



AGS VICTORIA 2017 SYMPOSIUM
Reactive clays and light structures

Wednesday, 25 October 2017, 8:15am – 7:00pm

Rydges Hotel, 186 Exhibition Street, Melbourne



AUSTRALIAN GEOMECHANICS SOCIETY
VICTORIA CHAPTER



PREFACE

The Victorian chapter of the Australian Geomechanics Society invited academics and practitioners in the field of geotechnical and ground engineering to attend the 2017 Australian Geomechanics Society Victorian Symposium on 'Reactive clays and light structures' held on 25 October 2017.

The reactive soils of the Melbourne region form a large portion of its complex and variable geology. In particular, the basaltic volcanics situated to the north and west of Melbourne, which cover some 40% of the Melbourne region present numerous geotechnical challenges, particularly for lightly loaded structures. The geotechnical design and behaviour of lightly loaded structures on reactive soils is one aspect of geotechnical engineering where the public tend to have greater awareness, which is often not the case for the variety of soil and rock mechanics problems geotechnical engineers deal with. This is often borne out through their experience with their own residence, and rightly or wrongly, this contributes greatly to the public's perception of the geotechnical profession.

The 2017 Australian Geomechanics Society Victorian Symposium covered a variety of geotechnical challenges associated with reactive soils including residential slabs and footings, roads, pavements and other sensitive infrastructure that interact with reactive soils. The Symposium brought together practitioners from consulting, construction and academia to share and discuss their experiences on the topic of reactive soils and their related geotechnical applications.

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Keynote Address

Ground movement and soil structure interaction – recent findings

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ABSTRACT

Recently, unsatisfactory performance of some domestic structures founded on reactive soils has been reported. In Victoria, many instances of significant damage particularly in the western suburb are associated with houses built during the millennium drought. Abnormal moisture conditions (e.g., extreme climate conditions or pipe leak) lead to changes in soil moisture content under the footing system causing differential movement of slabs and supported superstructure. This paper presents a summary of research undertaken by Swinburne University of Technology with support from a number of organisations investigating the main causes of damage and some of the shortcomings in current design and construction practice.

Keywords: reactive soil, climate conditions, moisture, ground movement

1 INTRODUCTION

There have been a number of media reports (ACA, 2012, THE-AGE, 2011, THE-AGE, 2014a, THE-AGE, 2014b) and anecdotal evidences of footing movements and damage in houses recently built houses on reactive soils. Reactive soils undergo volume changes due to variations in moisture content and create differential movements within light structures. The Australian Standard for residential footing design -AS2870 (AS2870, 2011) provides a procedure to estimate characteristic ground movement due to normal moisture changes and provide deem-to-comply footing designs for expected ground movement. However, recent records suggest that such footings have experienced movements beyond the designed limit, possibly due to abnormal moisture conditions created by back to back extreme climate events recorded in Australia.

The primary aims of the research were to identify and quantify the factors leading to damage in residential structures associated with ground movement. The research methodology included: review of inspection reports of damaged houses; field monitoring of ground movement due to seasonal changes; laboratory testing of expansive soils; structural assessment of slabs and superstructure systems; and advanced modelling to predict behaviour of houses under long term climate scenarios.

A number of publications and have been produced from this research including one thesis to date (Karunaratne, 2016). Published papers which cover various aspects of the research include Fardipour et al., 2016; Gad et al., 2012; Karunaratne et al. 2012; Karunaratne et al. 2014a; Karunaratne et al., 2014b; and Wagle et al., 2012. This paper provides a general summary of the key findings from this research work to date and outlines the major recommendations resulting from this work.

2 SUMMARY OF FINDINGS

2.1 Causes of damage

In Victoria, damage to houses is typically associated with expansive soil sites. Damage to houses occurs due to differential movement of footings. The largest amount of movement is usually at edges or corners of a house. The relevant design Australian Standard AS870 does not aim to prevent differential movement or damage, but minimise them.

