BRANZ

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BULLETIN

INSULATION OF CONCRETE SLAB-ON-GROUND FLOORS LESS THAN 300 M²

July 2023

- Revisions to the H1 Acceptable Solutions that came into force in 2022 and 2023 have changed the thermal performance requirements for buildings.
- The minimum thermal performance required of slab-on-ground floors has increased.
- This bulletin outlines options and challenges with insulating concrete slab-on-ground floors for all housing, and buildings up to 300 m², with a focus on housing.

1 INTRODUCTION

1.0.1 Concrete slab-on-ground floors are typically insulated by placing a layer of rigid foam board over the damp-proof membrane before the concrete is poured.

1.0.2 Approximately 80% of the heat lost from a slab is lost through the slab edge. Significant improvement in thermal performance can be achieved by incorporating slab edge insulation. Design of slab edge insulation should be considered as an integral part of slab insulation and design.

1.0.3 H1/AS1 5th edition amendment 1 (referred to just as H1/AS1 in this bulletin) has tables showing construction R-values for different insulation options (and no insulation at all) in Appendix F. They include R1.2 or R2.4 insulation for both full cover and a 1.2 m wide strip of insulation around the slab perimeter and also R1.0 vertical edge insulation. Proprietary raft or waffle slab systems are regarded as uninsulated under H1/AS1.

1.0.4 H1/VM1 Appendix F describes acceptable modelling methods to demonstrate compliance.

2 BUILDING CODE CLAUSE H1 REQUIREMENTS

2.0.1 The scope of H1/AS1 and H1/VM1 cover only housing, and buildings other than housing with an occupied space of less than 300 m^2.

2.0.2 H1/AS1 and H1/VM1 divide New Zealand into six climate zones, explained in Appendix C of each document. The minimum construction R-values required for building elements in each climate zone using the schedule method are given in the Acceptable Solution.

2.0.3 Slab-on-ground floor compliance with H1 is determined by:

- in H1/AS1 Appendix F, look-up tables for selected slab-on-ground floor scenarios to establish construction R-values using the schedule or calculation methods
- in H1/VM1 Appendix F, calculation based on two and three-dimensional computer modelling of the slab floor.

2.1 SCHEDULE METHOD

2.1.1 The schedule method in H1/AS1 contains tables that set out the minimum construction R-values for given building elements in each of New Zealand's six climate zones (Table 1).

2.1.2 The minimum construction R-values in H1/AS1 are given in Table 2.1.2.2B (unheated building elements) and Table 2.1.2.2A (heated building elements). BRANZ has a schedule method tool to assist in using this method – www.branz.co.nz/energy-efficiency/h1-schedule-method-tool.

2.2 CALCULATION METHOD

2.2.1 The calculation method in H1/AS1 compares the proposed building with a theoretical reference building insulated in accordance with the schedule method:

- Glazing area must be 40% or less of total wall area.
- Insulation level of any individual building element can be above or below (but no less than 50%) the reference building/schedule method figures.
- Higher insulation in one element can compensate for lower insulation in another, but the whole building must perform at least as well as the reference building.

2.2.2 Reference building heat loss equations are found in H1/AS1 Table 2.1.3.4, and the construction R-value of slab floors is verified using H1/AS1 Appendix F.

2.2.3 A calculation method tool is available on the BRANZ website – www.branz.co.nz/energy-efficiency/h1-calculation-method-tool.

2.3 MODELLING METHOD

2.3.1 With the modelling method in H1/VM1, energy use of the proposed building must be shown not to exceed the energy use of the reference building, using the computer modelling described in H1/VM1 Appendix D. This gives designers a lot of flexibility because higher thermal performance in one element can compensate for lower performance in another. Acceptable modelling tools include energy estimation tools as well as dynamic modelling.

