BRANZ

ISSUE 597 BULLETIN

TIMBER POLE HOUSE CONSTRUCTION

April 2016

- Timber pole houses are suited to steep sites and generally disturb less ground.
- The structural elements and bracing of pole houses require specific engineering design (SED).
- This bulletin replaces Bulletin 459 of the same name. Key changes cover treatment requirements for timber, durability issues for fixings and fasteners and updated references to current standards.

1.0 INTRODUCTION

1.0.1 Pole house construction is particularly suited to steep sites where minimal disruption to soil and vegetation is desirable.

1.0.2 Pole houses can be constructed either as pole frames (where the poles extend the full height of the structure, providing support and bracing to floors, walls and roof) or as a pole platform upon which a conventional framed house is built.

1.0.3 Specific engineering design (SED) and full detailing is required for all structural junctions and connectors, together with a complete specification for all materials.

1.0.4 Comprehensive weathertightness details are also required where structural elements pass through the wall cladding or roof.

1.0.5 This bulletin updates and replaces Bulletin 459 of the same name.

2.0 MATERIALS

2.1 POLE SELECTION AND QUALITY

2.1.1 NZS 3605:2001 *Timber piles and poles for use in building* defines the quality of poles in terms of:
- strength
- straightness
- minimum number of growth rings
- grade, i.e. the permitted limits on defects (cuts, checks, splits, knots, nodal swelling and spiral grain)
- debarking or peeling options and their effect on pole strength
- preparation and seasoning specifications
- preservative treatment
- pole end dimensions
- brands
- regimes for testing
- precautions for handling.

2.1.2 NZS 3605:2001 allows all timber species that are suitably durable and for which appropriate design stresses are available (as defined in NZS 3603:1993 *Timber structures standard*). NZS 3602:2003 *Timber and wood-based products for use in building* lists radiata pine treated to hazard class H5 as suitably durable for house poles. Section 113.3 of NZS 3602:2003 provides information on the use of other timbers as alternative methods that could be used for house poles so long as evidence can be provided that their durability is adequate for the given application.

2.2 POLE SIZES

2.2.1 The maximum length of suitable, readily available poles is approximately 12 m. For lifting and placing large poles, consider:
- site access for delivery and lifting equipment
- availability of cranes
- availability of helicopters of sufficient capacity.

2.2.2 Pole lengths should be determined at the time of design and confirmed when setting out. It is safer to order poles slightly longer than required. Note that only the top should be cut to adjust the length so the treatment protection is not compromised.

2.3 TIMBER COMPONENTS (OTHER THAN BRACING FOR POLES)

2.3.1 NZS 3602:2003 and NZS 3603:1993 should be used for the design of all timber components other than poles. NZS 3604:2011 *Timber-framed buildings* can be used when sizing floor joists, wall framing and rafters when they are not part of the bracing system for the poles. Note that the house must fit within the envelope and therefore not be taller than that specified in NZS 3604:2011, otherwise the building must be specifically engineered.

2.4 DURABILITY REQUIREMENTS

2.4.1 Pole structures must meet the provisions of New Zealand Building Code (NZBC) clause B2 *Durability*. B2 requires a durability of 50 years for structural elements including poles, beams, braces, fixings and fasteners.

2.5 TIMBER TREATMENT

2.5.1 If using treated radiata pine for house poles, NZS 3602:2003 Table 1A.5 and section 106.2 specify H5 treatment as the minimum required. Section 113.3 of NZS 3602:2003 provides information on the use of other timbers as alternative methods that could be used for house poles so long as evidence can be provided that their durability is adequate for the given application.

2.5.2 Timber tie beams, braces and joists must be installed at least 300 mm above ground level to ensure that ground moisture, which may be transmitted up the pole, does not affect the structural connections.

2.5.3 Where timbers above ground (beams, braces, joists, etc.) are subjected to regular wetting or continuously damp conditions, they must be treated to hazard class H3.2. Timbers under the building (bearers and joists) that are protected from wetting may be treated to hazard class H1.2. Timber treated to a higher hazard class than that specified here is acceptable.

