STABILITY OF A HISTORIC LEANING CHURCH WALL

G2

Jian Hao Chan Supervised by Dr J. Standing

Geotechnics Section, Department of Civil and Environmental Engineering, Imperial College London

INTRODUCTION

Leaning walls are quite common in UK, but few are actively monitored. Movement of a leaning wall frequently goes unnoticed until a severe level is reached, when the wall is at risk of collapse. This study focusses on a historic church boundary wall in Rainham, Essex which shows clear signs of leaning and ongoing movement. Potential causes of wall lean were assessed and thermal expansion of a curved section identified as the primary cause. Geometrical modelling was used to predict this expansion.

MONITORING SETUP

The Rainham wall rotates about its base, thus it is a rigid-body movement, and translational movements are likely to be small. The wall lean i.e. tilt is measured by positioning an inclinometer stick on monitoring points installed on the wall.

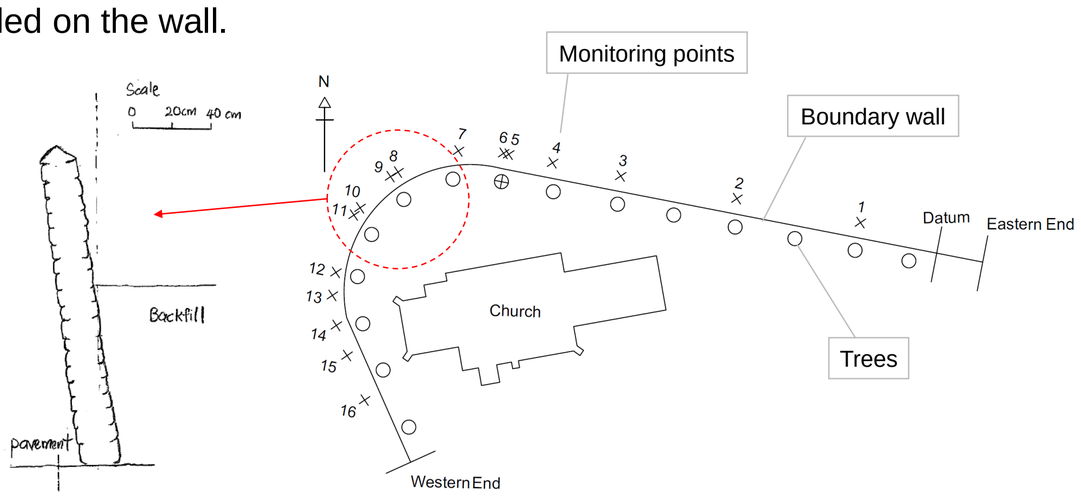

Figure 1: Wall cross-section showing rigid body movement

Figure 2: Monitoring locations on the wall.

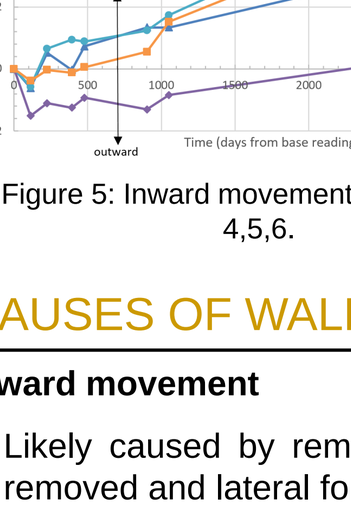

Figure 3: Taking a tilt measurement with inclinometer.

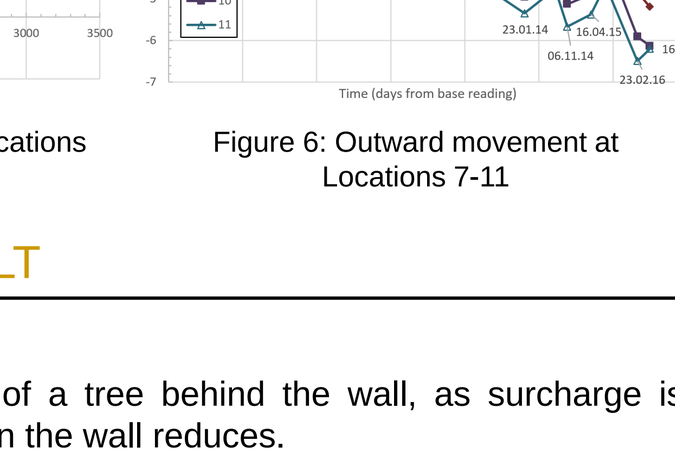

Figure 4: Initial wall tilt (measured on 26.6.07).

