Materials
Concrete slab floors

Concrete slab floors come in many forms and can be used to provide great thermal comfort and lifestyle advantages. Slabs can be on-ground, suspended, or a mix of both. They can be insulated, both underneath and on the edges. Conventional concrete has high embodied energy. It has been the most common material used in slabs but several new materials are available with dramatically reduced ecological impact.

Different types
Some types of concrete slabs may be more suitable to a particular site and climate zone than others.

Slab-on-ground
Slab-on-ground is the most common and has two variants: conventional slabs with deep excavated beams and waffle pod slabs, which sit near ground level and have a grid of expanded polystyrene foam pods as void formers creating a maze of beams in between. Conventional slabs can be insulated beneath the broad floor panels; waffle pods are by definition insulated beneath. Both may benefit from slab edge insulation.

Suspended slab
Suspended slabs are formed and poured in situ, with either removable or ‘lost’ non-loadbearing formwork, or permanent formwork which forms part of the reinforcement.

Precast slab
Precast slabs are manufactured off site and craned into place, either in finished form or with an additional thin pour of concrete over the top. They can be made from conventional or post-tensioned reinforced concrete, or from autoclaved aerated concrete (AAC). (see Autoclaved aerated concrete)
**Benefits of concrete slabs**

**Thermal comfort**

‘Thermal mass’ describes the potential of a material to store and re-release thermal energy. It is sometimes referred to as ‘building conditioning’, which is much more effective than air conditioning. Materials with high thermal mass, such as concrete slabs or heavyweight walls, can help regulate indoor comfort by acting like a temperature flywheel: by radiating or absorbing heat, they create a heating or cooling effect on the human body. (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 and should also consider the inclusion of high mass walls, as they can provide the benefits of ‘building conditioning’ instead of, or as well as, concrete slab floors. (see *Design for climate; Passive solar heating; Passive cooling*)

In winter, slabs should be designed so they can absorb heat from the sun (or other low energy sources). This heat is stored by the thermal mass and re-radiated for many hours afterwards.

In summer, slabs must be protected from direct sunlight and exposed to cooling night breezes and night sky radiation so that heat collected during the day can dissipate.

A slab-on-ground can be ground coupled (uninsulated) or insulated. An uninsulated slab in a good passively designed house has a surface temperature approximately the same as the stable ground temperature at about 3m depth. Depending upon your location, this may or may not be desirable. Ground coupling in mild climate zones such as Perth, Brisbane or coastal NSW allows the floor slab of a well insulated house to achieve the stable temperature of the earth: cooler in summer, warmer in winter. In winter, added solar gain boosts the surface temperature of the slab to a very comfortable level.

In climates with colder winters, such as Melbourne or the southern highlands of NSW, the deep ground temperature is too low to allow passive solar heating to be effective enough. In these locations, slabs should be insulated underneath, which reduces the amount of heat required to achieve comfortable temperatures. In northern Australia, ground coupling still works well, unless the building is to be air conditioned, in which case insulating the slab — especially the edges — is essential.

Insulating the underside decouples the slab from the ground temperatures.
The effectiveness of earth coupling is determined by climate. For further details refer to the isothermic maps of Australia prepared by David Baggs (Baggs 1991).

Slab insulation can be done with large sheets of high density foam, laid all the way under the internal floor panels, with only the edge and internal beams penetrating to foundation level. Alternatively, the common and very cost effective waffle pod slab supplies sufficient insulation in all but alpine climate zones (see ‘Waffle pod slabs’ in Construction systems).

Insulating the edges of floor slabs is beneficial in all but the mildest climates. Protection against termites needs careful attention, and the detail here shows an example of how to do that.

**Durability**

**Long life** — 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 can have an almost unlimited life span.

To ensure longevity of the slab, control cracking with:

- proper preparation of foundations
- appropriate water content: excess water causes cracking and weakens the slab
- appropriate placing and compaction
- appropriate curing, employing a curing membrane in the first 3–7 days (continuous wetting is a common practice but also consumes large amounts of water)
- appropriate construction scheduling allowing 28 days, or the duration specified by your structural engineer, for the concrete to reach design strength before placing significant loads.

**Termite resistance** — For minimum termite risk construction, concrete slabs should be designed and constructed in accordance with Australian Standards to have minimal shrinkage cracking. Joints, penetrations and the edge of the slab should be treated.