2.4 HEATED FLOORS

2.4.1 Floors with embedded heating systems require insulation giving a greater construction R-value to ensure the heat energy is not lost to the outside of the building. The minimum construction R-values of floors with embedded heating systems must be determined by the schedule method using H1/AS1 Table 2.1.2.2A. R-values of these floors cannot be reduced when using the calculation or modelling methods. Full cover underslab insulation is required with heated floors – 1.2 m perimeter insulation is not suitable. If floor coverings (such as carpet or cork) are proposed, insulation R-value should be increased because the floor covering will reduce the efficiency of the heating.

Table 1. Minimum construction R-values for floors in the different climate zones using the schedule method in H1/AS1.

Options	Minimum construction R-values (m^2K/W)					
	Climate zone 1	Climate zone 2	Climate zone 3	Climate zone 4	Climate zone 5	Climate zone 6
Slab-on-ground floors	1.5				1.6	1.7
Other floors and all heated floors	2.5			2.8	3.0	

3 DETERMINING CONSTRUCTION R-VALUES

3.0.1 The required thermal performance of building elements in H1/AS1 and H1/VM1 is generally expressed in terms of construction R-value. For a floor, this is the total thermal resistance of all the physical elements that make up the floor, including the:

- insulating effect of the ground beneath
- the slab itself
- effective thickness of the external wall (this has a small impact on the slab's thermal performance)
- floor coverings (in H1/VM1 modelling only).

3.0.2 H1/AS1 ignores the effects of floor coverings such as carpets.

3.0.3 The thermal conductivity of the ground beneath the building affects the construction R-value, which is:

- enhanced by dry, sandy loam soil
- reduced by wet or saturated clay soils

3.0.4 H1/VM1 uses default values. Where site-specific ground conductivity is known, the value can be used in modelling calculations as an Alternative Solution.

3.0.5 To use the tables in H1/AS1 Appendix F, the slab area-to-perimeter ratio (Figure 1) and the effective external wall thickness (Figure 2) must be determined. For the area-to-perimeter ratio, use either:

- overall internal slab dimensions in accordance with Equation F.1 or
- external slab dimensions in accordance with Equation F.2.

3.0.6 For the same floor area:

- a complex shaped slab will have a lower area-to-perimeter ratio and a lower slab R-value
- larger slabs have higher area-to-perimeter ratios and therefore higher R-values than smaller slabs with similar shape and insulation
- the greater the area-to-perimeter ratio, the higher the slab R-value, all else being equal.

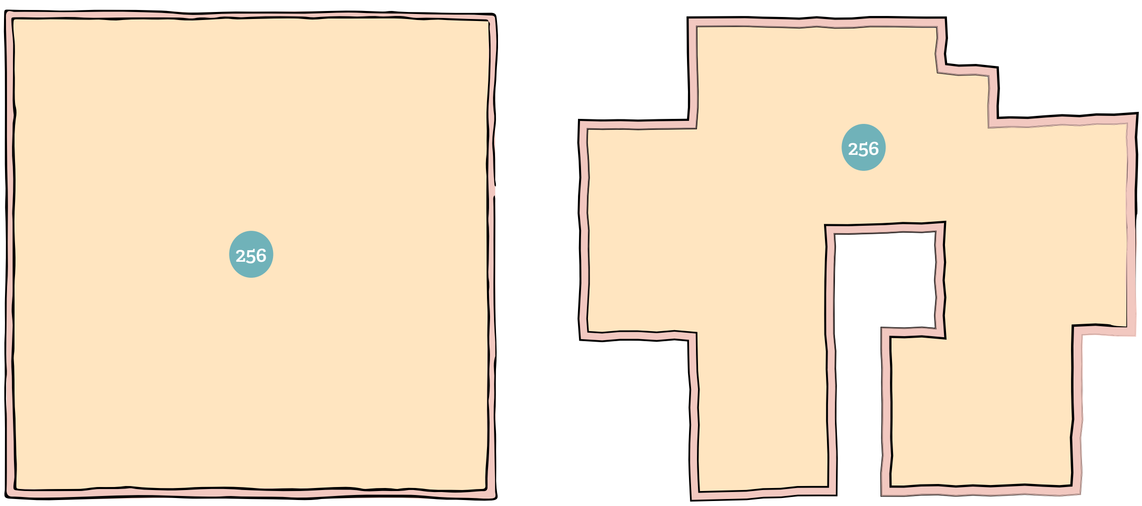
3.0.7 The effective thickness of an external wall is the horizontal distance between the external concrete slab edge at floor level and the interior surface of the wall (Figure 2). Thicker walls potentially mean a reduced amount of heat transfer (including through the slab) so the thermal performance of the slab is slightly greater.

