REPORT ON RETAINING WALL

11B KEBLE HEIGHTS

COLLEGE GROVE

Andrew Laughton

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Contents

1.0 Introduction 1
2.0 Background 2
3.0 Observations 3
4.0 Commentary 4
5.0 Discussions and conclusions 6
Appendices 7

1.0 Introduction

A) This report has been prepared by Mr Stephen Woodhouse of WML Consultants, a company providing professional Civil, Structural and Geotechnical Engineering services. WML Consultants is located at:

First Floor, 62 Wittenoom Street, Bunbury, Western Australia, 6230.

B) The author of this report (Stephen Woodhouse) certifies that he has been provided with a copy of the "Code of Conduct – Expert Witnesses" prior to preparing the experts report. This report complies with the code.

C) Stephen Woodhouse has the following qualifications and experience relevant to this report:

- Bachelor of Engineering Degree with Honours in Civil Engineering.
- Qualified as a Chartered Engineer with the Institution of Structural Engineers (UK) in 1992.
- Chartered Professional Engineer with Engineers Australia.
- Fellow of Engineers Australia.
- Past Chairman of Engineers Australia South West Region 2007-2012.
- On the National Profession Engineers Register for Structural Engineering (NPER No 2085271)
- Registered Engineer Queensland (RPEQ).
- CEO and Director of WML Consultants a company with 30 staff providing Civil, Structural and Geotechnical Engineering services.
- Manager of the Structural Engineering Group within WML Consultants.
- Over thirty years' experience working in the field of Structural Engineering.
- Has a wide experience of working with a range of building types, new build and refurbishment of existing buildings.
- Spent many years carrying out investigations and remedial works on a variety of structures.
- Experienced in the design and construction of retaining walls.

D) Refer to the body of the report and appendices for the material referenced in this report.

E) The report distinguishes between facts and opinions as stated in the text of this report.

J) There are no matters of significance which Stephen Woodhouse has knowledge of that are not contained in this report.

K) The report addresses only items in which the author has technical skills.

L) Refer to the body of the report as to those items where an opinion is stated.

M) There are numerous documents held by Mr Laughton in respect to this issue. I have read through most of those documents for background to the case. For the purposes of this report I rely upon my own observations and the measurements recorded by one of my Graduate Engineers. Where I refer to specific documents by third parties I identify them in the text.

2.0 Background

The retaining wall which is the subject of this report is located on the eastern boundary of the land occupied by 11B Keble Heights and specifically the northern section of that wall where it abuts 14 Trinity Rise.

The retaining wall supports the ground to the eastern side of the lot, with the house and garden of 11B Keble Heights being on the low side of the wall. The wall has been constructed with reconstituted limestone blocks at a date unknown to me. The height originally had a height of approximately 1700mm above ground level.

I first attended the site in or about August 2014 at the request of Mr Andrew Laughton to view the collapse fence panel and the damaged retaining wall on the eastern boundary. Subsequent to that visit I was instructed to design a remedial repair method for the retaining wall. This was undertaken by myself at WML Consultants. Two schemes were prepared, one extending the height of the wall to take into account the additional soil that had been placed behind the wall and a second option maintaining the original height of the wall. The second option would have necessitated the removal of the soil behind the fence that caused the fence to collapse, at least to angle that the sand would remain stable.

I also attended the site on the 12th February 2016 in order to prepare this report.

In this report I have been asked to comment upon :

- The suitability and effect upon the fence of the 700mm of soil that the fence retained.
- The effect upon the reconstituted limestone retaining wall of the additional 700mm of soil.
- The effects that construction vehicle may have upon a retaining wall and fence.
- The likelihood that the additional 700mm of soil contributed to the failure of the fence and damage to the retaining wall.

3.0 Observations

On my first visit I observed the following:

- A "SuperSix" fibre cement fence had collapsed to the northern end of the eastern boundary of 11B Keble Heights. The area of the collapsed fence approximately aligned with the boundary to 14 Trinity Rise.
- I was of the opinion that the fence had collapse due to the 700mm build-up of soil behind the fence on the land of 14 Trinity Rise. Fences are not designed to support soil like a retaining wall and fences frequently fail as result of such activities such as was observed.
- I observed a number cracks to the reconstituted limestone wall particularly close to the boundary with 12 Trinity Rise which is the northern neighbour to 11B Keble Heights.
- I observed the retaining wall had a pronounced curve and lean towards 11B Keble Heights.
- I observed that an immature tree was secured to the retaining wall via an 'eye' bolt.
- I observed that further to the south where 15 Keble Heights is the neighbouring eastern property the retaining wall had a small lean towards 11B Keble Heights and had been strengthened at some time I the past with reconstituted limestone piers.

