



APPENDIX 1

Photographic Record of Works



South Elevation (facing Great Hall)



Figure 1: Pre-commencement



Figure 2: During contract works
(detail of 'raking out' of existing pointing shown)



Figure 3: At completion
(note extents of repointing)



Great Hall Porch Tower



Figure 4: Pre-commencement



Figure 5: During contract works
(detail of repointing shown)



Figure 6: At completion
(note extents of repointing at high-level)



East Elevation (facing Lower Bailey)



Figure 7: Pre-commencement



Figure 8: During contract works
(detail of repointing shown)



Figure 9: At completion
(note extents of repointing at high-level)



Detail of East Corner to Great Hall Porch Tower Parapet



Figure 10: Pre-commencement
(note severe cracking and displacement)



Figure 11: During contract works
(detail of bedding mortar and Helibar installation shown)



Figure 12: At completion



North Elevation (facing Lesser Hall)



Figure 13: Pre-commencement



Figure 14: During contract works



Figure 15: At completion



Detail of Wall Ledge on North Elevation



Figure 16: Pre-commencement



Figure 17: During contract works
(lime wash 'slip-plane' shown)



Figure 18: At completion
(‘patinating’ of Prompt natural cement capping shown)



Detail of Chimney Base on North Elevation



Figure 19: Pre-commencement



Figure 20: During contract works
(discreet holes from stainless-steel bar installation shown)



Figure 21: At completion



Main Roof (East-End)



Figure 22: Pre-commencement



Figure 23: During contract works
(installation of new joists and insulation shown to roof over stairwell)



Figure 24: Nearing completion
(Entirety of roof plant configuration shown in 'fisheye' view)



Main Roof (West-End)



Figure 25: Pre-commencement



Figure 26: During contract works
(removal of existing full-fill insulation shown, i.e. no ventilation path)



Figure 27: Nearing completion
(Remaining ductwork covering shown being installed)



Detail of South Elevation Gable at Roof-Level



Figure 28: Pre-commencement



Figure 29: During contract works
(detail of repointing shown)



Figure 30: At completion
(‘patinating’ of Prompt natural cement capping shown)



Detail of South Elevation Gable at Roof-Level



Figure 31: Pre-commencement



Figure 32: During contract works
(detail of natural slate capping & flaunching shown)

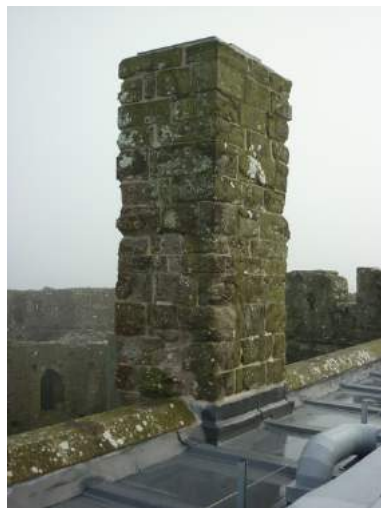


Figure 33: At completion
(note low visual impact of slate capping)



Great Hall Porch Tower Roof



Figure 34: Pre-commencement



Figure 35: During contract works



Figure 36: At completion



Interior of Earl's Chamber (East-End)



Figure 37: Pre-commencement



Figure 38: During contract works
(detail of ceiling electrical 'first-fix' shown)



Figure 39: At completion



Interior of Earl's Chamber (West-End)



Figure 40: Pre-commencement



Figure 41: During contract works
(detail of ceiling electrical 'first-fix' shown)



Figure 42: At completion



Interior of Great Hall Porch Tower



Figure 43: Pre-commencement
(wall visibly damp below northern gutter line & sustaining algae growth)



Figure 44: During contract works
(shown at introduction of gutter ventilation path detail)



Figure 45: At completion
(wall noted to be visibly 'drying out')



Detail of Wall Vents installed in Great Hall Porch Tower



Figure 46: Pre-commencement



Figure 47: During contract works
(misinterpreted vent detail formed by Contractor shown, ultimately omitted)



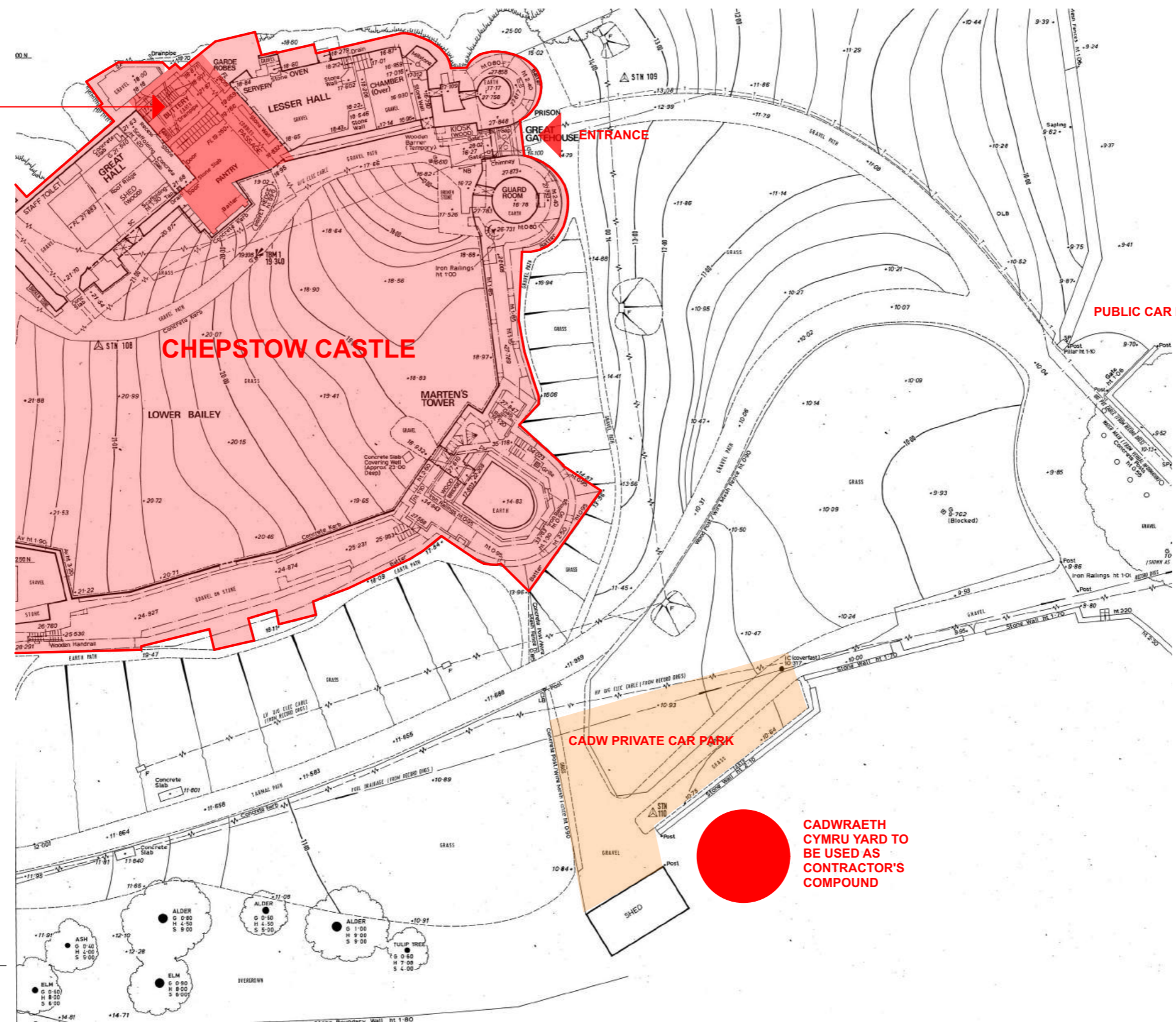
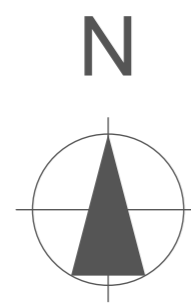
Figure 48: At completion
(visually unobtrusive, practical and non-intrusive installation)



APPENDIX 2

Site Location Plan

EARL'S CHAMBER
& GREAT HALL
PORCH TOWER
(ABOVE BUTTERY
& PANTRY)



SITE LOCATION PLAN 1:500 APPROX

Drawing Title		Scale		Date	Drawn	MT
SITE LOCATION PLAN		1:500 APPROX		Sept 2015	MT	MT
J14-091		4000*				

Client	Cadw
Job Title	Earl's Chamber Chepstow Castle, Monmouthshire
SURVEY	

Revisions:	By:	Q.A.:	Assistant:
" " First Issue 17/09/15	MT	RG	
Project Leader	Designer		
MT	MT		

UKAS MANAGEMENT SYSTEMS 003

bsi.

Certificate No FS 21557

Prefer larger scale drawings.
Prefer figured dimensions to scaled dimensions. Check all relevant dimensions and levels on site before proceeding with the work. Take site dimensions for fabrication of joinery and other fittings. Refer all discrepancies to the architect for his/her decision before putting work in hand. Copyright in this drawing and in the work executed from it remains the property of the architect.



APPENDIX 3

'As Constructed' Drawings



FS 21557

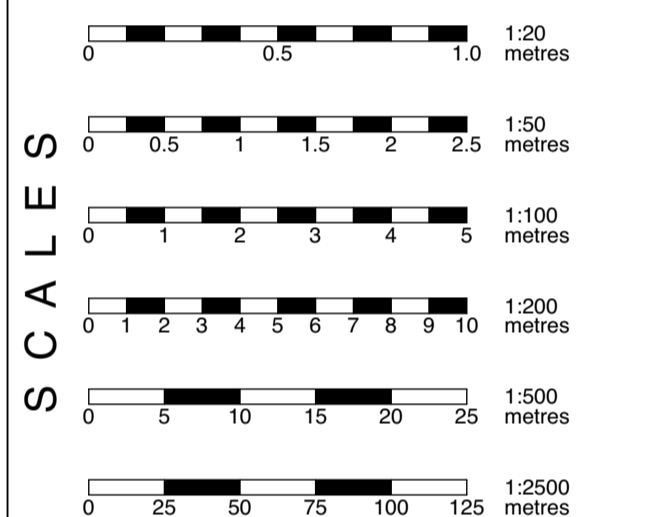
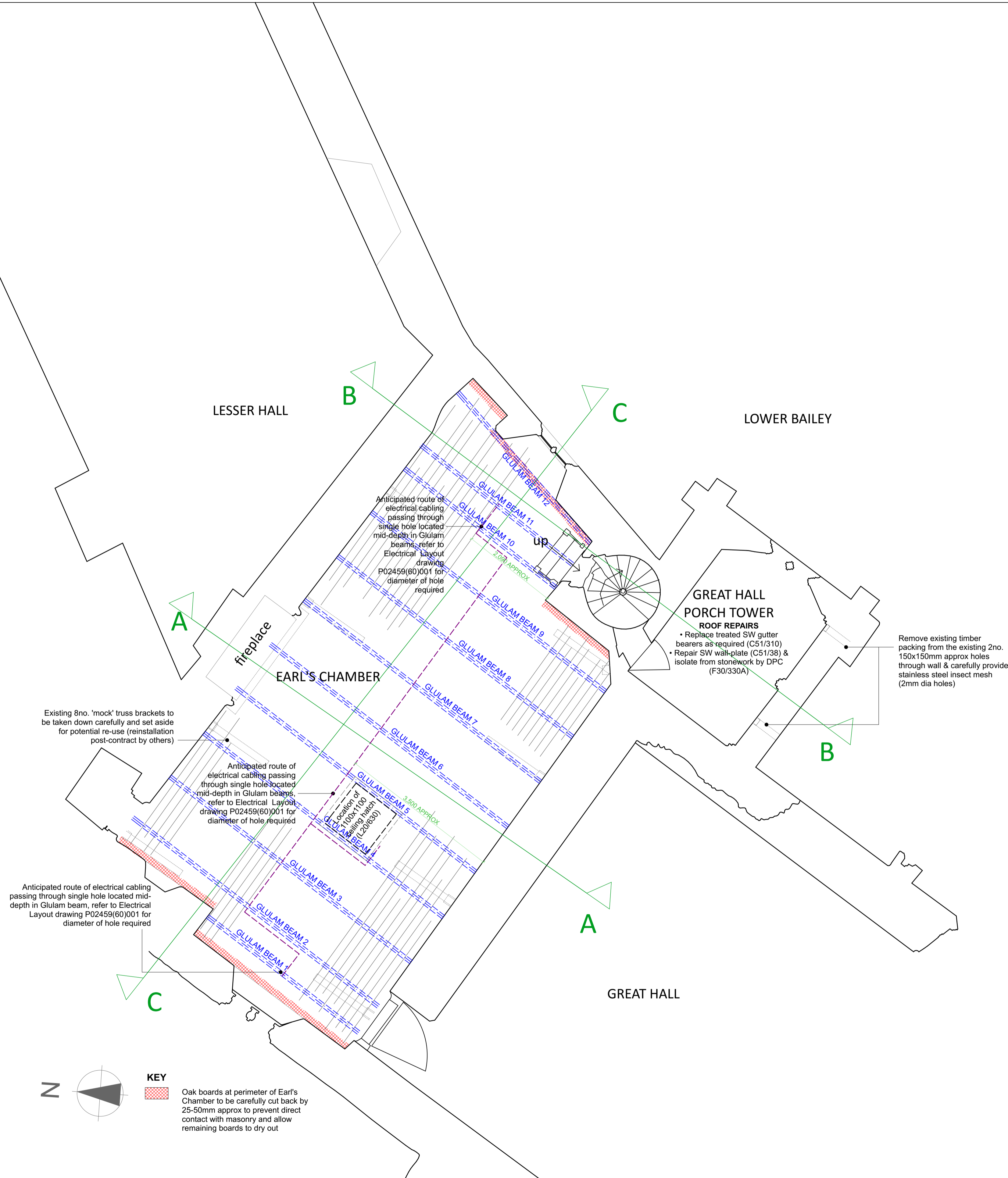
This drawing is © pdp Green Consulting Ltd.

Notes.

1. This drawing is to be read in conjunction with drawings, details and specifications issued for construction purposes as appropriate.
2. The Contractor is responsible for all dimensions and for the correct setting out of the work on site. Only figured dimensions are to be used. Any discrepancies are to be reported before proceeding.
3. All materials and workmanship to comply with current British Standards and Codes of Practice.
4. This drawing is not to be used for construction unless marked in the drawing status box 'FOR CONSTRUCTION'.
5. The user of the designs and details represented by this document are recommended to ensure that they are fully conversant with the Design (Construction and Management) Regulations 2015 in respect of any construction activities for which this document may be used.

In particular, the user must ensure that a Principal Designer and Principal Contractor have been appointed and in addition, they have the appropriate experience and capability for those functions.

If the user of this document has any doubts as to their statutory obligations in this regard, they should contact pdp Green on 01872 265400 and ask for the Health and Safety Advisor.



D	12/01/2018	As constructed	MT	DB
Rev:	Date:	Amendments:	BY:	QA:

AS CONSTRUCTED

Project Leader:	Designer:	Assistant:
MT	MT	KP

Drawing:
**PROPOSED REPAIRS
Floor Plan**

Client:
Cadw

Job Title:
Earl's Chamber
Chepstow Castle, Monmouthshire

Date: September 2015 Scale: 1:50

pdpgreen Consulting Ltd.
Calenick House
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Architecture, Structural and Civil Engineering

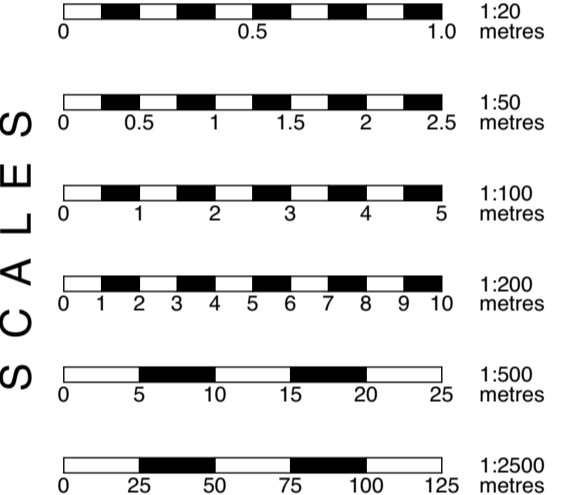
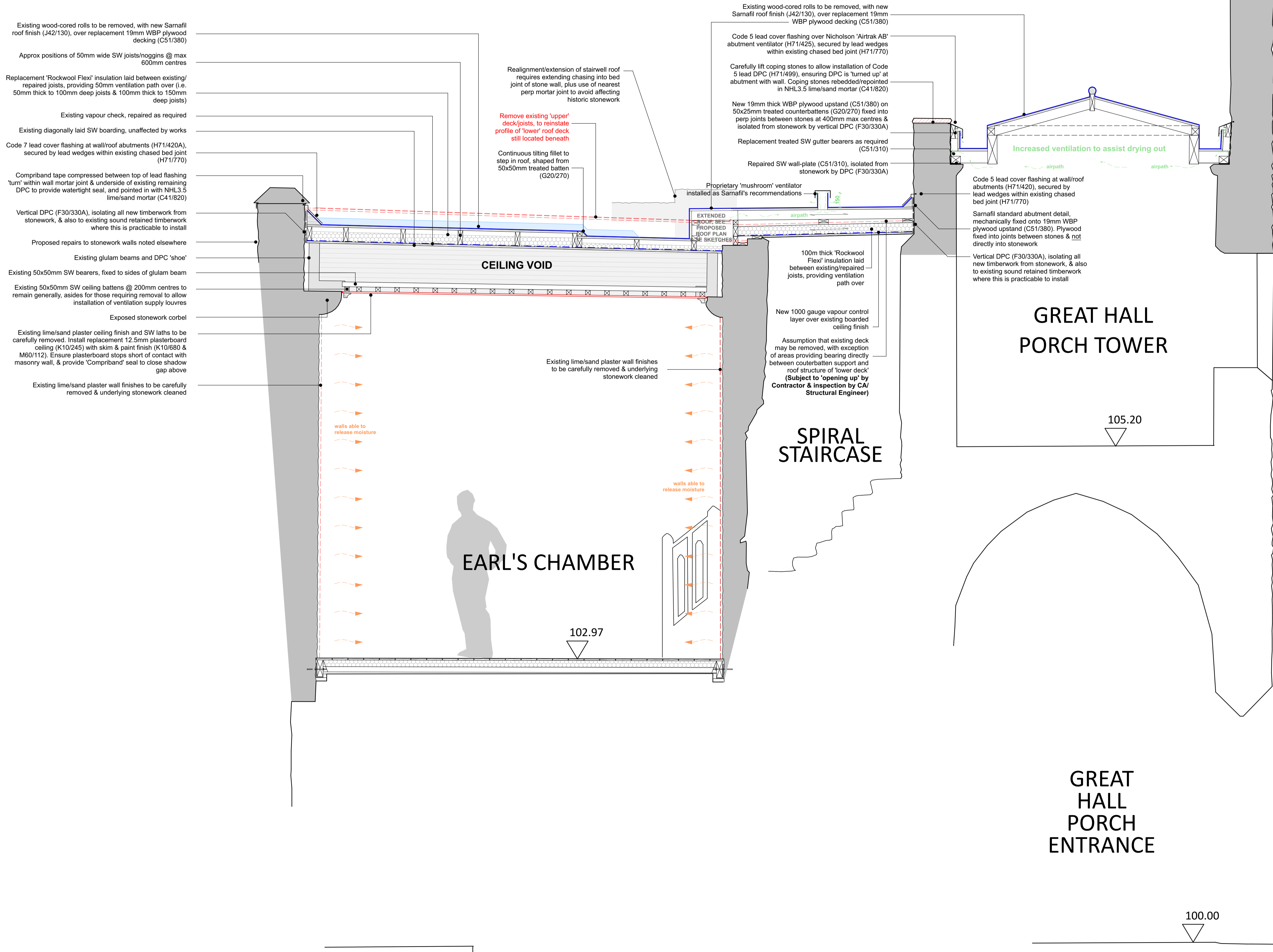
Job No: **J14-091** Dwg No: **4012** Rev: **D**

This drawing is © pdp Green Consulting Ltd. Notes.

- This drawing is to be read in conjunction with drawings, details and specifications issued for construction purposes as appropriate.
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F	12/01/2018	As constructed	MT	DB
Rev:	Date:	Amendments:	BY:	QA:

AS CONSTRUCTED		
Project Leader:	Designer:	Assistant:
MT	MT	KP

Drawing:
PROPOSED REPAIRS Section BB

Client:
Cadw

Job Title:
Earl's Chamber
Chepstow Castle, Monmouthshire

Date: September 2015 Scale: 1:20

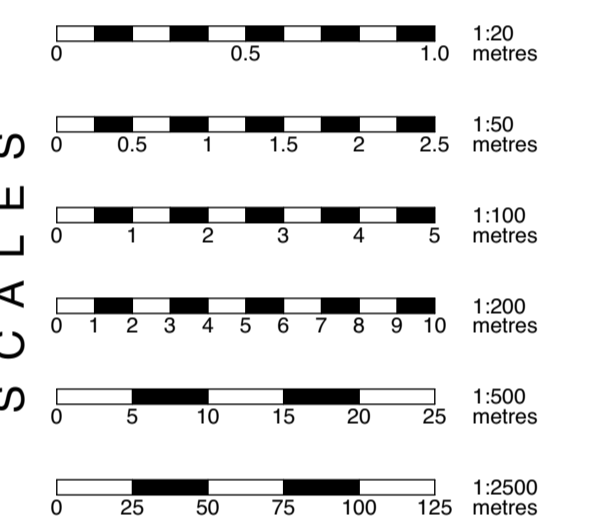
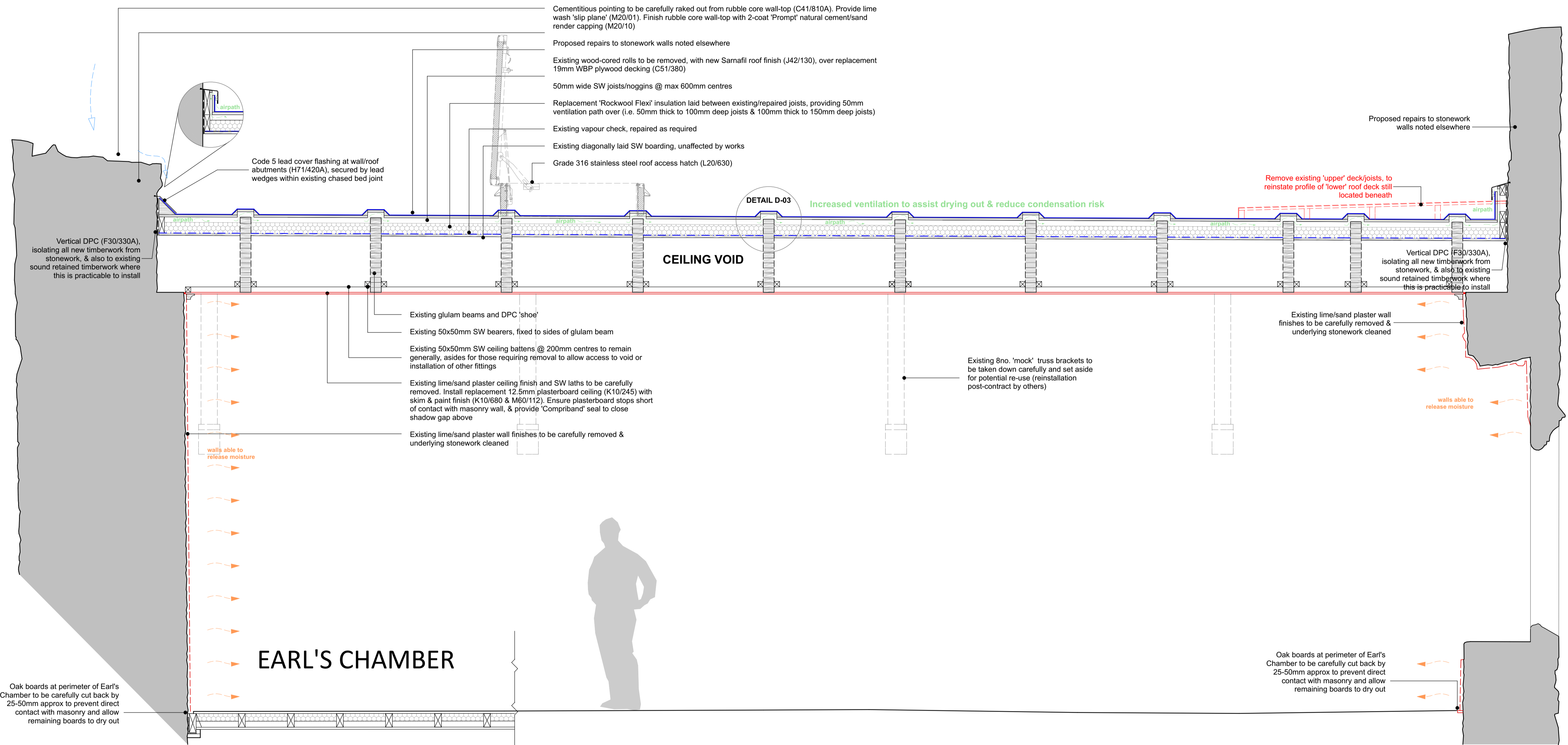
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G	12/01/2018	As constructed	MT	DB
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AS CONSTRUCTED

Project Leader:	Designer:	Assistant:
MT	MT	KP

Drawing:
PROPOSED REPAIRS Section CC

Client:
Cadw

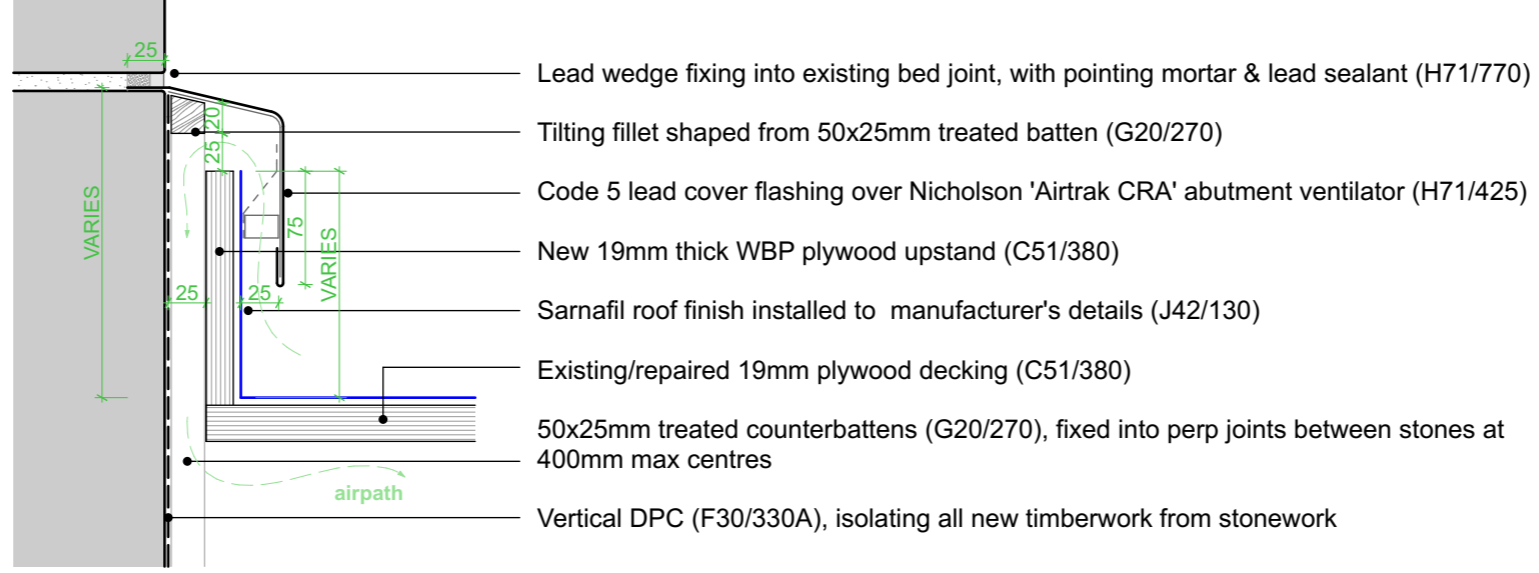
Job Title:
Earl's Chamber
Chepstow Castle, Monmouthshire

Date: September 2015 Scale: 1:20

pdpGreen Consulting Ltd.
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Architecture, Structural and Civil Engineering

Job No: **J14-091** Dwg No: **4016** Rev: **G**



- Lead wedge fixing into existing bed joint, with pointing mortar & lead sealant (H71/770)
- Tilting fillet shaped from 50x25mm treated batten (G20/270)
- Code 5 lead cover flashing over Nicholson 'Airtrak CRA' abutment ventilator (H71/425)
- New 19mm thick WBP plywood upstand (C51/380)
- Sarnafil roof finish installed to manufacturer's details (J42/130)
- Existing/repaired 19mm plywood decking (C51/380)
- 50x25mm treated counterbattens (G20/270), fixed into perp joints between stones at 400mm max centres
- Vertical DPC (F30/330A), isolating all new timberwork from stonework

Prefer larger scale drawings.
 Prefer figured dimensions to scaled dimensions. Check all relevant dimensions, lines and levels on site before proceeding with the work. Take site dimensions for fabrication of joinery and other fittings. Refer all discrepancies to the architect for his/her decision before putting work in hand. Copyright in this drawing and in the work executed from it remains the property of the architect.



