

Briefing

Houses for Flood-prone Areas

More than nine out of ten houses now built in Australia have a concrete slab ground floor. This is the most practical, economical, structurally-sound and thermally-efficient footing/floor for houses. These advantages (and those of other concrete elements) are available on all sites, including those prone to flooding. This Briefing covers the viable approaches for flood-prone areas.

1 INTRODUCTION

Statistics from the Insurance Council of Australia show that 95% of significant catastrophes in this country have been caused by extreme weather events. In the face of adverse natural events the built environment, especially residential buildings, needs the capacity to survive and to protect occupants and contents. Building codes have addressed, with considerable success, the requirements for high winds (cyclones), earthquakes and, to a lesser extent, bushfires, but make only very limited provision for flood or hailstorm events. This is a significant omission, considering flood

damage alone accounts for almost 30% of the average annual costs incurred as a result of natural hazards in Australia.

The number of Australians making their homes in bushland or coastal areas continues to grow. These are the areas most prone to bushfires, high winds, storm-surge, flood and hail. It is estimated that there are already 400,000 dwellings on flood-prone land and it is unavoidable that demand for houses on such land will increase.



The creek under the foreground driveway bridge rises in flood conditions. The house has been built on raised ground with a concrete driveway to limit scouring. In the worst case the garage may flood, but as all lower walls are of resilient masonry, little but cosmetic damage is caused.



House-scale sports amenity building with the main floor raised 2.4 m. The reinforced concrete sub-floor structure is robust enough to withstand moving floodwater.

Four approaches to designing houses for flood-prone sites are:

- **Flood resistant housing** (also called Dry Flood-proofing) involves making houses watertight and able to withstand significant hydrostatic pressure. In effect, the house walls form a dam, with temporary dam structures of sandbags or planks at all low-level window and door openings.
- **Raising the floor level** of a house above expected flood levels.
- **Flood resilient houses** (also called Wet Flood-proofing) make use of materials that are undamaged by minor inundation during significant flood events.
- **Combination** of raising the floor level and resilient materials.

Of these approaches, flood resistant or dammed houses are expensive, plus they need preparation effort and time which is rarely available when floods threaten. The viable options are: raising the house; a floodwater resilient house;

or a combination of raising the house floor above minor flood levels and building a resilient house that will survive (with only cosmetic damage) the occasional higher flood level.

Raising the house (ie a high-set or medium-set house) requires a confidence in the maximum flood level height on the subject site, and the construction of that house to survive the forces placed on the structure by floodwater.

Resilient house design requires resilient materials and construction. The first instinct is to keep floodwater out, but at times there are advantages in allowing floodwater into the house. For resilient (and resistant) type houses the buoyancy, or lack of it, is an important consideration.

This document deals with the design and materials selection for resilient and/or raised dwellings for flood-prone sites.

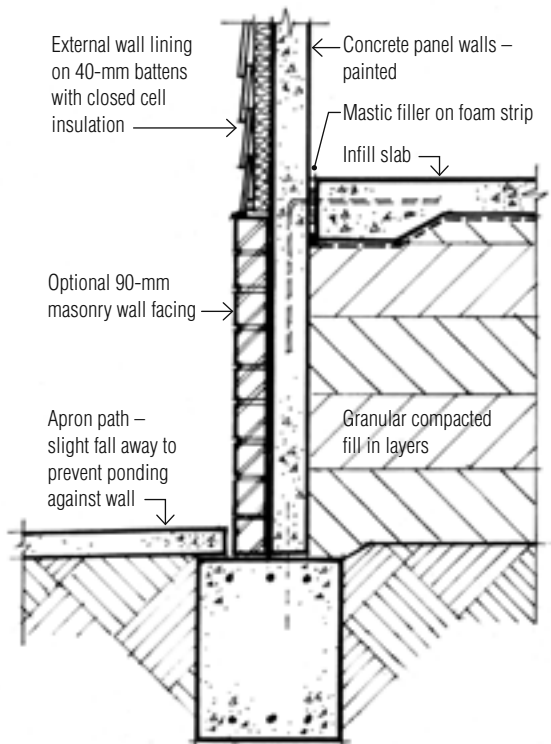
DEFINITIONS

CONCRETE PANEL CONSTRUCTION

There are various methods for casting concrete wall panels for commercial buildings and houses. Those cast off-site in a factory are known as **precast wall panels**. Those cast on-site are generally **tilt-up panels**. Concrete panels for internal walls are a single layer of solid reinforced concrete. Concrete panels for external walls of habitable rooms need to be insulated and are usually two layers of concrete with closed-cell insulation foam between. These are known as sandwich panels and may be precast or site-cast.

CONTROLLED FILL

Compacted material, preferably coarse sand or gravel. It is to be placed in layers about 200 mm thick and each layer is compacted with a vibrating plate or roller. Controlled fill should be graded away from walls or contained by walls of the building or separate retaining walls. Controlled fill used externally is usually covered by apron paths or with topsoil (possibly underlain by geotextile fabric) and planting.



