AN AUSSIE PHYSICIST IN QUEEN ELIZABETH'S COURT

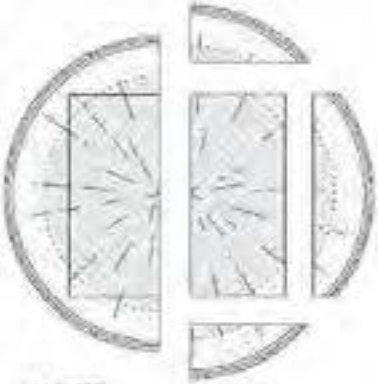
DR ROBYN PENDER

BUILDING CONSERVATION + RESEARCH TEAM
CONSERVATION DEPARTMENT

METHODS OF CONVERTING A LOG INTO BUILDING TIMBERS

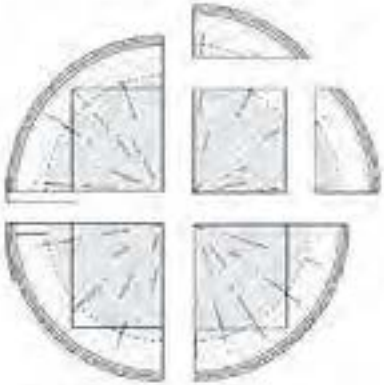
BOXED-HEART

used for posts, beams, purlins, plates, ridges, rafters



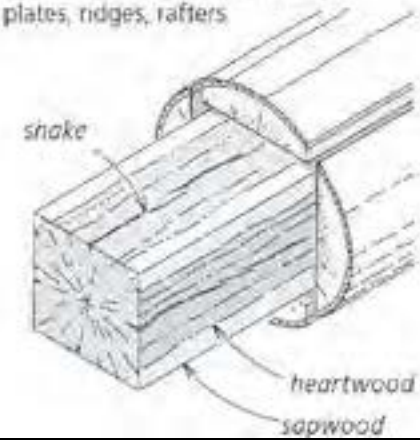
HALVED

used for girdings, bressumers, roof truss components, studs, braces, joists, rafters



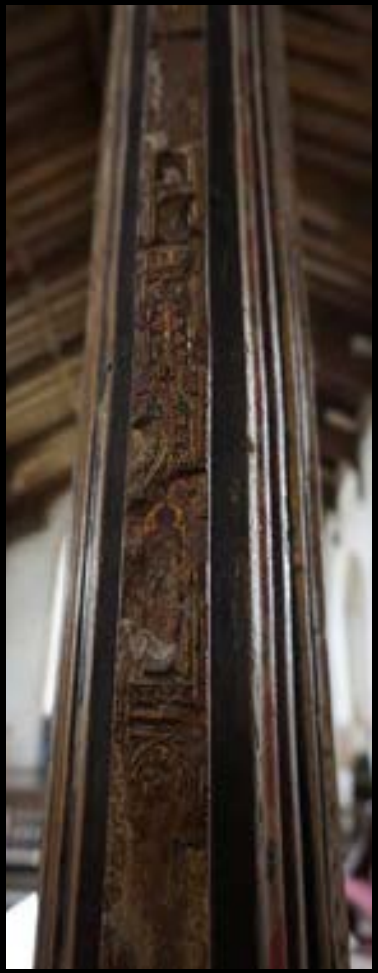
QUARTERED

used for plates, joists, ridges, rafters



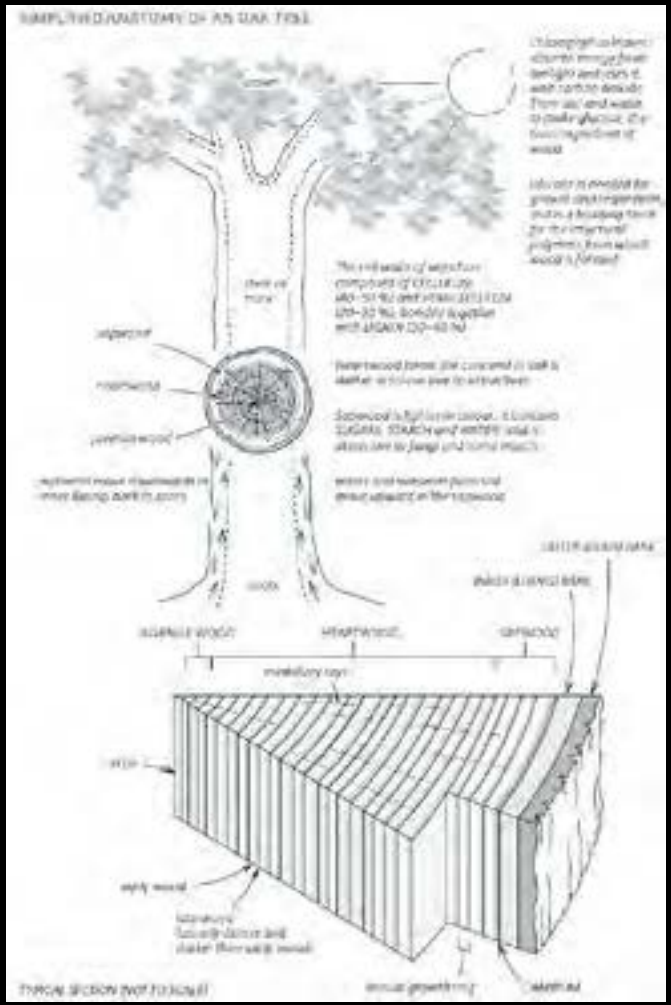
As a boxed-heart timber dries, shakes that follow the planes of the medullary rays tend to develop towards the centre of each face of the timber

SAWN DEALS AND PLANKS




alamy
alamy
alamy
alamy

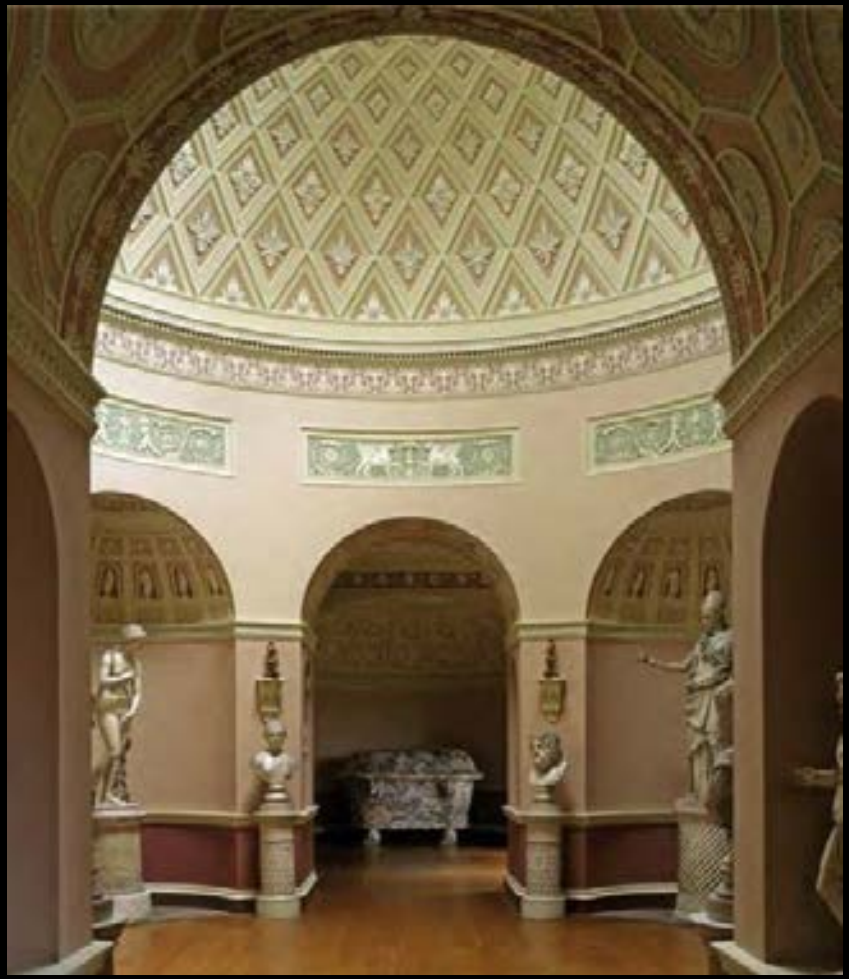
SCOTS OR BALTIC PINE




20 YEARS
35 YEARS

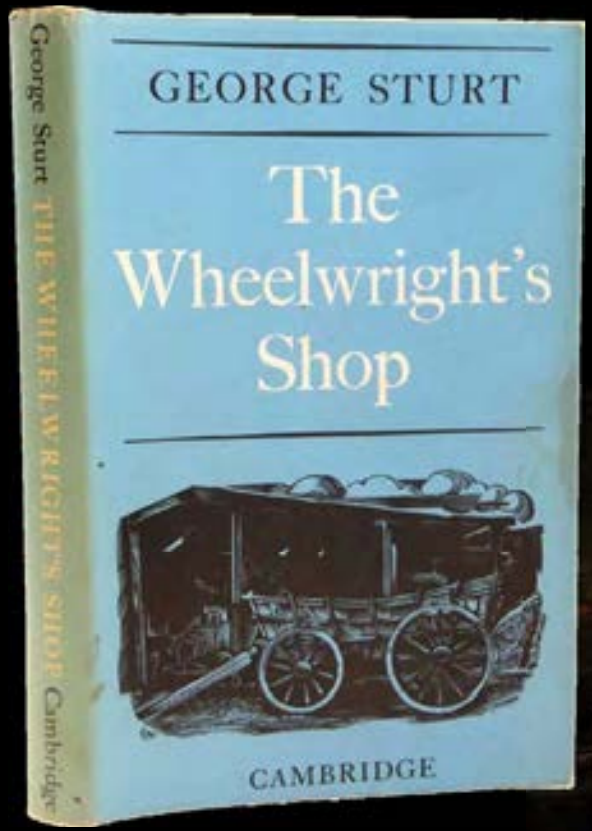

65 YEARS
sapwood

Restoring one of Adam's finest

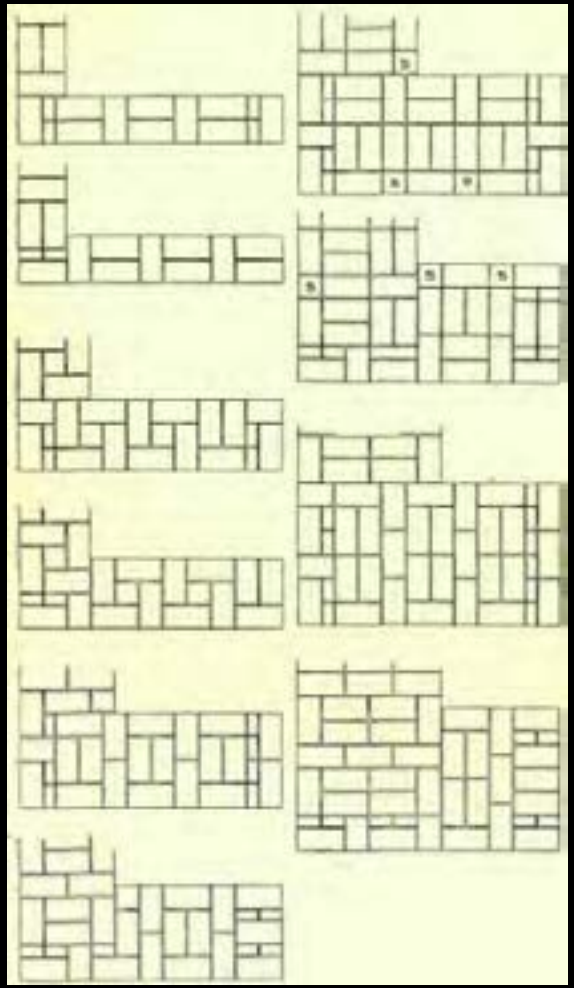


LIME WOOD
(2000-year-old coppiced lime tree)

WALNUT


GEORGE STURT
The Wheelwright's Shop
CAMBRIDGE
George Sturt THE WHEELWRIGHT'S SHOP Cambridge

BONDS




Liverpool
Lime Street


Lime Kiln Point State Park
Washington

THE LIME CYCLE !

