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TECHNICAL FACTSHEET

FOOTINGS ON EXPANSIVE SOILS

RESIDENTIAL FOOTINGS

A building's footing is arguably the most important aspect of its design however several factors can contribute to poor footing performance. Firstly, soil properties can vary greatly between sites and even vertically through the soil profile at the same site. Unlike large scale construction projects, residential footings have a limited budget making a detailed site investigation uneconomical. It is also uneconomical to design residential footings to resist all possible ground movements.

The Australian Standard AS2870: Residential slabs and footings, specifies the performance criteria for these types of footings as well as specific deemed-to-comply designs for common footing types. For footings that fall outside these standard solutions, it provides guidance of footing systems designed by engineering principles.

SITE CLASS

AS2870 classifies sites based on the expected ground surface movement (i.e. characteristic surface movement) and the depth to which this movement extends. The majority of soil in Roma, and many towns in south west Queensland, is characterised by deep expansive clays subjected to intense wetting and drying cycles producing surface movements commonly in excess of 130 mm. The classification of deep reactive soils is broken down as follows by AS2870:

- **M-D:** Moderately reactive clay or silt sites, which may experience moderate ground movement (21-40 mm) from deep-seated moisture changes.
- **H1-D:** Highly reactive clay sites, which may experience high ground movement (41-60 mm) from deep-seated moisture changes.
- **H2:D:** Highly reactive clay sites, which may experience very high ground movement (61-75 mm) from deep-seated moisture changes.
- **E-D:** Extremely reactive sites, which may experience extreme ground movement (>75 mm) from deep-seated moisture changes.

WHAT TO EXPECT FROM A FOOTING

The biggest misunderstanding regarding residential footings concerns both how they are expected to perform and how this performance is influenced. AS2870 states on several occasions what should be expected:

- **Clause 1.1:** Economical designs that avoid significant damage are practicable only if the soil moisture content of the foundation material under the footing or slab is stable or within reasonable limits of stability over the design life of the house or structure.
- **Clause 1.3.1:** Building systems designed and constructed in accordance with this Standard on a normal site... are expected to experience usually no damage, a low incidence of damage category 1 [1 mm cracks in walls] and an occasional incidence of damage category 2 [5mm cracks in walls].
- **Clause B1:** Importantly, significant damage may be avoided provided the foundation site conditions are properly maintained... It is neither practicable nor economical to design for the extreme conditions that could occur if a site is not properly maintained... Some minor cracking and movement will occur in a significant proportion of buildings, particularly those on reactive clays...
- **Clause C1.1:** The Standard has been based on methods of construction that are generally well accepted throughout Australia. Nonetheless, footing design is a developing field and it is possible that new or locally effective footing systems may not have been included.
- **Clause C1.3:** The current cost of building failure are modest compared with the costs of overly conservative design.

THE PROBLEM WITH EXPANSIVE SOILS

The construction of a footing essentially seals the ground surface preventing natural changes in soil moisture from occurring due to rain and evaporation. If the moisture content around the perimeter of the building is increased through rainfall or watering, a dishing effect will occur as the soil under the exterior footings expands more than that under the interior footings. As the moisture spreads under the building the dishing effect will be reduced but often unevenly. If the perimeter of the building begins to dry out (as is the typical weather cycle), the external footings will begin to lower as the soil contracts creating a doming effect. As the drying moves under the footing the entire building begins to lower and the cycle begins again.

CONSTRUCTION TYPES

Along with the site class, the type of building construction affects the choice of footing. In general, the best practice is to make the footing a stiff as possible and the building frame and cladding as flexible as possible. AS2870 takes the myriad of potential construction types and attempts to sort them into five equivalent constructions based on their tolerance to differential movement. Uniform movement of the entire footing is significantly less damaging than differential movement. The equivalent construction types are:

- **Clad Frame:** Timber or metal frame construction with the exterior wall clad with timber or sheet material not sensitive to minor movements. Maximum 40 mm differential deflection.
- **Articulated Masonry Veneer:** Masonry veneer construction incorporating articulation of the masonry veneer. Includes rendered claddings on a clad frame. Maximum 30 mm differential deflection.
- **Masonry Veneer:** Construction consisting of a loadbearing frame clad with an outer leaf of masonry. Maximum 20 mm differential deflection.
- **Articulated Full Masonry:** Full masonry construction incorporating articulation of external and internal walls. Maximum 15 mm differential deflection.
- **Full Masonry:** Construction with masonry double-leaf external walls and masonry single-leaf integral walls without full articulation. Maximum 10 mm differential deflection.

