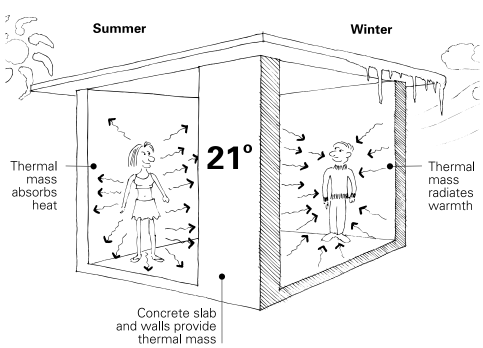
Concrete slab floors

Concrete slab floors come in many forms and can be used to provide great thermal comfort and lifestyle advantages.

THE BENEFITS OF CONCRETE SLABS

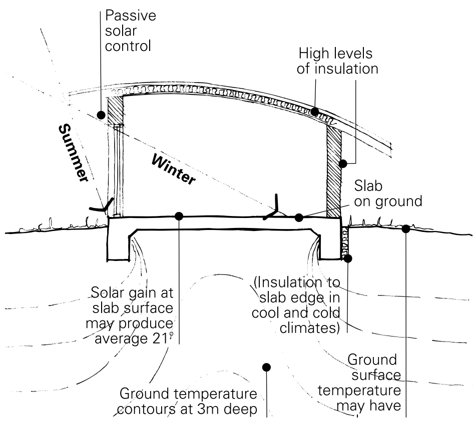
Thermal Mass describes the potential of a material to store and re-release thermal energy. Materials with high thermal mass, such as concrete slabs or heavyweight walls, can help regulate indoor comfort by radiating or absorbing heat, creating a heating or cooling effect. [See: Thermal Mass]

Thermal mass is useful in most climates, and works particularly well in cool climates and climates with a high day/night temperature range. To be effective, thermal mass must be used in conjunction with good passive design. [See: Design for Climate, Passive Solar Heating, Passive Cooling]



Design slabs to absorb heat from the sun or other sources during winter. Heat can be stored in the slab and re-radiated for many hours afterwards. In summer, allow slabs to be exposed to cooling night breezes so that heat collected during the day can dissipate.

Earth coupling is achieved when the thermal mass of the slab is in direct contact with the additional thermal mass of the earth below. This greatly enhances thermal performance. Earth coupling is most simply achieved using slab-on-ground construction.



Earth coupling allows the floor slab of a well insulated house to achieve the same temperature as the earth a few metres below the ground surface, where temperatures are more stable (cooler in summer, warmer in winter). In winter, added solar gain boosts the surface temperature of the slab to a very comfortable level.

Durability is one of the other main advantages of concrete slabs. Concrete's high embodied energy can be offset by its permanence. If reinforcement is correctly designed and placed, and if the concrete is placed and compacted well so there are no voids or porous areas, concrete slabs have a long lifespan.

Control of cracking is important. A number of factors affect this and should be considered, including:

> **Size of slab** – if it is large or has two distinct separate parts, control and/or movement joints may be needed;

> **Proper preparation of foundations** – this will prevent settlement cracking;

> **Curing** – curing will help reduce surface cracking. Concrete typically takes 28 days to reach its design strength, and the first 3 to 7 days are critical, beginning as soon as finishing of the slab is complete. An applied liquid curing membrane is usually the most practical method. Covering with a plastic sheet will also work but is harder to maintain. Keeping the concrete continuously wet, while the best method of curing, is not advised due to the large amounts of water that may be required;

> **Addition of water** – excess water added to the concrete mix prior to placing will increase the risk of cracking and may result in dusting of the surface and a decrease in the strength of the concrete;

> **Placing and Compaction** – inadequate placing and compaction will result in a lower strength and/or honeycombed (porous) concrete and lead to increased cracking.

Termite resistance is achieved with concrete slabs by designing and constructing them in accordance with the Australian Standards to minimise shrinkage cracking, and by treating any joints, penetrations and the edge of the slab.

> Slab edge treatment can be achieved simply by exposing the concrete edge for a minimum height or width of 75mm above the ground, forming an inspection zone at ground level.