MONITORING RESULTS

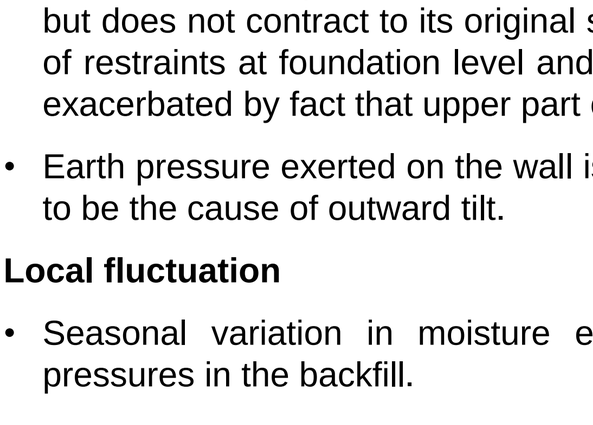

Figure 5: Inward movement at Locations 4,5,6.

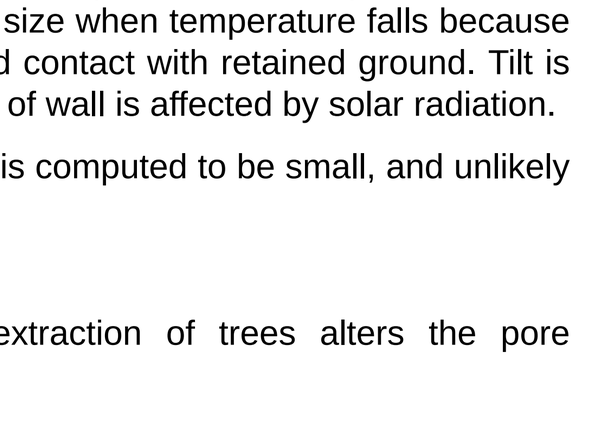

Figure 6: Outward movement at Locations 7-11

CAUSES OF WALL TILT

Inward movement

- Likely caused by removal of a tree behind the wall, as surcharge is removed and lateral force on the wall reduces.

Outward movement

- Likely caused by a combination of cyclic moisture and thermal effects, which are *not* fully reversible. The wall expands when temperature rises, but does not contract to its original size when temperature falls because of restraints at foundation level and contact with retained ground. Tilt is exacerbated by fact that upper part of wall is affected by solar radiation.
- Earth pressure exerted on the wall is computed to be small, and unlikely to be the cause of outward tilt.

Local fluctuation

- Seasonal variation in moisture extraction of trees alters the pore pressures in the backfill.

BROMPTON ORATORY BOUNDARY WALL

Another leaning curved boundary wall at Brompton Oratory was identified and measurements provide additional validation to the hypotheses.