2.5.4 When ordering treated timber poles, the supplier should be asked for a certificate that records:
- quality of preservative treatment (chemical retention level) determined by taking and analysing samples from two positions along each pole
- level of preservative treatment as defined by NZS 3640:2003 *Chemical preservation of round and sawn timber*
- registered number of the treatment plant
- purchaser's full address as well as the building site address.
- evidence that the supplier is complying with a third-party audited quality assurance scheme.

2.5.5 All treated sawn timber must be clearly branded with the treatment level and treatment plant number in accordance with NZS 3640:2003.

2.5.6 No cuts or penetrations are allowed on the portion of the pole that is embedded in the ground or concrete as this will compromise the treatment protection. Additionally, for piles, NZS 3604:2011 does not allow any cuts for fixings or other purposes closer than 150 mm from the finished ground level.

3.0 FIXINGS AND FASTENERS

3.0.1 Durability requirements for subfloor structural connectors are defined in NZS 3604:2011. Metal connectors must be hot-dip galvanised as specified in AS/NZS 4680:2006 *Hot-dip galvanized (zinc) coatings on fabricated ferrous articles* or stainless steel depending on the exposure, as other metal connectors are not suitable.

3.0.2 Type 304 stainless steel fixings and fasteners are required in sea spray zones open to airborne salts or within 600 mm of the ground but not closer than 200 mm to the ground.

3.0.3 Type 316 stainless steel should also be specified for other areas where the 'tea staining' that can occur with type 304 would not be visibly acceptable.

3.0.4 SED is required for fixings and fasteners in geothermal hot spots as defined in NZS 3604:2011 section 4.2.4.

3.0.5 See Tables 20, 21 and 22 in Acceptable Solution E2/AS1 to NZBC clause E2 *External moisture* for specification and compatibility of materials.

4.0 ARCHITECTURAL DESIGN

4.1 DESIGN OPTIONS

4.1.1 A pole structure can either be a platform, where the floor level rests on top of the poles or a pole frame. In a pole frame, the poles may extend to roof level or beyond or a combination of both.

4.1.2 Design rules for pole housing:
- Space poles to suit floor beam spans and floor joist spans conforming with NZS 3604:2011 using standard timber sizes for beams and floor joists. Otherwise, specific design is required for beams and joists.
- Use single length (continuous) poles.
- Limit notches in poles for seating beams to a maximum depth of 40 mm where they will be exposed to moisture, and brush on proprietary preservative to protect exposed timber in accordance with NZS 3640:2003.
- Do not cut, notch or drill poles where they will be embedded in the ground or concrete.
- Use beams in pairs, one to each side of the pole, to prevent eccentric loading.
- Use shorter beam spans rather than longer to reduce deflection and vibration.
- Cap the ends of poles and beams that are exposed to the weather with copper or synthetic rubber to prevent water absorption into the end grain and reduce the risk of splitting. (Unprotected steel is not a suitable capping for timber containing copper-based treatment chemicals.)

4.1.3 Poles will perform better where they are:
- painted, stained or waxed to prevent rapid drying (which can cause cracking) – this also seals the pole surface
- not located close to radiant heat sources, such as open fires and wood-burning stoves, which can lead to unsightly splitting.

Pole structure with frame for lower level and platform for higher levels.

4.2 POLE PLATFORMS

4.2.1 Design benefits when using a pole platform:
- It provides a level floor platform for conventional construction on a steep, sloping site.
- Shorter poles are used, which are easier to handle.
- There are no poles within the building.
- No poles penetrate the building cladding – reducing weathertightness issues.
- Pole tops are protected from the weather.
- A working platform is created, which allows easier frame erection.
- Conventional framing methods may be used for walls and roofs. (Note that the risk matrix result for weathertightness may be increased because of increased height above ground level.)