START WITH LIMESTONE

$CaCO_3$

CALCIUM CARBONATE

GRIND IT UP AND CALCINE (BURN) IT

$CaCO_3$

+ 900°C

YOU GET QUICKLIME

$$CaCO_3$$

+ 900°C

$$= CaO$$

CALCIUM OXIDE

‘SLAKE’ IT WITH WATER

$$CaCO_3 \xrightarrow{+\ 900^{\circ}C} CaO \xrightarrow{+\ 3H_2O}$$

YOU GET SLAKED LIME

$$CaCO_3$$

$$+ 900^{\circ}C$$

$$CaO$$

$$+ 3H_2O$$

$$= Ca(OH)_2$$

CALCIUM HYDROXIDE

MIX WITH SAND, HAIR etc

$CaCO_3$

+ 900°C

CaO

+ $3H_2O$

$Ca(OH)_2$

PLACE AND EXPOSE TO AIR

$CaCO_3$

+ 900°C

CaO

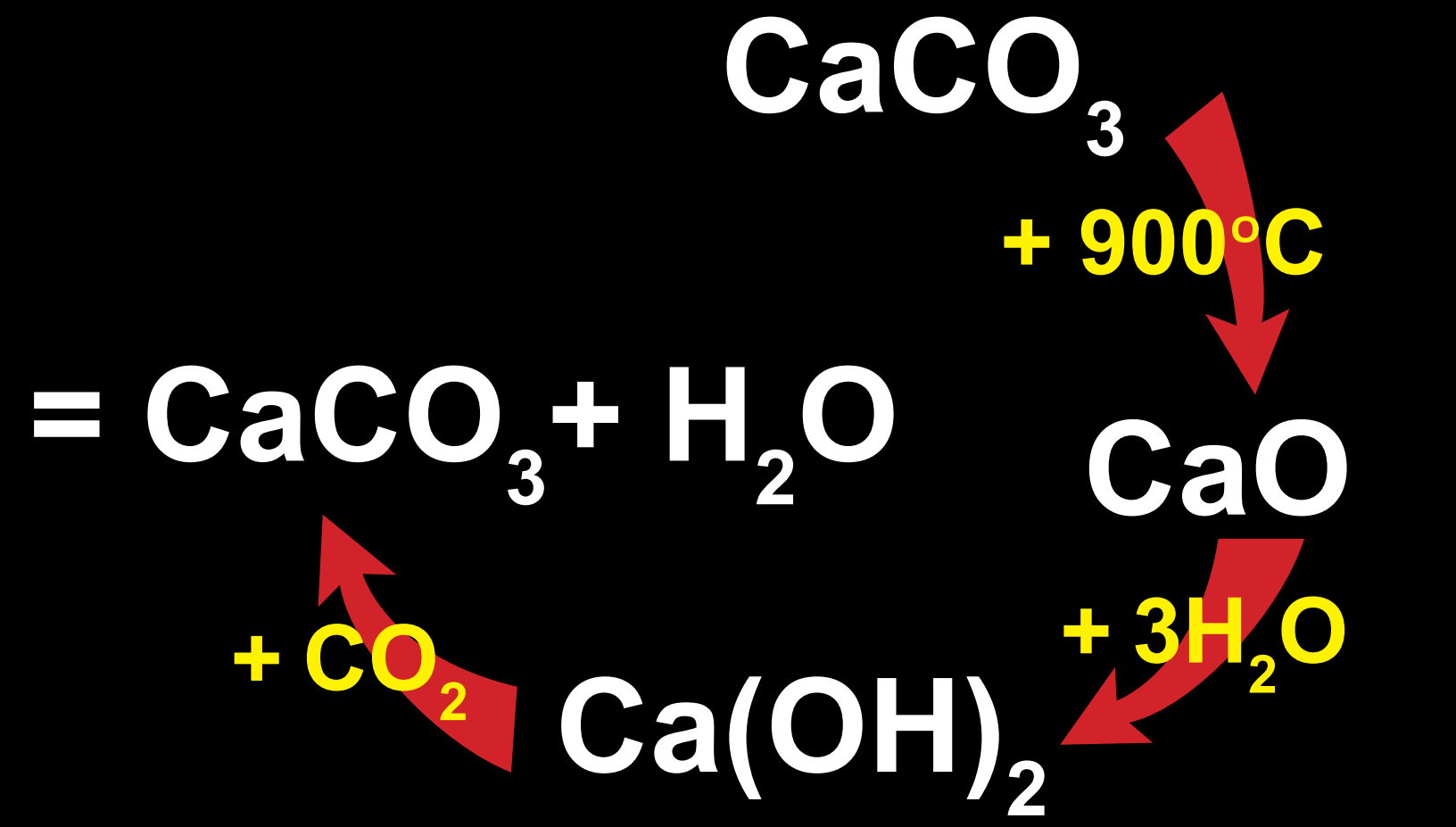
+ $3H_2O$

$Ca(OH)_2$

+ CO_2

CARBON DIOXIDE

IT CARBONATES...



...GOING BACK TO LIMESTONE !

$CaCO_3$

+ 900°C

CaO

+ $3H_2O$

$Ca(OH)_2$

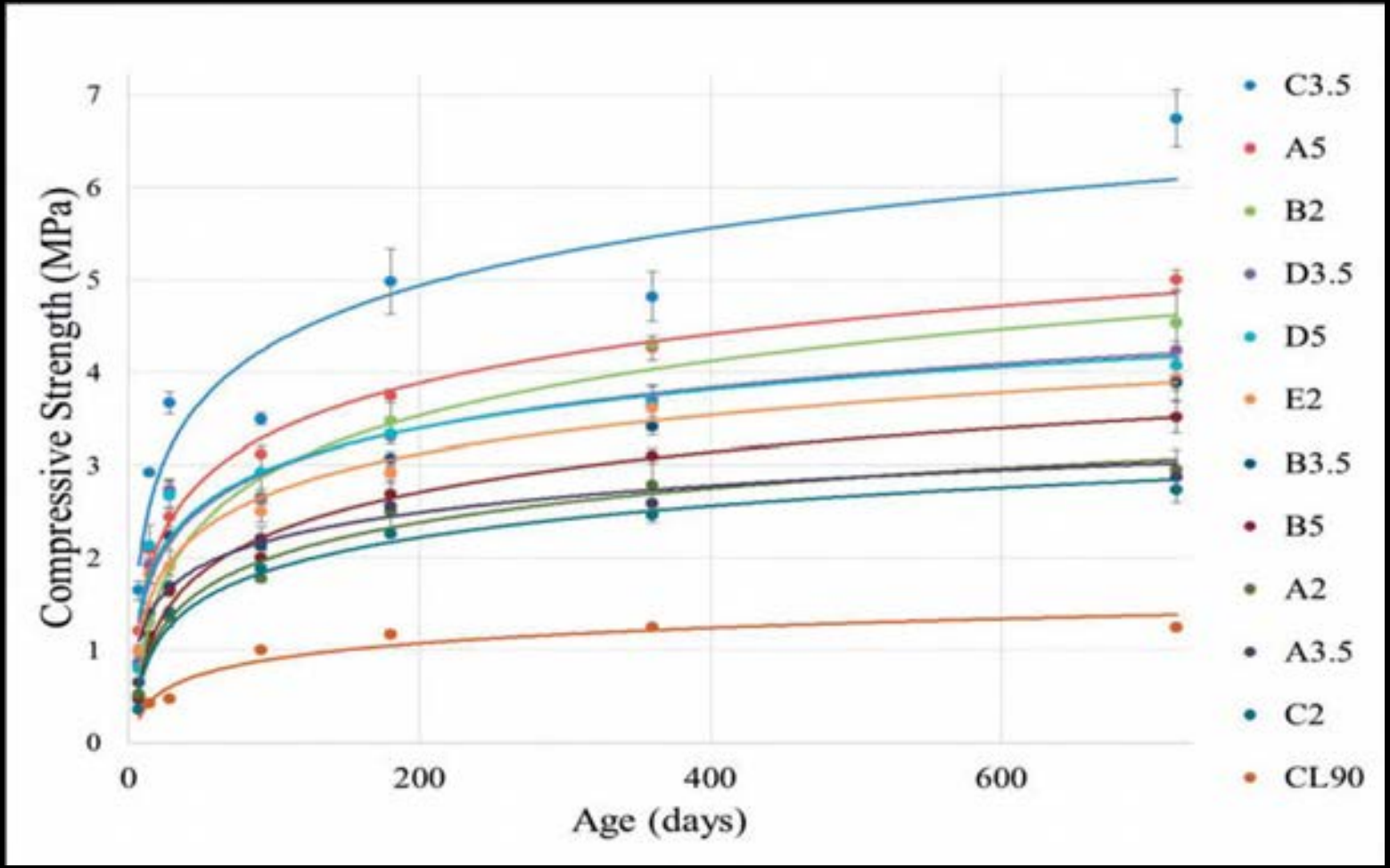
+ CO_2

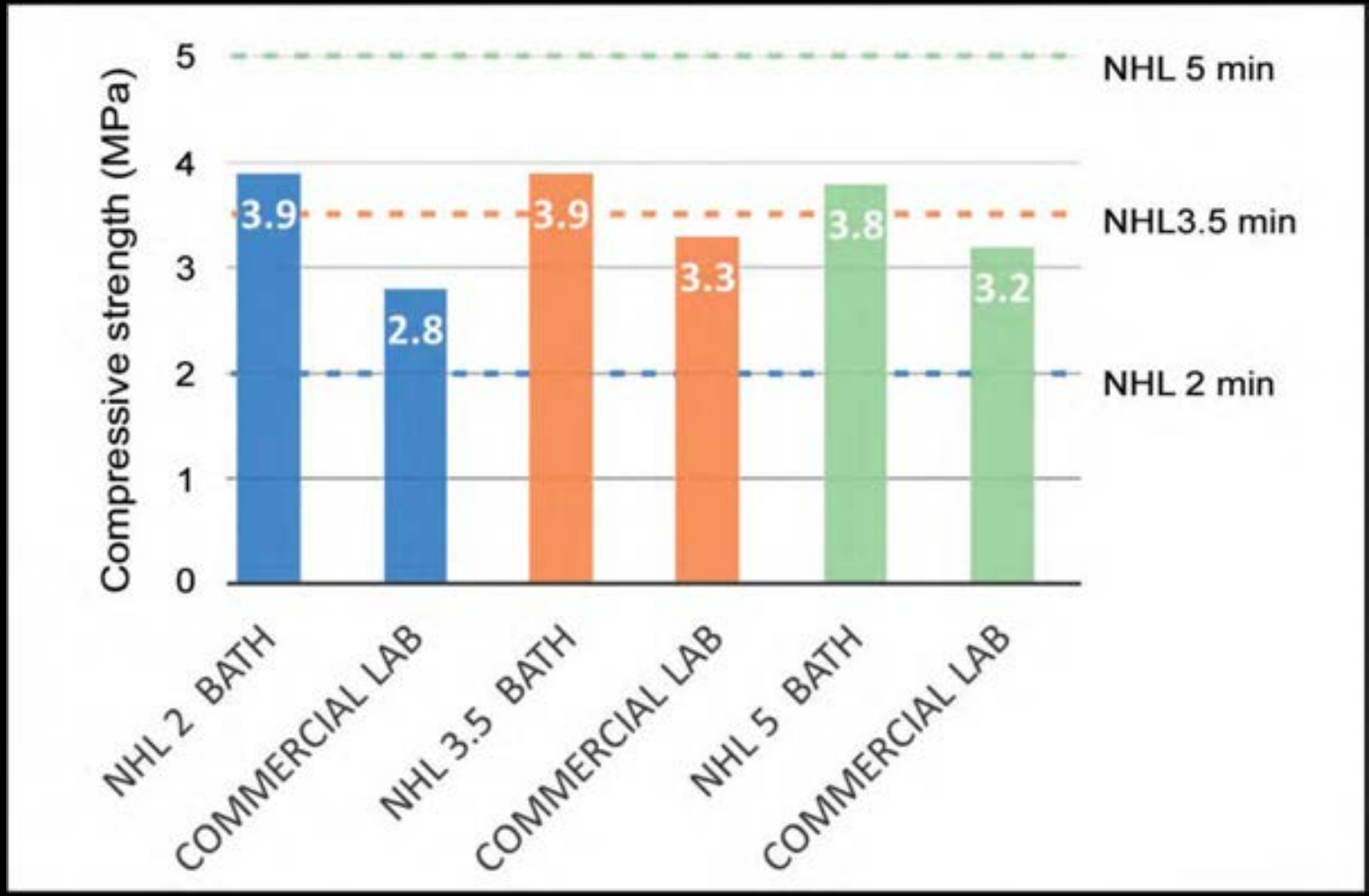
- H_2O

BUT...

HOT-MIXED LIME

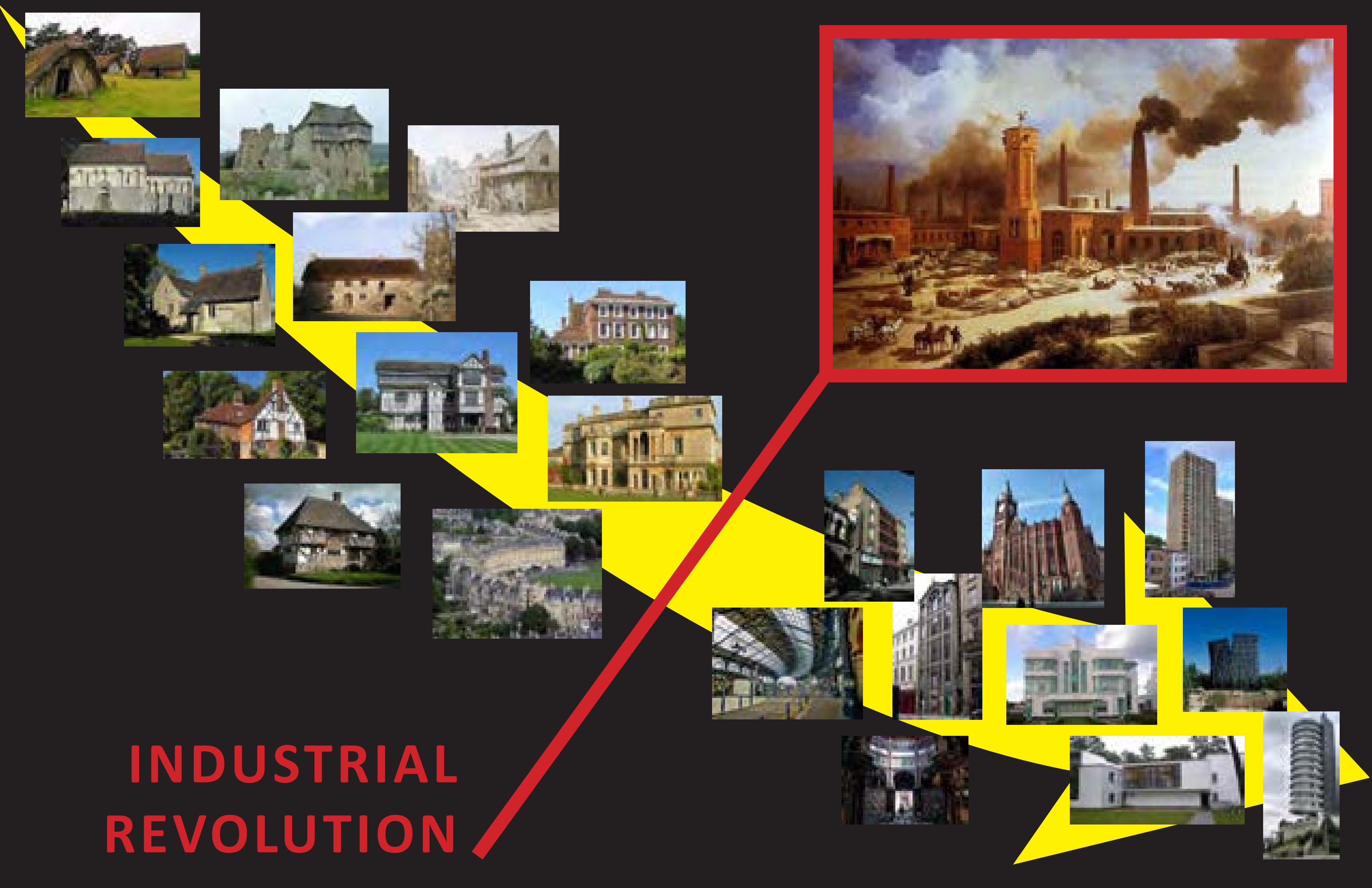

SECIL
natural
lime
NHL 2
25kg
SECIL
natural
lime
NHL 3.5
25kg
CE
SECIL
natural
lime
NHL 5
25kg
CE