CONCRETE PANEL WALLS WITH RAISED INFILL SLAB FLOOR

FINISHED GROUND LEVEL

The ground level adjacent to a building at the completion of construction and landscaping.

FLOOD-PROOF

A house that is not substantially affected by exposure to floodwater. There are two types of flood-proofing, dry and wet.

FLOOD-PROOFING

Making a house that is not substantially affected by exposure to floodwater. There are two types of floodproofing, dry and wet.

- **DRY** floodproofing involves keeping the habitable parts of a house away from water exposure. This may be done by raising the height of the house floor above expected flood levels, or by having removable flood shields for all doors and low-sill windows, then relying on walls between these shields to act as impervious dams.
- **WET** floodproofing is the essence of 'resilient' construction. It involves building a house that will tolerate floodwater exposure with cosmetic damage that needs only cleaning or minor repair when the water recedes.

FLOOD-PRONE SITE

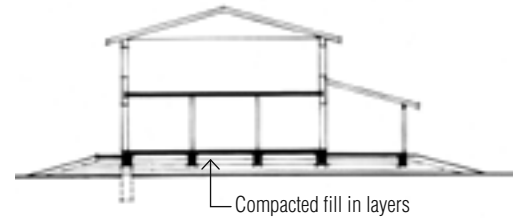
A building site for which there is a high risk of floodwater inundation. Flood levels may be expressed with a probability of frequency, for example 20, 50, or 100 years. But, it must be understood that two 100-year flood events could occur within a year or two of each other.

FOOTING SLAB

A reinforced concrete slab floor supported on the ground or fill with edges supported on surrounding walls that are built on a separate strip footing.

FOOTING SYSTEM

General term for slabs, strip footings, pads, piers and pile systems that transfer building loads to the foundations. Most footing systems are wholly or partly made of reinforced concrete.

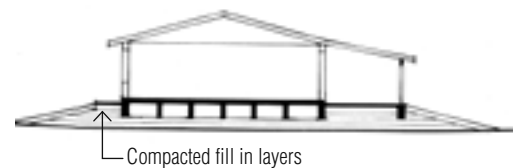


SLAB-ON-GROUND OR STIFFENED RAFT SLAB

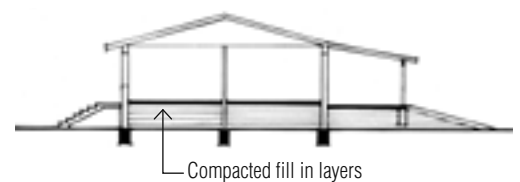
set on layers of compacted fill – may require pier footings (depending on foundation soil)



WAFFLE-POD SLAB on ground with deep styrene void formers



WAFFLE-POD SLAB on compacted fill with shallow styrene void formers



INFILL SLAB with strip footing subfloor wall to retain fill



FOOTING SLAB with reinforced subfloor walls connected with strip footings

Any of these examples:

- may have a floor 1–1.2 m above ground level;
- apply to one- or two-storey houses;
- allow 1 m depth of floodwater to pass around.

DEFINITIONS

FOUNDATIONS

The ground in or on which footings are built. The foundations or foundation soil may be clay, sand, shale, rock, or any natural material that is levelled, then excavated or shaped to form strip, pad, pile or slab concrete footings.

FRAMED WALLS or CLAD FRAMES

Timber or galvanized steel framed wall construction with top and bottom plates connected with regularly spaced vertical studs between. At about mid-height studs have horizontal spacing members (noggings). Wall frames must have diagonal bracing of galvanized steel. Sheet bracing (which is otherwise common and effective) should be avoided for framed walls that may be inundated as plywood or particleboard sheets lose much of their strength after wetting. Water can be trapped in framed walls until well after floodwater has receded. Silt deposits may also be trapped in them.

HYDRODYNAMICS

The forces in, or motions of liquids.

HYDROSTATICS

The statics of fluids, the equilibrium and pressure exerted by liquids.

PRECAST CONCRETE FLOOR SYSTEMS

Factory-made, precast, prestressed concrete beams or panels that are set on walls or beams as permanent formwork for an insitu concrete slab. This system reduces the need for temporary propping and formwork, it is a quick, economical way of building a suspended slab floor.

PRECAST CONCRETE WALL PANELS (See *Concrete Panel Construction* above)

Factory-made, reinforced concrete wall panels, usually one-storey high and up to 8 m long with cast-in window/door openings. These panels are usually flat, but some have returns at one or both ends. Typically they are made in steel forms, so have a smooth flat finish that can be painted or have decorative exposed aggregate external finish.

PROBABLE MAXIMUM FLOOD (PMF)

This term defines the highest expected flood level. It may be anything from a few millimetres to many metres above the 1 in 100 year flood level. The PMF varies from river to river and along the length of any one river. It is important to know the PMF for any proposed, flood-prone building site.