> Cavity physical barriers are used where a brick cavity extends to below ground, and can be formed by using sheet materials, a fine stainless steel mesh, or finely graded stone.

> Pipe penetrations through concrete slabs should have some form of physical barrier. Options include sheet materials, stainless steel mesh or graded stone.

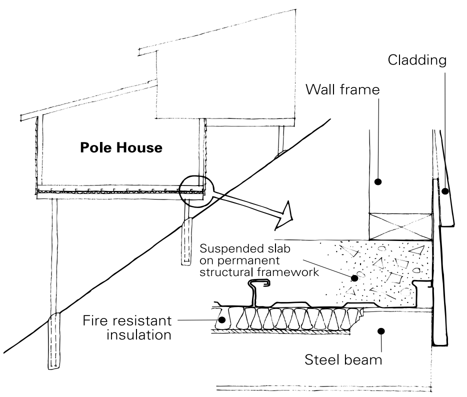
> Although physical barriers are environmentally preferable, chemical deterrents are also available. These must be re-applied at regular intervals to maintain efficacy.

STRUCTURAL ISSUES

Reactive soil sites can be difficult to build on, but 'floating' stiffened concrete raft slabs cope well with these conditions. Some stiffened raft slabs known as waffle raft slabs use void formers at regular intervals, forming closely spaced deep reinforced beams criss-crossing the slab underside.

These void formers are mostly expanded foam boxes, which interfere with earth coupling, but more thermally connective alternatives are available. These include proprietary systems that use recycled tyres, or reused detergent bottles filled with water and grouped together as void formers.

Steep sites may have geotechnical requirements which make slab-on-ground construction impracticable. Although slab-on-ground construction is more thermally efficient, a suspended slab can be a suitable way to gain the advantage of thermal mass on a steep site. Typical pole frame construction can be adapted easily to incorporate a slab. The slab underside should be insulated in some climates. [See: Insulation Overview, Insulation Installation]



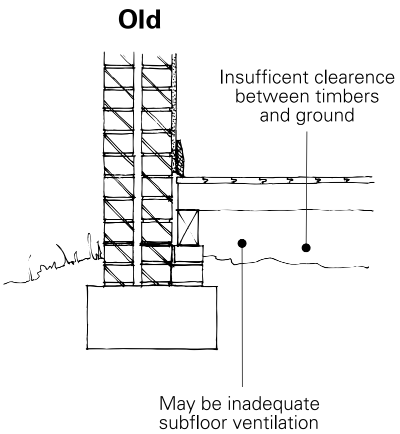
Permanent structural formwork or one of the many precast flooring alternatives are usually the most cost effective way of constructing high set suspended slabs. These are normally designed by an engineer and installed by builders.

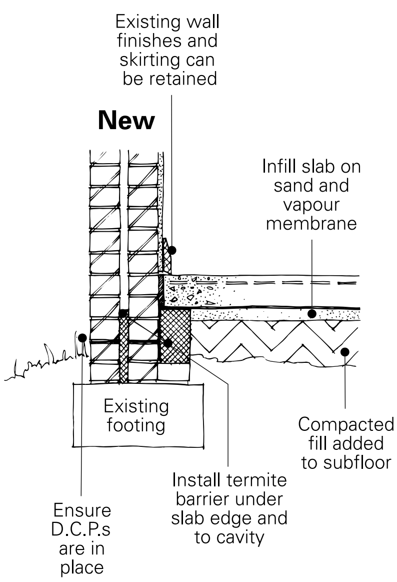
These systems can provide useful thermal mass in situations where long spans are needed, such as pole homes or upper floors of two storey homes. These systems are often designed and installed as part of one supply contract by the manufacturer.

Suspended autoclaved aerated concrete (AAC) panels can provide clear spans with acoustic and thermal benefits, and allow speedy installation on site. AAC floor panels have approximately 25 percent of the mass of normal concrete but still provide thermal comfort due to their insulation properties. [See: Construction Systems – Aerated Concrete Block]

Level sites are well suited to slab-on-ground construction. Use of slab-on-ground allows earth coupling and, because floor levels are close to ground level, facilitates free flow from interior to exterior spaces.

