THiSolutions Ltd

Structural Inspection Report

Distortion of Estate Wall
Bretton Lodge
1, Park Lane
West Bretton
WF4 4JT

Client: Mr. David Woodhead

Date: 29th April 2022

TSI 22115

THiSolutions Ltd			Document Verification	
Distortion of Estate Wall, Bretton Lodge, WF4 4JT			Job no.	22115

Revision	Date	Filename			
P1	29/04/2022	Description	First Issue		
			Prepared by	Checked by	Approved by
		Name	Tristram Hope	Tristram Hope	Tristram Hope
		Initials	TH	TH	TH

Revision	Date	Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Initials			

Revision	Date	Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Initials			

Revision	Date	Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Initials			

Contents

Appendices

1.0 Client

1.1 Mr David Woodhead
Bretton Lodge
1, Park Lane
West Bretton
WF4 4JT

2.0 Structure inspected

2.1 The estate wall to the east of the main property,

3.0 Date inspected

3.1 12th April 2022.

4.0 Terms of reference

4.1 To assess and comment upon the likely causes of the northward lean that is present in the estate wall, immediately adjacent to the main Grade II Listed residential property at Bretton Lodge.

5.0 Limitations

5.1 The investigation is generally confined to the agreed terms of reference. This report does not constitute a full structural investigation or assessment of the property as a whole.

5.2 We have not inspected parts of the structure which are covered, unexposed or inaccessible and we are therefore unable to report that any such parts of the structure are free from defect.

6.0 Brief description

6.1 The estate wall is located immediately to the east of the Grade II listed residential property at Bretton Lodge. The Historic England Listing Number for Bretton Lodge is 1184768, and the approx. National Grid location of the wall is SE 28753 13532.

6.2 The wall is understood to have been constructed in the late 1700s, at the same time as the adjacent main residential property.

6.3 For the purposes of orientation when reading this report, the wall runs in an east-west direction, with the gravel approach driveway to the north, the greenhouse and potting shed to its eastern end, the paved courtyard garden and open countryside to the south, and the main property at Bretton Lodge to its western end.

6.4 Reference should be made to the photographs included in Appendix A1 and to the structural calculation sheets included in Appendix A2 of this report.

7.0 Observations

7.1 General construction details

7.1.1 The wall appears to be built of hand-made clay brick construction, bedded in a soft lime ash mortar. In most locations, it is 1 ½ bricks (approx. 350mm) thick.

7.1.2 The wall extends over a length of approx. 20m, has a step in its top edge approx. half way along its length, and stands between approx. 4m and 4.5m high above the adjacent ground levels. (Photo A1.1).

7.1.3 The wall is capped by sandstone coping slabs.

7.1.4 The depth, nature and bearing strata of the foundations to the wall were not investigated directly, however reference was made to the online BGS Geology of Britain Viewer, which indicated that the local geology comprises shallow, weathered sandstone over Middle Coal Measure Sandstones and Mudstones.

7.2 Distortion of the wall

7.2.1 The wall has a pronounced lean to the north, and in the worst location is estimated visually to be approx. 600mm out of plumb. (Photo A1.2).

7.2.2 The top edge of the wall has distorted accordingly into a smooth curve over approx. three quarters of its length. (Photo A1.3).

7.3 Condition

7.3.1 There are widespread signs of freeze / thaw damage and saturation-related decay to the brickwork. The decay was noted generally to be worse on the northern (shaded / damper) side of the wall. (Photo A1.4).

7.3.2 Erosion of the pointing and mortar is visible to both sides of the wall, though this was noted generally to be worse on the northern (shaded / damper) side.

7.3.3 There has been no visible disruption to the sandstone copings at the head of the wall.

7.3.4 There are no visible signs of impact or abrasion to the south face of the wall. (Photo A1.5).

7.4 Previous openings

7.4.1 The wall appears previously to have been penetrated by two semi-circular arched pedestrian access openings, and by a single cyclical-arched carriage access opening.

7.4.2 The crown of the cyclic arch was noted to have undergone historical settlement, and is disrupted by approx. 30mm at mid-span.

7.4.3 The sandstone coping directly above the arch disruption was noted to slope downward by approx. 30mm to the east, corresponding to the degree of disruption in the brickwork below.