4 MATERIALS

4.0.1 The commonly used product for insulating concrete slab-on-ground floors is rigid polystyrene foam sheet (Table 2). Two types of polystyrene are available – expanded (EPS) and extruded (XPS).

4.0.2 Expanded polystyrene (EPS):

- S, SL, H and VH grades are available. S grade is most commonly used for underslab insulation for residential and H grade for residential or commercial.
- Density range is 12–28 kg/m³.
- Although it has a closed-cell structure, water can be absorbed into interstitial spaces.
- It is not recommended where moisture absorption is a risk (moisture reduces the thermal insulation properties).
- For underslab insulation, specify EPS that is suitable for ground contact.



Floor area = 256 m²
Perimeter = 64 m
Area-to-perimeter ratio = 256/64 = 4
Concrete raft foundation slab and 90 mm framed wall:
without perimeter insulation = R1.8
with perimeter insulation = R2.2

Floor area = 256 m²
Perimeter = 100 m
Area-to-perimeter ratio = 256/100 = 2.56
Concrete raft foundation slab and 90 mm framed wall:
without perimeter insulation = R1.3
with perimeter insulation = R1.7

Figure 1. Slab area-to-perimeter ratio.

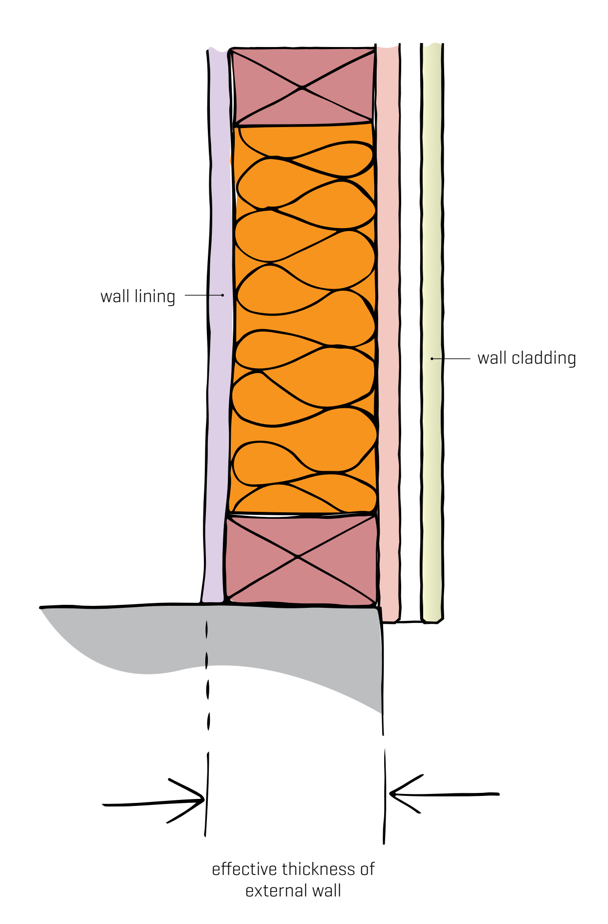


Figure 2. Effective thickness of an external wall.

4.0.3 Extruded polystyrene (XPS):

- Density range is 28–45 kg/m³.
- It has a closed-cell structure.
- Commonly used for slab edge insulation.

4.0.4 In comparison with EPS, XPS:

- is more water resistant
- has greater compressive and cross-breaking (bending) strengths
- has higher thermal performance for a given thickness
- is more expensive and may have higher embodied carbon (for the same thickness).

5 UNDERSLAB INSULATION

5.0.1 Underslab insulation may be full cover (under the entire slab) or a strip of insulation beneath the perimeter of the slab only. In H1/AS1 Appendix F, the perimeter insulation is 1.2 m wide.

