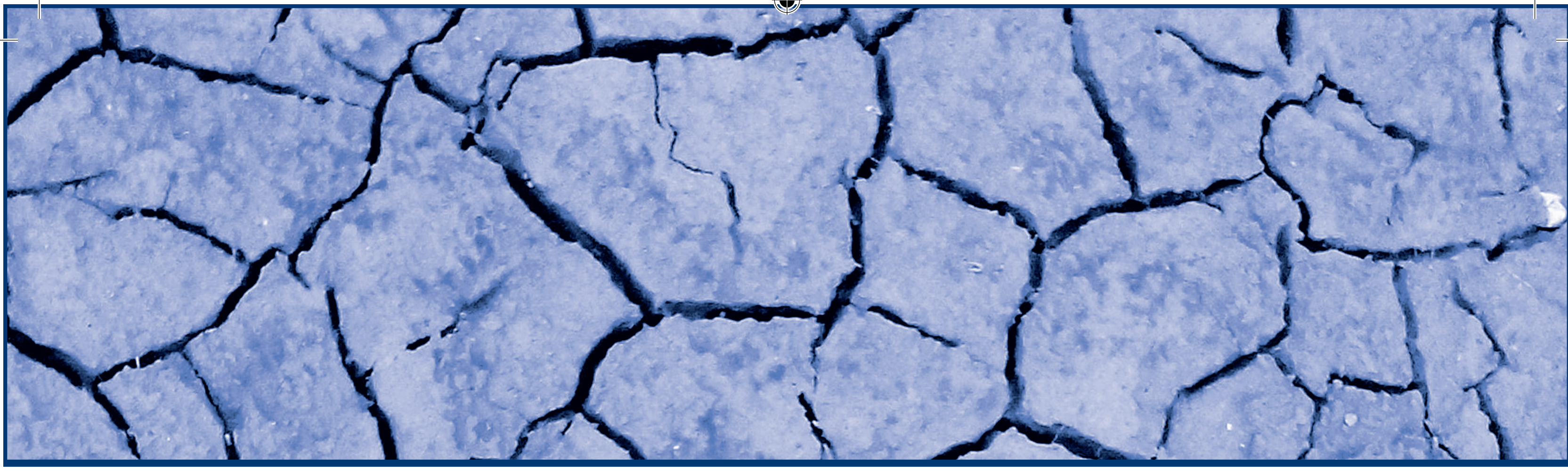
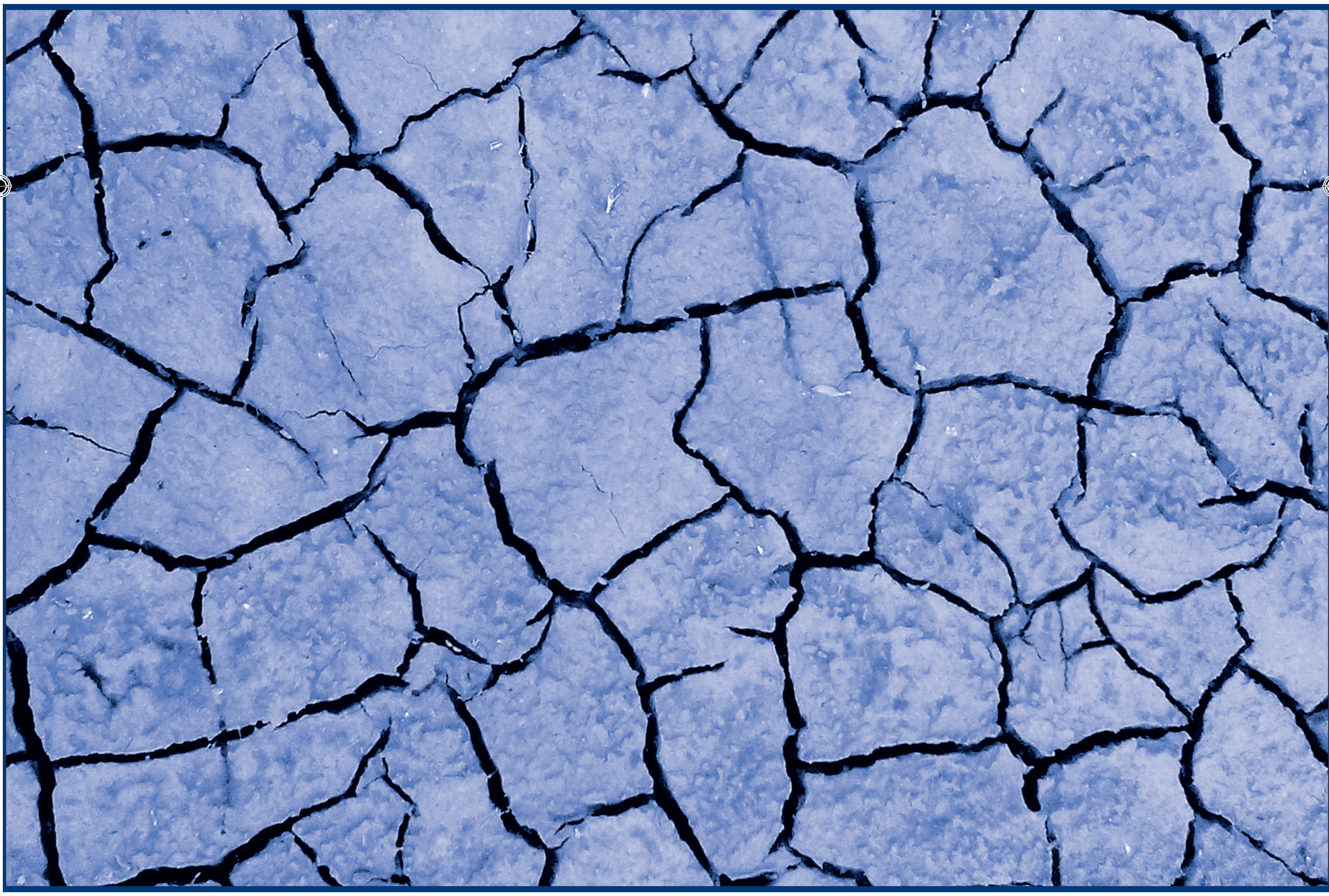