7.4.4 The northern face of the wall above the cyclic arch was noted to have separated from the main body of the wall by approx. 25mm towards mid-span.

7.4.5 Infill walls approx. 230mm thick have been built within all three arched openings. The brickwork appears to be of a comparable age and quality to the adjacent wall, and is thought to have been provided to offer support to the disrupted arch, and possibly to provide additional in-plane thrust resistance along the line of the wall.

7.4.6 The infill brickwork runs flush with the south face of the wall and is recessed by approx. 120mm to the north face.

7.5 Planting

7.5.1 A sub-mature Magnolia tree was noted to be present to the south side of the wall, at a distance of approx. 2m from the gable of the adjacent main residential property.

7.5.2 It was noted that a semi-mature Magnolia tree had previously stood at a distance of approx. 3m to the south side of the wall, approx.12m from its western end. The tree is understood to have been removed in December 2021, when alteration work was carried out to the adjacent courtyard garden area.

7.5.3 Several low-level shrubs were noted to be present in the planted bed to the north side of the wall.

7.6 Winter Storms, February 2022

7.6.1 It is noted by way of record that the weather during the week from 13th to 19th February 2022 was particularly bad, with the severe impact of two Met. Office named storms, Dudley and Eunice, being felt across this part of the UK.

7.6.2 Wind speeds of around 80mph, or 22 m/s, were recorded in the area, corresponding very closely to the maximum anticipated site wind speed proposed in BS6399 pt.2, Code of Practice for Wind Loads, as used in structural engineering calculations.

7.6.3 The storms caused significant damage and disruption across the UK, including damage to buildings and the loss of many trees.

7.6.4 This was the case in the vicinity of Bretton Lodge, where several trees were either snapped off, or were uprooted, though fortunately, none of them landed on the buildings themselves, or on the estate wall described in this report. (Photos A1.6, A1.7, A1.8).

8.0 Discussion

8.1 Structural stability of the wall.

8.1.1 Structural calculations have been produced to assess the likely strength and overall stability of the estate wall, and its ability to resist severe wind loading. (See Appendix A2).

8.1.2 The calculations show that in theory, the wall should not have sufficient strength to withstand the maximum applicable wind loading, which is a matter of some concern. Nevertheless, the wall has remained standing, though in a distorted condition.

8.1.3 It is thought that this is either because the winds did not actually reach peak values in the immediate area, the adjacent buildings and trees provided some degree of shelter from the prevailing winds, or that secondary effects within the wall build-up (comparatively weak bricks, soft, pliable lime mortar) allowed the absorption and dissipation of energy internally. It is probable that all three of these effects played a contributory role in enabling the wall to survive.

8.2 Causes of the distortion

8.2.1 It would not appear that tree branch impact has played a part in causing the wall to lean, as there are no signs of localised damage or abrasion to the south face of the brickwork, or of shifting of the sandstone lintels at the head of the wall, as might be expected.

8.2.2 Moreover, the even, curved shape of the distorted wall would suggest that a more longitudinally distributed, progressive load has been applied, such as would be the case due to lateral wind loading.

8.2.3 The lean of the wall has also reached a point where the vertical line of thrust through the wall's centre of mass lies well outside the middle third of its width. Indeed, in places, the line of thrust would appear to lie outside the northern face of the wall altogether.

8.2.4 The implication of this is that in order for stability to be maintained, tensile stresses will be being induced in the southern face of the wall. Brickwork has a very low capacity to resist tensile stress, and the structural calculations indicate that the applied stress may be between two and three times greater than the resistance that would typically be expected.

8.2.5 It is therefore clear that unquantifiable but beneficial secondary effects are helping to keep the wall standing. However, it should not be presumed that those effects will remain active indefinitely, as the soft mortar within the brickwork and the ground beneath the foundations could be expected to yield gradually under excess stress, and this would eventually lead to the collapse of the wall.

8.2.6 It is therefore considered essential that the area to the north side of the wall should be cordoned off to prevent local access, and that temporary shoring measures should be considered, in order to ensure the stability of the wall in the short term.