Certificate No FS 21557

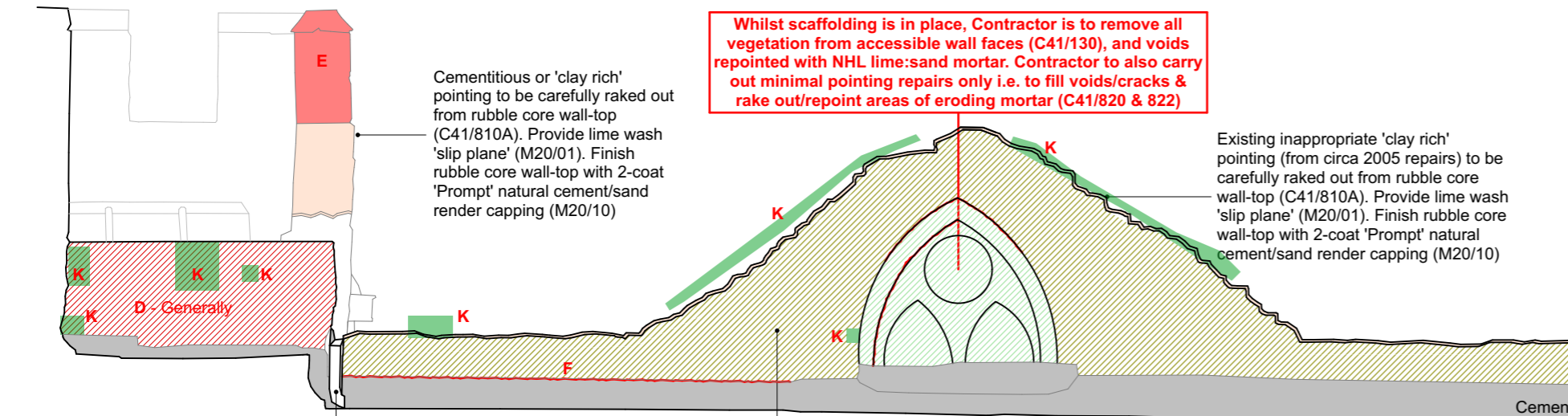
Revisions:	By:	Q.A.:	Project Leader	Designer	Assistant
'B' As constructed 12/01/18	MT	DB	MT	MT	KP

Client	Cadw
Job Title	Earl's Chamber Chepstow Castle, Monmouthshire
AS CONSTRUCTED	

Drawing Title	DETAIL D-01 Ventilated wall/roof abutment	
Scale	Date	Drawn
1:5	Sept 2015	MT
J14-091		4017B

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INTERNAL NORTH ELEVATION



Cementitious or 'clay rich' pointing to be carefully raked out from rubble core wall-top (C41/810A). Provide lime wash 'slip plane' (M20/01). Finish rubble core wall-top with 2-coat 'Prompt' natural cement/sand render capping (M20/10)

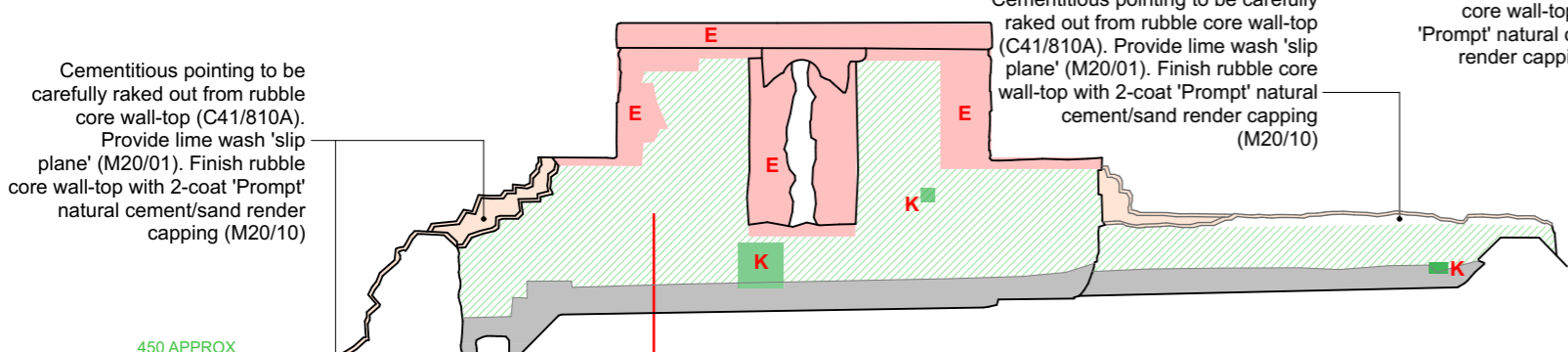
Temporarily remove existing RW goods as required to allow access to wall top through which RWP penetrates. Ensure Prompt render capping is applied before reinstallation of RWP

Existing inappropriate 'clay rich' pointing (from circa 2005 repairs) to be carefully raked out from wall-face (C41/810A). Repoint using NHL3.5 lime/sand mortar (C41/820)

Cementitious pointing to be carefully raked out from rubble core wall-top (C41/810A). Provide lime wash 'slip plane' (M20/01). Finish rubble core wall-top with 2-coat 'Prompt' natural cement/sand render capping (M20/10)

Existing inappropriate 'clay rich' pointing (from circa 2005 repairs) to be carefully raked out from rubble core wall-top (C41/810A). Provide lime wash 'slip plane' (M20/01). Finish rubble core wall-top with 2-coat 'Prompt' natural cement/sand render capping (M20/10)

INTERNAL EAST ELEVATION

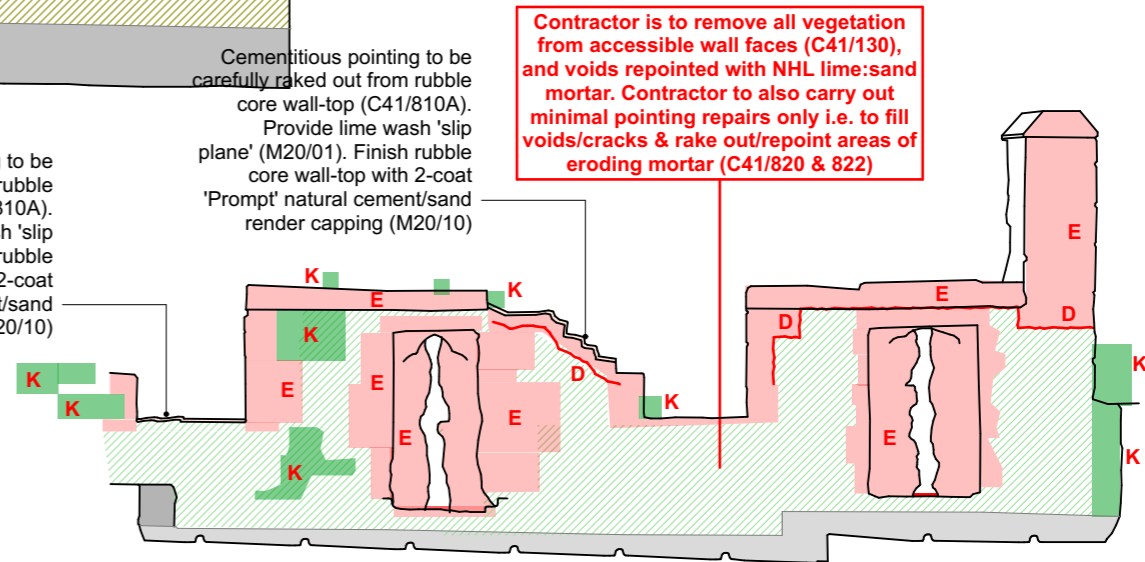


Cementitious pointing to be carefully raked out from rubble core wall-top (C41/810A). Provide lime wash 'slip plane' (M20/01). Finish rubble core wall-top with 2-coat 'Prompt' natural cement/sand render capping (M20/10)

Contractor is to remove all vegetation from accessible wall faces (C41/130), and voids repointed with NHL lime:sand mortar. Contractor to also carry out minimal pointing repairs only i.e. to fill voids/cracks & rake out/repoint areas of eroding mortar (C41/820 & 822)

D & E - To chimney perp joints
D - Entirety of chimney stack generally

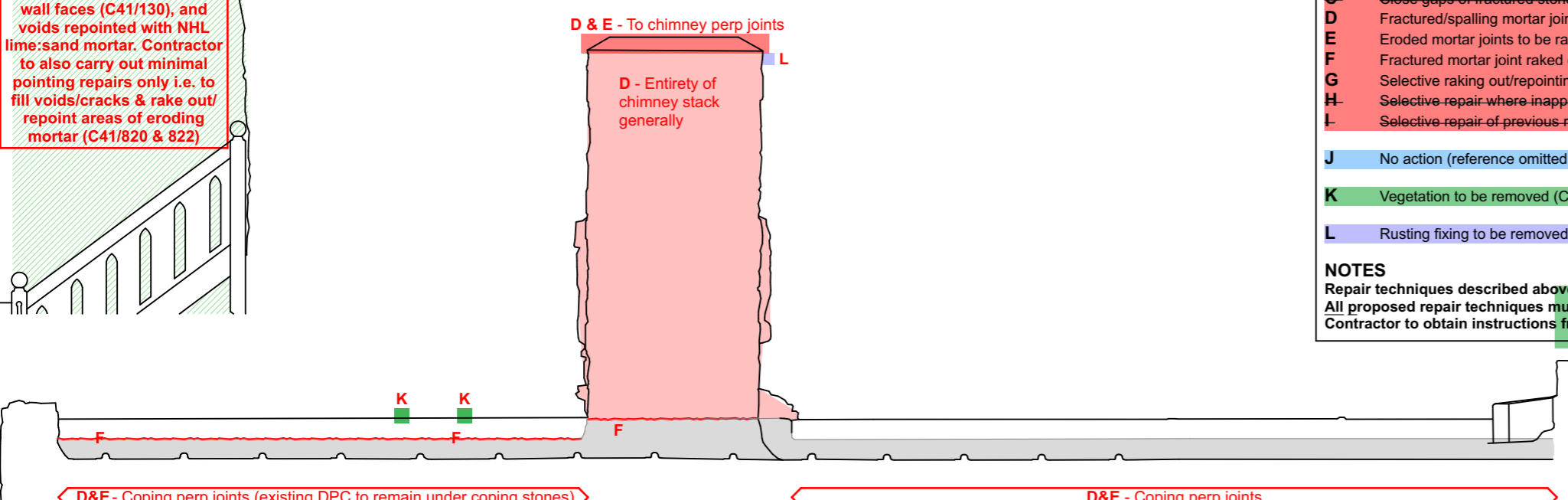
INTERNAL WEST ELEVATION



Cementitious pointing to be carefully raked out from rubble core wall-top (C41/810A). Provide lime wash 'slip plane' (M20/01). Finish rubble core wall-top with 2-coat 'Prompt' natural cement/sand render capping (M20/10)

Contractor is to remove all vegetation from accessible wall faces (C41/130), and voids repointed with NHL lime:sand mortar. Contractor to also carry out minimal pointing repairs only i.e. to fill voids/cracks & rake out/repoint areas of eroding mortar (C41/820 & 822)

INTERNAL SOUTH ELEVATION



Whilst scaffolding is in place, Contractor is to remove all vegetation from accessible wall faces (C41/130), and voids repointed with NHL lime:sand mortar. Contractor to also carry out minimal pointing repairs only i.e. to fill voids/cracks & rake out/repoint areas of eroding mortar (C41/820 & 822)

D & E - To chimney perp joints
D - Entirety of chimney stack generally

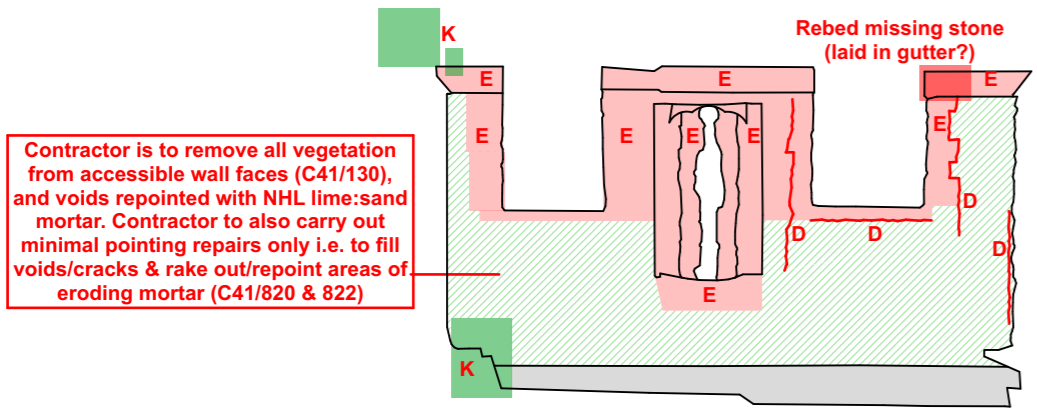
D&E - Coping perp joints (existing DPC to remain under coping stones)

D&E - Coping perp joints (existing DPC to remain under coping stones)

KEY TO STONEMWORK REPAIRS

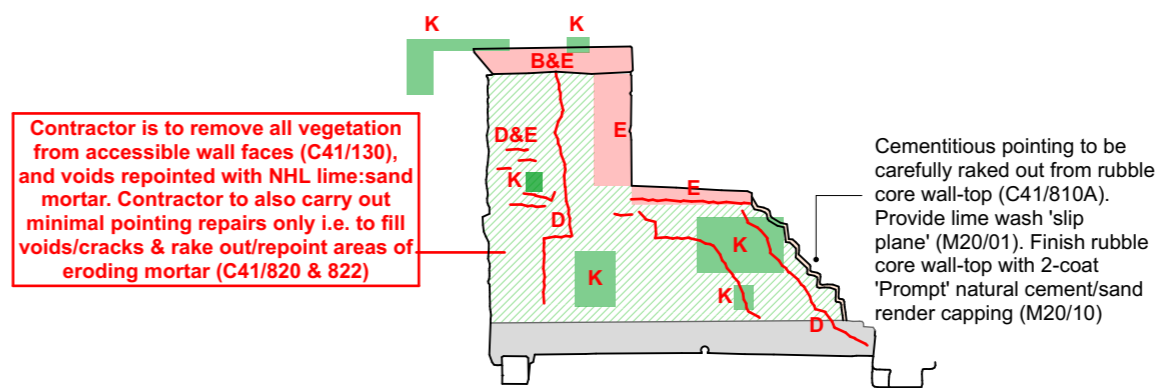
- A** Refer to drawings for proposed capping repair treatments to exposed rubble core walls
- B** Assess delaminating/loss of profile to stonework repair on careful selected basis (Provisional Sum in A54)
- C** Close gaps of fractured stonework using 'plastic' mortar repair or NHL lime:sand pointing (C41/530A, 820 & 822)
- D** Fractured/spalling mortar joints to be raked out (C41/810A) & repointed with NHL lime:sand mortar (C41/820 & 822)
- E** Eroded mortar joints to be raked out (C41/810A) & repointed with NHL lime:sand mortar (C41/820 & 822)
- F** Fractured mortar joint raked out & repointed as part of cover flashing replacement (H71/420 & 425)
- G** Selective raking out/repointing where cement has been used in previous repair
- H** Selective repair where inappropriate 'plastic' repair to stonework face is present (Provisional Sum in A54)
- I** Selective repair of previous repointing repairs where 'smeared' over adjacent stonework (Provisional Sum in A54)
- J** No action (reference omitted from drawing as lime leaching relates to other defects)
- K** Vegetation to be removed (C41/130), and void repointed with NHL lime:sand mortar (C41/820 & 822)
- L** Rusting fixing to be removed, repair hole using appropriate mortar/repointing technique

NOTES
Repair techniques described above may be dependent upon success of trials/samples presented in C41/190
All proposed repair techniques must be carefully assessed on site between CA & Specialist Masonry Contractor
Contractor to obtain instructions from CA before proceeding with any repair work



Contractor is to remove all vegetation from accessible wall faces (C41/130), and voids repointed with NHL lime:sand mortar. Contractor to also carry out minimal pointing repairs only i.e. to fill voids/cracks & rake out/repoint areas of eroding mortar (C41/820 & 822)

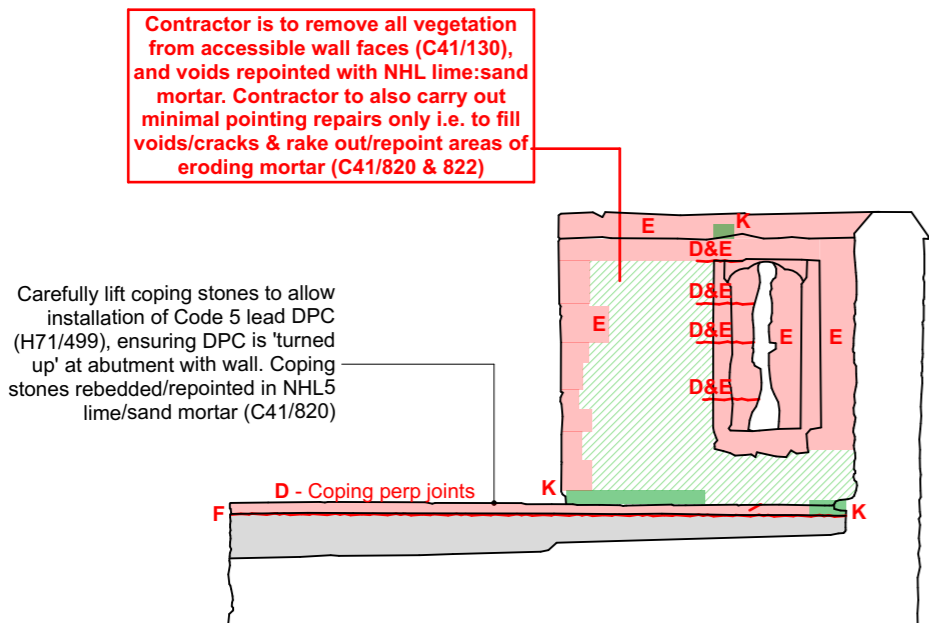
INTERNAL NORTH ELEVATION OF TOWER



Contractor is to remove all vegetation from accessible wall faces (C41/130), and voids repointed with NHL lime:sand mortar. Contractor to also carry out minimal pointing repairs only i.e. to fill voids/cracks & rake out/repoint areas of eroding mortar (C41/820 & 822)

Cementitious pointing to be carefully raked out from rubble core wall-top (C41/810A). Provide lime wash 'slip plane' (M20/01). Finish rubble core wall-top with 2-coat 'Prompt' natural cement/sand render capping (M20/10)

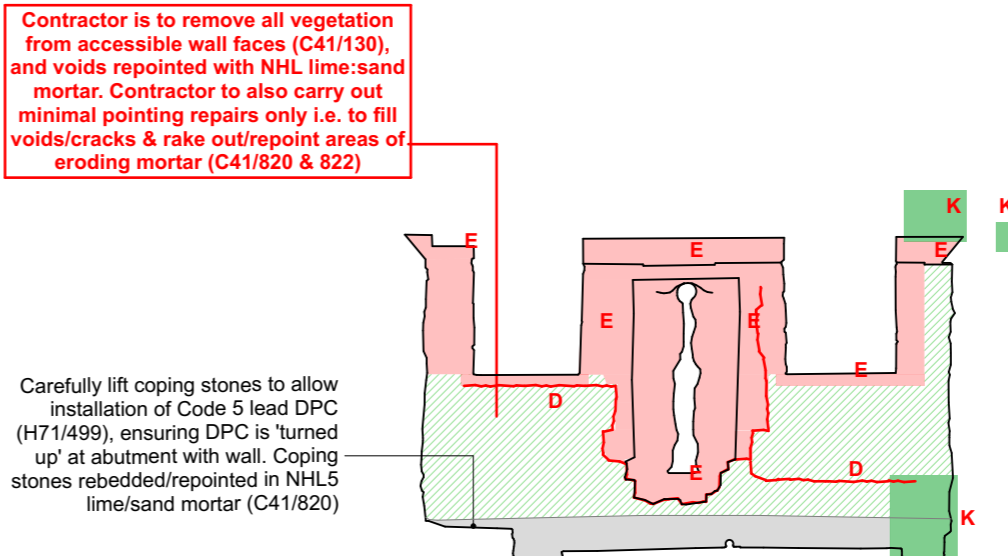
INTERNAL EAST ELEVATION OF TOWER



Contractor is to remove all vegetation from accessible wall faces (C41/130), and voids repointed with NHL lime:sand mortar. Contractor to also carry out minimal pointing repairs only i.e. to fill voids/cracks & rake out/repoint areas of eroding mortar (C41/820 & 822)

Carefully lift coping stones to allow installation of Code 5 lead DPC (H71/499), ensuring DPC is 'turned up' at abutment with wall. Coping stones rebedded/repointed in NHL5 lime/sand mortar (C41/820)

INTERNAL SOUTH ELEVATION OF TOWER



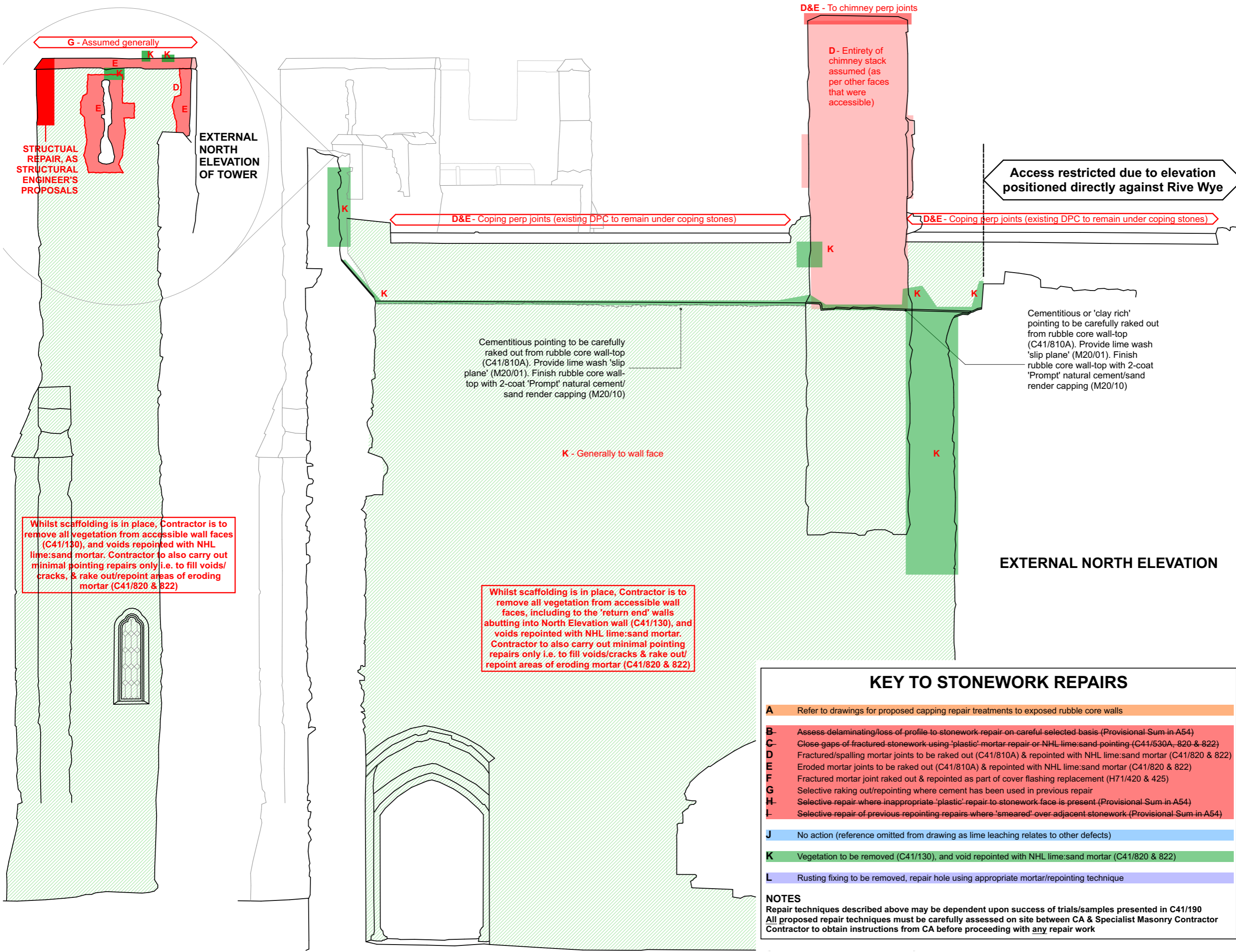
Contractor is to remove all vegetation from accessible wall faces (C41/130), and voids repointed with NHL lime:sand mortar. Contractor to also carry out minimal pointing repairs only i.e. to fill voids/cracks & rake out/repoint areas of eroding mortar (C41/820 & 822)

Carefully lift coping stones to allow installation of Code 5 lead DPC (H71/499), ensuring DPC is 'turned up' at abutment with wall. Coping stones rebedded/repointed in NHL5 lime/sand mortar (C41/820)

INTERNAL WEST ELEVATION OF TOWER

KEY TO STONEMWORK REPAIRS	
A	Refer to drawings for proposed capping repair treatments to exposed rubble core walls
B	Assess delaminating/loss of profile to stonework repair on careful selected basis (Provisional Sum in A54)
C	Close gaps of fractured stonework using 'plastic' mortar repair or NHL lime:sand pointing (C41/530A, 820 & 822)
D	Fractured/spalling mortar joints to be raked out (C41/810A) & repointed with NHL lime:sand mortar (C41/820 & 822)
E	Eroded mortar joints to be raked out (C41/810A) & repointed with NHL lime:sand mortar (C41/820 & 822)
F	Fractured mortar joint raked out & repointed as part of cover flashing replacement (H71/420 & 425)
G	Selective raking out/repointing where cement has been used in previous repair
H	Selective repair where inappropriate 'plastic' repair to stonework face is present (Provisional Sum in A54)
I	Selective repair of previous repointing repairs where 'smeared' over adjacent stonework (Provisional Sum in A54)
J	No action (reference omitted from drawing as lime leaching relates to other defects)
K	Vegetation to be removed (C41/130), and void repointed with NHL lime:sand mortar (C41/820 & 822)
L	Rusting fixing to be removed, repair hole using appropriate mortar/repointing technique

NOTES
 Repair techniques described above may be dependent upon success of trials/samples presented in C41/190
 All proposed repair techniques must be carefully assessed on site between CA & Specialist Masonry Contractor to obtain instructions from CA before proceeding with any repair work



Drawing Title		Scale		Date		Drawn		MT	
SURVEY AS EXISTING		1:50		Sept 2015		Drawn		MT	
External North Elevations									
showing Stonework Repairs									
J14-091		4020E							

Client	Cadw
Job Title	Earl's Chamber
	Chepstow Castle, Monmouthshire
AS CONSTRUCTED	

Revisions:	By:	Q.A.:	Project Leader	Designer	Assistant
'E' As constructed 12/01/18	MT	DB	MT	MT	KP

UKAS MANAGEMENT SYSTEMS 003

bsi.

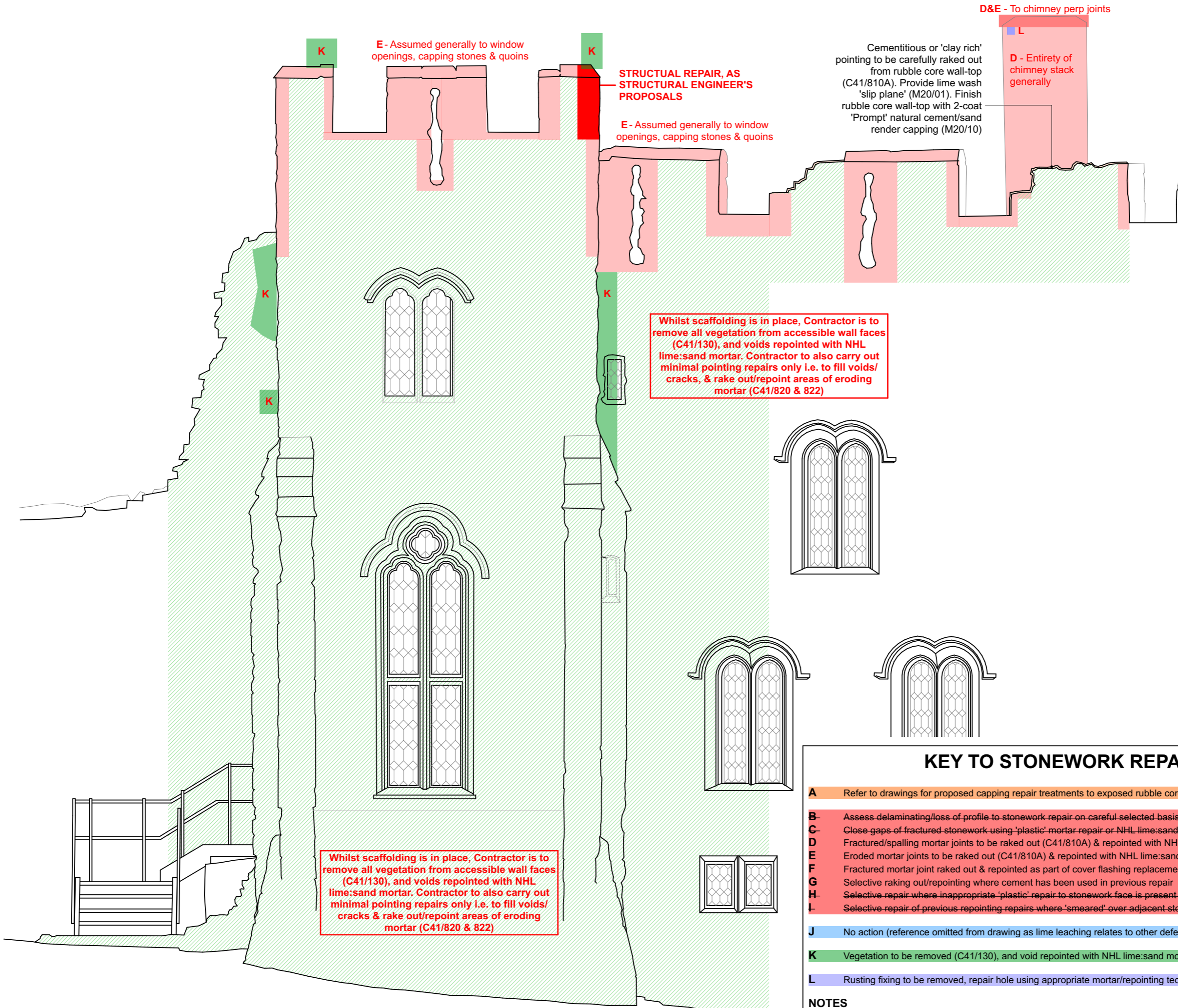
Certificate No FS 21557

Prefer larger scale drawings. Prefer figured dimensions to scaled dimensions. Check all relevant dimensions, lines and levels on site before proceeding with the work. Take site dimensions for fabrication of joinery and other fittings. Refer all discrepancies to the architect for his/her decision before putting work in hand. Copyright in this drawing and in the work executed from it remains the property of the architect.