On my second visit I observed the following:

- The tree had been removed.
- Remedial works to the retaining wall in accordance with my design had commenced but were not complete. The retaining wall was suitably propped to prevent further movement.
- The soil level remained approximately 700mm above the height of the retaining wall but sloped down to the retaining wall at an angle of 32°. That angle is the Nature Angle of Repose of the sand, that is the angle at which the sand will remain stable. If the angle exceeds 32° then it will slump until 32° is achieved. A slope of 2 horizontally and 1 vertically is approximately 32°.
- I observed that the cracks to the wall appeared to have enlarged since my previous visit. I did not take measurement of the cracks during my first visit so my observations are based upon memory and comparison of photographs.
- I instructed one of my Graduate Engineers to carry out probing and testing to the rear of the retaining wall. He encountered backing blocks at a depth of 600mm behind the wall which is in contradiction to the "Structerre" report dated 6 November 2012 which suggests the backing blocks were 1000mm down. The penetrometer tests revealed the sand to be loose to medium dense. The location of the backing blocks at a depth of 600mm approximately equates to two blocks deep. Until the introduction of the AS 4678 in 2002 it was standard practice to commence backing blocks two courses down from the top. This allowed 'dug in' fences such as "SuperSix" to be located behind the upper two blocks which required 600mm embedment for stability. The backing blocks were found to be 550mm wide giving an overall width of 800mm. This indicates a wall that does not conform to current design requirements but was not uncommon in the early 1990's.
- I observed that between the driveway of 14 Trinity Rise and the garden of 12 Trinity Rise there is a limestone block retaining wall with a similar top level as that of 11B Keble Heights and that to the rear of it on the 14 Trinity Rise side of the common boundary was a further retaining wall made from precast concrete posts and panels added at a later date. It would appear that the block retaining walls for 11B Keble Heights and 12 Trinity Rise had similar levels to the top of the original walls and the later construction of the precast concrete post and panel retaining wall raised the garden level in 14 Trinity Rise for the length adjacent to 12 Trinity Rise but that that post and panel retaining wall was not continued through to the common boundary between 11B Keble Heights and 14 Trinity Rise.

4.0 Commentary

Load onto the retaining wall from soil

The load applied to a retaining wall is proportional to the height of the soil retained by the wall. The soil imposes a horizontal force on the wall which tries to cause the wall to overturn.

Condition	Height of soil	Horizontal Soil Pressure at base of wall	Overturning moment induced
Original Wall	1700mm	10.1 kPa	4.86 kNm
Additional 700mm of soil behind fence	2400mm	14.25 kPa	13.67 kNm

It can be seen from the above that the soil pressure increases by over 40% due to the additional depth of soil applied. Of greater importance is that the overturning to the wall increases by 281%. It is apparent that the additional sand placed behind the fence resulted a substantial increase in the forces acting upon the wall.

Load onto the retaining wall from vehicles

During the construction of the retaining walls at 14 Trinity Rise construction plant/vehicles such "Bobcats" would have been used to transport and place the large reconstituted limestone block used to form the retaining wall. Due to the proximity of the construction to the retaining wall and fence of 11B Keble Heights it is inevitable that the vehicle would have travelled close enough to apply loads onto the retaining wall and the fence. Taking a typical "Bobcat" with a Gross Vehicle Weight of 2.5 tonnes (2500kg) carrying a block weighing 200kg. Each front wheel would impart a load of 840kg onto the ground (using a 40/60 axle load spilt). Using similar equations to those used in the table above and by converting the wheel load into an equivalent soil load I have calculated :

Condition	Horizontal pressure at base due to vehicle	Overturning moment induced
Fence at top of wall no vehicle load	4.1 kPa or kN/m2	0.33 kNm
Fence at top of wall location with vehicle	2.73 kPa	0.22 kNm
Combined Load at base of fence from soil and vehicle	6.83 kPa	1.51 kNm
At base of retaining wall	19.98 kPa	23.06 kNm

Note - that the pressure increase with depth is linear so that the combination of pressures are additive, the overturning moment equation is an exponential so the combined overturning is not additive but based upon one component being 'squared'. Note also that kPa (Kilo Pascals) can also be written as kN/m2 (Kilo Newtons per square metre).