8.3 Remedial options

8.3.1 It is understood that the wall was substantially plumb prior to the February 2022 storms, so it is possible that some tilting of the foundations to the wall may have occurred as a result of the overstress brought about by the lateral loading. If this is the case, then it would suggest that the problem is now deep-seated, and that dismantling and re-building of the wall are likely to be unavoidable.

8.3.2 Given that the adjacent property at Bretton Lodge is listed, it is assumed that any remedial work to the wall should either be 'in kind', using similar materials and construction techniques to the existing, or at least be of a similar visual appearance. This matter should be discussed in detail with representatives of Historic England, prior to the implementation of remedial works.

8.3.3 The calculations indicate that a wall of the same thickness to the existing, and using similar materials, could not be expected to carry anticipated wind loadings. A change in technical approach will therefore be necessary, and this is likely to involve either the provision of some form of internal reinforcement, or the application of some degree of vertical pre-compressive force, in order to overcome any tensile forces that would be created under lateral loading conditions.

8.3.4 The last two sheets of the structural calculations explore the possibility of re-building the wall from new, salvaging as many of the existing bricks as possible to provide two outer faces of similar visual appearance to the existing, and filling the gap in between with concrete, incorporating a central layer of steel mesh reinforcement.

8.3.5 If desired, this approach could be also used to enable the recreation of the original arched openings that are visible in the north face of the wall.

9.0 Conclusions and recommendations

9.1 The most probable cause of the damage is considered to be strong differential wind pressure occurring across the wall. Suitable conditions for this situation to arise would have occurred during the severe storms of February 2022.

9.2 The area to the north side of the wall should be cordoned off to prevent local access, and temporary shoring measures should be considered to ensure the stability of the wall in the short term.

9.3 It has been demonstrated by calculation that the wall does not have sufficient capacity to resist anticipated wind loading, unless some form of strengthening reinforcement is introduced.

9.4 The lean of the wall has reached a point where the vertical line of thrust through the wall's centre of mass lies well outside the middle third of its width. The implication of

this is that tensile stresses will be being induced in the southern face of the wall, which the wall may not be able to resist.

9.5 It is possible that further, gradual deformation will occur, and therefore it should not be presumed that the wall will remain stable indefinitely.

9.6 It is recommended that permission should be sought from Historic England to dismantle the wall carefully, salvaging as many of the original bricks as possible, and to reconstruct the wall as a reinforced masonry wall of substantially similar visual appearance.

Signed: Date: 29th April 2022

Director

Thisolutions Ltd

Appendix A1:

Photographs

Photo A1.1 : The wall as viewed from the north-east.

Photo A1.2 : The wall has a pronounced lean of up to approx. 600mm to the north.

Photo A1.3 : The head of the wall has distorted into a smooth curve over approx. three quarters of its length.

Photo A1.4 : There are widespread signs of erosion to the brickwork.

Photo A1.5 : There are no signs of physical impact or abrasion to the south face of the wall.

Photo A1.6 : View across the open land to the south and west of the estate wall at Bretton Lodge, showing tree damage caused by Storms Dudley and Eunice, February 2022.

Photo A1.7 : Cypress trees felled by Storm Eunice, February 2022.

Photo A1.8 : Close-up of tree trunks at Bretton Lodge, split by Storm Eunice.

Appendix A2:

Structural Calculation Sheets

THiSolutions Ltd

Structural Calculations

The Estate Wall
Bretton Lodge
1, Park Lane,
West Bretton
WF4 4JT

For Client

Mr. David Woodhead

Date

29th April 2022

Project Reference

TSI 22115

THiSolutions Ltd
Director: Tristram E J Hope MEng CEng FIStructE MICE email: tristram.hope@thisolutionsltd.co.uk
UK Company Reg. 7048422 UK VAT Reg. 150 7740 21

THiSolutions Ltd	Contract BRETTON LODGE			Job ref. 22115
	Part of structure DAMAGED GARDEN WALL			Calc. sheet no. 00
	Drawing ref.	Calcs by TH	Checked by	Date 04/22
Ref.	CALCULATIONS			OUTPUT

INDEX

THiSolutions Ltd	Contract BRETTON LODGE			Job ref. 22115
	Part of structure DAMAGED GARDEN WALL			Calc. sheet no. 01
	Drawing ref.	Calcs by TH	Checked by	Date 04/22
Ref.	CALCULATIONS			OUTPUT

PROJECT DESCRIPTION

THE COURTYARD GARDEN AT BRETTON LODGE, WF4 4JT IS BOUNDED TO ITS NORTHERN SIDE BY A CLAY BRICKWORK GARDEN WALL, WHICH MEASURES APPROX. 4m IN HEIGHT, 20m IN LENGTH AND 350mm IN THICKNESS.