- Slab edge treatment can be achieved simply by exposing a minimum 100mm of slab edge above the ground or pavers, forming an inspection zone at ground level.
- Where a brick cavity extends below ground, physical barriers must be installed using sheet materials including stainless steel, a termiteicide-impregnated polyethylene vapour barrier (tPVC) and/or damp course, a fine stainless steel mesh, or finely graded stone.
- Pipe penetrations through concrete slabs require a physical barrier. Options include sheet materials such as tPVC, stainless steel mesh or graded stone.
- Although physical barriers are environmentally preferable, chemical deterrents are also available, which must be reapplied at regular intervals to maintain efficacy. Benign natural deterrents can be applied by permanent reticulation pipework similar to a drip irrigation system.
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 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, to allow heat stored in the slab to dissipate on summer evenings, particularly 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 in cooler climates prevents warmth escaping through the edges of the slab. This insulation needs to be designed to complement the footing design (as shown in the sample detail below) and should be undertaken in consultation with a structural engineer. (see Insulation)

Balconies that extend from the main slab of a house act as a thermal bridge, conducting uncontrolled heat into or out of the building. Design these slabs to be thermally independent of the main slab by incorporating an insulator at the joint, concealed beneath the external doors and walls.

Open plan houses may transmit more noise than is convenient from one living area to another. Thermally efficient hard flooring exacerbates this, so other elements in 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 reflect too much noise. Dropped bulkheads, sloped ceilings or suspended cupboards around kitchens help to absorb and dissipate sound, especially if lined with textured or softer materials.
- Use absorbent materials on wall panels or add large fabric wall hangings. Heavy drapes and curtains can also help to absorb sound. (see the appendix Noise control)
- AAC floor panels have approximately 30% of the mass of normal concrete and therefore offer significant acoustic benefits along with thermal comfort due to their insulation properties. Tiled floors on a sand-cement bed can boost the thermal mass noticeably. (see Autoclaved aerated concrete)

It is possible to retro-fit slab edge insulation to existing slabs-on-ground. Although renovations are an ideal time to do this, it can be done at any time. First seek advice from an engineer on disturbance to foundations and reinstatement of material, and do not breach termite barriers.
**Materials**

**Concrete slab floors**

**Renovations** can often incorporate concrete slabs even when the original building does not. Added rooms can use slab-on-ground or suspended slabs. When renovating rooms with timber floors, it is often possible to replace the timber with a concrete slab for added thermal mass and quietness underfoot.

These slabs can be suspended on the original subfloor walls and footings, or if the old floor is close to the 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)

Termite protection to both the new and old structures requires careful attention at the joint between them. Take care to construct continuous physical barriers, and always provide full inspection access to the junction in houses with raised timber floors.

**Finishing**

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, reduces the effectiveness of the thermal mass. However, the wide variety of finishes available does allow thermal mass to be utilised.

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**Tiles** fixed by cement or cement-based adhesives are commonly available in many colours, sizes and patterns, but avoid rubber-based adhesives which have an 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** includes two distinct types of finishes: trowel finished floors (with or without post-applied finishes), and ground and polished or abrasive blasted floors. Many finishes can be used in combination 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, preferably a low volatile organic compound (see the appendix The healthy home)
- 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 is advisable to use experienced specialist contractors to carry out this work. The colours can be applied as oxides in the mix, or as ‘dry shake’ pigments applied to freshly screeded concrete and then trowelled in, or as chemical staining.

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 and polished finishes include:

- exposed aggregate, where the normal grey concrete is ground back by several millimetres to expose whatever aggregate exists in the slab; 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 to reveal varied effects and give a safer surface particularly in areas that may be prone to moisture, including entrances and wet areas.

Toppings such as terrazzo 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.

Some options require careful protection of the slab during subsequent construction works.

Many sealer finishes have some level of toxicity; environmentally preferred alternatives are available such as beeswax or other natural wax polishes, although these need regular reapplication and buffing to maintain sheen.

**Additional heating**

Additional heating may be required if there is inadequate solar access. Because concrete slabs offer so much thermal mass, they lend themselves well to long cycle in-slab heating systems, provided they are efficient. In-slab heating’s slow response time of two hours or more makes it unsuitable for part-time occupancy or for sites where it may be required intermittently, unless it is purely solar powered. Slab heating is best suited to houses with permanent or high occupancy, where it is in operation for the whole of winter. Insulation is required in all cases to reduce heat loss to the ground. (see Insulation; Insulation installation; Heating and cooling)

*Hydronic heating uses solar-heated water in rooftop collectors to convey heat to the slab. It is very energy efficient and has low running costs.*
Solar boosted hydronic heating: Hydronic heating is very energy efficient, as it is a kind of ‘de facto’ passive solar heating, where the solar input is picked up by rooftop collectors and water (which has very high thermal mass) is used to carry it into the slab. It is especially useful where windows and doors are not exposed to the sun. Designed properly, it has very low running costs. Very warm water delivers heat to the slab through special pipework embedded in the concrete near the top. Solar hydronics can also be boosted by a range of energy sources, including ground-source heat pumps, gas burners and heat recovery units. Unlike electric coil heating, in low humidity climate zones, hydronic heating can be reverse cycled in summer, dumping excess heat into the night sky.

