given the restricted geometry of the connection and the inability to achieve the AS 1720.1 edge distances, it is recommended that the maximum number of nails at each purlin connection be limited to three, and the AS 1730.1 design capacity for nails in shear in the side grain be discounted by 25%.

Based on 75% of the AS 1720.1 value, the design capacities are:

- 0.75 x 3.30 = 2.47 kN shear for 3 / 75 x 3.15φ galvanized nails , side grain in Strength Group J2 hardwood;
- 0.75 x 4.51 = 3.38 kN shear for 3 / 75 x 3.75φ galvanized nails , side grain in Strength Group J2 hardwood;

- 0.75 x 2.35 = 1.76 kN shear for 3 / 75 x 3.15φ galvanized nails , side grain in Strength Group JD4 softwood;
- 0.75 x 2.27 = 1.70 kN shear for 3 / 75 x 3.75φ galvanized nails , side grain in Strength Group JD4 softwood.

Part 8 – DANCER Design Actions

Part 8 provides guidance on the determination of design actions for the countries of the South Pacific.

Background

In cities of the South Pacific region, structural design and construction generally follow established building regulations and design standards. However, remote village housing and infrastructure in these countries often incorporate traditional materials and detailing, which do not necessarily have the structural resilience implicit in modern regulations.

This Handbook documents design principles and details that ensure consistent resistance to applicable cyclonic wind, earthquake and tsunami loads for detached houses and small buildings in located in villages in the Pacific region.

The following four parts describe the derivation and application of the relevant design actions.

1 – Structural Design Principals

(a) Where Building Regulations are Enforced

In those locations where building regulations are enacted and routinely enforced, design and construction should adhere to those regulations. For example, construction in cities and in developed countries should adhere to local building regulations.

(b) Where Building Regulations are Unclear, Not Enacted or Not Routinely Enforced

This applies only to small detached village buildings (such as houses and small community buildings), presenting a low degree of hazard to life and other property in case of failure.

It is limited to single storey buildings, with cladding on elevated braced timber frames, or to reinforced concrete masonry buildings built on concrete slab-on-ground. The maximum dimensions of such buildings shall not exceed 12.5 m x 8.0 m, 2.7 m storey height, maximum eaves height 6.0 m, maximum ridge height 8.5 m, and maximum pitch 35^{o}.

The intended design life shall not be less than 25 years. The Handbook deals with:

1. Design for Ultimate Limit State, based on an Annual Probability of Exceedance of 1 in 250
2. Load Combinations
3. Permanent Loads
4. Imposed Loads
5. Wind Loads
6. Earthquake Loads
7. Tsunami Loads
8. Flood Loads
9. Soil properties.

2 – Country Analysis, Design and Checking Assumptions

This section provides assumptions for the analysis, design and checking of both unregulated and regulated small detached village buildings (such as houses and small community buildings) and in each of the countries covered by this Handbook, taking account of the location, proximity to cyclonic wind zones, proximity to high earthquake areas and plate boundaries, typical topography and susceptibility to tsunamis.

1 – Structural Design Principles

Background

In cities of the South Pacific region, structural design and construction generally follow established building regulations and design standards. However, village housing and infrastructure in developing countries often incorporate traditional materials and detailing, which do not necessarily have the structural resilience implicit in modern regulations.

Countries Covered by this Handbook

The following countries are covered by this Handbook – American Samoa, Cook Islands, Fiji, French Polynesia, Kiribati, Nauru, New Caledonia, Niue, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, Wallis and Futuna. For wind and earthquake actions, four cases are covered:

Assumptions for Structural Design and Structural Design Checking

It is common practice for structural design to be more conservative than that which is mandated by the minimum requirements of building regulations or other design policies. This conservatism is normal and arises through several mechanisms:

(a) Most structural components are supplied in discreet sizes.

For example, structural bolts are available in M12, M16, M20 etc. If analysis based on the assumed design actions dictates that a bolt must be at least (say) 13.7 mm in diameter, the design engineer must adopt the next available size, M16, which implies conservatism.

(b) In many cases, design for one action will lead to conservatism in another action.

For example, the depth of long span flexural members (such as bearers) may be dictated by deflection serviceability, and therefore will be conservative in respect of ultimate load capacity.

(c) The adoption of conservative design assumptions may minimise disputes arising from differing analysis assumptions of the design checking process.

Recognising this latent conservatism, the following assumptions for “structural design” and “structural design checking” are recommended.

1. Design of Regulated Buildings

For the design of regulated buildings, <u>slightly conservative</u> assumptions (in excess of those based on a probability of exceedance of 1 in 500 years) are recommended for the <u>design</u> of structures for wind and earthquake actions, where:

(a) the building is of Importance Level 2; and

(b) relevant building regulations are enforced; and

(c) a probability of exceedance of 1 in 500 years is specified.

2. Checking Regulated Buildings

For the checking of regulated buildings, <u>precise</u> assumptions (based on a probability of exceedance of 1 in 500 years) are recommended for the <u>checking</u> of structures for wind and earthquake actions, where:

(a) the building is of Importance Level 2; and

(b) relevant building regulations are enforced; and

(c) a probability of exceedance of 1 in 500 years is specified.

3. **Design of Unregulated Village Buildings**

For the design of remote unregulated village buildings, slightly conservative assumptions (in excess of those based on a probability of exceedance of 1 in 250 years) are recommended for the design of structures for wind and earthquake actions, where:

(a) the building is of Importance Level 1 or 2; and

(b) they offer low risk to occupants; and

(c) the design life is under 25 years; and

(d) there is no other practical way of determining the design actions and soil properties, and;

(e) relevant building regulations are not routinely enforced.

This is not applicable in Australia or New Zealand.

4. **Checking of Unregulated Village Buildings**

For the design of remote unregulated village buildings, precise assumptions (based on a probability of exceedance of 1 in 250 years) are recommended for the checking of structures for wind and earthquake actions, where:

(a) the building is of Importance Level 1 or 2; and

(b) they offer low risk to occupants; and

(c) the design life is under 25 years; and

(d) there is no other practical way of determining the design actions and soil properties, and;

(e) relevant building regulations are not routinely enforced.

This is not applicable in Australia or New Zealand.

Probability of Structural Failure

The following extracts from the “Guide to NCC Volume One 2016”, published by the Australia Building Codes Board provide background to the probabilities of structural failure implicit in the Australian National Construction Code. This approach is reflected in this handbook.

Performance attributes

BP1.1(a) *uses the term "with appropriate degrees of reliability” which can be judged with due regard to the possible consequences of failure and the expense, level of effort and procedures necessary to reduce the risk of failure. The measures that can be taken to achieve the appropriate degree of reliability include:*

- *choice of a structural system, proper design and analysis;*
- *implementation of a quality policy;*
- *design for durability and maintenance; and*
- *protective measures.*

Degrees of reliability of structural elements can be quantified in terms of probabilities of failure with the use of probabilistic models for actions and resistances.

BP1.1(a)(i) *is concerned with the serviceability limit states of buildings in terms of local damage, deformation and vibration. Expected actions are actions with high probabilities of occurrence. The acceptable level of serviceability is subjective. The design for serviceability depends to a large extent on professional judgement. The risk of serviceability failure is, historically, of the order of* 10^{-1} *to* 10^{-2}.

BP1.1(a)(ii) *is concerned with the ultimate limit states of buildings in terms of strength and stability. Extreme actions are actions with low probability of occurrence. Repeated actions are actions, with high frequencies of occurrence in a given time period, that may cause fatigue or other cumulative failures. The notional probability of failure of structural elements is of the order of* 10^{-3} *to* 10^{-4} *for a 50 year reference period. The probability of structural failure is historically of the order of* 10^{-6} *per year.*

BP1.1(a)(iii) *is concerned with consequences of unspecified actions and is often referred to as "structural robustness". It includes, but is not limited to, progressive collapse. Ways to improve structural robustness include providing redundancies, minimum resistances, protective measures, etc.*

Importance Level	***Examples of building types***
1	*Farm buildings and farm sheds Isolated minor storage facilities Minor temporary facilities.*
2	*Low rise residential construction Buildings and facilities below the limits set for Importance Level 3.*
3	*Buildings and facilities where more than 300 people can congregate in one area. Buildings and facilities with a primary school, a secondary school or day care facilities with a capacity greater than 250. Buildings and facilities with a capacity greater than 500 for colleges or adult educational facilities Health care facilities with a capacity of 50 or more residents but not having surgery or emergency treatment facilities Jails and detention facilities Any occupancy with an occupant load greater than 5000 Power generating facilities, water treatment and waste water treatment facilities, any other public utilities not included in Importance Level 4 Buildings and facilities not included in Importance Level 4 containing hazardous materials capable of causing hazardous conditions that do not extend beyond property boundaries.*
4	*Buildings and facilities designated as essential facilities Buildings and facilities with special post disaster functions Medical emergency or surgery facilities Emergency service facilities: fire, rescue, police station and emergency vehicle garages Utilities required as backup for buildings and facilities of Importance Level 4 Designated emergency shelters Designated emergency centres and ancillary facilities Buildings and facilities containing hazardous materials capable of causing hazardous conditions that extend beyond property boundaries.*

Locations Where Building Regulations are Enforced

In those locations where building regulations are enacted and routinely enforced, all new construction should adhere to those regulations. For example, construction in cities and in developed countries should adhere to local building regulations.

The following clause appears in the National Building Codes for Cook Islands, Fiji, Niue, Solomon Islands, Tuvalu and Vanuatu.

Schedule of Referenced Documents

The Standards and other documents listed in Table 1 are referred to in this Code. In order to reduce possible confusion/conflict, the Standards produced by the Standards Association of Australia or by the Standards Association of New Zealand as seen to be particularly relevant, have been called up. However Code users are free to use any suitable mix of Australian and New Zealand Standards provided care is taken to follow consistent technical principles and prevalent practices. Where Standards from either Australia or New Zealand do not cover any specific area, the relevant Standards issued by the British Standards Institution or the American Society for Testing Materials may be used.

Small Buildings where Building Regulations are Not Enforced

This applies only to small detached village buildings (such as houses and small community buildings), presenting a low degree of hazard to life and other property in case of failure.

It applies only to single storey buildings, with cladding on elevated braced timber frame or to reinforced concrete masonry buildings built on concrete slab-on-ground.

The maximum dimensions of such buildings shall not exceed 12.5 m x 8.0 m, 2.7 m storey height, maximum eaves height 6.0 m, maximum ridge height 8.5 m, and maximum pitch 35^o.

The intended design life shall not be less than 25 years.

Unless specifically over-ridden by existing in-country building regulations, requirements shall be interpreted in the light of the most recent Australian and Australian/New Zealand Standards listed below.

1. Design for Ultimate Limit State – Annual Probability of Exceedance is 1 in 250. Reference Period (design life) is 25 years, leading to a probability of exceedance during the life of 0.10. Load factors (applied to the representative loads) and capacity reduction factors (applied to a specified “lower 5 percentile” characteristic strengths of components) shall ensure that the probability of failure is “low” (e.g. Target Reliability Index $\beta = 3.1$)
2. Load Combinations– As per AS/NZS 1170.0
3. Permanent Loads – As per AS/NZS 1170.1
4. Imposed Loads – As per AS/NZS 1170.1
5. Wind Loads – Analysis as per AS 4055, using wind speeds from the relevant Building Regulations or, if appropriate, HB 212
6. Earthquake Loads – Analysis assumptions set out in AS 1170.4, EDC II, using hazard factors appropriate to the region
7. Tsunami Loads – For structures that are required to be designed for tsunami (except those that should be moved), analysis shall be in accordance with using the method in Australian Building Codes Board Handbook, *Construction of Buildings in Flood Hazard Areas* for a velocity of 1.5 m/s. Structural components shall be designed to withstand the design event, assuming that the cladding is partially destroyed.
8. Flood Loads – For structures that are required to be designed for flood (except those that should be moved), analysis shall be in accordance with using the method in Australian Building Codes Board Handbook, Construction of Buildings in Flood Hazard Areas for a velocity of 1.5 m/s. Structural components shall be designed to withstand the design event, assuming that the cladding remains intact.
9. Soil Properties – Site classification, construction and analysis to AS 2870; Soil loads to AS 4678

Similar to the situation where the “Building Regulations are enforced” the following clause (from the National Building Codes for Cook Islands, Fiji, Niue, Solomon Islands, Tuvalu and Vanuatu) is considered applicable.

> *Schedule of Referenced Documents*
>
> *The Standards and other documents listed in Table 1 are referred to in this Code. In order to reduce possible confusion/conflict, the Standards produced by the Standards Association of Australia or by the Standards Association of New Zealand as seen to be particularly relevant, have been called up. However Code users are free to use any suitable mix of Australian and New Zealand Standards provided care is taken to follow consistent technical principles and prevalent practices. Where Standards from either Australia or New Zealand do not cover any specific area, the relevant Standards issued by the British Standards Institution or the American Society for Testing Materials may be used.*

Notes on Annual Probability of Exceedance

Australia

While the Australian National Construction Code is formatted as performance code (thus permitting Performance Solutions) it does not contain quantified structural Performance Requirements.

The Australian National Construction Code (NCC) Verification Methods, NCC 2016 Volume One Parts BV1 and BV2 and NCC 2016 Volume Two Parts V2.1.1 and V2.1.2, apply only to Performance solutions.

Therefore, there are no overarching quantified probabilities of structural reliability that apply to both Performance Solutions and Deemed-to-Satisfy Solutions.

The following approach is recommended:

(a) Design using the referenced DTS Australian and Australian/New Zealand Standards for both design actions and capacities; and

(b) Check designs and apply acceptance / rejection criteria using the same referenced DTS Australian and Australian/New Zealand Standards.

NCC Volume One Table B1.2a and Table B1.2b are reproduced below. NCC Volume Two Table 3.11.3a and 3.11.3b includes similar information for Importance Levels 1 and 2.

Table B1.2a IMPORTANCE LEVELS OF BUILDINGS AND STRUCTURES

Importance Level	Building Types
1	Buildings or structures presenting a low degree of hazard to life and *other property* in the case of failure.
2	Buildings or structures not included in Importance Levels 1, 3 and 4.
3	Buildings or structures that are designed to contain a large number of people.
4	Buildings or structures that are essential to post-disaster recovery or associated with hazardous facilities.

Table B1.2b DESIGN EVENTS FOR SAFETY

Importance Level	Annual probability of exceedance			
	Wind		Snow	Earthquake
	Non-cyclonic	Cyclonic		
1	1:100	1:200	1:100	1:250
2	1:500	1:500	1:150	1:500
3	1:1000	1:1000	1:200	1:1000
4	1:2000	1:2000	1:250	1:1500

In Australia, houses and small buildings with an Importance Level of 2 must be designed for an Annual Probability of Exceedance for wind loads and earthquake loads of 1 : 500.

The Building Regulations require the capacity to be based on the “lower 5 percentile” characteristic strengths of components) but do not regulate the probability of failure.

New Zealand

The approach in New Zealand is similar to that of Australia, except that the definitions of design events are in the Standards. Cyclonic winds do not apply and there is significantly more emphasis on earthquake loads.

Other South Pacific Countries

Section 2 of this policy applies only to small detached village buildings (such as houses and small community buildings such as clinics and small school buildings. It is further limited to single storey buildings, with cladding on elevated braced timber frame, or to reinforced concrete masonry buildings built on concrete slab-on-ground. The maximum dimensions of such buildings shall not exceed 12.5 m x 8.0 m, 2.7 m storey height, maximum eaves height 6.0 m, maximum ridge height 8.5 m, and maximum pitch 35°.

Such buildings are deemed to “present a low degree of hazard to life and other property in case of failure”.

Based on the above-mentioned limitations, an Annual Probability of Exceedance of 1 in 250 has been selected for design for Ultimate Limit State.

These small, single storey houses are (in general) considerably smaller than most new houses in Australia and New Zealand. Further, the likely design life will also probably much shorter. A design life “not exceeding 25 years” has been selected.

The Reference Period (design life) of 25 years for 1 in 250 leads to a probability of exceedance during the life of 0.10.

This Handbook seeks to achieve consistency of approach when dealing with various loads; in particular wind and earthquake loads. To achieve this the basic variables (3 second wind gust speed at a height of 10 m and earthquake hazard) are determined and reported for a Probability of Exceedance of 1 : 500. A factor, k_p, is then applied to the resulting forces, after (in the case of wind) provision has been made for terrain category, shielding, topography and pressure/suction factors.

Annual Probability of Exceedance	Application	Probability Factor, k_p		
		Earthquake Loads AS 1170.4 Table 3.1	AS/NZS 1170.2 and HB 212	
1 : 500	Ultimate limit state in Australia, New Zealand and in places where 1 : 500 is regulated	1.0	1.0	
1 : 250	Ultimate limit state in villages where 1 : 500 is not regulated	0.75	Zone I	0.90
			Zone II	0.91
			Zone III	0.86
			Zone IV	0.88
			Zone V	0.86
1 : 50	Serviceability in villages where 1 : 500 is not regulated	0.35	Zone I	0.64
			Zone II	0.75
			Zone III	0.60
			Zone IV	0.62
			Zone V	0.66

The following approach is recommended:

(a) Design using the referenced (or otherwise appropriate) Australian and New Zealand Standards; and

(b) Initially check the design using the referenced (or otherwise appropriate) Australian and New Zealand Standards, but carry out further checks if necessary using the applicable Importance, Design Life and corresponding Probability of Exceedance (based on the applicable factor, k_p). @@@@

Tonga

The Tonga Building Code 2007 Part B Performance Requirements state:

BP1.3 Design criteria

The following criteria must be satisfied –

(a) during the designed life of the building the probability of experiencing unacceptable deflections or vibrations must not exceed 5%;

(b) the probability of risk of structural failure must not exceed 0.1% within the designed life of the building.

For a 50 year building design life, this equates to an annual probability of exceedance of 1 in 500, and a factor $k_p = 1.0$.

For a 25 year building design life, this equates to an annual probability of exceedance of 1 in 250, and a factor $k_p = 0.75$.

Table 1.1 – Importance levels of buildings

(Based on Table 3.2 of AS/NZS 1170.0 – see 1.1.3)

Importance level	Description
Building types covered by this Standard	
1	Structures of a secondary nature
2	Single family dwellings and structures not in other importance levels
Building types not covered by this Standard	
3	Structures that may contain crowds or contents of a high value to the community
4	Structures with special post-disaster functions
5	Special structures

This infers that single family dwellings (including in villages) are considered to be of Importance Level 2.

The Australian and New Zealand Standards that are referenced as Deemed-to-Satisfy (DTS) provisions in the Tongan Building Code are based on Annual Probability of Exceedance of 1 in 500 ($k_p = 1.0$), which correspond to Importance Level 2 and design life of 50 years. This is similar to the design in Australia and New Zealand using these Standards.

If a shorter design life (say 25 years) were to be considered appropriate for village houses and similar buildings, $k_p = 0.75$ would be applicable and design actions less that those assumed in the references Australian and New Zealand Standards would apply. In other words, the referenced Standards would be a little more conservative than the calculated design actions would indicate.