Based on detailed engineering forensic reports provided by the consultants who members of the Foundation and Footings Society Victoria (FFSV), 367 houses in Victoria were selected for analysis as they best reflected the type of houses considered modern (built between 1986 and 2009). Out of these, 262 (71%) houses are single storey and the remainder are double storey. Out of the 367 houses, 95% are of brick veneer construction with the remainder having light cladding or of solid brick construction. By analysing the data contained in these reports, the most common reported causes of damage are found as:

- Poor site drainage
- Trees and vegetation
- Climatic conditions (primarily drought)
- Plumbing leaks.

Figure 1 shows the identified causes of damages and their percentages. The abovementioned four reasons accounted for more than 70% of the causes of damage with poor site drainage accounting for approximately 25% of all causes. This is quite significant especially for house owners who undertake their own landscaping, as they may not be fully aware of the ramification of changes to site conditions.

For these houses, approximately 30% of damaged houses were identified to have more than one cause of damage. The presence of multiple causes makes the development of remedial actions more complex. It appears that filled sites have significant contribution to

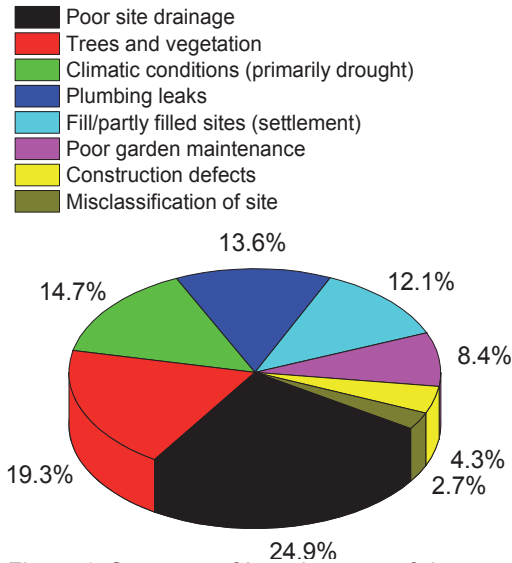


Figure 1: Summary of broad causes of damages

damage. This could be due to under or over compaction for the full or part of the site.

For all the 367 damaged houses reviewed, approximately 60% of all damaged houses were identified to be on highly reactive soils and approximately 30% are on moderately reactive soils. Hence, greater attention should be given to the design and construction of houses on highly reactive sites.

2.2 Study of climate conditions

AS2870 uses the Thornthwaite Moisture Index (TMI) to describe the climate zone (humid to arid). The lower the TMI value the greater the aridity. Expansive soils in arid climates experience greater amount of movement compared to humid climates. This is due to the fact that soil moisture changes to greater depths in arid environments resulting in greater volume of soil which can expand and contract.

Based on calculation of TMI over time, this study has confirmed that most locations in Victoria have