RESILIENCE or RESILIENT CONSTRUCTION

A building's ability to recover from adversity with minimum maintenance cost and effort. Resilience, as a design concept, has come to imply a broader approach, which includes an ability of the house and its environment to sustain itself through extreme events.

RESISTANCE

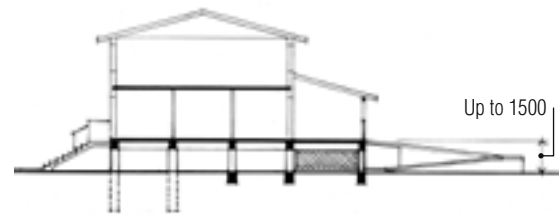
The potential to oppose or withstand without effect.

SANDWICH PANELS (See *Concrete Panel Construction* above)

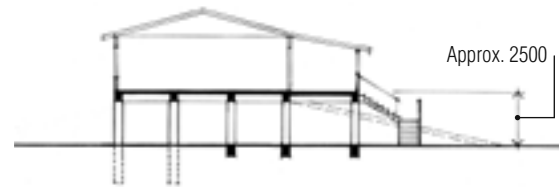
Both precast and tilt-up panels can be constructed as sandwich panels. Such panels are often used to comply with U-value (insulation) requirements for external walls of habitable rooms. Typically, a sandwich panel will have one thick (structural) layer of reinforced concrete, then a layer of rigid foam insulation material and then another, thinner, surface layer of reinforced concrete. Another method is to use concrete panel construction for the inner leaf of external walls, and then apply insulation and a second (sandwich) finishing layer over that. This layer may be sheet material fixed to battens on the inside, or brick walling tied to the concrete panels externally.

STIFFENED RAFT

A reinforced concrete footing and floor slab set on the ground (or controlled fill) stiffened by integral edge beams and a grid of internal beams several metres apart.



MEDIUM-SET SUSPENDED SLAB with two-storey house above. The suspended slab could be conventionally formed, placed on steel deck forms, or part-precast.



HIGH-SET SUSPENDED SLAB with single-storey house above. Note the possibility of a vehicle ramp to have one flood-protected car space at floor level.

STRIP FOOTINGS

Reinforced concrete building footings placed in trenches formed by excavation in the ground or compacted fill. Strip footings usually follow the plan of masonry walls above. Deep strip footings, sometimes with piers under, are used for reactive-soil or filled sites.

TILT-UP CONCRETE WALL PANELS (See *Concrete Panel Construction* above)

While tilt-up construction is more commonly used for commercial/ industrial buildings, it can be adapted for housing, and with appropriate construction details, built to resist the lateral pressures of floodwater.

WAFFLE RAFT

A reinforced concrete raft slab with closely spaced ribs resting on the ground or fill, with floor slab panels between the ribs. The waffle-like shape is created by a series of box-like forms for the concrete. Waffle rafts (also called 'waffle pod slabs') are suitable for buildings on stable or reactive-soil sites.

2 FLOODWATER BEHAVIOR AND IMPACTS

The effects of flood events on houses depend on several factors:

- Depth of floodwater inside the house (above floor level).
- Length of time before floodwaters recede.
- Directions in which floodwaters flow as they rise and fall.
- Velocity of floodwater flow (typically 10 km/h, but up to 30 km/h).
- Impact of contaminants or debris carried by floodwater.

A benchmark level for floodwater is often expressed as a 20-, 50- or 100-year flood. The 100-year term does not mean once in a hundred years, but that a flood of that level has a 1% chance of being equalled or exceeded in a given year. The 20- and 50-year floods have respectively a 5% or 2% chance of occurring in any given year.

Floodwater depths assumed herein are measured from the typical ground level of a relatively flat site, which is a common situation on flood-prone land. The following floodwater depths have been assumed for illustration of various approaches to houses on flood-prone land:

- 1.0–1.5 m – minor flood, occasionally of 1.5 m.
- 1.5–2.0 m – moderate flood, occasionally of 2.0 m.
- 2.0–2.5 m – major flood, occasionally of 2.5 m.
- 2.5 m plus – extreme flood level.

The duration floodwater remains near its peak height varies from a few minutes to several days. Typically, the longer floodwaters linger, the more resilient house construction materials need to be and the more post-flood clean up work and cosmetic repair is necessary.

The direction and velocity of floodwater movement is often critical. Generally the direction of flow is predictable; if flooding is caused by a nearby swollen creek or river the flow of floodwater is usually in the direction of flow of that watercourse. For flash floods travelling overland the direction of flow tends to be towards lower ground in the general vicinity of the subject site.

Whenever possible, a house designed to be resilient to floods should be planned to be well braced against the hydrostatic pressure of water and the hydrodynamic, lateral force of moving floodwater. For flood resilience the bracing of a partially submerged house must be substantial. In the worst case, heavy buoyant items such as vehicles and trees may be carried by flowing floodwater.