Electric resistance heating: Electric resistance heating coils have been the most common type of slab heating and are attached to the reinforcement before pouring the slab. They are usually controlled by timed switching so that a relatively even temperature can be maintained over a daily cycle with top-up periods of just a few hours a day. Unless such a system is powered by renewable energy, such as a large rooftop PV system, it will incur high running costs and greenhouse emissions.

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.

Void formers are expanded foam boxes that insulate the slab, but more ground-coupled alternatives are available. These include proprietary systems that use recycled tyres or reused detergent bottles filled with water, grouped together as void formers.

Steep sites may have geotechnical requirements that make slab-on-ground construction impracticable. A suspended slab may then 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 most climates. (see Insulation; Insulation installation)

Permanent structural formwork or one of the many precast flooring alternatives is usually the most cost effective way of constructing elevated suspended slabs. They are normally designed by an engineer and installed by builders or specialist subcontractors. Suspended concrete floors can be supported on timber structures, and do not necessarily require steel or masonry support, if designed by a qualified engineer with experience in timber design. This reduces the overall embodied energy and makes for less costly construction.

In cyclonic areas, concrete slabs, especially on ground, are a means of anchoring the whole building against extreme wind loads. The structure must be engineered holistically to ensure compliance with the relevant codes.

Curing of all cement-based building materials is key 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 during placement 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. Deeper beams should be compacted; thin slabs (typically 100mm thick) receive adequate compaction through the placing, screeding and finishing operations.

Suspended precast floor panels can make clear spans over difficult terrain, with acoustic and thermal benefits over a timber floor, and allow speedy installation on site. However, their loads are higher, and structural support at each end must be given more attention.
Embodied energy and life cycle

Low embodied energy cements

New cements such as geopolymers (‘e-concrete’) and magnesium cements reduce greenhouse gas emissions. Until recently these have been available in very limited quantities, but increasing commercialisation is making them available more broadly. Some set by absorbing carbon dioxide, which dramatically reduces the carbon footprint of the concrete.

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Alternative forms of concrete with very low embodied energy are also becoming more widely available, such as hempcrete. This uses industrial hemp fibres in conjunction with lime-based binders to sequester carbon dioxide for the life of the building. It is based on an ancient technology, but uses modern production techniques to make it cost effective.

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

Lowered embodied energy with recycled content

Concrete is composed of three main components: coarse aggregate (stone), fine aggregate (sand) and cement, with water added to the mix to catalyse the reaction that causes it to solidify. 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 can significantly reduce embodied energy and greenhouse gas emissions. These are called ‘extenders’, and are commonly available from most concrete batching plants.

Coarse aggregate and sand can be replaced by recycled materials such as crushed concrete from demolition, slag aggregates and recycled sand. This decreases landfill, reduces embodied energy and can lower costs (see Embodied energy). A common approach is to use 30% recycled aggregate for typical structural concrete. There is no noticeable difference in workability and strength, although a structural engineer should always specify the final mix. It is possible to use up to 100% recycled coarse aggregate in concrete under controlled conditions.

Recycling of masonry can also produce finely ground sand, as can other industrial by-products such as ground glass, fly ash, bottom ash and slag sands. However, the properties of these products can change the characteristics of concrete, and should always be used with expert engineering guidance.

Portland cement substitutes (also called ‘supplementary cementitious materials’) include fly ash, ground blast furnace slag and silica fume, which are waste materials from other manufacturing processes. New technologies include the use of reactive magnesia in combination with Portland cement. Various blended cements are available, some with high proportions of extenders (up to 85%) replacing Portland cement. Using these extenders greatly reduces greenhouse gas emissions.

Most batch plants can 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.

Demolition and recycling

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

Demolition waste makes up 40% 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 stored separately from other demolition materials, a more usable product can be achieved from the crushing for recycling into new concrete.

References and additional reading

Ash Development Association of Australia. www.adaa.asn.au
Australasian (Iron and Steel) Slag Association. www.asa-inc.org.au
Cement Concrete & Aggregates Australia. www.concrete.net.au
Cement Industry Federation. www.cement.org.au

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