Movement of bored piers / screw piles relative to the slab / structure.

INTRODUCTION:

The residential screw piling industry, in Australia and New Zealand, has grown rapidly over the past 15 years. There are significantly different approaches to the depth specified by engineers for bored piers and screw piles.

In particular, AS2870 Appendix G, clause G6.3 (Informative) states that for "**screw piles** in reactive foundations should not be less than 1.25Hs".

AS2870 is however silent on the depth required for **bored piers**.

This paper addresses the key points related to the potential movement that can be expected from how AS2870 approaches bored piers and screw piles and the risk that engineers may be exposed to when they choose to approach these two foundation types differently.

HEAVE:

When a dry reactive material, such as expansive clay soil, experiences a prolonged period of saturation, it will absorb water over time. This leads to a significant increase in volume as the soil expands (usually affected by seasonality).

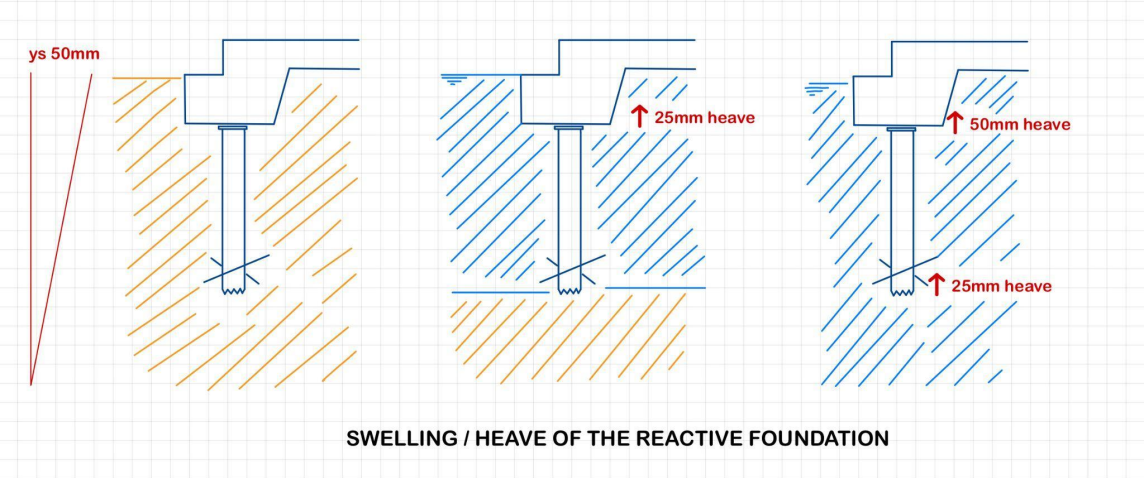
In this scenario, the surface movement due to ground heave will typically be greater than the movement at the underside of the bored pier or screw pile. As you move deeper into the ground, the heave tends to diminish proportionally.

Where slabs are NOT tied into the piers / piles the slab will lift off the piles and return when the moisture content reduces with drying.

The impact on slabs tied to piers/piles will vary depending on the connection and the extent of the heave. The potential scenarios are:

1. Short piers/piles being pulled out of the ground: If the piers or piles are relatively short in length, they may not be embedded deep enough to resist the upward forces caused by ground heave. As a result, the piers or piles may experience uplift forces that exceed their capacity, causing them to be pulled out of the ground.

2. Failure at the connection point between the pier/pile and the slab: In the case of deeper piers/piles, the failure may occur at the connection point between the pier/pile and the slab. As the ground heaves, the upward forces can exert significant pressure on the connection, potentially causing it to fail or rupture. This failure can result in a loss of load transfer between the slab and the pier/pile.