The lateral force of flowing water also requires that a house structure be well founded, ie substantially connected onto or into the ground or foundation material of the site. Flowing water can also have a significant scouring effect on the foundation soil, so this needs to be protected against erosion.

A well-founded house needs to have robust, non-buoyant structures for floors and walls above the footing. The resilience and robustness of the floor and walls may be tested only when a house, designed for minor flood levels is subjected to the occasional worst-case flood (perhaps half-a-metre deeper than more frequent flood levels).

Beyond having a well founded, well-braced, robust and non-buoyant house, with a floor raised above expected flood levels and a design to optimise water flow around and away from the house, the use of breakwaters deserves consideration. They may be shaped landforms (earthworks) consolidated with planting, or low, resilient walls (perhaps part of site boundary fencing or planter boxes).

Along with building the lowest floors above the predicted flood level must come the understanding that occasionally a severe flood event may result in floodwater rising to above such floors. For

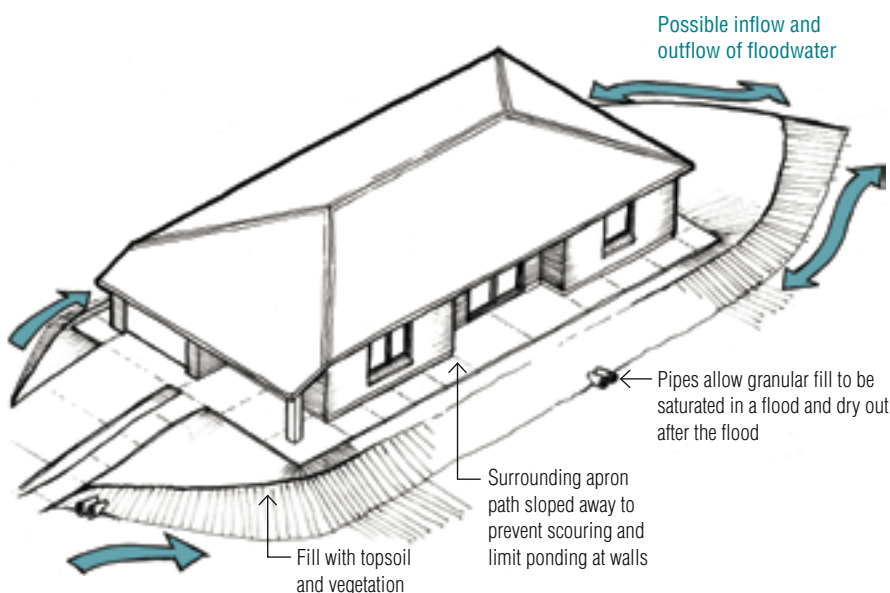
such events, houses need to be designed to be resilient to floodwater damage. Walling materials must be robust enough to survive the forces imposed by moving floodwater and resilient enough to not be significantly affected by several days of inundation.

Experience of flooding shows that for urban locations, the area surrounding an individual building has to be planned with flood mitigation in mind or risk-management principles. Many flood mitigation works, such as dam safety, stormwater retention basins, culverts, bridges and stormwater pipes are not solely the responsibility of individual home owners.



Circular column supporting high-set structure that is subject to rapidly flowing floodwater. The leading columns have reinforced concrete buttresses to withstand possible impacts from floating debris.

In minor floods the front of this house could become a waterway, so the house is raised on reinforced concrete retaining walls that form a garage. Against this wall, fill has been placed to create the raised edge of a depression for the waterway. Note that the ramp to the garage on the left is raised to limit flood backflow.



HOUSE WITH SLAB ON FILL

Fill is shaped to optimise the flow of floodwater around the building

3 GENERAL CONSIDERATIONS

An important objective for a flood resilient house is to provide the potential for continued occupation during a flood event, when services may be cut for several days. To this end, house designs should be conceived to be self sufficient in power, water and food supply. Food is the residents' responsibility, but the house itself should be a passive solar design with potable water and bottled gas storage facilities and solar collectors for water heating and partial electricity supply. This allows continued occupation of the house – an important consideration for residents, and a saving of otherwise finite rescue and temporary accommodation resources.

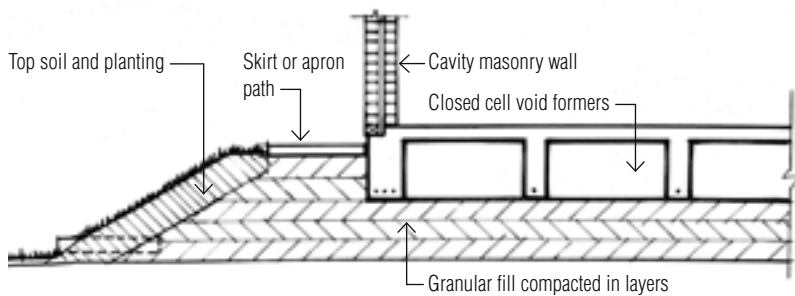
For some residential building sites that have been declared flood-prone, local authorities can usually provide estimated flood level heights Probable Maximum Flood (PMF) figures and frequencies. Other sites may not be known to flood, but changing weather patterns, or 'upstream' developments may make it prudent to assess the potential to flood. Before considering a house design, a PMF or a reasonable estimate of the height of potential flooding, say, 1.0, 1.5 or 2.0 metres above the immediate surrounding ground level of the subject site, should be established. Along with floodwater height, an estimate of the potential incoming and outgoing direction and velocity of floodwaters should be made.