4.3 POLE FRAMES

4.3.1 Design considerations for pole frames in general:
- Outer rows of poles can either be inside or outside the line of the walls.
- Fitting external framed walls between poles should be avoided as this creates weatherproofing difficulties and finishing problems.
- Designs where internal poles penetrate the roofing should be avoided as this causes flashing and material compatibility difficulties with metal roofing (except for copper roofing).
- Treated timber will be exposed within the building.

4.3.2 Benefits for pole frames where the poles are inside the line of the framed walls include:
- all pole to beam connections are protected from the weather

- a lower level of preservative treatment can be specified for beams and joists protected from the weather
- beams do not penetrate the wall cladding, which reduces weathertightness complications
- it provides large areas of open wall for windows.

4.3.3 Where the poles are outside the line of the wall framing, the advantages include:
- the wall framing is easier to erect
- there are fewer poles interrupting floor space
- fewer poles penetrate the flooring, reducing the number of awkward junctions.

4.3.4 Drawbacks of locating the poles outside the line of the walls are:
- ensuring there is sufficient space between the poles and wall for maintenance of the cladding
- flashing difficulty where the beams penetrate the cladding
- allowing sufficient clearance for the spouting between outside poles taken above roof level
- ensuring the tops of poles are sloped and covered with a copper cap (the capping can be done before the poles are erected).

5.0 POLE STRUCTURE ENGINEERING DESIGN

5.1 STRUCTURAL DESIGN OF POLES AND POLE BRACING

5.1.1 Each pole structure, whether a platform or a frame, requires a specific structural engineering design in accordance with the suite of loadings standards AS/NZS 1170 *Structural design actions* and timber design standard NZS 3603:1993. The design should consider all conditions likely to affect the stability of the structure, including:
- ground conditions
- site slopes and earth pressure
- self-weight
- imposed gravity loads arising from use
- wind, snow and earthquake actions
- differential movement
- vegetation
- influence of equipment, services, non-structural elements and contents
- time-dependent effects including creep and shrinkage
- removal of support.

5.1.2 Test boreholes to determine soil properties will generally be necessary. The engineer will need to engage geotechnical specialists.

5.1.3 Enclosure of part or all of the underfloor basement area must be considered at the design stage as enclosed basements will increase wind loads and have a bearing on stability requirements.

5.1.4 Future possible excavations – for example, to provide vehicle access – should be anticipated and sufficient hole depth and pole length provided to cope with later excavation. Any subsequent excavations not documented on the original consent will require new engineering design and an amendment to the building consent.

5.2 POLE SYSTEM BRACING DESIGN

5.2.1 The foundations and subfloor system must resist vertical loads such as building mass and contents as well as horizontal loads generated by wind and earthquakes. Uplift forces may also have to be taken into account. Horizontal loads may be resisted by:
- using cantilevered poles – poles sufficiently embedded in the ground can act as cantilevers in resisting horizontal loads
- installing braces between poles – braces will generally be required across the slope on the downhill side of the structure to stiffen more flexible cantilever poles.

5.2.2 Braces are most effective in resisting twisting of the structure (rotation) when:
- they are spread evenly around the perimeter of the structure
- several braces carrying lighter loads are used instead of fewer very heavily loaded braces
- they are used in conjunction with a diaphragm floor structure to distribute loads to the perimeter braces – a floor diaphragm can consist of appropriately fixed sheet flooring such as particleboard or plywood
- they are tightly connected to the poles and incorporate a means of fixing that allows retightening from time to time.

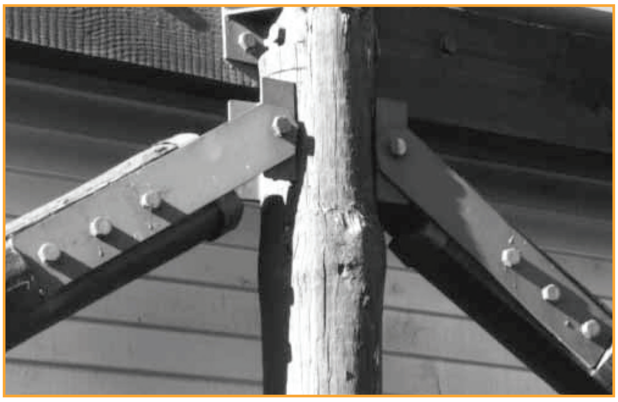
5.3 POLE BRACING SYSTEMS

5.3.1 The effectiveness of pole bracing depends on the fixing method employed (see examples in Figure 1 and the photo on page 5) and whether these fixings remain tight over time or can be retightened. A wide range of bracing options can be used.