KEY TO STONEMWORK REPAIRS

- A** Refer to drawings for proposed capping repair treatments to exposed rubble core walls
- B** Assess delaminating/loss of profile to stonework repair on careful selected basis (Provisional Sum in A54)
- C** Close gaps of fractured stonework using 'plastic' mortar repair or NHL lime:sand pointing (C41/530A, 820 & 822)
- D** Fractured/spalling mortar joints to be raked out (C41/810A) & repointed with NHL lime:sand mortar (C41/820 & 822)
- E** Eroded mortar joints to be raked out (C41/810A) & repointed with NHL lime:sand mortar (C41/820 & 822)
- F** Fractured mortar joint raked out & repointed as part of cover flashing replacement (H71/420 & 425)
- G** Selective raking out/repointing where cement has been used in previous repair
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- J** No action (reference omitted from drawing as lime leaching relates to other defects)
- K** Vegetation to be removed (C41/130), and void repointed with NHL lime:sand mortar (C41/820 & 822)
- L** Rusting fixing to be removed, repair hole using appropriate mortar/repointing technique

NOTES
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 All proposed repair techniques must be carefully assessed on site between CA & Specialist Masonry Contractor to obtain instructions from CA before proceeding with any repair work



EXTERNAL EAST ELEVATION


Whilst scaffolding is in place, Contractor is to remove all vegetation from accessible wall faces (C41/130), and voids repointed with NHL lime:sand mortar. Contractor to also carry out minimal pointing repairs only i.e. to fill voids/cracks & rake out/repoint areas of eroding mortar (C41/820 & 822)

Whilst scaffolding is in place, Contractor is to remove all vegetation from accessible wall faces (C41/130), and voids repointed with NHL lime:sand mortar. Contractor to also carry out minimal pointing repairs only i.e. to fill voids/cracks, & rake out/repoint areas of eroding mortar (C41/820 & 822)

KEY TO STONEMWORK REPAIRS

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- F** Fractured mortar joint raked out & repointed as part of cover flashing replacement (H71/420 & 425)
- G** Selective raking out/repointing where cement has been used in previous repair
- H** Selective repair where inappropriate 'plastic' repair to stonework face is present (Provisional Sum in A54)
- I** Selective repair of previous repointing repairs where 'smoered' over adjacent stonework (Provisional Sum in A54)
- J** No action (reference omitted from drawing as lime leaching relates to other defects)
- K** Vegetation to be removed (C41/130), and void repointed with NHL lime:sand mortar (C41/820 & 822)
- L** Rusting fixing to be removed, repair hole using appropriate mortar/repointing technique

NOTES
 Repair techniques described above may be dependent upon success of trials/samples presented in C41/190
 All proposed repair techniques must be carefully assessed on site between CA & Specialist Masonry Contractor
 Contractor to obtain instructions from CA before proceeding with any repair work



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J14-091 4021D

Scale 1:50 Date Sept 2015 Drawn MT

Drawing Title
SURVEY AS EXISTING
External East Elevation
showing Stonework Repairs


Client Cadw
 Job Title
Earl's Chamber
 Chepstow Castle, Monmouthshire

Revisions:
 D/As constructed 12/01/18

By: MT
 Q.A.: DB
 Assistant: KP


Project Leader: MT
 Designer: MT

AS CONSTRUCTED



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Certificate No FS 21557



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Whilst scaffolding is in place, Contractor is to remove all vegetation from accessible wall faces (C41/130), and voids repointed with NHL lime:sand mortar. Contractor to also carry out minimal pointing repairs only i.e. to fill voids/cracks & rake out/repoint areas of eroding mortar (C41/820 & 822)

Existing inappropriate 'clay rich' pointing (from circa 2005 repairs) to be carefully raked out from rubble core wall-top (C41/810A). Provide lime wash 'slip plane' (M20/01). Finish rubble core wall-top with 2-coat 'Prompt' natural cement/sand render capping (M20/10)

Existing inappropriate 'clay rich' pointing (from circa 2005 repairs) to be carefully raked out from wall-face (C41/810A). Repoint using NHL3.5 lime/sand mortar (C41/820)

Temporarily remove existing RW goods as required to allow access to wall top through which RWP penetrates. Ensure Prompt render capping is applied before reinstallation of RWP

Cementitious or 'clay rich' pointing to be carefully raked out from rubble core wall-top (C41/810A). Provide lime wash 'slip plane' (M20/01). Finish rubble core wall-top with 2-coat 'Prompt' natural cement/sand render capping (M20/10)

Cementitious pointing to be carefully raked out from rubble core wall-top (C41/810A). Provide lime wash 'slip plane' (M20/01). Finish rubble core wall-top with 2-coat 'Prompt' natural cement/sand render capping (M20/10)

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Whilst scaffolding is in place, Contractor is to remove all vegetation from accessible wall faces (C41/130), and voids repointed with NHL lime:sand mortar. Contractor to also carry out minimal pointing repairs only i.e. to fill voids/cracks & rake out/repoint areas of eroding mortar (C41/820 & 822)

Whilst scaffolding is in place, Contractor is to remove all vegetation from accessible wall faces (C41/130), and voids repointed with NHL lime:sand mortar. Contractor to also carry out minimal pointing repairs only i.e. to fill voids/cracks & rake out/repoint areas of eroding mortar (C41/820 & 822)

Remove existing timber packing from the existing 2no. 150x150mm approx holes through wall & carefully provide stainless steel insect mesh (2mm dia holes)

EXTERNAL SOUTH ELEVATION

KEY TO STONEMWORK REPAIRS

- A** Refer to drawings for proposed capping repair treatments to exposed rubble core walls
- B** Assess delaminating/loss of profile to stonework repair on careful selected basis (Provisional Sum in A54)
- C** Close gaps of fractured stonework using 'plastic' mortar repair or NHL lime:sand pointing (C41/530A, 820 & 822)
- D** Fractured/spalling mortar joints to be raked out (C41/810A) & repointed with NHL lime:sand mortar (C41/820 & 822)
- E** Eroded mortar joints to be raked out (C41/810A) & repointed with NHL lime:sand mortar (C41/820 & 822)
- F** Fractured mortar joint raked out & repointed as part of cover flashing replacement (H71/420 & 425)
- G** Selective raking out/repointing where cement has been used in previous repair
- H** Selective repair where inappropriate 'plastic' repair to stonework face is present (Provisional Sum in A54)
- I** Selective repair of previous repointing repairs where 'smeared' over adjacent stonework (Provisional Sum in A54)
- J** No action (reference omitted from drawing as lime leaching relates to other defects)
- K** Vegetation to be removed (C41/130), and void repointed with NHL lime:sand mortar (C41/820 & 822)
- L** Rusting fixing to be removed, repair hole using appropriate mortar/repointing technique

NOTES

Repair techniques described above may be dependent upon success of trials/samples presented in C41/190
 All proposed repair techniques must be carefully assessed on site between CA & Specialist Masonry Contractor to obtain instructions from CA before proceeding with any repair work

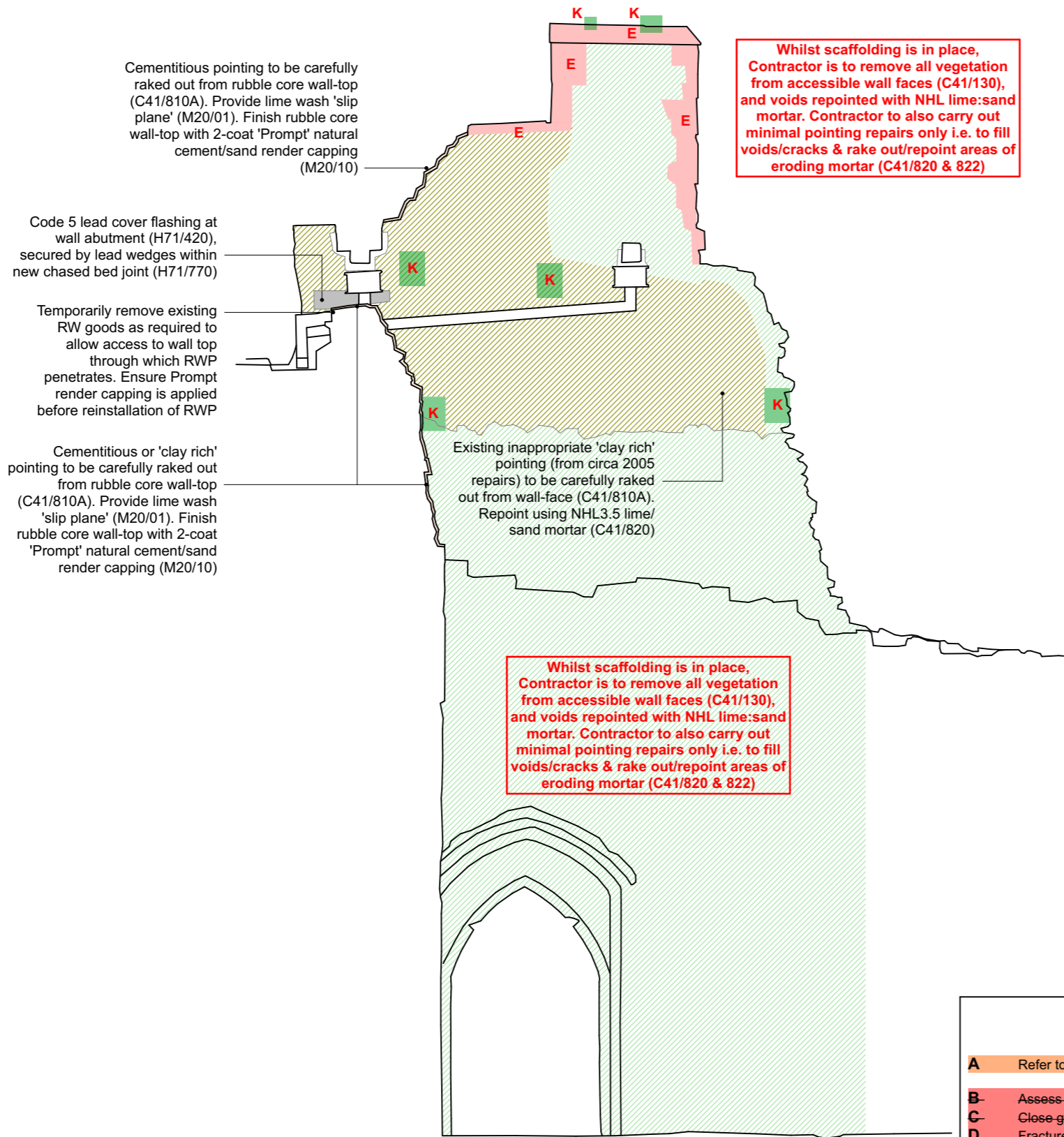
Drawing Title	SURVEY AS EXISTING External South Elevation showing Stonework Repairs		
Scale	1:50	Date	Sept 2015
Drawn	MT	Drawn	MT
J14-091		4022E	

Client	Cadw
Job Title	Earl's Chamber Chepstow Castle, Monmouthshire
AS CONSTRUCTED	

Q.A.:	DB	Assistant	KP
By:	MT	Designer	MT
Revisions:	'E' As constructed 12/01/18		
Project Leader	MT	Designer	MT

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Cementitious pointing to be carefully raked out from rubble core wall-top (C41/810A). Provide lime wash 'slip plane' (M20/01). Finish rubble core wall-top with 2-coat 'Prompt' natural cement/sand render capping (M20/10)

Code 5 lead cover flashing at wall abutment (H71/420), secured by lead wedges within new chased bed joint (H71/770)

Temporarily remove existing RW goods as required to allow access to wall top through which RWP penetrates. Ensure Prompt render capping is applied before reinstallation of RWP

Cementitious or 'clay rich' pointing to be carefully raked out from rubble core wall-top (C41/810A). Provide lime wash 'slip plane' (M20/01). Finish rubble core wall-top with 2-coat 'Prompt' natural cement/sand render capping (M20/10)

Whilst scaffolding is in place, Contractor is to remove all vegetation from accessible wall faces (C41/130), and voids repointed with NHL lime:sand mortar. Contractor to also carry out minimal pointing repairs only i.e. to fill voids/cracks & rake out/repoint areas of eroding mortar (C41/820 & 822)

Whilst scaffolding is in place, Contractor is to remove all vegetation from accessible wall faces (C41/130), and voids repointed with NHL lime:sand mortar. Contractor to also carry out minimal pointing repairs only i.e. to fill voids/cracks & rake out/repoint areas of eroding mortar (C41/820 & 822)

EXTERNAL WEST ELEVATION OF TOWER

KEY TO STONEMWORK REPAIRS

A	Refer to drawings for proposed capping repair treatments to exposed rubble core walls
B	Assess delaminating/loss of profile to stonework repair on careful selected basis (Provisional Sum in A54)
C	Close gaps of fractured stonework using 'plastic' mortar repair or NHL lime:sand pointing (C41/530A, 820 & 822)
D	Fractured/spalling mortar joints to be raked out (C41/810A) & repointed with NHL lime:sand mortar (C41/820 & 822)
E	Eroded mortar joints to be raked out (C41/810A) & repointed with NHL lime:sand mortar (C41/820 & 822)
F	Fractured mortar joint raked out & repointed as part of cover flashing replacement (H71/420 & 425)
G	Selective raking out/repointing where cement has been used in previous repair
H	Selective repair where inappropriate 'plastic' repair to stonework face is present (Provisional Sum in A54)
I	Selective repair of previous repointing repairs where 'smeared' over adjacent stonework (Provisional Sum in A54)
J	No action (reference omitted from drawing as lime leaching relates to other defects)
K	Vegetation to be removed (C41/130), and void repointed with NHL lime:sand mortar (C41/820 & 822)
L	Rusting fixing to be removed, repair hole using appropriate mortar/repointing technique

NOTES
 Repair techniques described above may be dependent upon success of trials/samples presented in C41/190
 All proposed repair techniques must be carefully assessed on site between CA & Specialist Masonry Contractor
 Contractor to obtain instructions from CA before proceeding with any repair work

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Drawing Title
**SURVEY AS EXISTING
 External West Elevation
 showing Stonework Repairs**

Scale 1:50

Date Sept 2015

Drawn MT

J14-091

4023E

Client Cadw

Job Title
Earl's Chamber
 Chepstow Castle, Monmouthshire

Q.A.: DB

By: MT

Revisions:
 'E' As constructed 12/01/18

Assistant KP

Designer MT

Project Leader MT

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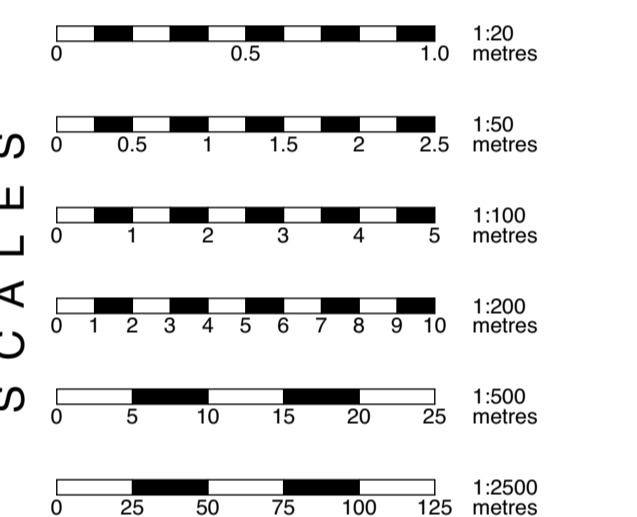
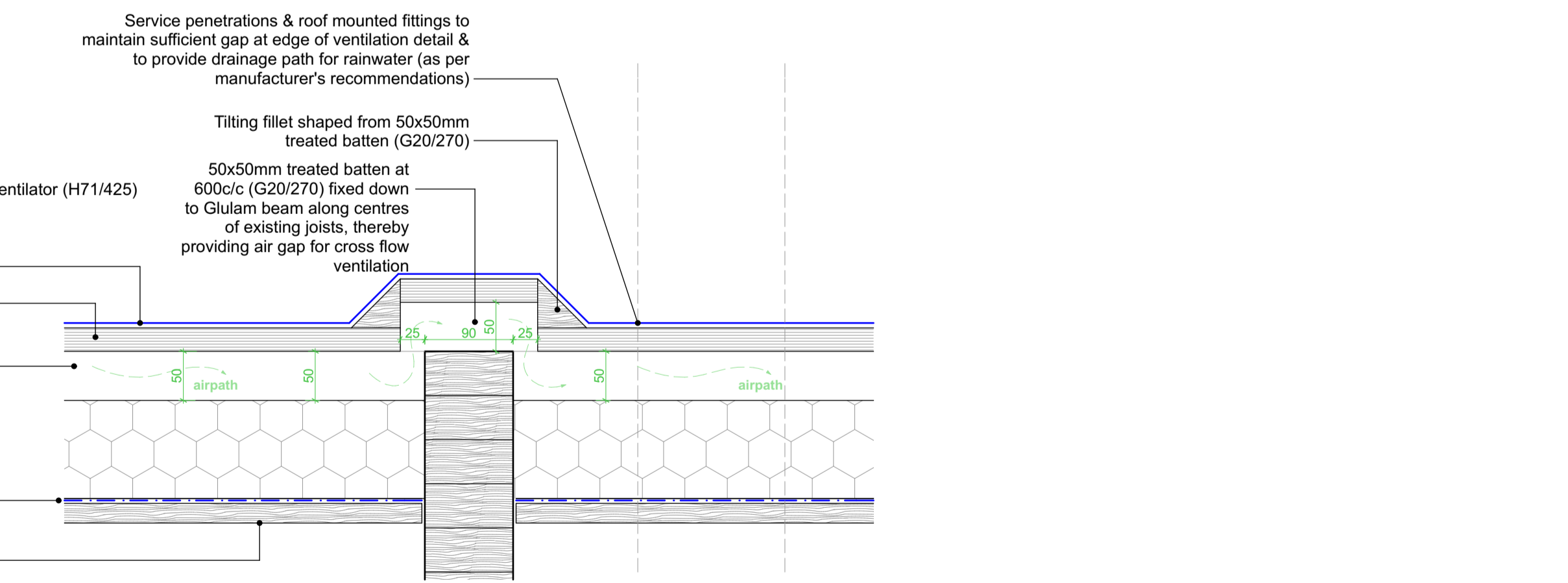
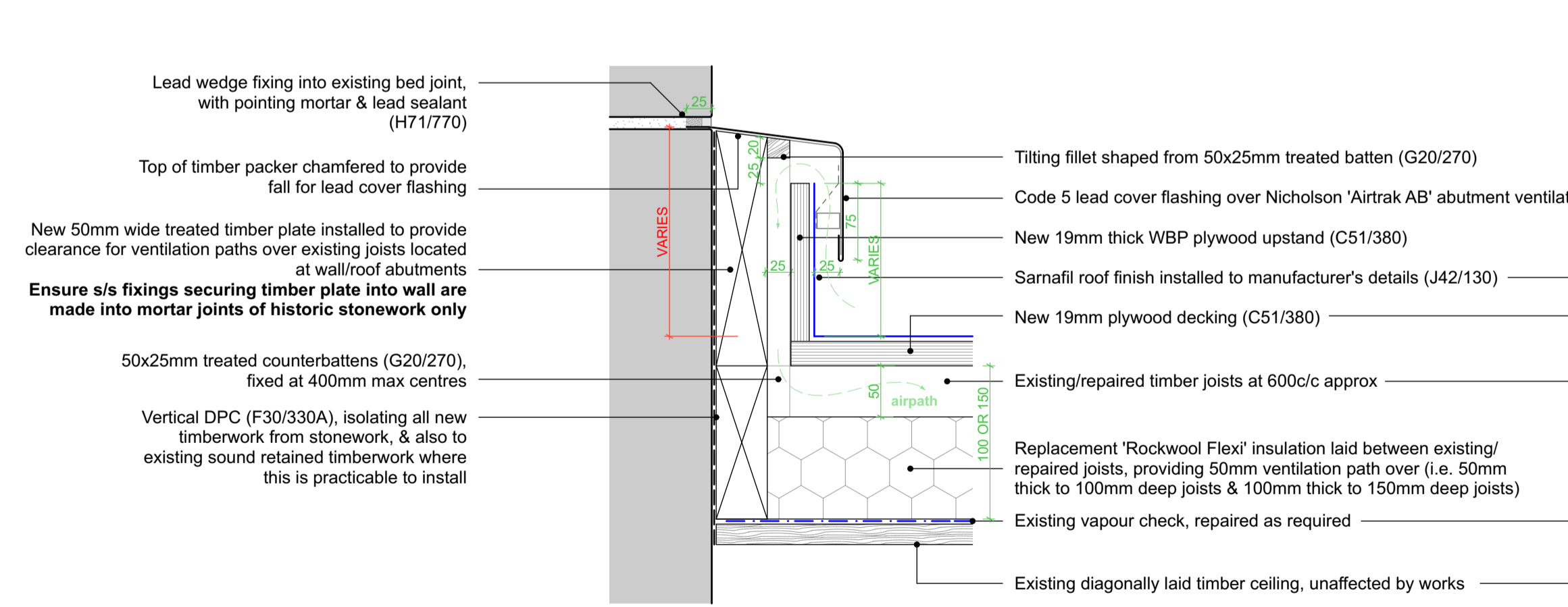
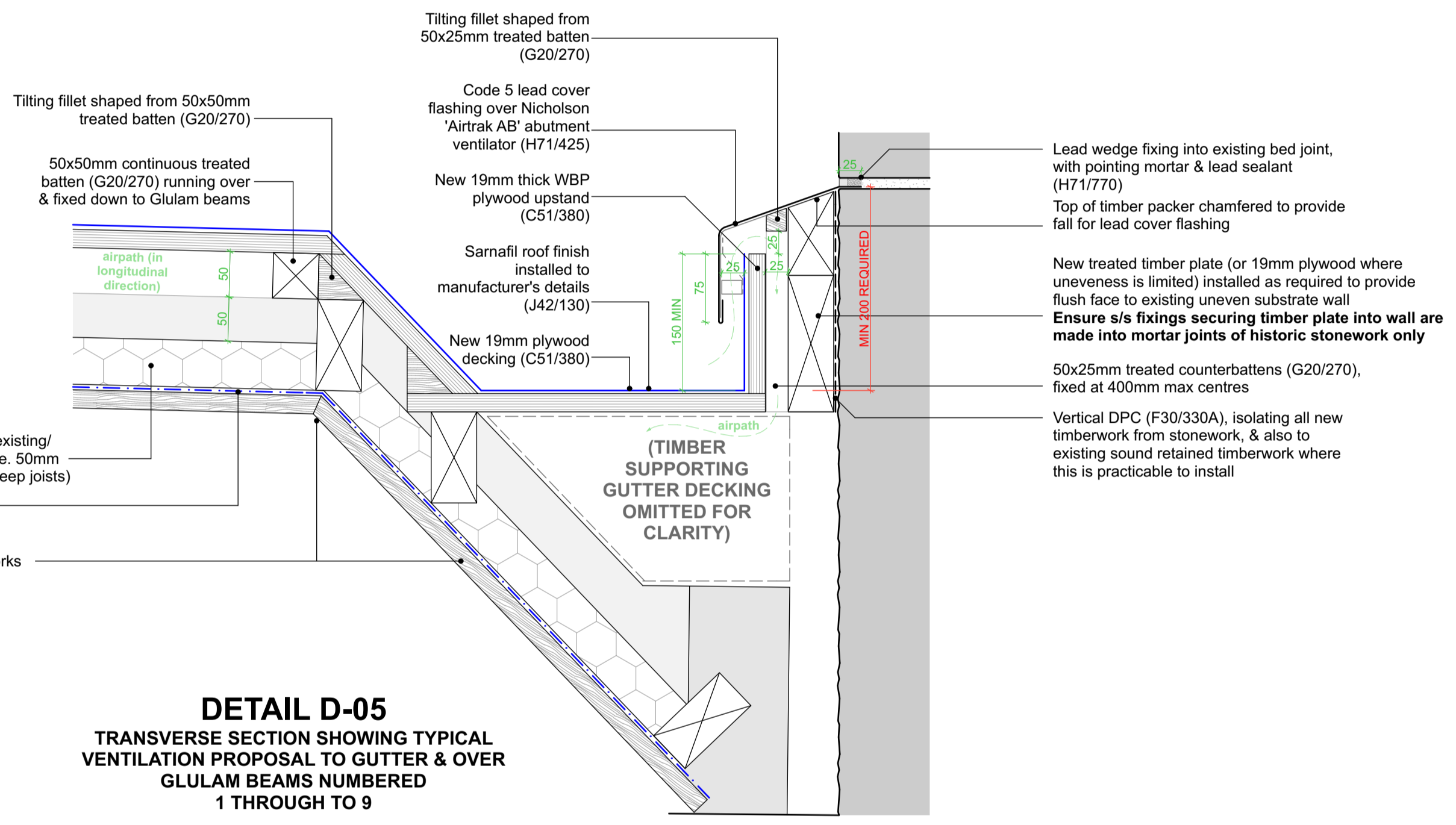
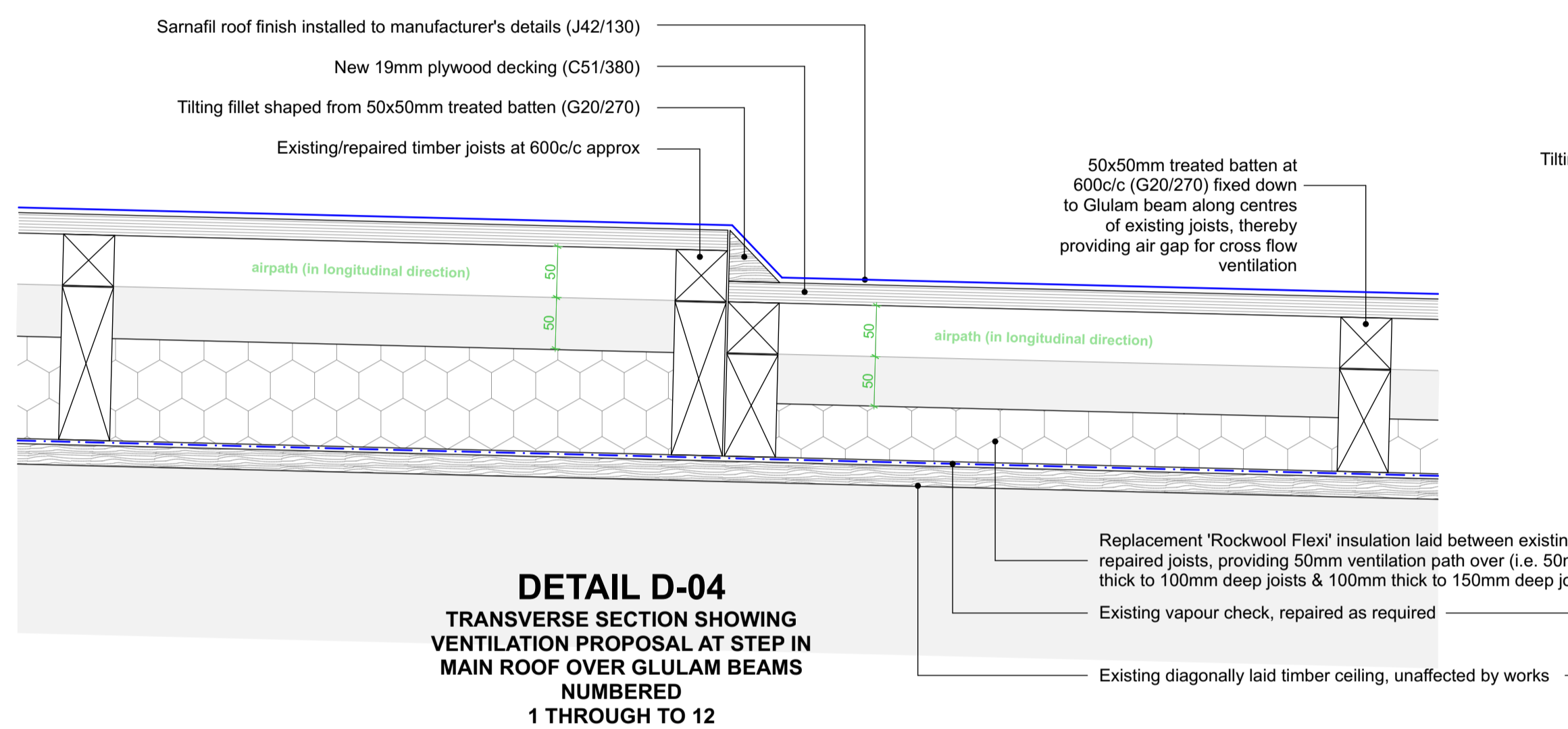
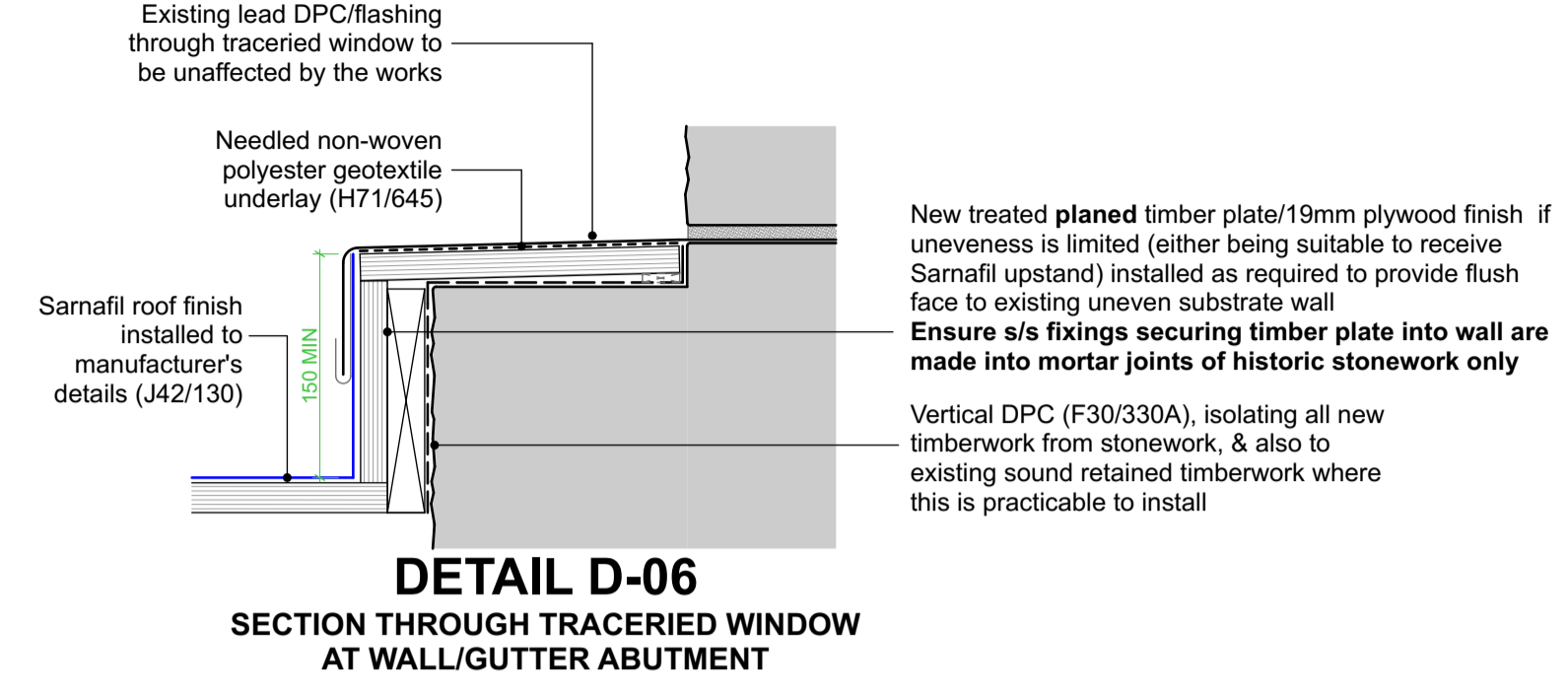
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- All materials and workmanship to comply with current British Standards and Codes of Practice.
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C	12/01/2018	As constructed	MT	DB
Rev:	Date:	Amendments:	BY:	QA:

AS CONSTRUCTED

Project Leader:	Designer:	Assistant:
MT	MT	KP

Drawing: **Proposed Details D-02 to D-06 inclusive**

Client: **Cadw**

Job Title: **Earl's Chamber**
Chepstow Castle, Monmouthshire

Date: December 2016 Scale: 1:5

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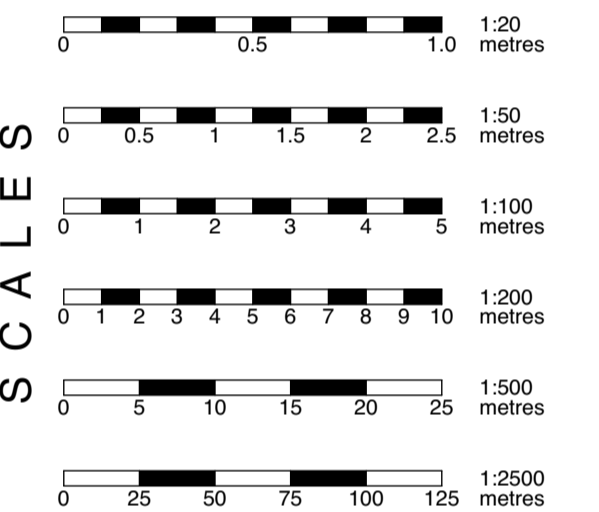
Job No: **J14-091** Dwg No: **4024** Rev: **C**