FOOTING TYPES

A footing is the structural element that transfers the building's load to the ground; the foundation is the ground that supports the footing. The following are common footing styles utilised in south west Queensland:

- **Stiffened Raft:** Perhaps the most traditional form of slab on ground type construction in the area, it consists of a concrete slab cast on ground stiffened by integral edge beams and a grid of internal beams. The beams are usually arranged on a maximum four metre grid and can be cast separately to the slab as long as sufficient reinforcement is provided to link the two elements. The intention of the beams is to provide stiffness to the slab to allow it to move monolithically without any differential movement (a raft floating on a sea of expansive soil). AS2870 provides deemed-to-comply designs for most forms of construction up to highly reactive sites. For extremely reactive sites they must be designed from engineering principles which often involves deep, heavily reinforced beams and a thicker slab.

- **Waffle Raft:** Developed in South Australia in the late 1980s and also known as a waffle pod, it consists of a stiffened raft with closely spaced ribs constructed on the ground with a slab suspended over the grid of void formers. Best suited to level sites, polystyrene void formers are arranged on the surface of the ground to create close grid with narrow ribs based on a 1200 mm module. The intention of the design is for the soil to expand around the narrow footing beams into the void leaving the slab relatively unaffected. Having the footing beams elevated above the ground also eliminates the soil clinging to the side of the footings. This system provides savings in both materials and construction as there is minimal excavation and lower quantities of materials (reinforcement & concrete) compared to traditional raft slabs. Waffle rafts are prone to poor workmanship due the tighter construction tolerances produced from their more refined design and so good set out is vital. AS2870 provides deemed-to-comply designs for several forms of construction up to highly reactive sites. For extremely reactive they must be designed from engineering principles which often involves stacking two void form modules together to create deeper beams, and a thicker slab.

- **Suspended Slab:** Designed from engineering principles specifically to cope with expansive soils or collapsing fill, it consists of a reinforced slab and beam system supported on piers with collapsible void former under the entire footprint of the footing. The footing is essentially isolated from the soil and is designed as a fully suspended system with the slab spanning between beams and the beams in turn spanning between piers. The piers extend down below the depth of seasonal moisture change which can be several metres. As well as the slab being thicker than a stiffened or waffle raft, often two layers of mesh need to be utilised to allow the slab to span between beams.

- **Adjustable Stumps:** Designed from engineering principles specifically to cope with expansive soils, they consist of steel stumps cast into concrete bored piers. The top of the stump is fitted with an adjustable top which can be adjusted post construction to ensure the building remains level. The stumps support a suspended lightweight framed floor, constructed from either traditional timber framing, manufactured timbers or steel bearers and joists. The concrete bored pier is typically 300/450 mm in diameter and extends down below the depth of seasonal moisture change. As will be discussed later, additional measures such as sleeves and belled bases can be used to improve the performance of the stump.

There other footing types not covered here which included but are not limited to: screw piers (steel piers with a helical base that are drilled into the soil), slippery stumps (a steel stump sitting on a concrete base in an oversized hole surrounded by an pervious granular fill) and strip footings (a grid of concrete beams supporting the wall with infill floor panels, typically not suited to expansive soils).