5.3.2 Safety should always be a primary consideration, and in the situation where tightening of braces will be required, it is important to consider how this tightening will be done and by whom. Steep sites can potentially have braces that are placed high off the ground. This can create a challenging situation for tightening and may require the use of scaffolding or specialised climbing gear that only professionals will be able to use.

5.3.3 Stainless steel tension cross-bracing rods are an option, installed into inclined holes through the top and bottom of adjacent poles. The rods are threaded at the ends and tightened onto load-spreading brackets. Splicing the rods at mid-length with a tensioning mechanism can assist with installation and regular tightening. Lock nuts ensure that pre-tension is not lost.

5.3.4 Sawn timber cross-braces consist of treated timber planks bolted to the side of a pair of adjacent poles. Engineered timber products such as laminated veneer lumber (LVL) can also be used in these applications so long as they have adequate strength, stiffness, fastener holding capacity and durability. A mid-point connection between the crossed braces provides out-of-plane brace stability. This system is easy to install but cannot be pre-tensioned or retensioned. Appropriate end and edge distances of bolt holes are required and described in NZS 3603:1993 to ensure that the structural integrity of these connections is maintained.



Pole braces with non-adjustable metal brackets.

5.3.5 Other options available for pole bracing can include proprietary fastening and retightening devices.

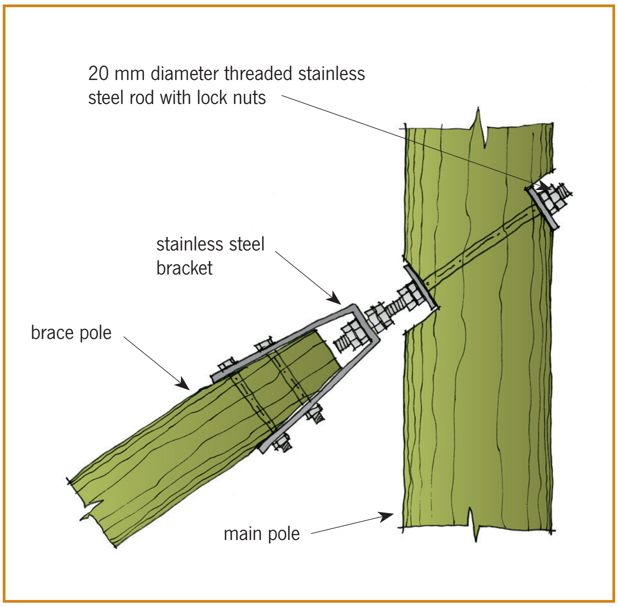


Figure 1. Adjustable bracing bracket.

5.4 CONTROL OF VIBRATIONS

5.4.1 All buildings have a natural frequency of horizontal movement – that is, they vibrate when subject to wind gusts, earthquake loads and vibrations from other sources such as washing machines and footsteps. Humans are particularly sensitive to very small vibration movements (usually much less than half a millimetre).

5.4.2 Due to the subjective nature of the problem and the inherent variability of the design parameters, specifying precise vibration limits to cover all situations is not possible. However, detailing that allows for pre-tensioning and later retensioning will be an advantage as movements tend to get worse over time.

5.4.3 Structures supported on poles can be more flexible than other foundation systems and tend to have a lower natural frequency of vibration, which occupants notice more. The minimum number and size of braces in a building is governed by the requirement to ensure adequate strength against the severe loads experienced in major storms and earthquakes. Large movements of the structure should be limited under these circumstances. Additional braces are likely to be required to reduce small movements that occupants may find uncomfortable. Excess movement will limit some cladding options such as stucco.