5.0.2 BRANZ research has shown that the greatest gain in thermal performance comes from insulating a 1.2 m wide strip around the perimeter of the slab. Insulating beneath all habitable spaces of a generic slab-on-ground floor provides only limited additional thermal resistance.

5.0.3 Installing a 1.2 m wide strip of insulation requires a reduced amount of insulation and hence reduced material cost and potentially reduced embodied energy.

5.0.4 If full cover insulation is used, the insulation must continue beneath the slab thickenings at internal loadbearing walls.

5.0.5 Underslab insulation for raft slab floors has traditionally been reserved for high-performance floors. However, H1 5th edition amendment 1 regards raft floors with polystyrene pods but no additional insulation as uninsulated. To achieve H1 compliance, it may therefore be necessary to provide edge insulation and/or continuous (full slab) insulation that also covers the concrete ribs between the pods.

5.1 INSULATION UNDER FOOTINGS

5.1.1 H1 does not require insulation of underslab footings, and this is not included in the tables in Appendix F. Adding insulation under the footings can provide increased thermal performance (which can be demonstrated by modelling) but requires specific engineering design (SED). Many proprietary raft slab systems have options for full slab insulation, including insulation beneath the perimeter beam/footing.

5.2 INSULATION UNDER GARAGE FLOORS

5.2.1 Attached garages are difficult to make airtight and are generally designed as unconditioned spaces. The garage slab is typically uninsulated and may be set at a different level from the main floor slab. While the adjoining internal wall is usually insulated, the junction between the (insulated) house and (uninsulated) garage slab is a potential thermal bridge and therefore an area of heat loss. Bridging elements can include reinforcing as well as the slab itself. Design solutions such as a thermal break between insulated and uninsulated elements (recommended in a comment in H1/AS1) are complex and require SED.

5.2.2 To allow greater flexibility of building use, it would be prudent to insulate the floor (including the slab edge) of any unconditioned space that could possibly be converted to a habitable space in the future (for example, conversion

Table 2. Approximate material R-values for different grades of polystyrene.

	Typical density	R-value							
Grade		30 mm	40 mm	50 mm	60 mm	75 mm	80 mm	90 mm	100 mm
S grade	12–15 kg/m³	0.79	1.05	1.32	1.58	1.97	2.11	2.37	2.63
H grade	18–22 kg/m³	0.83	1.11	1.39	1.67	2.08	2.22	2.50	2.78
VH grade	28 kg/m³	0.86	1.14	1.43	1.71	2.20	2.29	2.57	2.86
XPS	28–45 kg/m³	1.1	1.4	1.8		2.7			

of an unconditioned garage space to a bedroom). Similarly, insulating the walls and ceiling of unconditioned spaces is recommended.

5.2.3 Where part of a slab (such as a garage) has no insulation and there is no vertical perimeter insulation separating the house and garage, a correction will need to be made to account for the extra heat loss. The BRANZ *House insulation guide* 6th edition has a calculator to determine this. (See the note at 2.1.3.7 in H1/AS1.)

5.3 INSULATION AND PROPRIETARY SLAB FLOOR SYSTEMS

5.3.1 The main type of proprietary slab-on-ground systems are concrete raft foundation/waffle slab systems. These systems are increasingly common. Their key features include:

- slab and foundations are integrated and sit 'on' the ground rather than 'in' it
- proprietary systems are specifically designed for each site
- they typically comprise a grid of formers (usually solid EPS blocks, honeycomb EPS blocks or hollow plastic pods) installed over a damp-proof membrane (DPM)
- reinforcing steel and concrete are placed between and on top of the formers to create a grid of beams and slab
- some systems have options to include a base insulation of EPS or XPS on top of the DPM
- some systems use an XPS edge former with EPS interior formers.

5.3.2 As noted, proprietary raft or waffle slab systems are regarded as uninsulated under H1/AS1. Construction R-values can be increased by insulating the vertical slab edge and/or by providing a layer of rigid foam board beneath the waffle slab and/or beneath footings (which will require SED).