AGS VICTORIA 2017 SYMPOSIUM

Reactive clays and light structures

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

Rydges Hotel, 186 Exhibition Street, Melbourne



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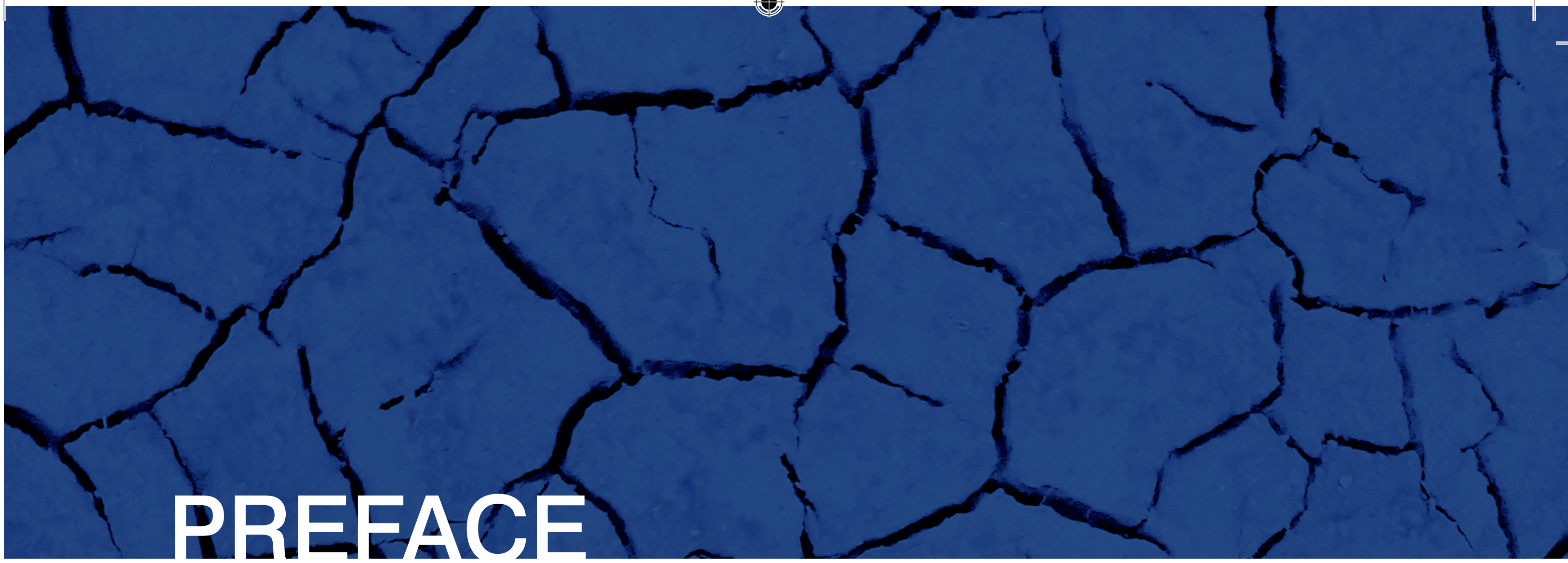

PREFACE

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.

