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Briefing

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Concrete Floor Heating

An effective non-conventional method of space heating

Concrete floor heating is a an alternative method of heating that provides a warm floor and unobtrusive space heating, delivering high levels of comfort, safety and indoor air quality to the occupants. This briefing provides guidance on the types of concrete floor heating systems available, their installation, use and compatibility with various floor finishes.

Introduction

Concrete floor heating involves exploiting the high thermal mass of a concrete slab or floor by storing heat in the floor and having it act like a large heating panel, to warm the internal space above it and provide a comfortable living environment for the occupants.

Unlike conventional heating systems, which tend to be localised and cause hot spots, draughts and cold areas, the warm floor heats the entire space above it and is ideal for finishes such as polished concrete floors.

The heated concrete floor, because of its radiant output, is able to achieve comfortable living conditions at a lower air temperature than normal air heating systems. It is one of the simplest forms of space heating, providing uniform, unobtrusive heat.

The concrete slab is heated by embedding either electric elements or pipes that circulate hot water (known as hydronic systems) within the concrete slab or topping screed. Off-peak domestic heating tariffs may also provide significant economy to the homeowner if the energy source is electricity for either type of system.

Ideally, using concrete floors for heating is

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best suited to buildings of solid construction where external and internal walls also have a high thermal mass (ie concrete panel, brick or block walls). These materials, together with the concrete floor act as a heat bank or reservoir, storing the heat. The approach can also be satisfactory in buildings of lighter construction including brick veneer, provided that some consideration is given to adequate insulation.

Advantages of Floor Heating

- Heat is supplied evenly and from a low level (floor) providing improved occupant comfort levels.
- The absence of heating appliances or fitments increases the usable floor area or space and allows complete flexibility of use and furniture placement.
- Should provide low operating cost.
- Low maintenance costs.
- Completely silent operation.
- Warm dry floor inhibits the growth of house dust mites.
- No ducting required which minimises the circulation of allergens and dust mites.
- Reduced problems with dampness, condensation and draughts.
- Clean and odourless. Reduces discolouration of furniture, fittings and soft furnishings.
- The operation of the system can be fully automatic.
- Can be zoned by the use of independent thermostats to provide heating to the entire floor area, or to individual rooms.
- Suitable for use with an extremely wide range of floor coverings.
- Absence of flammable materials or exposed hot surfaces ensures safety.

Floor Heating Systems

Concrete floors are often used as part of a passive solar design system for buildings, due to their high thermal mass and ability to store heat from the sun during the day, and then release this heat during the cooler evenings. An extension of this is to provide an alternate means of heating the entire floor, to allow heating at any time night or day to maintain an even temperature within the building under all weather conditions.

There are basically two different systems to heat concrete floors:

- Electric floor heating systems commonly involve embedding an electrical element either directly into the concrete slab, or laying the element at the surface of the concrete slab and subsequently covering it with a concrete topping screed or mortar bedding for tiles. Other types of applications may be possible and these should be discussed with the installer. For new construction it is generally more economical to cast the elements directly into the concrete slab, avoiding the need for a separate topping screed.
- Hydronic systems involve circulating hot water through water pipes also embedded in either the concrete slab, or located within a topping screed placed over the structural slab.

The installation of both types of heating systems calls for specialised knowledge and skills and should be undertaken only by experienced operators.

Floor Temperatures

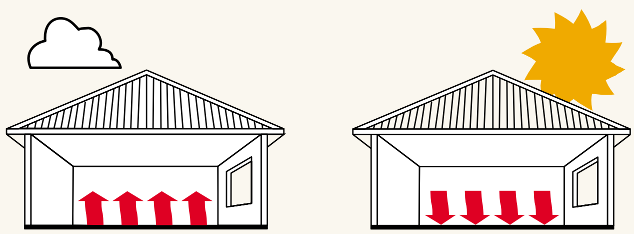
Floor heating systems operate at a moderate slab temperature of 22-30°C. One particularly useful feature of these low-temperature heat sources is their 'self-regulatory' nature in regard to heat output **Figure 1**. That is, if on a warm day the temperature of the room exceeds that of the surface of the slab, not only will heat not be emitted, but the slab will absorb heat from the warmer air effectively assisting to cool the room. High temperature heat sources such as fires and radiators would continue to give off heat.