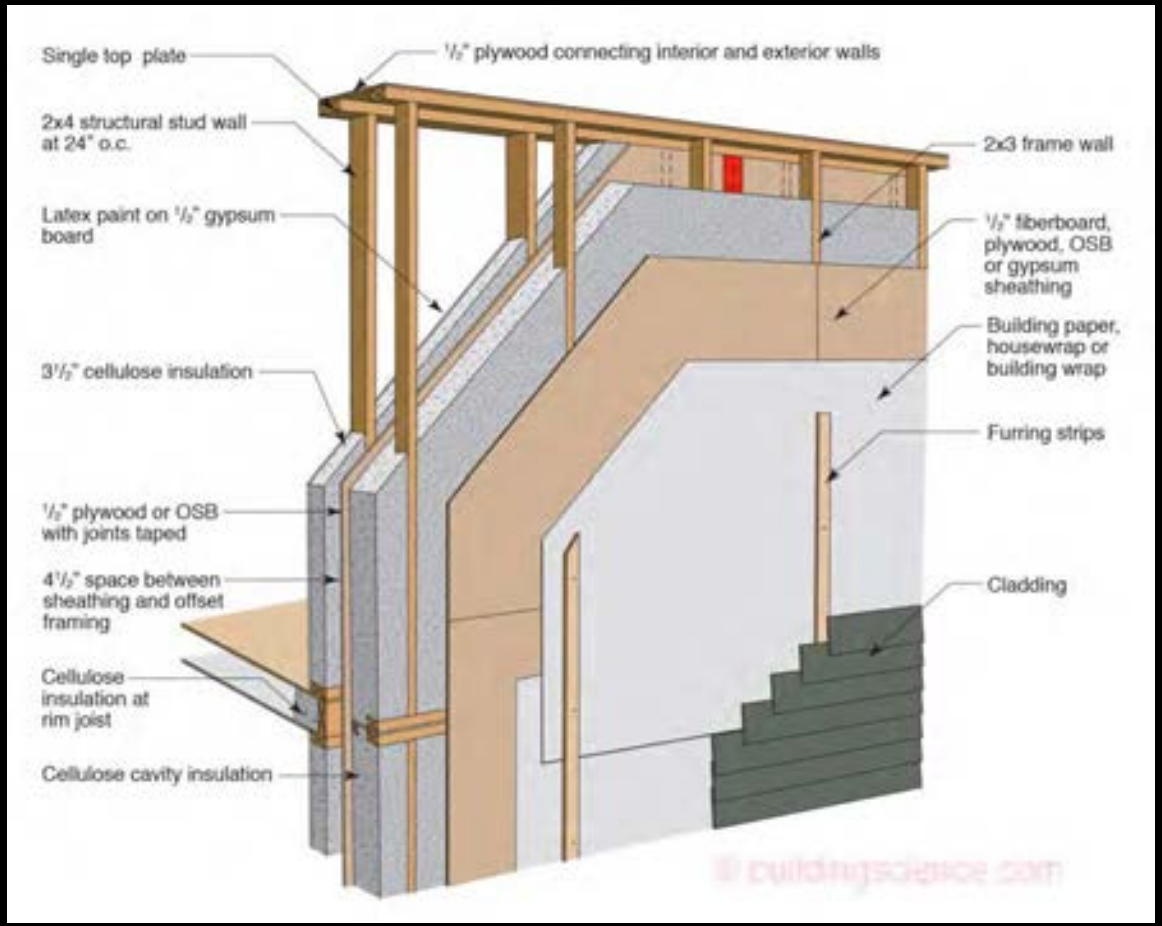

Compressive Strength (MPa)
0
1
2
3
4
5
6
7
0
200
400
600
Age (days)
C3.5
A5
B2
D3.5
D5
E2
B3.5
B5
A2
A3.5
C2
CL90


Compressive strength (MPa)
5
4
3
2
1
0
NHL 5 min
NHL3.5 min
NHL 2 min
3.9
2.8
3.9
3.3
3.8
3.2
NHL 2 BATH
COMMERCIAL LAB
NHL 3.5 BATH
COMMERCIAL LAB
NHL 5 BATH
COMMERCIAL LAB


folles
malleu
incudis
Ferrarij duo demul
cent ferrum.

Late 16th Century conspicious consumption


INDUSTRIAL
REVOLUTION


Single top plate
½" plywood connecting interior and exterior walls
2x4 structural stud wall at 24" o.c.
2x3 frame wall
Latex paint on ½" gypsum board
½" fiberboard, plywood, OSB or gypsum sheathing
Building paper, housewrap or building wrap
3½" cellulose insulation
Furring strips
½" plywood or OSB with joints taped
4½" space between sheathing and offset framing
Cladding
Cellulose insulation at rim joist
Cellulose cavity insulation


I hate you so much right now!
ICANHASCHEEZBURGER.COM

c.1170, with C18 and C19 alterations



Historic England
ENGLISH HERITAGE
Historic England
ENGLISH HERITAGE




Historic England









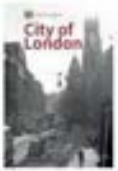



REVERE OR REMOVE?
The battle over statues, heritage and history


HISTORIC ENGLAND
ANGEL AWARDS
Historic England
A survey of listed building owners in England

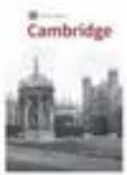













CONSERVATION

CONSERVATION

=

“MANAGING CHANGE”

ANGLO-SAXON

NORMAN

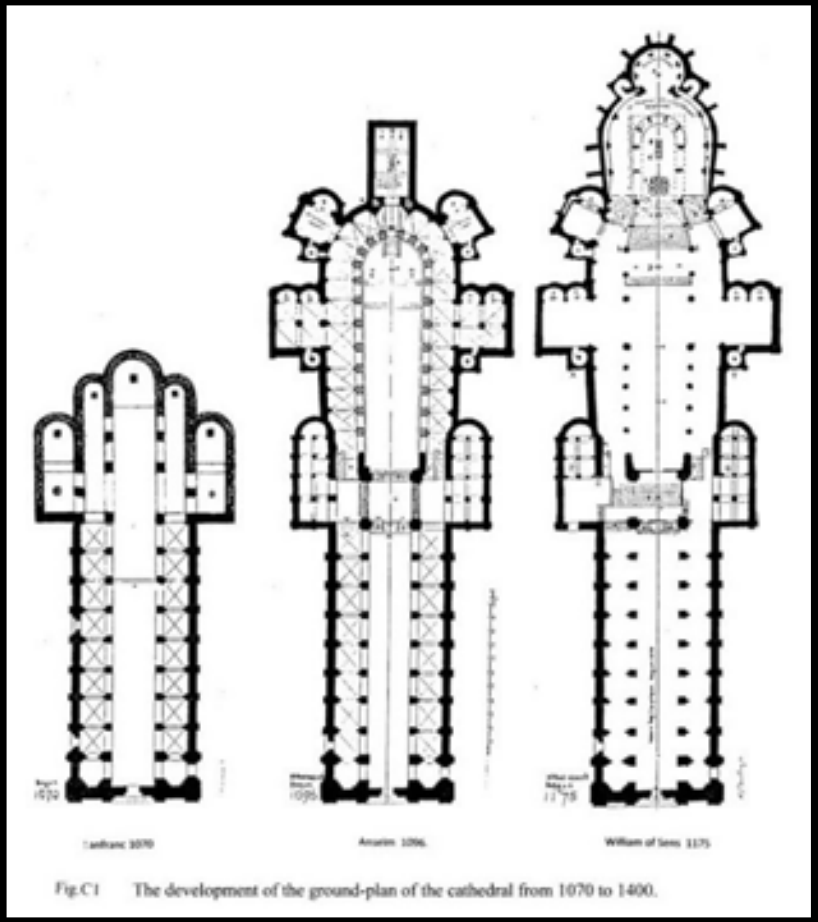
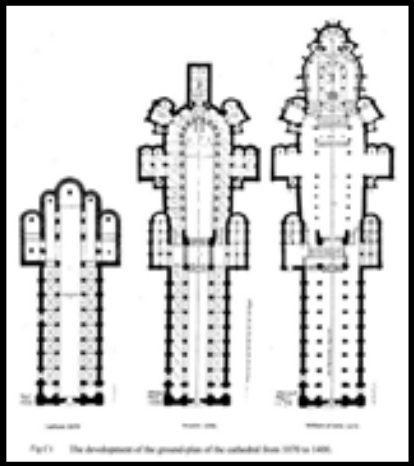
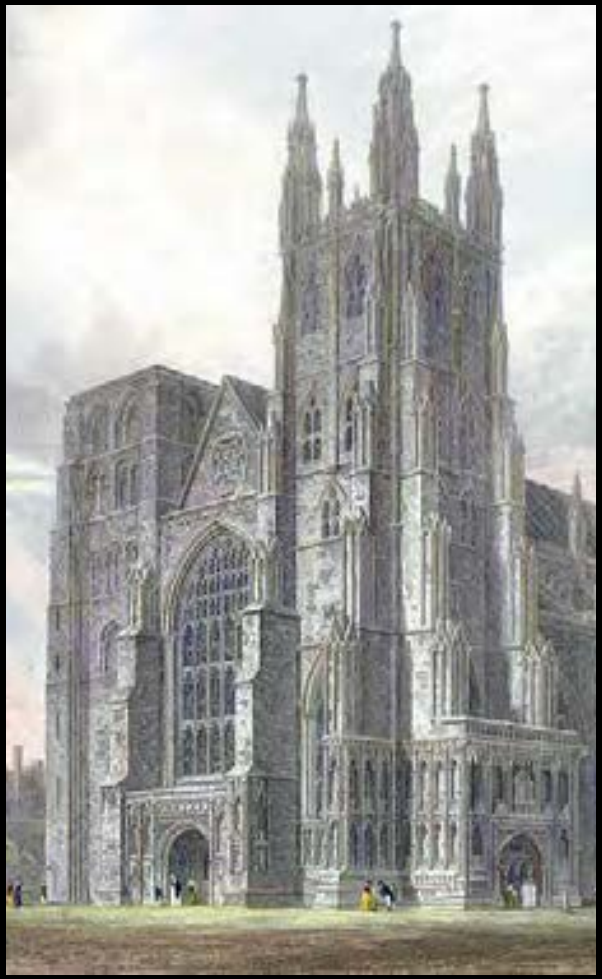


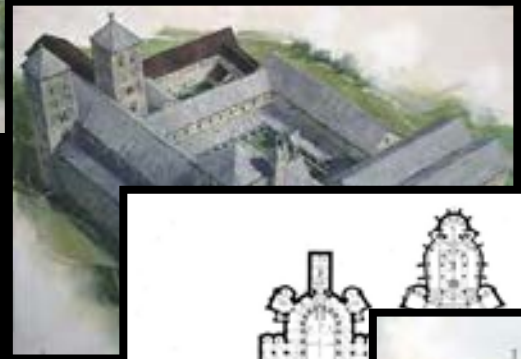
Fig.C1 The development of the ground-plan of the cathedral from 1070 to 1400.