5.3.3 Tables in H1/AS1 Appendix F show the construction R-values for concrete raft foundation floors with different types of insulation.

5.3.4 A raft foundation incorporating concrete or driven timber piles is a common design solution for soil with poor bearing capacity (Figure 3). Energy efficiency calculations should consider the thermal bridging effect of the piles and ideally also the specific thermal conductivity of the ground. For this situation, the modelling method will probably identify the most efficient solutions. Options may include insulating the piles for a calculated depth or increasing the overall slab insulation.

6 SLAB EDGE INSULATION

6.0.1 Approximately 80% of the heat loss from a concrete slab occurs through the slab edge. Significant

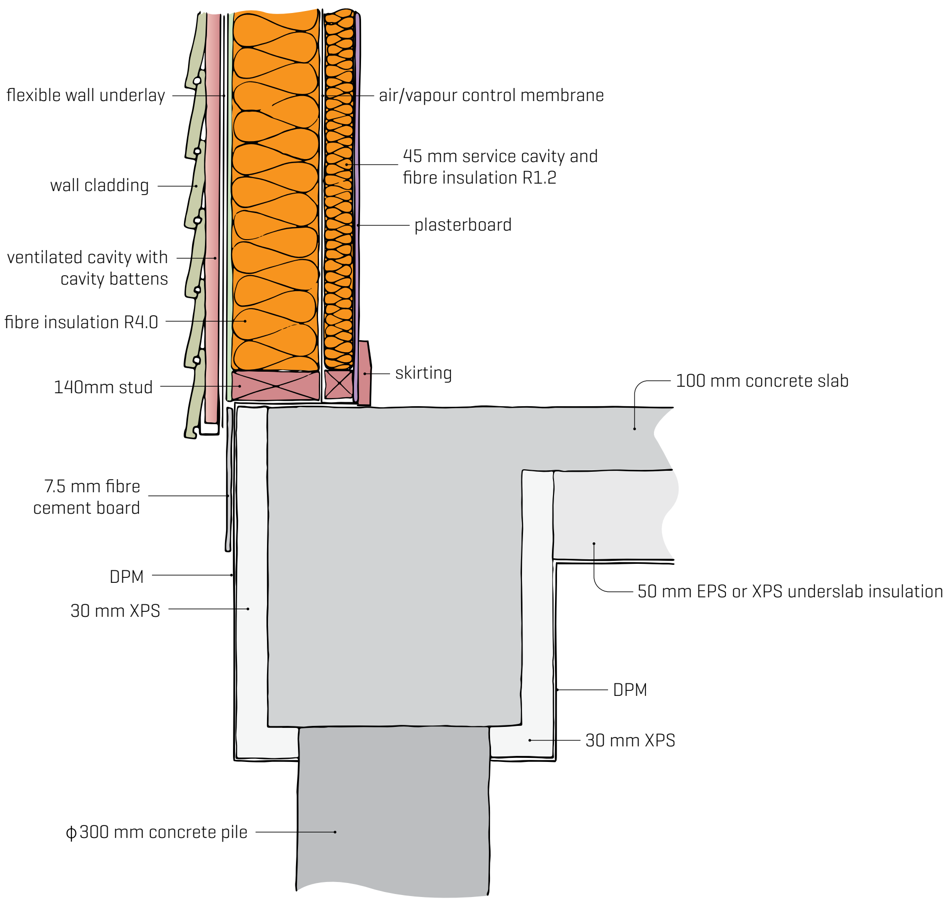


Figure 3. Concrete pile to insulated slab on ground.

thermal performance improvement can be achieved by incorporating slab edge insulation on the outside face of the foundation wall (Figure 4). Tables in H1/AS1 Appendix F include construction options with R1.0 vertical edge insulation with or without additional underslab insulation. (BRANZ research has found that installing edge insulation beyond R1.0 has limited additional benefits.)