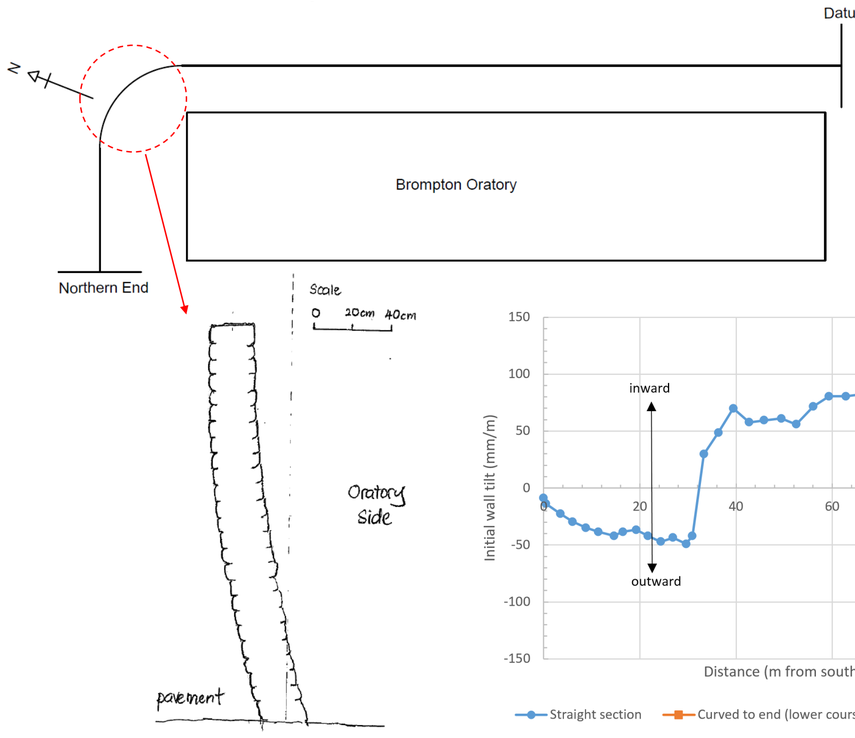

Figure 7: Layout of the Oratory boundary wall.

Figure 8: Wall cross-section showing distortion.

Figure 9: Oratory boundary wall tilt.

GEOMETRICAL MODELLING

The curved section of the Rainham wall is modelled as a hyperbola. Using measured tilt readings as input, the wall is 'stretched' and elongation of the wall computed. The Oratory wall was also modelled but using a quadrant.

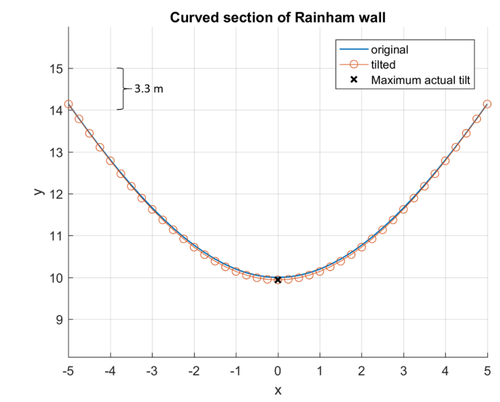

Figure 10: Model of wall's curved section.

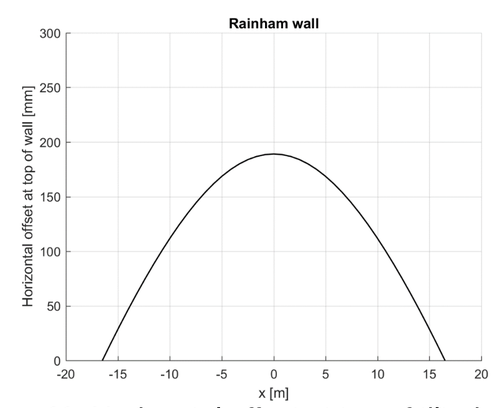

Figure 11: Horizontal offset at top of tilted wall.

MODELLING RESULTS

	Rainham wall	Oratory wall
Total length (m)	105	125
Age (years)	170	130
Temperature difference, Δt (°C)	19	19
Thermal expansion per year (mm)	13	15.4
Thermal expansion cumulative (mm)	2205	2007
Model-predicted expansion (mm)	261	245
Ratio of model expansion to thermal expansion cumulative (**entire wall length**)	0.104	0.103
Ratio of model expansion to thermal expansion cumulative (**curved section only**)	0.814	0.999

For both walls, expansion predicted by the model for the curved section of the wall is roughly equivalent to the cumulative annual thermal expansion.

REMEDIAL ACTIONS

Remedial actions include using duckbill anchors or a combination of anchors and steel walers to tie the tilting wall back. Introducing movement joints is viable as the main driver of tilt is thermal expansion. Rebuilding the wall remains an option, but could be prohibitively expensive.

CONCLUSIONS

- Outward tilt of the wall is primarily driven by thermal expansion of the curved section itself.
- For unmonitored walls, it may be possible to estimate wall tilt using the geometrical model, based on the input of wall age, shape, length and surrounding temperatures. Tilt monitoring data from other walls with curved sections are needed to further validate results from the geometrical model.
- The inclinometer is a simple yet effective method for tilt monitoring.

ACKNOWLEDGEMENTS

I would like to express my gratitude to my project supervisor Dr Jamie Standing, for his continued guidance and support throughout the project.