This self-regulatory feature coupled with the large thermal storage capacity of a 'solid' building means that overheating is seldom a problem even when a mild day follows a cold night.

Due to the thermal mass of concrete floors, it may take several hours to initially raise the temperature of the slab from a cold start to the required operating temperature. For this reason, it is normal practice to leave the system turned on throughout the heating season, with full temperature settings during the winter months and reduced by 2°C for the early autumn and late spring periods. If the residence is unoccupied for short periods during the heating season, the heating system should be left on but with the thermostat reduced by 4°C.

If the building has a large number of big windows or high ceilings, it is likely that some auxiliary heating will be required when the occupants are inactive or on very cold evenings. It is doubtful whether this auxiliary heating would be required in either sleeping or working areas.

Figure 1: Air temperature controls heat emission



Cold day - heat transferred from slab to room.

Warm day - heat transferred from room to slab if room temperature is higher than the slab.

Reducing Heating Losses

To ensure that indoor temperatures can be maintained within acceptable limits it is essential that:

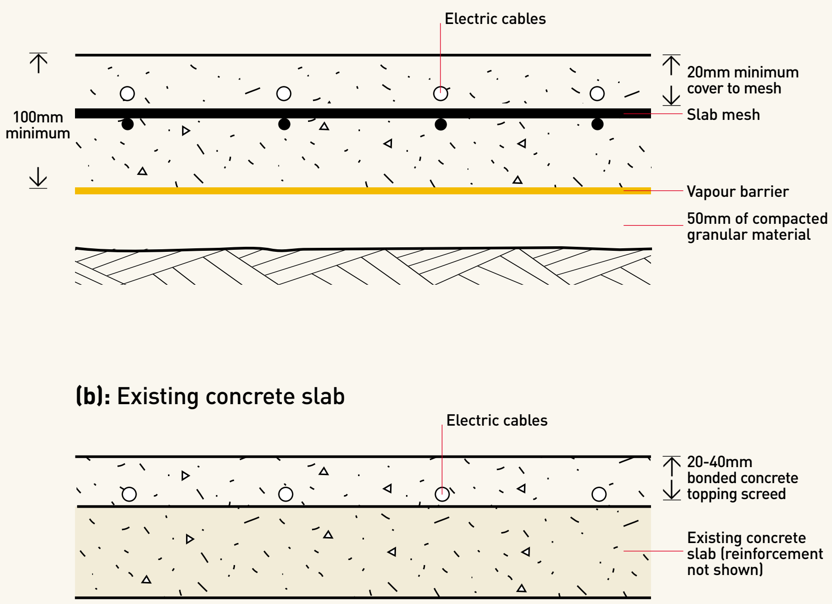
- the ceiling of the building is properly insulated;
- building heat losses are minimised by the choice of appropriate building materials and building design, eg walls of light construction such as weatherboard and brick veneer should be adequately insulated;
- exposed edges of the slab (and the lower surfaces of suspended slabs in which heating elements are embedded) are insulated.

These measures will ensure minimal heat loss to unwanted areas. Refer also to the section on insulation.

Figure 2: Installation of electric cables

(a): New slab-on-ground

(b): Existing concrete slab



Electrical Element Systems

General

The electrical elements embedded in the concrete floor slab heat the concrete slab, which in turn acts as a large, low-temperature radiant heating panel. Due to the heat that can be stored in the mass of the concrete slab, it will continue to warm the space long after the power to the electrical element is turned off. This same principle is applied when passive solar design is incorporated into the building, only here the sun is used to warm the concrete slab. Once warmed, heat will continue to be emitted for many hours due to the heat stored within the concrete slab.

Electric systems are often fitted with a time switch so that the main heating period is during the off-peak hours (which may have lower tariffs), with the heat input to the slab being regulated by a wall-mounted room thermostat normally set to between 10 and 22°C. When the room temperature reaches the thermostat setting, the electric element automatically switches off and comes on again only when needed (called the charge period). Due to the stored heat in the slab, the floor will warm the room continuously without noticeable temperature fluctuation, providing the building has adequate thermal mass or insulation.