ORGANISING COMMITTEE*

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Clare Bridgeman (Co-chair)

David Glover

Farshid Maghool

Vladimir Lopez Suarez

*a sub-committee of the AGS Victoria committee

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Methods of investigation and repair of light construction on reactive soil not complying with expectations

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ABSTRACT

Following the procedures of Australian Standard AS2870 does not always give correct, concise, or usable answers to determine why buildings fail. In fact, the answers can be misleading. Throughout the evolution of Australian Standard 2870, stump and bearer construction has been eliminated from reactive sites as has hold down screw piles; neither are in the current edition of Australian Standard 2870. Further, there is a lack of literature on the research that went into Australian Standard 2870 (1986) and why there are now beams for H2D sites (i.e. highly reactive) having an I value (uncracked stiffness) 2.7 that of the 1986 edition. Methods of investigation used today include relative level survey via a water level only, photographic record of cracks and distortion, and geotechnical investigations (bore logs) to determine soil moisture, free swell, and consistency index (Atterbergs Limits). This paper recommends, in necessary cases, that plumbing investigations utilising a newly developed methodology be implemented. This methodology has verified that water is flowing from trenches external to the site in close to 100% of the cases where heave was observed. Three example cases are used as points of discussion, including recycled sites, which have problems of abnormal moisture before construction starts, new construction on new subdivisions, and a case where abnormal moisture conditions happened well after construction. Ultimately the method of repair permanently is hold down screw piles retrofitted, or attempt to control moisture variations after the failure methodology has been corrected.

Keywords: abnormal moisture, failure, investigation, adjustable stumps, screw piles, AS2870.

1 INTRODUCTION

This paper is written on the predication that the reader has a knowledge and understanding of the Australian Standard 2870, and the various elements contained within.

Over 40 years of investigation, it has become apparent that AS2870 (2011) has an absence of comment on soils that become excessively wet post-construction, and soils that were excessively wet pre-construction and in turn dry out. Whilst there is a lack of information regarding excessive wetting, AS2870 (2011) does give comment on abnormal moisture conditions generated by trees, providing two methods of analysing tree effect.

Based upon data from the research initiated at Swinburne University, information is now available that surface suctions due to normal conditions can range up to 1.60 in the Western suburbs of Melbourne and that the maximum depth of significant effect is approximately 1.50 m down. This paper suggests that the added soil suction mentioned should be used to amplify the effects of excessive soil moisture contents highlighting the point that reactive soils swell significantly more than that which is predicted by the standard I_{pt} model included in AS2870 (2011).

This paper is limited in its scope in that several key deficiencies of AS2870 (2011) have not been addressed; its incapacity to coincide well with AS3600, its variance to VBA guidelines for deflection, the lack of delegation of the responsible party for site drainage, and specific direction in the engineering design when deemed to comply is invalid.

2 METHODS OF INVESTIGATION

Collation of Available Documents

Review all available documentation related to the project including architectural, engineering, and soil tests. Additionally, 'Dial Before You Dig' data is beneficial to determine all services around the property. Review of Google Earth aerial images going back 20 years (if possible) to pick up dams, roads, trees etc. A review of photographs taken during construction or in previous expert investigations, however, to avoid developing a biased opinion, under no circumstances should the opinions of experts be interpreted prior to reviewing the project.

Soil Profile, Characterisation, and Laboratory Testing

Bore logs and soil samples are taken, typically three per borehole, and tested in the laboratory for moisture content followed by a free swell test. The data is then related from the free swells to previously accumulated information using Atterberg Limits to determine the instability index (I_{pt}) as per AS2870 (2011) Cl.2.3.2 which is derived from the shrinkage index, allowing an identification of the soil reactivity to within +/-20% using AS2870 (2011) 2.3.1. This allows an assessment of whether there are abnormal moisture conditions on the site.

Observation and Assessment of Defects

Levels are measured at every corner of small to medium sized rooms, additional intermediate levels are measured for larger rooms. Only water levels should be used and it is necessary to go back to the base datum at least three times to verify accuracy to +/-2mm.

Photographic surveys are initiated to pick up and keep a record of the site features and external facades noting crack characteristics including location, width and length. This can be assisted with the use of a ruler, tags by back working gaps to widths of perps etc.

Discussions with occupier to get time frame of when the problems started to manifest and where and when such occurred for each defect.

Plumbing and Trench Investigations

Request a plumbing test on-site as follows; a registered plumber should dig beside the service pipes in nominated locations to expose the bottom of the trenches, followed by block flood testing with dyes of different colours in the sewer and the stormwater. In the event of a failure, observe which colour is evident in the trenches. After determining a failure, a CCTV survey can be used to determine where the defect exists, and it can be suitably rectified.

If doubt exists after moisture levels are taken (during borelogs) and the above plumbing test has been implemented, a float device/probe should be installed to determine whether the trenches on site and adjacent are flowing water intermittently. See Figure 1.

In the event that a plumbing failure on-site is not identified, but the trenches are noted as wet, it may be due to an external influence. A sample of the natural soil (trench wall or base) should be taken and laboratory tested for moisture content, assuming a typical clay soil type, a moisture content above 35%±2% indicates there is a probable leak, whereas moisture contents above 40%±2% indicate a certain leak. In the authors experience, on only one occasion have moisture contents been discovered above 40% which were not the result of a plumbing failure.