6.0.2 The insulation sheets must remain dry and be protected from damage, which is a challenging design detail. Details need to also allow the wall cavity to drain while minimising any gap at the top of the insulation.

6.0.3 Slab edge insulation:

- should be continuous from the top of the slab to the base of the footing for all slabs, including concrete masonry foundations, which are commonly used for poured slab-on-ground floors
- is typically XPS (which absorbs less ground moisture than EPS and is thinner for the same thermal performance)
- may require bottom plate fixings to be cranked or angled to achieve adequate edge distance, particularly where 90 mm wide wall framing is used.

6.1 PROPRIETARY SLAB EDGE INSULATION

6.1.1 A range of proprietary slab edge insulation systems is available as well as various types of rigid foam permanent formwork to create a fully insulated perimeter footing. Some systems are installed on the inside face of the formwork, prior to pouring the slab. Others are fixed to the slab edge after pouring.

6.2 PROTECTION AND MAINTENANCE OF SLAB EDGE INSULATION

6.2.1 Slab edge insulation should be protected against water absorption, ultraviolet (UV) exposure and impact damage. Property owners should be advised to check the protection occasionally to ensure it remains in good condition.

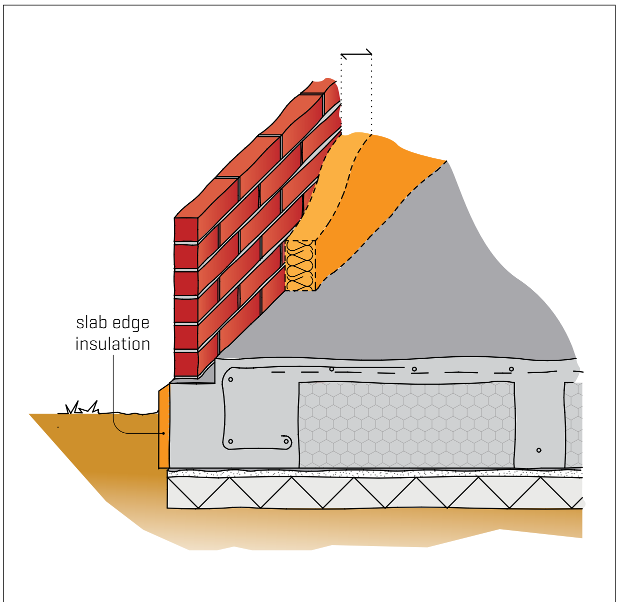


Figure 4. Slab edge insulation.

6.2.2 Typical methods include:

- acrylic or cement-based plaster finishes suitable for below-ground use, applied with or without a compatible reinforced liquid tanking membrane
- large tiles with a low rate of moisture absorbency, held in place by backfilling
- extruded uPVC or waterproof mineral sheet products.

6.2.3 Some proprietary systems are prefinished with a plaster skin.

6.2.4 Fibre-cement sheet on its own is not recommended because it may not be durable in situations where water absorption is likely. However, it can be used to protect tanking.

6.2.5 E2/AS1 clause 2.5 states: "Maintenance shall be carried out as necessary to achieve the required durability of materials, components and junctions." This applies to the protective material added to polystyrene insulation on the outside face of foundation walls.

6.2.6 Regular maintenance includes:

- inspecting surfaces and junctions
- repairing or replacing items when necessary to preserve weathertightness and insulation properties
- maintaining finish coatings.

7 FLOOR TOPPER INSULATION

7.0.1 Insulation (typically XPS) is sandwiched between the structural slab and a minimum 75 mm thick unreinforced topping slab. The edge of the topping slab is isolated from the exterior – for example, by insulated wall framing.

7.0.2 Advantages of a topping slab include:

- the insulation does not require protection from UV or damp
- underfloor heating can be installed in the topping slab
- installation of insulation is simplified – for example, it is not required beneath slab thickenings and foundations
- the system provides good sound insulation.

7.0.3 A topping slab design is likely to be more expensive to construct than a single slab and may have a higher carbon footprint as it not only uses more material but also requires two concrete pours.