Installation

As a guide the installation will generally require a concrete slab with a minimum thickness of 100 mm laid on a good quality (minimum 200 micron) polythene membrane, which in turn overlays a minimum 50-mm-thick layer of compacted sand or other granular material **Figure 2 (a)**.

The cable lengths and fittings are usually made up in the sub-contractor's workshop and delivered to the building site. The heating cables are laid out in grids to suit different areas or zones, with cables nominally spaced at 200-mm centres, but varying from 100 to 300 mm apart. The cable is clipped to either a light steel mesh (with bar spacings of 200 mm), or to the steel reinforcement of the floor slab. The most widely used reinforcement in concrete floors on the ground is a mesh reinforcement such as SL72 or SL82.

Reinforcement in most concrete floors on the ground is located 20 mm from the top surface of the slab. It is vital that the reinforcement is properly located and firmly supported on bar chairs in order to keep the heating cables in the top of the slab so that the majority of the heat flows to the top of the slab and into the building.

An alternative method to embedding the cables within the concrete slab, is to fix them to the top of the slab and embed them within a 20-40-mm-thick concrete topping or screed, bonded to the base slab **Figure 2 (b)**. This method is suitable for installing floor heating to an existing concrete floor, provided that the accompanying reduction in ceiling height and levels at doors are acceptable.

The heating installation is terminated at an electrical junction point located at either the thermostat position or the heating switchboard, depending on the electrical loading involved.

If cables are embedded within the concrete slab, it is important that all heating cables be tested continuously during placement of the concrete, to ensure that if a cable is damaged, the fault can be found and rectified before the concrete has set and hardened.

Experience indicates that while

the incidence of faults is very low, they can be further reduced by eliminating poor installation techniques, mechanical damage and the use of unsuitable cables.

Attention to the following points will minimise the risk of faults.

- Use only experienced installation crews.
- Always carry out insulation and core-continuity tests throughout cable and concrete placement processes.
- Do not use installation designs which allow the cables to become overheated, leading to stress and corrosion.
- Keep cables clear of walls or areas where excavation by other tradesmen may occur.
- Do not allow cables to cross or touch, and maintain recommended cable spacing.
- Exercise reasonable care in the transporting, placing and compacting of the concrete.
- Ensure that toppings or screeds are well compacted in order to reduce the possibility of voids which may result in overheating of cables.
- Avoid sharp changes of direction of cables.
- Ideally, place the concrete in the direction of the cable runs to minimise possible displacement.
- Avoid the use of lightweight aggregate having a high thermal resistivity.