4 DETAILS OF THE VIABLE APPROACHES

4.1 General

Concepts of the form of a flood-resilient house will depend on the nature of the site. On large sites, considerable land modification (an encircling earth dam, or fill and drainage channels) is possible, on small urban sites the potential to fill and create drainage will be limited. In either case, earthworks or fill and the house building shape should be planned to divert floodwater away from buildings.

More than nine out of ten houses now built in Australia have a concrete slab ground floor. This



WAFFLE SLAB ON FILL



Deep edge of waffle-pod slab with floor raised about 1 m. Note the concrete edge step at ground level to take the outer leaf of brickwork.

is the most practical, economical, structurally sound and thermally efficient footing/floor for houses. While usually being set close to ground level, concrete slab floors in flood-prone areas need to be raised. The advantages of slab-on-ground construction can be maintained and the floor level raised by one of several methods:

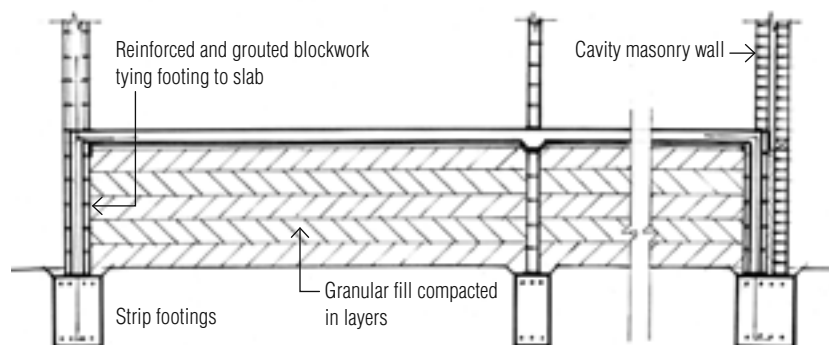
- Fill over the area on which the house is to be built, plus a reasonable skirt of fill around it. To deal with and drain floodwater, the fill must be a coarse granular material, well compacted and drained. On this fill (say 850 mm deep) a slab-on-ground or stiffened raft slab can be built with a finished floor level one metre above surrounding natural ground. After construction, the surrounding fill is covered with an apron path and/or a layer of topsoil, sufficiently deep to grow grass and plants to stabilise the soil during rain or flood events. Added protection can be provided with a layer of geotextile fabric over the fill before topsoil is placed. Topsoil consolidated with vegetation is satisfactory where floodwater flow will not exceed 10 km/h, or 3 m/s.

- A waffle-pod system. With this the ground is levelled and a grid of closed-cell foam boxes is used to create an egg-crate or waffle form on the ground. With deep edge formwork such a waffle-pod slab can finish 0.75 to 1 metre above the immediate ground level.

- A combination of the fill and waffle-pod options with the waffle-pod slab built on a platform of compacted and drained granular fill. In this way the finished floor could be up to 1.5 m above the surrounding ground level.

- A footing slab with strip footings, sub-floor walls containing compacted granular fill and supporting an infill slab. This is a particularly viable approach on restricted urban sites. The floor level may be a metre or more above ground level.

All raised slab-on-ground (or fill) options must consider the potential incoming and drainage outflow of floodwaters around them. In this respect the raised footing slab offers potential clearance around the outer walls of a house for floodwater movement. Well-founded strip footings and reinforced subfloor walls offer sufficient robustness to be resilient to the lateral forces of floodwater and most water-born debris.



BUILT-UP TIED FOOTING SLAB

Further to the well-established method of constructing raised footing slabs on sub-floor grouted block walls, precast concrete panel walls have become a viable option for housing. Such walls are widely used in commercial and industrial applications where they are ideal resilient external and internal walls which, when painted, appear as smooth, flat interior wall finishes. Precast concrete panels are made with high-strength dense concrete, are impervious to water and, with appropriate construction, resist lateral water pressure and the impact of floating debris. Precast walls tolerate footing movement on reactive soil sites, and offer excellent bracing and tie-down for the house structure, roof or upper floors. They have excellent noise reduction properties and, because of their thermal mass, provide a passive internal environment.