It can be seen from the above that the additional short term load due to any vehicle driving close to the wall greatly increases the overturning forces on the retaining wall. Although these forces are transient and short term they can be sufficient to cause damage.

In addition the table shows the effect the sand and vehicles have upon the fence itself. The fence is not designed to act as a retaining structure.

Load onto the retaining wall from the recently constructed retaining walls in 14 Trinity Rise

The recently constructed retaining walls located at 14 Trinity Rise are positioned in a position and with a depth of base that will apply a small horizontal load onto the retaining wall at 11B Keble Heights using the natural angle of the sand as a guide. This load is unlikely to be significant. It does indicate that the base of the wall is higher than it should have been, both from a load spread and the assumed level of the ground after construction of the wall at 11B Keble Heights. I observed that the base of the southern neighbouring retaining wall at 15 Keble Heights is some 500mm lower than the wall at 14 Trinity Rise. The level of the base of the neighbours' wall would be considered acceptable. The sketch in the appendix shows the relationship between the retaining walls and soil height.

Fixing for Tree

There was at one time a small tree secured to the retaining wall by an 'eye' bolt. The tree was an immature specimen and has now been removed. I observed the tree in or about August 2014.

The canopy of the tree was not large, I estimate the canopy to be no larger than 2.5 diameter. This equates to an area of approximately 5 m2. The tree was located in a shielded location, being between the house and eastern wall/fence. The north side was shielded by the neighbouring property at 12 Trinity Rise and the south side by the garage of 11B Keble Heights. A tree canopy is not a solid sail area and typically a porosity value is used to derive wind loads. The Avocado tree had an open canopy so I have applied a porosity of 50%, a shielding value of 50 % due its sheltered location and simplified area wind load on 1kPa which is typical for the region for a substantial storm event (a substantial design storm event can be expected once every 500 years, which did not occur during the life of the tree).

The wind load on the tree can be approximated as 5 x 1 x 0.5 x 0.5 = 1.25 kN. This is a relatively small load equal to a force of 127 kg and would be distributed over several metres of the wall. The overturning moment would be 2.125 kNm over at least two metres of wall, a result of 1.06 kNm at a distance of approximately 2.4m from the crack. I am of the opinion that the wind load from the tree had no significant effect on the wall. The cracking observed to the wall was not in the vicinity of the 'eye' bolt where any load would have been transferred to the wall. The cracks observed were several metres from the location of the 'eye' bolt. By comparison with the loads and forces due to the soil any force on the wall from the tree wind load is not significant and unlikely to be a contributing factor on the wall cracking.

5.0 Discussions and conclusions

It is not within my remit to speculate upon the history of the issues that have arisen in relation to the damage to the retaining wall and fence. I have formed some opinions with regard to the retaining wall and undertaken calculations to demonstrate the significant effect that, what may be perceived as small, changes can have on the loads applied to the retaining walls.

The following points are opinions I have formed :

- It is unlikely that the wall to 11B Keble Heights was built lower than it should have been. It was most likely built to the pre-existing slope. I am of the opinion that as one of the earlier homes developed in the sub-division the builder/owner had an opportunity to minimise the cost of the build by keeping the wall to its minimum viable height.
- The property 14 Trinity Rise was built after its neighbours at 16 Trinity Rise, 12 Trinity Rise and 11B Keble Heights as it is a requirement of the latter building works to take into consideration the surrounding buildings and structures. The property 15 Keble Heights appears to have been the most recent house to have been constructed in the vicinity, however its retaining wall which predates those at 14 Trinity Rise, is set at a lower level so as not to surcharge the wall to 11B Keble Heights. The retaining walls at 14 Trinity Rise do not appear to take into consideration the proximity of the neighbouring walls.
- The cost of the retaining walls built at 14 Trinity Rise was minimised by constructing the base level where it currently is. To construct at the most appropriate level would have required two addition courses of block, equating to 8 additional blocks per metre. Refer to the sketch in the appendix.

The following statements are based upon engineering judgement and observations :

- A fence does not have the structural capacity to act as a retaining wall. The 700mm of sand would have caused the fence to fail. The load from the vehicles during the construction phase may have hastened the failure.
- The additional height of soil has significantly increased the overturning moments to the retaining wall. I am unaware of when the cracking to the wall first occurred, however the increased loading to the wall with the additional 700mm of soil could have been the cause or major contributor to the damage seen. The vehicle loading may also be a contributor.

Appendices

Sketch