Therefore, the following approach is recommended:

(c) Design using the referenced (or otherwise appropriate) Australian and New Zealand Standards; and

(d) Initially check the design using the referenced (or otherwise appropriate) Australian and New Zealand Standards, but carry out further checks if necessary using the applicable Importance, Design Life and corresponding Probability of Exceedance (based on the applicable factor, k_p).

Notes on Load Combinations

Australia and New Zealand

Australia and New Zealand Building Regulations call up the 2002 version (with amendments) of AS/NZS 1170.0:2002, which includes formulae for load combinations. This includes a combination factor of 1.2 on permanent loads (in combination with imposed loads), rather than the value of 1.25 in the earlier 1989 standard.

Other Countries

The 2002 version (with amendments) of AS/NZS 1170.0:2002, including the combination factor of 1.2, is used in this "Policy for Small Buildings where Building Regulations are Not Enforced", although some other countries do not specifically refer to them.

Notes on Permanent Loads

The 2002 version (with amendments) of AS/NZS 1170.1:2002 is used in this policy to determine permanent loads, although some other countries do not specifically refer to it.

In providing default values for standard calculations, the following permanent loads of particular components (expressed as kN / m^2 of plan footprint area) have been assumed.

Surface Weight of Components of Timber Framed Houses

Surface weight of roof sheeting	0.080	kN/m^2
Surface weight of roof battens	0.037	kN/m^2
Surface weight of roof framing	0.135	kN/m^2
Surface weight of ceiling battens	0.033	kN/m^2
Surface weight of ceiling lining	0.076	kN/m^2
Surface weight of external wall cladding	0.215	kN/m^2
Surface weight of external wall framing	0.167	kN/m^2
Surface weight of external wall lining	0.076	kN/m^2
Surface weight of internal wall framing	0.167	kN/m^2
Surface weight of internal wall lining	0.260	kN/m^2
Surface weight of floor sheeting	0.220	kN/m^2
Surface weight of floor Joists	0.138	kN/m^2
Surface weight of floor bearers	0.092	kN/m^2
Surface weight of subfloor posts	0.183	kN/m^2
Surface weight of sub-floor bracing	0.014	kN/m^2
Surface weight of steps	0.748	kN/m^2
Surface weight of windows	0.150	kN/m^2
Surface weight of doors	0.330	kN/m^2

Surface Weight of Components of Reinforced Concrete Masonry Houses

Surface weight of roof sheeting	0.080	kN/m^2
Surface weight of roof battens	0.037	kN/m^2
Surface weight of roof framing	0.135	kN/m^2
Surface weight of ceiling battens	0.033	kN/m^2
Surface weight of ceiling lining	0.076	kN/m^2
Surface weight of external wall cladding	2.158	kN/m^2
Surface weight of internal wall framing	0.167	kN/m^2
Surface weight of internal wall lining	0.260	kN/m^2
Surface weight of windows	0.150	kN/m^2
Surface weight of doors	0.330	kN/m^2

The permanent loads should be calculated for each building, although, for small detached village buildings, the following default permanent loads acting at floor level may be used.

- Elevated timber building, w = 2.0 kN/m^2 (of plan footprint area),
- Reinforced masonry building w = 3.0 kN/m^2 (of plan footprint area)

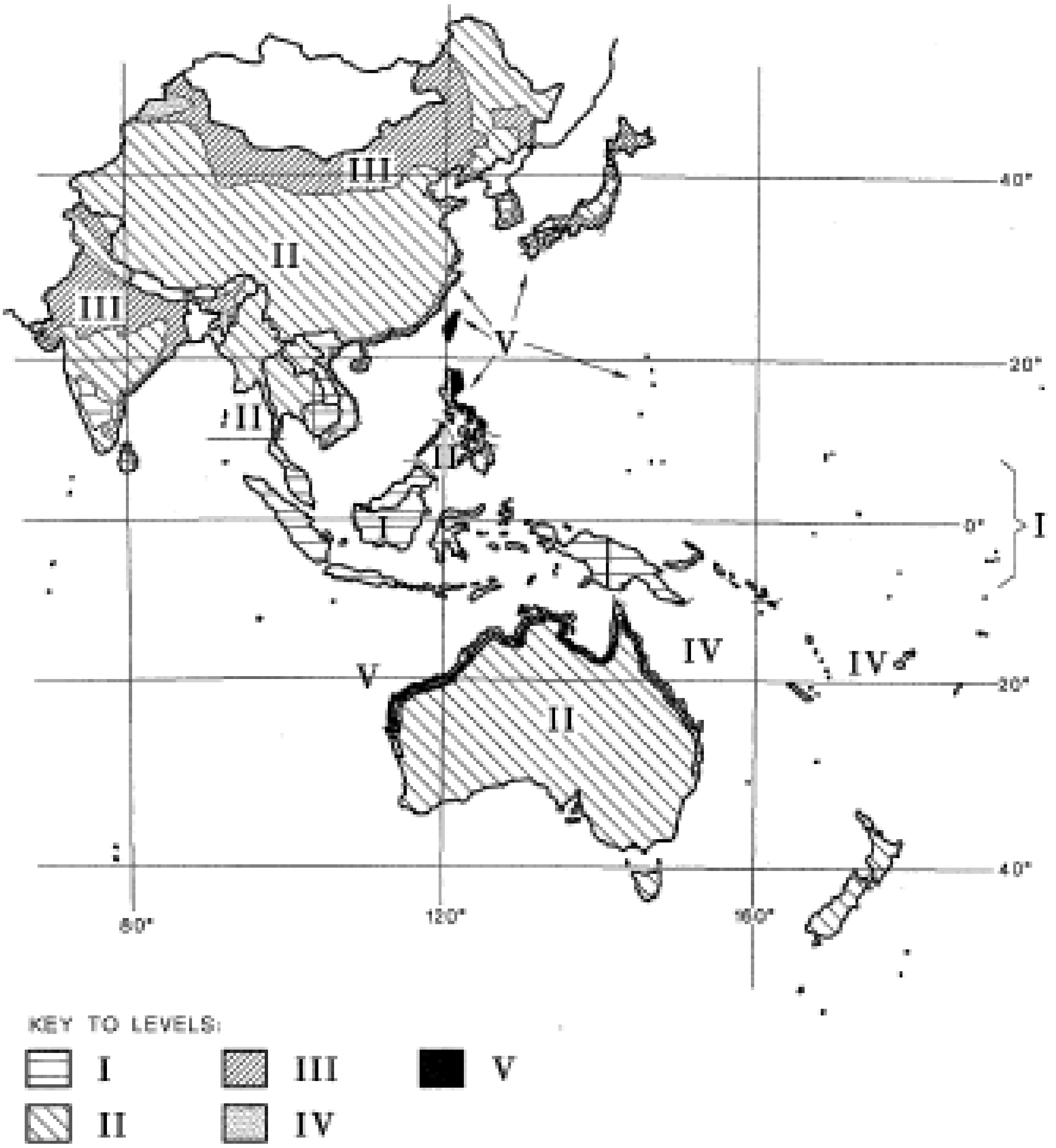
Notes on Imposed Loads

The 2002 version (with amendments) of AS/NZS 1170.1:2002 is used in this policy to determine imposed loads, although some other countries do not specifically refer to them.

In particular, for small detached village buildings, an imposed floor load of 1.5 kPa and an imposed roof load of 0.25 kPa are used.

Notes on Wind Loads

Basic wind speeds shall be determined in accordance with the following map and table, except where overridden by more recent Australian or New Zealand Standards.



Note: This map gives a general indication only, as many of the areas are too small to show. Refer to the text and maps in Section 5 (Figures 2 to 11) for classifications of particular locations.

Reference: Standards Australia Handbook HB 212:2002

Wind Categories	Description	Equation	$V_{u\ 500\ (3,10)}$ m/s	$V_{u\ 250\ (3,10)}$ m/s	$k_{p\ 250}$
Zone I - Pacific islands adjacent to the equator, East Timor, Papua New Guinea, Solomon Islands , Indonesia, Malaysia, Singapore, Inland Karnataka (India),	Strong thunderstorms and monsoon winds	$70 - 56\ R^{-0.1}$	40	**38**	0.90
Zone II (A) - South-west tip of Papua New Guinea, most of southern India, western Indial coastal strip (Mumbai, inland Madhya Pradesh, Orissa), western Mindanao, Australia & New Zealand Zones A1-A7(Southern & inland)	Moderately severe thunderstorms and extra-tropical gales	$67 - 41\ R^{-0.1}$	**45**	**43**	0.91
Zone III (B) - Coastal strips of Tamil Nadu (including Chennai), Andhra Pradesh, Orissa, Gujaret, West Bengal (including Calcutta), Assam, northern India (inclusing Delhi), central Tamil Nadu, Eastern Mindanao, Palawan(Philippines) Australia Zone B (South-east Queensland)	Severe thunderstorms and moderate or weakening typhoons or tropical cyclones	$106 - 92\ R^{-0.1}$	**57**	**53**	0.86
Zone IV (C) - Pacific Islands below 6°S, Tripiura & Mizoram, Ladakh (India), remainder of Philippines Australia Zone C (Northern coast)	Strong typhoons or tropical cyclones	$F_C\ (122 - 104\ R^{-0.1})$	**66**	**62**	0.88
Zone V (D) - Eastern Luzon (Philippines) Australia Zone D (West coast)	Very strong typhoons or tropical cyclones	$F_D\ (156 - 142\ R^{-0.1})$	**80**	**74**	0.86
Zone W New Zealand Wellington Region		$104 - 70\ R^{-0.045}$	**51**	49	0.92

Notes
1.Wind speeds are for a 3 second gust, at 10 m height in open country terrain.
2. For R < 50 years, F_c abd F_d = 1.0
3.Sources: HB 212 *Design wind speeds for the Asia-Pacific Region* , 2002 and AS/NZS 1170.2:2011; Standards Australia
4. Pink shaded areas are for 1 : 500 Probability of Exceedance (e.g. Housing in Australia and New Zealand).
5. Blue shaded areas are for 1 : 250 Probability of Exceedance (e.g. Village housing in developing countries).
6. Probability Factor, $k_p = (V_{u\ 500\ (3,10)} / V_{u\ 500\ (3,10)})^2$, and is applied to resulting pressures, suctions and forces.

This Handbook seeks to achieve consistency of approach when dealing with various loads; in particular wind and earthquake loads.

To achieve this the basic variable (3 second wind gust speed at a height of 10 m) is determined and reported for a Probability of Exceedance of 1 : 500.

A factor, k_p, is then applied to the resulting forces, after provision has been made for terrain category, shielding topography and pressure/suction factors.

Noncyclonic	Level I	$V_{u\ 500\ (3,10)}$ = 40 m/s	$k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.90
Noncyclonic	Level II(A)	$V_{u\ 500\ (3,10)}$ = 45 m/s	$k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.91
Noncyclonic	Level III (B)	$V_{u\ 500\ (3,10)}$ = 57 m/s	$k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.86
Cyclonic	Level IV (C)	$V_{u\ 500(\ 3,10)}$ = 66 m/s	$k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.88
Cyclonic	Level V(D)	$V_{u\ 500\ (3,10)}$ = 80 m/s	$k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.86
Noncyclonic	Level III (W)	$V_{u\ 500(\ 3,10)}$ = 51 m/s	$k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.92

The relevant Wind Classifications (N1 to N6 or C1 to C4) are calculated using AS 4055 from the Basic Wind Speeds (for a 3 second gust at a height of 10 m in open terrain [TC 2]), taking account of the terrain category, shielding and topography.

The following table is based on AS 4055 Table 2.2.

Wind Classifications (for Probability of Exceedance 1 in 500)														
Region	Terrain Category	Topographic classification												
		T0			T1			T2			T3		T4	T5
		FS	PS	NS	FS	PS	NS	FS	PS	NS	PS	NS	NS	NS
I	3	N1	N1	N1	N1	N1	N1	N1	N1	N1	N2	N2	N2	N2
	2.5	N1	N1	N1	N1	N1	N1	N1	N2	N2	N2	N2	N3	N3
	2	N1	**N1**	N1	N1	N1	N2	N1	N2	N2	N2	N2	N3	N3
	1.5	N1	N1	N1	N1	N1	N2	N2	N2	N2	N2	N3	N3	N3
	1	N1	N2	N2	N1	N2	N2	N2	N2	N3	N3	N3	N3	N4
II (A)	3	N1	N1	N1	N1	N2	N2	N2	N2	N2	N3	N3	N3	N3
	2.5	N1	N1	N2	N1	N2	N2	N2	N3	N3	N3	N3	N4	N4
	2	N1	**N2**	N2	N2	N2	N3	N2	N3	N3	N3	N3	N4	N4
	1.5	N2	N2	N2	N2	N3	N3	N3	N3	N3	N3	N4	N4	N4
	1	N2	N3	N3	N2	N3	N3	N3	N3	N4	N4	N4	N4	N5
III (B)	3	N2	N2	N3	N2	N3	N3	N3	N3	N4	N4	N4	N5	N5
	2.5	N2	N3	N3	N3	N3	N3	N3	N4	N4	N4	N4	N5	N5
	2	N2	**N3**	N3	N3	N3	N4	N3	N4	N4	N4	N5	N5	N5
	1.5	N3	N3	N4	N3	N4	N4	N4	N4	N4	N5	N5	N5	N6
	1	N3	N4	N4	N4	N4	N4	N4	N5	N5	N5	N5	N6	N6
IV (C)	3	C1	C1	C2	C1	C2	C2	C2	C2	C3	C3	C3	C3	C4
	2.5	C1	C2	C2	C2	C2	C2	C2	C3	C3	C3	C3	C4	
	2	C1	**C2**	C2	C2	C2	C3	C2	C3	C3	C3	C4	C4	
	1.5	C2	C2	C3	C2	C3	C3	C3	C3	C4	C4	C4		
	1	C2	C3	C3	C3	C3	C3	C3	C4	C4	C4			
V (D)	3	C2	C3	C3	C2	C3	C3	C3	C4	C4	C4	C4		
	2.5	C2	C3	C3	C3	C3	C4	C3	C4	C4	C4			
	2	C3	**C3**	C4	C3	C4	C4	C4	C4					
	1.5	C3	C4	C4	C4	C4		C4						
	1	C3	C4	C4	C4									

Notes:

1. This table is derived from AS 4055 Table 2.2.
2. The wind classifications for Region I have been determined by extrapolation from Region II.
3. Regions are defined as in HB212.
4. AS/NZS 1170.2 and AS 4055 regions (A, B, C and D) have been indicated in brackets.
5. Region W has been omitted for clarity. It may be conservatively taken as the same as Region III.
6. FS = full shielding PS = partial shielding NS = no shielding
7. The classification shown in large bold red lettering are those taken as defaults in the following data

For Annual Probability of Exceedance 1 : 500

For structures with Importance Level 2 (including most houses, small community buildings, clinics and the like), The design of buildings with Importance Level 2 (including most houses, small community buildings, clinics and the like) in Australia, New Zealand and several other countries shall be based on wind loads with a probability of Exceedance of 1 : 500, $k_{p\ 500}$ = 1.0.

The corresponding basic wind pressures, derived from AS 4055 for 1 : 500, $k_{p\ 500}$ = 1.0, (used for Australia and New Zealand) are:

Non-cyclonic	Wind Level N1	$V_{h,u\ 500\ (3,6.5)}$ = 34 m/s;	k_p = 1.0	q_u = 0.69 kPa
Non-cyclonic	Wind Level N2	$V_{h,u\ 500\ (3,6.5)}$ = 40 m/s;	k_p = 1.0	q_u = 0.96 kPa
Non-cyclonic	Wind Level N	$V_{h,u\ 500\ (3,6.5)}$ = 50 m/s;	k_p = 1.0	q_u = 1.50 kPa
Non-cyclonic	Wind Level N4	$V_{h,u\ 500\ (3,6.5)}$ = 61 m/s;	k_p = 1.0	q_u = 2.23 kPa
Non-cyclonic	Wind Level N5	$V_{h,u\ 500\ (3,6.5)}$ = 74 m/s;	k_p = 1.0	q_u = 3.29 kPa
Non-cyclonic	Wind Level N6	$V_{h,u\ 500\ (3,6.5)}$ = 86 m/s;	k_p = 1.0	q_u = 4.44 kPa
Cyclonic	Wind Level C1	$V_{h,u\ 500\ (3,6.5)}$ = 50 m/s;	k_p = 1.0	q_u = 1.50 kPa
Cyclonic	Wind Level C2	$V_{h,u\ 500\ (3,6.5)}$ = 61 m/s;	k_p = 1.0	q_u = 2.23 kPa
Cyclonic	Wind Level C3	$V_{h,u\ 500\ (3,6.5)}$ = 74 m/s;	k_p = 1.0	q_u = 3.29 kPa
Cyclonic	Wind Level C4	$V_{h,u\ 500\ (3,6.5)}$ = 86 m/s;	k_p = 1.0	q_u = 4.44 kPa

For Annual Probability of Exceedance 1 : 250

If the design life of a structure such as a village house or similar is (say) 25 years, a Basic Wind Speed with an Annual Probability of Exceedance of (say) 1 : 250 (10% in 25 years) may be more appropriate than the published Basic Wind Speeds with an Annual Probability of Exceedance of 1 in 500 (10% in 50 years).

To convert from 1 in 500 to 1 in 250, the published 1 in 500 wind speeds must be multiplied by a factor of k_p in accordance with AS/NZS 1170.2.

Further to the above general comment, the "Policy for Small Buildings where Building Regulations are Not Enforced" in this Handbook applies only to small detached village buildings (such as houses and small community buildings).

It is further limited to single storey buildings, with:

(a) cladding on elevated braced timber frame; or

(b) reinforced concrete masonry buildings built on concrete slab-on-ground.

The maximum dimensions of such buildings shall not exceed 12.5 m x 8.0 m, 2.7 m storey height, maximum eaves height 6.0 m, maximum ridge height 8.5 m, and maximum pitch 35^o.