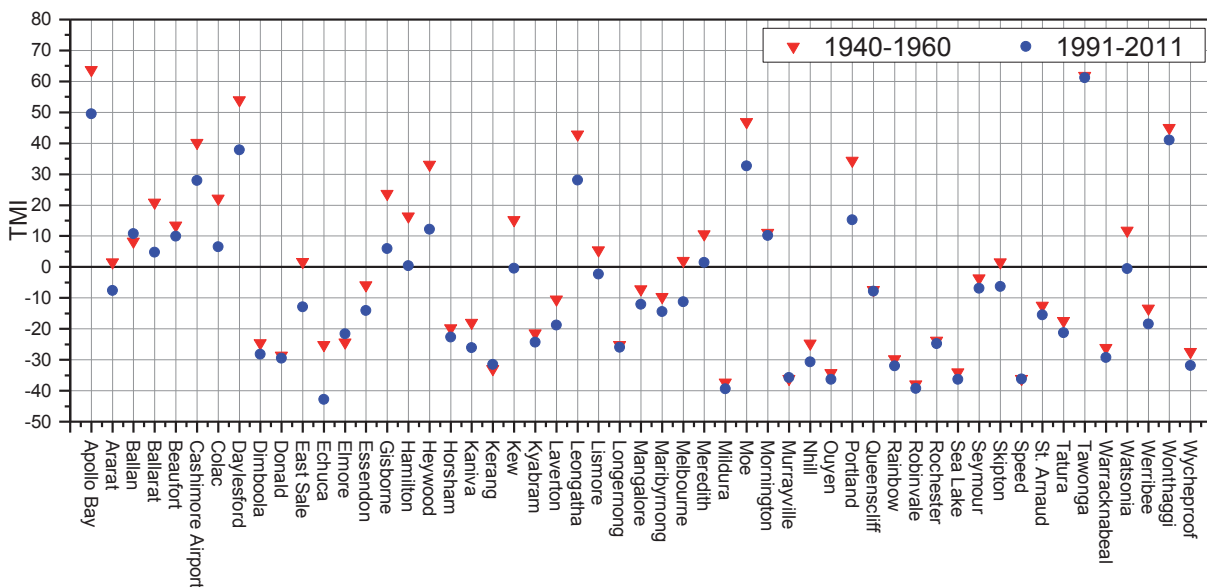


Figure 3: Calculated TMI for different localities in Victoria for two different periods showing drying conditions for most locations

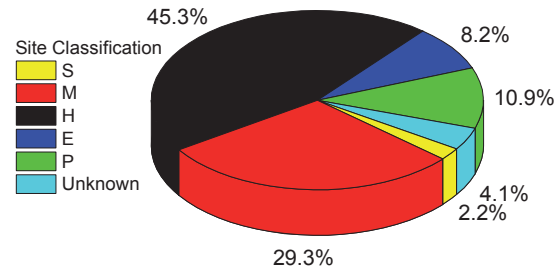


Figure 2: Summary of site classification of damaged houses

experienced drying resulting in increased aridity over the last 50 years as shown in Figure 3 (TMI values are based on average of 20 years), Up until the latest revision of AS2870 in 2011, the TMI and corresponding climate zones appear to have been based on 1940-1960 climate data. In 2011, the climate zones were revised to become better aligned with recent climate data. However, if this drying trend continues, the updated zones may not be sufficient to describe future conditions. This is demonstrated in Figure 4 for the city of Melbourne showing the calculated TMI based on past data (pre 2014) and forecast data based on AustRoads predictions from 2014 to 2030 (Austroads, 2004).

2.3 Characterisation of typical basaltic clay and measurements of seasonal movement

In order to predict the maximum ground surface movement due to soil heave and settlement, knowledge of the soil properties is critical. While soil test laboratories collect different soil information, there is generally lack of comprehensive soil characterisation of common soils available for practitioners in the housing market.

Based on field and laboratory testing, a comprehensive dataset for typical highly expansive basaltic clay in Melbourne has been established (Braybrook clay) (Karunaratne, 2016, Karunaratne et al., 2014a). This unique dataset

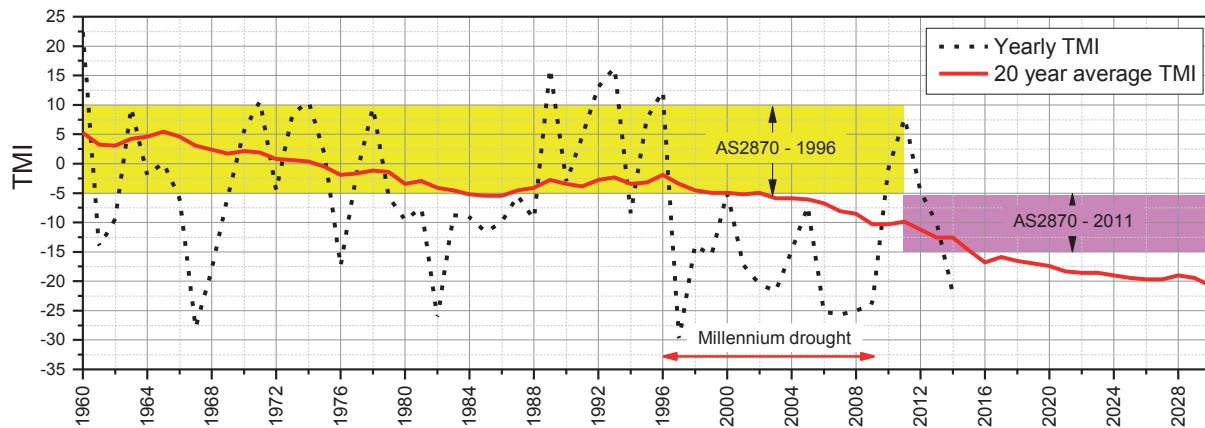


Figure 4: Calculated TMI for Melbourne over time showing on going drying trend. In the 1996 version of AS2870 it was assumed that the TMI is 10 to -5 for this locality which has been revised to -5 to -15 in the 2011 version.

can be used to calibrate future models and also provide benchmark soil characteristics for both practitioners and researchers.