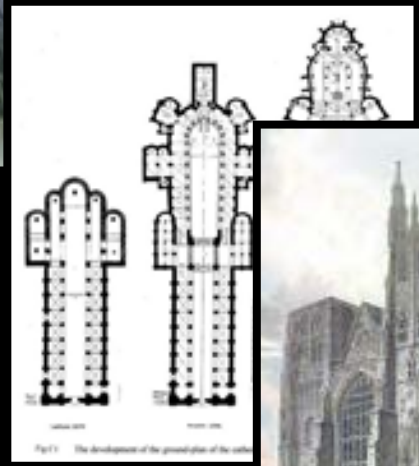
GOTHIC



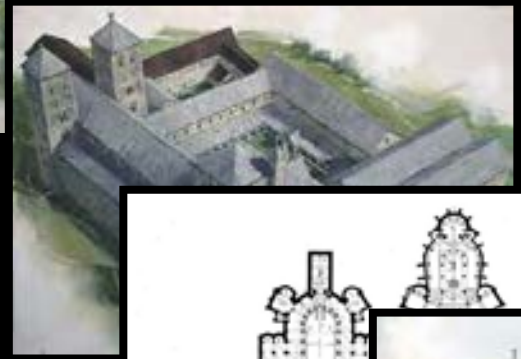


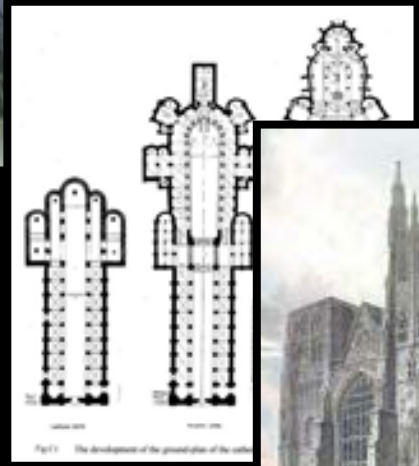
GEORGIAN



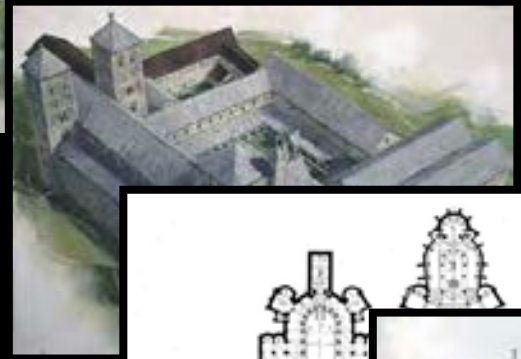


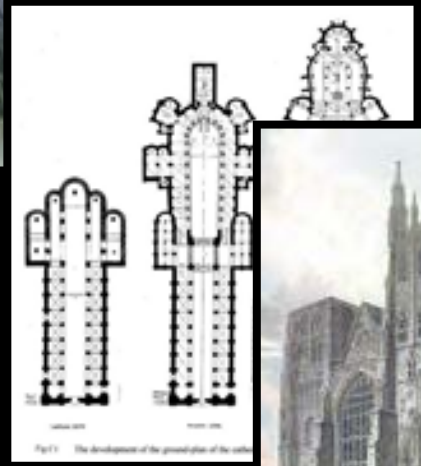
EARLY VICTORIAN





LATE VICTORIAN






NOW

LLOYD'S BUILDING LONDON

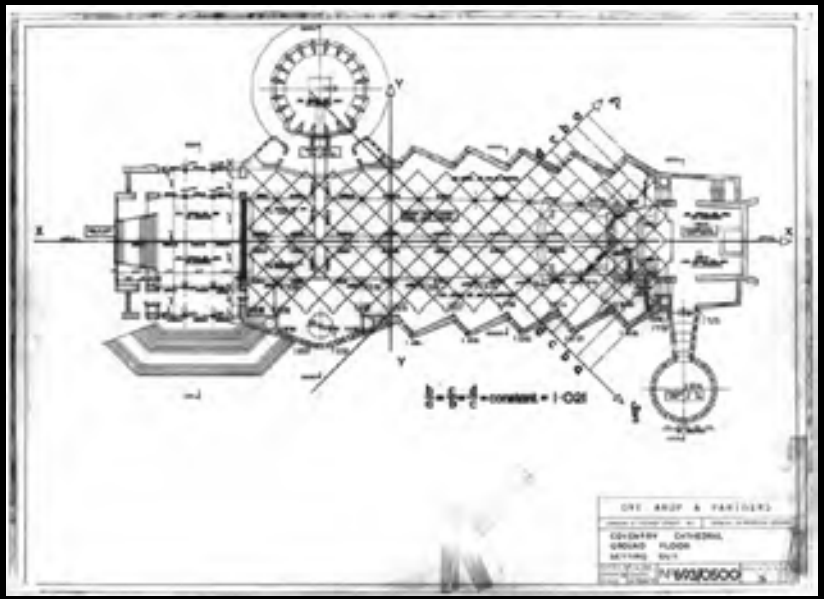
Grade 1- listed

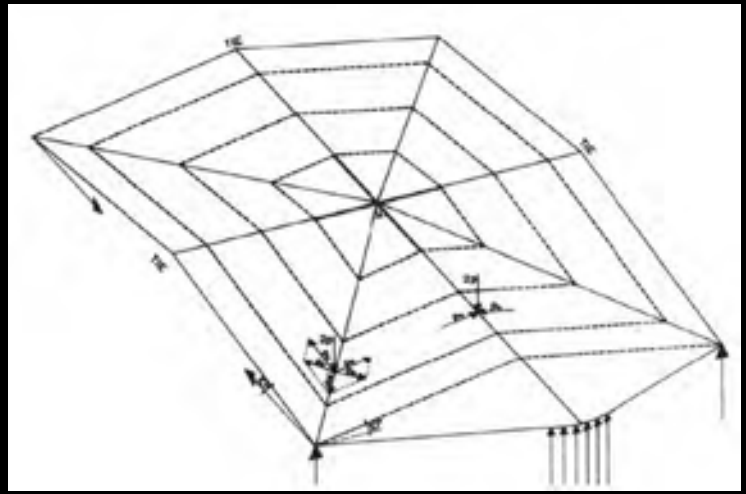
TRELLICK TOWER

Grade II*

14 November 1940

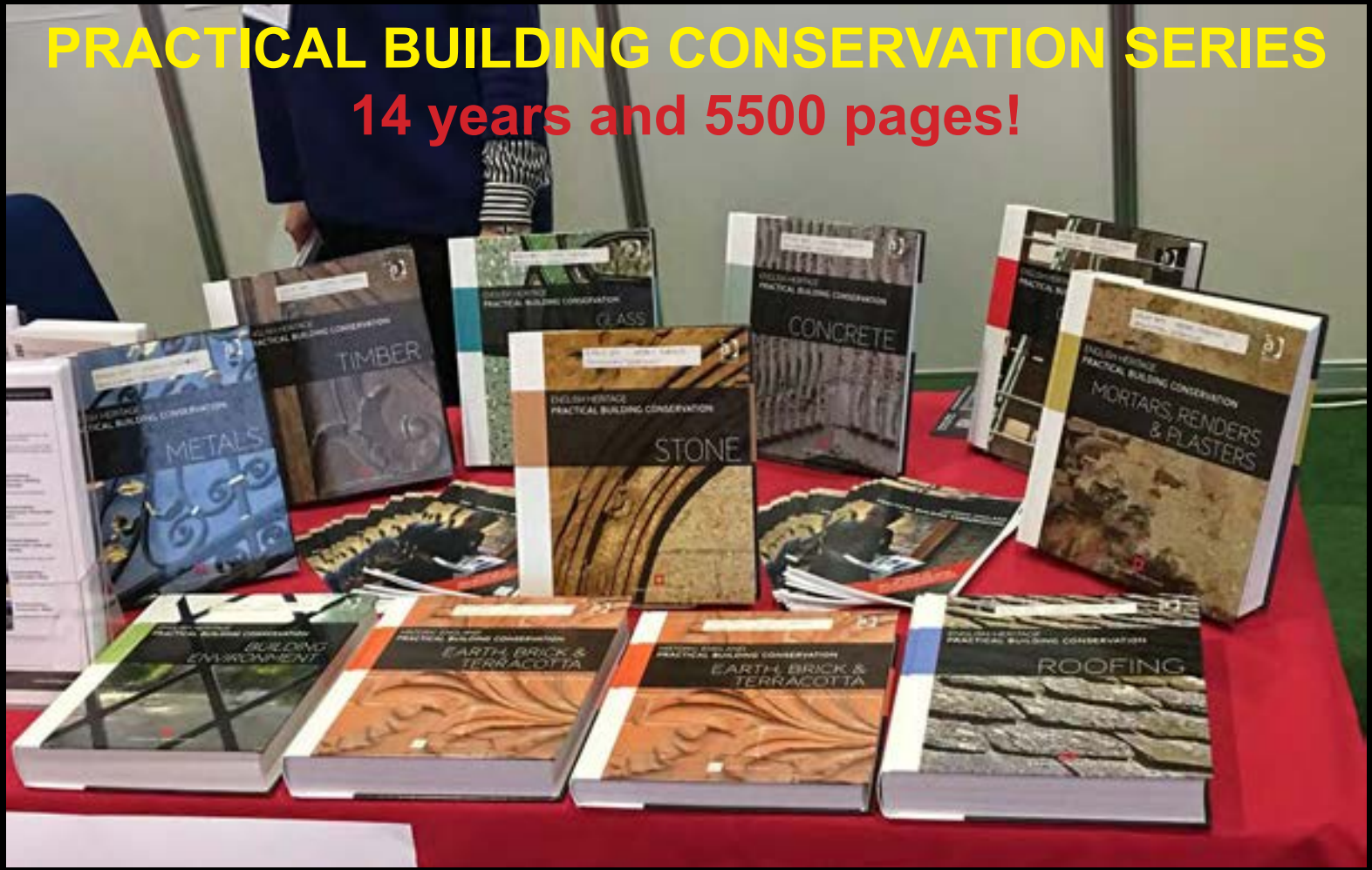

BISHOP OF COVENTRY
ELLEN EDITH BARDSLEY
1912 - 2001





CONCRETE COVER TOO THIN, PLUS CONDENSATION

BUILDING CONSERVATION & RESEARCH TEAM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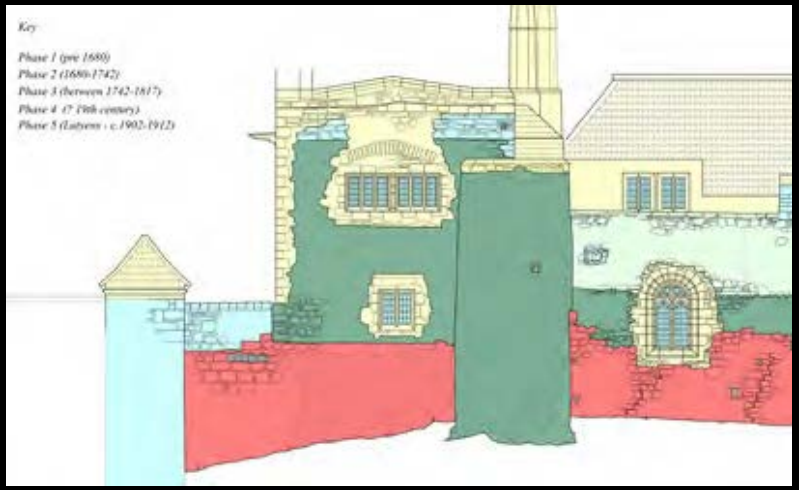
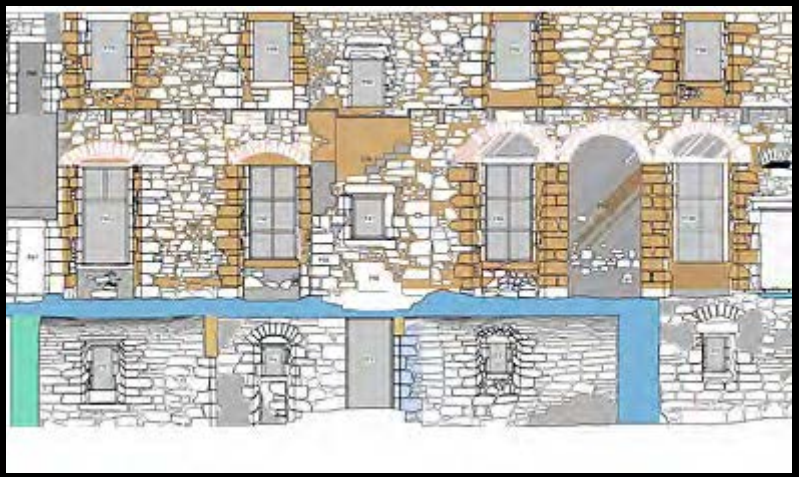
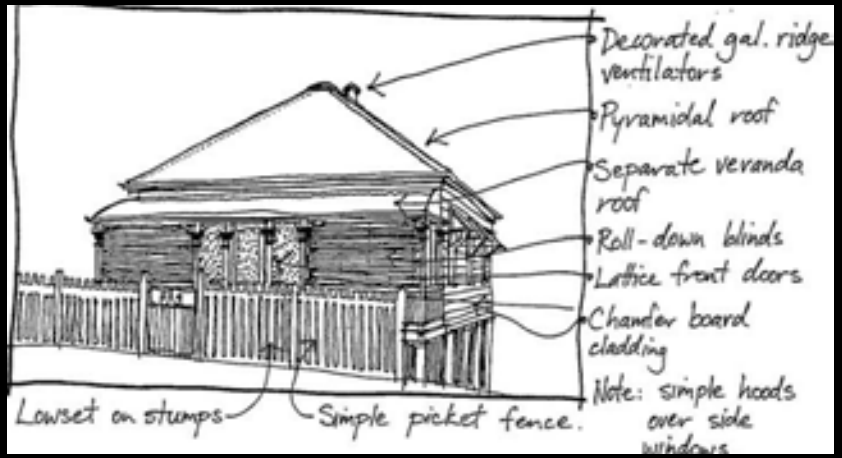
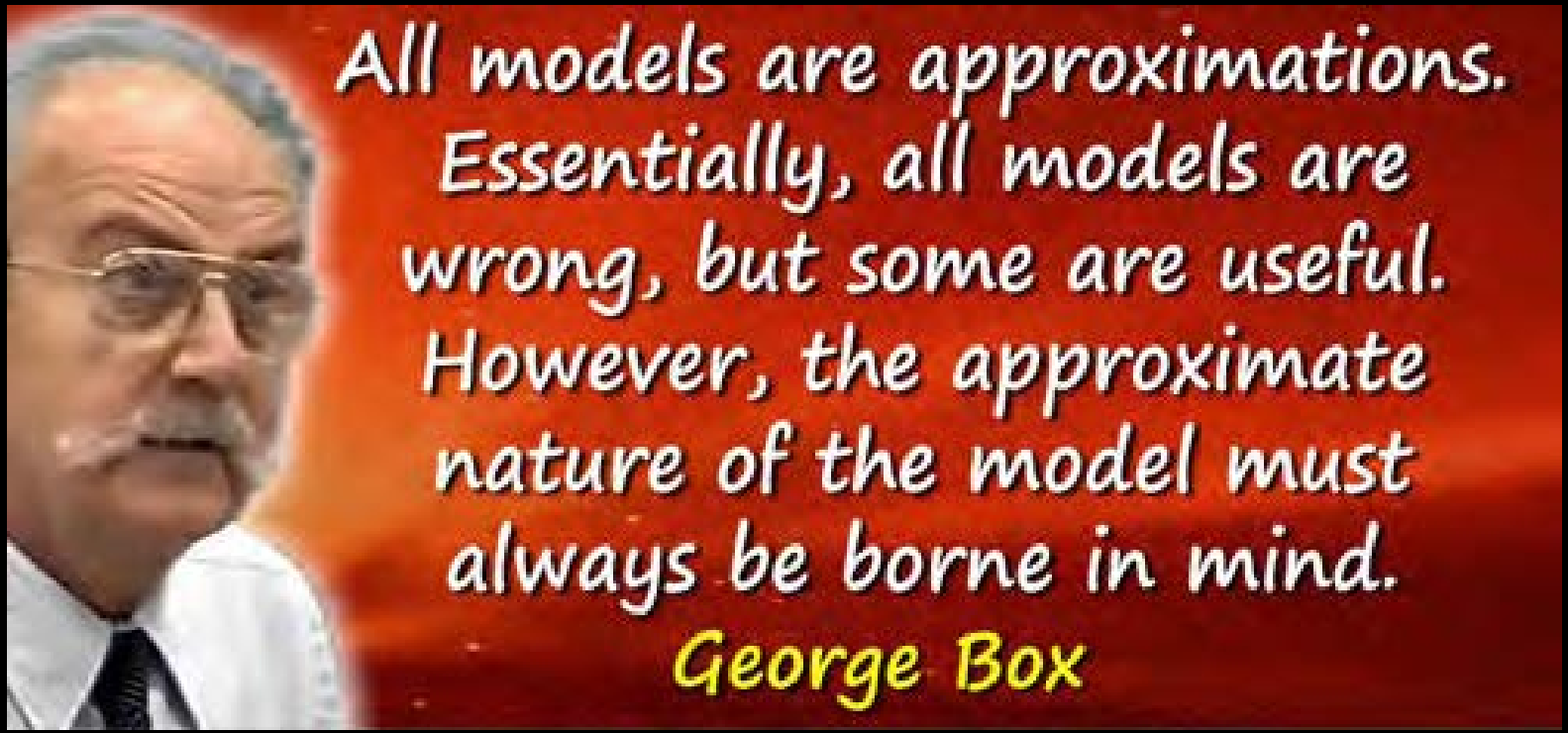
EARTH, BRICK & TERRACOTTA
ROOFING