5.5 BUILDING CONSENT FOR POLE HOUSES

5.5.1 Building consent application documents should include:

- pole embedment details
- test results of bearing strength of the soil/ground
- site and slope stability assessments
- pole spacing and diameter
- size and strength of any concrete plug in the base of the hole
- pole lengths – longer poles will deflect more under load than short poles, and this can lead to rotation of the floor in the horizontal plane during storms or earthquakes
- connector plates and fasteners for connections between poles and beams and between poles and braces
- the amount and type of bracing required and how this will be achieved
- size and span of the beams spanning between the poles using specific design according to NZS 3603:1993
- design and detail of such items as ground beams (where required)
- proposed methods of achieving the required durability of components
- recommended inspection and maintenance regime.

6.0 CONSTRUCTION TECHNIQUES

6.1 SETTING OUT

6.1.1 Setting out pole houses is difficult on steep sites using traditional carpentry methods, and surveyors are generally employed.

6.1.2 Each pole position may be located by pegs, with further pegs for offset lines some 2 m outside the building boundaries for every line of poles. These offset lines are the only reference after the holes are bored. Alternatively, survey pegs may be placed 1 m uphill from each pole position.

6.1.3 On steep sites, profiles may not be a practical option. If the building site contains trees that are to be retained, care must be taken to ensure that string and sight lines will not be obstructed.

6.1.4 Another method is to cast a concrete working platform not less than 750 mm square around each peg location, leaving a circular hole in the centre of the concrete with 100 mm clearance all around for the auger. This collar may be level to provide a safer working platform, and recessing it below ground allows for backfilling with topsoil to hide the concrete (Figure 2).

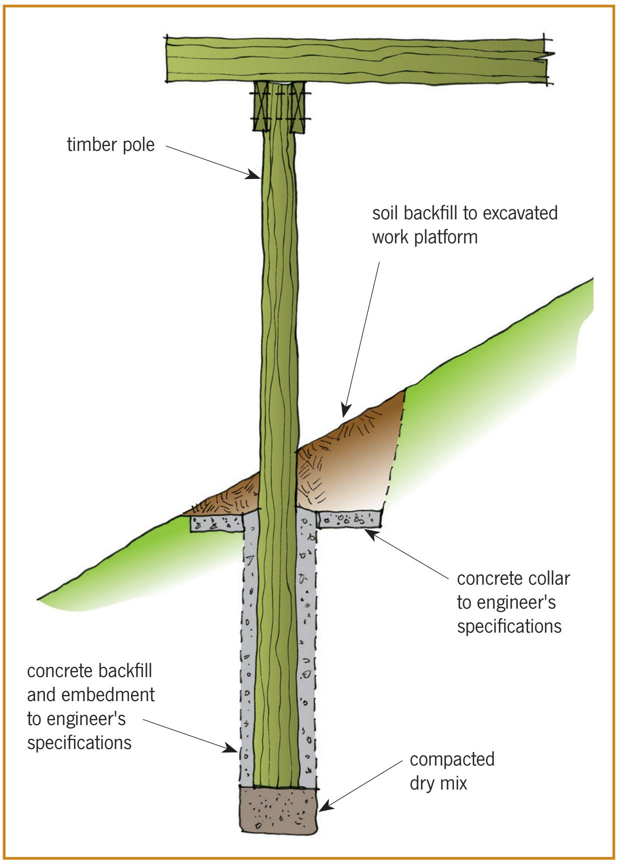


Figure 2. Concrete collar for poles on steep sites.

6.2 HOLES FOR POLES

6.2.1 Devices that can be used to make holes for poles are:

- truck or tractor-mounted power augers (can be difficult on steep sloping sites)
- specially developed lightweight tripod drilling rigs using a remote compressor as power source
- hand-held motorised augers in friable soils (can be difficult to remove debris from holes)
- motorised augers supported by a crane in heavy clay soils
- tracked digger with power auger.