SWELLING / HEAVE OF THE REACTIVE FOUNDATION

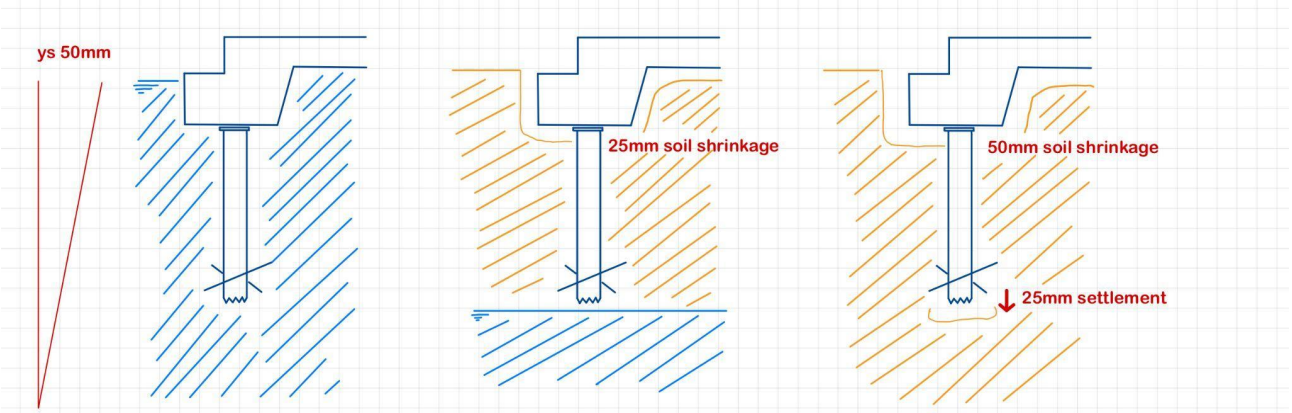
CONCLUSION FOR THE HEAVE CASE:
In all cases of heave, the slab will be subject to larger movements at the surface than the pier / pile movement at the base of the pier / pile. Where slabs are tied into shallow piers / piles, the piers / piles may be pulled out of the ground and may not be able to return to their original position once moisture content reduces.

NOTE: As estates are built out, the ingress of stormwater is reduced over the estate, so even in dry conditions, the relative ingress of moisture in an estate is limited and reduces over time.

SHRINKAGE:
The worst case for shrinkage is a saturated material that is subject to a prolonged period of drying / drought.

Drying will take place from the surface first, resulting in the material under the slab shrinking and creating a widening shrinkage gap between the slab and the pier / pile support.

Once the material starts to dry out below the founding depth of the pier / pile, there may be settlement of both concrete bored piers and screw piles.



SETTLEMENT / SHRINKAGE OF THE REACTIVE FOUNDATION

CONCLUSION FOR THE SHRINKAGE CASE:
Shrinkage causes piers and piles and the structure to settle. The same shrinkage will occur for both bored piers and screw piles and the shrinkage depends on the depth of the pier / pile relative to Hs.

The settlement (mm) is indicated in the table below for the class and depth compared to Hs.

Site Classification	0.5Hs	0.75Hs	Hs
S (0-20mm)	0-10mm	0-5mm	0mm
M (20-40mm)	10-20mm	5-10mm	0mm
H1 (40-60mm)	20-30mm	10-15mm	0mm
H2 (60-75mm)	30-75mm	15-18.75mm	0mm
E (>75mm)	>37.5mm	>18.75mm	0mm

Currently AS2870, Appendix G, clause G6.3 (Informative) states that for “screw piles in reactive foundations should not be less than 1.25Hs”.
The code remains silent on the required depth or bored piers in reactive foundations.

Following table 2.4 in AS2870, we can determine shrinkage for various locations. The table below calculates the expected shrinkage for a **H1 (40-60mm)** Site for a 1m bored pier, a 2m screw pile and a 3m screw pile in these locations.

Location and Hs	**1m Bored Pier**	**2m Screw Pile**	**3m Screw Pile**
Sydney 1.8m	*17.8-26.7mm	0mm	0mm
Melbourne and Brisbane 2.3m	22.6-33.9mm	5.2-7.8mm	0mm
Hobart and the Hunter 3.0m	26.7-40mm	13.3-20mm	0mm
Adelaide 4.0m	30-45mm	20-30mm	10-15mm

*** [1-(depth / Hs)] x reactivity = [(1 - 1 / 1.8) / 40mm)] = 17.8mm**
Movement above 10mm highlighted.

Following table 2.4 in AS2870, we can determine Hs for various locations. The table below calculates the expected shrinkage for a **H2 (60-75mm)** Site for a 1m bored pier, a 2m screw pile and a 3m screw pile in these locations.