THE WALL IS BELIEVED TO BE PART OF THE ORIGINAL CONSTRUCTION OF THE BRETTON LODGE ESTATE, DATING TO APPROX. 1760, AND IS BUILT OF SOFT HANDMADE CLAY BRICKWORK, BEDDED IN LIME ASH MORTAR.

OVER ITS LIFETIME THE WALL HAS SUFFERED LOCALISED SETTLEMENT DAMAGE, LEAF SEPARATION AND WEATHERING EROSION, PARTICULARLY TO ITS NORTHERN FACE.

THE HEAD OF THE WALL IS DISPLACED BY APPROX 600mm TOWARDS THE NORTH. THIS RECENT DAMAGE WAS CAUSED BY THE EXTREME WIND CONDITIONS THAT RESULTED FROM STORM EUNICE, ON OR AROUND 14TH FEBRUARY 2022, DURING WHICH SEVERAL TREES ON THE ESTATE WERE UPROOTED OR SNAPPED OFF.

THiSolutions Ltd	Contract: BRETTON LODGE			Job ref.: 2215
	Part of structure: DAMAGED GARDEN WALL			Calc. sheet no.: 02
	Drawing ref.	Calcs by: TH	Checked by	Date: 04/22
Ref.	CALCULATIONS			OUTPUT

THE HEAD OF THE WALL HAS BEEN DISPLACED TO SUCH AN EXTENT THAT ITS CENTRE OF MASS LIES CONSIDERABLY OUTSIDE THE MIDDLE THIRD OF THE WALL THICKNESS, THEREFORE MEANING THAT TENSILE FORCES WILL BE BEING INDUCED IN THE SOUTHERN FACE OF THE WALL, RESULTING IN INCIPIENT INSTABILITY, AND THE LIKELIHOOD OF COLLAPSE. THE WALL WILL THEREFORE NEED TO BE CAREFULLY DISMANTLED AND RE-BUILT.

THE WALL FEATURES TWO INFILLED SEMI-CIRCULAR ARCHED OPENINGS AND A CYCLICAL THIRD ARCH, WHICH APPEARS TO HAVE SETTLED AND BEEN DISRUPTED AT THE CROWN. THE INFILLING BELOW APPEARS TO HAVE BEEN ADDED IN, TO STABILISE THE OVERHANGING WALL ABOVE.

IN RE-BUILDING THE WALL, IT WOULD BE SEEN AS DESIRABLE TO RE-OPEN THE ORIGINAL ARCH FEATURES TO ALLOW IMPROVED LOCAL ACCESS.

THiS olutions Ltd	Contract: BRETTON LODGE	Job ref.: 22115
	Part of structure: DAMAGED GARDEN WALL	Calc. sheet no.: 03
	Drawing ref. / Calcs by: TH / Checked by	Date: 04/22
Ref.	CALCULATIONS	OUTPUT

LOADINGS

DEAD LOADS : SERV.

BRICKWORK : DENSITY : TAKEN AS : 22.00 kN/m³

WIND LOADING : (BS 6399 pt 2)

WALL HEIGHT H = 4.0m.

BASIC WIND SPEED (BRETTON) Vb = 22.75 m/s.