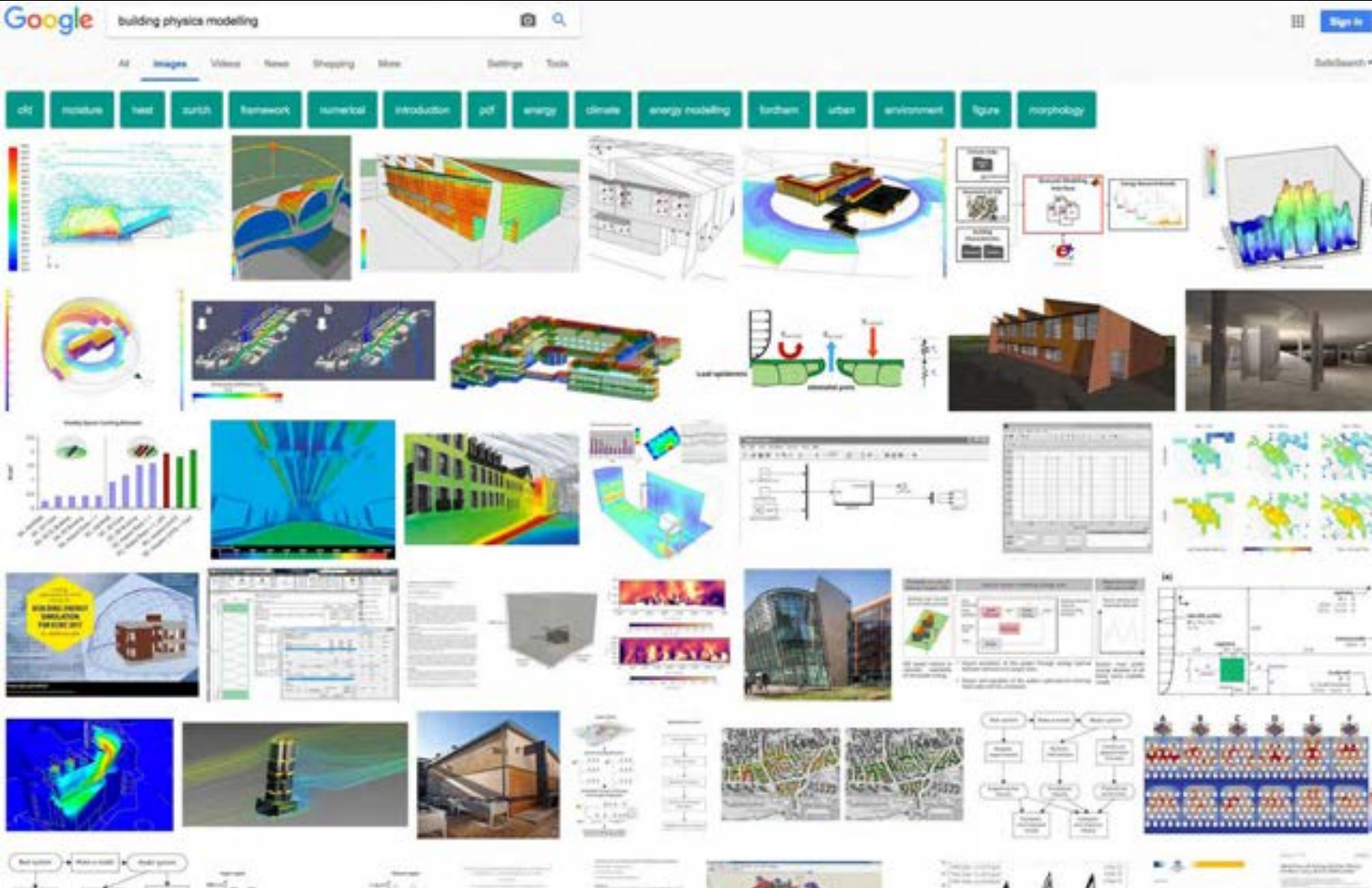
SCONEHENGE


Key
Phase 1 (pre 1680)
Phase 2 (1680-1742)
Phase 3 (between 1742-1817)
Phase 4 (? 19th century)
Phase 5 (Lutyens - c.1902-1912)




Decorated gal. ridge ventilators
Pyramidal roof
Separate veranda roof
Roll-down blinds
Lattice front doors
Chamfer board cladding
Note: simple hoods over side windows
Lowset on stumps
Simple picket fence.


All models are approximations.
Essentially, all models are
wrong, but some are useful.
However, the approximate
nature of the model must
always be borne in mind.
George Box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numerical
introduction
pdf
energy
climate
energy modelling
fordham
urban
environment
figure
morphology

HOW LONG IS A PIECE OF STRING?

2 377 978 metres

686 metres

ANSWER:

1 m

ANSWER:

$$1 \pm 10^4 \text{ m}$$

YOU NEED TO SEE THE ERROR TO UNDERSTAND THE NUMBER

RESEARCH INTO THE THERMAL PERFORMANCE OF TRADITIONAL BRICK WALLS

ENGLISH HERITAGE
RESEARCH REPORT

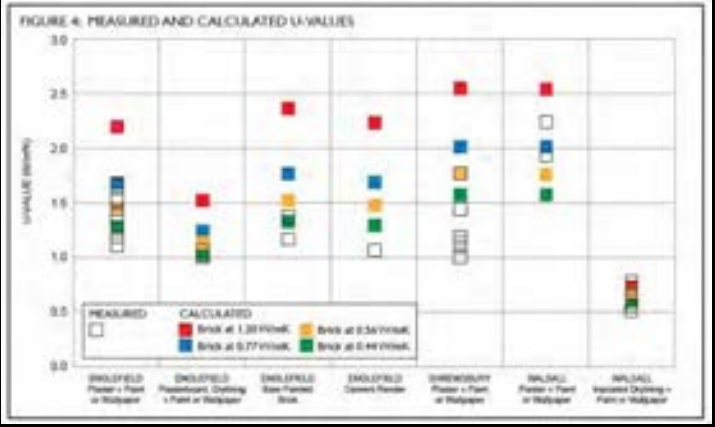
TABLE 3: COMPARISON OF CALCULATED U-VALUES

WALL DESCRIPTION	RANGE OF MEASURED VALUES Average, Y and standard deviation	CALCULATED U-VALUES Assumed brick thermal conductivities			
		1.2 W/mK	0.77 W/mK	0.56 W/mK	0.44 W/mK
ENGLEFIELD 13-inch brick with plaster + wallpaper or paint	1.2 to 1.6	2.2	1.7	1.5	1.3
ENGLEFIELD 13-inch brick drylined with plasterboard + paint or wallpaper	1.0 to 1.1	1.5	1.2	1.1	1.0
ENGLEFIELD 13-inch bare painted brick	1.1 to 1.4	2.4	1.8	1.5	1.3
ENGLEFIELD 13-inch brick with cement render	0.9 to 1.3 [1]	2.2	1.7	1.3	1.3
SHREWSBURY 9-inch brick with plaster + wallpaper or paint	1.0 to 1.5	2.6	2.0	1.8	1.6
WALSALL 9-inch brick with plaster + paint or wallpaper	1.9 to 2.3	3.6	3.0	1.8	1.6
WALSALL 9-inch brick drylined with insulated plasterboard + paint or wallpaper	0.6 to 0.7	0.7	0.7	0.6	0.6

NOTES:
1. One measured result only: the range is expressed as the value ± the measurement uncertainty

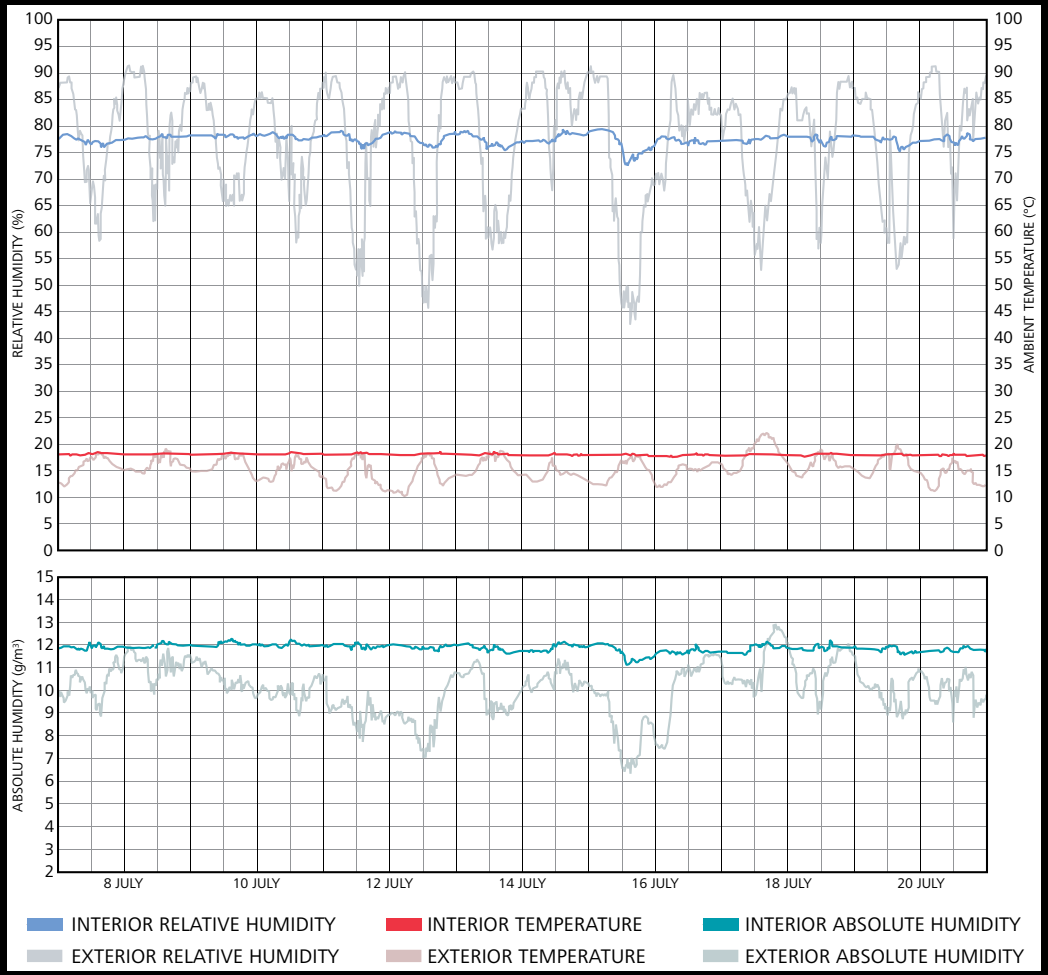
The calculated values are also compared with the measured results in *Figure 4*. The calculated values assume that the plastered walls use lime, and the insulation in the Walsall drylined walls is phenolic insulation.

