LADBROKE CHURCH

Comments on Dessication statement in Ground Investigation report by Client and subsequent meeting with Structural Engineer and Architect to how to proceed

PART 1 Client comments of Ground investigation report

Emailed question from client to report author.   How was dessication calculated?

Response

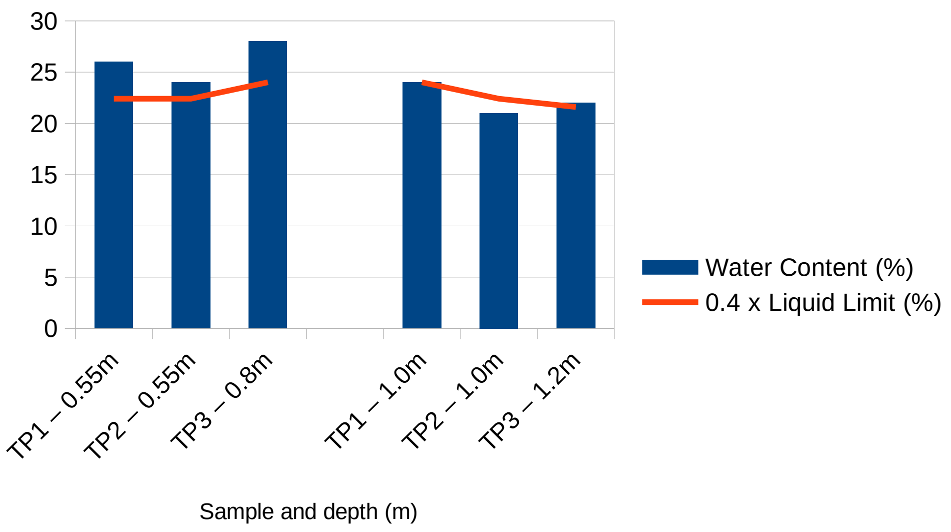
"As regards BRE 412, we only have a hard copy document as it was first issued back in 1996 . Essentially there are many ways to determine desiccation, but this is the simplest most cost effective and a good indicator of the presence of desiccation: Desiccation occurs when the soils water content is 0.4 times the Liquid Limit. If therefore w<0.4wl then the soil is desiccated.

Our conclusions are based entirely on the data presented, TP1 and TP2 were closer to the Yew tree than TP3 hence the 'likely cause' being the Yew tree or any other environmental factor which we are not aware of hitherto. (e.g. other trees in vicinity removed)."

Data from the report with calculation of 0.4x liquid limit

Ref	Depth m	Liquid Limit (W_L) %	Calculation 0.4 x W_L %	Water content (W_C) %
TP1	0.55	56	22.4	26
	1.00	60	24	24
TP2	0.60	56	22.4	24
	1.00	56	22.4	21
TP3	0.80	60	24	28
	1.20	54	21.6	22

Comparison of the water content of each sample with the calculated 0.4x liquid limit



Discussion

1. The amount of experimental error is unknown as there is only a single result for each sample/test.

2. The depths for TP1 and TP2 are the same but TP3 samples are taken at lower levels.

3. The author of the proposal that "0.4 x liquid limit" should be used to define dessication subsequently clarified this was a proposal for discussion rather than an absolute limit. See attached.

4. For the higher level samples, all three had water content results are slightly above the matching value for "0.4 x liquid limit".

5. For the lower level samples, all three were close to the matching value for "0.4x liquid limit", with only sample TP2 below it. Note TP2 was a reference position, close to the tree, by the porch buttress with no evidence of twisting or cracks in the masonry.

6. The samples were taken on 11th November 2022 following a dry spring and summer and wet autumn, with abnormally high temperatures.
Average rainfall in Ladbroke 1 April - 30 Jun = 34mm/month,
1 July – 31 Aug = 14mm/month
1 Sept – 31 Oct = 79mm/month

Conclusion
As a general scientist, I question if the evidence supports the bold items in this statement given in the conclusions of the report:

> "The founding material is a clay classified as medium volume change potential with **desiccation evident in TP1 and TP2 at 1.00m depths** also allied with tree roots which were present to 1.10m depths. The clay stratum in **TP3 was normally hydrated."**

I think it is safer to say that all the lower samples are drier and close to the "0.4 x the liquid limit", considered by some to be the cut off for dessication. However, there is **no** strong evidence of a lower water content nor more dessication for TP1 (the test position) vs TP2 and TP3 (the reference positions) nor between TP1 and TP2 (near the remnant yew/rose) vs TP3 (other end of the aisle).