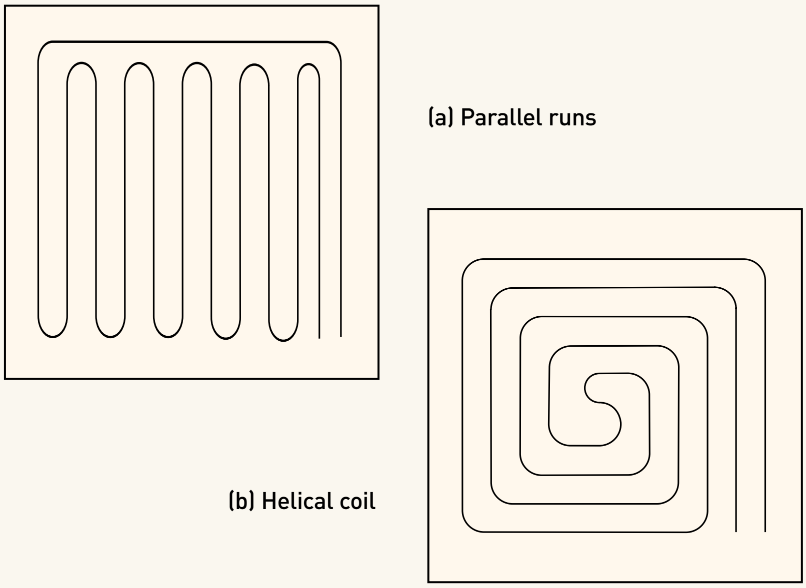
Hydronic Systems

General

These systems use pipes embedded in the concrete floor slab to carry hot water. The temperature of the water entering the slab is typically 40-55ºC. While low-density polythene pipes have been used, most manufacturers use a cross-linked, high-density polyethylene material which is more robust and less likely to be damaged during placement of the concrete. These pipes typically have an oxygen barrier layer on the outside to exclude oxygen from the closed water circulation system. The water pipes have sufficient flexibility to allow them to be laid in coils with gently rounded bends. This permits the whole of the installation to be done without joints or connection fittings. Coils for the common pipe diameters of 16mm and 20mm are generally 100-120 m long allowing a 20-m^2 area to be covered and have a heat output of about 2.5 kW per coil.

As the water is circulated through the pipes, it cools down as heat is gradually transferred from the water to the concrete. There are two laying patterns employed, both of which are equally widely used **Figure 3**. One laying pattern distributes the hottest water around the coldest walls of the room (usually exterior walls), while the other distributes the heated water evenly over the entire floor area. In the first method the pipe is laid in parallel runs, the first length from the distribution point running along the external wall, or walls, and subsequent runs laid parallel to each other and at right angles to this wall until the whole of the floor area is covered. In the second method, a helical coil is used, where the pipe is coiled towards the centre of the room in loops of decreasing diameter. The pipe is then continued in the reverse direction, giving alternative warm and cooler runs of water, resulting in a more-even distribution of the available heat.

Figure 3: Laying patterns



(a) Parallel runs

(b) Helical coil

Heat Emission

With the jointless water pipe laid at the usual 200-mm centres and operating at a water temperature of 50ºC, a floor temperature of around 25ºC and room temperature of approximately 20ºC can be readily maintained.

Installation

Generally, the water pipes are located towards the slab surface, so that the majority of heat transferred into the slab will warm the area above the slab.

Australian Standard AS 2870 **Residential slabs and footings — Construction**, contains some requirements on heating cables and pipes within slab-on-ground construction. For hot water heating pipes embedded in the slab, to ensure that the required slab thickness is not reduced by the pipes, the slab thickness must be increased to at least 125 mm **Figure 4 (a)**. Also, the reinforcement is to be increased by one level, from say SL72 to SL82 mesh.

Water pipes can also be installed within a topping screed placed on the structural slab, with some details given in **Figure 4 (b)**. If this method is used for existing slabs the implications of the topping thickness need to be considered.

For suspended slabs, the cover at the top of the slab is adjusted to allow for the pipes, and reinforcement designed to allow for this increased cover. If insulation is provided under the slab to avoid excessive heat loss, pipes could be located further down (on top of the bottom layer of reinforcement), avoiding the need to increase the cover to the top of the slab.

For slab-on-ground construction, reinforcement may be provided in one of two ways:

- A single layer of reinforcement mesh such as SL82 or SL92 (ensuring it is one level above that which is required by AS 2870) is positioned near the upper surface of the slab and the water pipe is positioned and tied to the mesh. Note that the minimum covers to the mesh must be in accordance with the Standard. Concrete is then placed, compacted, finished and cured.

  While this method has the disadvantage of moving the reinforcement further from its most effective position for controlling cracking, ie near the upper surface of the slab, it is compensated to a degree by using a larger mesh (one level up) and increasing the slab thickness.
- Two layers of reinforcing mesh can be used, one in the top and one lower down in the slab **Figure 4 (c)**. This allows the top cover to be maintained and a lighter reinforcing mesh to be used for each layer. The water pipe is located and tied to the top of the bottom layer of mesh, offering better protection against damage during the placing of the concrete.

  While the heating system will still function with the pipes located further down in the slab, the efficiency will improve by insulating the underside of the slab to prevent heat loss to the ground below.

In both cases, the use of a good quality (minimum 200-micron) vapour barrier laid under the slab on a 50-mm sand bed is necessary.