FIGURE 4: MEASURED AND CALCULATED U-VALUES

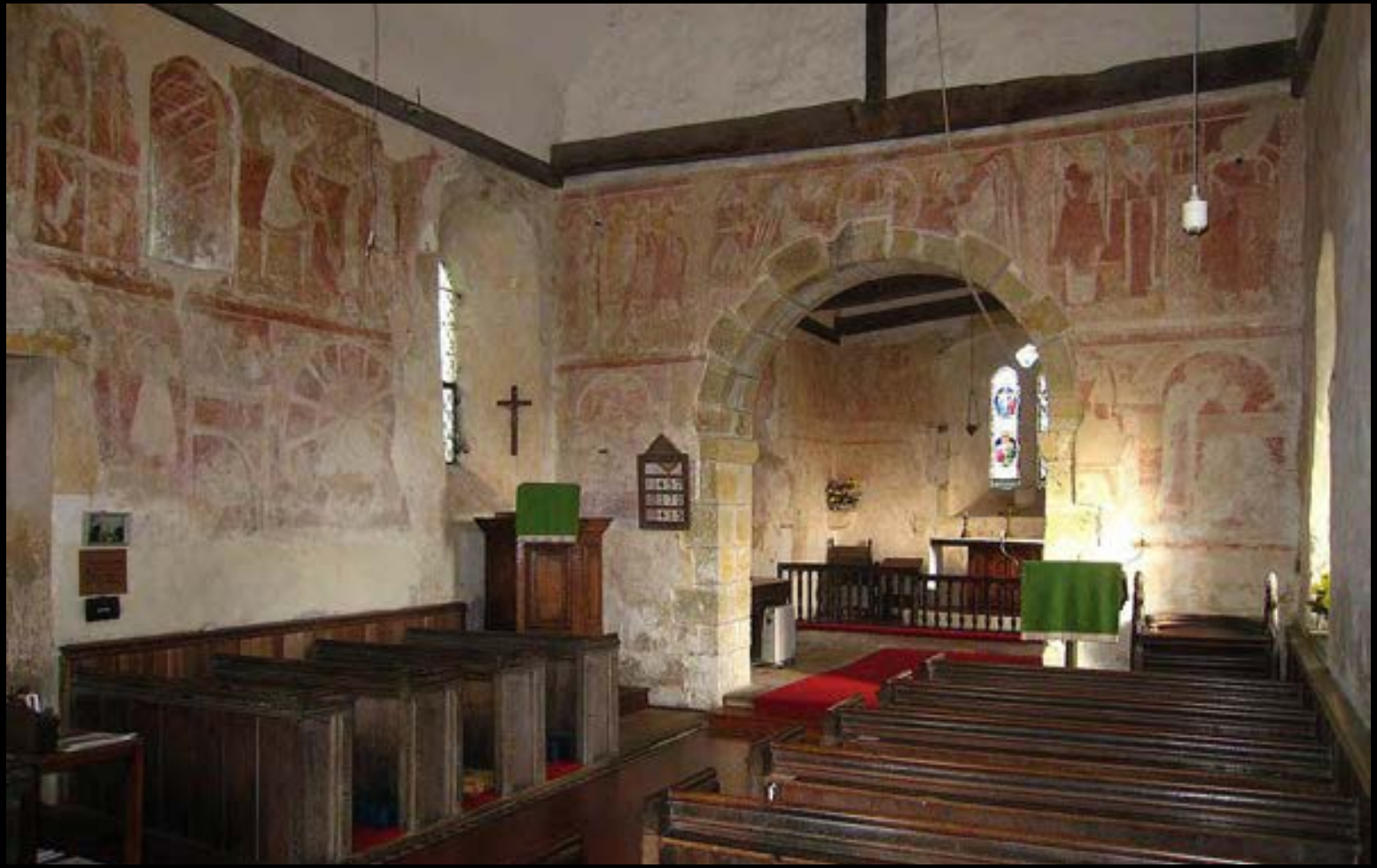


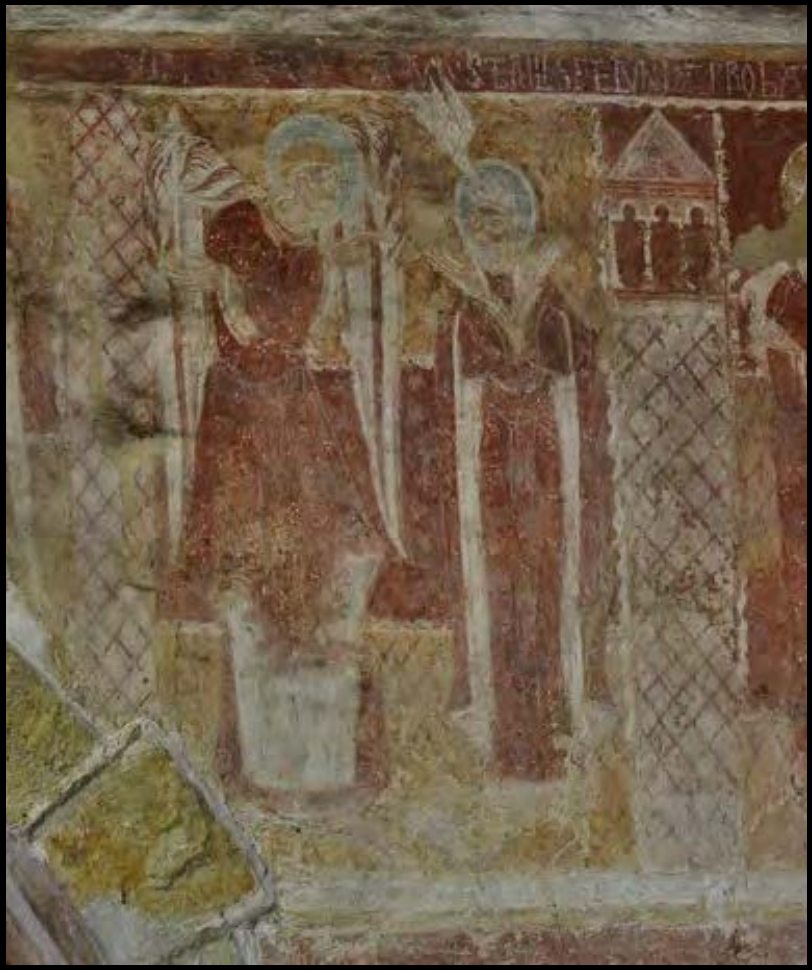
THE COURTAULD Institute of Art

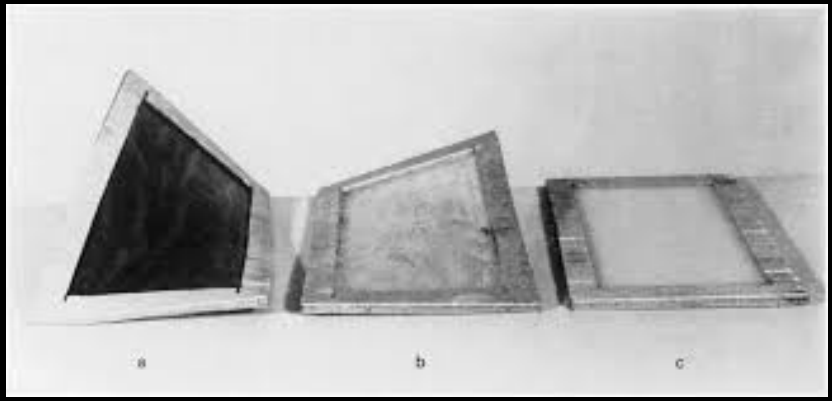

In the land of the
blind the one eyed
man is king


RELATIVE HUMIDITY (%)
AMBIENT TEMPERATURE (°C)
ABSOLUTE HUMIDITY (g/m³)
8 JULY
10 JULY
12 JULY
14 JULY
16 JULY
18 JULY
20 JULY
INTERIOR RELATIVE HUMIDITY
INTERIOR TEMPERATURE
INTERIOR ABSOLUTE HUMIDITY
EXTERIOR RELATIVE HUMIDITY
EXTERIOR TEMPERATURE
EXTERIOR ABSOLUTE HUMIDITY