To allow floodwater to flow under a house by raising the lower floor and leaving a gap of about a metre between natural ground and the underside of the floor slab is an alternative. This is termed a 'medium-set' house, as distinct from a 'high-set' house that has a usable space with 2 m or more clearance. It will necessitate robust concrete ramps and/or steps to access the building. This is a practical approach in medium-density or grouped housing developments. When floodwater flows under a house, it imposes lateral forces from the hydraulic pressure of moving water and water-born debris on the supporting structure. A stout, robust, well-founded (or anchored) structure is therefore required.

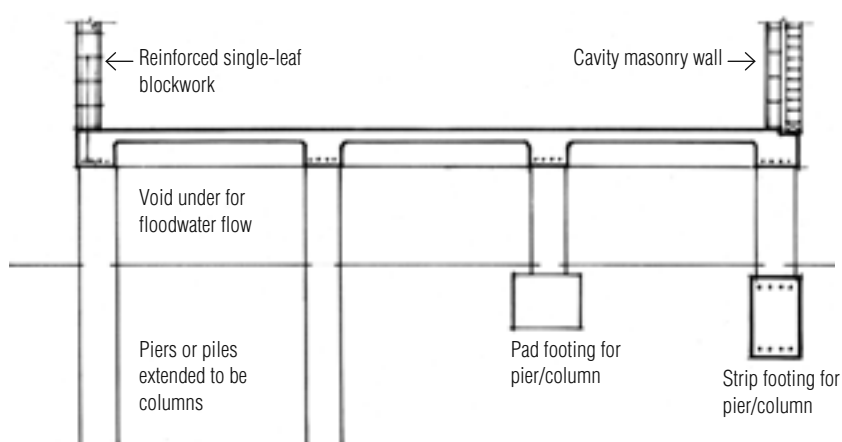
Two recommended approaches are:

- Concrete piers set on pile, pad or strip footings in the ground and extending above ground to support the floor slab.
- Precast culvert units and/or insitu concrete or reinforced masonry walls or piers. This approach is possible when the likely direction of flow of floodwaters is known and the culverts or support walls can be placed appropriately to accommodate that flow.

Any of the above options should be designed, built and used with the understanding that a future flood event may rise above the PMF height allowed, so the ground or lower floor of the building may, in a worst-flood scenario, be inundated. This possibility dictates the selection of finishes and construction materials for floors and walls that are resilient to water pressure or inundation damage. Resilient finishes for concrete slabs include a smooth trowelled surface, a ground-and-polished surface, terrazzo or ceramic tile.



This medium-set building has been raised leaving a 1.2-m space for floodwater flow below a concrete slab floor. Note the lattice to deter children and pets.



MEDIUM-SET SUSPENDED SLAB ON PIERS

The single-leaf and cavity masonry walls illustrated above represent optimum floodwater-resistant walling materials. This quality is a useful option when an extreme flood rises higher than the built-up height provided to protect from typical flood levels.

4.2 Low-set houses

These are the most often built houses and they require basic consideration of the form when built on flood-prone sites. When a concrete slab-on-ground system or footing/floor is used, it should be raised above the surrounding finished ground level by placing it on controlled fill. Typically, 300 to 600 mm of fill should cover the building area, plus about a one-metre width around the building perimeter. This forms a low platform on which the ground-floor slab is placed. This fill should be shaped to

facilitate floodwater flow and prevent floodwater from ponding against walls.

The controlled fill layer—being stable, coarse granular material (eg gravel)—allows moisture penetration. Around the building there may be an apron path but generally the fill, which is graded away from the building, should be covered with a layer of topsoil (and maybe geotextile fabric) and planting. On each side of the fill mound there should be pipes at natural ground level going through the topsoil to permit easy flow of surface water into and out of the fill layer.

Fast-moving floodwaters usually come from high ground and flow to lower areas. The exception may be when a flooding creek or river rises up to a house then recedes in the direction from which it came. Once it is established which way floodwaters will travel, the fill areas and house plan should be such as to facilitate, not hinder, floodwater movement.

For 'medium-set' suspended slab 'ground' floors set about a metre above ground level (allowing floodwater to flow beneath) it is important to simplify and minimise the piers or walls supporting the floor structure. A simple, robust structure allows easy passage of floodwaters, with little to snag debris. This

simplicity also facilitates post-flood cleaning and drying. For suspended concrete slabs there are three practical options:

- Conventionally formed, insitu reinforced slabs
- Insitu reinforced slabs on steel sheet lost forms (ie Bondek)
- Precast concrete permanent formwork and an insitu finishing slab placed over.

Single-storey buildings with an appropriate roof structure can have attic storage in the main roof space or above a low-ceiling section of the building above garages or non-habitable rooms. This allows a floor slab to be set above typical flood levels, but lower than the maximum flood level, accepting that the worst-case flood will cause minor inundation (less than one metre) of the habitable areas. It is possible to use water resistant fittings such as kitchen cupboards and vanities, or accept that they will have to be replaced after a major flood. The slab floor, with appropriate finishes, will be floodwater resilient. If the walls are also built of resilient material, such as concrete panels or masonry, then only furniture and appliances will be at risk and may need to be moved, possibly into the attic. To facilitate furniture movements a wide straight stair makes it easy to move items up and down. A lockable door on such a store is advised to limit possible looting after evacuation.