Site Drainage

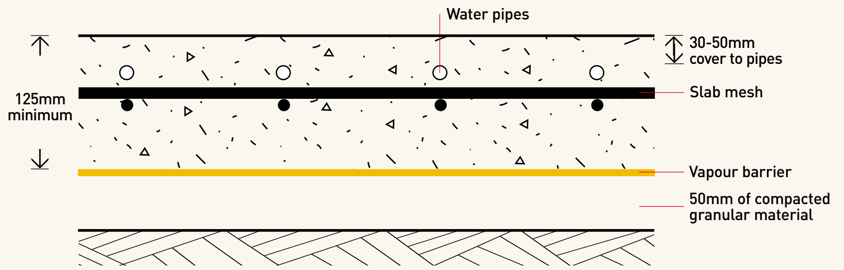
The area around a slab-on-ground should allow the drainage of surface water away from the building, as well as drainage of any subterranean water seepage from under the slab.

Movement of underground water beneath a heated slab must be avoided because it will continuously draw heat away from the slab, and this would cause a substantial and unnecessary heat loss.

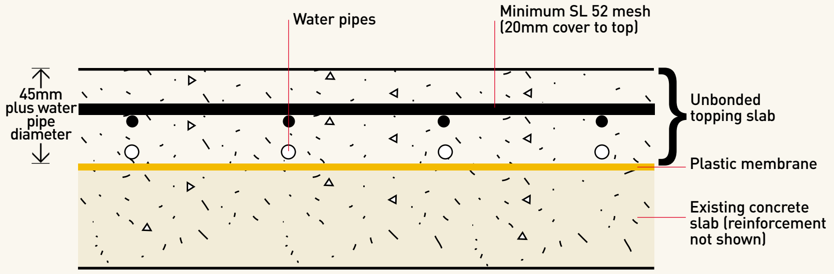
With concrete floor heating on excavated or cut-and-fill sites, the installation of surface drains is recommended, as well as sub-soil drains adjacent to any banks or cuts. Some Municipal Council's building regulations include these drainage

Figure 4: Installation of water pipes

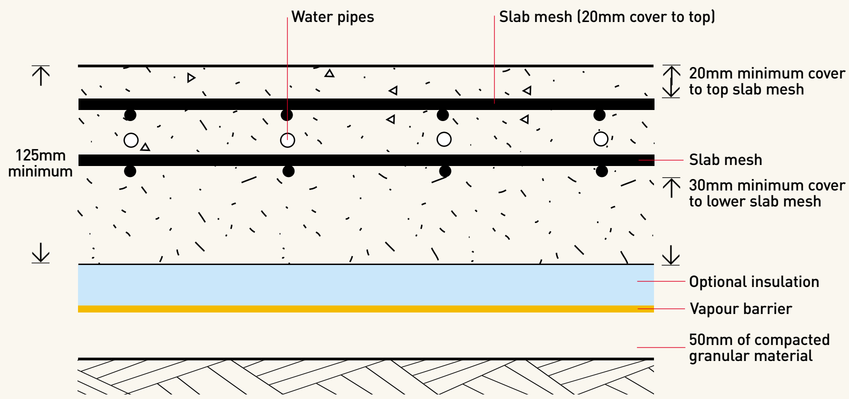
(a): New slab-on-ground - single layer of reinforcement



(b): Existing concrete slab



(c): New slab-on-ground with double layer of reinforcement



requirements. Similarly where water migration could occur on flat sites, surface and sub-surface drains should be installed.

Insulation

Solid type constructions such as cavity brickwork, masonry block or concrete panels are ideally suited to floor heating since the wall materials together with the concrete floor serve as heat banks which store the heat. Buildings of lighter construction such as brick veneer are also suitable provided that wall insulation equivalent to double sided aluminium foil is provided.