Renovations can often incorporate concrete slabs even when the original building does not. Added rooms can use slab-on-ground or suspended slabs. Renovated rooms with timber floors are often capable of having the timber replaced with a concrete slab, for added thermal mass and quietness underfoot.





These slabs can be either suspended on the original subfloor walls and footings, or if the old floor is close to ground they can be an infill slab on fill. Most advantage is gained if passive design principles are followed. [See: Passive Solar Heating, Passive Cooling, Clarke – Alteration]

Curing of all cement-based building materials is critical to achieving the design strength and other desired properties, especially with structural concrete slabs. Concrete takes 28 days to reach the design strength, although a sufficient minimum design strength may be achieved in less time if the concrete is specified accordingly. It is essential that the curing regime specified by the design engineer is followed exactly.

Compaction is usually achieved by vibrating the concrete. This reduces the air entrapped in the concrete giving a denser, stronger and more durable concrete better able to resist shrinkage cracking. While deeper beams should be compacted, thin slabs (100mm-thick typically) receive adequate compaction through the placing, screeding and finishing operations.

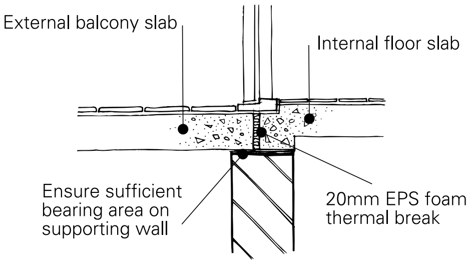
DESIGN ISSUES

Passive solar design principles and high mass construction work well together, and concrete slabs are generally the easiest way to add thermal mass to a house. Living rooms should face north in all but warm and hot humid climates to enable winter sun to invest warmth into the slab. Concrete slabs perform better as the diurnal temperature range increases. [See: Design for Climate]

Natural ventilation must be provided for in the design. On summer evenings, heat stored in the slab must be allowed to dissipate. This is particularly important for slabs on upper storeys, where warm air accumulates. Zone off the upper space from lower living areas where possible and ensure the space can be naturally ventilated. This is particularly important if bedrooms are located upstairs, to maintain night time sleeping comfort.

Insulation of the slab edge is important in cooler climates, to prevent warmth escaping through the edges of the slab. This insulation needs to be designed to complement the footing design, and should be undertaken in consultation with a structural engineer. [See: Insulation Installation]

It is possible to retro-fit slab edge insulation to existing slabs on ground. Renovations are an ideal time to do this, but it can be done at any time. Advice from an engineer should first be sought regarding disturbance to foundations and reinstatement of material, and termite barriers must not be breached.



Balconies extended from the main slab of a house may act as cooling or heating fins, carrying precious warmth away to the cold exterior during winter, or transferring heat from summer sun inside. Consider building such slabs independently of the main slab and incorporating a thermal break at the interface.

Acoustics need to be considered. Generally concrete slabs are a great way to reduce music or conversation noise being transferred from one level of a home to another, and between rooms on the same level. These noises will not be transmitted through a slab.

Impact noise needs to be considered. For instance, the sound of high heels on a tiled floor will be transmitted directly to the room below. While seldom a problem in detached houses, an acoustic barrier can be included in the ceiling below.

Open plan houses may transmit more noise than is convenient from one living area to another. Thermally efficient hard flooring will exacerbate this, so other elements within the room need to be designed to limit noise:

> Design the floor plan to be able to close spaces off from each other when needed.

> Large flat ceilings can transmit too much noise. Dropped bulkheads or suspended cupboards around kitchens will help to absorb and dissipate sound.