The corresponding basic wind pressures, extrapolated from AS 4055 for 1 : 250 (used for other countries) are:

Non-cyclonic	Wind Level N1	$V_{h,u\ 500\ (3,6.5)}$ = 34 m/s;	k_p = 0.90	q_u = 0.62 kPa
Non-cyclonic	Wind Level N2	$V_{h,u\ 500\ (3,6.5)}$ = 40 m/s;	k_p = 0.90	q_u = 0.86 kPa
Non-cyclonic	Wind Level N3	$V_{h,u\ 500\ (3,6.5)}$ = 50 m/s;	k_p = 0.90	q_u = 1.35 kPa
Non-cyclonic	Wind Level N4	$V_{h,u\ 500\ (3,6.5)}$ = 61 m/s;	k_p = 0.90	q_u = 2.01 kPa
Non-cyclonic	Wind Level N5	$V_{h,u\ 500\ (3,6.5)}$ = 74 m/s;	k_p = 0.90	q_u = 2.96 kPa
Non-cyclonic	Wind Level N6	$V_{h,u\ 500\ (3,6.5)}$ = 86 m/s;	k_p = 0.90	q_u = 3.99 kPa
Cyclonic	Wind Level C1	$V_{h,u\ 500\ (3,6.5)}$ = 50 m/s;	k_p = 0.88	q_u = 1.32 kPa
Cyclonic	Wind Level C2	$V_{h,u\ 500\ (3,6.5)}$ = 61 m/s;	k_p = 0.88	q_u = 1.96 kPa
Cyclonic	Wind Level C3	$V_{h,u\ 500\ (3,6.5)}$ = 74 m/s;	k_p = 0.88	q_u = 2.89 kPa
Cyclonic	Wind Level C4	$V_{h,u\ 500\ (3,6.5)}$ = 86 m/s;	k_p = 0.88	q_u = 3.91 kPa

Some national building codes call up AS 1170.2:1989, which was in place at the time that the regulations were drafted. They also refer to the permissible stress method of design.

However, this "Policy for Small Buildings where Building Regulations are Not Enforced" provides ultimate limit state loads, based on the following assumptions:

- Analysis shall be consistent with AS 4055, except as follows.
- Basic wind speeds shall be determined from the relevant Building Regulations or, if appropriate, HB 212 factored to achieve a Probability of Exceedance of 1 : 500 or 1 : 250 as appropriate.
- Terrain category, shielding and topography should be assessed for each particular site. Default values, accounting for the location, basic wind speed, most common terrain, typical topography and partial shielding, are provided in Part 3 of this Handbook to give guidance.
- AS/NSZ 1170.2 and HB212 require the calculated value of V_R to be rounded to the nearest 1 m/s.
- HB 212 states, "The basic wind speed, V_R, ….. is 3 s gust at 10 m height in flat open country terrain.
- The Terrain/Height Multiplier, $M_{z,cat}$, for a height of 8 m and Terrain Category 2 is 0.985.
- Calculation of Pressures

- Pressure calculation is as follows:
- $p = k_p (0.5 \rho_{air}) [V_h]^2 C_p$

Where

p	=	Design wind pressure acting normal to a surface (Pascals) Pressures are taken as positive, indicating pressures above ambient and negative, indicating pressures below ambient.
k_p	=	Probability factor (to account for changed Probability of Exceedance)
ρ_{air}	=	Density of air, taken as 1.2 kg/m^3
V_h	=	Design 3 second gust wind speed
C_p	=	Pressure coefficient (External, internal or net, as appropriate)

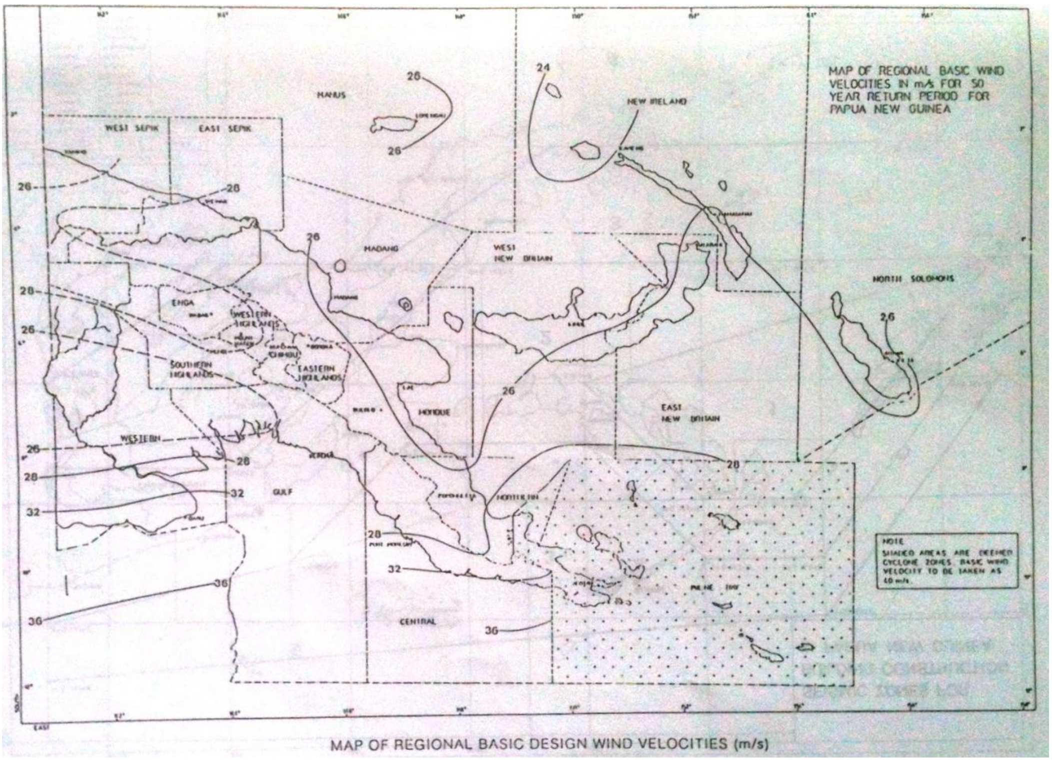
Basic Wind Speeds for Australia

The Australian National Construction Code BCA Volume Two refers to AS/NZS 1170.2:2011(Including Amendments 1 and 2) and to AS 4055:2012.

Basic Wind Speeds for New Zealand

The New Zealand building regulations refer to AS/NZS 1170.2:2011(Including Amendments 1 and 2.

Basic Wind Speeds for Papua New Guinea



Reference: Papua New Guinea Building Regulation 1994

Basic Wind Speeds for Solomon Islands

Similar to Fiji (# to be confirmed)

Basic Wind Speeds for Vanuatu

Similar to Fiji (# to be confirmed)

Basic Wind Speeds for Fiji

The Fiji Building Code 1990 states:

B1.2 Loads

The loading requirements of B1.1 are satisfied if the building or structure can resist loads determined in accordance with the following:

(a) Wind loads: AS 1170 – Minimum design loads on structures (known as SAA Loading Code) Part 2 – Wind loads

When using Part 2 of the Standard the following provisions apply: a limit state basic wind speed of 70 m/s to all areas. The equivalent basic wind speed for permissible stress methods of design is 57 m/s. When the simplified procedure of AS 1170 part 2 is followed, the value of the factor B, to be applied is 2.3. The map of Australia at Figure 2.5.1 and 3.2.2 in the Standard are to be disregarded.

Discussion:

In this Handbook, design for win actions is in according to the limit state method set out in AS/NZS 1170.2, with a regional wind speed of 70 m/s.

Basic Wind Speeds for Tonga

The Tonga National Building Code 2007 states:

B1.2 Loads

The loading requirements of B1.1 are satisfied if the building or structure can resist loads determined in accordance with the following:

(a) Wind loads: AS/NZS 1170.2 – Structural design actions – Wind actions.

When using this Part of the Standard the following provisions apply: A limit state regional wind speed of 70 m/s to all islands of the Kingdom. The equivalent regional wind speed for permissible stress methods of design is 57 m/s. All maps of Australia and New Zealand in the Standard are to be disregarded.

Discussion:

In this Handbook, design for win actions is in according to the limit state method set out in AS/NZS 1170.2, with a regional wind speed of 70 m/s.

Basic Wind Speeds for Other South Pacific Countries

Discussion:

In this Handbook, design for win actions is in according to the limit state method set out in AS/NZS 1170.2, with a regional wind speeds determined in accordance with Standards Australia Handbook HB212. Refer to individual country calculations.

Notes on Earthquake Loads

Earthquake Hazard Factors for Australia

The Australian National Construction Code BCA Volume Two refers to AS 1170.4:2018. The design of houses and minor buildings (Importance 2) in Australia shall be based on earthquake loads with a Probability of Exceedance of 1 : 500.

Peak Ground Acceleration, adjusted for Probability of Exceedance **k_p z** (Where k_p = 1.0)		
Country	**Location**	**Probability of Exceedance** **1 : 500**
Australia	As per AS 1170.4 Table 3.2 and Fig 3.2	
	Mekering region (Ranges from 0.14 to 0.22)	0.22
	Tennant Creek	0.13
	Newcastle, Bundaberg	0.11
	Adelaide, Wyong	0.10
	Darwin, Geraldton, Gladstone, Wyndham, Wollongong, Whyalla	0.09
	All other locations	0.08

Earthquake Hazard Factors for New Zealand

The New Zealand building regulations refer to NZS 1170.5:2004. The design of houses and minor buildings (Importance 2) in New Zealand shall be based on earthquake loads with a Probability of Exceedance of 1 : 500.

Peak Ground Acceleration, adjusted for Probability of Exceedance k_p z (Where k_p = 1.0)		
Country	**Location**	**Probability of Exceedance**
		1 : 500
New Zealand	As per NZS 1170.5 Table 3.3 and Figs 3.3, 3.4, 3.5	
	Auckland, Dunedin, Palmerston	0.13
	Hamilton, Akaroa	0.16
	Christchurch	0.22
	Wellington, Seddon, Hutt Valley, Ward, Cheviot, Otaki	0.40
	Otira, Arthurs Pass (maximum value)	0.60

Discussion:

NZS 1170.5 - Commentary

C3.1.4 Hazard factor

The hazard factor Z has been derived as 0.5 times the magnitude-weighted (Idriss, Ref. 14) 5% damped response spectrum acceleration for 0.5 s period for site class C (shallow soil) that has a return period of 500 years. It corresponds to the value in g of the peak ground acceleration (corresponding to 0.0 s period) for site classes A and B (rock) for R = I. The range of Z has been limited by a lower bound of 0.13. The Z-values have been spatially smoothed over a distance of 10 from the values resulting directly from the hazard analysis. The selection of the period of 0.5 s to normalize the hazard spectra is a change from New Zealand Standard NZS 4203, which used 0.2 s. The unusual selection of the mid-period value of 0.5 s for the normalization provided sufficiently small variations over the country between the code spectra and the 500-year magnitude-weighted spectra of the hazard study to allow spectra to be defined from the values at only one normalization period, rather than two as in recent U.S. codes (UBC, 1997, Ref. 16, NEHRP, 2000, Ref. 13, and IBC, 2000, Ref. 15)

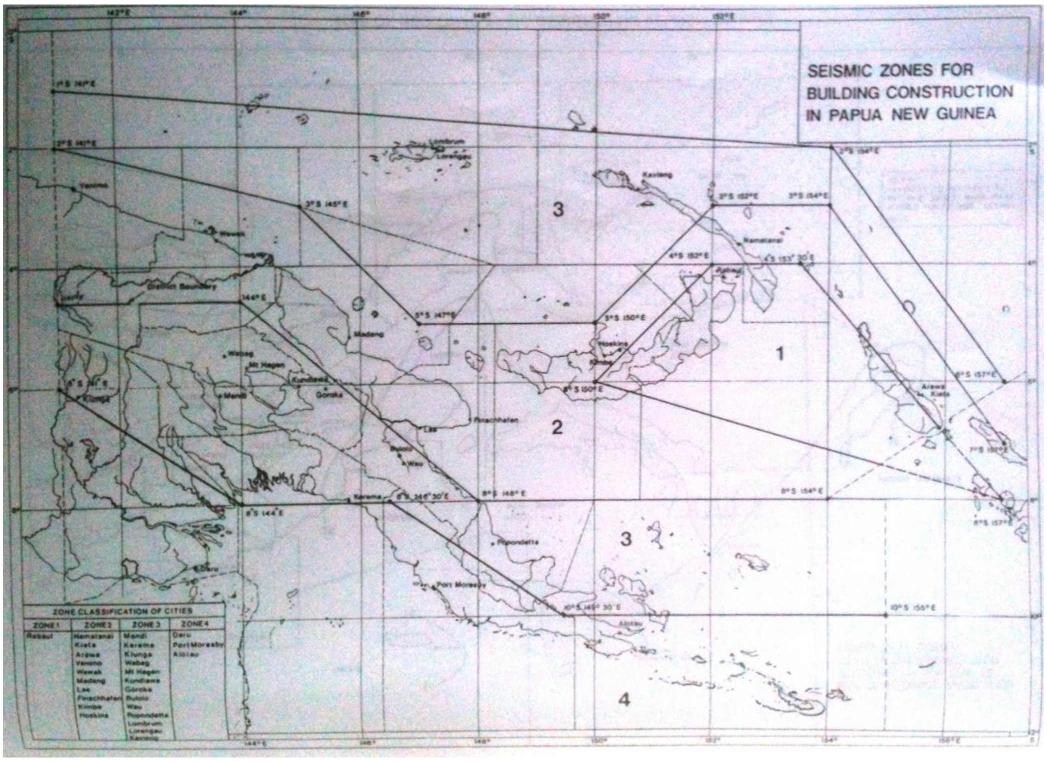
Earthquake Hazard Factors for Papua New Guinea

The Papua New Guinea Building Code has the following earthquake design requirements for an Annual Probability of Exceedance of 1 : 500.

Peak Ground Acceleration, adjusted for Probability of Exceedance $k_p\ z$			
Location		**Probability of Exceedance**	
		1 : 500	1 : 250
Papua New Guinea	Zone 1 (Extremely High Hazard) – Bougainville, Eastern and Central New Britain, Southern New Ireland (Includes Rabaul)	1.00	0.75
	Zone 2 (Moderately High Hazard) – Northern coast of the mainland, Western New Britain, Central New Ireland, Lihir Group (Includes Namatani, Kieta, Arawa, Vanimo, Wewak, Madang, Lae, Finchhafen, Kimbe, Hoskins)	0.40	0.30
	Zone 3 (Moderate Hazard) – Central region of the mainland, Northern Province, D'Entrecasteaux and Trobriand Islands, Northern New Ireland and Admiralty Islands (Includes Mendi, Kerema, Klunga,Wabag, Mt Hagen, Kundiawa, Goroko, Bulolo, Wau, Popondetta, Lombrum, Lorengau, Kayieng)	0.24	0.18
	Zone 4 (Very Low Hazard) – Papuan Peninsula - Louisiade Archipelago and St. Mathias Group (Includes Daru, Port Moresby, Alotau)	0.16	0.12

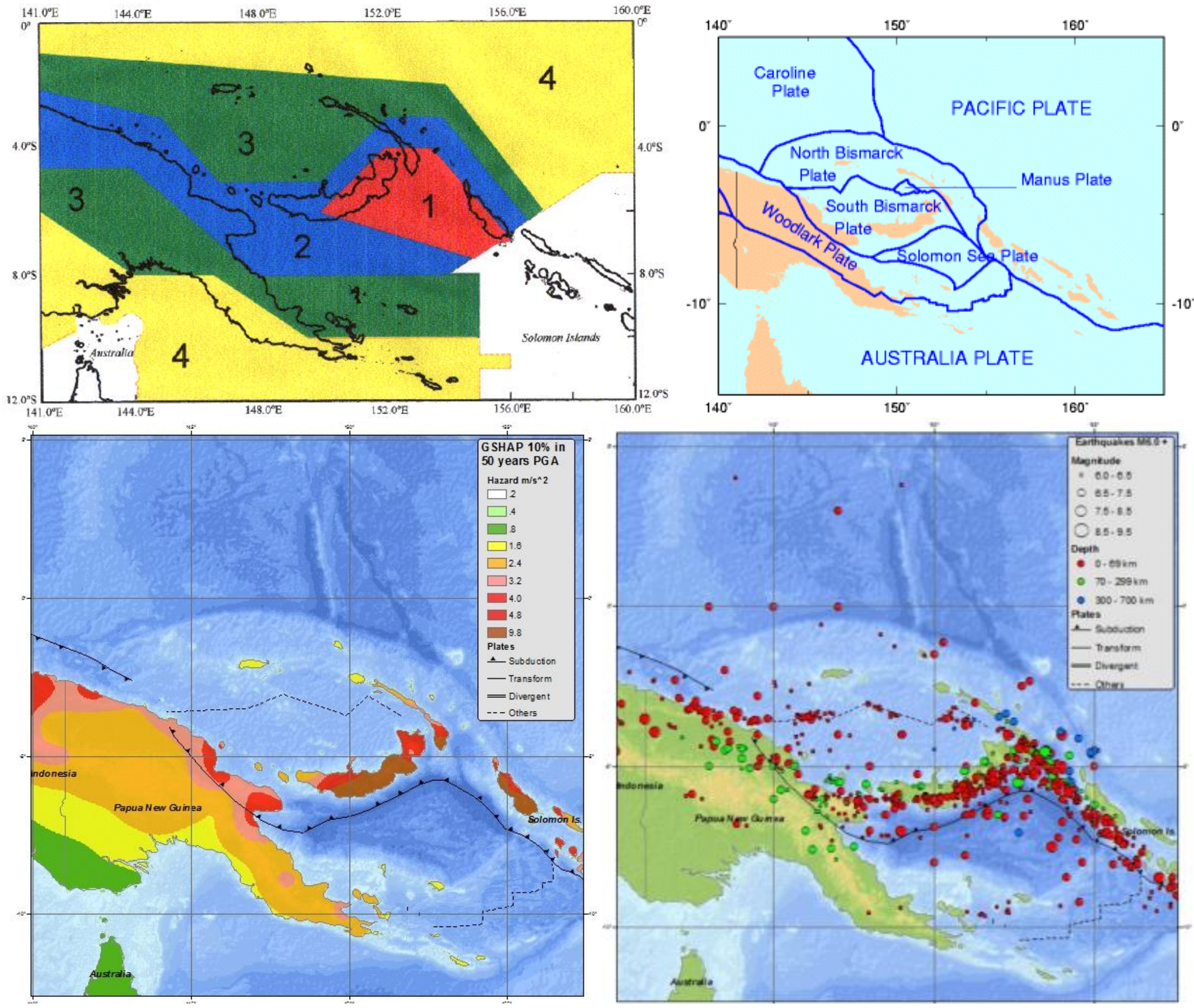
Note:

1. If the design life of a structure such as a village house or similar is (say) 25 years, a Hazard Factor (Z) corresponding to Peak Ground Acceleration with an Annual Probability of Exceedance of (say) 1 : 250 (10% in 25 years) may be more appropriate than the published Hazard Factors (Z) for Peak Ground Acceleration with an Annual Probability of Exceedance of 1 in 500 (10% in 50 years). To convert from 1 in 500 to 1 in 250, the published 1 in 500 hazard factors must be multiplied by a factor of kp = 0.75 in accordance with AS/NZS 1170.4 Table 3.1.



Discussion:

The following maps provide context to the PNG Building Code. It is important to note that these maps and the Code requirements predate the 2018 Southern Highlands earthquake of magnitude 7.5.