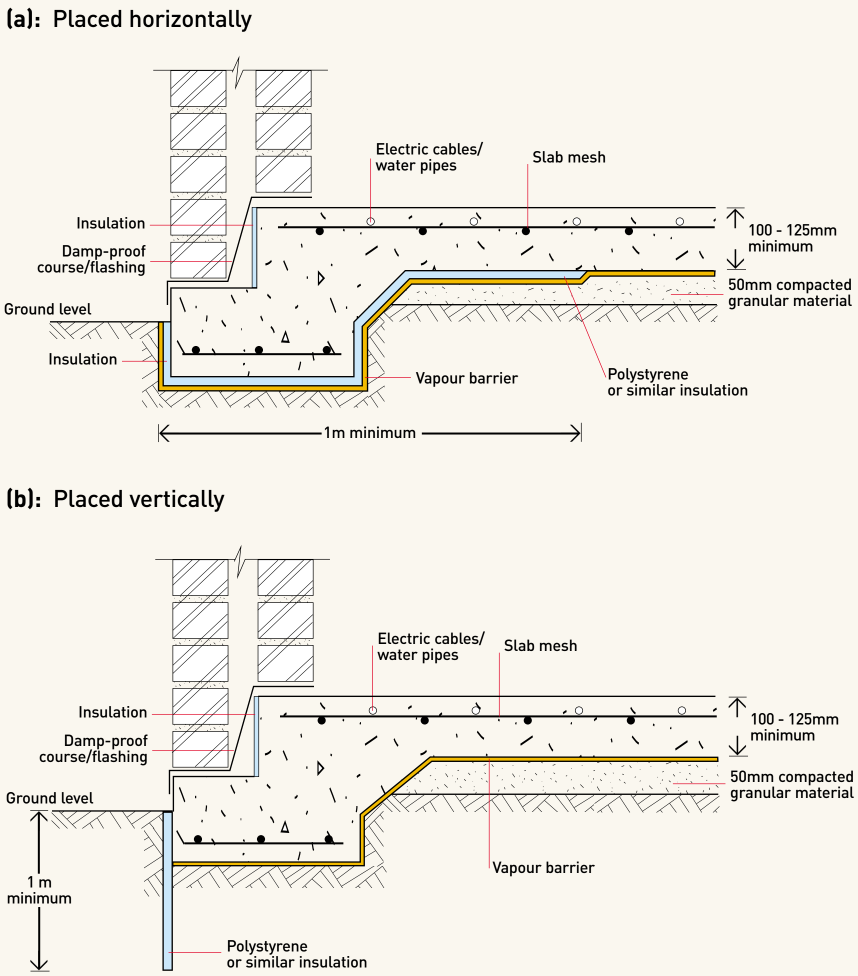
The efficiency of a heating system will depend largely on the rate of heat loss from the building being heated. Heat can be lost from the underside and edges of the slab as well as from the building walls and roof. Edge losses are the most important component of the heat lost from a slab-on-ground and while not commonly installed, edge insulation is recommended. For suspended slabs where the underside of the slab is exposed to an unheated area, the underside should be insulated with a 25-mm-thick layer of polystyrene or equivalent insulation.

For floor slabs laid on well drained soils it is sufficient to insulate the edges of the slab with 25-mm-thick insulation material and to continue it horizontally underneath and around the perimeter of the floor for a width of one metre. An alternative is to install the insulation around the perimeter of the building vertically **Figure 5**.

For floor slabs laid on poorly drained soils, the slab should be insulated over the whole area by a high quality thermal insulation and this should be continued up the sides of the slab to insulate the edges. In all instances, the insulation should be laid above the vapour barrier or membrane.

Since the roof is often responsible for the largest single component of a building's heat loss, attention to adequate insulation is vital.

Figure 5: Edge insulation



Note:
When installing the insulation vertically, ensure the trench is backfilled in a way that will avoid settlement under the footings.

Zones and System Control

It is recommended that the floor heating system be arranged into zones with automatic independent controls for each zone. A typical breakdown would include the kitchen, family room and lounge room as one zone, and the bedrooms and hall as a second zone. The system can also be designed to have one zone for each room if required. Each zone is controlled by a separate thermostat, strategically mounted on a wall. Suggested temperature settings are 20ºC for living areas and 16ºC for bedrooms and service areas.

At the distribution points, where electricity or heated water is distributed into the individual elements or coils, controls can be provided to both cut off and bring in the various rooms or zones that have been incorporated into the system. In this way, operating costs can be minimised by having areas that are unused for any length of time taken off the system (ie bedrooms during the day and living areas at night). Operating costs can also be minimised by installing automatic timing devices. These can incorporate a thermostat with a night set-back feature, allowing a lower temperature to be set for overnight running.

With electrical systems, the loading for the total area of floor heated would be about 160-200 watts per square metre depending upon the type of area, proportion of the building being heated and living requirements. Building design, layout, and type of construction will also influence the loading required.