HARDHAM
ST BOTOLPH'S
C.1100



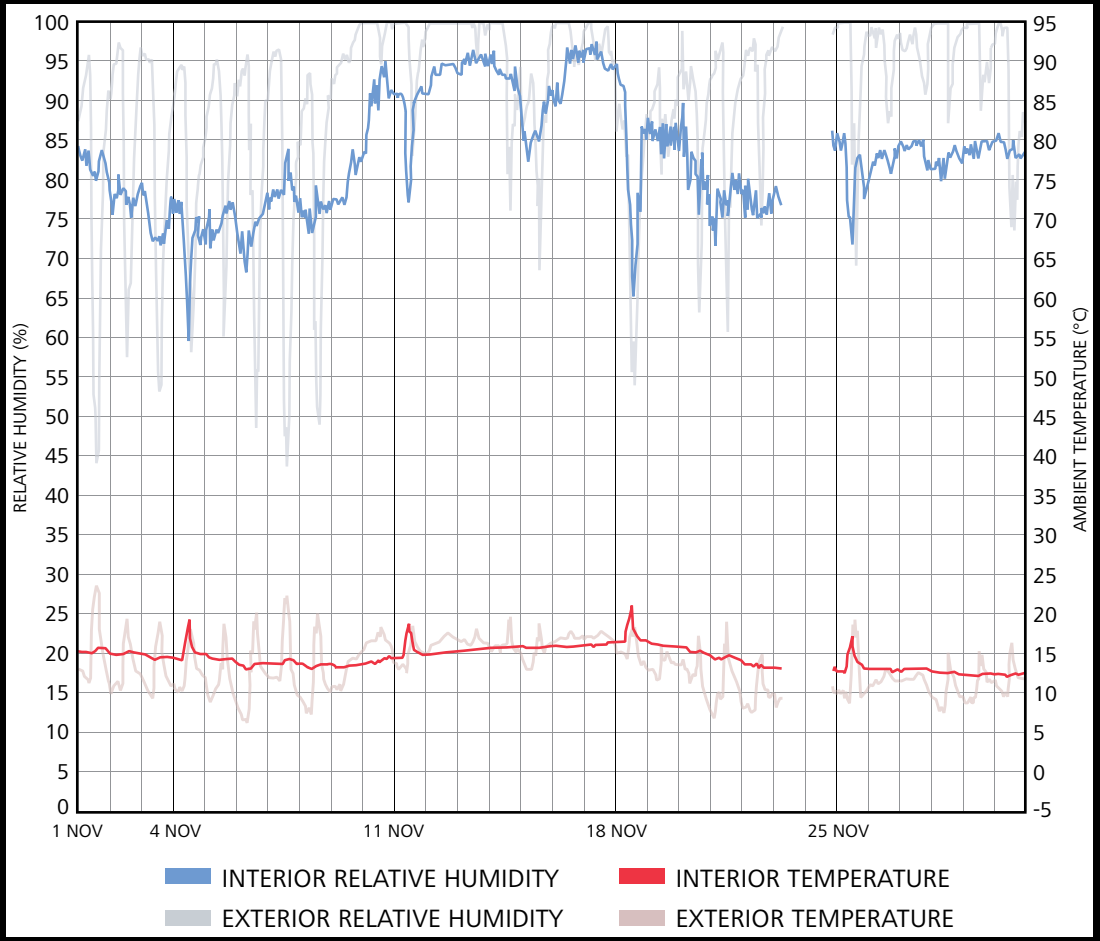


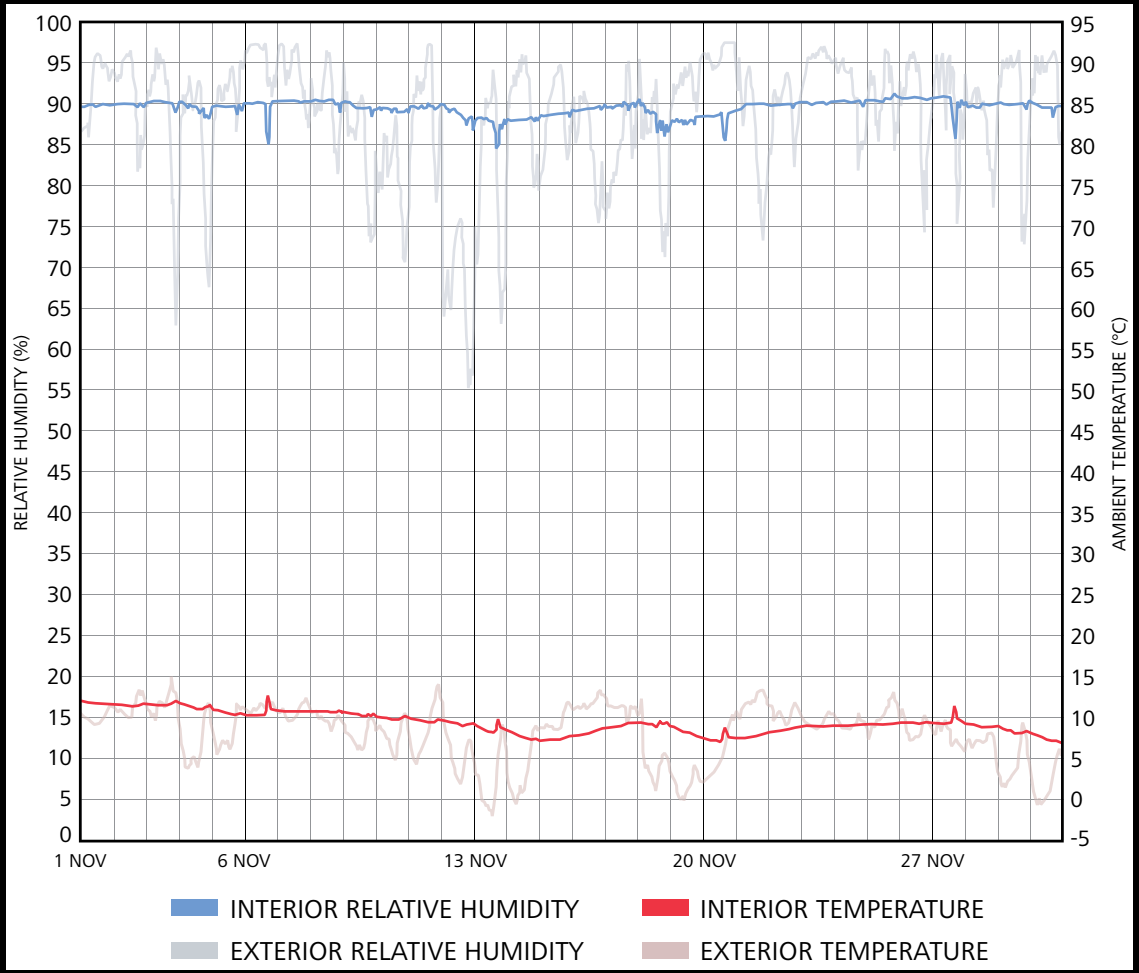


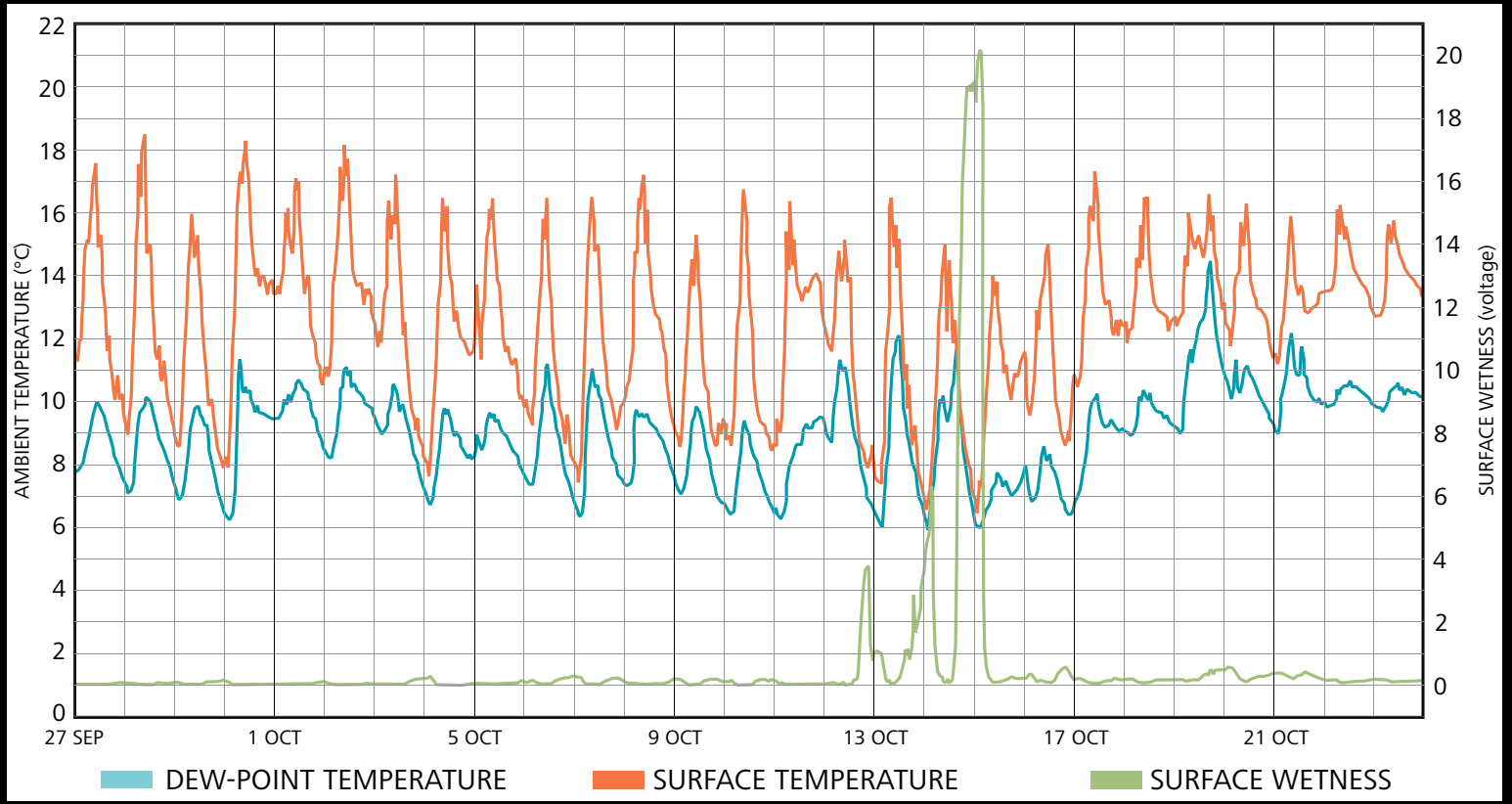
'S OLUBLE" NYLON =

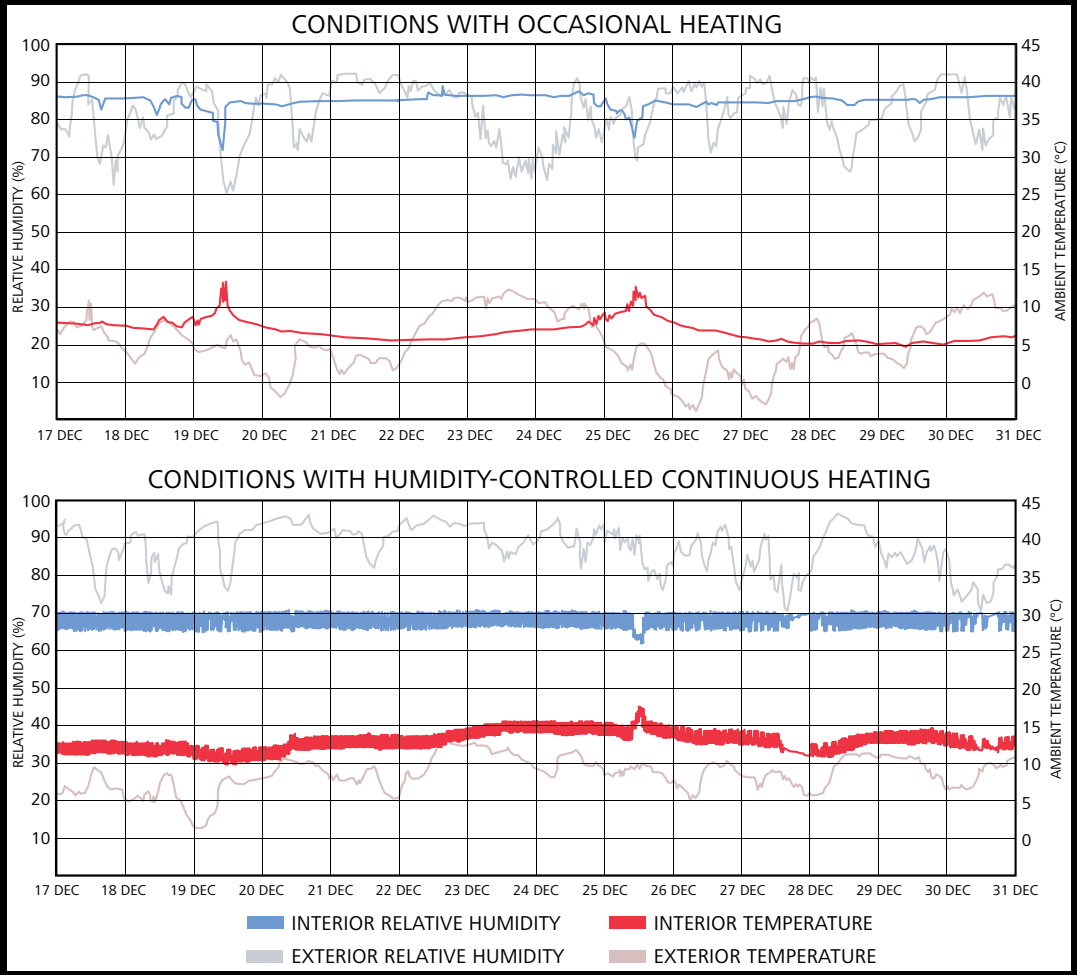
INSOLUBLE PROBLEM

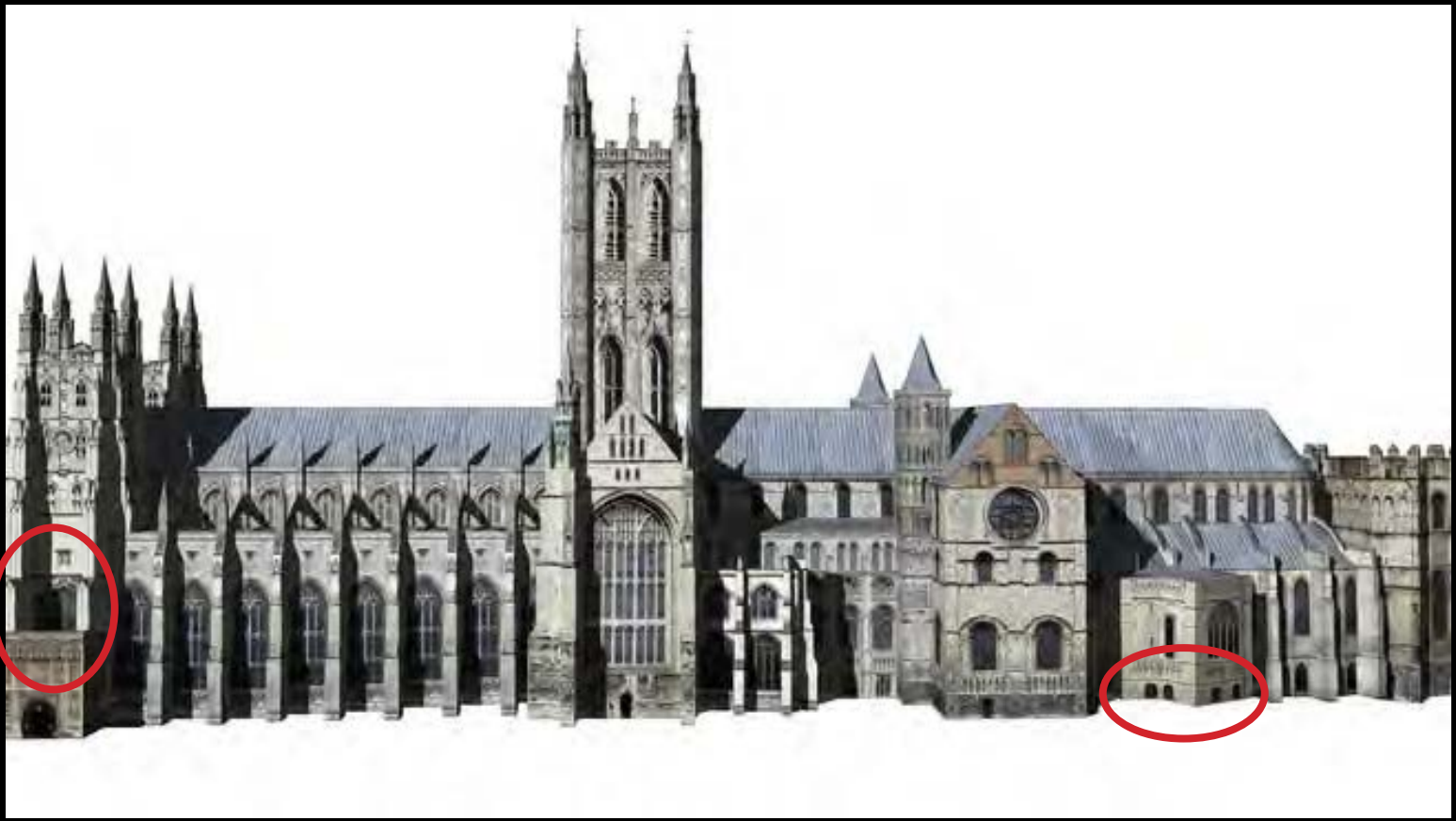
Watercolours c.1805

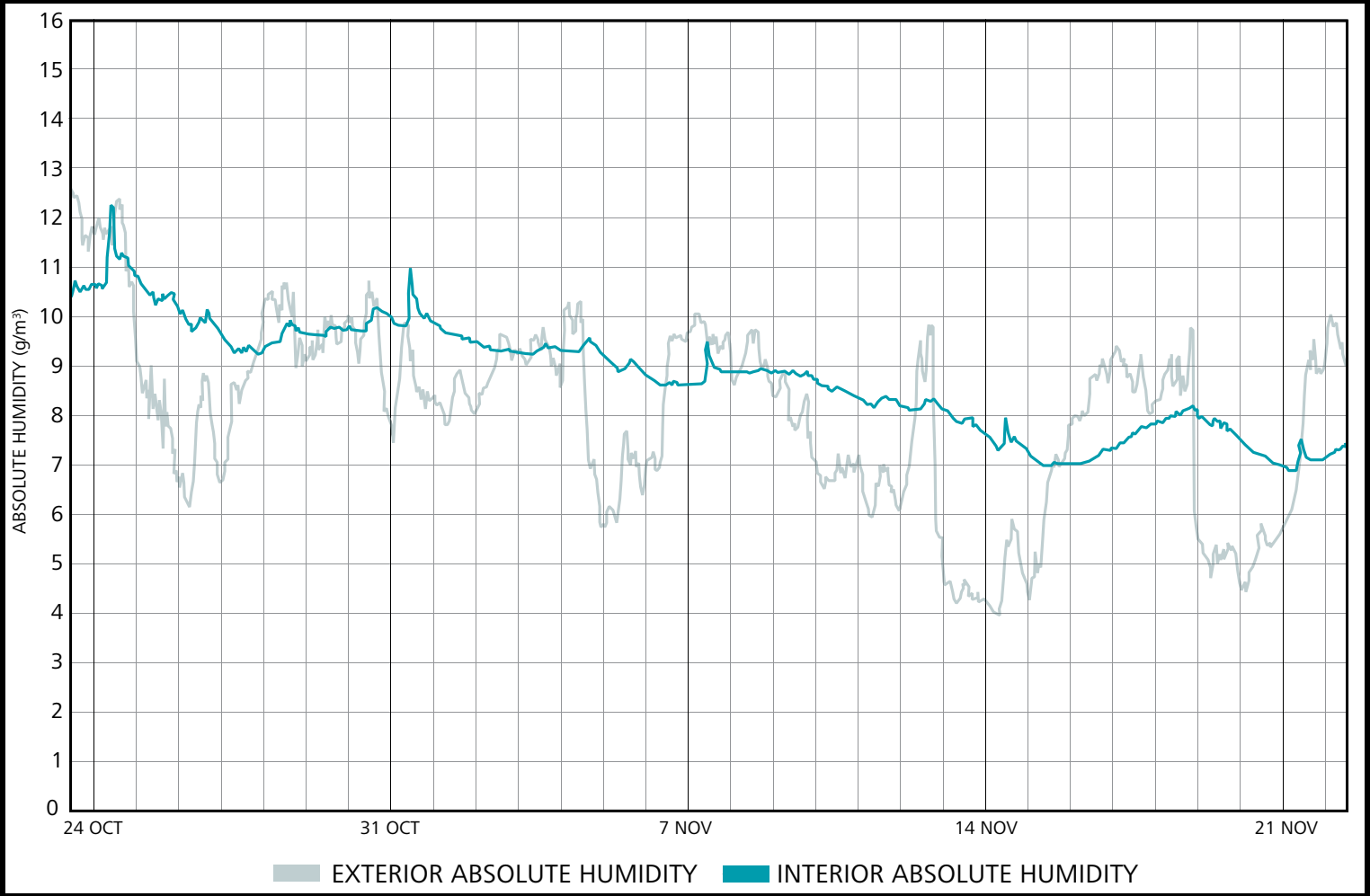

RELATIVE HUMIDITY (%)
AMBIENT TEMPERATURE (°C)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
1 NOV
4 NOV
11 NOV
18 NOV
25 NOV
INTERIOR RELATIVE HUMIDITY
EXTERIOR RELATIVE HUMIDITY
INTERIOR TEMPERATURE
EXTERIOR TEMPERATURE

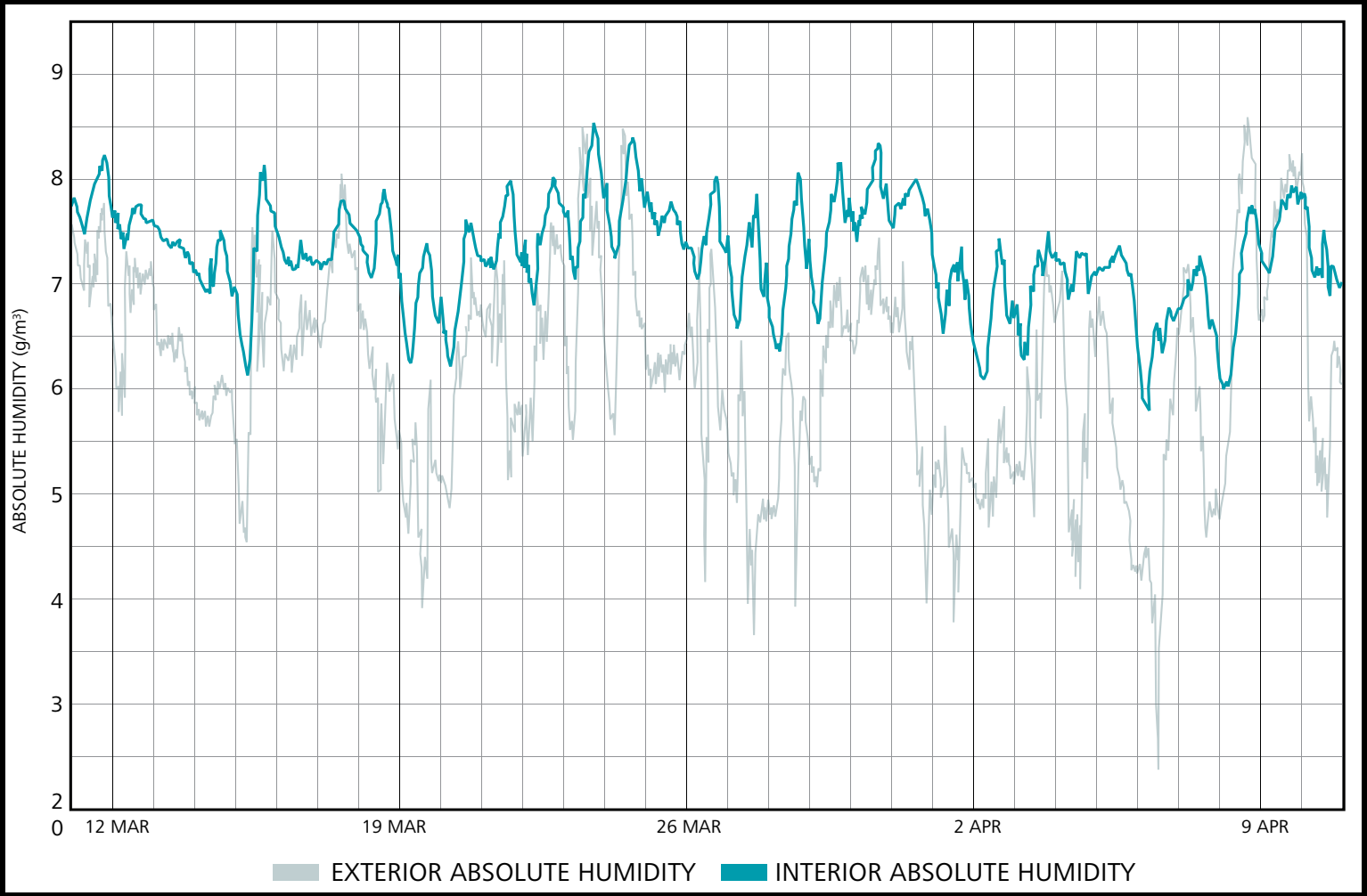

RELATIVE HUMIDITY (%)
AMBIENT TEMPERATURE (°C)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
1 NOV
6 NOV
13 NOV
20 NOV
27 NOV
INTERIOR RELATIVE HUMIDITY
EXTERIOR RELATIVE HUMIDITY
INTERIOR TEMPERATURE
EXTERIOR TEMPERATURE