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Rev:	Date:	Amendments:	BY:	QA:
A	12/01/2018	As constructed	MT	DB

AS CONSTRUCTED

Project Leader:	Designer:	Assistant:
MT	MT	KP

Drawing:
Proposed Chimney Capping Detail

Client:
Cadw

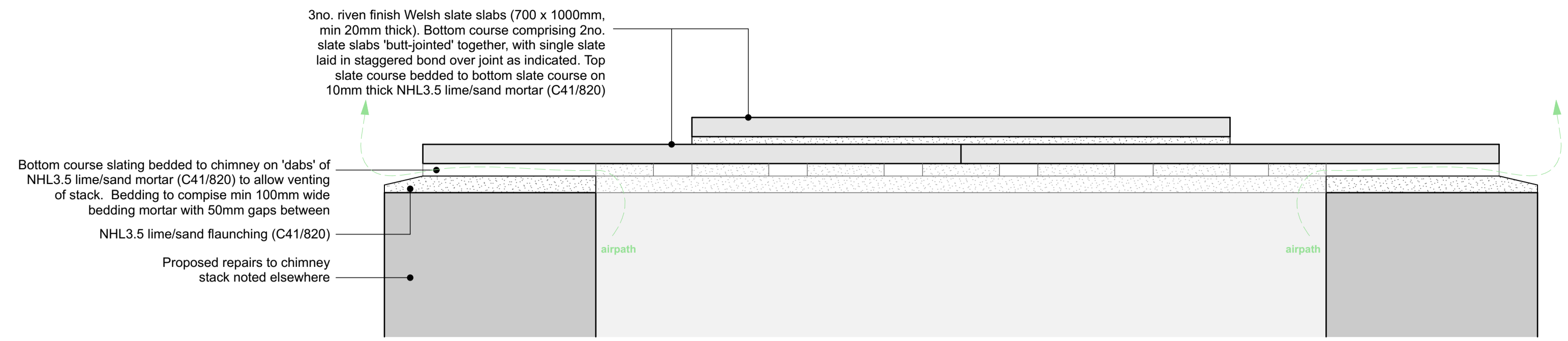
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Earl's Chamber
Chepstow Castle, Monmouthshire

Date: December 2016 Scale: 1:5

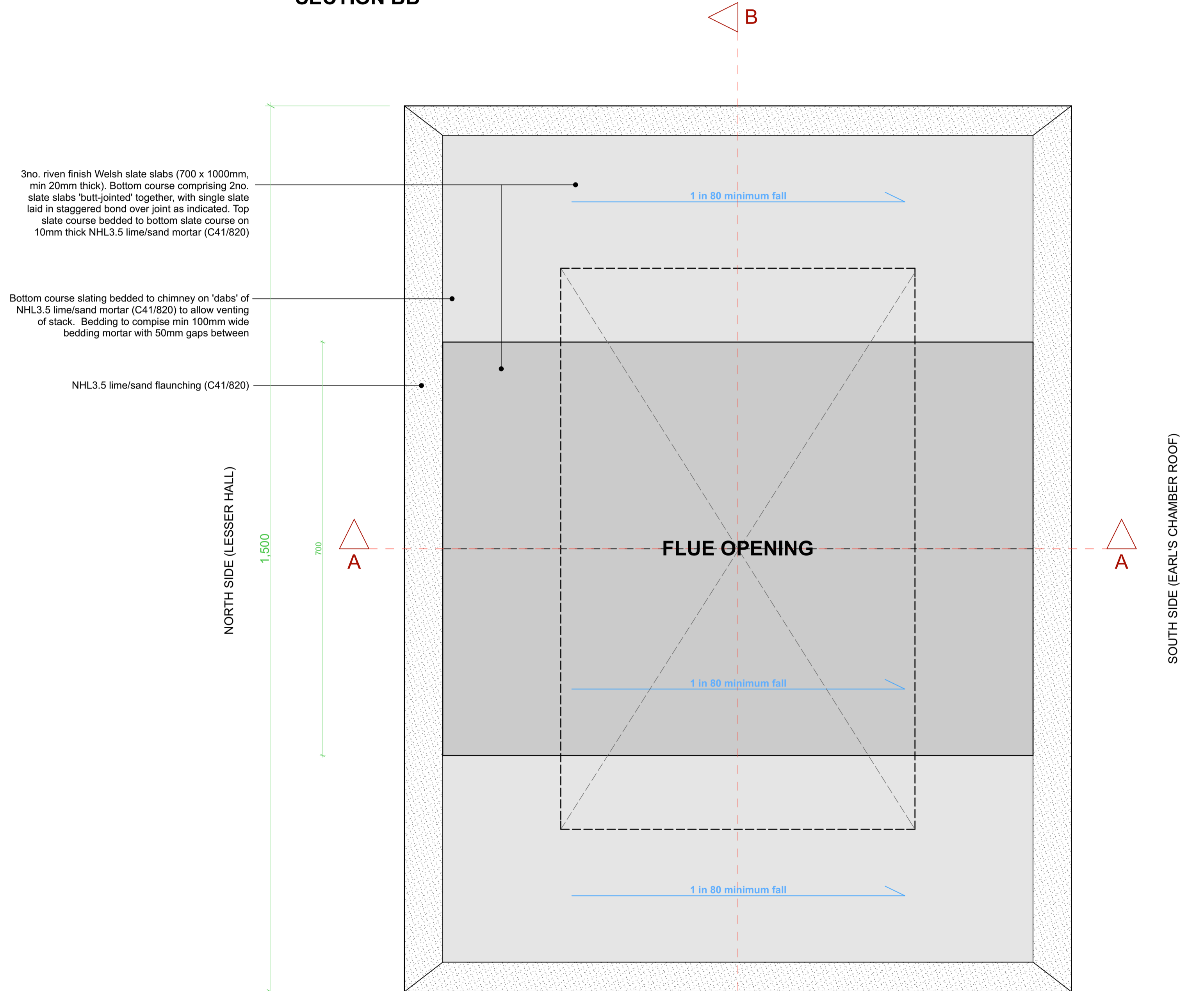
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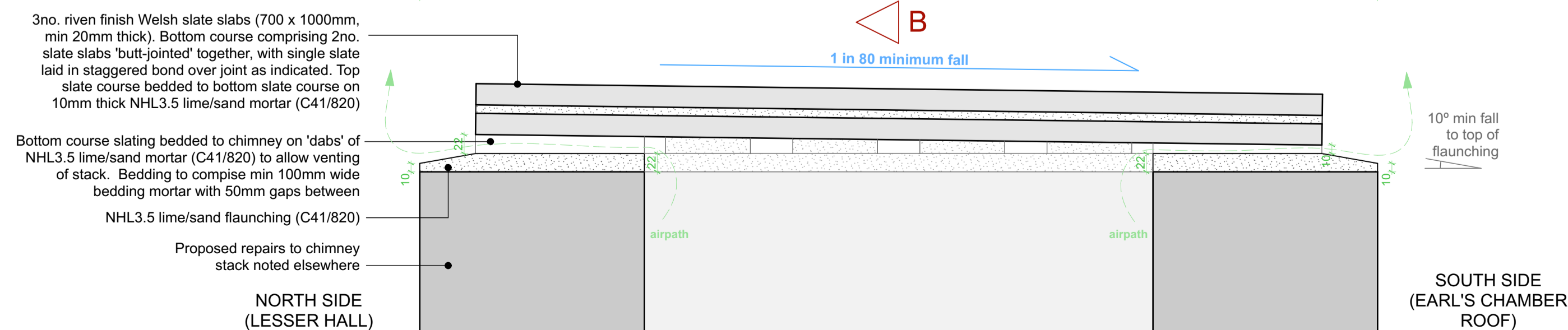
Job No: **J14-091** Dwg No: **4025** Rev: **A**



SECTION BB



PLAN SHOWING CHIMNEY CAPPING

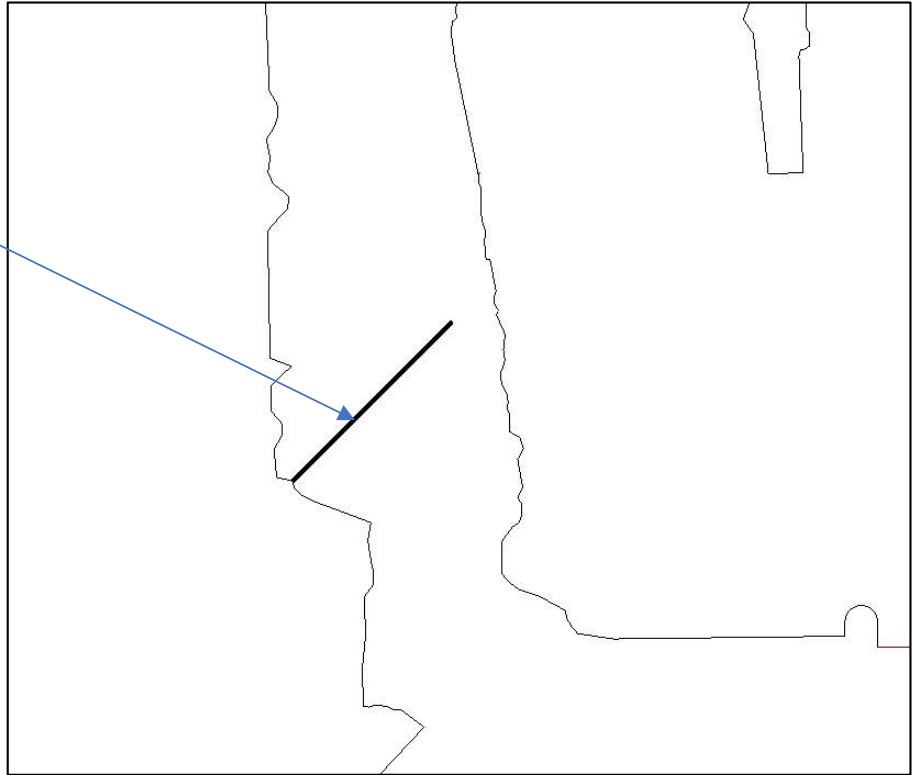


SECTION AA

EARL'S CHAMBER

CHIMNEY STABILISATION (AS CONSTRUCTED 12/01/18)

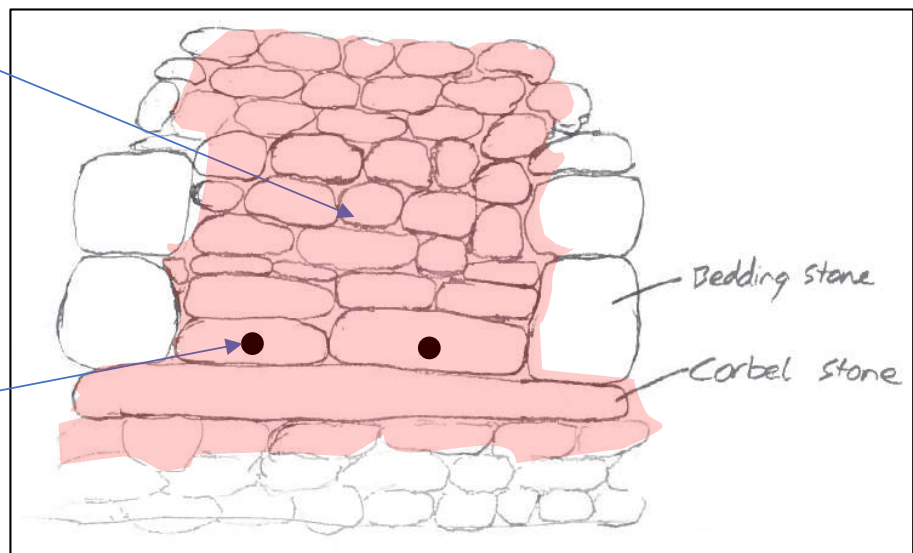
Install 2No. 700mm long 8mm dia. Helifix Cemtie bars at 45degrees into stonework, to stabilise the 2No. inner stones present above the corbel between the outer bedding stones. Bars to be installed in accordance with Helifix approved methods. To be fixed in place using Helibond cementitious grout.



SECTION

Loose and friable mortar to be raked out and repointed using NHL3.5 lime mortar as specified elsewhere. Approximate area = 3m²

Install the 2No. Helifix Cemtie bars to stabilise the 2No. inner stones present above the corbel and between the outer bedding stones. Bars to be installed in accordance with Helifix approved methods. To be fixed in place using Helibond cementitious grout.



ELEVATION

NOTES:

- Helifix Cemtie bars to be Grade 304 Stainless Steel
- Bars to be 8mm diameter, 700mm long

Our Ref: J14-091
(please quote this reference on all correspondence)

Date: 11 January 2017

Mr Paul Hughes
Cadw
Welsh Government
Plas Carew
Unit 5/7 Cefn Coed
Parc Nantgarw
Cardiff
CF15 7QQ



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Dear Mr Hughes

CRACK IN PARAPET OF GREAT HALL PORCH TOWER, CHEPSTOW CASTLE – VISUAL STRUCTURAL APPRAISAL

pdp Green Consulting Ltd were appointed by Cadw to undertake a visual structural appraisal of the crack in the north-east corner of the parapet of the Great Hall Porch Tower, Chepstow Castle and provide recommendations as required.

The inspection was undertaken on 4th January 2017 by Jane Buckroyd and Matthew Terrell of pdp Green Consulting Ltd in the presence of Paul Hughes of Cadw. At the time of the inspection the weather was dry and cold.

This report is based on data obtained from visual structural appraisal only, without the benefit of any opening up or removal of any of the fabric of the building to expose concealed structure. The inspection was therefore limited to the accessible and visible areas only. Accordingly, no guarantee can be given as to the adequacy or otherwise of any parts of the structure and its related system which cannot be seen.

Only defects which are considered to be relevant for the purposes of this report are mentioned below. It follows therefore that there may be old cracks, repairs and other blemishes which may be visible but not mentioned in the report.

Any use of this report without the authorisation of pdp Green Consulting Ltd will be entirely at the risk of the user.

Observations

- On the eastern elevation of the parapet in the north-east corner of the turret there is a large crack within the mortar joint adjacent to the quoins. The crack is widest (approximately 15mm) immediately below the coping stone (Photo 1). The crack runs in the vertical mortar joint down for approximately 1400 mm before diminishing completely. Temporary restraint to the quoins has been provided in the form of ratchet straps as per previous recommendations by pdp Green Consulting Ltd (Photo 2).



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Architecture, Structural & Civil Engineering

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- On the northern elevation there is a similar but less severe crack in the mortar joint adjacent to the same quoins (Photo 3). On this side the crack appears to be approximately 6mm at its widest point below the coping stone (Photo 4).

Conclusions

In our opinion, the crack in the mortar joint adjacent to the quoins has formed due to the effects of weathering over time from a combination of water ingress, freeze-thaw action and growth of organic material within the mortar joint.

It was noted that while the crack is typically widest near its top, there is no significant cracking through the coping stone or in the mortar joint adjacent to the coping stone atop the wall. For this pattern to have occurred is likely that the corner coping stone has been repositioned and rebbed (possibly when the wall was repointed) since the crack developed. There is only a very minor crack in the mortar joint adjacent to the coping stone which would indicate, if our hypothesis is correct, that there has not been significant movement since the coping stone was reset and supports the theory that this crack developed slowly over a much longer period of time.

Recommendations

The following repair procedure is recommended as it minimises intrusive/invasive work and the disturbance of existing masonry is limited as far as practicable.

- Before the removal of any stone, the exact position and orientation of each stone to be removed should be recorded with care such that later reinstatement will accurately reflect the original construction.
- Carefully dismantle and remove the corner coping stone and the stone work below including three quoins to the extent indicated on sketches J14-091-STR-SK-004 and J14-091-STR-SK-005.
- Remove old mortar and any debris and organic material from the exposed interface of the masonry where stonework has been removed. Similarly, remove any remains of old mortar from the faces of the individual stones that have been removed.
- Chase out the old mortar bed joints to a depth of 50mm in the locations indicated for placement of HeliBar (helical stainless steel reinforcing bar) in sketches J14-091-STR-SK-004 and J14-091-STR-SK-005. At the furthest extent that bars are indicated on the sketches, drill 10mm diameter hole 100mm further embedment normal to the face of the wall as shown in sketch J14-091-STR-SK-003 using a non-percussive drill.
- Secure U-shaped 6mm diameter HeliBars into the chase, with one leg in the drilled hole using HeliBond grout applied in strict accordance with the manufacturer's specification but leaving the outer 15mm of the joint to be finished with lime mortar to ensure a consistent finish to all the remedial works. The other part of the HeliBar will be placed in the new lime mortar bedding joints of the reinstated stonework on the corner.
- Reinstatement the dismantled corner stonework in a position that would reflect their original location using lime mortar to bedding and vertical joints. External edges of the quoins should be plumb and the mortar joint in the vertical interface a consistent

width, i.e. correcting the previous movement. The ends of the HeliBars which are acting as ties between original and reinstated masonry are to be placed within the new lime mortar bedding joints of the reinstated masonry as shown in sketches J14-091-STR-SK-003, J14-091-STR-SK-004 and J14-091-STR-SK-005.

- Repointing of the mortar joint adjacent to the quoins is also required for a minimum of 600 mm below the reinstatement works to repair the continuation of the crack where it is less significant.

Please do not hesitate to contact me if you require further information.

Yours sincerely



JANE BUCKROYD
Senior Structural Engineer

Pdp Green Consulting Ltd

Attachments:

Attachment A – Photographs

Attachment B - Sketches

Attachment A - Photographs



Photo 1: Widest point of crack in eastern elevation



Photo 2: Crack visible in eastern elevation under temporary restraints



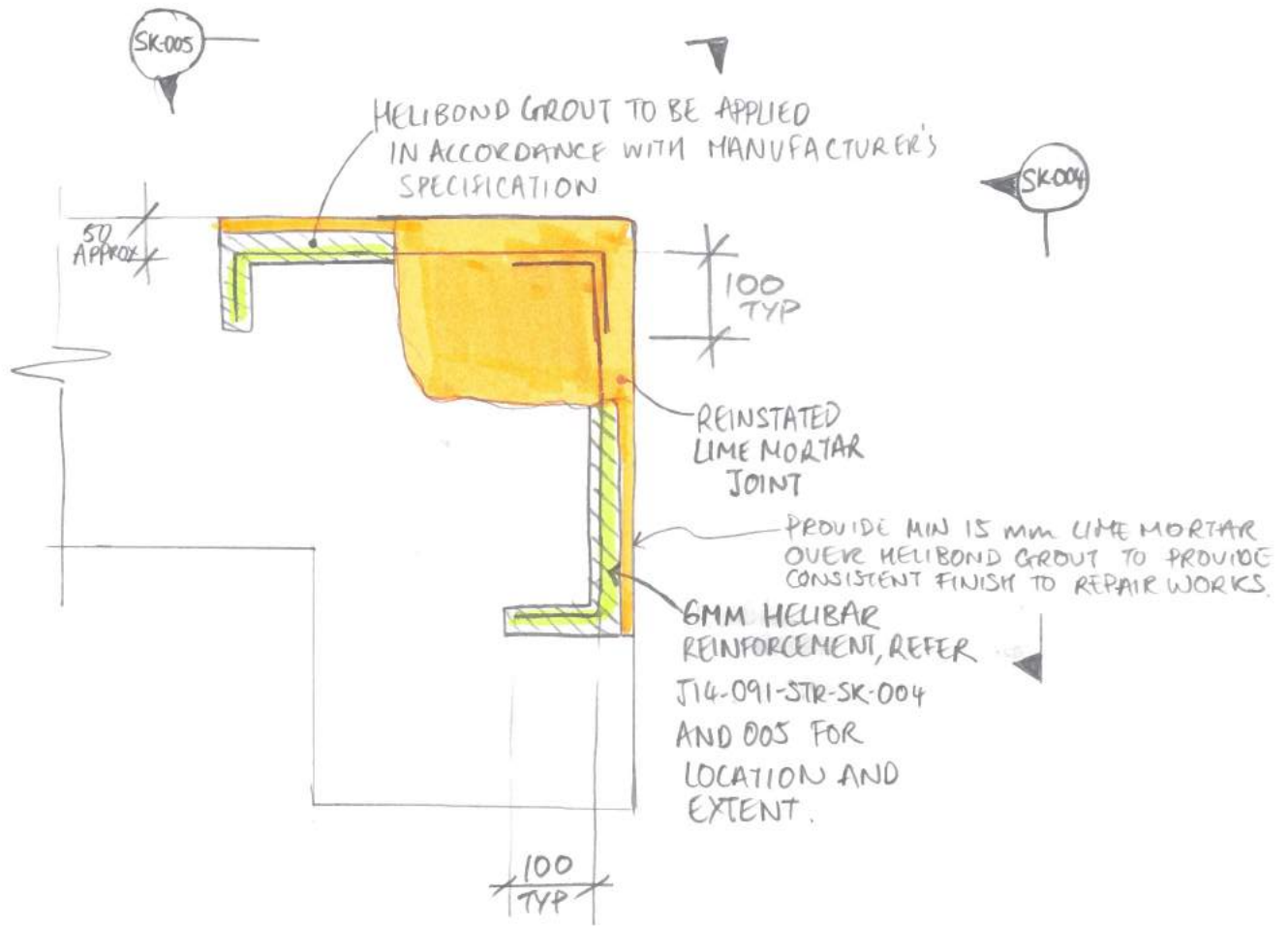
Photo 3: Crack visible in northern elevation under temporary restraints




Photo 4: Widest point of crack in northern elevation

Attachment B - Sketches

PLAN THROUGH MORTAR JOINT SHOWING REMEDIAL WORKS TO PARAPET OF NORTH-EAST CORNER OF GREAT HALL PORCH TOWER



J14-091-STR-SK-003
09/01/17 JB

 INDICATES EXTENT OF STONEWORK TO BE DISMANTLED AND REINSTATED.

 INDICATES POSITION OF REINBAR IN MORTAR JOINT



J14-091-STR-SK-004
09/01/17

JS

(TO BE READ IN
CONJUNCTION WITH
J14-091-STR-SK-003
& 005)

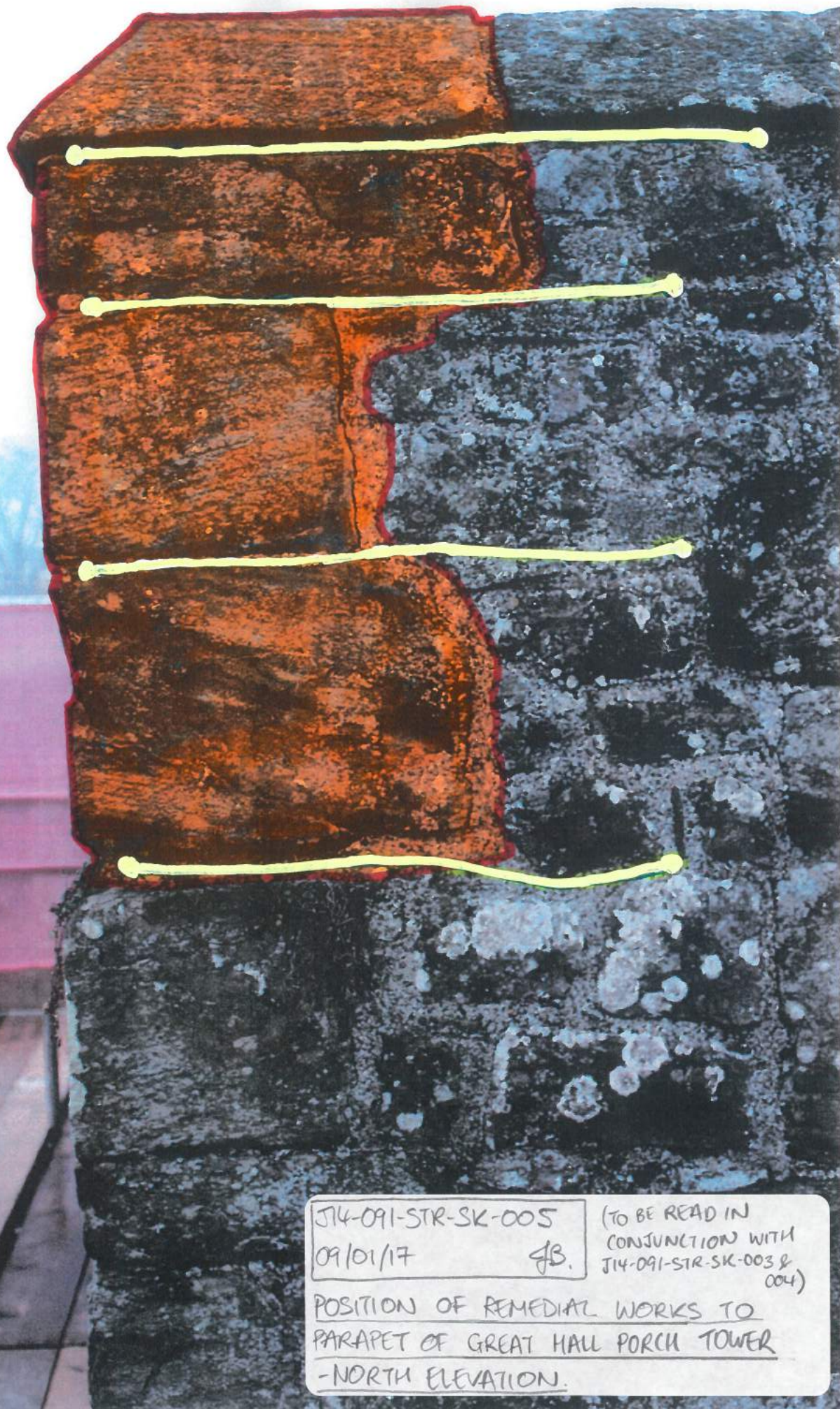
POSITION OF REMEDIAL WORKS TO
PARAPET OF GREAT HALL TOWER
- EAST ELEVATION



INDICATES EXTENT OF STONEWORK TO BE DISMANTLED AND REINSTATED.



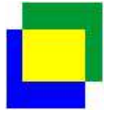
INDICATES POSITION OF HELIBAR IN MORTAR JOINT



J14-091-STR-SK-005
09/01/17 J.S.

(TO BE READ IN
CONJUNCTION WITH
J14-091-STR-SK-003 &
004)

POSITION OF REMEDIAL WORKS TO
PARAPET OF GREAT HALL PORCH TOWER
-NORTH ELEVATION.



APPENDIX 4

Archaeological Watching Brief Report

Watching Brief Report

28th November 2016

Chepstow Castle (MM003)



Figure 1. Chepstow Castle



Llywodraeth Cymru
Welsh Government

This watching brief report has been produced within the Historic Environment Branch of Cadw.

Cadw, Welsh Government
Plas Carew
Unit 5/7 Cefn Coed
Parc Nantgarw
Cardiff CF15 7QQ

Telephone: 01443 336000

Email: cadw@wales.gsi.gov.uk

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Cadw yw gwasanaeth amgylchedd hanesyddol Llywodraeth Cymru, yn gweithio i sicrhau amgylchedd hanesyddol hygyrch a ddiogelir yn dda i Gymru.

Cadw is the Welsh Government's historic environment service, working for an accessible and well-protected historic environment for Wales.

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Contained within this report:

1. Summary Description..... 5
 Additional information: 7
2. Non-Technical Summary 8
3. Objectives 8
4. Watching Brief Report..... 8
5. Conclusions 9
6. Map of the Scheduled Area showing location of excavation 10
7. Photographs..... 11

SAM name and reference number	MM003 Chepstow Castle
Grid reference	ST 533 940
Cadw funded schemes (MA /AM Grant)	None Current

Non-Historic Environment Designations	None
--	------

Report produced by Cadw FMW	<p>Dr Amelia Pannett Field Monument Warden Cadw Welsh Government Tel: 01633 866410 Mobile: 07837 213453 E-mail: amelia.pannett@wales.gsi.gov.uk</p>
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I. Summary Description

The following provides a description of the Scheduled Ancient Monument.

This monument comprises the remains of a medieval castle begun in 1067 by William fitz Osbern, earl of Hereford. It is situated on a limestone promontory on top of tall cliffs overlooking the river Wye. The castle dominated the medieval town that developed around its foot; the bridge which provided access for travellers into south Wales; and the river which was a main highway of the period.

The oldest building in the castle is the Great Tower. Rectangular and measuring 36m long by 14m wide, it dominates the centre of the castle. The tower contains some reused building materials, probably brought from the ruins of the Roman town Venta Silurum – modern day Caerwent. It was probably used as an audience chamber – a place where the King conducted ceremonial or judicial functions.

Connecting the Upper and Middle Baileys is the gallery, a single-storey building which formed a roofed passage. The Upper Bailey is likely to have been the centre of William fitz Osbern's original Norman castle. The end of the Upper Bailey is closed by Marshal's Tower – a two storey rectangular tower built by William Marshal (d. 1219) in the very early thirteenth century. The first floor contains the remains of an elegant chamber lit by five finely dressed windows.

Beyond the Upper Bailey gateway is a small defended platform which crosses a deep, rock-cut ditch to the Upper Barbican. This ditch marks the western limit of the castle under the Normans and William Marshal. The heavily defended Upper Barbican was created in the second quarter of the thirteenth century when the defensive line was extended further along the promontory to the west. The curtain wall runs from Marshal's Tower in the Upper Bailey across the ditch to the south-west tower. From the south-west tower the curtain wall curves around to the Upper Gatehouse. From this gatehouse access there was access to the castle's gardens and the home farm. The curtain wall continues to cut off the end of the promontory and returns for a short length to deter any attackers from clambering around the cliff into the castle.

The walls and towers of the Middle Bailey were added to the castle by William Marshal in the late twelfth century as part of his complete remodelling of the castle's defences. However, the break in slope near the centre of this bailey may mark the position of the western defences of the Norman castle. The entrance to the Middle Bailey is through a simple gateway in the curtain wall which is protected by a three-storey D-shaped tower projecting forward from the curtain wall. A low curtain wall links this tower to another of very similar design at the outer angle of the middle bailey, but this was significantly modified with the insertion of fireplaces and doorways during the early sixteenth century. The curtain wall returns from the corner tower to a D-shaped tower – modified during the Civil War. The Middle Bailey does not seem to have contained any buildings in the Middle Ages, perhaps because they would have reduced the grandeur of the approach to the main entrance of the great tower.