With hydronic systems, when considering zoning, it is essential to ensure that for areas controlled by a single thermostat, all pipe-coil lengths from the distribution point are the same and pipes are evenly spaced at 200-mm centres to provide equal heat transfer into the slab. Different pipe centres and pipe lengths will vary the heat transfer to the slab and result in varying temperatures from area to area or room to room. Where the typical pipe-coil length of 100 m is used, the length is generally too large for a single room, and additional areas can be heated at the same rate of heat output. Heating a single room will usually require a smaller length of pipe (increasing the heat output) and the room to have its own thermostat.

Choice of Floor Heating System

Concrete floor heating systems have many benefits in comparison to conventional space heating systems and these were listed earlier.

The choice of the floor heating system is essentially an economic decision based upon local availability of fuel types, cost, storage capacity for fuel (eg gas cylinder) and space available for the heating unit.

Advice should be sought from the various fuel authorities, whilst many of the companies which install floor heating systems will be able to advise on suitable equipment and other more specific details.

Floor Coverings

Concrete floor heating can be used where the concrete floor is the finished surface (ie polished concrete floors) or where a floor covering is provided.

Most types of floor coverings can be laid over heated floors without being harmed by the heat output and without severely restricting this output. Coverings such as ceramic tiles, slate and vinyl are the most suitable as they have the lowest thermal resistance to heat flow.

Carpet is acceptable and has a medium to high thermal resistance. Low and medium pile carpets are better as their insulating effect is lower than high pile carpets. The best underlay to use is corrugated profile rubber (cellular type) with a relatively thin profile (approximately 5 mm). While granulated foam rubber underlay is not suitable, hair underfelt is satisfactory. If using rubber-backed carpet or underlay, it is important to ensure proper drying of the concrete slab as some moisture or 'sweating' at the floor surface may occur.

The floor heating system must not be used to prematurely dry out the concrete floor in order to facilitate the laying of floor coverings set in adhesive which may be affected by moisture. As a rule of thumb, one month should be allowed per 25 mm of concrete thickness for drying out of the concrete prior to fixing floor coverings. A field test to check the likely suitability of the floor to receive adhesives may be done by laying a sheet of impermeable material such as glass or rubber (about 500 x 500 mm in size) on the floor and sealing the edges with an adhesive, polythene tape or putty. The material is removed after 24 hours and the moisture level is considered too high if there are any beads of moisture on the underside, or if the slab appears damp. A more precise test can be made using a resistivity moisture meter. This test should be performed by a floor laying contractor prior to fixing of the covering.

'Floating' timber floors are also suitable for laying on heated concrete slabs. Consultation with the heating contractor is required to ensure that over-temperature cut-out sensors are installed in the slab prior to laying of the covering. Solid timber flooring is not generally suitable unless special installation procedures are adopted.

Floor surface temperatures are usually between 20ºC and 30ºC and it is recommended that any floor covering adhesives used be satisfactory for use at temperatures up to 30ºC.

Commissioning the Floor Heating System

Because of the mass of concrete floors, both electric and hydronic heating systems have a slow thermal response due to the heat required to initially raise the temperature of the slab from a cold start to the required operating temperature. Therefore, it can be eight hours or more before effective room heating is achieved.

For hydronic systems, unequal pipe lengths or pipe spacings will require balancing of the system to ensure relatively uniform heating of the slab. Given that it may take several hours or even a full day for the slab to reach its operating temperature, each adjustment of the circuit header valves (that control the flow of water into the individual pipe lengths) will require a long setting period. Balancing the system may therefore take several days.

Conclusion

Concrete floor heating provides a warm floor and unobtrusive space heating, delivering high levels of comfort, safety and indoor air quality to the occupants.

The system is versatile, can be combined with passive solar design and be zoned to provide comfortable temperatures in individual rooms. The installation requires minimal changes to the structural slab and the method is suitable for a variety of floor finishes and coverings such as polished concrete and tiles.

Being able to use the concrete floor for heating further adds to the established benefits that concrete floors offer such as economy, quietness and durability.

More Information

More information on toppings and polished concrete finishes can be found on the Cement and Concrete Association of Australia's web site at www.concrete.net.au.

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