The higher samples are wetter, which **may** reflect the weather conditions in the preceding months - the ground having become dry over the spring and summer and more recent rain not having rehydrated the lower levels to the same extent.

JW 3.1.23

PART 2 Meeting by Zoom 11.1.23

Present: Jackie West (Ladbroke Church), David Girling (Structural Engineer) , Andrew Salter (Church Architect)

There had been phone conversations and emails between the parties in advance of the meeting which was called decide how to proceed with the current cracks in and stabilise the masonry of the west end of the south aisle.

Structural engineer's comments on report from GIS

As anticipated it has found soft to firm clay below the foundations. This clay has been found to have a medium shrink potential and to be desiccatedat about 1m below ground level in the two trial pits closest to the yew tree. In non-engineering speak, that means the clay has the potential to change its volume when the moisture content changes and in this case the clay has been found to have less water in it than it should i.e. desiccated. The conclusion is that the yew tree is the most likely cause of this desiccation

The good news is the layer of clay below the foundations appears to only be about 600mm thick, before it becomes limestone rock. Limestone isn't impacted by shrinkage and is also quite stable when loaded. By this we mean, if there was only clay below the building, if it was underpinned then the layer clay at the base of the underpinned, which previously hadn't supported the foundation would squash under the weight of the building and there would be a risk of settlement cracking, But with limestone the risk of settlement is minimal.

The recommendation in the GIS report is to either remove the tree, which they acknowledge probably isn't possible, the alternative is to underpin the affected area of the building down to the limestone layer. This will prevent the tree from impacting that area of the church further.

Underpinning doesn't come without its own risk of problems. Underpinning creates a stable area of foundation that is no longer impacted by the tree, but that also means that area of the building becomes 'stiffer' relative to the rest of the building that is still founded on the clay. The result of which can be further cracking appearing elsewhere as the building adjusts itself to its new foundation.

Structural engineer's comments on Jackie's comments

It is nice to see a Client take an active interest in the result of the investigation report. We had also considered whether it was reasonable to point the finger at the tree as the likely cause of the damage. Whilst you are not wrong that potentially the desiccation is a result of the low rainfall and very high temperature this summer drying out the ground to a greater depth than normal and then the subsequent rainfall has yet to rehydrate the soil yet. Could it not also be considered equally likely that the tree is the cause of it? The high temperatures will have stressed the tree causing it to extract more water from the ground. **In fact it is more likely, it is a combination of the two.** We could suggest a year of ground monitoring by GIS to determine what the annual average desiccation condition is, but suspect that would simply be delaying the intervention by a year, whilst incurring further investigation costs.

We must also consider that the damage had already occured to the building prior to this summer's heat wave. So whilst the heat wave may have been a contributing factor to the recorded level of dessications, **it would be reasonable to assume that the historic ground movement that caused the damage, was likely caused by the tree prior to it being very heavily pruned/cut-back**.

Underpinning or resin grouting (if suitable) would mitigate against further movement caused by the ground, whether that movement be caused by trees or the climate.

Unfortunately, there isn't a perfect solution when historic buildings are damaged in this way.

Options

1. Do nothing at all - cracking may remain as it currently is, or through seasonal moisture content variation and tree growth, it could get worse.

> Not appropriate. Water will enter the current cracks and accelerate damage to fabric

2. Remove the tree

> Not appropriate. Although a remnant yew, like all the trees in the church it is covered by a TPO. Removal will not guarantee no future problems as the level of moisture in the clay layer will still fluctuate (*post meeting thought – as roots die will there be more voids?*)

3. Underpin this area, in the knowledge that it may actually cause cracking elsewhere. recent quote for structural engineer was £2500/metre (a significant increase on £1000-£1500 per metre typical pre-pandemic cost).

> Not at this time. Expensive, and may cause problems in other areas.
> Note: there is **slight** cracking inside (in lime plaster or mortar between stones) in several other areas

4. Don't underpin and provide some light touch masonry repairs/pinning and repointing to keep the water out. (The structure engineer confirmed he was NOT proposing Helifix ties or socks within the walls as previously). But similar to option 1, the ground will continue moving so the risk of cracking remains   Consider it as on-going maintenance that periodically the cracks may reopen and require repointing, and a more drastic intervention **may** be needed in future.