FOOTING SELECTION ADVICE

AS2870 Site Class & Characteristic Surface Movement		Construction Type		Footing Type			
		AS2870 Equivalent Construction	Recommendation	Stiffened Raft	Waffle Raft	Suspended Slab	Adjustable stump
M-D (21-40 mm)		Clad Frame	Recommended	Recommended	Recommended	Not Required	Recommended
		Articulated Masonry Veneer	Recommended	Recommended	Recommended	Not Required	Suitable
		Masonry Veneer	Recommended	Recommended	Suitable	Not Required	Not Suitable
		Articulated Full Masonry	Recommended	Recommended	Not Recommended	Not Required	Not Suitable
		Full Masonry	Suitable	Suitable	Not Suitable	Recommended	Not Suitable
H1-D (41-60 mm)		Clad Frame	Recommended	Recommended	Suitable	Not Required	Recommended
		Articulated Masonry Veneer	Recommended	Recommended	Not Recommended	Not Required	Suitable
		Masonry Veneer	Recommended	Recommended	Not Recommended	Not Required	Not Suitable
		Articulated Full Masonry	Suitable	Suitable	Not Suitable	Recommended	Not Suitable
		Full Masonry	Suitable	Suitable	Not Suitable	Recommended	Not Suitable
H2-D (61-75 mm)		Clad Frame	Recommended	Recommended	Not Recommended	Recommended	Recommended
		Articulated Masonry Veneer	Recommended	Suitable	Not Recommended	Recommended	Suitable
		Masonry Veneer	Suitable	Suitable	Not Suitable	Recommended	Not Suitable
		Articulated Full Masonry	Suitable	Not Recommended	Not Suitable	Recommended	Not Suitable
		Full Masonry	Not Recommended	Not Suitable	Not Suitable	Required	Not Suitable
BRANDON & ASSOCIATES RECOMMENDED DIVISIONS	E-D (76-85 mm)	Clad Frame	Recommended	Suitable	Not Recommended	Recommended	Recommended
		Articulated Masonry Veneer	Recommended	Suitable	Not Recommended	Recommended	Not Suitable
		Masonry Veneer	Suitable	Not Recommended	Not Suitable	Recommended	Not Suitable
		Articulated Full Masonry	Suitable	Not Suitable	Not Suitable	Required	Not Suitable
		Full Masonry	Not Recommended	Not Suitable	Not Suitable	Required	Not Suitable
	E-D (86-100 mm)	Clad Frame	Recommended	Suitable	Not Recommended	Recommended	Recommended
		Articulated Masonry Veneer	Suitable	Not Recommended	Not Suitable	Recommended	Not Suitable
		Masonry Veneer	Suitable	Not Suitable	Not Suitable	Required	Not Suitable
		Articulated Full Masonry	Not Recommended	Not Suitable	Not Suitable	Required	Not Suitable
		Full Masonry	Not Suitable	Not Suitable	Not Suitable	Required	Not Suitable
	E-D (101-115 mm)	Clad Frame	Recommended	Suitable	Not Suitable	Recommended	Recommended
		Articulated Masonry Veneer	Suitable	Not Recommended	Not Suitable	Recommended	Not Suitable
		Masonry Veneer	Suitable	Not Suitable	Not Suitable	Required	Not Suitable
		Articulated Full Masonry	Not Recommended	Not Suitable	Not Suitable	Required	Not Suitable
		Full Masonry	Not Suitable	Not Suitable	Not Suitable	Required	Not Suitable
	E-D (116-130 mm)	Clad Frame	Recommended	Not Recommended	Not Suitable	Recommended	Recommended
		Articulated Masonry Veneer	Suitable	Not Recommended	Not Suitable	Required	Not Suitable
		Masonry Veneer	Not Recommended	Not Suitable	Not Suitable	Required	Not Suitable
		Articulated Full Masonry	Not Recommended	Not Suitable	Not Suitable	Required	Not Suitable
		Full Masonry	Not Suitable	Not Suitable	Not Suitable	Required	Not Suitable
	E-D (>130 mm)	Clad Frame	Recommended	Not Recommended	Not Suitable	Required	Recommended
		Articulated Masonry Veneer	Suitable	Not Recommended	Not Suitable	Required	Not Suitable
		Masonry Veneer	Not Recommended	Not Suitable	Not Suitable	Required	Not Suitable
		Articulated Full Masonry	Not Suitable	Not Suitable	Not Suitable	Required	Not Suitable
		Full Masonry	Not Suitable	Not Suitable	Not Suitable	Required	Not Suitable

These recommendations are for lightweight, single storey residential style construction. There are other footing systems available, this table presents those most commonly used in expansive soils. Recommendations that are shaded fall outside the scope of the deemed-to-comply standard footings presented in AS2870 and must be designed from engineering principles. These recommendations are only valid for normal sites and not those with a site class of 'P' or controlled fill sites.