The Lower Bailey is the most complicated part of the castle with buildings of many different periods represented. The bailey was added to the castle by William Marshal in the late twelfth century and substantially remodelled by Roger Bigod a hundred years later with the construction of a large domestic range and Marten's Tower. Bigod developed a suite of apartments and lodgings appropriate for one of the richest magnates of King Edward I's reign. The domestic range consisted of two adjoining blocks linked by a central service passage, built to take advantage of the changes in height across the site. The hall and ceremonial and private chambers of the earl occupied the higher ground to the west, and the service rooms, kitchen and additional accommodation were constructed below. The earl's chamber (known as the 'gloriette') was situated above the service rooms. This room would have been a combination of bedchamber, a private sitting room and an audience chamber. To earn the name gloriette, this chamber must have been very special or exotic. Close to the entrance of the castle, Marten's Tower, or the 'New Tower' as it was referred to in Roger Bigod's accounts, was started around 1288 and brought into use by 1293. It was begun after the earl's domestic apartments had been completed and almost certainly replaced an earlier tower dating from the Marshal period. Marten's Tower has been described as a 'mural tower to end all mural towers', but it is far

more than a simple defensive work. In addition to the three storeys visible from the courtyard, there is a basement, a room in the roof space and a private chapel carried out over the curtain wall to the east. The castle well is just alongside the door.

The Main Gatehouse is of revolutionary design. It consists of two round towers of slightly different diameter built close together and well equipped with arrowloops to provide a wide field of fire. Outside there was a small barbican which further protected the entrance. The round tower to the left was the castle's prison and that to the right was a guardroom. This is thought to be the oldest twin-towered gatehouse in Britain and demonstrates that William Marshal and his master craftsmen were at the forefront of castle design, building on their experiences in France and the Holy Land.

A number of wooden doors have survived at Chepstow Castle and these have been dated using dendrochronology (tree-ring dating). The doors in the upper and middle bailey gateways at Chepstow are made of two layers of elm and oak boards, clenched together with a regular pattern of iron nails. At over 800 years old, they are believed to be the oldest castle doors surviving in Europe.

This monument is of national importance for its potential to enhance our knowledge of medieval social and domestic life and warfare. The scheduled area comprises the remains described and an area around them within which related evidence may be expected to survive.

Additional information:

The watching brief was carried out during the excavation of a cable trench to allow new electrics to be fitted to the Buttery and Earl's Chamber. The new cable trench was designed to follow the line of an existing cable trench which ran through the Great Hall.

2. Non-Technical Summary

The watching brief was undertaken during the hand excavation of an electricity cable trench through the Great Hall.

All of the material that was disturbed during the excavations was modern, largely comprising the backfill of an earlier cable trench.

No features of archaeological interest were revealed.

3. Objectives

To ensure that no features of archaeological significance were impacted by the groundworks.

4. Watching Brief Report

The watching brief was undertaken on the 25th October 2016 by Dr Amelia Pannett. It was carried out in dry conditions.

The cable trench extended for roughly 20m from the door of the Buttery to the junction box housed in the base of the tower at the SW end of the Great Hall. The trench varied in width between 0.3m and 0.4m, and was excavated to reveal the existing cables in the base of the trench, which were 0.35m below the modern ground surface in the Great Hall and 0.15m below the surface in the tower.

The short section of cable trench within the tower cut through a deposit of brownish sand. To connect with the cable trench in the Great Hall, the existing cables had been fed through a hole made in the mortar between stones in the step. The new cable was fed through the same hole in the mortar.

Within the Great Hall the upper deposit in the trench comprised a modern red sandy gravel that was around 0.05m thick and which covered the whole floor. This overlay a layer of redeposited topsoil containing numerous stones and some modern rubbish (plastic wrappers, a tango can, off-cuts of copper wire and plastic hazard tape), which was 0.2m thick. The base of the cable trench was filled with a deposit of

sterile sand, 0.1m thick, which overlay the existing electricity cables. The section revealed that the base of the original trench had cut through a red/brown clay soil containing stones and fragments of brick.

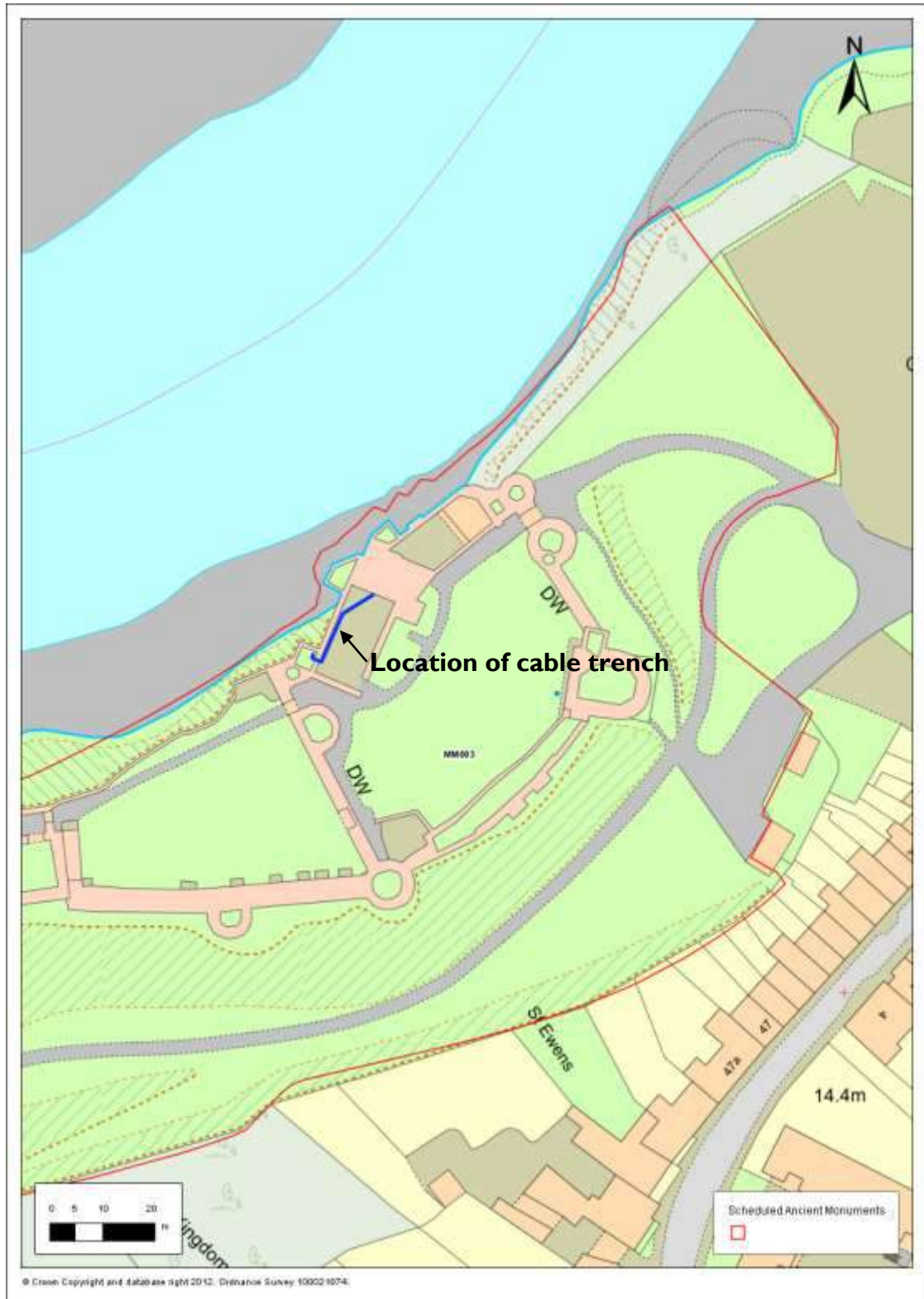
The new trench had to deviate slightly from the existing trench in the area below the wooden stairs leading to the Earl's Chamber as the support post for the stairs had been positioned directly over the earlier trench. The new trench cut through 0.6m of ground not previously disturbed by trenching, but no deposits different from those identified elsewhere in the excavation were revealed.

No finds or features of archaeological significance were identified during the excavation of the electricity cable trench.

5. Conclusions

No features of archaeological interest were revealed or damaged during the groundworks.

6. Map of the Scheduled Area showing location of excavation



7. Photographs



Figure 2. Existing cables exiting the junction box



Figure 3. Cables fed through a hole in the mortar within the step between the tower and the Great Hall



Figure 4. View NE along cable trench



Figure 5. Section of cable trench



Figure 5. Cable trench under stairs showing slight deviation required to pass around the support post for the stairs.



APPENDIX 5

**Historic Mortar Analysis Report,
prepared by Peter Ellis – Historic Buildings Consultancy**

Our Ref: J14-091/MT
(please quote this reference on all correspondence)

1st November 2016

FAO Peter Ellis
Rose of Jericho
Horchester Farm
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Dear Peter

Mortar Samples, Earl's Chamber, Chepstow Castle

Please find enclosed three mortar samples requiring testing, in order to identify the constituents and proportions of the mortars. These are required so that we can develop repair proposals at the above site, including appropriate 'matching' of the hearing mortar using appropriate modern lime-based materials.

1. **Repointing mortar extracted from wide joint within centre of southern wall:** This appears to be representative of the repointing throughout Earl's Chamber, suspected to result from repair work circa 1985, and highly likely to contain OPC (due to hard/brittle nature).
2. **'Hearing' mortar, obtained from 'behind' repointing mortar described above:** We anticipate that this is a sample representative of the mortar mix arising from the original construction phase.
3. **'Hearing' mortar, obtained from wide joint to RH-side of door in northern wall:** We anticipate that this is a sample representative of the mortar mix arising from the original construction phase.

We understand that you will issue us with an invoice for £720.00 (ex VAT), following distribution of the sample analysis reports. We also appreciate you usually operate to a 3-4week lead-time, but with this project being on site we would be extremely grateful if you are able to improve upon this, as together with the Principal Contractor we are working to a tight programme.

We look forward to receiving the results at your earliest convenience, and many thanks for your assistance in advance. Please do not hesitate to call should you have any further queries.

Yours sincerely

Matt Terrell
Associate Architect
pdp Green Consulting

Enc. Bagged mortar samples, numbered as described



pdp Green Consulting Ltd

Architecture, Structural & Civil Engineering

Registered in England and Wales No: 03016834

Peter Ellis

Historic Buildings Consultancy
Materials, Method and Mortar Analysis

Matt Terrell Esq
pdp Green Consulting Ltd
Unit 3, Calenick House
Heron Way
Truro TR1 2XN

Dear Matt

**Chepstow Castle, Earl's Chamber.
Results summary. Test Reports 4578 – 4580.**

I enclose the results of my analysis of the three mortar samples.

The two hearting samples 2: 4579 and 3: 4580 are similar mortars. They are crudely mixed non- (or very weakly) hydraulic lime mortars. Many 'nodules' of unmixed lime probably indicate the mortars to have been produced using the so-called 'hot-mix' method. Interestingly, neither mortar has carbonated, presumably due to their location in the core of the wall, and probably also a continually moist environment, but despite this these mortars have the appearance of significant age, and are likely to be early construction mortars. The aggregate in both mortars is rounded particles of mixed mineral and geological types, almost certainly collected from the Wye riverbank. The clay and silt proportion is low.

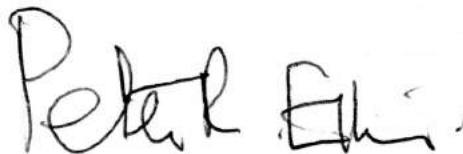
I have suggested lime putty plus pozzolan as an accurate matching repair mortar, although Natural Hydraulic Lime NHL2 could also be considered. A washed aggregate with mixed rounded 8mm or 10mm particles will be difficult to source, and I assume that quarrying the riverbank would be out of the question. Bristol grit may be a reasonable match, and although the Bristol Channel is not being dredged for sand at present, I believe that the Cornish Lime Company has stocks. It will probably need to be sieved to 10mm and you should check that it has been washed to remove salts and silt.

The re-pointing mortar sample 1: 4578 is clearly later and is more hydraulic than the two hearting mortars. It is relatively soft however, and although probably a weak cement lime/blend, hydraulic lime cannot be totally discounted. The aggregate is principally fine quartz although larger rounded particles of various geological types are also present, as is, slightly confusingly, occasional particles of coal ash.

Clearly, if this mortar is a cement/lime blend, a strict like-for-like match should not be considered, and Natural Hydraulic Lime is more likely to be appropriate. I understand that the proposed repairs are deep and surface external re-pointing and you may wish to consider NHL3.5 especially as these works are to be undertaken in winter, although it is extremely important that the mortar remains both more porous and more permeable than the masonry. Note that hydraulic limes (and cements) continue to gain strength over time and there is an inverse relationship between porosity and permeability in relation to compressive strength.

Please do contact me if you would like to discuss

Yours sincerely



Peter Ellis FSA

December 7, 2016

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Mortar Analysis**Test Report No. 4578.****Chepstow Castle – Earl's Chamber****Sample 1. Re-pointing Mortar.**

One sample of re-pointing mortar, (weight 28.0g), collected from a wide joint in the centre of the southern wall and thought to date from the circa 1985 repair phase has been analysed chemically and microscopically.

Sample Assessment, Preliminary Tests and Observations:

Fairly dry sample. Generally un-carbonated (phenolphthalein carbonation test). Disrupted moderate (variable?) strength (small thin brittle fragments could be broken by hand with moderate ease but not crumbled in fingers; crushed with moderate ease using pestle) pale cream-grey mortar fragments and powder. Aggregate is principally fine quartz but occasional rounded particles of various mineral and geological types are present. Apparently well-mixed. Occasional fuel ash particles (apparently coal ash) noted. Calcareous aggregate (limestone) determined. Fibre re-inforcement not found.

Reaction Comments:

Vigorous effervescence on addition of dilute hydrochloric acid.

Chemical Dissolution Analysis (% dry mass) to BS4551:2005+A2:2013 (+ICP-OES).

%	Initial Moisture (oven @ 105°C)	4.75
%	Total Calcium as CaO (titrimetric method)	16.5
%	Total Magnesium as MgO (titrimetric method)	0.896
%	Acid & alkali soluble Silicon as SiO ₂ (gravimetric method)	1.81
%	Total (acid-soluble) sulphate as SO ₃ (gravimetric method)	0.479
%	Soluble Aluminium as Al ₂ O ₃ (ICP-OES method)	0.802
%	Soluble Iron as Fe ₂ O ₃ (ICP-OES method)	0.524
%	Total Acid Insolubles	63.9

BINDER

The binder(s) in this sample is hydraulic as confirmed by the soluble silica and aluminium test results and is either a cement/ lime blend or hydraulic lime. It has not carbonated. The sulphate result confirms that gypsum was not a deliberate original mix ingredient.

AGGREGATE

Insoluble particle size range: 4.10mm to 63µm (97.0%) : <63µm (3.0%)

The insoluble residue comprises principally:

Fine yellow/brown Quartz

Occasional rounded particles of various mineral types

Yellow-brown clay (in very low proportion)

Occasional fine fuel ash (apparently coal ash) particles. (Kiln-fuel residue)

(cont.)

TEST REPORT 4578 (page 2)

MORTAR BY VOLUME

Acid-soluble calcareous sand/aggregate particles (limestone) were observed to be present and an allowance has therefore been made. The results adjusted for typical bulk density indicate a calculated volumetric mix of **approximately:**

1 part	Cement	Or:	1 part Hydraulic lime
2 parts	Lime		2.5 parts Aggregate
9 parts	Aggregate.		

SUGGESTED MATCHING MIX

This is not a specification for a repair mortar, nor must it be treated as one.

If this mortar were to be matched on a 'like-for-like' basis, the following approximate volumetric matching mix recipe might be helpful.

This does not necessarily imply that we recommend a 'like-for-like' repair mortar mix design in this particular situation, as there are many relevant factors in addition to mortar analysis that must be taken into account.

1 part	Ordinary Portland Cement* (CEM 1)
2 parts	Non-hydraulic hydrated lime
8 to 9 parts	Washed mixed quartz sand <4.10mm

***Note:** The use of Portland cement for historic building repair is generally considered inappropriate, and consideration should be given to the use of a Natural Hydraulic Lime (NHL3.5?) at c. 1: 2.5 by volume in place of cement and lime.

SOURCES OF MATERIALS

Many limes, sands, stonedusts and aggregates are available from **Rose of Jericho.**

NOTES:

1. Sample mixes must always be prepared to ensure suitability and an accurate colour and texture match.
2. Aggregates with a particle size and grading appropriate for the intended use must be selected. Sands conforming to the relevant British/European Standard should be used especially with **hydraulic** limes.
3. The repair mortar should be no weaker than 1: 2½. Manufacturers advice should be sought and recommended application mix proportions and 'Best Practice' guides must be complied with.
4. It should be remembered that mortars change over time. When analysing an aged material, one is ascertaining what it now is and looking for evidence for what it originally was. Calcium hydroxide carbonates to form calcium carbonate, and calcium silicate hydrate (C-S-H), the principal reaction product in hydraulic limes and pozzolanic limes itself reacts over time with carbonic acid to produce calcium carbonate and hydrous siliceous, aluminate and silico-aluminate gels.

06.12.2016

Mortar Analysis**Test Report No. 4579.****Chepstow Castle – Earl's Chamber****Sample 2. Hearting Mortar.**

One sample of hearting mortar, (weight 24.8g), collected from the centre of the southern wall behind the re-pointing mortar (Sample 1: 4578) and believed to be the original early mediaeval construction mortar, has been analysed chemically and microscopically.

Sample Assessment, Preliminary Tests and Observations:

Moist sample. Generally un-carbonated (phenolphthalein carbonation test). Disrupted cream-grey powdered mortar. Mixed coarse aggregate includes quartz and rounded particles of various mineral and geological types. Many unmixed white lime 'nodules' possibly indicative of 'hot-mix' method. Occasional fuel ash particles (apparently coal ash) noted. Calcareous aggregate (limestone) determined. Occasional fibrous material (straw) present.

Reaction Comments:

Vigorous effervescence on addition of dilute hydrochloric acid.

Chemical Dissolution Analysis (% dry mass) to BS4551:2005+A2:2013 (+ICP-OES).

%	Initial Moisture (oven @ 105°C)	7.84
%	Total Calcium as CaO (titrimetric method)	17.5
%	Total Magnesium as MgO (titrimetric method)	1.04
%	Acid & alkali soluble Silicon as SiO ₂ (gravimetric method)	1.15
%	Total (acid-soluble) sulphate as SO ₃ (gravimetric method)	0.193
%	Soluble Aluminium as Al ₂ O ₃ (ICP-OES method)	0.411
%	Soluble Iron as Fe ₂ O ₃ (ICP-OES method)	0.385
%	Total Acid Insolubles	63.2

BINDER

The binder in this sample is generally un-carbonated lime. Some very weak hydraulicity of lime binder may be indicated by the soluble SiO₂ test result. The sulphate result confirms that gypsum was not a deliberate original mix ingredient.

AGGREGATE

Insoluble particle size range: 10mm to 63µm (89.9%) : <63µm (10.1%)

The insoluble residue, apparently river or estuary sand, comprises principally:

Clear/colourless Quartz

Rounded particles of various mineral types

Yellow-brown clay and/or silt

Occasional fine fuel ash (apparently coal ash) particles. (Kiln-fuel residue)

Occasional straw reinforcement

(cont.)

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TEST REPORT 4579 (page 2)

MORTAR BY VOLUME

Acid-soluble calcareous sand/aggregate particles (limestone) were observed to be present and an allowance has therefore been made. The results adjusted for typical bulk density indicate a calculated volumetric mix of **approximately:**

1 part Lime
2 to 2.5 parts Combined Aggregate.

SUGGESTED MATCHING MIX

This is not a specification for a repair mortar, nor must it be treated as one.

If this mortar were to be matched on a 'like-for-like' basis, the following approximate volumetric matching mix recipe might be helpful.

This does not necessarily imply that we recommend a 'like-for-like' repair mortar mix design in this particular situation, as there are many relevant factors in addition to mortar analysis that must be taken into account.

1 part **Chalk Lime Putty* (Properly matured for a minimum of 6 months)**
2 to 2.5 parts **Mixed rounded particle grey-brown coarse grit sand. <10mm**
+ **Metakaolin pozzolan* at 10% by volume to mixed mortar**

***Note:** Careful consideration should be given to the use of a Natural Hydraulic Lime (NHL2?) in place of lime putty + pozzolan for external repairs especially in exposed locations.

SOURCES OF MATERIALS

Many limes, sands, stonedusts and aggregates are available from **Rose of Jericho.**

NOTES:

1. Sample mixes **must always** be prepared to ensure suitability and an accurate colour and texture match.
2. Aggregates with a particle size and grading appropriate for the intended use must be selected. Sands conforming to the relevant British/European Standard should be used especially with **hydraulic** limes.
3. The repair mortar should be no weaker than 1: 2½. Manufacturers advice should be sought and recommended application mix proportions and 'Best Practice' guides must be complied with.
4. It should be remembered that mortars change over time. When analysing an aged material, one is ascertaining what it now is and looking for evidence for what it originally was. Calcium hydroxide carbonates to form calcium carbonate, and calcium silicate hydrate (C-S-H), the principal reaction product in hydraulic limes and pozzolanic limes itself reacts over time with carbonic acid to produce calcium carbonate and hydrous siliceous, aluminate and silico-aluminate gels.

06.12.2016

Mortar Analysis**Test Report No. 4580.****Chepstow Castle – Earl's Chamber****Sample 3. Hearting Mortar.**

One sample of hearting mortar, (weight 22.5g), collected from a wide joint to RH-side of door in northern wall and believed to be the original early mediaeval construction mortar has been analysed chemically and microscopically.

Sample Assessment, Preliminary Tests and Observations:

Moist sample. Partially carbonated (phenolphthalein carbonation test). Disrupted cream-grey powdered mortar. Mixed coarse aggregate includes quartz and rounded particles of various mineral and geological types. Many unmixed white lime 'nodules' possibly indicative of 'hot-mix' method. Occasional fuel ash particles (apparently coal ash) noted. Calcareous aggregate (limestone) determined. Fibrous material not found.

Reaction Comments:

Vigorous effervescence on addition of dilute hydrochloric acid.

Chemical Dissolution Analysis (% dry mass) to BS4551:2005+A2:2013 (+ICP-OES).

%	Initial Moisture (oven @ 105°C)	8.10
%	Total Calcium as CaO (titrimetric method)	15.9
%	Total Magnesium as MgO (titrimetric method)	0.986
%	Acid & alkali soluble Silicon as SiO ₂ (gravimetric method)	0.95
%	Total (acid-soluble) sulphate as SO ₃ (gravimetric method)	0.241
%	Soluble Aluminium as Al ₂ O ₃ (ICP-OES method)	0.307
%	Soluble Iron as Fe ₂ O ₃ (ICP-OES method)	0.244
%	Total Acid Insolubles	68.3

BINDER

The binder in this sample is partially carbonated lime. Some very weak hydraulicity of lime binder may be indicated by the soluble SiO₂ test result. The sulphate result confirms that gypsum was not a deliberate original mix ingredient.

AGGREGATE

Insoluble particle size range: 8mm to 63µm (94.8%) : <63µm (5.2%)

The insoluble residue, apparently river or estuary sand, comprises principally:

Clear/colourless Quartz

Rounded particles of various mineral types

Yellow-brown clay and/or silt (in low proportion)

Occasional fine fuel ash (apparently coal ash) particles. (Kiln-fuel residue)

(cont.)

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TEST REPORT 4580 (page 2)

MORTAR BY VOLUME

Acid-soluble calcareous sand/aggregate particles (limestone) were observed to be present and an allowance has therefore been made. The results adjusted for typical bulk density indicate a calculated volumetric mix of **approximately:**

1 part Lime
2.5 parts Combined Aggregate.

SUGGESTED MATCHING MIX

This is not a specification for a repair mortar, nor must it be treated as one.

If this mortar were to be matched on a 'like-for-like' basis, the following approximate volumetric matching mix recipe might be helpful.

This does not necessarily imply that we recommend a 'like-for-like' repair mortar mix design in this particular situation, as there are many relevant factors in addition to mortar analysis that must be taken into account.

1 part **Chalk Lime Putty* (Properly matured for a minimum of 6 months)**
2.5 parts **Mixed rounded particle grey-brown coarse grit sand. <8mm**
+ **Metakaolin pozzolan* at 10% by volume to mixed mortar**

***Note:** Careful consideration should be given to the use of a Natural Hydraulic Lime (NHL2?) in place of lime putty + pozzolan for external repairs especially in exposed locations.

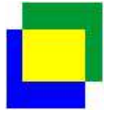
SOURCES OF MATERIALS

Many limes, sands, stonedusts and aggregates are available from **Rose of Jericho.**

NOTES:

1. Sample mixes **must always** be prepared to ensure suitability and an accurate colour and texture match.
2. Aggregates with a particle size and grading appropriate for the intended use must be selected. Sands conforming to the relevant British/European Standard should be used especially with **hydraulic** limes.
3. The repair mortar should be no weaker than 1: 2½. Manufacturers advice should be sought and recommended application mix proportions and 'Best Practice' guides must be complied with.
4. It should be remembered that mortars change over time. When analysing an aged material, one is ascertaining what it now is and looking for evidence for what it originally was. Calcium hydroxide carbonates to form calcium carbonate, and calcium silicate hydrate (C-S-H), the principal reaction product in hydraulic limes and pozzolanic limes itself reacts over time with carbonic acid to produce calcium carbonate and hydrous siliceous, aluminate and silico-aluminate gels.

06.12.2016



APPENDIX 6

Pointing Mortar Specification

C41 Repairing/ Renovating/ Conserving masonry

C41 Repairing/ Renovating/ Conserving masonry

WORKMANSHIP GENERALLY

150 POWER TOOLS

- Usage for removal of mortar: Not permitted .

155 PUTLOG SCAFFOLDING

- Usage: Not permitted .

160 PROTECTION OF MASONRY UNITS AND MASONRY

- Masonry units: Prevent overstressing during transit, storage, handling and fixing. Store on level bearers clear of the ground, separated with resilient spacers. Protect from adverse weather and keep dry. Prevent soiling, chipping and contamination. Lift units at designed lifting points, where provided.
- Masonry: Prevent damage, particularly to arrises, projecting features and delicate, friable surfaces. Prevent mortar/ grout splashes and other staining and marking on facework. Protect using suitable nonstaining slats, boards, tarpaulins, etc. Remove protection on completion of the work.

165 STRUCTURAL STABILITY

- General: Maintain stability of masonry. Report defects, including signs of movement that are exposed or become apparent during the removal of masonry units.

170 DISTURBANCE TO RETAINED MASONRY

- Retained masonry in the vicinity of repair works: Disturb as little as possible.
- Existing retained masonry: Do not cut or adjust to accommodate new or reused units.
- Retained loose masonry units and those vulnerable to movement during repair works: Prop or wedge so as to be firmly and correctly positioned.

180 WORKMANSHIP

- Skill and experience of site operatives: Appropriate for types of work on which they are employed.
 - Documentary evidence: Submit on request.

185 ADVERSE WEATHER

- General: Do not use frozen materials or lay masonry units on frozen surfaces.
- Air temperature: Do not bed masonry units or repoint:
 - In cement gauged mortars when ambient air temperature is at or below 3°C and falling or unless it is at least 1°C and rising, unless mortar has a minimum temperature of 4°C when laid and the masonry is adequately protected.
 - In hydraulic lime:sand mortars when ambient air temperature is at or below 5°C and falling or unless it is at least 3°C and rising.
 - In nonhydraulic lime:sand mortars in cold weather, unless approval is given.
- Temperature of the work: Maintain above freezing until mortar has fully set.
- Rain, snow and dew: Protect masonry by covering during precipitation, and at all times when work is not proceeding.
- Hot conditions and drying winds: Prevent masonry from drying out rapidly.
- New mortar damaged by frost: Rake out and replace.

MATERIALS/ PRODUCTION/ ACCESSORIES

TOOLING/ DRESSING STONE IN SITU

C41 Repairing/ Renovating/ Conserving masonry

455 DESCALING STONE

- Requirement: Carefully remove loose scaling and powdering from stones to the extent agreed.
- Method: Suitable bristle brushes or carborundum blocks. Do not use wire brushes.

POINTING/ REPOINTING

810A PREPARATION FOR REPOINTING

- Existing mortar: Working from top of wall downwards, remove mortar carefully, without damaging adjacent masonry or widening joints, to a minimum depth of 1½times the thickness for stonework joint widths exceeding 3mm. Fine joints up to 3mm wide are only to be cut out, prepared and repointed where the existing mortar joint has eroded to a depth of 2-3 times the joint width; otherwise if the joint is sound then the existing joint should be left.
 - Loose or friable mortar: Seek instructions when mortar beyond specified recess depth is loose or friable and/ or if cavities are found.
- Raked joints: Remove dust and debris.
- Disc cutters not to be used without the consent of the Architect/CA.

820 POINTING EXISTING EXTERNAL RUBBLE STONWORK AS SCHEDULED

- Preparation of joints: Carefully brush away loose mortar and wash out the back of the aperture with clean cold water to remove any debris ensuring that the substrate is sufficiently wet to remain damp for at least 24 hours.
- Mortar: As section Z21.
 - Mix: 1:2.5 St Astier NHL3.5 hydraulic lime:sand.
 - Sand source/ type: CLS 22 - 'Ocean Rough Sand', supplied by Cornish Lime Company, with sieving to <10mm.
- Joints profile/ finish: To match existing and recessed back from weathered arrises to retain original joint widths. Brush finish as clause 860.
- Other requirements: No mortar smearing to the surrounding stonework will be accepted. Ensure that the newly pointed joints are protected from the heat of the sun and drying wind. In warm weather ensure that the surrounding masonry and face of the joint are kept damp for at least 3 days to control curing of the mortar.

840 POINTING WITH TOOLS/ IRONS

- General: Press mortar well into joints using pointing tools/ irons that fit into the joints, so that they are fully filled.
- Face of masonry: Keep clear of mortar. Use suitable temporary adhesive tape on each side of joints where necessary. Finish joints neatly.

860 BRUSHED FINISH TO JOINTS

- Timing: After initial mortar set has taken place remove laitance and excess fines by brushing, to give a coarse texture. Do not compact mortar.