Preferred option at this time. The degree of pinning adjacent stones and whether to lime grout voids within the wall should be discussed with masons doing the work. Both pinning and lime grouting voids would make the wall stiffer. The architect had some but structural engineer no experience of lime grouting voids.

5. Injection grouting, whereby a resin is injected into the ground to stabilise the clay and remove the potential for movement. Potentially this would eliminate the need to provide concrete underpinning and could be done to a wider area of the building, which reduces the risk of differential cracking that localised underpinning can cause. One company that does this work is Geobear and would be able to advise if the ground conditions were suitable for this system.

As for option 3

The Geobear system has been used for warehouses, motorways and railways – Jackie wondered how long it would be effective, as ancient churches are on a completely different timescale to these structures – we want them to be standing for another millennium.   On 2 March Geobear have an on-line webinar **"Historic buildings and structural stabilisation with geopolymer injection"**

*Post meeting note T*here is also on 20th January **a webinar "Clay Shrinkage Subsidence - Technical deep dive**
Engineering Vice President of Geobear Andy Lee looks at the technical detail behind geopolymers and the fundamental principles of their use in subsidence cases in clay soil. The session will look at the impact of geopolymers in soils to change the properties and provide a stabilised area beneath structural foundations.

Another consideration
After the current project finishes, improving drainage is one of the next priorities for repairs. Any groundworks (options 3 or 5) should be reconsidered as part of those plans. The ground investigation has provided information for the target depth for such interventions. Underpinning or resin grouting (if suitable) would mitigate against further movement caused by the ground, whether that movement be caused by trees or the climate.

Conclusion & Actions

- Progress option 4, i.e. mason repairs, not helifix ties at this time   **JW, AS** (no structural engineering input required)
- Find out more about Geobear system **AS (& JW for interest)**
- Reconsider underpinning or geopolymer system as part of future drainage works **JW, AS**

JW 18.1.22

The Clay Research Group

The 'Driscoll Rule'

Richard Driscoll clarifies the use of the Atterberg Limits to assess desiccation

In my experience of the commercial investigation of subsidence cases, the so-called 'Driscoll rule'[1] has been widely and often misleadingly used. This 'rule' states that 'significant' desiccation exists if $w < 0.4w_L$ where w is the soil sample moisture content and w_L is the Liquid Limit (w_L and Plastic Limit w_P are Atterberg Limits).

As these quantities are routinely and cheaply provided from soil testing laboratories, the 'rule' may very readily be adopted. However, as explained in Digest 412[2], there are several reasons why the 'rule' may not apply. The 'rule' was written for a speciality symposium-in-print for geotechnical engineers, with the aim of generating interest in and further study of the relationships between w and other soil index values.

The w < 0.4wL criterion was proffered as a crude estimate of the onset of significant desiccation; it suffers from several problems:

- The changes in water content caused by desiccation are often small, especially for the more plastic clays. They may be difficult to detect within the limits of accuracy of determining Atterberg Limits or, indeed, the soil water content. Different techniques for measuring Liquid Limit are allowed in BS 1377 for soil testing; also, variations between different laboratories using the same technique, and between the same laboratory using different techniques, have been reported widely.

- Because w < 0.4wL is entirely empirical, it cannot take account of the differing stress histories to which natural clays have been subjected. Differing stress histories (or degrees of over-consolidation (arising from the removal of over-burden in geological time) may result in two soils in identical states of desiccation (or soil suction), with identical index properties, having different water contents; no criterion based on Atterberg Limits could hope to account for these differences.

- Furthermore, it does not take account of the general decrease in soil water content with depth encountered in most over-consolidated clays.

Clearly therefore, w < 0.4wL should be used only as a rough guide and it is unwise to use an assessment of desiccation solely on this criterion, particularly if desiccation is slight. The 'rule' should be applied with caution and should always be supported by other evidence.

1 Driscoll, R (1983). The influence of vegetation on the swelling and shrinking of clay soils in Britain. Géotechnique, Vol. 33, pp 93–105.

2 BRE (1996). Desiccation in clay soils. Digest 412. CRC Ltd.