6.2.2 Hand digging may be the only practical method to use on steep inaccessible sites but can be limited by the required depth of the holes.

6.2.3 Mechanised augers are available up to 600 mm in diameter to cope with poles up to 400 mm in diameter.

6.2.4 The depth of the holes is determined by the engineer at the design stage and depends on the bracing methods used and the soil properties.

6.2.5 Hole diameters should be at least 200 mm larger than the pole diameter. This permits pole adjustment during erection and allows concrete to be placed. Holes should not be smaller than the concrete footing required to provide adequate bearing in each location.

6.2.6 If unexpected soil conditions are struck during the preparation of the holes, the engineer must be consulted and, if necessary, alternative details provided and the design variation recorded.

6.2.7 It is important that all loose and disturbed soil is removed from the bottom of the hole to ensure solid end-bearing.

6.2.8 Once the holes have been inspected and signed off by the engineer, a 200 mm thick concrete plug is poured in the base using a tremie (hopper and tube for concrete placement). The concrete should be as specified by the engineer and be thoroughly compacted. Precast concrete pads in the bottom of holes are not suitable for this purpose as they do not provide even end-bearing for the poles.

6.2.9 Prepared holes should be temporarily covered until the poles are placed as a safety measure and to prevent soil contaminating the hole.

6.2.10 Pole-framed structures require accuracy of alignment that can not normally be achieved when driving poles. Pole platforms, which have greater tolerance, can use driven poles.

6.3 POLE INSTALLATION

6.3.1 Use fabric slings (or adequate protection when using wire strops) to lift poles to avoid spoiling their appearance.

6.3.2 Cast-in poles for framed structures are installed wide end down and backfilled with concrete after being aligned.

6.3.3 After the poles are placed in the bored holes, the corner poles are:

- located accurately (using offset lines) – see Figure 3
- plumbed using a theodolite or a level and a 3 m straight edge with offset blocks to accommodate the pole taper
- braced securely with temporary braces until the concrete has been placed and cured
- immediately backfilled (checking to ensure alignment is maintained).

6.3.4 The remainder of the poles are lined up and plumbed using the secured corner poles as reference points before being concreted.

6.3.5 Concrete must cure for 3 to 4 days before fitting the beams. Framing loads should not be applied to the concrete until it has cured for 7 days (temporary braces remain in place for this time).

6.3.6 Fitting the beams:

- Use offset string lines to set the beam levels. This enables the positions and depths of the checks in the poles into which the beams are fitted to be accurately determined.
- Set-out for check depths so that their maximum depth is determined by the pole nearest to the line and does not exceed 40 mm (Figure 3). Neatly cut checks so that the beams sit on the shoulders of the check when bolted into place.

6.3.7 Builders may prefer to fix the main beams at two levels before concreting the base of the poles to allow positioning of poles.