From a comprehensive test site, seasonal soil movements and corresponding moisture change were recorded for a 2 year period. This site is in western Melbourne (Braybrook). Seasonal surface movement was measured to be up to 40mm.

2.4 Use of Shrink-Swell Index (I_{ss})

The shrink swell index (I_{ss}) which is calculated based on results from soil testing is used to determine the degree of soil reactivity. As it is currently used, it is assumed that I_{ss} is a constant value for a given soil. While I_{ss} does reflect the degree of reactivity, it is has been found that the calculated value can change depending on the initial moisture condition of the soil at testing as shown in the Figure 5. This means that if one site is tested at two different times of the year with two different moisture conditions (e.g. wet and dry), two different values of I_{ss} can be obtained. This can result in the same site be given two different classifications (e.g., H2 or E). Hence, the way I_{ss} is currently used needs to be improved to recognise its dependence on initial moisture condition.

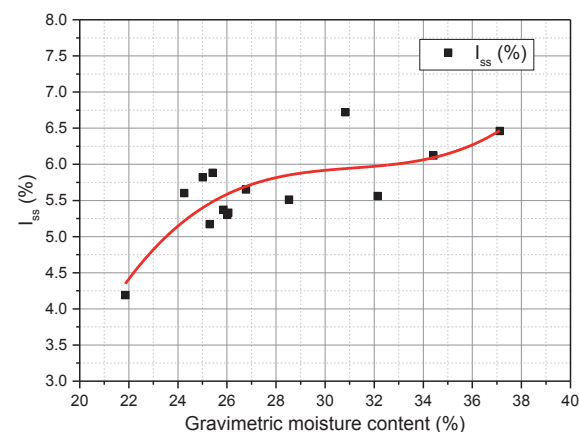


Figure 5: I_{ss} value variation with starting moisture content – Braybrook site

2.5 Millennium drought

There have been very limited experimental studies related to long term behaviour of expansive soils for residential construction in Australia. Further, there has been limited research on climate-soil interaction to predict ground movement.

As part of this study an advanced numerical modelling approach was developed to predict ground movement for different soils and climate conditions. While this approach has some simplifications, it is deemed adequate for demonstrating trends. The details of modelling approach is described in (Karunaratne (2016)).

Using this modelling it was found that the millennium drought (1997-2009) appears to have the most impact on ground movement in the last 70 year as shown in the Figure 6 (simulated ground movement for Braybrook). The millennium drought is estimated to have caused additional ground movement of about 20% to what was experienced in the preceding 50 years.

Even though the drought broke with the two years 2010 and 2011 receiving above average rainfall, the modelling shows that the ground condition appears not to have fully recovered and is still in moisture deficit.

Figure 7 shows that wettest suction profile during drought breaking rainy period did not reach the wettest suction for typical climate condition in preceding 50 years. Some ground recovery (heave) did occur following the breaking of the drought, but it is not sufficient on its own to have cause widespread damage.

However, as the soil has moisture deficit, it has the potential for significant heave if moisture was allowed to build up (e.g., due to poor drainage or broken pipes).

2.6 Waffle slabs

Waffle slabs have become very common for houses due to a number of benefits including their simple formation, minimal site excavation and high accuracy in estimating required concrete quantities.