For two-storey houses on flood-prone sites, the stair connecting the two floors needs to be wide, with easy going and landings that facilitate the movement of furniture before and after flood events. Lower floors, walls, stairs and fixtures need to be appropriate floodwater resilient materials.

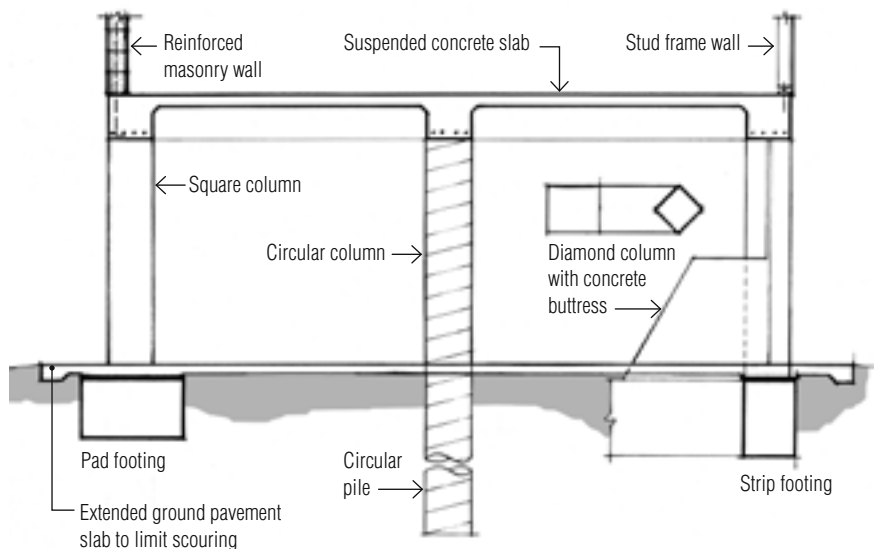
4.3 High-set and medium-set houses

Houses with garages or parking space beneath, or other utility areas such as laundries, garden or tool stores, are a practical design approach sites at risk from 2-m floods. They should have at least two access stairs or a stair plus ramp and adequate verandahs on



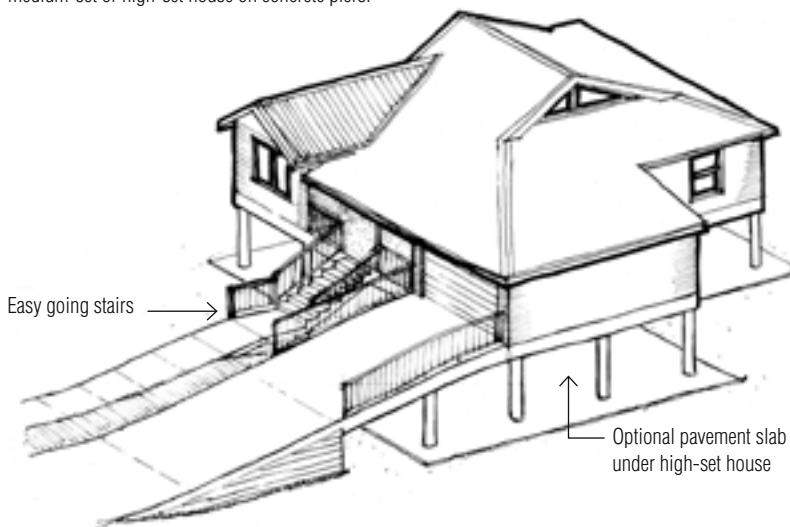
BAND BEAMS ARE AN OPTION TO CONVENTIONAL DEEP BEAMS

These band beams keep the slab edge and house profile low.



HIGH-SET HOUSE CONSTRUCTION

Suspended slab supported by concrete piers and beams. Consider raising the garage or carport with a medium-set or high-set house on concrete piers.



Reinforced concrete piers provide robust support able to sustain floodwater loads. If large floating debris items are a risk concrete piers can be buttressed. Circular or diamond columns allow optimum water flow and with a smaller cross-section area are appropriate for residential construction loadings.

the upper level. Items from below should be easily able to be moved up and stored when floods threaten. High-set houses are common in tropical and subtropical areas, where the raised living areas are exposed to cooling breezes and the floor is raised well above frequent minor floods caused by tropical rain. This approach is equally useful on flood-prone sites in non-tropical areas.

Footings, support columns, beams and slabs for high-set houses require specific structural engineering design. Foundation soil type, house walling materials, live loads and wind loads, along with possible floodwater flow rates and direction must be considered. The slab, beams and columns structure may be designed as a portal frame, not requiring diagonal bracing. This leaves an open and usable covered area under the house.