> Use absorbent materials on wall panels, or add large fabric wall hangings. Heavy drapes and curtains can also assist to absorb sound, as well as keeping warmth in during winter. [See: Noise Control]

FINISHES

For the thermal mass of a concrete slab to work effectively, it must be able to interact with the house interior. Covering the slab with finishes that insulate, such as carpet, will reduce the effectiveness of the thermal mass. However, a wide variety of finishes are available that allow thermal mass to be utilised:

Tiles

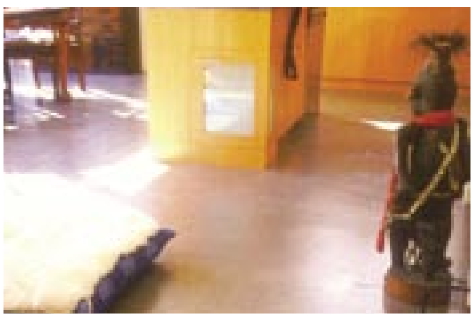
Tiles fixed by cement or cement-based adhesives are commonly available in many colours, sizes and patterns. (If thermal mass is to be utilised, avoid rubber-based adhesives due to their insulating effect). Darker colours with a matt surface work better than light shiny finishes. Choices include ceramic tiles, slate tiles, terracotta tiles, pavers and bricks.

Polished concrete

Polished concrete is a term which covers two distinct types of finishes:

> Trowel finished floors, with or without post-applied finishes;

> Ground and polished or abrasive blasted floors.



Some of the finishes below can be used in combination with other finishes to achieve a wider range of results, to suit any style or taste.

Trowel finishes include:

Steel trowel finish, where a normal hand or machine trowelled finish is used for the surface of the slab, usually with a clear sealer applied.

Burnished concrete, where the surface is finely steel trowelled, bringing the surface up to a glossy finish free of any trowelling marks.

Coloured concrete can be used in either steel trowel or burnished finishes, to achieve various results. It may be advisable to use experienced specialist contractors to carry out this work. These can be applied as oxides in the mix, or as ‘dry shake’ pigments applied to freshly screeded concrete and then trowelled in, or by chemically staining the concrete.

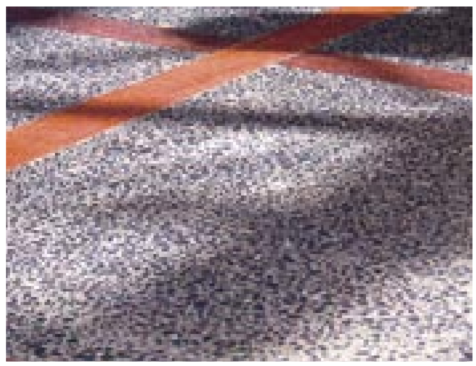
Chemical stains are used with either steel trowel or burnished finishes. Metallic salts are carried into the surface of the concrete by mild acids, making the stains deep and permanent.

Saw cuts can be added to enhance or separate panels of colour.

Ground & polished finishes include:

Exposed aggregate, where the normal grey concrete is ground back by several millimetres to expose whatever aggregate exists in the slab. This is often used in renovations of older buildings to reveal some of their history.

Exposed selected aggregates, where the cement colour and aggregate in a new slab are carefully selected, so when the surface is ground back they produce desired effects.



Abrasive blasting of the concrete surface will also provide varied effects.

Toppings can also be used on their own or together with some of the effects listed above to provide interesting visual finishes that do not interfere with thermal performance. Terrazzo is one of many toppings which is also ground and polished. Other toppings may be left in the ‘as placed’ or ‘as trowelled’ state.

Note that some of these options require careful protection of the slab during subsequent construction works. Also note that many sealer finishes have toxicity impacts but environmentally preferred alternatives are available such as bees wax or other natural wax polishes. These will need regular buffing to maintain sheen.

HEATING

Because concrete slabs offer so much thermal mass, they lend themselves well to long cycle in-slab heating systems. Slab heating is usually used in colder climates where limited solar access is available to the slab. Insulation is required to minimise heat loss to the ground. Despite the fact that latest systems provide flexible thermostat settings for different house zones, slab heating is in operation for the whole of winter and is therefore best suited to houses with permanent or high occupancy. [See: Heating and Cooling; Insulation Overview; Insulation Installation]

Electric resistance heating coils are the most common type of slab heating, and are attached to the reinforcement. These are usually controlled by timed switching so a relatively even temperature is maintained over a daily cycle with top up periods of just a few hours per day. They have a greenhouse gas penalty when fed with coal-fired electricity.