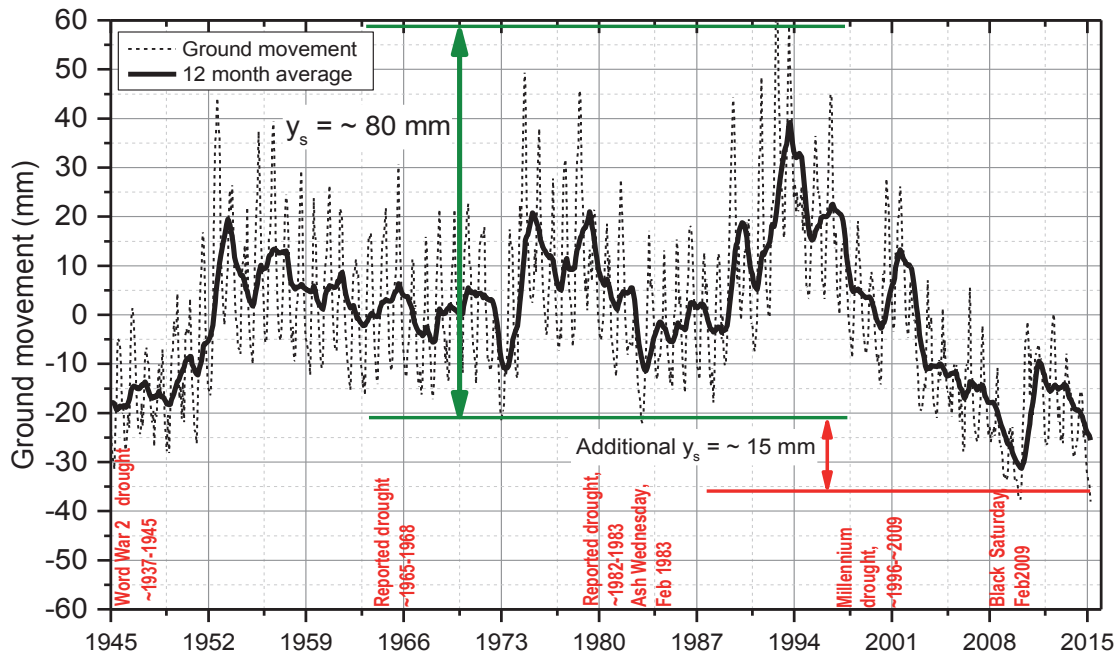


Figure 6: Calculated ground movement over time showing the impact of the millennium drought

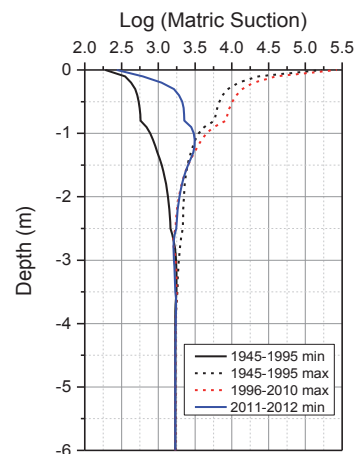


Figure 7: Prediction of changes in wettest and driest suction profiles for Braybrook in Victoria.

As waffle slabs are placed close to the ground surface, they are more sensitive to changes in soil moisture. Furthermore, they are more flexible under edge heave compared to edge settlement. Indeed, there has been limited research on the performance of waffle slabs subject to edge heave.

AS2870 provides deemed to satisfy solutions for different types of footings for different site classifications. Simple specifications are provided for waffle slabs for site classifications up to H2. Design of slabs, including waffle slabs, can also be undertaken using softwares such as CORd and SLOG which are developed in Australia. However, for brick veneer construction on H2 sites, the deemed to satisfy solution of AS2870 for a waffle slab may not be as conservative as those obtained by engineering principles or design softwares.

2.7 AS2870

AS2870 was first introduced in 1986 and updated in 1996 and 2011. While the updates refined the standard, the fundamental design philosophy and approach remained the same. The performance

targets for AS2870 in terms of acceptable cracking to walls and floors are modest and are likely to be below contemporary consumer expectations. The standard offers only one level of performance and does not reflect different consumer expectations.

There have been significant changes in construction techniques and materials in recent times such as wide spread adoption of large open plan areas and use of rendered surfaces. The implications of these changes and performance of such materials have not been fully considered for compatibility with AS2870 design assumptions.

Further, the standard does not cover ground movement due to abnormal moisture conditions such as pipe leaks. Importantly, the standard does not clearly state the degree of extreme climate condition it covers. This is different from other loading standards as wind and earthquakes where designs are clearly made for a given return period (e.g., 1 in 500 years).