Identifying if there is a moisture source external to the site may be investigated via a float device/indicator with an infrared motion detection camera as per Figure 1. This device reacts to free water in the trench. Upon conclusive evidence that water exists, the builder/plumber can initiate preventative and corrective measures via an engineered design.

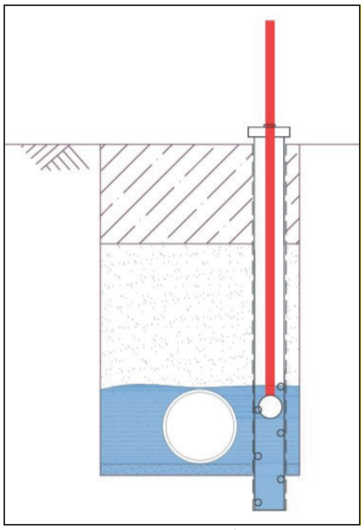

Figure 1. Float device for monitoring water in trenches

3 TYPICAL CAUSES OF EXCESSIVE MOVEMENTS IN NEW CONSTRUCTION ON NEW SUBDIVISIONS

Locality

Case studies are predominantly derived from new subdivisions constructed on highly reactive quaternary basaltic soils only. These locations include regional flat plain areas such as; Sunbury, Werribee and various other areas North and West of Melbourne.

Issue with Bulk Earthworks

Most subdivisions undergo earthworks to achieve design site gradients and maintain a cut/fill balance from filling derived from road and service excavations. This filling is typically used to build up the housing blocks.

Deep filling often results in quite variable compaction even in controlled filled in accordance with AS3798 (2007). Trucks/machinery run over small widths of the subdivision and locally compact the soil to the extent where no air voids remain. Adjacent to these highly compacted zones are areas where compaction is much lower leading to differential movements of the filling over short distances.

AS3798 (2007) sets requirements for filling lots where proposed structures are to be found in filling. The Australian Standard notes that filling is to be placed and compacted under Level 1 inspection and testing, and a certificate of compliance provided for each lot.

The provision of a certificate does not confirm compaction has been undertaken correctly. There is one instance of certificates being written out on a Friday afternoon with little or no supervision on site from Monday through to Friday morning, other than to write the certificates Friday afternoon. However, there were no conjectures to the poor bulk earthworks, rather it was decided to design a screw pile footing system with hold down capacity. Thus there is no need to do further investigations on new sites under suspicion of over/under compaction, instead a suitable footing system can be designed to cater to the abnormal conditions.

Issues with Trenches

In residential house construction there are likely to be many service trenches including but not limited to; sewer, storm water, pressure water, gas, electricity, NBN, etc.

There is nothing in AS3500.2 (2015) or AS3500.3 (2015) that requires the trench to have a gradient, only that you can use up to 150mm of crushed rock to achieve gradient in the pipes [the pipes have fall, the trench may not]. Thus both house sewer and stormwater trenches on very flat blocks possibly connect to the sewer main trench and/or the stormwater main trench, both of which can be full of water for some period of time and have water flowing into the site.

Approximately 20 years ago service main pits incorporated 100mm diameter pipe set below the invert of the main for the purpose of draining any water in the service main trench. This design component was removed to stop both excess storm water discharging to the sewerage treatment plants, and contaminated sewerage water discharging into the bay.

Construction methods force the pits of buried assets to perform as dams and allow for a build-up of water to the top of the pits at which point the water flows overland. However, given enough depth in the pit the dammed water has the potential to flow numerous residential LPOD trenches and beneath the house, permeating the trench walls and locally wetting natural soils.

The dammed back-flowing water will travel the outlet trench, and provided it crosses another service trench, the water has the potential to disperse into that particular trench too, allowing the water to be conveyed around the site. This initiates edge heave, and in some cases the sewer trench travels beneath the building, lifting the slab locally inside. Waffle rafts are particularly vulnerable as they are generally 200mm higher in terms of founding depth than raft slabs.

Typically the reaction is to blame on-site leaks in the sewerage and stormwater system, however, they may not be the culprits. If defects on-site cannot be found, attention needs to be turned to the outlet trenches for water coming from external to the site.

Service trenches holding water for an extended period of time allows for the over-absorption of moisture to the point where a loss of shear capacity occurs. This means the typically adopted angle of repose for dry Quaternary Basaltic soils of 45° can actually reduce to 10° under extreme wetting. Figure 2 shows an exert of Melbourne Water's 'Build Over Guide' which provides good recommendations on placement of footings close to a prolonged wetted trench, however, is at variance to AS2870 (2011), Figure C6.1.

Issues with Site Boundaries

Smaller blocks force designs to become boundary to boundary, and in some cases to the very limit of an easement. In these cases where the footings cannot get horizontal offset from service trenches, the piers should found to a depth greater than that of the trenches of which they are adjacent in accordance with Figure 2.