Square or circular section columns are simple to form, the circular column offering less obstruction to flowing water from any direction. Square columns may be turned diagonally (with the diagonal being the length of one side of a square column under a specific width beam above) so it has about 60% of the area of the square and presents a sharp 'bow' to oncoming water.

While concrete column and floor systems, are generally robust and can sustain the lateral forces of rapidly moving floodwaters, if there is a risk of heavy, buoyant items (vehicles or trees) in floating debris the columns on the oncoming side of a flow may need to be buttressed. Stair or ramp access up to a high-set house floor needs to be robust. These stairs or ramps become useful access points for emergency service boats. Where space and budgets allow, it is worth considering a vehicle ramp up to the high-set floor level, with a high-set garage. This greatly improves everyday access to the house and provides flood protection and security for a vehicle.

4.4 Attached houses

When groups of buildings, usually in a row, are built on flood-prone sites it is important to consider the direction of flow of floodwaters. Any group of buildings should, where possible, be sited with the longer plan dimension in the direction of oncoming flow. If such siting is not possible an alternative is to have a series of open-ended car spaces on the ground with a group of attached buildings above, floodwater can then flow under and away. These concepts apply to townhouses or blocks of home units with car spaces beneath.

For groups of villa-type dwellings without car spaces below, the concept of building suspended ground floors, or slabs on compacted fill, are viable options.

5 OTHER CONSIDERATIONS

5.1 Appliances

As resilient houses are intended to allow entry of floodwater, the construction materials and finishes of floors, walls and built-in items need to be able to withstand inundation. Consideration needs to be given to the choice of appliances (stoves, refrigerators, freezers, dishwashers, waste disposal units, clothes washers and dryers, stereos, televisions) and to their connections.

Even with warnings before a flood event, it is impractical to consider raising or moving appliances to upper levels of a house to be kept dry. This leaves three options for a house on a flood-prone site.

- Build the lowest floor above potential flood levels.
- Accept that significant cleaning, maintenance, or replacement, of appliances may be required.
- Have the daytime-use rooms (where most of the appliances will be) on an upper floor level, and only family room and minor bedrooms at the lower level. The latter may be inundated, but the occupants can remain upstairs.

5.2 Fixtures and fittings

Houses with internal masonry walls on slab floors can be built without skirting boards, or architraves on windows and doors. The omission of these items simplifies cleaning and makes for a more resilient finish.

A resilient house that is inundated requires any low-level, built-in wardrobes, kitchen cupboards, bathroom vanities, linen presses and laundry stores to be made of resilient materials. Where possible, cupboards should be suspended from walls with a gap between floor and cupboard bases.

More-robust alternatives for cupboards are terrazzo or masonry vertical supports and terrazzo, reconstituted stone or polished concrete bench tops with painted fibre cement shelving. Plinths for these cupboards can be formed concrete.

5.3 Electrical and plumbing systems

Licensed electricians and plumbers must do electrical and plumbing installations respectively. They should be consulted when planning houses for flood-prone areas.

The electrical system, including meter, power outlets and light switches can be short-circuited or damaged by floodwater exposure.

Installing electrical systems as high as possible minimises these problems. All internal wiring, power outlets and switches should, where possible, be set above the worst-case flood height. Positioning power outlets about a metre above the floor is unusual, but convenient for everyday use. Where lower power connections are unavoidable they should incorporate an above-flood isolation switch.

For plumbing installations, sewage backflow during a flood is a possibility. Backflow can be prevented by the installation of a reflux valve in the sewer line.

SUMMARY

- Residential areas of Australia that are deemed to be flood-prone are increasing with climate change and population pressure.
- The four approaches to houses for flood-prone areas are: flood resistant (dammed); raised floor; flood resilient; and a combination of raised and resilient. The last three offer the most practical solutions.
- Flood-prone house design must consider floodwater depth, duration, flow rates and directions, and the effect of debris.
- There are differences between building on sites that are prone to flood levels up to 1 m or over 1 m.
- The flood resilient ability of well founded, well braced, robust, and non-buoyant concrete and masonry houses should be more widely applied to minimise individual and community costs.
- Houses, fences and surrounding landforms should be planned to facilitate the flow of floodwaters.
- Floor levels can be increased up to 1.5 m with concrete slabs built on compacted, controlled fill.
- Medium-set house designs allow floodwater to flow beneath, and give a raised floor 1.5 m or more above ground.
- High-set house floors can be up to 2.5 m above ground and may incorporate wide verandahs and garages on the raised level.
- A house that can be occupied during a flood event answers important personal and community needs at stressful times.
- Consider plumbing and electrical installations in flood-prone houses. Be mindful of the effect of inundation on appliances.
- Design and select materials that can be readily cleaned of silt and mud deposited by floodwaters. This is particularly relevant to floor and wall finishes plus the skirting and architraves on them.

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