APPENDIX 7

**'Prompt' Natural Cement Capping Specification,
Application Guidance & Product Info**

M20 PLASTERED/RENDERED/ROUGHCAST COATINGS

- 01 LIMEWASH TO RUBBLECORE WALLS, TO PROVIDE 'SLIP PLANE'
(BEFORE APPLICATION OF PROMPT RENDER CAPPING)
- Surface: Repointed rubble core walls as shown on drawings.
 - Preparation: Ensure wall is appropriately cleaned down using hydrogen peroxide based bleach and/or wire brush to remove all vegetation/moss/lichen. Flush wall clear of chemical residues using clean water. Dampen background before application, control drying by re-wetting with fine spray or suspended damp fabric in front of previously applied paintwork.
 - Coats: 2 coats.
 - Paint: White lime mixed on site from hydraulic lime (NHL3.5). Sieve before application, apply thinly.
- 10 TWO COAT NATURAL CEMENT:SAND RENDER (CAPPING TO RUBBLECORE WALLS)
- Background: Rubblecore walls as shown on drawings.
 - Preparation: Limewash to provide 'slip plane' as M20/01 above.
 - Workmanship: To be carried out in accordance with application guidance & mix method sheet, provided by Cornish Lime Company.
 - Undercoat:
 - 1 coat (Key between undercoat and final coat is required, note that final coat needs to be applied on 'fresh' undercoat, see below).
 - Natural Cement: Vicat 'Prompt', available from Cornish Lime Company, Bodmin.
 - Sand: 'CLS 21' by Cornish Lime Company (note that CLS 21 is the same sand as CLS 22 used elsewhere on project, but has been screened off site to less than 5mm aggregate size by Cornish Lime Co).
 - Admixture (to increase period of 'workability' of mix, if required): 'Tempo' retarder, supplied by Cornish Lime Co. Seek instructions from Edd Walker of Cornish Lime Co to ensure correct method of site mixing.
 - Mix proportions: 1:1 Prompt: sand, with polypropylene fibres to control shrinkage cracks. Size of fibres will depend on how it is applied:
 - If by hand then use 18mm polypropylene fibres, or
 - If sprayed, use longest polypropylene fibres that can run through the machine (likely 6mm or 12mm).
 - Note that addition rate for the 18mm fibres typically sits at the 4kg/m³ mark (2kg per tonne of mixed mortar). Shorter fibres can have higher addition rates but again this will be dictated by what can be ran through the sprayer (ideally the more fibres the better, without impacting too much on 'workability').
 - Thickness: Minimum 10mm.
 - Application/Finish: Floated or spray applied (quicker/denser method of applying, by compressed air sprayer such as Sablon gun). Coating to closely follow contours of existing underlying masonry, introducing 'flaunching' as required over individual stones to prevent water from ponding/sitting on render surface, and to provide 'trickle path' for water to run-off rendered capping. The surface of the base coat should be scratched to provide a mechanical key for the next coat.
 - If spraying, base coat will need to be levelled by hand just to take out the dips and mounds to give a roughly even thickness.
 - Final coat:
 - Applied 'fresh on fresh', so same day or following day application of the top coat. A key between the base coat and top coat is required.
 - Natural Cement: Vicat 'Prompt', as for undercoat.
 - Sand: 'CLS 21', as for undercoat.
 - Admixture (to increase period of 'workability' of mix, if required): 'Tempo' retarder, supplied by Cornish Lime Co. Seek instructions from Edd Walker of Cornish Lime Co to ensure correct method of site mixing.
 - Mix proportions: 1:1 Prompt: sand.
 - Thickness: Minimum 10mm.
 - Application/Finish: Floated or spray applied (quicker/denser method of applying, by compressed air sprayer such as Sablon gun) or floated. Sponge finish to bring

forward the aggregate. Coating to closely follow contours of existing underlying masonry, introducing 'flaunching' as required over individual stones to prevent water from ponding/sitting on render surface, and to provide 'trickle path' for water to run-off rendered capping.

- If spraying, top coat will need to be levelled by hand and floated to finish as specified above.

Wall Capping with Prompt

As with any render; preparation of the background is very important therefore the surface to be rendered should be free of any biological colonisation, relatively clean and free of dust and deleterious matter.

When rendering with Prompt one should always bring out all coats green on green.

Prompt should not be used in the rain or if the temperature is below 5°C.

In this instance a limewash "slip membrane" is being incorporated into the design to give reversibility. This should be applied and left to set and dry.

Mixing Prompt

Batch the required volume of sand buckets prior to mixing.

Batch the required volume of Prompt into buckets and add the required addition of Tempo (retarder) to each bucket.

Add the required sand, the fibres and 2/3 of required water into the mixer.

Turn on mixer and then add the Prompt and Tempo.

Add water to the desired workability, mix until the render is a uniform consistency and leave to mix for a further 30 seconds to a minute.

Turn out the mix and rinse the mixer out after every mix.

Basecoat

Dampen the background sufficiently to control suction. Spray or cast on the render to 10mm to 12mm depth. Take a trowel and "level" any high spots or "fill" any low spots to even out the thickness.

Scratch the basecoat to 1/3 of the render depth to create a mechanical key, diamond crosshatch scratching is advised.

Often a sprayed application will give a good mechanical key meaning so scratching is not required, but inspect the render to ensure that all sections are suitably keyed.

Float coat:

This should be applied once the base coat has gone firm, but still in a damp state (same day). Depending on environmental conditions, this would usually be 20 to 30 minutes after the basecoat has begun to set.

If the float coat is to be applied the following day, sufficiently dampen the background.

Spray, cast on or hand apply the render at a minimum thickness of 10mm; smooth over the whole render with a trowel to create a relatively "flat" and even finish.

Create flaunches where required to give the best possible run off channels for water.

When the render has picked up enough go over with a sponge to close off as much of the surface as possible.

~~Sheltercoat~~ ↓ NOT REQUIRED AT CHRISTIAN CASTLE, (MT. 02/05/18.)

~~This should be applied once the float coat has gone firm, but still in a damp state (same day). Depending on environmental conditions, this would usually be 20 to 30 minutes after the basecoat has begun to set. If the float coat is to be applied the following day, sufficiently dampen the background.~~

~~Mix the sheltercoat to milk like consistency and paint onto the substrate.~~

~~Finish TBD with Cadw – either sponge float or left as is~~

Other things to consider

Prompt cannot be knocked back up – once it has started to set, clean off tools and empty out buckets.

Prompt should still be protected as if it were an NHL based render; protect from sunlight, direct rain and drying winds.

Mist spraying for several days after the application will also allow the material to hydrate better.

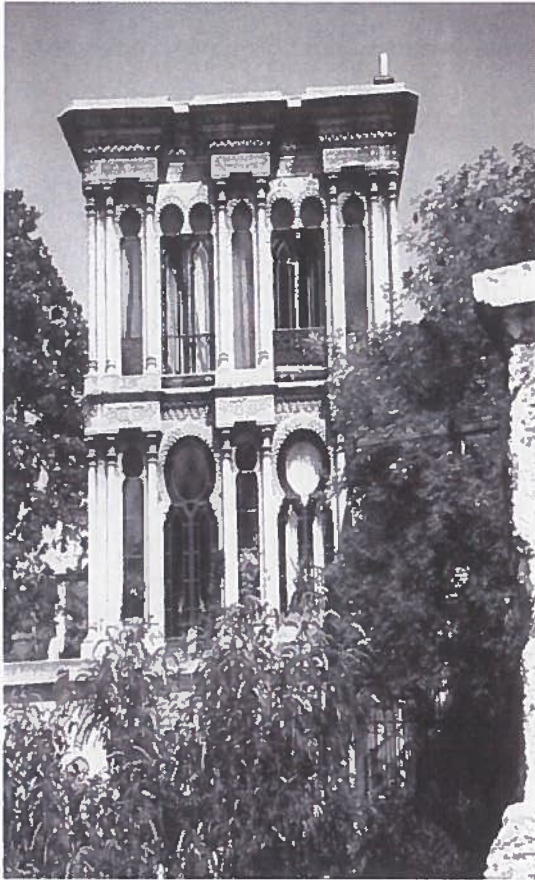
Due to the short set time with Prompt it will likely be easier to make smaller batches but more frequently.

It is advised that there is an adequate number of contractors on site; one person mixing, one person applying, one person leveling. This can help mitigate issues with the Prompt undertaking its set too soon or during the mixing phase.

Adding too much Tempo can reduce final strength or even stop the set of the Prompt so accuracy when measuring is very important.

We have allowed an error margin for site mixing within our guide, however it is paramount that due care is still to be taken.

THE CORNISH LIME CO LTD



**PROMPT
Natural Cement**



La Casamaures Built in 1855 (Grenoble France) is something of a milestone in concrete terms as it is one of the first structures of its kind ever built, using concrete (from a natural cement). Grenoble has a number of other superb examples of 'early' concrete structures still surviving today. Standing testament to the unique properties of the indigenous cements available nearby of which Prompt is the only survivor

What is Natural Cement?

INTRODUCTION

Those Civil Engineers or Cement Professionals who know of Natural Cements have, with very few, very recent exceptions, long ago dismissed this family of materials in their search for ever greater compressive strengths. During the course of the 20th Century, Natural Cements have fallen into disuse, with one exception.

Natural Cements are so-called because they are made, simply and solely from natural rock. The rock is always limestone, with magnesium and clay contained within it in a naturally occurring fortuitous balance that, when fired and ground, makes a useful cement. Nothing, apart from coal or anthracite for fuel, is added or taken away during manufacture.

HISTORY

There is some anecdotal evidence of concretes made from Natural Cements having been used hundreds of years ago. Whatever the origins, it seems unlikely that lime manufacturers, who have been plying their trade since at least ancient Egyptian times, would not have come across suitable limestone laced with 'impurities' and made, from time to time, materials that we now call Natural Cement.

There are references, particularly in France, to Natural Cements and to Water Cements (later called Hydraulic Limes) in the 18th Century.

PARKER'S CEMENT

In 1796, at the Isle of Sheppey on the North Kent coast the Reverend James Parker disclosed the use of 'Cement-Stones' found on the shores of the Thames Estuary. These 'Cement-Stones' were of a limestone that contained an amount of clay within them. When they were fired and ground in a particular way a NATURAL CEMENT was produced. This, Parker patented and marketed as 'Roman Cement'.

At the same time (1796) a French military engineer, Lesage, found similar 'cement-stones' on the shoreline at Boulogne, and he too manufactured a type of Natural Cement from them. Other sources of Natural Cements were found at St Petersburg in Russia and at several sites in the Appalachians in the USA. As well as 'nodules' or stones found on shorelines, mines were started to exploit seams of material.

This material was a commercial success. Much military construction was going on at this time of revolution and Napoleon; fortifications, docks, wharves, barracks etc were being built at a greater rate. Parker's Cement was strong, waterproof, set quickly (in hours), set under water, and was used in concretes, mortars, and, very extensively, in stucco work.

COMPETITION

The Reverend Parker's patent ran out in 1810, and similar materials were produced almost immediately in Swanscombe, Harwich and Whitby and later at other sites throughout the UK. The same search for different sources was happening in France and the rest of Europe, in Russia, the USA and Canada. Each source produced a different cement with different properties, characteristics and consequent uses reflecting the different 'Natural' limestone's. Some are similar to Hydraulic Limes in make up, others are rich in Magnesium, some set in hours, others within seconds, some have relatively high compressive strengths when set, others have little strength. Colours varied from brown to beige.

At that time, it was not so easy to move bulk products around and these cements, from natural sources, were not necessarily found and manufactured near the cities. Parker had been lucky, he was on the Thames with easy access to London, and his cement rapidly became the standard product to be used for the stucco work of Georgian London which had become the vogue, the use of wood having not long been banned. In other places, an alternative was needed.

PORTLAND CEMENT

Louis Vicat working in France had the alternative, to make a cement industrially, an artificial cement that would duplicate the combination of minerals and thus the properties of Natural Cements and Hydraulic Limes. He explained the theory and had much to do with the first commercial factory of 'artificial lime' near Paris in 1818.

Messrs Aspdin, Frost etc in the UK, and other pioneers in France and Germany rapidly took up the development and so the 'artificial' Portland Cement industry was borne from the efforts to emulate the properties of the Natural Cements, which had begun to change the way civil engineers worked. It is no coincidence that North Kent and Boulogne, where the first cement-stones were found, later became important centres of artificial Portland Cement production. The local limestone contains clay, reducing the need for further addition in the factory.

Although Vicat himself pursued the 'artificial lime' option with vigour, he remained aware of the superior qualities of Natural Cements, recommending their use where they were available. Much later, in 1855, he helped his son, Joseph, set up his first factory at Grenoble (and the company 'Ciments Vicat') and that produced a Natural Cement as well as an artificial 'Portland' type cement, and a type of 'Marine' (Sulphate Resisting) cement.

For most of the 19th Century in Europe, and for longer in the USA, the two products (Natural and Artificial) were sold alongside each other at different prices and for different purposes.

In the USA, Natural Cements were used to build first the Erie and then other canals and by the turn of the century the production of Natural Cements was a very extensive industry indeed. Rosendale cement from New York State was among the most successful with some 25 mines exploiting a very large, consistent and homogenous seam of material. There were many other producers throughout the country. Rosendale had the advantage of access to New York, then growing rapidly.

It was not until the end of the 19th Century that the 'Artificial' cement plants introduced higher firing temperatures and rotary kilns enabling the use of lower grade limestone. This produced a much lower cost Portland Cement with far greater compressive strength. With the higher firing temperatures the C_3S reaction of modern Portland Cement becomes the predominant reaction, hence the greater strength. Prior to then it was the C_2S reaction (as in Prompt Natural Cement) that was the most important. This change in process allowed the use of a wider variety of limestone thus enabling limestone's in more convenient localities to be used. With improvements in the transport systems, it was soon universally available. The decline in use of Natural Cements began. The last production in the UK seems to have been at Harwich in the 1950's. In the USA production did not cease until 1971.

PRESENT DAY PRODUCTION

In France, Spain, Italy and Switzerland, however, the story was a little different. Small scale production of Natural Cement has never stopped and continues to the present day. All but one are products that are similar to Hydraulic Limes and are used, particularly, in restoration work.

The one exception is a particular Natural Cement mined in the French Alps near Grenoble. This is quite different from the others that are available or have been available in the past, and is

categorised in its own right under a French Norm(NF P15-314) as PROMPT NATURAL CEMENT. It cannot be classified as a lime, and is very different from the early Natural Cements. It is very much faster setting and rapid hardening than others, and has compressive strengths approaching those of modern Portland Cements. Some 200,000 MT of this material are produced annually, plus a further quantity of derivative binders. Commercial production started in 1842, at a factory called PORTE DE FRANCE on the then border with Italy, which is now owned by the company Ciments Vicat. At one time there were many other centres of production of this peculiar cement, throughout South and South-east France, and in the Lot and Dordogne areas. It was first manufactured at Pouilly en Auxois in 1827, and then Vassy in 1832. Only the mine at Grenoble survives today.

The seam of argillaceous limestone exploited by this production is large, stable and consistent. Firing is at moderate temperatures across a wide range (600-1100 °C) in traditional vertical kilns using generations of skill and judgement in charging each kiln and balancing the results to produce a consistent standard product from the natural limestone. Most of the rock is never sintered, and consequently the cement remains chemically stable and predictable. The complex chemistry thus produced gives the cement a number of properties, including the very fast setting and hardening reactions (thus no curing period) and no release of "Free Lime". This enhances its resistance to acid attack, waterproof properties, safety with drinking water and the maintenance of a high level of alkalinity which in turn means that any rusting of reinforcements is totally inhibited.

This particular Prompt Natural Cement continues in use to this day throughout France and Italy, to a lesser extent in Spain and Germany and very recently in the UK and is exported around the world, as far afield as Korea and Hawaii. It is valued as a water stopping material, as a cement resistant to sea water and acid attack, as a quick repair material and as a constituent of proprietary 'fast' mortars and concretes, especially for grouting and for shotcreting mixes.

RENEWED INTEREST

Some 20 years ago, the SNCF (French Railway) engineers were designing tunnels for the TGV train network. With the most sophisticated resources of the major cement and chemical admixture producers at their disposal, there were considerable problems meeting the designers' specifications. High strengths were possible, but not without the brittleness that comes with ultra fast strength gain. Fast setting to combat water ingress was possible, but not without a cocktail of admixtures whose interactions were not totally understood and had Health and Safety implications. So it was that Prompt Natural Cement was 'rediscovered'. Changes to the production methods increased the compressive strengths to exceed the engineering requirements. The mine at Grenoble was modernised to increase production. The necessary quality controls were brought in, and the revised cement (now more properly termed a 'Hydraulic Binder') called VICALPES has become a component of Dry Shotcrete used in tunnelling in France and is currently being used in difficult situations in the mining, railway and drinking water storage industries in the UK. It is intriguing to see this traditional material helping the modern engineer overcome some of the most complex and difficult problems of the late twentieth century.

SUMMARY

Natural Cement does not fit into any classification of modern cements and is therefore usually consigned to a footnote in the 'discovery' of Portland Cement. The role that Natural Cement played as a catalyst at the start of the 'Portland' cement industry is overlooked. The very large part that it played in 19th Century construction in Europe and the USA is forgotten. The rivalry of the early patentees and their competitors and successors, the wide variation in type, make-up, production methods and properties of the cements plus the drive for greater and greater compressive strength conspired against the use of these materials. Like other minerals, Natural Cements could only be produced where the mineral deposits were exploitable, and could not easily and economically be moved around the Country. Those conveniently situated (Parker near London, Rosendale near New York) thrived, but in other places 'Artificial' substitutes had a big advantage.

Recent work is showing that these materials still do have a lot to offer. The experience of the French Railway engineers has shown the considerable value in reassessing these old materials. Resins, polyurethanes and the plethora of admixtures available to the contemporary Cement Technologist have their place and purpose, but the simplicity, the safety (they are, for example, approved for use with drinking water) the versatility and the predictability of their 'low tech' precursors should not be forgotten. A great many structures and buildings now 150 years or more of age are available as testament to the durability of Natural Cements, particularly around Grenoble in France where Prompt Natural Cement is produced.

Quick Reference guide

This truly remarkable material has to be used to be fully appreciated and should be regarded more as a tool for contractors, rather than a material, for further information please contact

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Special Binders



PROMPT TECHNICAL DOCUMENT

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PROMPT TECHNICAL DOCUMENT

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A NATURAL hydraulic binder



A NATURAL hydraulic binder is a binder manufactured from a single natural raw material, without additives.

PROMPT is a NATURAL HYDRAULIC BINDER which results from firing an argillaceous limestone of regular composition extracted from homogeneous rock strata, between 800 and 1200 °C, followed by very fine grinding.

It is a **fast-setting and fast-hardening binder**

European Technical Agreement is expected in 2003



Natural deposit

For more than 150 years, in the Chartreuse mountains, a unique natural deposit has been exploited to manufacture Prompt.

This limestone deposit, in the French Alps to the north of Grenoble, consists of folds of sedimentary strata formed during the formation of the Alps.

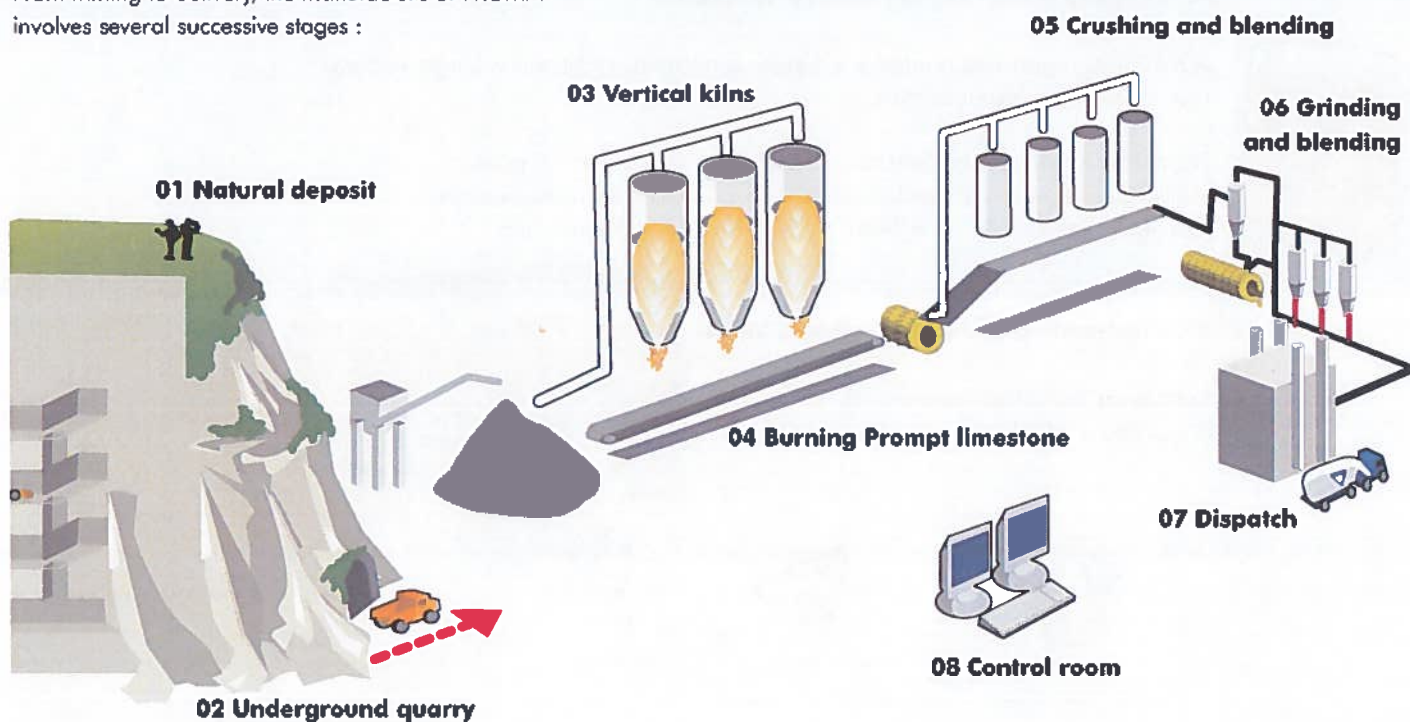
A single geological layer makes up this unique natural deposit. It consists of an argillaceous limestone whose chemical and mineralogical compositions are consistent, precise and ideal for manufacturing cement without external additives :

Prompt is a NATURAL binder



Manufacture of PROMPT

From mining to delivery, the manufacture of PROMPT involves several successive stages :



Physical characteristics of PROMPT (NF P 15-314)

The tables below show the average values of the physical characteristics of PROMPT obtained after completion of factory quality control inspections.

Physical characteristics

Characteristics	Standards	Averages	Specifications
Specific Gravity		2,97 g/cm ³	
Apparent density		0,7 à 1,0 g/cm ³	
Blaine Surface area	EN 196-6	7000 cm ² /g	> 5000
Initial set (pure paste)	EN 196-3	1,5 mn	< 4
Expansion at 80 °C	EN 196-3	5 mm	< 15
Shrinkage (mortar 1-1 by weight) at 28 days	NF P 15-433	700 µm/m	< 1200
Heat of Hydration at 1 hour	NF P 15-436	120 J/g	70 ≤ H ≤ 150

Compressive strength (MPa)

Age	Test Method	Average Value	Requirement
15 minutes	EN 196-1	5	>4
1 hour	EN 196-1	7	>6
3 hours	EN 196-1	9	>8
1 day	EN 196-1	13,5	>10
7 days	EN 196-1	22	>14
28 days	EN 196-1	31	>19
90 days	EN 196-1	40	

mortar 1-1 by weight

1 MPa = 1 N/mm² = 10,2 kgf/cm² = 10 bars



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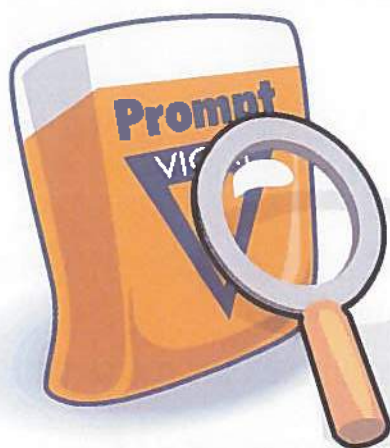
Chemical characteristics of Prompt (NF P 15-314)

The table below shows the average values of the chemical characteristics of PROMPT obtained after completion of factory quality control inspections

Chemical characteristics	Test Method	Average Value (%)	Standard Requirement (%)
Silica (expressed as SiO ₂)	EN 196-2	18,4	≥ 17
SO ₃ content	EN 196-2	3,2	≤ 4
Loss on Ignition	EN 196-2	9,4	≤ 14
Insoluble content	EN 196-2	3,2	≤ 6
Al ₂ O ₃ /Fe ₂ O ₃ ratio	EN 196-2	2,3	≥ 2

Properties

The mineralogical composition of **PROMPT** gives it some particular properties :



Main Properties

Speed

- ⊕ Very fast setting and hardening
- ⊕ To delay setting time

Strength

- ⊕ Compressive strength after 28 and 90 days
- ⊕ Adhesion to all substrates

Durability

- ⊕ Strength gain over the long term
- ⊕ Resistance to corrosive water (above/equal pH 4)
- ⊕ Resistance to sea water

Complementary property

- ⊕ Waterproofing



To delay setting time



Setting of PROMPT mortar can be delayed by the addition of a retarding agent
(Caution! Many retarding agents used for common cements do not work with PROMPT)

The most effective retarding agent is citric acid (E330) sold in 80 grams bottles under the trade name **TEMPO**

PROMPT mortar 1-1 by weight (2 vols PROMPT - 1 vol sand)
with addition of TEMPO :

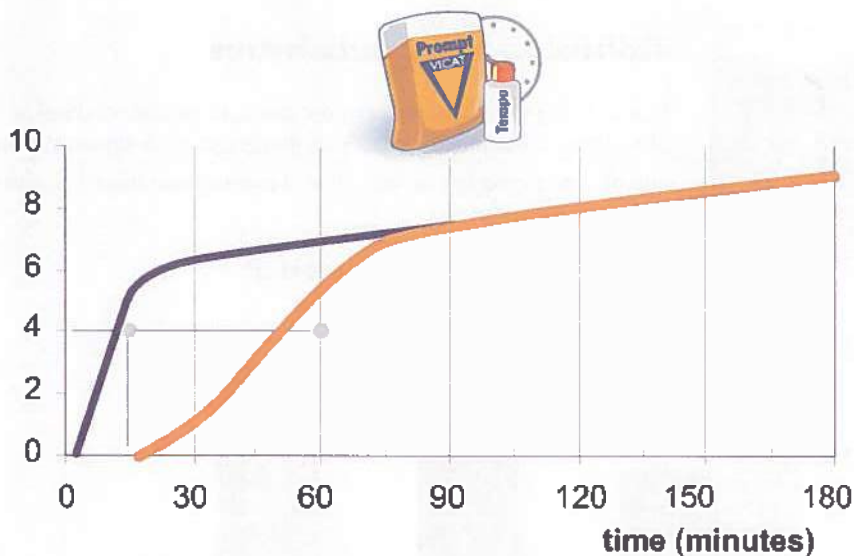
"TEMPO dosage" = one capful (7 g)/ litre of PROMPT

Setting and hardening are fast

At 20 °C : Start of setting : > **15 minutes**

Hardening : **4 MPa is obtained after 1 hour**

Compressive strength (MPa)



— very fast setting/almost instantaneous hardening at 20 °C

— fast setting and hardening with the addition of **TEMPO**

PROMPT mortar 1-1 by weight (2 volumes PROMPT - 1 volume sand) W/C = 0.4

NB: When PROMPT mortar 1:1 by volume is used, the above strengths are reduced by 30% ; with TEMPO, 4 MPa is obtained after 90 minutes

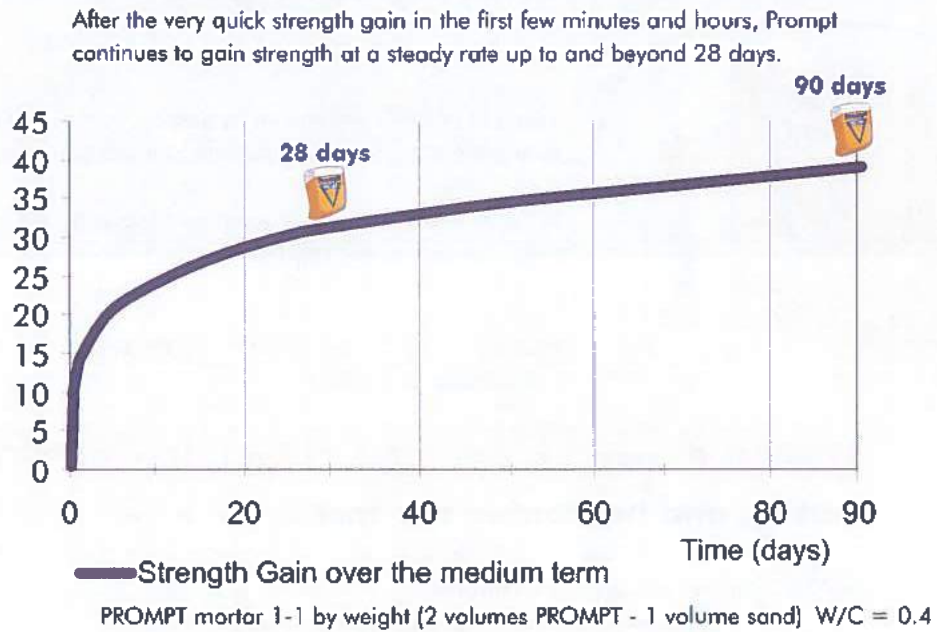


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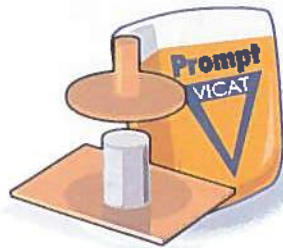
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Compressive strength after 28 and 90 days



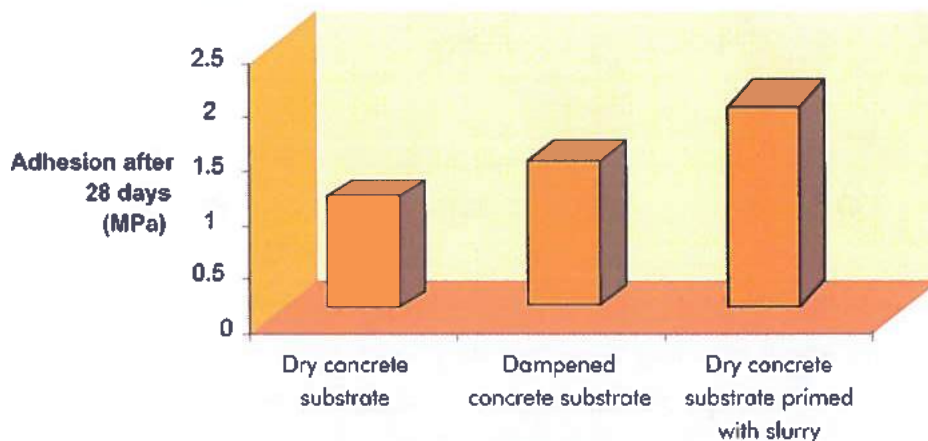
NB : When PROMPT mortar 1:1 by volume is used the above strengths are reduced by 5 MPa



Adhesion to all substrates

Due to its high fines content, Prompt develops excellent adhesion to all types of building material ; adhesion to a damp surface is significantly better than that obtained on a dry surface ; it is improved even more if a **slurry*** is applied beforehand.

Adhesion of Prompt mortar



* A layer of mortar on the substrate of almost zero thickness used to prime the substrate before laying a full thickness of mortar.