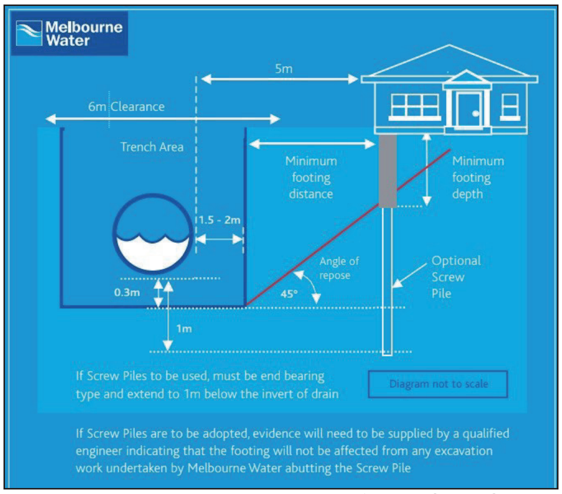

Figure 2. Melbourne Water (n.d) 'Build Over Guide'

Issues with House Construction

Waffle rafts [accounting for more than 90% of construction in the north and western suburbs on new developments] typically have a crushed rock, sand, or similar sub-grade underneath. If the underlying soil is dry and desiccated, with cracks and fissures, this sub-grade material can infill those cracks and fissures amplifying the vertical movement. Furthermore, infilling with granular material facilitates moisture to move more readily beneath the slabs.

Issues with Vegetation

Typically most trees will not affect a structures footings and foundations within the first two to three years post construction. For very early failures and defects, attention should be turned to plumbing failures, poor site filling and compaction, or sub-standard building practices as causations.

Issues with Long Term Sources of Moisture

Two problems occur from excess water from a long-term source; edge heave and weakening of the soil structure to the point where the internal angle of friction reduces substantially and it becomes dispersive, loses bearing capacity, and initiate collapse under piers/footings.

Issues with Unprepared Home Owners

More information and education should be provided to the homeowners as forewarning of potential defects that are likely to occur over the design life of the structure based on allowable defects in accordance with AS2870 (2011) Section 4 - Table 4.1. This is typically absent from documentation.

For example AS2870 (2011) allows for 30mm of movement of a brick veneer construction on a slab. The implication is that the 30mm of movement may occur over only 1.8-2.1m, which will initiate significant cracking. Photographs/sketches to signify what this effect looks like for doors, walls and wall bracing, floor finishes, and plumbing etc. (despite complying with the Australian Standards) should be created to help the homeowner understand compliance with AS2870 (2011) .

4 EXCESSIVE MOVEMENTS DUE TO PRE-EXISTING ABNORMAL MOISTURE CONDITIONS

Background

This scenario typically arises from extensions onto existing structures, and a failure to identify pre-existing abnormal moisture conditions prior to assigning a site classification.

This discussion surrounds various composite case studies from projects in Northcote, Richmond, Williamstown, Seddon, Footscray, and North Melbourne. Investigation of the failure comprised; water levels, at least two bore logs per site, soil testing to determine moisture levels, free swell/ consistency index tests, and photographic surveys. Most were visited more than once over a period of time.

The basic soil profile only comprised Quaternary Basalt clays, with some locations being highly plastic alluvially deposited material. The depth of reactive material exceeds 1.8m in all cases.

Existing Structure

The subject sites are all comprised of weatherboard construction, timber stumps and timber sole plates. The houses consisted of a “lean-to” construction at the rear, with a central corridor connecting four basic rooms towards the front that have been re-stumped on concrete blockers stumps. Down the side of the building exists a concrete driveway with ample grates to pick up surface water.

Extension Details

The works to the property consists of demolishing the rear portion of the building (bathroom, kitchen, laundry, small recreational zone, external concrete paved area and roofed zone with downpipe discharging to the ground) and parts of the landscaping to almost the rear of the site. The pre-existing pervious area of the site was approximately 60%. The new construction now restricts the site to less than 20% pervious, of which is spread across the front and the easement at the rear.

The extension is a raft slab extending to the sewer easement at the rear, locally supported by mass concrete piers (i.e. no hold down reinforcement) supporting a well-articulated brick veneer construction, with the entire system detailed to “H Configuration” as per AS2870 (1996).

Vegetation

Town planning restricts change of the front four rooms, which is located within 4m of the road pavement. Between the house and road exists a wide bitumen footpath, grass nature strip and a row of large plane trees. The trees exceed their height to distance requirements by almost three times the length. The extension towards the rear required the removal of eight large mature fruit trees from the backyard.

Drainage

At the front of the house is a stormwater system that discharges into a bluestone gutter. At the rear of the house exists a very old sewerage system, the easement of which is contained within the property boundary.