NOTES CONCERNING TABLE

The recommendations made in the table are based on the following definitions defined by Brandon & Associates.

For construction type:

- **Recommended:** This form of construction is considered the best for the given site class.
- **Suitable:** This form of construction can be used for the given site class but there are better forms available.
- **Not Recommended:** This form of construction should generally be avoided for the given site class.
- **Not Suitable:** This form of construction is likely to experience problems and/or may require extensive engineering.

For footing type:

- **Required:** This footing is generally the best/only type of footing suitable. Consider changing construction type.
- **Recommended:** This footing will generally perform well for the given combination of site class and construction type.
- **Suitable:** This footing can be used for the given combination of site class and construction type but there may be better options.
- **Not Recommended:** This footing should be avoided for the given combination of site class and construction type.
- **Not Suitable:** This footing is likely to experience problems and/or may require extensive engineering for the given combination of site class and construction type.
- **Not Required:** This footing although it can be used may be excessive for the given combination of site class and construction type.

PIERS

The use of piers (bored or screw-in) is a necessity for suspended slabs and adjustable stumps and they are generally added to stiffened raft and waffle rafts to improve their performance in expansive soils. Piers provide support to the footing from below the depth of seasonal moisture changes in the soil which can be in the order of three to four metres. The upper portion of a bored pier is generally sleeved with a smooth pier liner to allow the soil to expand upwards around the pier with minimal influence. In contrast the bottom of a bored pier can be belled out to anchor it into the ground below the zone of influence. For filled sites piers are generally used to extend the footing though the fill so that it is founded in natural ground. If piers are to be used, generally the best performance is achieved if they are distributed across the entire footing and not just along the perimeter of the building.

GENERAL RECOMMENDATIONS

- Footing performance is governed greatly by pre and post construction practices. The recommendation of the CSIRO 'Foundation Maintenance and Footing Performance: A homeowner's Guide' should be followed.
- Controlling moisture change is generally the best method of promoting longevity in foundation performance: it does not matter so much if the soil is wet or dry, rather it is keeping the moisture content constant that is important.
- Good site drainage is imperative. Consideration should be made for shaping the clay soils correctly before being top dressed in a pervious material for laying of turf. Even if the finished surface appears to drain correctly, the water can seep through the top dressing and travel along the clay profile and towards the footing if not shaped correctly.
- Service trenches should be plugged with clay/bentonite close to the building outline to prevent ingress of moisture along the trench bedding.
- Flexible plumbing fixtures capable of handling the expected ground movement should be installed on all sites.
- Only one footing type should be used for a given building. For example a slab on ground garage should not be connected to a house on stumps as invariably one will move differentially to the other. Should mixed forms of construction be used, consideration needs to be given to articulation and vertical stability between the constructions.

FURTHER READING

This factsheet is no substitute for specific engineering advice and is taken to be general in nature for footings on expansive soils in south west Queensland. The following references provide further general information:

- CSIRO 'Foundation Maintenance and Footing Performance: A Homeowner's Guide'.
- Cement, Concrete & Aggregates Australia 'Guide to Residential Floors'
- Cement, Concrete & Aggregates Australia TN61 'Articulated Walling'.

BRANDON & ASSOCIATES

Brandon & Associates, founded in 1956, remains Queensland`s largest rural based consulting engineering firm, operating across South-West and Central Queensland with offices located in Chinchilla, Roma and Toowoomba. We take great pride in having expert local knowledge of the areas we live and work in.

Supported by our associate company South Queensland Soils, Brandon & Associates has developed a thorough knowledge of the prevailing soil conditions in many towns across the region as well as how these conditions vary between different areas within the same town.

We have designed numerous residential footing across the region many of which on sites subjected to expansive clay soils. To address this, we have developed specific in-house designs suited to local conditions that are proven to perform well and minimise damage to buildings.

Should you require any further advice or a specific engineered design please contact one of our offices.