Strength gain over the long term



As far as the development of compressive strengths over time is concerned, the 2 main characteristics of PROMPT are :



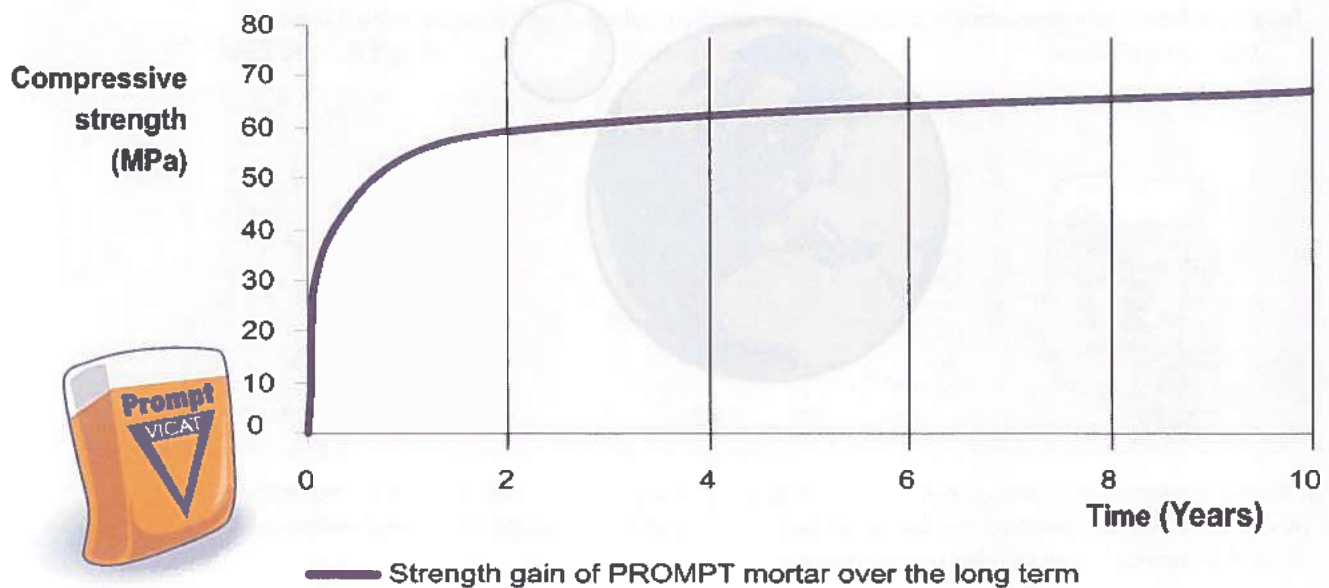
Very quick onset in the first few minutes



Continued increase over a very long period (several years)

This continued increase in strength improves the compactness of the mortar as the years progress ; this is an important factor in the **DURABILITY** of PROMPT-based mortars and concretes.

Hydration of the highly reactive PROMPT aluminates enables development of strength in the very first quarter of an hour ; slow hydration of the C_2S generates a strength gain over several years ; this phenomenon, which provides the possibility of autogenous healing over a long period, is another important factor in **DURABILITY**.



Special Binders

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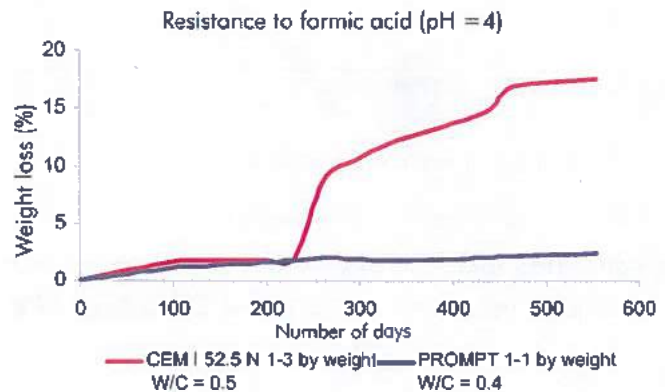
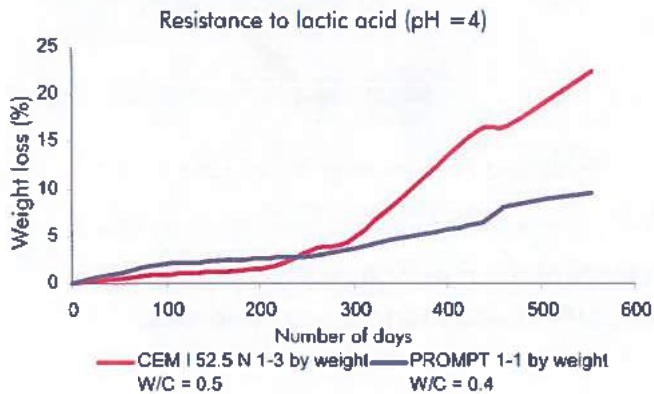
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Resistance to corrosive water



Resistance to pure and acidic water

The mineralogical composition of PROMPT means that there is a minimal release of lime during hydration, unlike common cements ; the resistance to pure and acidic water of a Prompt mortar is therefore excellent up to pH = 4



Resistance to sulphated water

PROMPT mortar behaves very well in the presence of sulphated water.

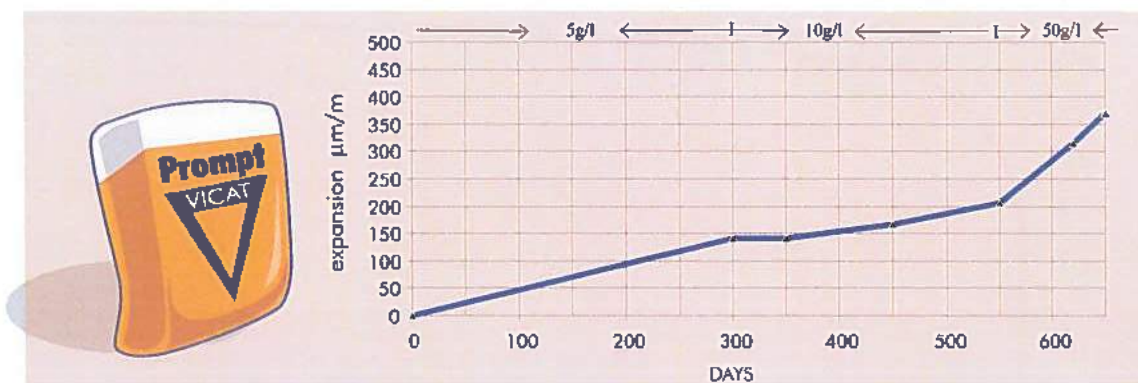
Test pieces 4 x 4 x 16 cm were prepared ; mortar 1-2 by weight, W/C = 0.40

They were kept totally immersed in a solution of magnesium sulphate with a concentration fixed at :

5 g/l for 300 days

10g/l for 250 days

50g/l for 100 days



This slow increase in expansion is explained by the gradual reduction in permeability of the Prompt mortar, as well as the limited release of lime during hydration; these results demonstrate the excellent resistance of PROMPT mortar to concentrated sulphated water.



Resistance to sea water

PROMPT meets French Standards for sea-water setting cements.

Having demonstrated excellent behaviour during long-term tests, PROMPT has been deemed suitable for work at sea.

It therefore has good resistance to attack from sea air.

These durability tests were performed on cubes of PROMPT mortar submerged

for 50 years

in the port of **La Rochelle** (France)

They demonstrated that the cubes were still in a completely satisfactory state of preservation.

Port of La Rochelle

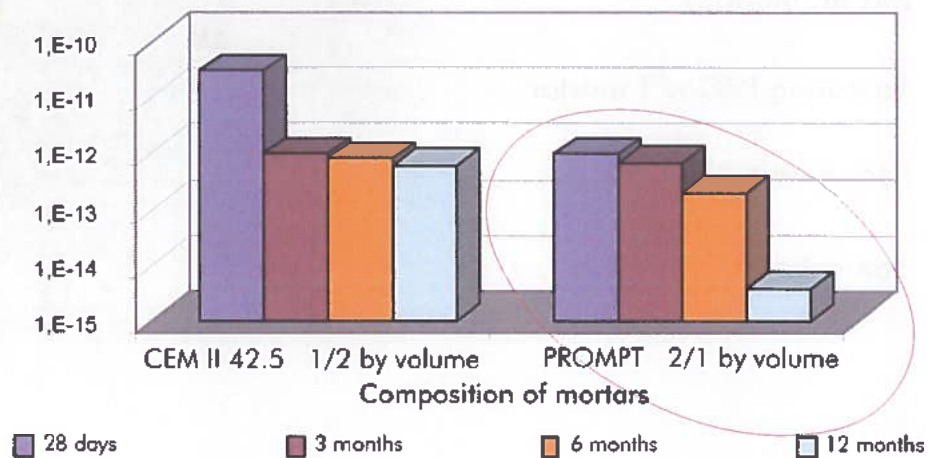
Waterproofing

The permeability of common cement mortars remains constant after 3 months.

In contrast, that of PROMPT mortar continues to decrease over time : In parallel with the strength gain, porosity is reduced, and **waterproofing enhanced**.



Water permeability coefficient (m/s)



Special Binders

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A multifunctional binder for construction

Projects

with **PROMPT** mortar

PROMPT is used to make fast-setting traditional mortars and renders



FAST TRADITIONAL MASONRY WORK

Fast masonry work

Fixing - Bedding-in

Repair work

Waterproof rendering

DECORATION

Decoration and restoration of façades

Works with lime mixes

PROMPT mortar Application

Using TEMPO

Mix proportions

Preparing PROMPT mortar

Recommendations for use

Some Rules



PROMPT is packed in 25 kg bags



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Using TEMPO

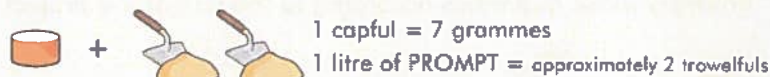


Choose

EASE of APPLICATION

TEMPO (citric acid) is the admixture for PROMPT.
It is added in proportion to the VOLUME OF PROMPT USED :

"TEMPO dosage" : 1 capful per litre of PROMPT




The addition of TEMPO delays setting in PROMPT mortar
by 10 to 30 minutes depending on the temperature :
(above this dosage, Tempo has little effect)


Mortar temperature	10°C	20°C	30°C
Setting time without Tempo	4 minutes	2 minutes	1 minute
Setting time with "TEMPO dosage"	30 minutes	15 minutes	10 minutes


Below 10 °C, half the TEMPO dosage can be used to keep the setting time less than 30 minutes

PROMPT + "TEMPO dosage" : Work AT YOUR OWN PACE



 TEMPO gives you the time to :
do a good job
clean your tools properly

 It allows you to mix a larger quantity of
mortar at one time

 The compressive strength of PROMPT mortar
is maintained with TEMPO

Tempo

PROMPT + "TEMPO dosage" : Work QUICKLY and WELL



Special Binders

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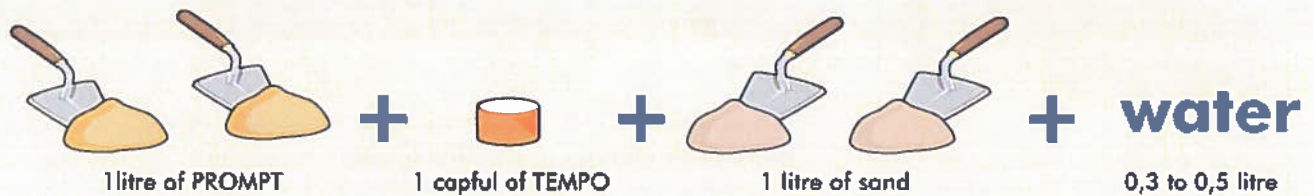
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Mix proportions

USUAL APPLICATION of PROMPT mortar (setting time = 15 minutes at 20 °C) :

Usual mix : 1 volume PROMPT/1 volume sand

(multiply these quantities according to the size of the project to be undertaken and the job time)



For the following applications :

- high resistance fixings
- working in damp, harsh conditions or exposed to sea water
- waterproofing

Add the water gradually so as to obtain the desired consistency

Double the proportions of PROMPT and TEMPO

Preparing PROMPT mortar

(setting time = 15 minutes at 20 °C)

1

Sprinkle **Tempo** on PROMPT



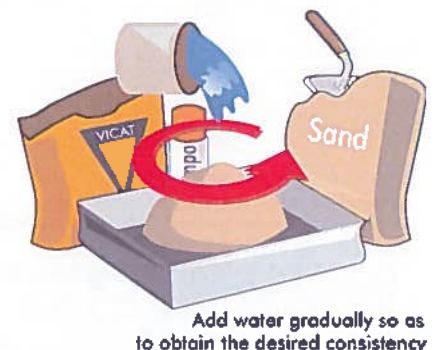
2

Add **sand** and mix



3

Add **water** and mix



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Recommendations for use



Prepare site before preparing PROMPT mortar



Use clean sand



Do not mix PROMPT and sand in advance : the moisture in the sand hydrates PROMPT and triggers the start of setting



Avoid excessive water, a main cause of shrinkage and cracking. Mortar with very wet sand will need less water



Only prepare as much as can be used before the mortar starts to set



Some Rules

Work on a **CLEAN DAMP** substrate (for adhesion)

The mortar must be laid completely **BEFORE setting starts** ; to have sufficient time to work at your convenience, use the **TEMPO admixture**

TEMPERATURE influences the initial setting time : warm weather reduces it, cold weather increases it ; the addition of TEMPO means that in warm weather you still have sufficient time to complete the job

AFTER setting starts :

Do not add water, stir or smooth over:
Setting only occurs once (risk of breaking the set)

CLOSE the bag carefully after use,
and store it upside down in a dry place



Special Binders

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Natural cement allows the rapid return to use in the short term, even in cold weather.

Work and application fields

In new construction as in renovation works, for sealings and fixing, repair of concretes, laying of masonry units, rapid setting concretes.

Advantages

- Rapid and adjustable setting with Tempo
- High initial strengths
- Vary good adhesion to all supports
- Excellent durability
- Ideal binder for blending and speeding up limes
- Low shrinkage

Usage precautions

- Do not overdose with water, beat or add water.
- In the presence of steel, visible steels should be passivated.
- In cold weather, it is not recommended to use frozen aggregates.
- The open time of your mixture can be adapted to fit your structure's needs by using the cement setting retarder Tempo.

VICAT PROMPT

FOUR GOOD REASONS TO CHOOSE VICAT PROMPT

- 1** Rapid masonry
- 2** Water & sanitation
- 3** Restoration & decoration
- 4** Eco construction

For more information or to receive the brochures, contact us at the following email address: vicat@vicat.fr

PROMPT Natural Cement is distributed in the UK through the IONIC group of companies. For further information on the supply and use of PROMPT please contact them on 0800 505 3802

www.ionicbuildingsupplies.co.uk

ionic
breathable building materials

VICAT International Trading

4, Quai Papacino
06300 NICE - France

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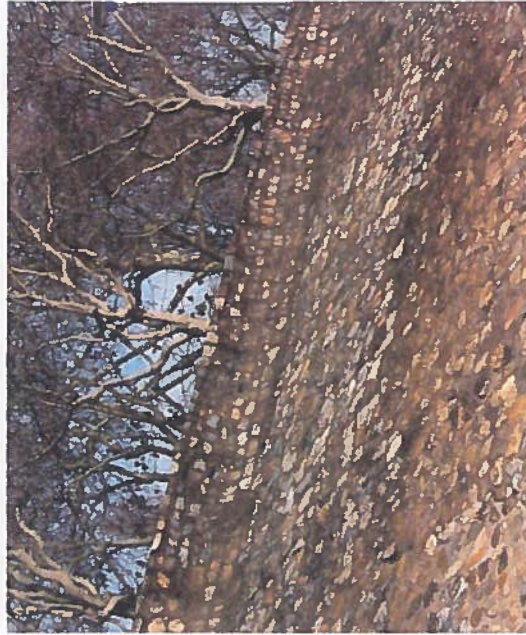
THE CONSTRUCTIVE PERFORMANCE

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VICAT PROMPT

NATURAL CEMENT

UNIQUE AND DURABLE



Rapid masonry





VICAT PROMPT FOR RAPID MASONRY

Speed up your work!

VICAT PROMPT is a light ochre coloured, rapid setting, adjustable natural cement. Manufactured according to the same process for more than 150 years, this natural hydraulic binder replaces common cements when your work has to be done fast.

VICAT PROMPT is authorized to display the NF trademark, NF P 15-314 (prompt natural cement) and NF P 15-311 (see work). It is a CE marking table since 13 June 2007 conforming to the European Technical Approval ETA - 07/0019 - Certificate No. 0679-07D-0227.



THREE USAGE SOLUTIONS

1 As a Prompt mortar

- > To fix and support wood or steel frames, joists, columns, handrails, gratings, benches, street furniture, etc.
- > To repair stairs, balcony soffits, thresholds, window cills, floors and all types of concrete structures.

DOSEAGE FOR THE PREPARATION OF PROMPT MORTAR

Common doses	Prompt 1 litre	Tempo 1 cap	Sand 1 litre	Water 0.3 to 0.5 litres
	+	+	+	
	+	+	+	
Dose for structures under stress	Prompt 2 litres	Tempo 2 caps	Sand 1 litre	Water 0.3 to 0.5 litres

The advantages

- + Rapid setting and hardening
- + Immediate fix/hook
- + Large load in one pass
- + Quick intake adjustable with Tempo



3 As a Lime/Prompt hybrid mortars

- For the laying of stone, decorative low walls made of stone or brick, outdoor pavings, etc. Cf. french DTU 201.

DOSE IN VOLUME

In your usual natural hydraulic lime (NHL) dose, replace 1/3 of the volume with Prompt.

NB: tempo does not need to be added to mixtures with a weak proportion of Prompt.

The advantages

- + Speeds up the lime
- + Limits creep in the fresh joint
- + Ensures fixing and joining in one pass
- + Allows working in cold weather

DOSEAGE FOR THE PREPARATION OF PROMPT CONCRETE

Common doses	Prompt 1 x 25 kg bag	Tempo 2 bottles	Sand + gravel 50 litres	Water 8 to 12 litres
	+	+	+	
Dose for structures under stress	Prompt 1 x 25 kg bag	Tempo 2 bottles	Sand + gravel 30 litres	Water 7 to 10 litres

The advantages

- + Rapid return to use
- + Fast stripping of structure

2 As a concrete using Prompt

- > To build foundation blocks, lintel supports and columns, small building structures and for all types sealing up of cracks or voids - large or small.

SETTING TIME - RATE

Moisture temperature	10°C	20°C	30°C
Setting time without Tempo	4 minutes	2 minutes	1 minute
Setting time with "Tempo dosing"	20 minutes	15 minutes	10 minutes

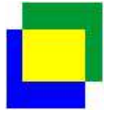


SHORT - AND LONG-TERM STRENGTH BUILDUP

Duration	16 min.	1 hour	3 hours	1 day	7 days	28 days
Average values (MPa)	5.5	7	8	16	23	32
Specific values NF P15-314	> 4	> 8	> 8	> 16	> 24	> 30
Duration	3 months	6 months	1 year	2 years	5 years	10 years
Average values (MPa)	40	48	52	68	63	67

(Sand/cement by weight = 0.7, 0.6 or 0.50)





APPENDIX 8

**Interim Damp & Environmental Assessment,
prepared by SMT Associates**

INTERIM DAMP & ENVIRONMENTAL ASSESSMENT

of

THE EARLS CHAMBER CHEPSTOW CASTLE



Prepared by SMT Associates

on the instructions of

PDP Green

JOB REF. No: 961

05th May 2018

CONTENTS:

- 1. INTRODUCTION**
- 2. BRIEF AND ASSUMPTIONS**
- 3. THE MONITORING WORKS**
- 4. RESULTS**
- 5. RECOMMENDATIONS AND CONCLUSION**

APPENDICES:

Appendix 1 Moisture Meter Readings & Locations of Loggers

1. INTRODUCTION

- 1.1. This report relates to our on going monitoring following preliminary investigations and analysis of the walls to the Earls Chamber at Chepstow Castle undertaken 05 February 2015, and completion of remedial works and commissioning of the air handling unit in January 2018.
- 1.2. The works were undertaken in accordance with our Invasive Survey Work Method Statement.
- 1.3. The report below is in the form of a schedule of monitoring and testing, all of which are referenced to floor plans at the end of the report.
- 1.4. We will provide a full report in September 2018 but are happy to continue monitoring over the winter 2018/19 to enable the success of the works to be fully determined.

2. BRIEF AND ASSUMPTIONS

- 2.1. The brief was received from PDP Green.
- 2.2. We were asked to investigate and report on the following:
 - The wall moisture contents using a standard moisture meter.
 - Data logging results to monitor the air temperature, humidities and dew points in the room and in 2No voids drilled into the walls.
 - A thermal imaging survey was undertaken.
 - Report on the effectiveness of the remedial works.
 - Report any further recommendations.
- 2.3. The Earls Chamber is not currently being used.

3. THE MONITORING WORKS

Moisture Meter Readings

- 3.1 The walls were initially tested with a standard moisture meter and 8No locations were chosen and positions recorded in February 2015 to record moisture contents with a standard moisture meter. These were: floor boards, 150mm, 1200mm, 2000mm high and to the underside of the corbel.
- 3.2 It should be noted that moisture meters must be interpreted with care, caution and experience. Moisture meters are calibrated for timber and use on masonry is only as a guide. Even when used on timbers care must be taken as other factors can influence the results, such as timber species, presence of salts or timber decay.
- 3.3 Traditionally, it has been stated that timbers are at risk of timber decay where moisture contents are above 20%. Dry rot can grow feebly at these moisture contents but actual timber decay will not occur until wood is at fibre saturation. For most types of wood this is typically around 28% moisture content.

Thermal Imaging Survey

- 3.3 The wall surface temperatures were recorded with a thermal imaging camera. In 2015 the walls were a uniform temperature and the survey did not show any useful results. Since the heating has been utilised there are good temperature differentials and useful images have been taken.

Data Logging

- 3.4 Data loggers were installed to record air temperatures and relative humidity of the air and within the walls in 2No locations.
- 3.5 Relative humidity is frequently used to analyse internal environments. There are weaknesses with using relative humidity because relative humidity is a proportion of moisture expressed as a percentage of the maximum amount of vapour can be present at the same temperature. Air at say 20 degrees celsius may have a relative humidity of 60%, but if this air cools to 15 degrees celsius the relative humidity would be 80%.
- 3.6 Water vapour exerts a pressure and measuring vapour pressure is directly related to the amount of water vapour. The more water vapour in air the greater the vapour pressure. Vapour pressure is not proportional to relative humidity or temperature.
- 3.7 In an unoccupied house or room such as the Earls Chamber, the external and internal vapour pressures would be similar because the level of internal vapour comes into equilibrium with the outside water vapour. In an occupied house during the colder months there is more vapour inside a property due to living activities which produce moisture. There is a difference in external and internal vapour pressures and this is the differential vapour pressure.

- 3.8 Under the old BS a dry occupancy was considered to have a differential vapour pressure of 0 - 0.3kPa where ventilation balances moisture production. 0.3-0.6kPa was a moist occupancy and 0.6kPa was considered wet.
- 3.9 The differential vapour pressure following a dry period and a week with 40mm of rain are both 0.10kPa. The average over the monitoring period was 0.09kPa. This would be considered a dry occupancy under the BS. Therefore the internal environment is closely linked to the external conditions as expected. There are no moisture generating uses within the Chamber and no heating or significant air flow to draw moisture out of the walls.
- 3.10 When dealing with internal conditions, relative humidity is the major factor because it is the relative humidity that potentially leads to health problems such as mould, bacteria and virus. Relative humidity is the amount of water vapour in the air at any given temperature expressed as a percentage of the maximum amount of water vapour that can be resident at the same temperature. Relative humidity is a proportion and not an amount.

Monitoring of Walls with Data Loggers

- 3.11 The concept of water activity (A_w) refers to the ability of water in a solid to take part in chemical reactions or support life. Salts which increase the readings of normal conductance type moisture meters do not affect water activity tests. Water activity tests were undertaken by drilling into the wall at various depths and heights. A humidity-measuring probe was inserted into the drill holes and the ends made airtight. The air inside the hole will come into moisture equilibrium with the surrounding walling materials. A data logger is used to measure and record the equilibrium relative humidity or water activity of the air pocket.
- 3.12 Water activity is precisely analogous to relative humidity in an atmosphere. Protimeter use this method and the results are expressed as a decimal fraction. Below 0.75 A_w decay is impossible, between 0.75 - 0.84 A_w is borderline and decay is inevitable at 0.85 A_w and above. A reading of 0.85 A_w equates to a timber moisture content of 20%.
- 3.13 There are concerns about this method mainly related to the accuracy of the probes at high moisture contents. However we have used this method since the mid 1990's and found it to be a useful tool in monitoring the moisture contents in walls without the need for continuously taking samples for weight/weight % moisture contents.

4. RESULTS

- 4.1 The investigation of the walls and environment included a visual inspection, survey with a conductance and capacitance type moisture meter and the measurement of % moisture content within the building fabric. Environmental monitoring was undertaken with data loggers recording the internal temperature and relative humidity at 15 minutes intervals during the monitoring period.

Visual & Moisture Meter Surveys

- 4.2 Salt bands were identified visually and with a moisture meter in the original survey in February 2015 - see photograph 1. The lime plaster to the walls has been removed and the walls finished as exposed stone work with the pointed joints beneath the plaster retained - see photograph 2. The moisture meter predictable gave very high readings where the salt bands were visible during the original survey.

Photograph 1 - Salt bands in plasterwork visually evident in February 2015



Photograph 2 - Plaster removed & walls finished as exposed stone work April 2018.



- 4.3 There was also a wet joint to the north west to the left side of the fire place in January 2018 where moisture was evident in the mortar joints - photograph 3. This joint has dried significantly by April 2018 with no moisture evident in the bedding joint - photograph 4. In January 2018 the moisture meter reading in the wet joint was 48% but this had reduced to 27% in April 2018, and therefore it could be concluded that the moisture penetration has stopped and the wall is drying out. We understand PDP Green have been investigating the cause of moisture penetration which is likely to be from the ledge above.

Photograph 3 - moisture penetration to bedding joint January 2018



Photograph 4- reduced moisture penetration of bedding joint April 2018



4.4 There was also signs of darkened bedding joints to the left and above the main Entrance door to the chamber in April 2018, but no moisture was visible in the joints, and no obvious source of moisture penetration externally. There are a number of joints which appear “damp” and this could be as a result of salts taking up moisture from the air. Further monitoring and sampling would be required to determine actual moisture contents.

4.5 In eight locations on the walls, a surface moisture meter reading was taken at various heights. These results of the moisture meter survey are shown as follows:

February 2015	1	2	3	4	5	6	7	8
Floor boards	27%	20%	21%	14%	20%	20%	24%	16%
150mm high	62%	28%	22%	11%	20%	43%	87%	14.5%
1200mm high	53%	18%	23%	38%	62%	27%	48%	28%
2000mm high	42%	33%	30%	28%	24%	26%	45%	51%
u/s corbel	24%	19%	27%	20%	25%	28%	30%	30%

January 2018	1	2	3	4	5	6	7	8
Floor boards	18%	16%	18%	15%	18%	18%	10%	14%
150mm high	17%	19%	28%	17%	20%	24%	15%	18%
1200mm high	18%	15%	30%	13%	30%	24%	48%	13%
2000mm high	13%	15%	28%	14%	20%	18%	30%	18%
u/s corbel	21%	23%	21%	18%	15%	17%	12%	14%

April 2018	1	2	3	4	5	6	7	8
Floor boards	14%	8%	10%	8%	11%	13%	14%	10%
150mm high	15%	14%	13%	17%	14%	18%	19%	17%
1200mm high	22%	19%	14%	15%	7%	15%	27%	18%
2000mm high	17%	10%	13%	15%	15%	11%	11%	15%
u/s corbel	13%	16%	18%	11%	8%	16%	14%	11%

4.6 As previously stated care must be exercised interpreting moisture meter readings. However, there is a clear downward trend in the moisture readings since the original survey in 2015 with 37 of the 40 readings being lower, many significantly lower, with what is considered “dry readings” shown in blue. The salt contaminated plaster has been removed and these salts would have given artificially high readings. However, the downward trend has

continued between January and April 2018 with 30No readings having reduced. The 2No readings above 20% were position 1, to the left side of the main door and position 7 to the left side of the fireplace where damp joints were visually evident.

February 2015	1	2	3	4	5	6	7	8
Floor boards	27%	20%	21%	14%	20%	20%	24%	16%
January 2018	1	2	3	4	5	6	7	8
Floor boards	18%	16%	18%	15%	18%	18%	10%	14%
April 2018	1	2	3	4	5	6	7	8
Floor boards	14%	8%	10%	8%	11%	13%	14%	10%

- 4.7 Moisture meters are calibrated for timber so it is interesting to compare the moisture readings taken in the floor boards. All floor board readings had reduced below 20% by January 2018. To 3No walls the floor boards have been cut back and isolated, but to the fireplace wall the floor boards were in contact with the wall - positions 5, 6 & 7. Between January and February the moisture meter readings to 5 & 6 had dried by 4% & 5% and the floor boards are considered air dry. Position 7 the door board moisture content had increased to 14% MC and this is almost certainly the result of moisture penetration of the joint above, but the moisture content of the timber floor boards is safe from timber decay.
- 4.8 Although we have to emphasise the limitations of moisture meter surveys, the overall trend from February 2015 to the January 2018 suggests the walls are significantly drier, Even allowing for the effect of salts in the original plaster. The readings have decreased further between January and April 2018 and when the readings were taken on the same walling material, it is therefore possible to conclude that the walls are drying further since the plant has been switched on.

Moisture Loading within the masonry

- 4.9 Visually there has been 2No areas of moisture penetration, to the left of the fireplace and main entrance door. These were also identified by the moisture meter. There are a number of joints where discolouration of the bedding count is evident and may be the result of salt contamination. To accurately determine moisture contents of the wall samples of mortar would need to be taken processed to establish absolute moisture content (mc) using the oven dried technique as set out in BRE245, and previously undertaken.

Thermal Imaging Survey

- 4.9 The thermal imaging survey in 2015 did not provide any useful images as the wall was “thermally dead” because there was no heating or temperature differentials.
- 4.10 We understand the air conditioning plant was turned on 3 days before our survey on 27th January 2018. Therefore the air had been heated and the thermal camera was able to detect surface temperature differences.
- 4.11 Using similar temperature parameters, scales and pallets the effect of the air conditioning plant between January and April is clearly demonstrated in images 1 & 2.

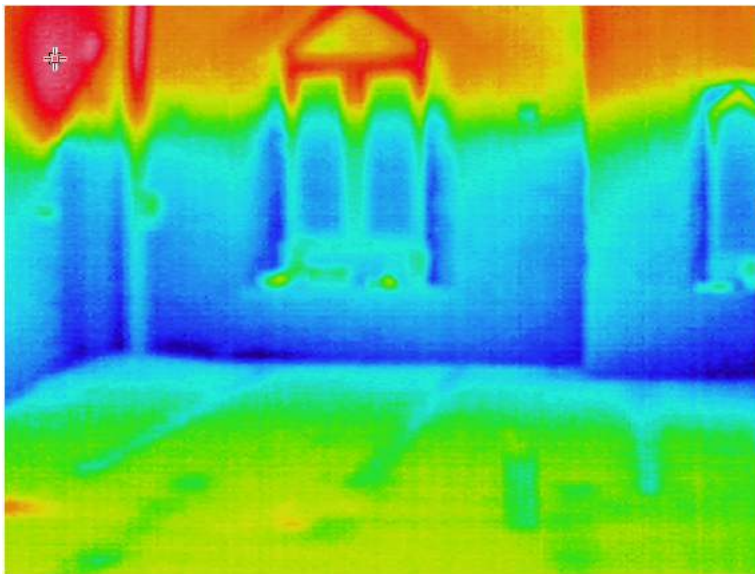


Image 1 - January 2018 - External Temperature 11.5 degrees Internal Temperature 19 degrees

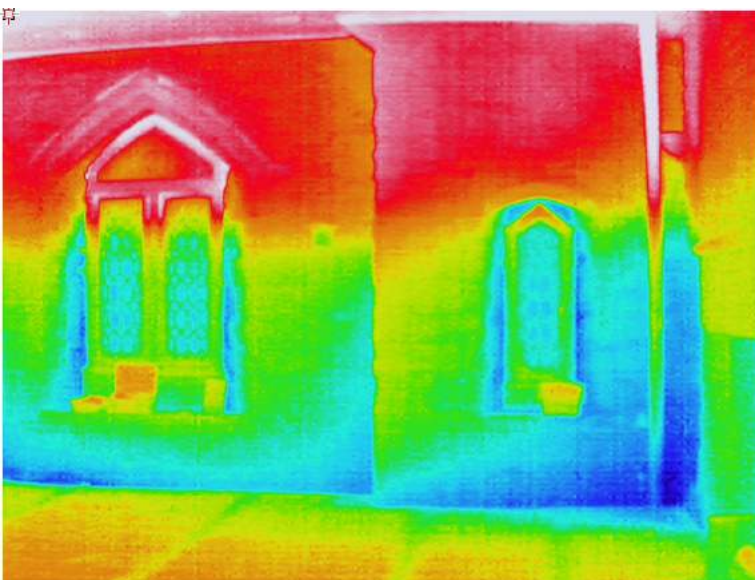


Image 2 - April 2018 - External Temperature 11.0 degrees Internal temperature 21 degrees

- 4.11 The building fabric has warmed and the condensation risk has significantly reduced. The colder areas identified in the corners of the room and around windows is normal. The image also shows the stratification of heat with warmest temperatures at the top of the room.