7.0.4 An alternative to the above method is to install timber-based sheet material (such as plywood or strand board) over the insulation instead of a topping slab (Figure 5).

8 OTHER DESIGN CONSIDERATIONS

8.0.1 Although there is currently no requirement for designers to measure the embodied carbon in house designs or to demonstrate waste minimisation or recovery plans, awareness of these issues is growing and they are likely to become requirements in the future.

8.0.2 There are a number of tools to help designers consider the embodied energy and carbon footprint of

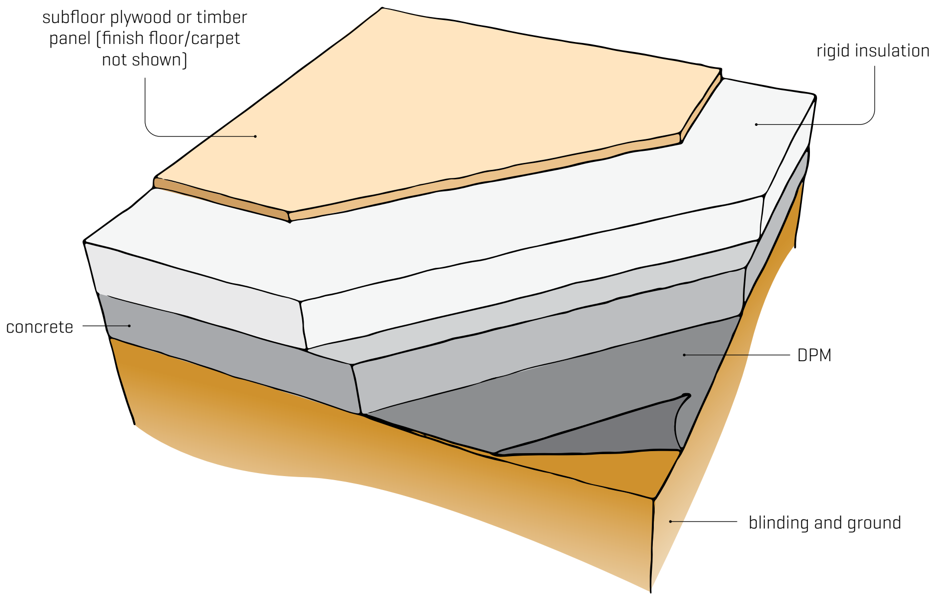


Figure 5. Insulation above the slab with rigid sheet material above the insulation.

building materials, including the BRANZ tools CO_2RE and CO_2NSTRUCT. The tools enable designers to make informed choices about building materials. For example, XPS has a higher R-value than EPS for a given thickness but a significantly larger carbon footprint.

8.0.3 Any design and specification of thermal insulation must also consider the risks of a house overheating. The high thermal mass of a concrete slab floor means it can absorb and retain heat, which is released as passive heating. The risk of overheating is increased by:
- improved insulation and airtightness requirements
- greater glazing areas
- a changing climate.

8.0.4 The risk of unwanted solar heat gain and resultant overheating can be addressed with careful window location, shading, sizing and specification and careful design of ventilation.

8.0.5 Moisture (in the slab and/or insulation) will dramatically reduce the insulation R-value so insulation material must be protected as far as practicable. With underslab insulation, the DPM must fully cover the underside of the slab insulation. Detailing should address thermal bridging (and risk of condensation) at the wall/slab junction and slab perimeter.

9 FURTHER INFORMATION

BRANZ

BRANZ CO_2NSTRUCT tool

BRANZ CO_2RE tool

BRANZ *House insulation guide* (6th edition)

Bulletin 676 *Complying with H1 - housing, and buildings up to 300 m²*

Bulletin 678 *H1 calculation method – housing, and buildings up to 300 m²*

Bulletin 684 *Thermal modelling methods for houses*

External Research Report ER70 *High-performance construction details handbook*

Study Report SR352 *Perimeter insulation of concrete slab foundations*

CONCRETE NZ

CCANZ CP01:2022 *Code of Practice for Weathertight Concrete and Concrete Masonry Construction*

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