Site Classification of Extension

The original soil testing includes a borehole in the front, and one or two in the rear. No moisture levels were measured in any of the bore logs, only tactile assessment had been made. Due to the existing construction at the rear (i.e. paving), no soil investigation was performed adjacent to or under the “wets areas”, boreholes were located in readily accessible areas.

The report classifies the site as a Class P site, typical of a site with existing construction and trees generating abnormal moisture conditions. Thereafter the report defines the site as a Class H with Y_s in the range of 60-70mm.

During Construction Changes to Moisture Conditions

The existing site plumbing system was that of an earthenware material which had long since failed, and had been discharging water into the ground for something in the order of 30 years, creating a high moisture regime to a great depth. During construction no attempt was made to remove or remediate the old plumbing system or correct the moisture regime.

The new construction comprises of properly glued plastic pipes, no water leaks across the site now exist, and it has the ability to dry to depth.

Post Construction Changes to Moisture Conditions

The old leaking “wets area” is now slowly drying out to substantial depth and gradually settling, including the old house that was recently re-levelled.

At the rear of the site, the fruit trees acted as a drying mechanism preventing excess water saturation from the sewer easement. The removal of these trees and construction of a slab in close proximity indicates that moisture in the trench of the sewer gradually seeps in, flows through the crushed rock, and underneath the slab, gently heaving it across the rear. Further the removal of tree roots with a corresponding wet winter can result in recharge and saturation of the site soils, resulting in heave due to climatic effects (as opposed to plumbing).

It was discovered that the house adjacent in one of the subject sites had a leak from the stormwater systems sole discharge point at the front of the property. It is possible that the leaking service was providing a steady supply of moisture to the large trees in the nature strip. The adjoining neighbour eventually discovers the failed storm water pipe and corrects it, terminating the water source for the Council trees. In turn, the trees now consume water from beneath the subject site and neighbouring site.

Damage Observed

The relative levels show the rear has risen to about 80mm, in the middle the junction between the old and the new has settled about 90mm, giving a tilt to slab of 170mm. Stumps at the front of the property are now starting to significantly drop as the nature strip trees consume moisture.

Due to the fact that the old weatherboard house had been re-stumped, re-levelled and re-painted, it did not give the indication of significant movement.

Repair Strategy for the House

Corrections can easily be made to the weatherboard house portion of the house by installing adjustable stumps. The slab at the rear requires underpinning, lifting, and relevelling, with a founding depth of at least 2.5m. It is not possible to lower the slab 80mm that it has heaved across the rear, as it is not possible to lower any form of slab.

The council can install cut-off trenches (root barriers) which do have the capacity to last somewhere in the order of three to five years before the roots go under, however, in the short term the front of the building heaves.

Some Outcomes and Comments

The homeowners engaged lawyers and experts as did all other parties involved. All parties spent significant periods of time in both VCAT and private negotiations to resolve.

The cost to fix, repair and make good exceeded the original cost of construction. The legal cost (unknown who paid) prosecuting on behalf of the property owners was five times the cost to put in screw piles, plus there were legal costs for the other four parties.

The site was already defined as abnormal or Class P, whilst there was no knowledge of the adjacent properties leak or under the “wets area” within the subject site, there was prior knowledge of the type, size and age of trees at both the front and rear.

In accordance with AS2870 (2011) requirements, if abnormal moisture conditions are observed then the degree of abnormality should be established. In this case, no initial moisture conditions were established for the site.

The design solution that would have worked is the same as that which was implemented as part of the repair strategy; screw piles down to a depth of 2.5m below that of all services and below that of major root interference [± 5mm expected movement] Additionally, adjustable stumps should have been retrofitted to the existing portion of the building.

5 CALCULATING CHARACTERISTIC SURFACE MOVEMENTS

An investigation into a distressed building has produced a relevant case study in the area of reactive soils and calculating characteristic surface movements. The existing development comprises of five two-storey units designated Unit A through to E. Each unit has been constructed on a stiffened raft slab with a suspended timber first floor and brick veneer wall system.

Figure 3 presents the degree of differential movement observed in Units A and C. Unit A is quite nominal [22mm ± 2mm]. The front of Unit A had some vegetation and was poorly watered. At the rear was a set of trees, some quite mature and reasonably large. These trees were the same distance from Unit A as they were from Unit C, however, the differential movement in Unit C was 188mm ± 2mm as measured.

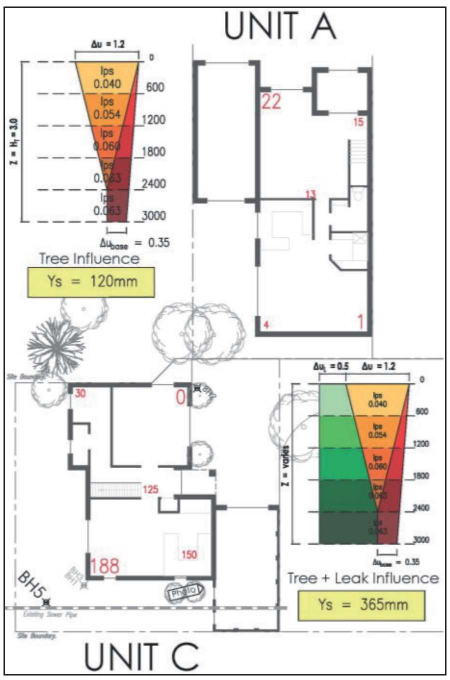

Figure 3. Levels, bore log location, Ys calculation.