Location and Hs	**1m Bored Pier**	**2m Screw Pile**	**3m Screw Pile**
Sydney 1.8m	**26.7-33.3mm	0mm	0mm
Melbourne and Brisbane 2.3m	33.9-42.4mm	7.8-9.8mm	0mm

Hobart and the Hunter 3.0m	40-50mm	20-50mm	0mm
Adelaide 4.0m	45-56.3mm	30-37.5mm	15-18.8mm

**** [1-(depth / Hs)] x reactivity = [(1 - 1 / 1.8) / 60mm)] = 26.7mm**

Movement above 10mm highlighted.

RECOMMENDATION:

In the case of HEAVE - risk exists where shallow bored piers are **tied into the slab**, and piers may be lifted out of the ground and not be able to settle to their original position.

Screw piles will offer more resistance to being pulled out of the ground than bored piers due to the cone of foundation material that will need to be pulled out, which will also be resisted by the underside of the slab.

In the case of bored piers being pulled out of the ground due to heave, bored piers only rely on the resistance of skin friction between the bored pier and the foundation material.

In the case of SHRINKAGE, movement will be the same for bored piers and screw piles and is related to the reactivity of the foundation.

There is significant risk with AS2870, remaining silent on the depth required for **bored piers** in **reactive foundations** considering the potential for settlement of “shallow” bored piers. The settlement of 1m bored piers, in the tables above, clearly indicates this risk even in low reactivity soils.

It is extremely conservative and costly for the industry and the homebuilder to apply clause G6.3 of AS2870 across **all site classifications or “reactive foundations”**, when a more appropriate approach can be taken.

The following approach should be adopted by the industry for both bored piers **and** screw piles to limit any significant settlement or piers / piles being lifted out of the foundation material and which considers the variation in movement between site classifications / reactivity of the foundations.

Where bored piers and screw piles are used in the same foundation, differential settlement will be minimised if piers and piles are located at the same depth.

This approach allows a factor of safety of 1.25 for H2 sites and 1.5 for E sites and where the tree effect needs to be considered.

Site Classification (mm)	**Min depth of Bored Piers and Screw Piles**
S (0-20)	0.75 x Hs
M and H1 (20-60)	1 x Hs
H2 (60-75)	1.25 x Hs
E (>75) + Risk of the effect of trees	1.5 x Hs

Given the adoption of the above table, and the adoption of pier / pile increments of 0.5m, the following founding depths for bored piers and screw piles can be calculated. The expected settlement is shown in brackets.

As an example in Melbourne for an **S** Site Classification 0.75 x 1.8m (Hs) = 1.35m. Rounding up to 1.5m. The expected settlement at **1.5m** with an Hs of 1.8m = **3.3mm**.

	S (0-20)	**M and H1 (20-60)**	**H2 (60-75)**	**E(>75) + Tree**
Location and Hs	**0.75Hs**	**1 x Hs**	**1.25 x Hs**	**1.5 x Hs**
Brisbane and Sydney 1.5m	1.5m (0mm)	1.5m (0mm)	2.0m (0mm)	2.5m (0mm)
Sydney and Melbourne 1.8m	1.5m (3.3mm)	2.0m (0mm)	2.5m (0mm)	3.0m (0mm)
Melbourne, Brisbane and Hobart 2.3m	2.0m (2.6mm)	2.5m (0mm)	3.0m (0mm)	3.5 (0mm)
Hobart and the Hunter 3.0m	2.5m (3.3mm)	3m (0mm)	4m (0mm)	4.5(0mm)
Adelaide 4.0m	3.0m (5mm)	4.0m (0mm)	5.0m (0mm)	6.0m (0mm)

CONCLUSION:
It is clear that the risk of movement (distress to a structure) is minimised where piers / piles are founded at the **same** depth by considering the reactivity of the foundation material.

A more cost effective foundation solution for S, M and H1 site classifications, should be considered, rather than applying the blanket approach of 1.25Hs across all reactive foundations for screw piles.

ASSUMPTIONS:
The guidelines of the CSIRO are followed and drainage is directed away from the footings.
There is no local ingress of water (due to plumbing failure) or saturated garden beds adjacent the footings creating differential moisture effects beyond the zone of influence (Hs).
Any pre-drilling which is undertaken, is backfilled appropriately by the piling contractor.

REFERENCES:
Foundations and Maintenance and Footing Performance. A Homeowner's guide. CSIRO BTF 18
AS2870-2011 Residential slabs and footings