Generalised Seismic Hazard Zones of PNG - (Modified from the PNG National Standards Council, 1983)

Zone 1 (Extremely High Hazard) – Bougainville, Eastern and Central New Britain, Southern New Ireland

Zone 2 (Moderately High Hazard) – Northern coast of the mainland, Western New Britain, Central New Ireland, Lihir Group

Zone 3 (Moderate Hazard) – Central region of the mainland, Northern Province, D'Entrecasteaux and Trobriand Islands, Northern New Ireland and Admiralty Islands

Zone 4 (Very Low Hazard) – Papuan Peninsula - Louisiade Archipelago and St. Mathias Group Hazard map of PNG

References: Geosciences Australia; Anton, L., "Earthquake and Tsunami Hazard Mitigation in Papua New Guinea"; Geological Survey of Papua New Guinea; Papua New Guinea Building Regulation 1994

Earthquake Hazard Factors for Solomon Islands

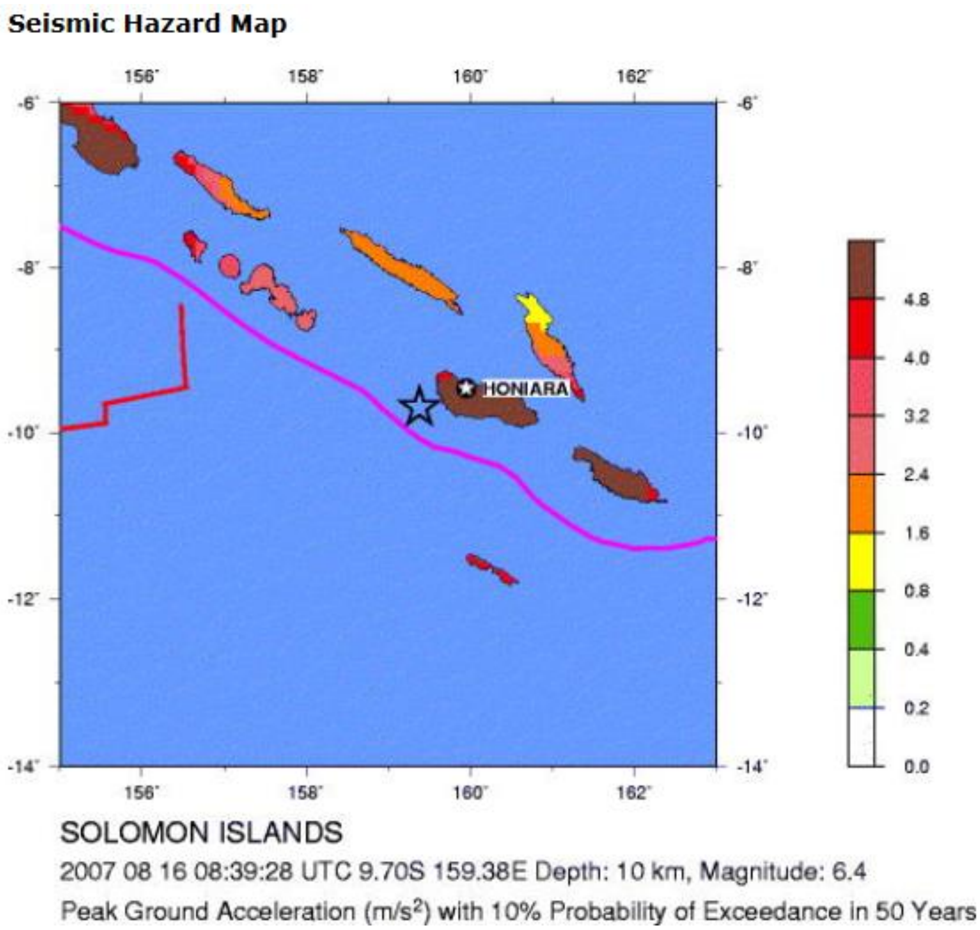
Peak Ground Acceleration, adjusted for Probability of Exceedance k_p z			
Country	**Location**	**Probability of Exceedance**	
		1 : 500	1 : 250
Solomon Islands	Eastern Province	0.80	0.60
	Guadalcanal	0.60	0.45
	Rest of Solomon Islands	0.50	0.37

Notes

1. The values given in this table are for buildings of Importance 1 and 2 only, and are estimates from various sources and maps provided in this handbook, together with the approach taken for Fiji, Tonga and Papua New Guinea.
2. The values for all countries should be checked against the requirements of local building regulations.
3. If the design life of a structure such as a village house or similar is (say) 25 years, a Hazard Factor (Z) corresponding to Peak Ground Acceleration with an Annual Probability of Exceedance of (say) 1 : 250 (10% in 25 years) may be more appropriate than the published Hazard Factors (Z) for Peak Ground Acceleration with an Annual Probability of Exceedance of 1 in 500 (10% in 50 years). To convert from 1 in 500 to 1 in 250, the published 1 in 500 hazard factors must be multiplied by a factor of kp = 0.75 in accordance with AS/NZS 1170.4 Table 3.1.

Discussion

The following maps provide context.



Reference: http://neic.usgs.gov/neis/eq_depot/2007/eq_070816_gccj/neic_gccj_w.html

Earthquake Hazard Factors for Vanuatu

Peak Ground Acceleration, adjusted for Probability of Exceedance $k_p\ z$			
Location		**Probability of Exceedance**	
		1 : 500	1 : 250
Vanuatu		1.00	0.75

Notes

1. The values given in this table are for buildings of Importance 1 and 2 only, and are estimates from various sources and maps provided in this handbook, together with the approach taken for Fiji, Tonga and Papua New Guinea.
2. The values for all countries should be checked against the requirements of local building regulations.
3. If the design life of a structure such as a village house or similar is (say) 25 years, a Hazard Factor (Z) corresponding to Peak Ground Acceleration with an Annual Probability of Exceedance of (say) 1 : 250 (10% in 25 years) may be more appropriate than the published Hazard Factors (Z) for Peak Ground Acceleration with an Annual Probability of Exceedance of 1 in 500 (10% in 50 years). To convert from 1 in 500 to 1 in 250, the published 1 in 500 hazard factors must be multiplied by a factor of kp = 0.75 in accordance with AS/NZS 1170.4 Table 3.1.

Discussion

The following maps provide context.

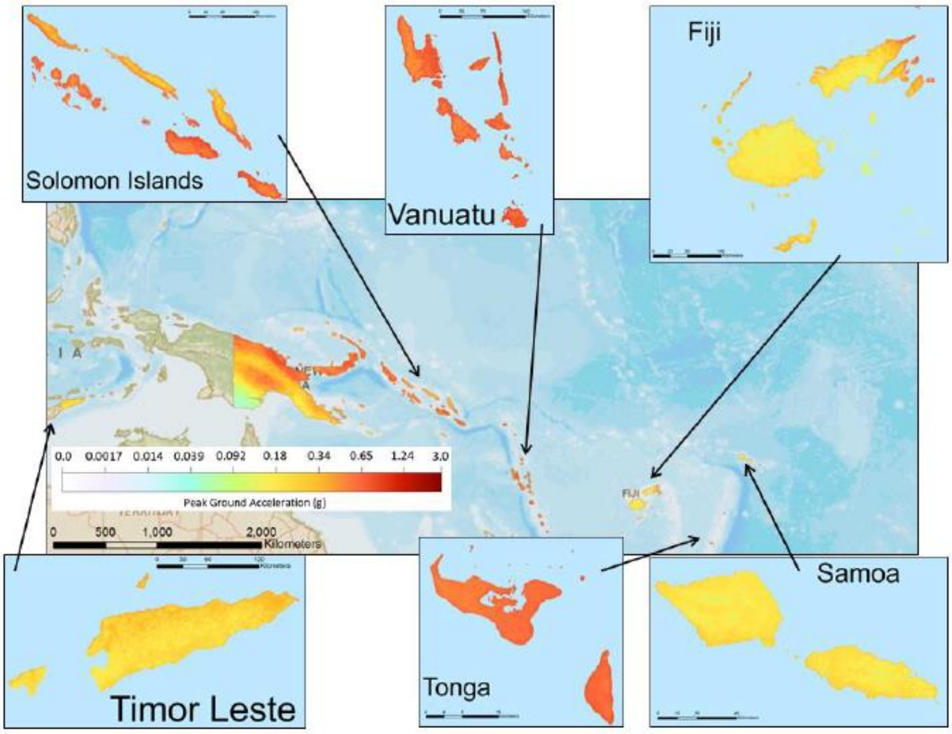


Figure 9. Map of free surface PGA, including site conditions, with 10% probability of exceedance in 50 years (475-year mean return period) for some of the Pacific Island Countries.

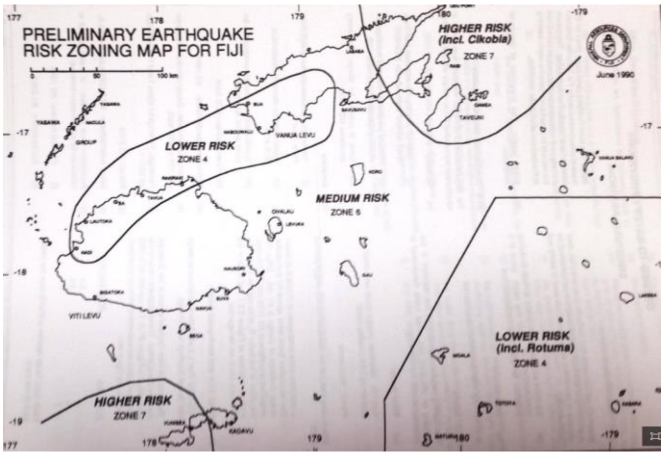
Y. Rong, Y, Park, J, Duggan, D, Mahdyiar, M and Bazzurro, P., *Probabilistic Seismic Hazard Assessment for Pacific Island Countries* 15 WCEE Lisboa, 2012

http://earthquake.usgs.gov/earthquakes/world/png/gshap.php

Earthquake Hazard Factors for Fiji

The Fiji National Building Code -1990 Part B1.2 (b) has the following requirements:

> *Dead, Live and earthquake loads: NZS4203 Part 1, 2 and 3 General structural design and design loadings for buildings. The maps of New Zealand shown in the Standard are to be disregarded. The earthquake zones for Fiji are marked in Figure B1.2. For use with NSZ 4203 the zone factors corresponding to the zone numbers given in the figure are:*
>
> | *ZONE NO.* | *ZONE FACTOR* |
> |---|---|
> | *4* | *0.4* |
> | *6* | *0.6* |
> | *7* | *0.7* |
>
> *Each zone factor applies uniformly over the whole area of the zone.*
>
> *Note: The zone numbers have been given on the basis of consistent values for Fiji, Vanuatu, Solomon Islands, Cook Islands, Tuvalu and Niue. This means that any particular zone number such as zone 6 and the value of its zone factor, have the same meaning in the codes of all these countries.*



National Building Code -1990 Figure B1.2

Peak Ground Acceleration, adjusted for Probability of Exceedance
k_p z

Country	**Location**	**Probability of Exceedance** 1 : 500	1 : 250
Fiji	Refer to Fiji Building Code Map. High Risk - East Vanua Levu, south-western islands Medium Risk – East & central Viti Levu, north-eastern islands North-western Viti Levu and south-western Vanua Levu	 0.70 0.60 0.40	 0.53 0.45 0.30

Notes:

The values for an Annual Probability of Exceedance of 1 in 250 are calculated using AS 1170.4:2007

The following alternative values have been suggested for Fiji:

West Vanua Levu	1:500 - 0.60,	1:250 - 0.45
Central and east Vanua Levu and north-eastern islands	1:500 - 0.40,	1:250 - 0.30
Viti Levu and south-eastern islands	1:500 - 0.24,	1:250 - 0.18

Discussion:

Based on the GNS Science Hazard Map and extracts below, it is suggested that t the more recent seismic hazard map, published by GNS Science, may be more appropriate in lieu of the preliminary hazard map in the current Fiji Building Code.

The following extract forms the basis of this observation.

Stirling, M.W. , Horspool, N.A., & Gerstenberger, M.C. *Recent Seismic Hazard Studies in SE Asia, Pacific, and USA ,* 2015 NZSEE Conference

GNS Science, Lower Hutt, New Zealand P.H. Nguyen Institute of Geophysics, Hanoi, Vietnam

*2 FIJI Z-FACTOR We have developed a probabilistic seismic hazard (PSH) model for Fiji (Stirling et al.2014), and produced a map of the hazard factor Z (Fig. 1) according to the NZS1170.5 definition of the Z-factor (Standards New Zealand, 2004). The NZS1170.5 Z-factor is defined as half the 0.5 second spectral acceleration (0.5 * SA(0.5s)) expected with a 10% probability of exceedance in 50 years (equivalent to a 500 year return period) on shallow soil sites. The use of a Next Generation Attenuation (NGA) model for Fiji has required the Class C site conditions to be approximated by an average shear-wave velocity to 30m depth (Vs30) of 450m/s. The PSH model is based on a gridded seismicity model that is developed from the 1960-2009 component of the International Seismicity Catalogue of the Global Earthquake Model (ISC-GEM; globalquakemodel.org). Prior to developing the Z-factor map we briefly evaluated the suitability of the NZS1170.5 code spectral shape for Fiji by comparing the unsmoothed 500 year Class C spectrum for the city of Suva to the NZS1170.5 spectrum, and also to the Australian AS1170.4 and International Building Code (IBC) spectra (Fig. 2). These code spectra have different spectral shapes and, in the case of IBC, alternative hazard parameters for their construction. We found that neither AS1170.4 or IBC code spectra provide a better match to the unsmoothed spectrum than the NZS1170.5 spectrum (Fig. 2), so the NZS1170.5-based Z-factor definition has been used to construct the Z-factor map and associated spectra. The Z-factor map shows hazard that is lowest in the southeast of Fiji, and progressively increasing to the north and northwest (Fig. 1).*

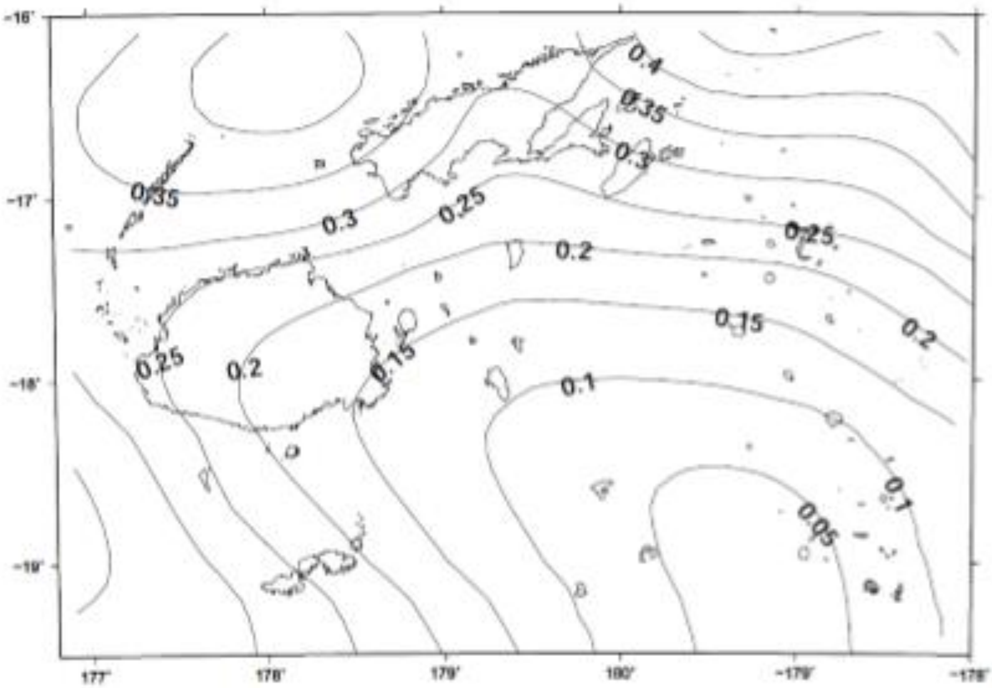


Figure 1. Z-factor map for Fiji. Accelerations are in units of g. See the text for further explanation.

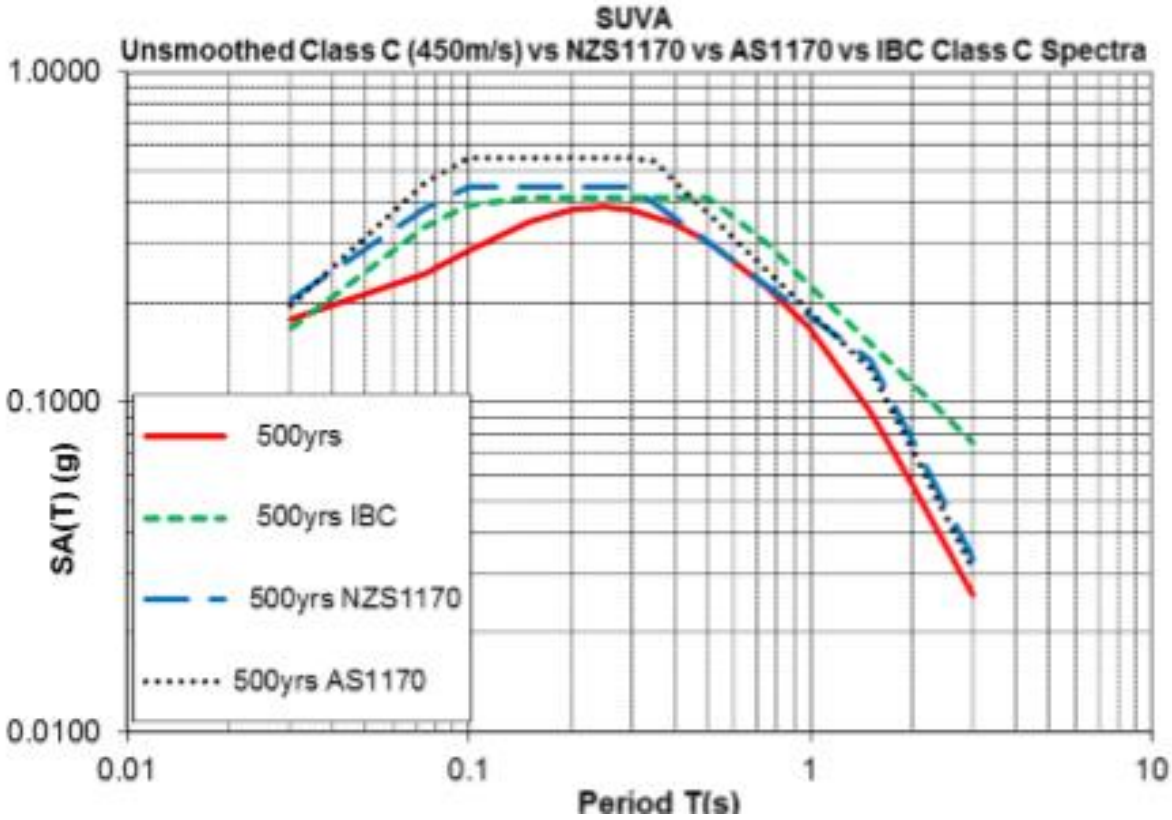


Figure 2. Unsmoothed horizontal Class C spectrum for the 500 year return period for Suva, with modified NZS1170.5, AS1170.4, and IBC code spectra shown for comparison. Note that SA(0.0s) is plotted at 0.03s as the plot is log-log.