Back Analysis of Characteristic Surface Movements (Y_s) - Investigation

Unit A

Using AS2870 (2011) for the calculation of the characteristic surface movement (Y_s) considering the effects of tree influence based on Unit A, if it is assumed that the site started off as wet. It is then assumed that soil is affected by the drying action of the tree, which aggregates the characteristic surface movements to approximately 120mm maximum.

Unit C

A slightly different calculation is required for Unit C. If it is assumed that the corner nearest the trees is affected by the trees from a natural moisture condition and thus the slab experiences local settlement. Unit C at the rear has a major downpipe failure, a very wet sewerage trench and is locally heaving.

The basic methodology is to assume that when the soil becomes saturated or beyond a certain point of wetness, the alpha (α) value becomes 2.0, however, AS2870 (2011) uses α=2.0-0.2(Z), but there is no literature to define how this value is derived, thus the research by Biddle (1998) proves for a more suitable value when amplifying the vertical soil movement. Regardless, for the purpose of these calculations a value of 2.0 is used.

A leak at a depth of over 3.0m was included in the model to represent the sewer line that is located at a depth of at least 3.3m at this location. Additionally, there were two downpipe leaks that were flowing into this sewer trench.

An additional suction value of 0.5 is added to the total change of suction due to the wetness of the soil (as noted in Figure 3, the soil was wet to depth). This has been justified by research undertaken by Swinburne University of Technology, whereby the surface suction increases to 1.60, not limited to 1.20 as per AS2870 (2011).

If we assume that the ground condition of the site was dry (due to the existing trees) the total characteristic surface movement increases to approximately 365mm as a result of the saturated trench.

The reason why the total maximum calculated Y_s can be 112mm in accordance with the design guidelines of AS2870 (2011), however, observed site movement is in the order of 22mm is that the site was very dry to start with (due to tree action, and/or drought) and had little more drying out available

As a consequence of the upper part of the soil profile being very wet, the alpha (α) value, as mentioned, must increase to 2.0 and doesn’t remain as 1.0. Once the soil moisture content increases above 35% (± 2%), the soil can only swell one dimensionally (upwards). No lateral swelling is capable as there are no open voids.

Table 2. Soil data from lab testing of soil samples

Location/Depth	Tin #	M.C %	Free Swell %	Modified Ys
BH4 @ 600	18	34	115	34
BH4 @ 1200	B	33	115	34
BH4 @ 1800	31	52	310	36
BH4 @ 2400	57	44	290	8
				112

If other calculations are adopted in lieu of the method provided in AS2870 (2011), for example those derived by Atchison and Richards (1965) (or similar calculations as derived by Biddle (1998)), the degree of movement observed correlates strongly with the recorded relative level measurements undertaken on site. If the site moisture conditions originally were dry, most of the Y_s movement in Unit C is heave.

Adopting AS2870 (2011) to estimate the characteristic surface movement provides contradicting results to that observed in the field. There has been no ongoing research performed by AS2870 (2011) to verify the alpha (α) value and its relationship to Y_s. A total Y_s from an originally wet site to a dry site (abnormal) is 112mm. However, a total Y_s from an originally dry site transitioning to a wet site (abnormal) is in the order of 365mm (see Figure 3).

A site is unlikely to achieve a total characteristic surface movement of 365mm as very few constructions begin with; an significantly dry site to a depth of ~3.0m, are constructed upon, and then become saturated to a similar depth. The key point is that extreme wetting has a much greater influence on total characteristic surface movements than the effects of extreme drying.

6 AUSTRALIAN STANDARD 2870 (ALL EDITIONS): THE NEGATIVES

Recent research shows that utilising the testing in AS2870 (2011) for the soil instability index (I_{pt}) gives I_{pt} values of 3-6%±0.3% on the same site taking samples at 600mm intervals. A similar Quaternary Basaltic clay sampled from Sunbury, has an I_{pt} of 9%±0.3%. This high variation in input values is not acceptable for a realistic estimation of Y_s.

The "moisture in/moisture out" calculations suggested by both Biddle (1998) and Aitchison & Richards (1965) are more applicable. The consistency index is also more accurate in giving an assessment of moisture content related to dryness and wetness.