Environmental Monitoring

- 4.12 Data loggers were installed to record air temperatures and relative humidity. Comparing the overall data logging results between February 2015 and April 2018 the results are as follows:

	Temperature			Dew Point			Relative Humidity		
	Ave.	Max.	Min	Ave.	Max.	Min	Ave.	Max.	Min
February 2015									
Internal	5.0.	7.5.	3.0	4.3.	7.4.	1.0	96%.	100%.	85%
External	5.8.	16.5.	1.5	3.4.	10.1.	-2.8	85%	100%.	50%

	Temperature			Dew Point			Relative Humidity		
	Ave.	Max.	Min	Ave.	Max.	Min	Ave.	Max.	Min
April 2018									
(i) Internal	15.1	21.0	8.0	4.4	11.0	-6.7	50%.	86%.	26%
(ii) Internal	15.4	21.5	8.0	5.4	11.7	-4.8	53%.	90%.	28%
External	8.6	32.0	0.5	3.7	15.7.	-9.5	73%	96%	23%

(i) - North-east Fireplace Wall. (ii) - South-west Wall to Great Hall as shown on plan Appendix I

- 4.13 Examining the overall data summary figures there has been a significant change to the internal environment since the air conditioning plant was commissioned. The external conditions were slightly warmer with an average temperature of 8.6 degrees in 2018 compared to 5.8 in 2015 and the relative humidity was an average of 73% in 2018 compared to 85% in 2015. For a short period on a small number of days the external temperature reached 32 degrees and I believe this is an anomaly caused by sunlight because the time occurred was consistently between 15.00hrs and 16.20hrs on each day. This would have had a marginal effect increasing the average temperatures and decreasing the average relative humidity figures.
- 4.14 The data logger on the fireplace wall had very similar temperature figures and the relative humidity figures were on average 3% drier. The probes were close to the walls and this could be a result of the moisture contents within the walls - see wall monitoring below.
- 4.15 In 2015 the average internal dew point was 4.3 degrees Celsius and the average temperature was 5.0 degrees and the wall surface temperatures were below the dew point temperature. There were visible runs of moisture down the wall from the corbel in 2015 and condensation was a significant cause of moisture. In 2018 the average dew point was 4.4 and 5.4 degrees Celsius - positions (i) and (ii) respectively, and the internal average temperature was 15.1 degrees Celsius at position (i) and 15.4 degrees Celsius at position (ii). The thermal image

taken on 13th April 2018 shows the coldest part of the rooms was above 11 degrees Celsius. Therefore there is no risk of condensation.

4.16 Analysing the data on a daily basis shows the following:

Date.	Time		Temperature	Relative Humidity	Dew Point
2018.01.28	8.40am	External	10.5	90.0%	8.9
		Internal	18.5	60.0%	10.5
2018.03.10	11.00am	External	-0.5	64.0%	-6.4
		Internal	12.0	36.0%	-2.5
2018.03.13	12.00	External	15.5	64.5%	8.8
		Internal	18.5	48.5%	7.4

4.17 These typical results indicate the system was working well when the relative humidities were very high externally with a 30% differential between the external and internal RH readings. When there was a cold snap with sub zero temperatures down to 0.5 degrees celsius internal the temperature remained within the control parameters and the relative humidity was low which would have encourage further drying of the building fabric.

4.18 The system continued to work well until 12.00 on 13th March. Following this time the temperatures and humidities internally closely mirrored the external conditions as follows:

2018.03.13	22.40	External	9.5	68.5%	3.5
		Internal	12.5	66.0%	6.3
2018.03.14	16.20	External	11.5	69.5%	6.1
		Internal	11.5	72.5%	6.1
2018.03.15	12.00	External	12.0	82.0%	9.0
		Internal	11.0	82.0%	8.0
2018.03.27	10.00	External	10.0	91.0%	8.6
2018.03.27	12.40	Internal	9.0	90.5%	7.5

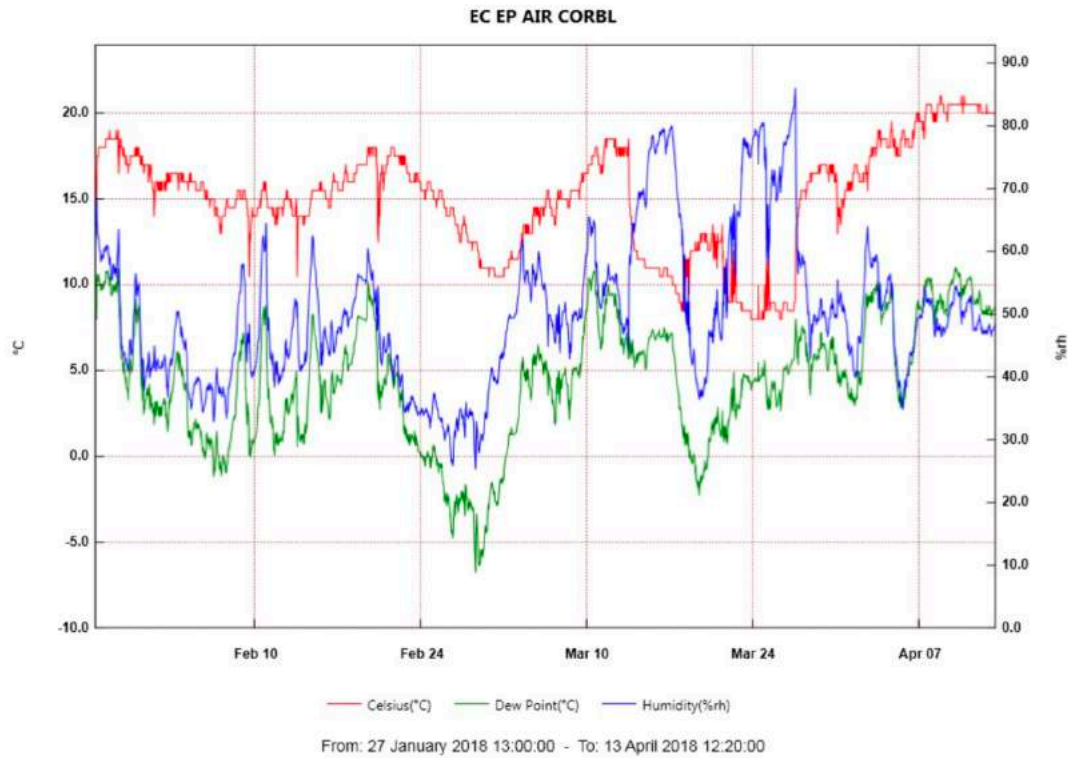
4.19 The building fabric, walls, roofs, windows and doors usually provide a buffer between the internal and external conditions when there is no heating. There was a slight delay on 27th March when it took 2 hours 40 minutes for the internal humidity to rise to the external conditions. However, internal humidities above 90% in extremely high and condensation is likely.

4.20 The fact the temperatures and humidities were so closely matched internally and externally indicates that the air exchange was still working during this period but the heating element was not working. This anomaly started after 12.00 on 13th March and continued until the temperature started to rise after 13.00 on 27th March. The plant was working well before and after these dates and therefore it can only be assumed that the controls were altered or inadvertently changed, it is extremely unlikely there was a control fault that rectified itself.

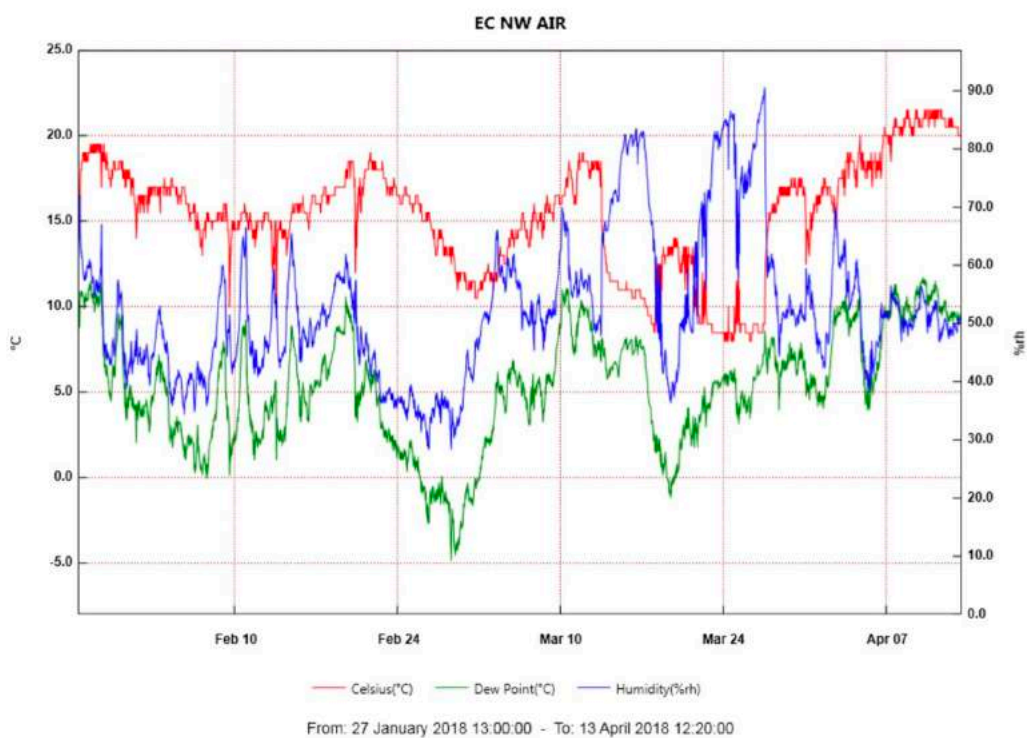
4.21 We understand this is currently being investigated.

4.22 The monitoring graphs 1 and 2 shows a significant drop in internal temperatures below 10 degrees celsius between 13th March and 27th March and an elected rise in the relative humidity.

Graph 1 - monitoring position (i)

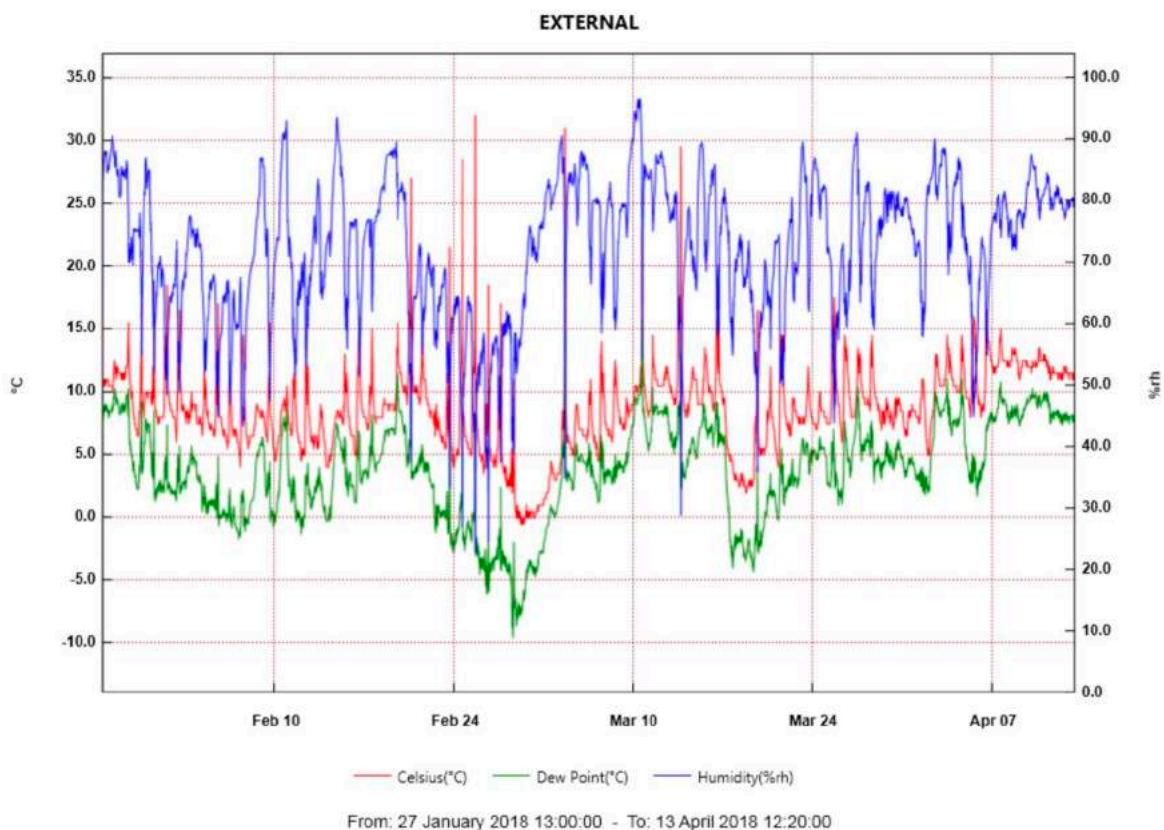


Graph 2 - Monitoring position (ii)



- 4.23 The internal temperature fell below 15 degrees between between 26th February and 6th March. The internal relative humidities were lower during this period reflecting the lower external relative humidities - see graph 3.
- 4.24 Examination of the external data shows there was a correlating drop in the external temperature between 26th February and 6th March and 13th March and 27th March. The cause of these fluctuations needs to be ascertained and either the control of the system needs to be adapted to maintain a consistent internal temperature, or was there something that the client had undertaken to the controls?

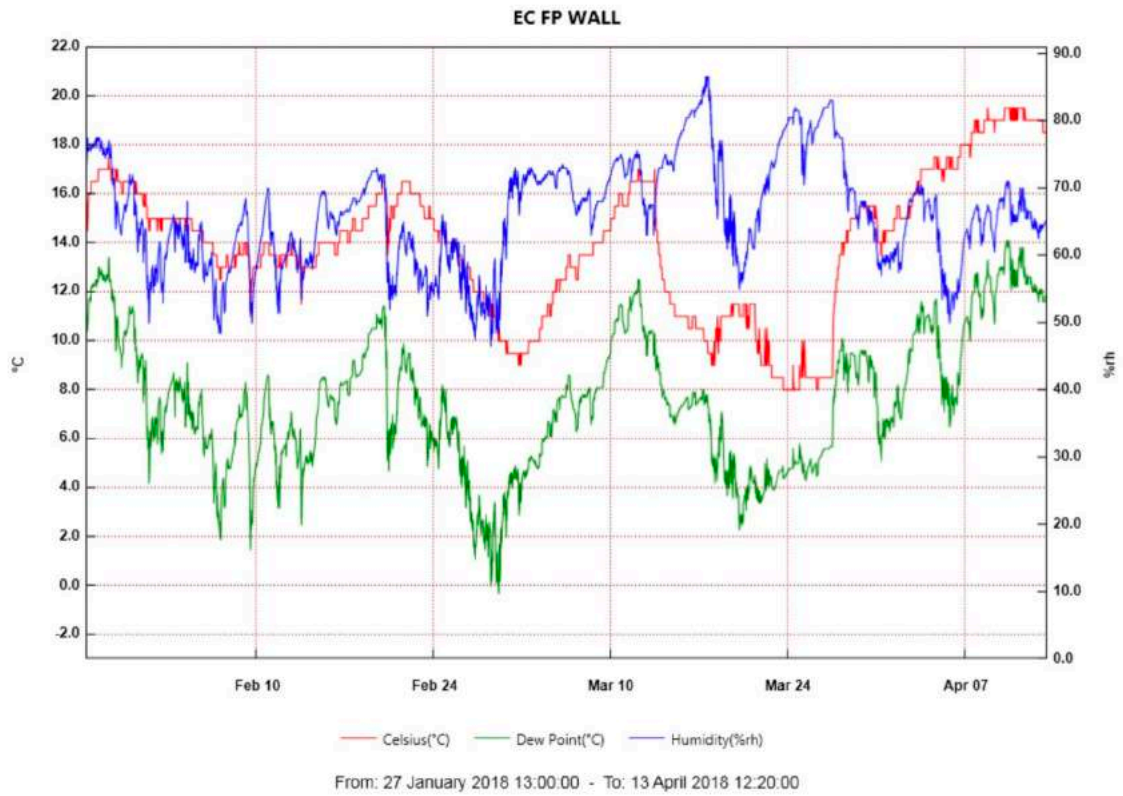
Graph 3 - External data - note spikes caused by direct sunlight on 5No occasions



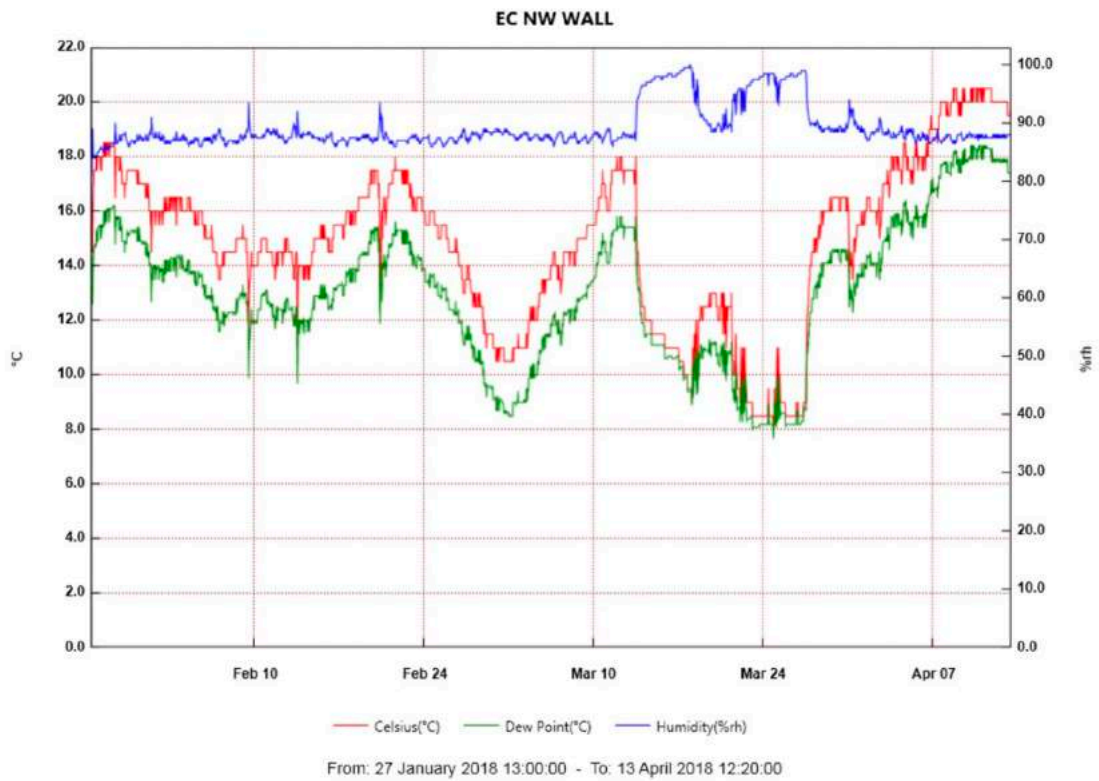
Monitoring of the walls with data loggers

- 4.25 The use of loggers to monitoring the air within a void can have limitations mainly concerning the accuracy of the probes at high relative humidities. However, we have found the process can provide useful results as part of a complete package of investigations. The holes drilled were approximately 100mm deep so the probes are measuring to moisture in equilibrium to that depth.
- 4.26 The readings from position (i) on the fireplace wall graph 4 below, were 77.5% at 17 degrees celsius on 28th January 2018. At the same temperature on 03rd April 2018 the relative humidity was 70%, which suggests the wall has dried over those three months. The relative humidity in the void has changed with temperature as expected. On the photometer scale the reading of 70%, or 0.7AW and is drying down well. This is the north-east facing wall.

Graph 4 - Wall void position (i)



Graph 5 - Wall void position (ii)



- 4.27 At wall position (ii) the relative humidity has remained around 86% in the void with an associated rise in RH when the temperature in the Chamber fell below 12 degrees celsius on 13th March. There RH and therefore the moisture levels have remained fairly constant. However, some of the original weight/weight % moisture contents taken from this wall were saturated and extremely wet and therefore this wall has dried since the original survey. This wall faces the predominant south-westerly moisture laden weather systems and receives a very high wind driven moisture load.
- 4.28 Monitoring over the summer will be continued and further drying down should be expected.
- 4.29 It would be possible to utilise the voids for the wall monitoring positions to collect further samples for weight/weight % analysis to confirm and compare the data logging readings. It would also be useful to undertake limited additional samples to confirm our preliminary findings.

5.0 RECCOMENDATIONS & CONCLUSIONS

- 5.1 The internal environment is significantly warmer with much lower relative humidities than noted in February 2018. The condensation risk appears to be negligible with the colder corners of the room remaining above dew point. Condensation was a significant cause of moisture penetration originally and the works have been successful reducing this risk.
- 5.2 The two long walls were considered very damp, with the wall to the former south-west facing Great Hall yielding extremely high moisture contents. Both walls have dried and we advise this will continue because the air in the Chamber is warmer and drier and will encourage evaporation from the walls. Without a lead capping or soft capping some penetration of moisture through the exposed wall core is to be expected, but the porous finishes internally and externally will allow evaporation and balance of the moisture contents. The prompt wall capping is a natural cement and will possible increase run off. The joints below the capping will need to be carefully monitored to ensure no small holes or cracks open up or are eroded, no such erosion was noted during our survey in April 2018.
- 5.3 The drying of such massive masonry walls is a long process but the interim results, visually, with a standard moisture meter and data loggers are all positive.
- 5.4 It appears that the heating controls have been altered resulting in the internal and external conditions being closely mirrored. This indicates the air exchange was happening but the incoming air was not heated resulting in high internal relative humidities and low temperatures and a significant risk of condensation. It would appear the alterations to the system happened between 12.00 and 12.20 on 13th March and 12.40 and 13.20 on 27th March. This requires further investigation.
- 5.5 Another potential issue with the high relative humidities is that salts can absorb water from the humid air in sufficient quantities to dissolve from the crystal form and appear as damp patches.
- 5.6 There was significant moisture penetration to a horizontal joint to the left hand side of the fireplace in February 2018 where moisture droplets were noted. This had dried by our April visit although the joints remained visible damp. There were some visually damp joints to the left side of the main door in April but this appeared fairly minor. Generally the joints may become discoloured due to salt contamination but controlling the temperatures and relative humidities will reduce cycles of salt crystallisation.

- 5.7 There are strengths and weaknesses in the various methods employed to investigate dampness and moisture contents in traditional masonry structures. No one method offers a complete solution. We have therefore used the various techniques we deem appropriate in this case and by careful interpretation of the results, and experience gained on previous works, we have formulated our results and recommendations.
- 5.8 Overall the works have significantly reduced the wall moisture contents and the internal environment has much drier relative humidities. Drying of the fabric will continue over the summer as moisture is evaporated internally and externally due to warmer conditions and air flow externally.
- 5.9 We advise limited samples are taken to establish weight/weight % moisture contents to confirm the data logging and moisture meter survey results.
- 5.10 Our full report and analysis will be prepared in October 2018.

SURVEYS BY S.M. TUCKER
 27, The Old Rectory,
 13th April 2018 - 13:20

KEY
 DATA LOGGERS
 i. Data Logger - Air & Wall
 ii. Data Logger - Air & Wall
 iii. External Data Logger
 MOISTURE METER TESTING
 1 - 8

Ref:	No. 1		No. 2		No. 3		No. 4		No. 5		No. 6		No. 7		No. 8			
	Feb 15	Jan 18	Apr 18	Feb 15	Jan 18	Apr 18	Feb 15	Jan 18	Apr 18	Feb 15	Jan 18	Apr 18	Feb 15	Jan 18	Apr 18	Feb 15	Jan 18	Apr 18
Floor Boards	27%	18%	14%	20%	18%	10%	14%	15%	8%	20%	16%	11%	24%	10%	14%	16%	14%	10%
+150mm	62%	17%	15%	28%	19%	14%	11%	17%	17%	20%	20%	14%	87%	15%	19%	15%	16%	17%
+1200mm	53%	18%	22%	18%	15%	19%	38%	13%	15%	62%	30%	7%	48%	48%	27%	28%	13%	18%
+2000mm	42%	13%	17%	33%	15%	10%	28%	14%	15%	24%	20%	15%	45%	30%	11%	51%	18%	15%
US corbel	24%	21%	13%	19%	23%	16%	20%	18%	11%	25%	15%	8%	30%	12%	14%	30%	14%	11%

NOTE: Discoloured joints
 by dust > 30%

MOISTURE METER READINGS - JANUARY 2018 - FEBRUARY 2018 & APRIL 2018

Notes:
 1. This drawing is for paper based consulting Ltd.
 2. The Contractor is responsible for all dimensions and for the accuracy of the drawings. It is the Contractor's responsibility to ensure that all dimensions are correct. Any dimensions shown on the drawings are to be used as a guide only. Any dimensions shown on the drawings are to be used as a guide only.
 3. Survey as at Code of the Job.
 4. This drawing is not to be used for construction unless marked in the drawing as 'FOR CONSTRUCTION'.
 5. The Contractor is responsible for ensuring that all dimensions are correct. It is the Contractor's responsibility to ensure that all dimensions are correct. Any dimensions shown on the drawings are to be used as a guide only.

In particular, the Contractor must ensure that it is not responsible for the accuracy of the drawings. It is the Contractor's responsibility to ensure that all dimensions are correct. Any dimensions shown on the drawings are to be used as a guide only. Any dimensions shown on the drawings are to be used as a guide only.

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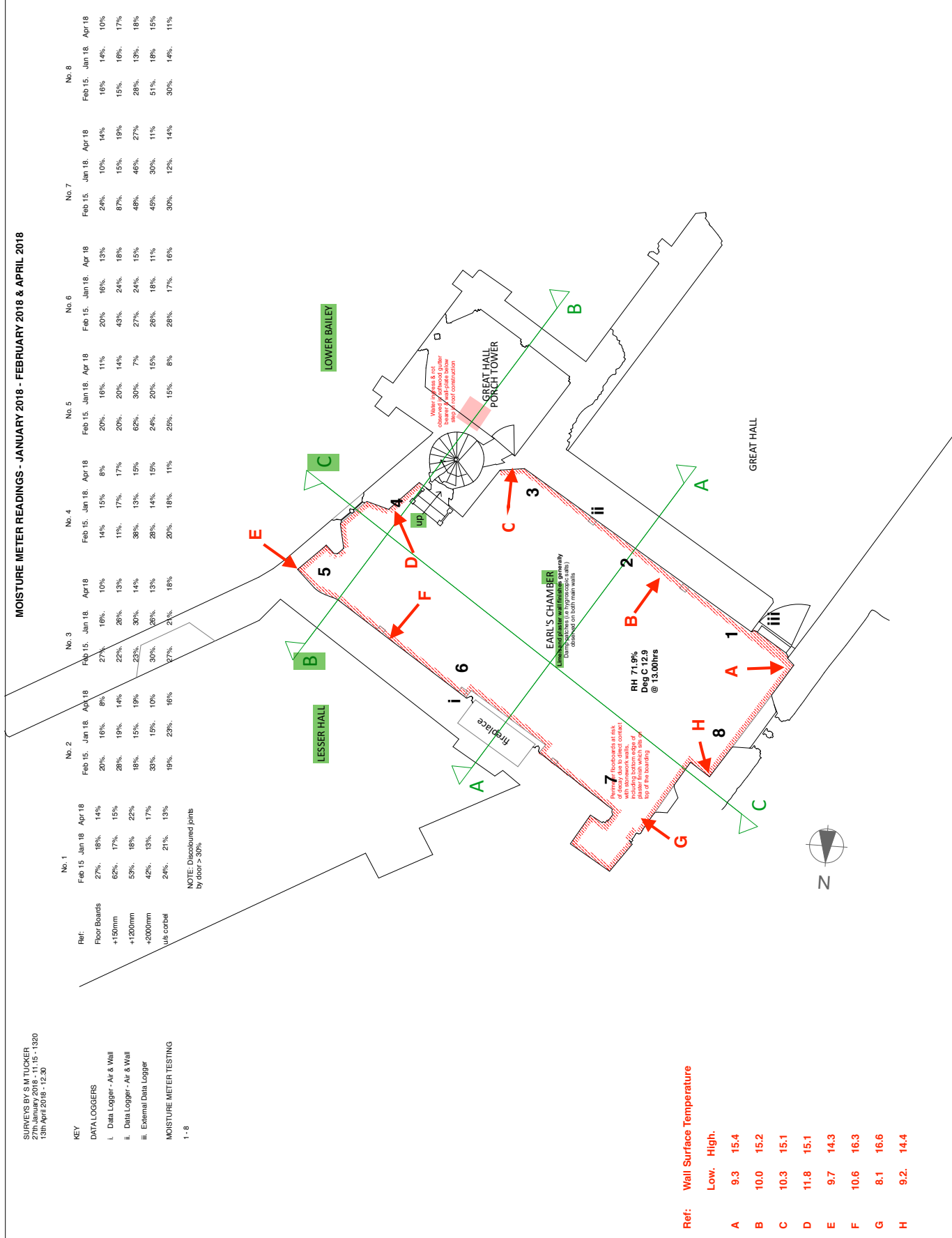
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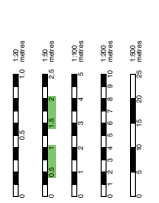
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Ref:	Wall Surface Temperature	
	Low.	High.
A	9.3	15.4
B	10.0	15.2
C	10.3	15.1
D	11.8	15.1
E	9.7	14.3
F	10.6	16.3
G	8.1	16.6
H	9.2	14.4



SURVEY	
Project No.	4001
Client	Earl's Chamber
Location	Chepstow Castle, Gloucestershire
Date	August 2015
Scale	1:50
Drawn by	pdq@pqr.com
Checked by	pdq@pqr.com
Approved by	pdq@pqr.com
Issue	1