Earthquake Hazard Factors for Tonga

The Tonga National Building Code 2007 states:

> *The seismic provisions of the California Building Code – 1998. Ignore all other provisions of the Code. The seismic zone factor Z is **0.4** (same as for San Francisco).*
>
> *As an alternative, AS 1170.4 – 1993 – Minimum design loads on structures – Earthquake loads, may be used using an "a" value of **0.4** (equivalent to California Building Code Z = 0.4)*

Discussion:

Based on the maps below, one would expect the ground acceleration with a 10% probability of exceedance in 50 years (Z), to be of the order of 0.8. However the Tonga National Building Code 2007 requires design to be based on Z = 0.4, inferring an acceptance of risk higher than 10% in 50 years.

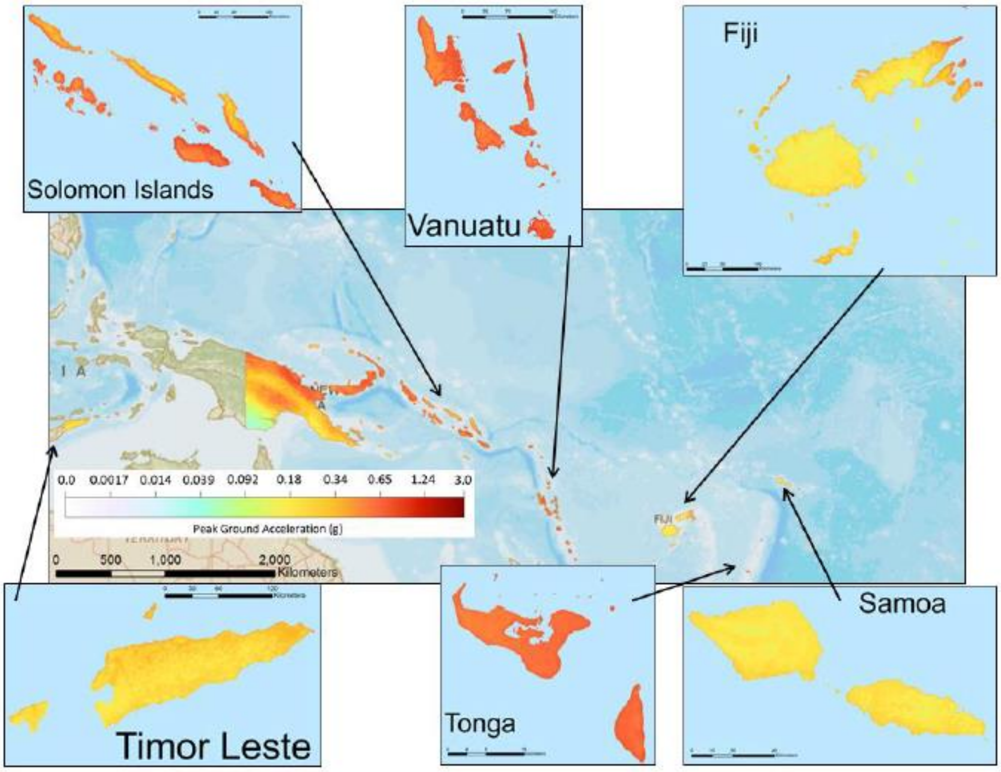


Figure 9. Map of free surface PGA, including site conditions, with 10% probability of exceedance in 50 years (475-year mean return period) for some of the Pacific Island Countries.

Y. Rong, Y, Park, J, Duggan, D, Mahdyiar, M and Bazzurro, P., *Probabilistic Seismic Hazard Assessment for Pacific Island Countries* 15 WCEE Lisboa, 2012

http://earthquake.usgs.gov/earthquakes/world/png/gshap.php

Earthquake Hazard Factors for Other South Pacific Countries

<table>
<tr><th colspan="4">Peak Ground Acceleration, adjusted for Probability of Exceedance
k_p z</th></tr>
<tr><th rowspan="2">Country</th><th rowspan="2">Location</th><th colspan="2">Probability of Exceedance</th></tr>
<tr><th>1 : 500</th><th>1 : 250</th></tr>
<tr><td>Cook Islands</td><td></td><td>0.10</td><td>0.075</td></tr>
<tr><td>French Polynesia</td><td></td><td>0.10</td><td>0.075</td></tr>
<tr><td>Kiribati</td><td></td><td>0.10</td><td>0.075</td></tr>
<tr><td>Nauru</td><td></td><td>0.10</td><td>0.075</td></tr>
<tr><td>New Caledonia</td><td>North-eastern islands
Main island</td><td>0.40
0.16</td><td>0.30
0.12</td></tr>
<tr><td>Niue</td><td></td><td>0.10</td><td>0.075</td></tr>
<tr><td>Samoa</td><td></td><td>0.16</td><td>0.12</td></tr>
<tr><td>American Samoa</td><td></td><td>0.24</td><td>0.18</td></tr>
<tr><td>Tuvalu</td><td></td><td>0.10</td><td>0.075</td></tr>
<tr><td>Wallis and Futuna</td><td>Wallis
Futuna</td><td>0.60
0.20</td><td>0.45
0.15</td></tr>
</table>

Notes

1. The values given in this table are for buildings of Importance 1 and 2 only, and are estimates from various sources and maps provided in this handbook, together with the approach taken for Fiji, Tonga and Papua New Guinea.
2. The values for all countries should be checked against the requirements of local building regulations.
3. For islands that are at least 200 km from the plate boundaries, and for which there is little data available. As an interim measure, a default value of 0.08 is assumed for the Peak Ground Acceleration for Probability of Exceedance or 1 : 500. These values are shown in red.
4. If the design life of a structure such as a village house or similar is (say) 25 years, a Hazard Factor (Z) corresponding to Peak Ground Acceleration with an Annual Probability of Exceedance of (say) 1 : 250 (10% in 25 years) may be more appropriate than the published Hazard Factors (Z) for Peak Ground Acceleration with an Annual Probability of Exceedance of 1 in 500 (10% in 50 years). To convert from 1 in 500 to 1 in 250, the published 1 in 500 hazard factors must be multiplied by a factor of kp = 0.75 in accordance with AS/NZS 1170.4 Table 3.1.

This policy provides ultimate limit state loads, based on the following assumptions:

- Analysis shall be consistent with AS 1170.4, except as follows.
- Hazard factors shall be determined from the relevant Building Regulations or, if appropriate estimated from published data, some of which is shown below.
- The values shown in the maps below correspond to the Peak Ground Acceleration with a Probability of Exceedance of 10% in 50 years (i.e. 1 : 500).

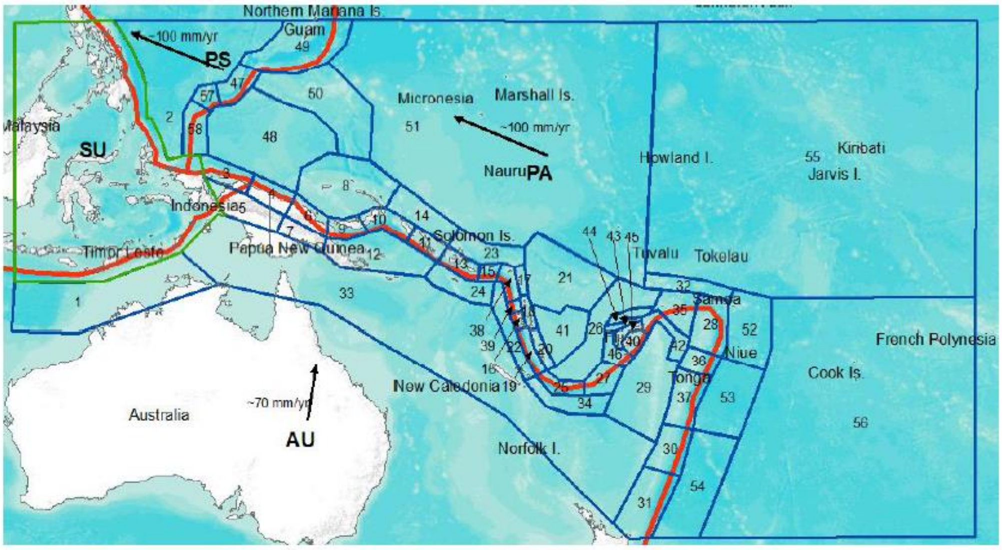
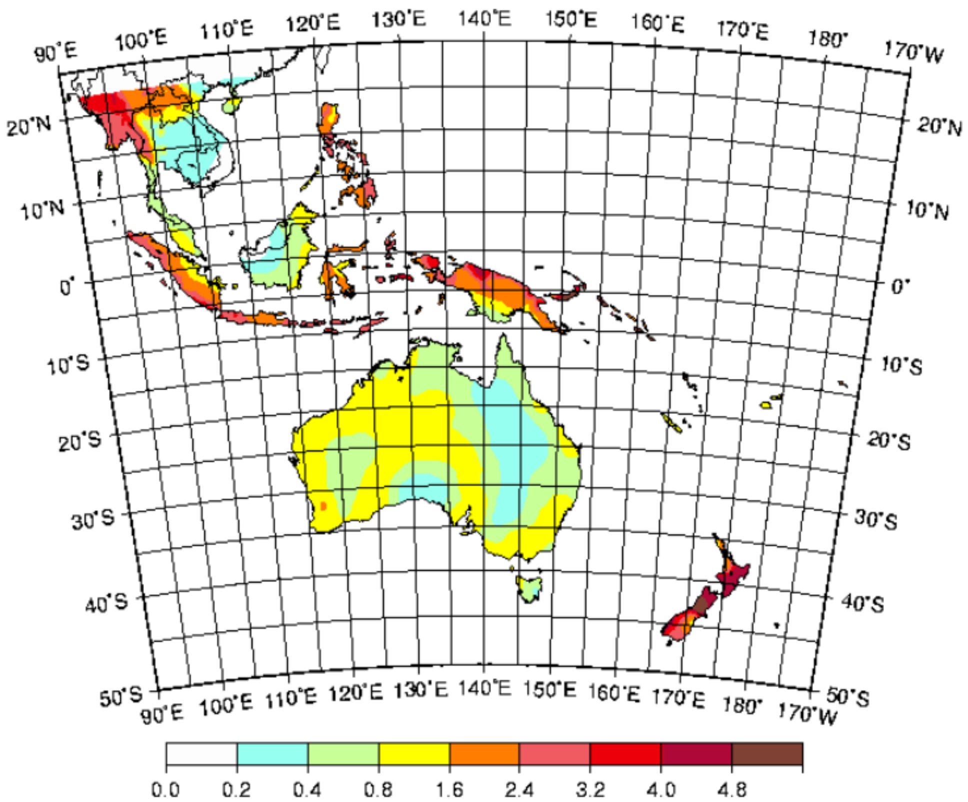


Figure 1. Regional tectonic setting and seismic source zones in the South Pacific region.Thick red lines indicate the major plate boundaries between the four major plates: Pacific (PA), Philippine Sea (PS), Sunda (SU), and Australia (AU) plates. Thick black arrows illustrate the movement of the PA, PS, and AU plates relative to the SU plate (Bird, 2003). The source zones are illustrated by blue polygons, and the numbers are the zone IDs. The area in the green polygon was covered by the AIR Southeast Asia earthquake model.

Reference: Y. Rong, Y, Park, J, Duggan, D, Mahdyiar, M and Bazzurro, P., *Probabilistic Seismic Hazard Assessment for Pacific Island Countries* 15 WCEE Lisboa, 2012

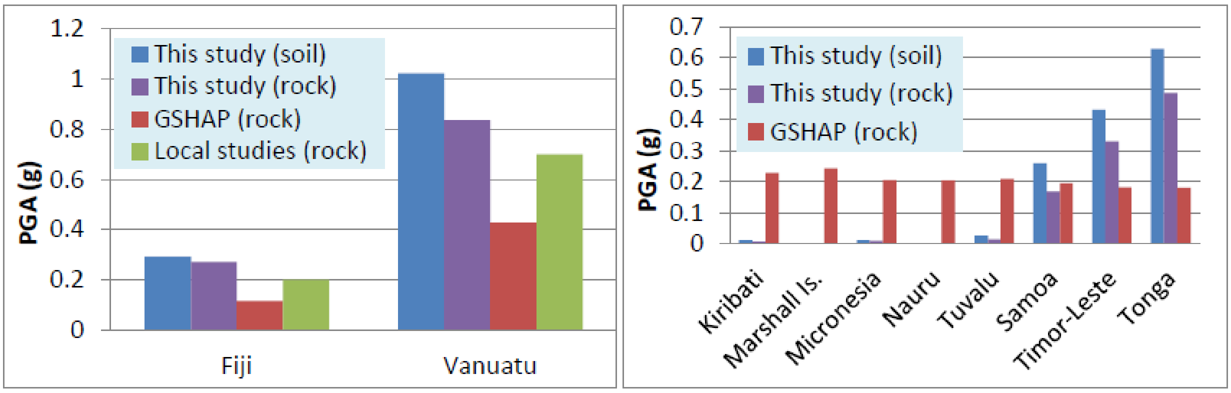


Peak Ground Acceleration with a Probability of Exceedance of 10% in 50 years (i.e. 1 : 500)

References:

McCue, K., "Seismic hazard mapping in Australia, the South-west Pacific and South-east Asia" Global Seismic Hazard Assessment Program, Geoscience Australia

http://www.seismo.ethz.ch/static/GSHAP/swpacific/swpac.gif



(a) (b)

Figure 10. Expected PGA (g), with a 10% probability of exceedance in 50 years (475-year mean return period), at the capitals of some of the PICs. The blue and purple bars are PGA values from this study with and without site conditions accounted for, respectively. The red bars are PGA values by GSHAP. The green bars in (a) are the results of local studies (Jones 1998 for Fiji; Suckale and Grünthal 2009 for Vanuatu).

Y. Rong, Y, Park, J, Duggan, D, Mahdyiar, M and Bazzurro, P., *Probabilistic Seismic Hazard Assessment for Pacific Island Countries* 15 WCEE Lisboa, 2012

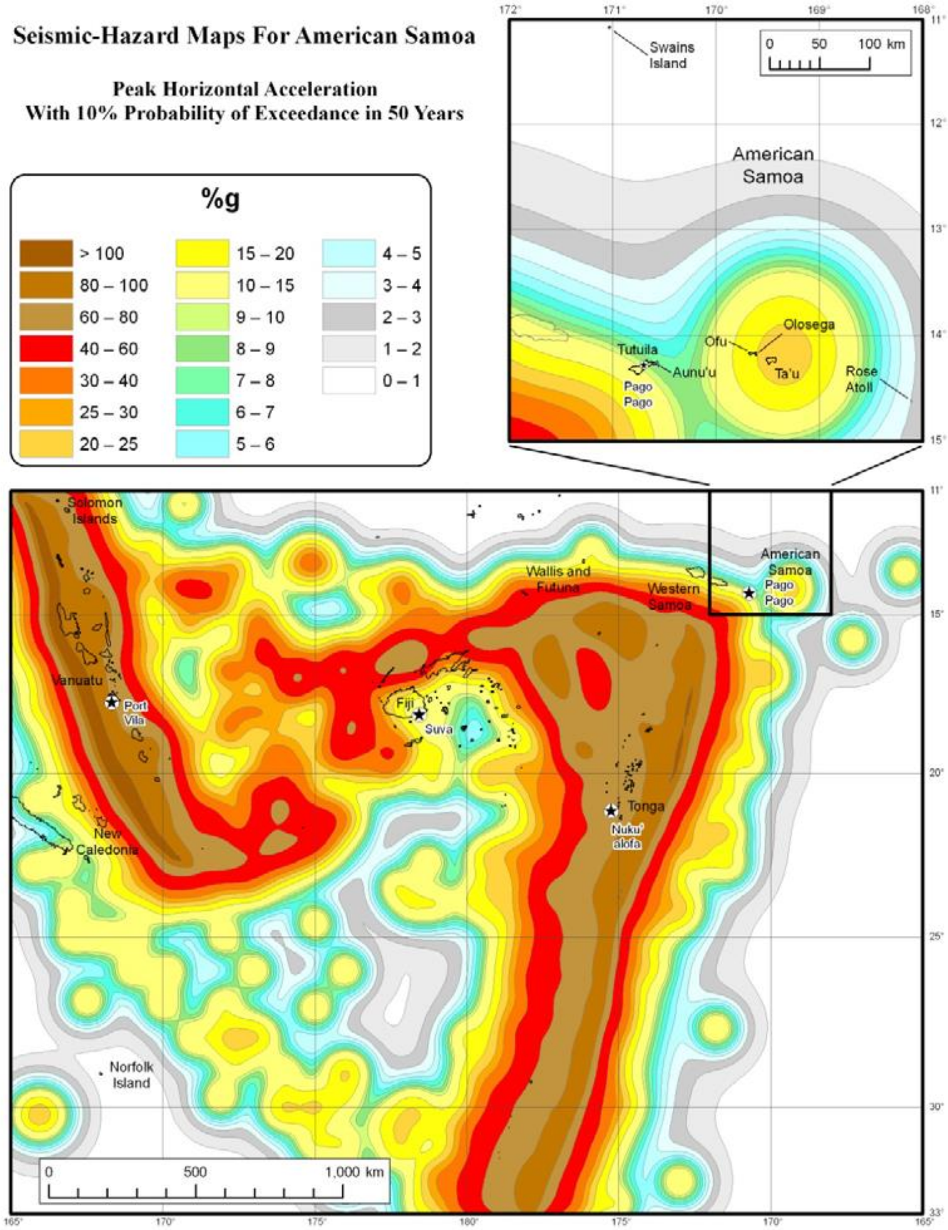
http://earthquake.usgs.gov/earthquakes/world/png/gshap.php

6. DISCUSSION

Figure 10 compares the hazard results from this study and the corresponding results from earlier studies. It shows that:

- *In general, our estimates of the 475-year mean return period rock PGA values are closer to the results from the detailed local studies than to those from the GSHAP study.*
- *Historical seismicity in the neighborhood of the PICs does not explain the very similar 475-year rock PGA estimates for Kiribati, Marshall Islands, Micronesia, Nauru, Tuvalu, Samoa, Timor-Leste, and Tonga in the GSHAP study (Figure 10b) because: (1) Tonga is on the seismically active Tonga subduction zone, while Tuvalu, Kiribati, Marshall Islands, and Nauru are not only far from the regional subduction zones but are also located in seismically inactive areas; (2) Samoa is located at about 130 km north of the northern tip of the Tonga subduction zone; and (3) Timor-Leste is in the middle of the seismically active Timor and Banda Sea trenches. The relative difference in the seismic hazard is correctly reflected in the PGA estimates from this study.*
- *It is important to account for site conditions in seismic hazard analysis. Based on the results from this study, the hazard with site conditions considered is about 20-30% higher than the rock hazard at the capitals of Vanuatu, Tonga, Timor-Leste and Micronesia, about 50% higher at the capital of Samoa, and more than 80% higher at the capitals of Tuvalu and Kiribati.*

The seismic hazard maps presented here have sufficient details to be used in local seismic risk studies and were developed using the current state of practice in probabilistic seismic hazard assessment. The large differences between this study and GSHAP can be attributed to the combined impact of differences in earthquake source models, GMPEs, site conditions, and the details of the hazard calculations.