Research presented at the ACSEV & FFSV Joint Technical Meeting (August 2017) being undertaken by Swinburne University in the western suburb of Brooklyn indicates that change in suction across the upper soil profile is in the order of 1.6+, and that the effective depth is approximately 1.4m to 1.6m. This is consistent with the suction graphs by Aitchison & Richards (1965). Moisture change below 1.4m to 1.6m appears to be very small (± 1%) irrespective of when the soil is sampled. This is amplified by the fact that alpha must vary in a soil profile.

The assumption that alpha is 1.0 in the upper 1.6m range for basaltic soils is incorrect. It must be less than 1.0 (approximately 0.7) when the soil has a dry moisture regime with desiccation cracks, and can thus expand into them. Equally, at a given moisture regime or soil suction, when all of the cracks are full or closed up, any additional water absorbed on a confined site will result in one dimensional expansion (upward), thus the alpha (α) value needs to be somewhere around 2.3, it may average 1.0 total.

AS2870 (2011) assumes that all filled sites are loose filling sites i.e. why else would bored piers be designed with no belling at the bottom and no method of hold down or tension reinforcement. If is it's in AS2870 (2011) as a means of handling loose/soft filling but it doesn't say "loose" and/or "soft". With modern construction equipment, most sites are either vigorously over compacted and thus alpha (α) value is more likely to be 2.3, or alternatively, the fill is under compacted and the alpha (α) value could be 0.6.

As per Cl.2.3.2 of AS2870 (2011), the alpha (α) value is 2.0 for five years and then on the eve of the sixth year, the alpha (α) value decreases to 1.0. It is commonly known that reactive soils self-consolidate and that is a sequential process that can affect soil for quite some time. To apply a straight line fit for five years and then a straight line fit for the rest of its design life is an over simplification.

Clause 1.3.1(a) of AS2870 (2011) is accurate in that it does not give advice on abnormal sites. Abnormal moisture conditions are likely to apply given;

- The VCAT requirement for a 50 year lifespan for houses and a 20 year design life for plumbing,
- Councils give approval for subdivisions and then plant large trees within 3.0m of small blocks with short setbacks,
- Plumbing failures and construction methodologies that allow water to flow in trenches and keep it there.

Over compaction, under compaction, plumbing failures, and the method by which sewers, stormwater trenches, and pits are detailed with crushed rock beneath them facilitates moisture to move around. This inhibits the deemed to comply designs of Section 3.0 AS2870 (2011) from being ever being functional, as an abnormal condition almost always exists or will exist. AS2870 (2011) is not a functional document and certainly investigations, several of which have been included in this paper, would indicate that.

7 CONCLUSION

When investigating failed buildings, it is usual to see gross movement in excess of the Y_s values calculated using AS2870 (2011). It could be implied from this that AS2870 (2011) is difficult/impossible to apply.

To analyse utilising curvature, bending stresses etc., becomes difficult as the fundamental controlling mechanism within the code does not facilitate analysis using AS3600 (2009), AS1170.1 (2002) or for abnormal moistures.

Over a 50 year house lifespan it is more than possible that every site will become moisture abnormal, the best methodology to guarantee a structure not to move is a hold down pile founded 2.5m to 3.0m.

Bored concrete piles come with the extra friction forces up/down, the requirement to incorporate tensile/hold down reinforcement and a belling at the base for hold down, all of which is costly.

Hold down screw piles eliminate the need for paving, site drainage, articulation joins, heavy and overly reinforced slabs. Screw piles do not restrain shrinkage, and slab lengths greater than 30m without any significant cracking can be achieved if detailed correctly.

Over the past 40 years, methods of investigating have become much more sophisticated incorporating water levels instead of laser or builders levels, extensive photographs, bore logs by hand, moisture level testing, 'dial before you dig', aerial photographs, proper plumbing investigation; all contribute to determining cause and effect in failed construction more accurately.

Ultimately, the end position is the same; if only the structure had been built not needing to know all of that information and that the build could have been completed at a price approximately one fifth the cost of; one party's lawyers/experts fees to 'solve' the problem for (i.e. ignore) the cost to rectify the structure, and the time lost in the legal system.

Full weatherboard construction should not be excluded as a construction methodology as it is proposed in the current edition of AS2870 (2011). In the author's opinion, weatherboard construction with adjustable stumps and adequate sub-floor room should be a preferred construction in highly reactive sites as any effects from trees and/or plumbing failures are readily correctable and economically viable to do, as when a slab moves, it is always costly to fully rectify.

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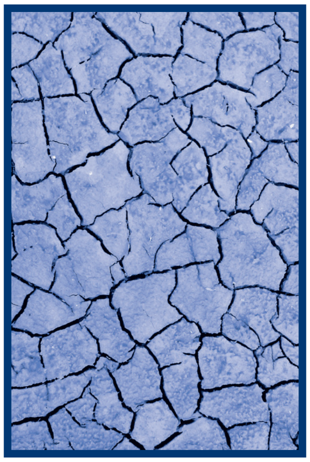
Reactive clays and light structures



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