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7th February 2014

our ref LD14004
your ref

Mr N D Moulton
Whymark and Moulton
20 North St
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Dear Mr Moulton,

Boundary Wall – Denyer House

Thank you for your recent instruction. This letter constitutes my interpretive report and recommendations relating to the damaged free-standing wall to the north-west boundary of Denyer House.

My advice is made on the basis of our joint inspection of the wall from the Denyer House side on Thursday 30th January 2014 and Bowbuild's site investigation reports dated 31st October and 5th December 2013.

1.0 Description

1.1 The wall appears to be of traditional brick construction and varies in height between 1.9m and 2.4m on the Denyer House side. The ground level on the remote side of the wall is generally higher. Whilst we have not had the opportunity to see the wall from the Grove End Lodge side, we gather from Bowbuild's survey that towards the rear of the site it acts to retain up to approximately 1.3m of soil. There is a mature Ash tree of approximately 20m height immediately beyond the wall close to this position.

1.2 The general topography continues to slope down towards the south with Denyer House standing on level ground cut a short distance into the slope. The edge of this shallow cutting is defined with a second low brick retaining

wall about two metres or so from the left (N) flank wall of Denyer House - see also item 8.0 below.

2.0 Geology and soil conditions

2.1 The geological map of the area indicates London Clay.

2.2 Soils are categorised according to various criteria, one of which is plasticity. Highly plastic soils such as clay are termed as being shrinkable. The volume of shrinkable clay is closely related to its moisture content. The moisture content, and hence volume, of the top metre or so of clay varies seasonally according to weather conditions and the surface rises and falls as a consequence. Shrinkage, as moisture is lost, causes downward settlement (subsidence) and swelling as the clay re-hydrates causes upward expansion (heave). Tree roots extend the depth of moisture variation considerably, sometimes to depths of up to five metres or so. As a tree grows its roots establish a zone of enduring or semi-permanent moisture deficit (sometimes called relative desiccation). Where this zone extends beneath building foundations the associated subsidence can cause structural damage. Damage caused by heave recovery (expansion) following removal of a tree is less common but can be particularly destructive.

2.3 Two trial pits have been dug. The first was on the neighbouring North side of the wall close to the base of the Ash tree. At this position it revealed a cemented rubble foundation with no outstand from the wall at a depth of 1.6m below local ground level - which at this position is about 0.85m above ground level on the Denyer House side. The soil was clay fill throughout. Root growth was found immediately below formation level. A botanical identification on a root sample from trial pit 1 identified it to be Ash.

2.4 A second trail pit was dug on a separate visit against the right hand side of the wall at a position approximately six metres forward of the tree. It revealed what appears to be a traditional concrete strip footing founded at a depth of one metre below local low-side ground level with an outstand of 150mm. The founding subsoil was weathered silty clay. A bore hole was continued in stiff orange-brown clay to a depth of five metres. Laboratory tests showed the clay to be class CV plasticity corresponding with high shrinkage potential as defined by NHBC chapter 4.2. Root growth was encountered to three metres depth.

2.5 The moisture content profile from samples at 0.5m intervals provides a clear indication of a substantial moisture deficit of up to a maximum of 8% to at least three metres depth.

3.0 Damage

3.1 The wall has sustained moderate but distinct crack damage in the vicinity if the ash tree. The pattern of cracking is directly consistent with foundation settlement including a vertical shear crack at the end of the second panel forward of the tree.

4.0 Verticality measurements

4.1 The wall leans to the left toward Denyer house over the entire length of the boundary. The magnitude of lean is generally modest but increases significantly towards its eastern end. Verticality measurements reveal a lean of up to 111mm immediately opposite the tree.

4.2 It is unclear from the survey how thick the wall is, but even at one and a half brick thick (330mm) a lean of this magnitude means that the wall is at, or very close to, its limit of stability. It doubtless derives additional strength from the stiffening piers but we are mindful of the cracked state of the most severely leaning section and the additional destabilising effect of retained soil.

4.3 The stability and safety issue has been addressed by the erection of a scheme of timber shoring over the most severely leaning section of wall. This shoring is under-designed and relies on the shear strength of a very few weak anchor bolts and the lateral resistance of crude timber stakes. The present arrangement is not adequate and further measures are required – see 6.4 below.

5.0 Conclusions

5.1 The damage has been caused by tree root induced clay shrinkage subsidence in all probability coupled with direct mechanical root action.

5.2 Whilst the out of plane lean of the wall has almost certainly been influenced by the lateral pressure of retained soil, the detailed vertically survey also strongly suggests that at least some of the rotational movement has been caused by growth of the tree imposing a direct lateral force on the wall.

5.3 We are able to conclude with confidence that the proximate and ultimate cause is the ash tree.

6.0 Remedial Options

6.1 Whilst the crack damage itself is repairable, the magnitude of distortion means that the 17.5m length of wall between piers 6 and 11 as referenced in Bowbuild's site report demands that it requires either substantial buttressing or demolition and rebuild on new foundations.

6.2 Even if the tree were to be removed, both options would require foundations designed to deal-with or otherwise accommodate a considerable depth of clay desiccation. On balance we doubt the buttressing option would be practical and the best value would be achieved by demolishing and rebuilding. Given the depth and magnitude of desiccation piled foundations would be most economical solution.

6.3 Subject to tree preservation status and conservation constraints, potential savings could be achieved by removing the Ash tree, erecting a temporary hoarding and then monitor ground heave before rebuilding a permanent replacement wall on a 'traditional' shallow foundation. Even given the unpaved adjacent surfacing I have to advise that the considerable depth of desiccation means there would be little prospect of any reasonable hope of sufficient heave recovery for at least three years.

6.4 In the meantime we are of the opinion that the present scheme of light-weight timber shoring does little to improve the factor of safety against collapse. A more robust scheme of shoring could readily be devised and installed, but in the circumstances of our present recommendation for demolition and rebuild we wonder if the more economical solution would be to demolish in the short-term and then erect a temporary boundary fence using Herras panels or similar pending the necessary approvals for procurement and construction of a permanent replacement.

7.0 Budget

7.1 Our initial budget estimate for construction of an appropriate scheme of remedial works [redacted]

8.0 Additional matters

8.1 On our inspection on Thursday 30th January 2014 we also noticed that there is damage to the adjacent and parallel brick retaining wall marking the boundary between the footpath surrounding the perimeter of Denyer House and the grassed embankment leading up to the damaged boundary wall.

8.2 The wall is constructed from what appears to be single brick thick semi-engineering brick with a bull-nosed coping. It is up to approximately 1.4m in height.

8.3 The wall has rotated at its base towards Denyer House by approx. 100mm over its height. There is evidence to suggest that this distortion has existed for some time and a brick pier has been erected which we take to probably be a well matched but non-original remedial measure to help stabilise the wall.

8.4 In essence the retaining wall appears to have been under-designed and incapable of resisting the lateral pressure of retained soil.

8.5 Whilst we have no information as to its thickness and construction, the magnitude of movement is such that the wall is now getting closer to its limit of stability. We doubt there is any disproportionate risk of imminent collapse, but steps should be taken to address the situation sooner rather than later. In

the first instance we recommend a site investigation to establish the profile of the wall and soil conditions immediately behind. These will be an essential prerequisite to designing remedial works.

8.6 At this stage our budget estimate for these works [redacted]

Yours faithfully,

Michael Smith BSC CEng MICE