Reference: Petersen, M.D., Harmsen, S.C., Rukstales, K.S., Mueller, C.S., McNamara, D.E., Luco, Nicolas, and Walling, Melanie, 2012, Seismic hazard of American Samoa and Neighboring South Pacific Islands—Methods, data, parameters, and results: U.S. Geological Survey Open-File Report 2012–1087, 98 p.

Notes on Tsunami Loads

Sites shall be analysed to determine whether they are prone to tsunamis, giving consideration to the following:

Distance from high water mark, T_{dhw} (km)

Height of finished floor above mean sea level, T_{ffl} (m)

Distance from high earthquake area (Z > 0.4), T_{equ} (km)

Site specific exposure, T_{exp} (2 is maximum risk; 1 is normal risk, 0 is no risk)

Tsunami risk factor (10 is maximum risk; 0 is no risk)

R_t =IF(T_{dhw}>2,0,IF(T_{ffl}>20,0,IF(T_{equ}>1000,0, T_{exp} *5/(MAX(T_{dhw},0.2)*MAX(T_{ffl},1)*MAX(T_{equ} /100,5)))))

Design strategy

IF(R_t <1,"No design required",IF(R_t <5,"Design structure","Move structure"))

For structures that are required to be designed for tsunami (except those that should be moved), analysis shall be in accordance with the method in Australian Building Codes Board Handbook, *Construction of Buildings in Flood Hazard Areas* for velocity equal to the maximum of the calculated risk factor (m/s) or 1.5 m/s.

Structural components shall be designed to withstand the design event, assuming that the cladding is destroyed. Remaining cladding and other water-borne material, of a combined area equal to 20% of the building elevation area facing the tsunami shall be assumed for determination of the tsunami forces. It is also assumed that the water flows at depth numerically equal to the risk factor (m).

The following map for South-east Asia tsunamis is included to give a typical indication for the wave heights for a Probability of Exceedance of 1 in 500. While this information is not transferrable to the South Pacific, it does give a feel for the possible magnitude of tsunamis.

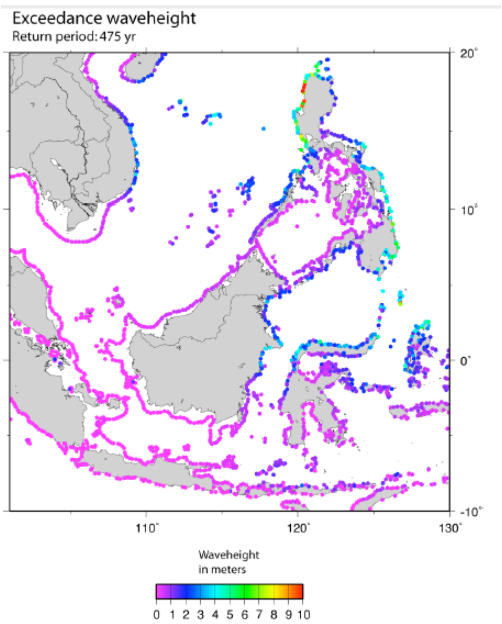


Figure 6. Probabilistic tsunami hazard map for Southeast Asia showing the peak wave height exceedance levels for 475 year return period. These results are based on earthquake sources in the Pacific Ocean only. The hazard on the Indian Ocean side of the Indonesian archipelago is therefore underestimated. Source: Report to Tokio Marine & Nichido Risk Consulting Co. Ltd., 2006.

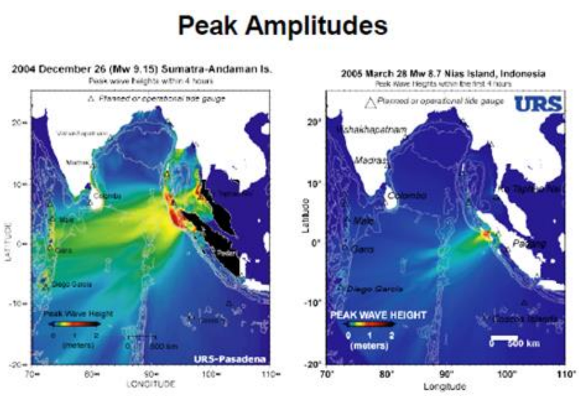


Figure 3. Peak calculated wave heights for the December 2004 (left) and March 2005 (right) Sumatra tsunamis.

Notes on Flood Loads

Sites shall be analysed to determine whether they are prone to flooding, giving consideration to the following:

Distance to closest water course, F_{dwc} (m)

Height of finished floor above normal level of water course, F_{ffl} (m)

Catchment area, F_{cat} (km^2)

Concentration of catchment runoff past structure, F_{con} (2 is maximum; 1 is normal, 0 is no risk)

Flooding risk factor (10 is maximum risk; 0 is no risk)

R_f =IF(F_{dwc} >200,0,IF(F_{ffl} >10,0,IF(F_{cat} <1,0, F_{con} *MIN(F_{dwc},100)/(MAX(F_{dwc},10)*MAX(F_{ffl},2)))))

Design strategy

IF(R_f <1,"No design required",IF(R_f <5,"Design structure","Move structure"))

For structures that are required to be designed for flood (except those that should be moved), analysis shall be in accordance with the method in Australian Building Codes Board Handbook, *Construction of Buildings in Flood Hazard Areas* for a velocity equal to the maximum of the calculated risk factor (m/s) or 1.5 m/s.

Structural components shall be designed to withstand the design event, assuming that 100% of the cladding remains intact and the water flows at depth calculated from the topography.

Notes on Soil Properties

For purposes of designing concrete slab-on-ground, concrete pad footings or concrete strip footings, sites shall be classified in accordance with AS 2870. Design of concrete slab-on-ground, concrete pad footings or concrete strip footings shall be in accordance with AS 2870. Determination of soil pressures and capacity reduction factors for earth retaining structures, or similar, shall in accordance with AS 4678. Design of earth retaining structures shall in accordance with AS 4678. AS 4768 Table D4 gives the following typical soil properties.

Soil Description	Characteristic Cohesion c' kPa	Characteristic internal friction angle ϕ' (degrees)
Soft and firm clay of medium to high plasticity, silty clays, loose variable clayey fill, loose sandy silts	0 to 5	17 to 25
Stiff sandy clays, gravelly clays, compact clayey sands and sandy silts, compacted clay fill (Class II)	0 to 10	26 to 32
Gravelly sands, compacted sands, controlled crushed sandstone and gravel fills (Class I), dense well-graded sands	0 to 5	32 to 37
Weak weathered rock, controlled fills (Class I) of road base, gravel and recycled concrete	0 to 25	36 to 43
Notes: Characteristic values are conservative estimates of the mean.		

Derivation of Characteristic Ultimate Bearing Capacity

Effective width of bearing pad, B'

Terzaghi Factors

$N_q = e^{\pi \tan \phi^*f} \tan^2 [\pi/4 + \phi^*_f /2]$

$N_c = (N_q - 1) \cot \phi^*_f$

$N_\gamma = 2 (N_q + 1) \tan \phi^*_f$

Shape factors

$\xi_c = 1.0$

$\xi_q = 1.0$

$\xi_\gamma = 1.0$

Factors for inclined load

$\xi_{qi} = [1 - P_H / (P_v + B' c^*_f \cot \phi^*_f)]^2$

$\xi_{ci} = \xi_{qi} - (1 - \xi_{qi}) / (N_c \tan \phi^*_f)$

$\xi_{\gamma i} = [1 - P_H / (P_v + B' c \cot \phi^*_f)]^3$

Factors for sloping bases

$\xi_{qt} = (1 - \alpha \tan \phi^*_f)^2 = 1.0$ for level base

$\xi_{ct} = \xi_{qt} - (1 - \xi_{qt}) / (N_c \tan \phi^*_f) = 1.0$ for level base

$\xi_{\gamma t} = (1 - \alpha \tan \phi^*_f)^2 = 1.0$ for level base

Average bearing capacity based on factored soil properties

$q_{av} = c N_c \xi_c \xi_{ci} \xi_{ct} + \gamma (H_{emb} + H_{bp}) N_q \xi_q \xi_{qi} \xi_{qt} + 0.5 \gamma B N_\gamma \xi_\gamma \xi_{\gamma i} \xi_{\gamma t}$

Bearing capacity of the foundation

$P_{v\ cap} = q_{av} B'$

Based on this information, the following properties are assumed for various soils classified in accordance with AS2870. The following assumptions have been used.

1. Characteristic internal friction angles and characteristic cohesions are conservative estimates of the mean values for the particular soil type, without capacity reduction factors.
2. Characteristic bearing capacities are determined using values for internal friction angle that have been factored in accordance with AS 4678 for in-situ soil.
3. Characteristic bearing capacities have been calculated by the Terzaghi method, for vertical concentric load on 450 mm wide strip footings buried not less than 300 mm deep on undisturbed in-situ soil.

Australia, New Zealand and Papua New Guinea

It is assumed that, due to the geological diversity of these countries, all of the following soil types are possible.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36^o	0 kPa	1060 kPa
Slightly reactive clay	S	30^o	3 kPa	670 kPa
Moderately reactive clay	M	27^o	6 kPa	640 kPa
Highly reactive clay	H1	24^o	9 kPa	609 kPa
Highly reactive clay	H2	24^o	9 kPa	609 kPa
Extremely reactive clay	E	20^o	9 kPa	150 kPa

Volcanic Islands

Sites on volcanic islands, will be assumed to have the following properties.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36^o	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27^o	6 kPa	640 kPa

Coral Atolls

Sites on islands consisting principally of coral atolls, will be assumed to have the following properties.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36^o	0 kPa	1060 kPa

References for Building Acts and Building Regulations – South Pacific

URL: *http://www.paclii.org/pg/legis/consol_act/br1994182*

Australia

National Construction Code 2014 – BCA Volume Two

Cook Islands

National Building Code for Cook Islands

Partial Commentary of the National Building Code Cook Islands

Home Building Manual Cook Islands

Cook Islands 1991 Building Controls and Standards

Cook Islands Building Controls and Standards (National Building Code) (Amendment) (No.2) Order 2005

Building Controls and Standard (National Building Code) (Amendment) (No.2) Order 2005 [32%]
(From Cook Islands Sessional Legislation; 1 January 2005

Building Controls and Standards Act 1991
(From Cook Islands Sessional Legislation;

Fiji

National Building Code for Fiji

Partial Commentary of the National Building Code Fiji

French Polynesia

Kiribati

Building Act 2006
(From Kiribati Sessional Legislation; 1 January 2006

Nauru

New Caledonia

New Zealand

Building Regulations

Niue

National Building Code for Niue

Partial Commentary of the National Building Code Niue

Home Building Manual Niue

Building Code Act 1992
(From Niue Consolidated Legislation; 1 January 1992

Papua New Guinea

Building Regulation 1994 [100%]
(From Papua New Guinea Consolidated Legislation; 1 January 1994

Building Act 1971 [51%]
(From Papua New Guinea Consolidated Legislation; 1 January 1971

Public Health Ordinance 1932-1938 - Building Regulations
(From Laws of the Territory of New Guinea 1921-1945 (Annotated)

Building Ordinance, 1929
(From Laws of the Territory of Papua 1888-1945 (Annotated)

Samoa

Ministry of Works Act 2002 [18%]
(From Consolidated Acts of Samoa 2011; 1 January 2002

American Samoa

Solomon Islands

National Building Code for Solomon Islands

Partial Commentary of the National Building Code Solomon Islands

Building Standards Ordinance 1991
(From Solomon Islands Western Province Consolidated Legislation 1999; 1 January 1991

Local Government Act - Subsidiary
(From Solomon Islands Consolidated Legislation

Tonga

Building Control and Standards Act 2002
(From Tonga Sessional Legislation; 1 January 2002

Building Code Regulations 2007 [31%]
(From Tonga Subsidiary Legislation; 1 January 2007

Tuvalu

National Building Code for Tuvalu

Partial Commentary of the National Building Code Tuvalu

Home Building Manual Tuvalu

Vanuatu

National Building Code for Vanuatu

Partial Commentary of the National Building Code Vanuatu

Wallis and Futuna

References for Load Combinations, Permanent Loads, Imposed Loads

Unless specifically stated otherwise in the relevant Building Regulations, the latest published version (including any published amendments) of the Standards specified in this policy shall be used.

Australian & New Zealand Standard AS/NZS 1170.0:2002 (Including Amendments 1, 2, 3, 4, and 5)

Australian & New Zealand Standard AS/NZS 1170.1:2002 (Including Amendments 1 and 2)

References for Wind

Australian & New Zealand Standard AS/NZS 1170.2:2011 (Including Amendments 1 and 2)

Australian Standard AS 4055:2012

Standards Australia Handbook HB212:2002

References for Earthquakes

Australian Standard AS 1170.4:2007

New Zealand Standard NZS 1170.5:2004

Anon, *Science Plan on Hazards and Disasters – Earthquakes Floods and Landslides,* ICSU Regional Office for Asia and the Pacific, 2008

Anon, *Suva Earthquake Risk Management Scenario Pilot Project (Sermp) Part I Summary Report* January 2002 South Pacific Disaster Reduction Program (Spdrp) Report

Anon, *Earthquake Intensity Risk Zones & Presence of UN/ISDR in Asia Pacific*, UN/ISDR 10 April 2008

Anton, L., *Earthquake and Tsunami Hazard Mitigation in Papua New Guinea*, Geological Survey Of Papua New Guinea, P.O. Box 323, Port Moresby, National Capital District, Papua New Guinea (p: +(675) 321 4500, f: +(675) 321 3976, e: Pmgo@Daltron.Com.Pg)

McCue, K., *Seismic hazard mapping in Australia, the South-west Pacific and South-east Asia,* ANNALI DI GEOFISICA, Vol 42, No 6, December 1999

Petersen, M.D., Harmsen, S.C., Rukstales, K.S., Mueller, C.S., McNamara, D.E., Luco, Nicolas, and Walling, M., *Seismic hazard of American Samoa and neighboring South Pacific Islands—Methods, data, parameters, and results:* 2012, U.S. Geological Survey Open-File Report 2012–1087, 98 p.

Rong, Y., Park, J., Duggan, D., Mahdyiar, M. & Bazzurro, *P. Probabilistic Seismic Hazard Assessment for Pacific Island Countries,* 15 WCEE, Lisboa 2012

Wilson, J & Lam, N., *A recommended earthquake response spectrum model for Australia*, Australian Journal of Structural Engineering, Vol 5, No 1, Institution of Engineers, Australia, 2003

Wijanto, S., *World Housing Encyclopedia Report Country: Indonesia Housing Type: Unreinforced clay brick masonry house,* 6/5/2002(Modified 7/2/2003)

References for Tsunamis and Floods

Australian Building Codes Board Handbook, *Construction of Buildings in Flood Hazard Areas*, Version 2012.2.

References for Soil Load and Movement

Australian Standard AS 2870:2011

Australian Standard AS 4678:2002 (Including Amendment 1 and 2)

General References

Johnston, R.K. (July 2001), *Australian Involvement in Constructing Affordable Housing in Developing Countries*, Deakin University, AID719

Schilderman, T. & Lowe, L., *Regulatory Issues Affecting Shelter Development by The Urban Poor*, ITDG

2. Country Design and Analysis Assumptions

The engineering design of structures should be based on professionally determined design life, annual probability of exceedance and the probability of exceedance during life of each design action. In locations where building regulations apply, this information is either specified in the building regulation, or in the relevant design standards.

Engineering design should also be based on professionally determined soil properties, permanent actions, imposed action, wind actions (including cyclonic wind), earthquake actions, tsunami actions and flood actions. When so regulated, or when the structure is of significance or importance, these properties must be determined by suitably qualified and experienced engineers.

However, many remote villages in the South Pacific are beyond regulatory coverage, the structure (houses, clinics and small school buildings) are small and present low risk to life in the case of exposure to extreme events. Due to remoteness, there may be little practical means of accurately determining from local inspection some of the listed properties.

This part provides some default design and analysis assumptions for each of the countries covered by this Handbook, taking account of the location, proximity to cyclonic wind zones, proximity to high earthquake areas and plate boundaries, typical topography and susceptibility to tsunamis.

1. Design of Regulated Buildings

Slightly conservative assumptions (in excess of those based on a probability of exceedance of 1 in 500 years) are recommended for the design of structures for wind and earthquake actions, where:

(a) relevant building regulations are enforced; and

(b) a probability of exceedance of 1 in 500 years is specified.

2. Checking Regulated Buildings

Precise assumptions (based on a probability of exceedance of 1 in 500 years) are recommended for the checking of structures for wind and earthquake actions, where:

(a) relevant building regulations are enforced; and

(b) a probability of exceedance of 1 in 500 years is specified.

3. Design of Village Buildings

Slightly conservative assumptions (in excess of those based on a probability of exceedance of 1 in 250 years) are recommended for the design of structures for wind and earthquake actions, where:

(a) they offer low risk to occupants; and

(b) the design life is under 25 years; and

(c) there is no other practical way of determining the design actions and soil properties, and;

(d) relevant building regulations are not routinely enforced.

This is not applicable in Australia or New Zealand.

4. Checking of Village Buildings

Precise assumptions (based on a probability of exceedance of 1 in 250 years) are recommended for the checking of structures for wind and earthquake actions, where:

(a) they offer low risk to occupants; and

(b) the design life is under 25 years; and

(c) there is no other practical way of determining the design actions and soil properties, and;

(d) relevant building regulations are not routinely enforced.

This is not applicable in Australia or New Zealand.

Australia

These design assumptions may not be used for applications that do not comply with the "Building" and "Design" conditions listed below.