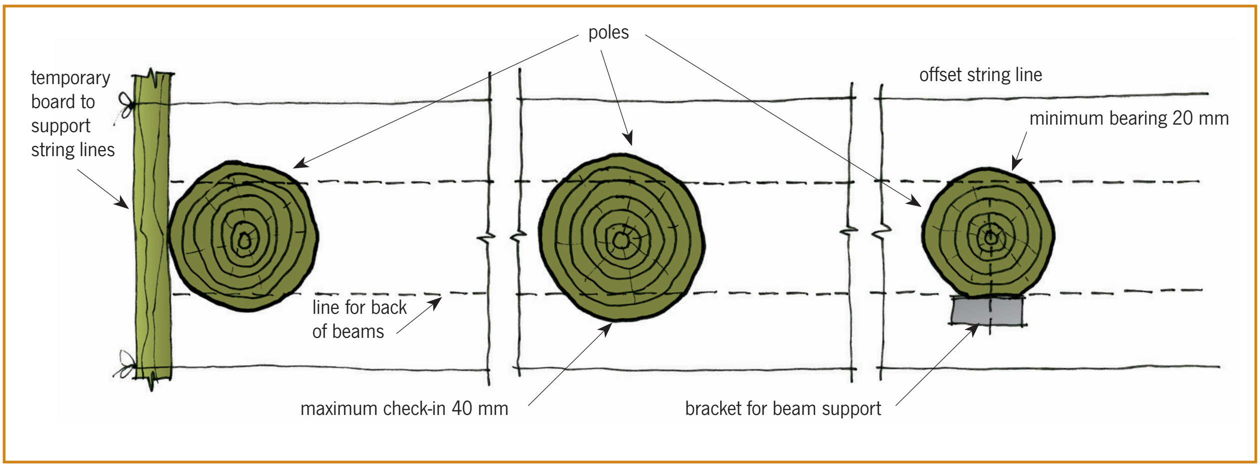


Figure 3. Beam to pole set-out.

6.3.8 Temporarily secure beams before drilling the bolt holes. Large proprietary screws are becoming available and may be a fixing option also.

6.3.9 Fixing sizes and numbers are determined by the design engineer. Additional loadbearing brackets are required to support beams in some instances and must be approved by the engineer.

6.4 IN SITU TREATMENT OF HOLES AND CUTS IN POLES

6.4.1 All holes, cuts and notches must be brush coated with a concentrated solution of proprietary wood preservative such as those described in NZS 3604:2011 section 6.4.3.3. Eyes and skin must be protected during application.

7.0 FLOOR INSULATION

7.0.1 NZBC clause H1 *Energy efficiency* makes the thermal insulation of suspended ground floors compulsory. Insulation in accordance with NZS 4218:2009 *Thermal insulation – Housing and small buildings* is one way of complying with the NZBC for buildings having a floor area of no more than 300 m². The BRANZ *House Insulation Guide* (5th edition) also provides information on effective designs to achieve thermal performance goals for houses.

7.0.2 Key requirements when insulating the floor structure of pole houses are to:

- carry out installation after the structure above is weathertight
- install bulk-fill or polystyrene insulation ideally to the full depth of the joists – using perforated foil is not recommended
- temporarily secure insulation with polypropylene tape
- install a sheet lining (fibre-cement or H3 CCA-treated plywood) to the underside of the joists to protect the insulation from moisture and wind. The sheet lining also prevents wind wash across the surface of the insulation, which reduces its effectiveness.

8.0 INSPECTION AND MAINTENANCE

8.0.1 All bolted connections to poles should be inspected for tightness at yearly intervals because they can loosen over time with dimensional changes in the timber. It is important that all the connections are kept tight to minimise damage at the brace when a major event such as a storm or earthquake occurs and to minimise unwelcome vibrations and deflections.

8.0.2 Other items to check regularly include:
- any corrosion on steel components
- timber deterioration particularly close to the ground.

9.0 STANDARDS

AS/NZS 1170.0:2002 *Structural design actions – Part 0: General principles*
AS/NZS 1170.1:2002 *Structural design actions – Part 1: Permanent, imposed and other actions*
AS/NZS 1170.2:2011 *Structural design actions – Part 2: Wind actions*
AS/NZS 1170.3:2003 *Structural design actions – Part 3 Snow and ice actions*
AS/NZS 4680:2006 *Hot-dip galvanized (zinc) coatings on fabricated ferrous articles*

NZS 1170.5:2004 *Structural design actions – Part 5: Earthquake actions – New Zealand*
NZS 3101.1&2:2006 *Concrete structures standard*
NZS 3602:2003 *Timber and wood-based products for use in building*
NZS 3603:1993 *Timber structures standard*
NZS 3604:2011 *Timber-framed buildings*
NZS 3605:2001 *Timber piles and poles for use in building*
NZS 3640:2003 *Chemical preservation of round and sawn timber*
NZS 4218:2009 *Thermal insulation – Housing and small buildings*

Cover image: The Dogbox, Whanganui, by Patch Work Architecture. Photo: ©Paul McCredie.

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