ALTITUDE FACTOR (As = 99m) Sa = 1.10

DIRECTIONAL FACTOR (200°) Sd = 1.00

SEASONAL FACTOR (ALL SEASONS) Ss = 1.00

PROBABILITY FACTOR (NORMAL) Sp = 1.00

SITE WIND SPEED:

Vs = 22.75 × 1.10 × 1.00 × 1.00 × 1.00 = Vs = 25.03 m/s

TERRAIN + BUILDING FACTOR:

He = 4.0m DIST TO SEA : 84 km IN COUNTRY:

Sb = 1.25

EFFECTIVE WIND SPEED:

Ve = 25.03 × 1.25 = 31.29 m/s. Ve = 31.29 m/s

DYNAMIC PRESSURE:

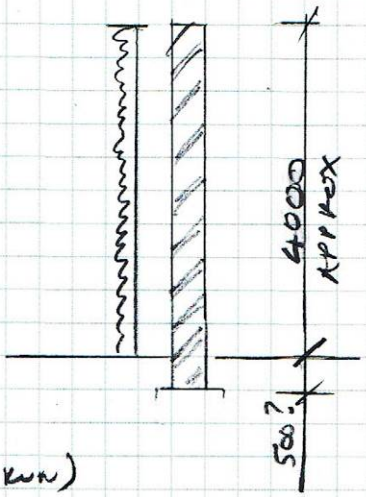
$qs = \frac{0.613 \times 31.29^2}{10^3} = 0.60 kN/m^2$ qs = 0.60 kN/m²

THiSolutions Ltd	Contract: BRETTON LODGE	Job ref.: 22115
	Part of structure: DAMAGED GARDEN WALL	Calc. sheet no.: 04
	Drawing ref. / Calcs by: TH / Checked by	Date: 04/22
Ref.	CALCULATIONS	OUTPUT

EXISTING WALL

350 APPROX. (WITH RETURN CORNERS)

LAYOUT:



L = 20m
h = 4.5m
L/h = 4.44.
∴ k = 0.7.

NET PRESSURE COEFFS:
Zone A: 2.1
Zone B: 1.8
Zone C: 1.4 ←
Zone D: 1.2.

LOADING: (PER m RUN)

WIND: 1.00 × 4.00 × 0.60 = 2.40 × 1.4 = 3.36 kN/m

APPLY Cp × k = 3.36 × 1.4 × 0.7 = 3.29 kN/m RUN. (OUT)

BENDING IN WALL:

M = 3.29 × 2.5 = 8.23 kNm/m M = 8.23 kNm/m.

MODULUS OF WALL:

$Z = bd^2/6 = 100 \times 35^2/6 = 20416\ cm^3/m.$

∴ STRESS = $\pm 8.23 \times 10^6 / 20416 \times 10^3 = \pm 0.40\ N/mm^2.$

DEAD PRE-LOAD: @ 0.6h DOWN FROM TOP, = 2.7m).

DEAD LOAD: 1.00 × 2.70 × 0.35 × 22.00 = 20.79 × 0.9 = 18.71 kN/m.

THiS solutions Ltd	Contract: BRETTON LODGE	Job ref.: 22115
	Part of structure: DAMAGED GAWDEN WALL	Calc. sheet no.: 05
	Drawing ref. / Calcs by: TH / Checked by	Date: 04/22

Ref.	CALCULATIONS	OUTPUT

PRE-COMPRESSIVE STRESS:

$= 18.71 \times 10^3 / 1000 \times 350 = 0.05 \text{ N/mm}^2$.

COMPRESSIVE STRESS, MAX. $= +0.40 + 0.05 = 0.45 \text{ N/mm}^2$

TENSILE STRESS, MAX. $= -0.40 + 0.05 = -0.35 \text{ N/mm}^2$

WALL WINDWARD FACE GOES INTO TENSION.

CONSIDER RESISTANCE OF WALL/m RUN.

- ALLOW 20 N/mm² COMPRESSIVE STRENGTH OF BRICK:
- ALLOW TYPE (iv) MORTAR: $f_k = 5.0 \text{ N/mm}^2$.