Location: Australia Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure; Single storey; Cladding on elevated braced timber frame OR reinforced concrete masonry on concrete slab-on-ground; Maximum dimensions: 12.5 x 8.0 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 50 years; Annual probability of exceedance 1 in 500; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36°	0 kPa	1060 kPa
Slightly reactive clay	S	30°	3 kPa	670 kPa
Moderately reactive clay	M	27°	6 kPa	640 kPa
Highly reactive clay	H1	24°	9 kPa	609 kPa
Highly reactive clay	H2	24°	9 kPa	609 kPa
Extremely reactive clay	E	20°	9 kPa	436 kPa

Permanent Loads: Elevated timber building, w = 2.5 kN/m^2 (floor area), Reinforced masonry building w = 3.5 kN/m^2 (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Based on AS/NZS 1170.2:2011

Noncyclonic	Region A	$V_{u\ 500\ (3,10)}$ = 45 m/s	$k_{p\ 500}$ = 1.0
Noncyclonic	Region B	$V_{u\ 500\ (3,10)}$ = 57 m/s	$k_{p\ 500}$ = 1.0
Cyclonic	Region C	$V_{u\ 500(\ 3,10)}$ = 66 F_c = 73 m/s	$k_{p\ 500}$ = 1.0
Cyclonic	Region D	$V_{u\ 500\ (3,10)}$ = 80 F_b = 88 m/s	$k_{p\ 500}$ = 1.0

Earthquake:

Probability k = 1.0; Subsoil = C; Ordinate $C_{h(T1)}$ = 3.68; Ductility, μ = 2.00; Performance, S_p = 0.77

Location	Peak Ground Acceleration, adjusted for Probability of Exceedance k_p z (Where K_p = 1.0) 1 : 500
As per AS 1170.4 Table 3.2 and Fig 3.2	
Mekering region (Ranges from 0.14 to 0.22)	0.22
Tennant Creek	0.13
Newcastle, Bundaberg	0.11
Adelaide, Wyong	0.10
Darwin, Geraldton, Gladstone, Wyndham, Wollongong, Whyalla	0.09
All other locations	0.08

Tsunami: Should be determined for each site. Provided the distance from high water mark > 2 km; OR height of finished floor above mean sea level >20 m; OR distance from high earthquake area (Z > 0.4) >1,000 km; the Tsunami Risk Factor = 0 (Site specific exposure = Value to be determined)

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km^2; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

Cook Islands

These design assumptions may not be used for applications that do not comply with the "Building" and "Design" conditions listed below.

Location: Cook Islands Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure; Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground; Maximum dimensions: 12.5 x 8.0 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36°	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27°	6 kPa	640 kPa

Permanent Loads: Elevated timber building, w = 2.5 kN/m^2 (floor area), Reinforced masonry building w = 3.5 kN/m^2 (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Cyclonic Level IV (C) $V_{u\,500(3,10)}$ = 66 m/s $k_{p\,500}$ = 1.0, $k_{p\,250}$ = 0.88

> The *National Building Code for Cook Islands* 1990 calls up the version AS 1170.2 that was in place at the time. It also provides further information for the permissible stress method. However this policy provides ultimate limit state loads, which may be derived using the following passages from the *National Building Code for Cook Islands* 1990. "When using Part 2 of the standard the following provisions apply: *a limit state basic wind speed of 60 m/s to all areas…… The bulk of the developing areas in the Cook Islands are such that simple buildings up to 6 m height, …… [and] category 2 terrain and an upwind slope of 1 : 10 for escarpments …"*

Earthquake: Probability $k_{p\,500}$ = 1.0, k_p = 0.75; Hazard Z_{500} = 0.08; Subsoil = C; Ordinate $C_{h(T1)}$ = 3.68; Ductility, μ = 2.00; Performance, S_p = 0.77

Tsunami: Should be determined for each site. Provided the distance from high water mark > 2 km; OR height of finished floor above mean sea level >20 m; OR distance from high earthquake area (Z > 0.4) >1,000 km; the Tsunami Risk Factor = 0 (Site specific exposure = Value to be determined)

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km^2; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

Fiji

These design assumptions may not be used for applications that do not comply with the "Building" and "Design" conditions listed below.

Location: Fiji Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 12.5 x 8.0 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36°	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27°	6 kPa	640 kPa

Permanent Loads: Elevated timber building, w = 2.5 kN/m^2 (floor area), Reinforced masonry building w = 3.5 kN/m^2 (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C) $V_{u\ 500(3,10)}$ = 66 m/s $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.88

The *National Building Code for Fiji* 1990 calls up the version AS 1170.2 that was in place at the time. It also provides further information for the permissible stress method. However this policy provides ultimate limit state loads, which may be derived using the following passages from the *National Building Code for Fiji* 1990. "When using Part 2 of the standard the following provisions apply: *a limit state basic wind speed of **70** m/s to all areas"*

Earthquake: Probability k_p = 0.75; Hazard Z_{500} = 0.60 (West Vanua Levu), 0.40 (Central and east Vanua Levu and north-eastern islands), 0.24 (Viti Levu and south-eastern islands); Subsoil = C; Ordinate $C_{h(T1)}$ = 3.68; Ductility, μ = 2.00; Performance, S_p = 0.77

Tsunami: Should be determined for each site. Distance from high water mark = …… km; Height of finished floor above mean sea level =…..m; Distance from high earthquake area (Z > 0.4) >….. km; Site specific exposure = ………. Tsunami Risk Factor = ……

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km^2; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

French Polynesia

These design assumptions may not be used for applications that do not comply with the "Building" and "Design" conditions listed below.

Location: French Polynesia Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 12.5 x 8.0 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36°	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27°	6 kPa	640 kPa

Permanent Loads: Elevated timber building, w = 2.5 kN/m^2 (floor area), Reinforced masonry building w = 3.5 kN/m^2 (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C) $V_{u\ 500(3,10)}$ = 66 m/s $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.88

Earthquake: Probability $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.75; Hazard Z_{500} = 0.08; Subsoil = C; Ordinate $C_{h(T1)}$ = 3.68; Ductility, μ = 2.00; Performance, S_p = 0.77

Tsunami: Should be determined for each site. Provided the distance from high water mark > 2 km; OR height of finished floor above mean sea level >20 m; OR distance from high earthquake area (Z > 0.4) >1,000 km; the Tsunami Risk Factor = 0 (Site specific exposure = Value to be determined)

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km^2; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

Kiribati

These design assumptions may not be used for applications that do not comply with the "Building" and "Design" conditions listed below.

Location: Kiribati Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 12.5 x 8.0 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35^{o}

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36^{o}	0 kPa	1060 kPa

Permanent Loads: Elevated timber building, w = 2.5 kN/m^2 (floor area), Reinforced masonry building w = 3.5 kN/m^2 (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Noncyclonic Level I $V_{u\ 500\ (3,10)}$ = 40 m/s $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.90

Earthquake: Probability $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.75; Hazard Z_{500} = 0.08; Subsoil = C; Ordinate $C_{h(T1)}$ = 3.68; Ductility, μ = 2.00; Performance, S_p = 0.77

Tsunami: Should be determined for each site. Provided the distance from high water mark > 2 km; OR height of finished floor above mean sea level >20 m; OR distance from high earthquake area (Z > 0.4) >1,000 km; the Tsunami Risk Factor = 0 (Site specific exposure = Value to be determined)

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km^2; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

Nauru

These design assumptions may not be used for applications that do not comply with the "Building" and "Design" conditions listed below.

Location: Nauru Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 12.5 x 8.0 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36°	0 kPa	1060 kPa

Permanent Loads: Elevated timber building, w = 2.5 kN/m² (floor area), Reinforced masonry building w = 3.5 kN/m² (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Noncyclonic Level I $V_{u\ 500\ (3,10)}$ = 40 m/s $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.90

Earthquake: Probability $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.75; Hazard Z_{500} = 0.08; Subsoil = C; Ordinate $C_{h(T1)}$ = 3.68; Ductility, μ = 2.00; Performance, S_p = 0.77

Tsunami: Should be determined for each site. Provided the distance from high water mark > 2 km; OR height of finished floor above mean sea level >20 m; OR distance from high earthquake area (Z > 0.4) >1,000 km; the Tsunami Risk Factor = 0 (Site specific exposure = Value to be determined)

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km²; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

New Caledonia

These design assumptions may not be used for applications that do not comply with the "Building" and "Design" conditions listed below.

Location: New Caledonia Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 12.5 x 8.0 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36°	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27°	6 kPa	640 kPa

Permanent Loads: Elevated timber building, w = 2.5 kN/m^2 (floor area), Reinforced masonry building w = 3.5 kN/m^2 (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C) $V_{u\,500(3,10)}$ = 66 m/s $k_{p\,500}$ = 1.0, $k_{p\,250}$ = 0.88

Earthquake: Probability $k_{p\,500}$ = 1.0, $k_{p\,250}$ = 0.75; Hazard Z_{500} = 0.40 (North-eastern islands), 0.16 (Main island); Subsoil = C; Ordinate $C_{h(T1)}$ = 3.68; Ductility, μ = 2.00; Performance, S_p = 0.77

Tsunami: Should be determined for each site. Distance from high water mark = …… km; Height of finished floor above mean sea level =…..m; Distance from high earthquake area (Z > 0.4) >….. km; Site specific exposure = ………. Tsunami Risk Factor = ……

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km^2; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

New Zealand

These design assumptions may not be used for applications that do not comply with the "Building" and "Design" conditions listed below.

Location: New Zealand Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 12.5 x 8.0 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36°	0 kPa	1060 kPa
Slightly reactive clay	S	30°	3 kPa	670 kPa
Moderately reactive clay	M	27°	6 kPa	640 kPa
Highly reactive clay	H1	24°	9 kPa	609 kPa
Highly reactive clay	H2	24°	9 kPa	609 kPa
Extremely reactive clay	E	20°	9 kPa	150 kPa

Permanent Loads: Elevated timber building, w = 2.5 kN/m^2 (floor area), Reinforced masonry building w = 3.5 kN/m^2 (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind:

Noncyclonic	Level II(A)	$V_{u\ 500\ (3,10)}$ = 45 m/s	$k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.91
Noncyclonic	Level III (W)	$V_{u\ 500(\ 3,10)}$ = 51 m/s	$k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.92

Earthquake:

Probability $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.75; Subsoil = C; Ordinate $C_{h(T1)}$ = 3.68; Ductility, μ = 2.00; Performance, S_p = 0.77

Location	Peak Ground Acceleration, adjusted for Probability of Exceedance k_p z 1 : 500 (Where K_p = 1.0)
As per NZS 1170.5 Table 3.3 and Figs 3.3, 3.4, 3.5	
Auckland, Dunedin, Palmerston	0.13
Hamilton, Akaroa	0.16
Christchurch	0.22
Wellington, Seddon, Hutt Valley, Ward, Cheviot, Otaki	0.40
Otira, Arthurs Pass (maximum value)	0.60

Tsunami: Should be determined for each site. Distance from high water mark = …… km; Height of finished floor above mean sea level =…..m; Distance from high earthquake area (Z > 0.4) >….. km; Site specific exposure = ………. Tsunami Risk Factor = ……

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km^2; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

Niue

These design assumptions may not be used for applications that do not comply with the "Building" and "Design" conditions listed below.

Location: Niue Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 12.5 x 8.0 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36°	0 kPa	1060 kPa

Permanent Loads: Elevated timber building, w = 2.5 kN/m^2 (floor area), Reinforced masonry building w = 3.5 kN/m^2 (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C) $V_{u\,500(3,10)}$ = 66 m/s $k_{p\,500}$ = 1.0, $k_{p\,250}$ = 0.88

Earthquake: Probability $k_{p\,500}$ = 1.0, $k_{p\,250}$ = 0.75; Hazard Z_{500} = 0.08; Subsoil = C; Ordinate $C_{h(T1)}$ = 3.68; Ductility, μ = 2.00; Performance, S_p = 0.77

Tsunami: Should be determined for each site. Distance from high water mark = …… km; Height of finished floor above mean sea level =…..m; Distance from high earthquake area (Z > 0.4) >….. km; Site specific exposure = ………. Tsunami Risk Factor = ……

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km^2; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

Papua New Guinea

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: Papua New Guinea Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 12.5 x 8.0 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35^o

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36^o	0 kPa	1060 kPa
Slightly reactive clay	S	30^o	3 kPa	670 kPa
Moderately reactive clay	M	27^o	6 kPa	640 kPa
Highly reactive clay	H1	24^o	9 kPa	609 kPa
Highly reactive clay	H2	24^o	9 kPa	609 kPa
Extremely reactive clay	E	20^o	9 kPa	150 kPa

Permanent Loads: Elevated timber building, w = 2.5 kN/m^2 (floor area), Reinforced masonry building w = 3.5 kN/m^2 (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Most of the country except south-east. (refer also to map for reduced velocities)

Noncyclonic Level I $V_{u\ 500\ (3,10)} = 40$ m/s $k_{p\ 500} = 1.0$, $k_{p\ 250} = 0.90$

South-eastern peninsular (Including Milne Bay)

Cyclonic Level IV (C) $V_{u\ 500(\ 3,10)} = 66$ m/s $k_{p\ 500} = 1.0$, $k_{p\ 250} = 0.88$

Earthquake: Probability $k_{p\ 500} = 1.0$, $k_{p\ 250} = 0.75$; Hazard Z_{500} = As per table below; Subsoil = C; Ordinate $C_{h(T1)} = 3.68$; Ductility, μ = 2.00; Performance, $S_p = 0.77$

Location	Hazard Z_{500}
Zone 1 (Extremely High Hazard) – Bougainville, Eastern and Central New Britain, Southern New Ireland (Includes Rabaul)	**1.00**
Zone 2 (Moderately High Hazard) – Northern coast of the mainland, Western New Britain, Central New Ireland, Lihir Group (Includes Namatani, Kieta, Arawa, Vanimo, Wewak, Madang, Lae, Finchhafen, Kimbe, Hoskins)	0.40
Zone 3 (Moderate Hazard) – Central region of the mainland, Northern Province, D’Entrecasteaux and Trobriand Islands, Northern New Ireland and Admiralty Islands (Includes Mendi, Kerema, Klunga,Wabag, Mt Hagen, Kundiawa, Goroko, Bulolo, Wau, Popondetta, Lombrum, Lorengau, Kayieng)	0.24
Zone 4 (Very Low Hazard) – Papuan Peninsula - Louisiade Archipelago and St. Mathias Group (Includes Daru, Port Moresby, Alotau)	0.16

Tsunami: Should be determined for each site. Distance from high water mark = …… km; Height of finished floor above mean sea level =…..m; Distance from high earthquake area (Z > 0.4) >….. km; Site specific exposure = ………. Tsunami Risk Factor = ……

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km^2; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

Samoa

These design assumptions may not be used for applications that do not comply with the "Building" and "Design" conditions listed below.

Location: Samoa Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 12.5 x 8.0 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36°	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27°	6 kPa	640 kPa

Permanent Loads: Elevated timber building, w = 2.5 kN/m^2 (floor area), Reinforced masonry building w = 3.5 kN/m^2 (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C) $V_{u\,500(3,10)}$ = 66 m/s $k_{p\,500}$ = 1.0, $k_{p\,250}$ = 0.88

Earthquake: Probability $k_{p\,500}$ = 1.0, $k_{p\,250}$ = 0.75; Hazard Z_{500} = 0.16; Subsoil = C; Ordinate $C_{h(T1)}$ = 3.68; Ductility, μ = 2.00; Performance, S_p = 0.77

Tsunami: Should be determined for each site. Distance from high water mark = …… km; Height of finished floor above mean sea level =…..m; Distance from high earthquake area (Z > 0.4) >….. km; Site specific exposure = ………. Tsunami Risk Factor = ……

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km^2; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

American Samoa

These design assumptions may not be used for applications that do not comply with the "Building" and "Design" conditions listed below.

Location: American Samoa Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 12.5 x 8.0 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35^{o}

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36^{o}	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27^{o}	6 kPa	640 kPa

Permanent Loads: Elevated timber building, w = 2.5 kN/m^2 (floor area), Reinforced masonry building w = 3.5 kN/m^2 (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C) $V_{u\ 500(3,10)}$ = 66 m/s $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.88

Earthquake: Probability $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.75; Hazard Z_{500} = 0.24; Subsoil = C; Ordinate $C_{h(T1)}$ = 3.68; Ductility, μ = 2.00; Performance, S_p = 0.77

Tsunami: Should be determined for each site. Distance from high water mark = …… km; Height of finished floor above mean sea level =…..m; Distance from high earthquake area (Z > 0.4) >….. km; Site specific exposure = ………. Tsunami Risk Factor = ……

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km^2; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

Solomon Islands

These design assumptions may not be used for applications that do not comply with the "Building" and "Design" conditions listed below.

Location: Solomon Islands Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 12.5 x 8.0 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36°	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27°	6 kPa	640 kPa

Permanent Loads: Elevated timber building, w = 2.5 kN/m^2 (floor area), Reinforced masonry building w = 3.5 kN/m^2 (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Noncyclonic Level I $V_{u\ 500\ (3,10)}$ = 40 m/s $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.90

Earthquake: Probability $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.75; Hazard Z_{500} = **0.60** (Eastern Province), 0.60 Guadalcanal, 0.50 (Rest of Solomon Islands); Subsoil = C; Ordinate $C_{h(T1)}$ = 3.68; Ductility, μ = 2.00; Performance, S_p = 0.77

Tsunami: Should be determined for each site. Distance from high water mark = …… km; Height of finished floor above mean sea level =…..m; Distance from high earthquake area (Z > 0.4) >….. km; Site specific exposure = ………. Tsunami Risk Factor = ……

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km^2; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

Tonga

These design assumptions may not be used for applications that do not comply with the "Building" and "Design" conditions listed below.

Location: Tonga Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 12.5 x 8.0 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36°	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27°	6 kPa	640 kPa

Permanent Loads: Elevated timber building, w = 2.5 kN/m^2 (floor area), Reinforced masonry building w = 3.5 kN/m^2 (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C) $V_{u\ 500(3,10)}$ = **70** m/s $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.88

Earthquake: Probability $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.75; Hazard Z_{500} = **0.40**; Subsoil = C; Ordinate $C_{h(T1)}$ = 3.68; Ductility, μ = 2.00; Performance, S_p = 0.77

Tsunami: Should be determined for each site. Distance from high water mark = …… km; Height of finished floor above mean sea level =…..m; Distance from high earthquake area (Z > 0.4) >….. km; Site specific exposure = ………. Tsunami Risk Factor = ……

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km^2; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

Tuvalu

These design assumptions may not be used for applications that do not comply with the "Building" and "Design" conditions listed below.

Location: Tuvalu Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 12.5 x 8.0 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36°	0 kPa	1060 kPa

Permanent Loads: Elevated timber building, w = 2.5 kN/m² (floor area), Reinforced masonry building w = 3.5 kN/m² (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C) $V_{u\ 500(3,10)}$ = 66 m/s $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.88

The *National Building Code for Tuvalu* 1990 calls up the version AS 1170.2 that was in place at the time. It also provides further information for the permissible stress method. However this policy provides ultimate limit state loads, which may be derived using the following passages from the *National Building Code for Tuvalu* 1990. "When using Part 2 of the standard the following provisions apply: *a limit state basic wind speed of **60** m/s to all areas"*

Earthquake: Given the very low earthquake hazard, design for cyclonic wind will effectively cater for any earthquake loads. (Probability $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.75; Hazard Z_{500} = 0.01; Subsoil = C; Ordinate $C_{h(T1)}$ = 3.68; Ductility, μ = 2.00; Performance, S_p = 0.77)

Tsunami: Should be determined for each site. Distance from high water mark = …… km; Height of finished floor above mean sea level =…..m; Distance from high earthquake area (Z > 0.4) >….. km; Site specific exposure = ………. Tsunami Risk Factor = ……

Flood: Design for flood can be ignored, given the flat nature of the atolls that comprise Tuvalu.

Vanuatu

These design assumptions may not be used for applications that do not comply with the "Building" and "Design" conditions listed below.