The soil-slab interaction model adopted in the standard has several simplifications regarding the profile of soil movement under a slab and the stiffness of the soil with different moisture content under the slab. These assumptions are critical and have been investigated by Payne and Cameron (2014) and Fardipour (2016). While some modifications have been incorporated in the latest revision of 2870 (2011), some further investigations are necessary to ensure conservatism especially for long slabs.

It should also be noted that the construction assumptions in AS2870 may not be consistent or observed in other related design standards. For example, detailing of connections between roof trusses and internal walls in AS1684 (2010) (Residential timber framed construction) only allow for settlement of trusses but not accommodate edge heave of slabs. Lack of consistency can also be found between AS2870 and AS/NZS3500.2 (Plumbing and

drainage) in relation to service trenches close to slabs.

A corner stone of AS2870 is that site classification is done correctly. Yet, such an important aspect of the design process can be undertaken by personnel who may not have adequate training or accreditation. This can lead to misclassification of sites especially for complex sites and when inadequate soil testing is performed.

2.8 Industry practices

While improvements to design can be made, there are improvements which can be made to construction which can lead to minimisation of damage potential.

Research completed by others suggest that in the subdivision planning and construction, drainage discharge points may be set too high in new developments. This leads to stormwater drainage pipes being too shallow and hence more vulnerable to breakage particularly during landscaping. Leaking from broken pipes leads to abnormal moisture change in soils which may not be noticed by occupants until significant distortion occurs.

Incorrect site preparation and poor construction practices can have detrimental effect on the performance of slabs. Common issues include:

- (I) Ground not sloping away from slab.
- (II) Excessive excavation beyond slab boundaries create passageways for moisture under slab.
- (III) Service trenches not sloped correctly.
- (IV) Service trenches filled with granular materials allowing for build-up of moisture around the slab.
- (V) Lack of plumbing of roof downpipes during construction leading to ponding of rain water around slab.

2.9 Home owners

New home owners do not normally know or are informed of the performance expectations and limitations of standard designs at the time of entering into a building contract. The consumer expectation may be that design in accordance with an Australian Standard is best standard rather than minimum standard.

New home owners are not normally given a choice of slabs with different performance levels. They may only become aware of their responsibility in maintaining moisture condition and limitations on vegetation at the time of handover. If landscaping is not part of the building contract, landscaping performed by owners or other contractors may not be compatible with the slab design.

Information about necessary maintenance and warnings regarding potential additions (e.g., paving with reverse slope and unplumbed pergolas) may not be available to new owners. Further, information about house maintenance may not be on from one owner to another.

2.10 Recommendations

Many of the deficiencies identified in the research particularly in areas related to common public good can be attributed to lack of sustained research which used to be offered by organisations such as CSIRO. Given the critical importance of residential construction to the economy and society, adequate investment in research and development should be made to ensure that individual homeowners have the necessary protections and the industry can continue to advance.

The following recommendations are provided based on the research completed to date.

- Develop and provide targeted educational materials for builders on avoiding common issues which can adversely affect the performance of slabs on reactive soils.
- New home owners should be made aware of design limitations in order that they make informed decisions prior to committing to a building contract.
- At hand over of a new house, new owners should be provided with detailed instructions for maintenance and principles for future works (e.g., landscaping if not part of building contract).
- Review subdivision planning requirements to ensure services are positioned appropriately. Furthermore, where fill is used, over and under compaction is to be avoided.
- Consider minimum qualifications and continuing professional development requirements for personnel performing site classifications.
- Undertake research to confirm contemporary consumer expectations and to recalibrate the cost-benefit model underpinning the minimum design requirements in AS2870.
- Review design demands in AS2870 to ensure that it caters for probable extreme events attributed to climate change. Furthermore, review and refine design assumptions in the standard to ensure optimum designs are produced for modern layouts, materials and construction practices.
- Develop new design models and solutions to cater for higher performing slabs which can cater for greater uncertainties during the design life of houses.
- Ensure compatibility of advice and assumptions in related building standards which are aimed at different trades and professionals.

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