Hydronic heating coils in the slab are very energy efficient, giving lower running costs and heating bills. Hydronic heating slabs can be powered by a range of energy sources, including solar, groundsource heat pumps, gas furnaces and heat recovery units. Unlike electric coil heating, hydronic heating can be reverse cycled in summer, dumping excess heat into the night sky.

Recycling concrete is cost effective, minimises waste, and reduces the need to use more of the earth's resources.

RECYCLED CONTENT IN SLABS

There are two ways to contribute to the recycling of concrete:

> During demolition, by recycling 'waste' concrete

Demolition waste makes up 40 percent of all landfill. Taking demolition waste to landfill is expensive as well as damaging to the environment. Crushable concrete can instead be recycled to make economic and ecological savings. [See: Waste Minimisation]

If demolition concrete is kept separate without mixing with other demolition materials, a more usable product can be achieved from the crushing for recycling into new concrete.

> During construction, by using recycled materials as a component of new concrete.

Concrete is composed of three main components, coarse aggregate (stone), fine aggregate (sand) and cement. Recycled concrete and masonry can be utilised, as well as other industrial wastes, within these components.

Concrete's main environmental impacts are greenhouse gas emissions from cement production and the mining of raw materials.

Replacing a proportion of the cement with waste products such as fly ash, slag and silica fume can significantly reduce embodied energy and greenhouse gas emissions.

Use of crushed concrete from demolition as aggregate, as well as the use of slag aggregates and manufactured sands to replace nature stone and sand within concrete, decreases landfill, reduces embodied energy and can be low cost. [See: Embodied Energy]

Using substitutes for natural stone:
Coarse aggregate can be replaced with recycled crushed concrete. The simplest approach is to use up to 30 percent recycled aggregate for structural concrete. There is no noticeable difference in workability and strength between concrete with natural stone aggregate and concrete with up to 30 percent recycled aggregate.

It is possible to use up to 100 percent recycled coarse aggregate in concrete under controlled conditions. However concrete with more than 30 percent recycled concrete aggregate can have a greater water demand, can be less workable and result in lower strengths.

Using substitutes for natural sand:
Fines from concrete crushing can be used to reduce natural sand content, as can other industrial by-products such as ground glass, fly-ash, bottom-ash and slag sands. However, the properties of these products can affect workability, strength and shrinkage cracking.

Using substitutes for portland cement:
Cement substitutes (called 'supplementary cementitious materials' or 'extender') for Portland cement include fly ash, ground blast furnace slag and silica fume. These are all waste materials from other manufacturing processes.

Various blended cements are available, some with high substitution of portland cement with SCM's (up to 85 percent). The reduced amount of portland cement results in a significant reduction in greenhouse gas emissions.

New technologies currently being researched have the potential to reduce greenhouse gas emissions even further.

Obtaining these substitutes:
Recycled aggregate (stone and sand) is readily available in many locations, with the only barrier being whether batching plants have the capacity to stockpile additional types of aggregate.

Most batch plants have the ability to provide blended cements. In some smaller plants it may not be feasible to have two cement silos, or an additional silo for fly ash or slag, but hand loading may be an option.

While slag aggregates are readily available in areas close to steelworks, cartage costs may prohibit their use in more remote areas. For similar reasons, manufactured sands and crushed concrete may not be readily available in all areas.

NOTE: The design of concrete structures and the composition of structural concrete MUST be undertaken by a suitably qualified person. The material in this fact sheet is not a substitute for professional advice- always consult a structural engineer.

ADDITIONAL KEY REFERENCES

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Cement & Concrete Association of Australia (2003) *Passive Solar Design*

Cement & Concrete Association of Australia (2002) *Concrete Floor Heating*

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Recycled Concrete Products ("Envirocrete" range) www.boral.com.au/docs/product/quarries/product_quarries_15102003_085737.asp

Recycled tyre void formers for raft slabs www.ecoflex.com.au/

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Principal author: Dick Clarke
Contributing authors: Bernard Hockings, Caitlin McGee
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