Location: Vanuatu Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 12.5 x 8.0 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36°	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27°	6 kPa	640 kPa

Permanent Loads: Elevated timber building, w = 2.5 kN/m^2 (floor area), Reinforced masonry building w = 3.5 kN/m^2 (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C) $V_{u\ 500(3,10)}$ = 66 m/s $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.88

The *National Building Code for Vanuatu* 1990 calls up the version AS 1170.2 that was in place at the time. It also provides further information for the permissible stress method. However this policy provides ultimate limit state loads, which may be derived using the following passages from the *National Building Code for Vanuatu* 1990. "When using Part 2 of the standard the following provisions apply: *a limit state basic wind speed of **70** m/s to all areas"*

Earthquake: Probability $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.75; Hazard Z_{500} = 0.60; Subsoil = C; Ordinate $C_{h(T1)}$ = 3.68; Ductility, μ = 2.00; Performance, S_p = 0.77

Tsunami: Should be determined for each site. Distance from high water mark = …… km; Height of finished floor above mean sea level =…..m; Distance from high earthquake area (Z > 0.4) >….. km; Site specific exposure = ………. Tsunami Risk Factor = ……

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km^2; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

Wallis and Futuna

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: Wallis and Futuna Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 12.5 x 8.0 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35^o

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36^o	0 kPa	1060 kPa

Permanent Loads: Elevated timber building, w = 2.5 kN/m^2 (floor area), Reinforced masonry building w = 3.5 kN/m^2 (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C) $V_{u\ 500(3,10)}$ = 66 m/s $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.88

Earthquake: Probability $k_{p\ 500}$ = 1.0, $k_{p\ 250}$ = 0.75; Hazard Z_{500} = 0.60 (Wallis), 0.20 (Futuna); Subsoil = C; Ordinate $C_{h(T1)}$ = 3.68; Ductility, μ = 2.00; Performance, S_p = 0.77

Tsunami: Should be determined for each site. Distance from high water mark = …… km; Height of finished floor above mean sea level =…..m; Distance from high earthquake area (Z > 0.4) >….. km; Site specific exposure = ………. Tsunami Risk Factor = ……

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km^2; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

Appendix 1 – Cyclone Categories

The information below on tropical cyclones is reproduced from the following Bureau of Metrology web site: http://www.bom.gov.au/cyclone/about/intensity.shtml

Tropical Cyclone Intensity

Tropical cyclone intensity is defined by the maximum mean wind speed over open flat land or water. This is sometimes referred to as the maximum sustained wind and will be experienced around the eye-wall of the cyclone.

Mean Wind

In most of the world the mean wind speed is defined as the wind speed averaged over a period of 10 minutes. It should be measured at 10 m above the surface. *The major exception is the USA where they use a 1-minute average*.

Wind Gust

In most of the world the wind gust speed is defined as the wind speed averaged over 2 or 3 seconds (in Australia we use 3 seconds).

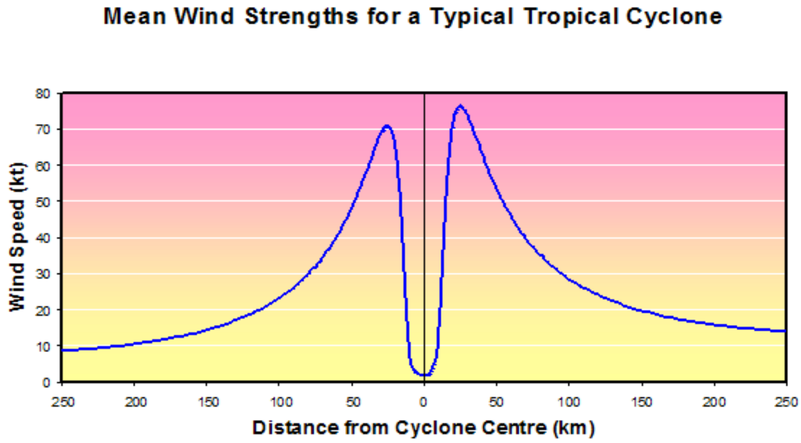
Typically gusts over open land will be about 40% greater than the mean wind and gusts over the ocean will be 25 - 30% greater than the mean wind. It is often the stronger gusts that cause the most significant damage to buildings

While a cyclone advice may refer to a certain maximum sustained wind or gust, there will be localised points where the winds will exceed this value, particularly in gullies, about ridges and between buildings where winds can be funnelled by the landscape.

Extent of Significant Winds

The extent of damaging winds will vary between cyclones. More importantly, the most severe winds will be confined to a small area around the outside of the eye. Often people will experience the winds in the outer part of a Category 4 or 5 cyclone. They will believe that they have experienced a major cyclone, yet the winds may have only been Cat 1 or 2 strength.

It is important to recognise the structure of a cyclone when assessing past experience. This will make a future direct hit less of a surprise.



Tropical Cyclone Category System

CATEGORY 1 *(tropical cyclone)* – Negligible house damage. Damage to some crops, trees and caravans. Craft may drag moorings. A Category 1 cyclone's strongest winds are GALES with typical gusts over open flat land of 90 - 125 km/h. These winds correspond to Beaufort 8 and 9 (Gales and strong gales).

CATEGORY 2 *(tropical cyclone)* – Minor house damage. Significant damage to signs, trees and caravans. Heavy damage to some crops. Risk of power failure. Small craft may break moorings. A Category 2 cyclone's strongest winds are DESTRUCTIVE winds with typical gusts over open flat land of 125 - 164 km/h. These winds correspond to Beaufort 10 and 11 (Storm and violent storm).

CATEGORY 3 *(severe tropical cyclone)* – Some roof and structural damage. Some caravans destroyed. Power failures likely. A Category 3 cyclone's strongest winds are VERY DESTRUCTIVE winds with typical gusts over open flat land of 165 - 224 km/h. These winds correspond to the highest category on the Beaufort scale, Beaufort 12 (Hurricane).

CATEGORY 4 *(severe tropical cyclone)* – Significant roofing loss and structural damage. Many caravans destroyed and blown away. Dangerous airborne debris. Widespread power failures. A Category 4 cyclone's strongest winds are VERY DESTRUCTIVE winds with typical gusts over open flat land of 225 - 279 km/h. These winds correspond to the highest category on the Beaufort scale, Beaufort 12 (Hurricane).

CATEGORY 5 *(severe tropical cyclone)* – Extremely dangerous with widespread destruction. A Category 5 cyclone's strongest winds are VERY DESTRUCTIVE winds with typical gusts over open flat land of more than 280 km/h. These winds correspond to the highest category on the Beaufort scale, Beaufort 12 (Hurricane).

Beaufort Scale

	Beaufort scale	Cyclone category	Average wind speed (knots)	Average wind speed (km/h)	Estimating speed over land	Estimating speed over water
0	Calm		Less than 1	less than 1	Calm, smoke rises vertically.	Sea like mirror
1	Light Air		1 - 3	1 - 5	Direction of wind shown by smoke drift, but not by wind vanes.	Ripples with the appearance of scales are formed, but without foam crests
2	Light breeze		4 - 6	6 - 11	Wind felt on face; leaves rustle; ordinary wind vane moved by wind.	Small wavelets, still short, but more pronounced; crests have a glassy appearance and do not break
3	Gentle breeze		7 - 10	12 - 19	Leaves and small twigs in constant motion; wind extends light flag.	Large wavelets; crests begin to break; foam of glassy appearance; perhaps scattered white horses
4	Moderate breeze		11 - 16	20 - 28	Raises dust and loose paper; small branches moved.	Small waves, becoming longer; fairly frequent white horses
5	Fresh breeze		17 - 21	29 - 38	Small trees in leaf begin to sway; crested wavelets form on inland waters.	Moderate waves, taking a more pronounced long form; many white horses are formed (chance of some spray)
6	Strong breeze		22 - 27	39 - 49	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.	Large waves begin to form; the white foam crests are more extensive everywhere (probably some spray)
7	Near gale		28 - 33	50 - 61	Whole trees in motion; inconvenience felt when walking against the wind.	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind
8	Gale	1	34 - 40	62 - 74	Breaks twigs off trees; generally impedes progress.	Moderately high waves of greater length; edges of crests begin to break into the spindrift; the foam is blown in well-marked streaks along the direction of the wind
9	Strong gale	1	41 - 47	75 - 88	Slight structural damage occurs	High waves; dense streaks of foam along the direction of the wind;

Beaufort scale		Cyclone category	Average wind speed (knots)	Average wind speed (km/h)	Estimating speed over land	Estimating speed over water
					(chimney pots and slates removed).	crests of waves begin to topple, tumble and roll over; spray may affect visibility
10	Storm	2	48 - 55	89 - 102	Seldom experienced inland; trees uprooted; considerable structural damage occurs.	Very high waves with long overhanging crests; the resulting foam, in great patches, is blown in dense white streaks along the direction of the wind; on the whole, the surface of the sea takes a white appearance; the tumbling of the sea becomes heavy and shock-like; visibility affected
11	Violent storm	2	56 - 63	103 - 117	Very rarely experienced; accompanied by widespread damage.	Exceptionally high waves (small and medium sized ships might be for a time lost to view behind the waves); the sea is completely covered with long white patches of foam lying along the direction of the wind; everywhere the edges of the wave crests are blown into froth; visibility affected
12	Hurricane	3,4,5	64 and over	118 and over	Severe and extensive damage.	The air is filled with foam and spray; sea completely white with driving spray; visibility very seriously affected

Global Tropical Cyclone Terminology

Tropical cyclones can be defined in different ways elsewhere in the world. Often news reports from the United States or Asia will refer to hurricanes or typhoons. These are all tropical cyclones, but with different names. While the category definitions are not identical, the following provides an approximate guide for comparison.

Australian name	Australian category	US*	US Saffir-Simpson category scale*	NW Pacific	Arabian Sea Bay of Bengal	SW Indian Ocean	South Pacific (East of 160E)
Tropical low	-	Tropical depression	-	Tropical depression	Depression or severe depression	Tropical depression	Tropical depression
Tropical cyclone	1	Tropical storm	-	Tropical storm	Cyclonic storm	Moderate tropical storm	Tropical cyclone (Gale)
Tropical cyclone	2	Tropical storm	-	Severe tropical storm	Severe cyclonic storm	Severe tropical storm	Tropical cyclone (Storm)
Severe tropical Cyclone	3	Hurricane	1	Typhoon	Very severe cyclonic storm	Tropical cyclone	Tropical cyclone (Hurricane)
Severe tropical cyclone	4	Hurricane	2 - 3	Typhoon	Very severe cyclonic storm	Intense tropical cyclone	Tropical cyclone (Hurricane)
Severe tropical cyclone	5	Hurricane	4 - 5	Typhoon	Super cyclonic storm	Very intense tropical cyclone	Tropical cyclone (Hurricane)

** Note that the USA uses 1-minute wind averages, which are generally greater than 10-minute wind averages used elsewhere in the world – hence their intensity definitions (wind strengths) will differ by about 10%.*

Appendix 2 – Earthquake Definitions

Earthquake Scales

Source: https://en.wikipedia.org/wiki/Richter_magnitude_scale

The Richter scale was defined in 1935 for particular circumstances and instruments; the particular circumstances refer to it being defined for Southern California and "implicitly incorporates the attenuative properties of Southern California crust and mantle."[17] The particular instrument used would become saturated by strong earthquakes and unable to record high values.

The scale was replaced in the 1970s by the moment magnitude scale (MMS, symbol M_w); for earthquakes adequately measured by the Richter scale, numerical values are approximately the same.

Although values measured for earthquakes now are (MMS), they are frequently reported by the press as Richter values, even for earthquakes of magnitude over 8, when the Richter scale becomes meaningless. Anything above 5 is classified as a risk by the USGS.

The Richter and MMS scales measure the energy released by an earthquake; another scale, the Mercalli intensity scale, classifies earthquakes by their *effects*, from detectable by instruments but not noticeable, to catastrophic. The energy and effects are not necessarily strongly correlated; a shallow earthquake in a populated area with soil of certain types can be far more intense in effects than a much more energetic deep earthquake in an isolated area.

Several scales have historically been described as the "Richter scale", especially the *local magnitude* and the surface wave scale. In addition, the *body wave magnitude*, and the *moment magnitude*, abbreviated MMS, have been widely used for decades. A couple of new techniques to measure magnitude are in the development stage by seismologists........

The Richter magnitude of an earthquake is determined from the logarithm of the amplitude of waves recorded by seismographs (adjustments are included to compensate for the variation in the distance between the various seismographs and the epicenter of the earthquake).

The following describes the typical effects of earthquakes of various magnitudes near the epicenter. The values are typical only. They should be taken with extreme caution, since intensity and thus ground effects depend not only on the magnitude, but also on the distance to the epicenter, the depth of the earthquake's focus beneath the epicenter, the location of the epicenter and geological conditions (certain terrains can amplify seismic signals).

Magnitude	Description	Mercalli intensity	Average earthquake effects	Average frequency of occurrence (estimated)
1.0–1.9	Micro	I	Microearthquakes, not felt, or felt rarely. Recorded by seismographs	Continual/several million per year
2.0–2.9	Minor	I to II	Felt slightly by some people. No damage to buildings.	Over one million per year
3.0–3.9		III to IV	Often felt by people, but very rarely causes damage. Shaking of indoor objects can be noticeable.	Over 100,000 per year
4.0–4.9	Light	IV to VI	Noticeable shaking of indoor objects and rattling noises. Felt by most people in the affected area. Slightly felt outside. Generally causes none to minimal damage. Moderate to significant damage very unlikely. Some objects may fall off shelves or be knocked over.	10,000 to 15,000 per year
5.0–5.9	Moderate	VI to VII	Can cause damage of varying severity to poorly constructed buildings. At most, none to slight damage to all other buildings. Felt by everyone.	1,000 to 1,500 per year
6.0–6.9	Strong	VIII to X	Damage to a moderate number of well-built structures in populated areas. Earthquake-resistant structures survive with slight to moderate damage. Poorly designed structures receive moderate to severe damage. Felt in wider areas; up to hundreds of miles/kilometers from the epicenter. Strong to violent shaking in epicentral area.	100 to 150 per year
7.0–7.9	Major	X or greater	Causes damage to most buildings, some to partially or completely collapse or receive severe damage. Well-designed structures are likely to receive damage. Felt across great distances with major damage mostly limited to 250 km from epicenter.	10 to 20 per year
8.0–8.9	Great		Major damage to buildings, structures likely to be destroyed. Will cause moderate to heavy damage to sturdy or earthquake-resistant buildings. Damaging in large areas. Felt in extremely large regions.	One per year
9.0 and greater			At or near total destruction – severe damage or collapse to all buildings. Heavy damage and shaking extends to distant locations. Permanent changes in ground topography.	One per 10 to 50 years

(*Based on U.S. Geological Survey documents.*)

Ground Acceleration

Source: https://en.wikipedia.org/wiki/Peak_ground_acceleration

Earthquake energy is dispersed in waves from the hypocentre, causing ground movement omnidirectionally but typically modelled horizontally (in two directions) and vertically. PGA records the acceleration (rate of change of speed) of these movements, while peak ground velocity is the greatest speed (rate of movement) reached by the ground, and peak displacement is the distance moved. These values vary in different earthquakes, and in differing sites within one earthquake event, depending on a number of factors. These include the length of the fault, magnitude, the depth of the quake, the distance from the epicentre, the duration (length of the shake cycle), and the geology of the ground (subsurface). Shallow-focused earthquakes generate stronger shaking (acceleration) than intermediate and deep quakes, since the energy is released closer to the surface.

Peak ground acceleration can be expressed in ***g*** (the acceleration due to Earth's gravity, equivalent to g-force) as either a decimal or percentage; in m/s^2 (1 g = 9.81 m/s^2); or in **Gal**, where 1 Gal is equal to 0.01 m/s^2 (1 g = 981 Gal).

The ground type can significantly influence ground acceleration, so PGA values can display extreme variability over distances of a few kilometers, particularly with moderate to large earthquakes. The varying PGA results from an earthquake can be displayed on a shake map. Due to the complex conditions affecting PGA, earthquakes of similar magnitude can offer disparate results, with many moderate magnitude earthquakes generating significantly larger PGA values than larger magnitude quakes.

During an earthquake, ground acceleration is measured in three directions: vertically (V or UD, for up-down) and two perpendicular horizontal directions (H1 and H2), often north-south (NS) and east-west (EW). The peak acceleration in each of these directions is recorded, with the highest individual value often reported. Alternatively, a combined value for a given station can be noted. The peak horizontal ground acceleration (PHA or PHGA) can be reached by selecting the higher individual recording, taking the mean of the two values, or calculating a vector sum of the two components. A three-component value can also be reached, by taking the vertical component into consideration also.

In seismic engineering, the effective peak acceleration (EPA, the maximum ground acceleration to which a building responds) is often used, which tends to be ⅔ – ¾ the PGA.

Study of geographic areas combined with an assessment of historical earthquakes allows geologists to determine seismic risk and to create seismic hazard maps, which show the likely PGA values to be experienced in a region during an earthquake, with a probability of exceedance (PE). Seismic engineers and government planning departments use these values to determine the appropriate earthquake loading for buildings in each zone, with key identified structures (such as hospitals, bridges, power plants) needing to survive the maximum considered earthquake (MCE).

Damage to buildings is related to both peak ground velocity (PGA) and the duration of the earthquake – the longer high-level shaking persists, the greater the likelihood of damage.

Peak ground acceleration provides a measurement of *instrumental intensity*, that is, ground shaking recorded by seismic instruments. Other intensity scales measure *felt intensity*, based on eyewitness reports, felt shaking, and observed damage. There is correlation between these scales, but not always absolute agreement since experiences and damage can be affected by many other factors, including the quality of earthquake engineering.

Generally speaking,

- 0.001 g (0.01 m/s²) – perceptible by people
- 0.02 g (0.2 m/s²) – people lose their balance
- 0.50 g – very high; well-designed buildings can survive if the duration is short.

Correlation with the Mercalli scale

The United States Geological Survey developed an Instrumental Intensity scale, which maps peak ground acceleration and peak ground velocity on an intensity scale similar to the felt Mercalli scale. These values are used to create shake maps by seismologists around the world.

Instrumental Intensity	Acceleration (g)	Velocity (cm/s)	Perceived shaking	Potential damage
I	**< 0.0017**	< 0.1	Not felt	None
II–III	**0.0017 – 0.014**	0.1 – 1.1	Weak	None
IV	**0.014 – 0.039**	1.1 – 3.4	Light	None
V	**0.039 – 0.092**	3.4 – 8.1	Moderate	Very light
VI	**0.092 – 0.18**	**8.1 – 16**	Strong	Light
VII	0.18 – 0.34	**16 – 31**	Very strong	Moderate
VIII	0.34 – 0.65	**31 – 60**	Severe	Moderate to heavy
IX	0.65 – 1.24	**60 – 116**	Violent	Heavy
X+	> 1.24	**> 116**	Extreme	Very heavy