COMPRESSIVE RESISTANCE $= 5.0/3.5 = 1.43 \text{ N/mm}^2$

$\gg 0.55$ ✓OK

ARBITRARILY ALLOW $f_k/10$ IN TENSION:

TENSILE RESISTANCE $= 0.50/3.5 = -0.14 \text{ N/mm}^2$

< 0.35 ∴ FAILS

WALL CANNOT BE PROVEN TO BE STABLE WITHOUT ENHANCED TENSILE RESISTANCE

THiSolutions Ltd	Contract: BRETTON LODGE			Job ref.: 22115
	Part of structure: DAMAGED GARDEN WALL			Calc. sheet no.: 06
	Drawing ref.	Calcs by: TM	Checked by	Date: 04/22
Ref.	CALCULATIONS			OUTPUT

N.B. WALL SURVIVED STORM EUNICE, HOWEVER SUFFERED PERMANENT DEFORMATION:

IF MAX. TENSILE STRESS IS LIMITED TO $0.14\ N/mm^2$,

THEN MAX. MOMENT APPLICABLE =

$$0.14 \times 20\,416 \times 10^3 / 10^6 = 2.86\ kNm/m$$

EQUIVALENT LOAD = $2.86/2.5 = 1.14\ kN$, i.e.

$$1.14/4.0 \times 1.4 = 0.20\ kN/m^2.$$

WALL HAS APPROX 1/3 OF CALCULATED RESISTANCE NEEDED TO RESIST q_s OF $0.60\ kN/m^2$

THiSolutions Ltd	Contract: BRETTON LODGE	Job ref.: 2215
	Part of structure: DAMAGED GABLE WALL	Calc. sheet no.: 07
	Drawing ref. / Calcs by: TM / Checked by	Date: 04/22
Ref.	CALCULATIONS	OUTPUT

CONSIDER REINFORCED MASONRY WALL:

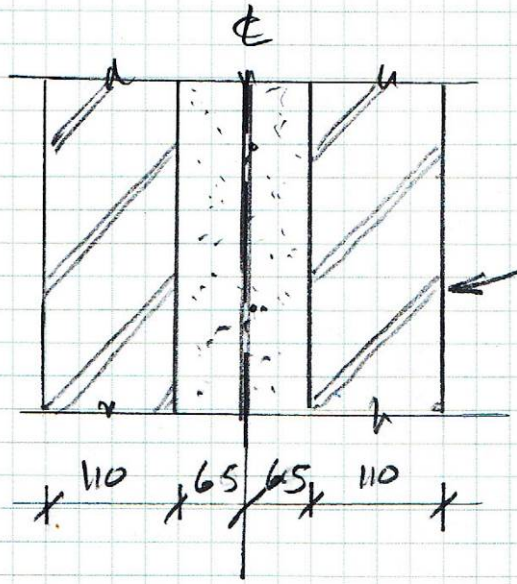
MATERIAL PROPERTIES:

MASONRY: ALLOW $f_k = 5.0\ N/mm^2$

CONCRETE: ALLOW $f_{cu} = 30.00\ N/mm^2$

STEEL: ALLOW $f_y = 500.00\ N/mm^2$

CONSIDER REINFORCED SECTION:



CONCRETE CORE INFILL WITH 8 mm VERTICAL BARS @ 200 X 200 CRS. (A252 MESH)

HARD-MADE BRICK FACING

LEVER ARM: $la = 175mm$ MOMENT = 8.23 kNm/m

$$M_u = \frac{0.156 \times 5.0 \times 1000 \times 175^2}{10^6} = 23.89\ kNm > 8.23\ kNm \checkmark$$

$$K = \frac{8.23 \times 10^6}{1000 \times 175^2 \times 5.00} = 0.05 \quad \therefore z = 0.94 \times 175 = 164mm$$

THiS olutions Ltd	Contract BRETTON LODGE		Job ref. 22115
	Part of structure DAMAGED GARDEN WALL		Calc. sheet no. 08
	Drawing ref.	Calcs by TM / Checked by	Date 04/22
Ref.	CALCULATIONS		OUTPUT

REINFORCEMENT:

$$A_s = \frac{8.23 \times 10^6}{0.87 \times 500 \times 164} = 115 \text{ mm}^2/\text{m}.$$

⇒ COULD LOOK TO USE A142 MESH: PLACED CENTRALLY IN WALL (6mm BAR @ 200 CRS).

$A_{s\,MIN.} = 0.0013 \times 1000 \times 130 = 169 \text{ mm}^2/\text{m}.$

⇒ USE A252 MESH PLACED CENTRALLY IN WALL. (8mm BAR @ 200 CRS)