AMBIENT TEMPERATURE (°C)
SURFACE WETNESS (voltage)
22
20
18
16
14
12
10
8
6
4
2
0
27 SEP
1 OCT
5 OCT
9 OCT
13 OCT
17 OCT
21 OCT
DEW-POINT TEMPERATURE
SURFACE TEMPERATURE
SURFACE WETNESS


CONDITIONS WITH OCCASIONAL HEATING
RELATIVE HUMIDITY (%)
AMBIENT TEMPERATURE (°C)
100
90
80
70
60
50
40
30
20
10
45
40
35
30
25
20
15
10
5
0
17 DEC
18 DEC
19 DEC
20 DEC
21 DEC
22 DEC
23 DEC
24 DEC
25 DEC
26 DEC
27 DEC
28 DEC
29 DEC
30 DEC
31 DEC
CONDITIONS WITH HUMIDITY-CONTROLLED CONTINUOUS HEATING
RELATIVE HUMIDITY (%)
AMBIENT TEMPERATURE (°C)
INTERIOR RELATIVE HUMIDITY
INTERIOR TEMPERATURE
EXTERIOR RELATIVE HUMIDITY
EXTERIOR TEMPERATURE




ABSOLUTE HUMIDITY (g/m³)
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
24 OCT
31 OCT
7 NOV
14 NOV
21 NOV
EXTERIOR ABSOLUTE HUMIDITY
INTERIOR ABSOLUTE HUMIDITY


ABSOLUTE HUMIDITY (g/m³)
9
8
7
6
5
4
3
2
0
12 MAR
19 MAR
26 MAR
2 APR
9 APR
EXTERIOR ABSOLUTE HUMIDITY
INTERIOR ABSOLUTE HUMIDITY



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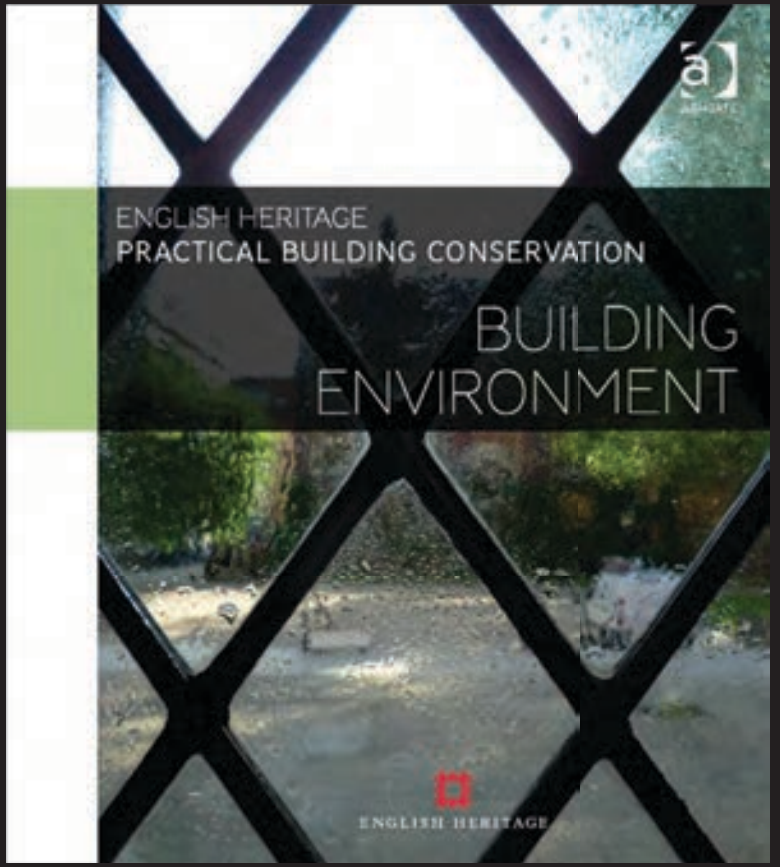
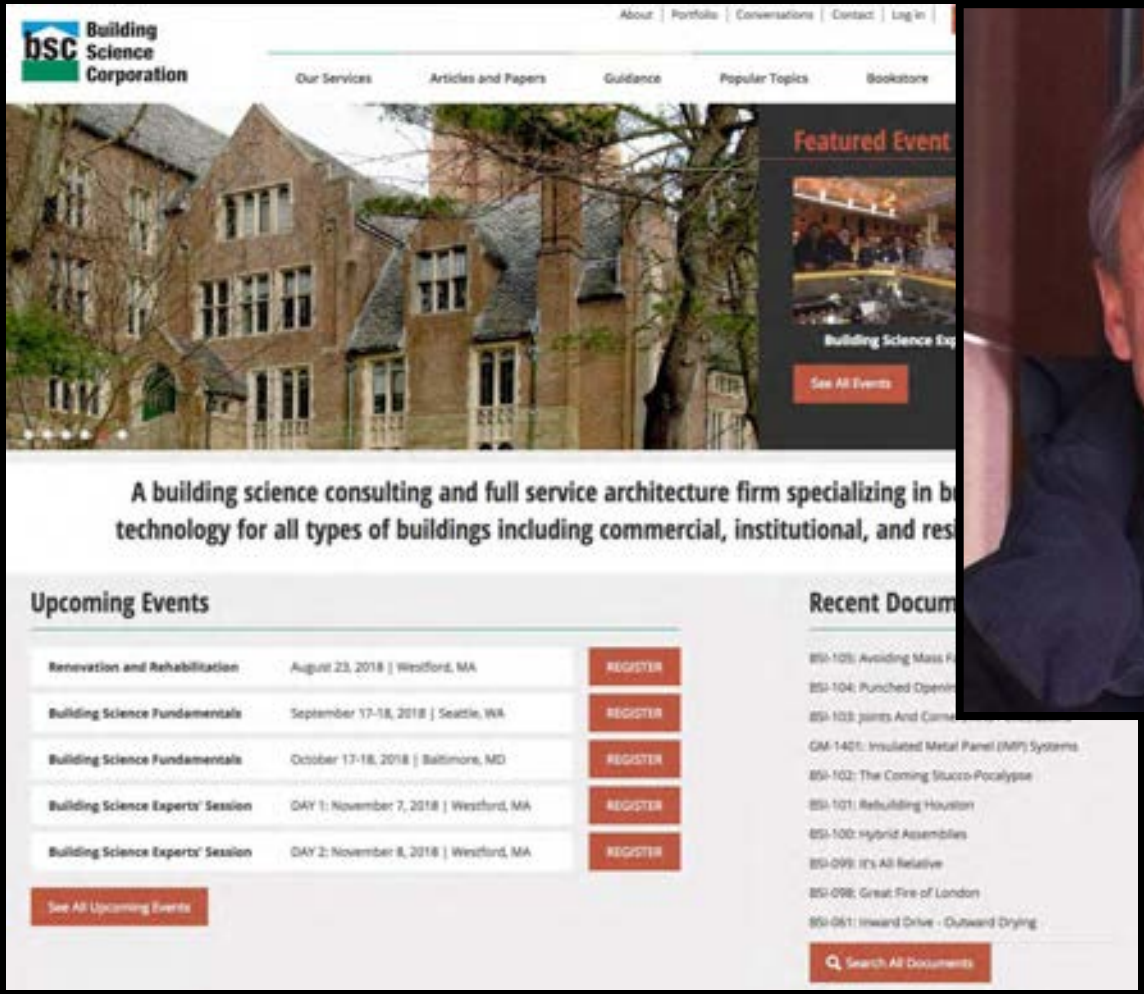


BUILDING ENVIRONMENT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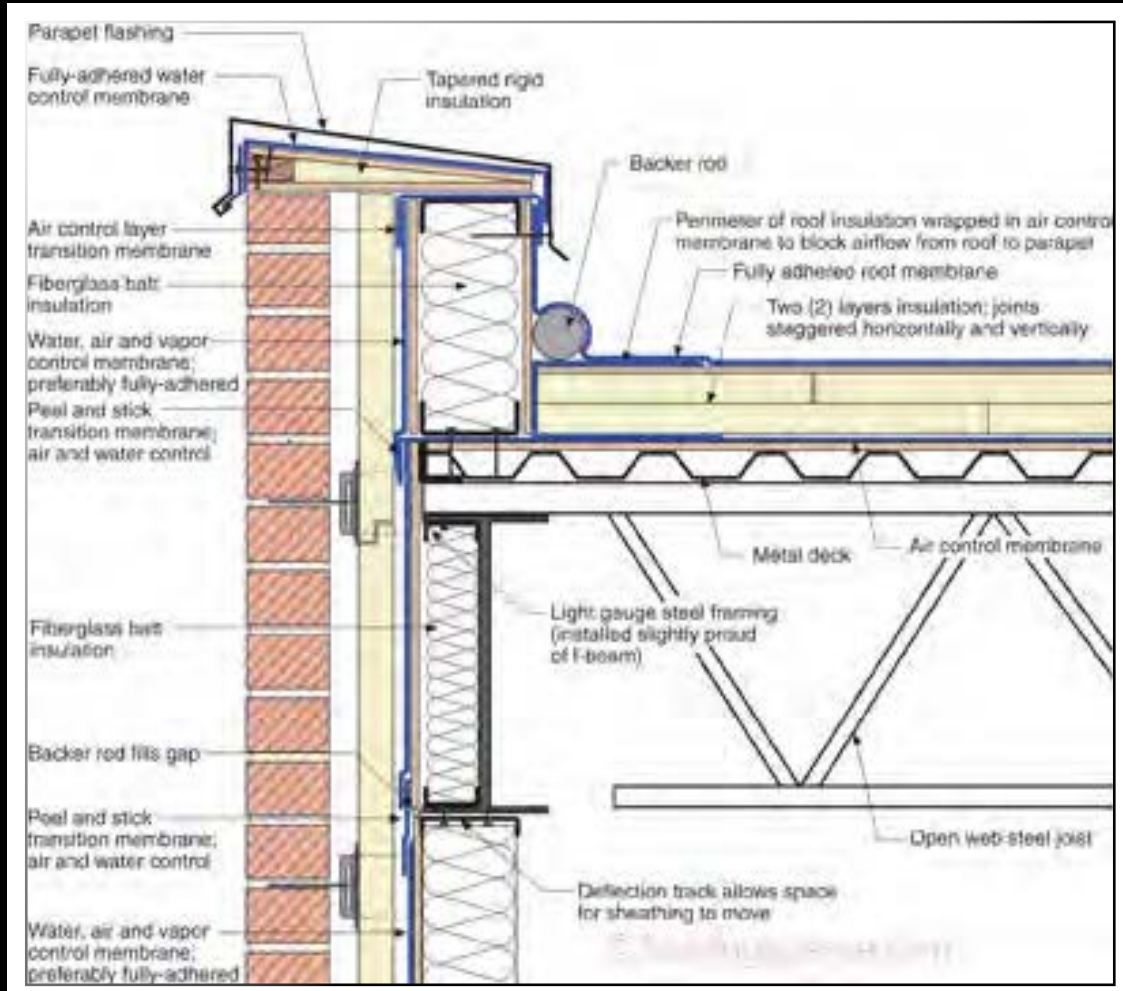
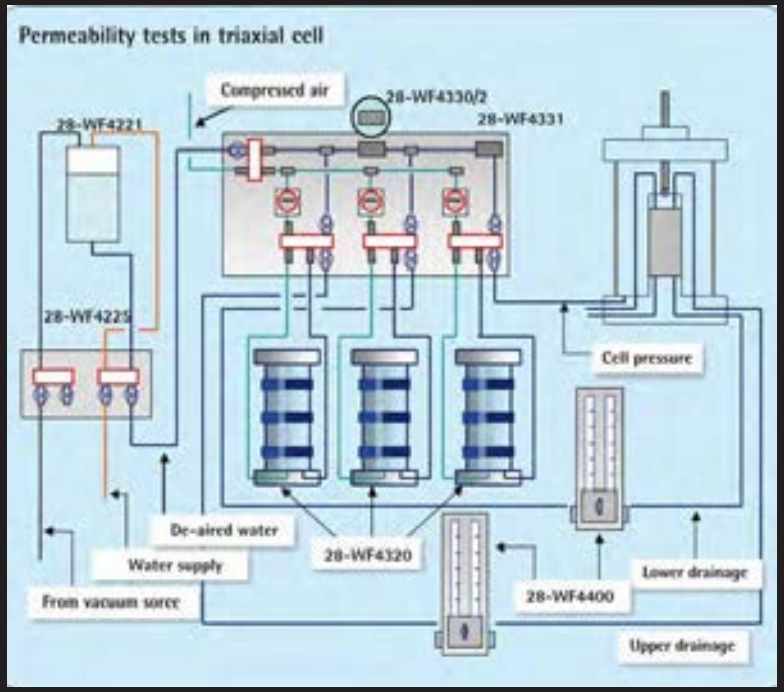

Parapet flashing
Fully-adhered water control membrane
Tapered rigid insulation
Backer rod
Perimeter of roof insulation wrapped in air control membrane to block airflow from roof to parapet
Fully adhered roof membrane
Two (2) layers insulation; joints staggered horizontally and vertically
Air control layer transition membrane
Fiberglass batt insulation
Water, air and vapor control membrane; preferably fully-adhered
Peel and stick transition membrane; air and water control
Metal deck
Air control membrane
Light gauge steel framing (installed slightly proud of I-beam)
Fiberglass batt insulation
Backer rod fills gap
Peel and stick transition membrane; air and water control
Open web steel joist
Deflection track allows space for sheathing to move
Water, air and vapor control membrane; preferably fully-adhered


BOLSOVER
LITTLE CASTLE
1613-21

W ATERWORKS”
Eadwine Psalter
c.1150

BREATHABLE

PERMEABLE

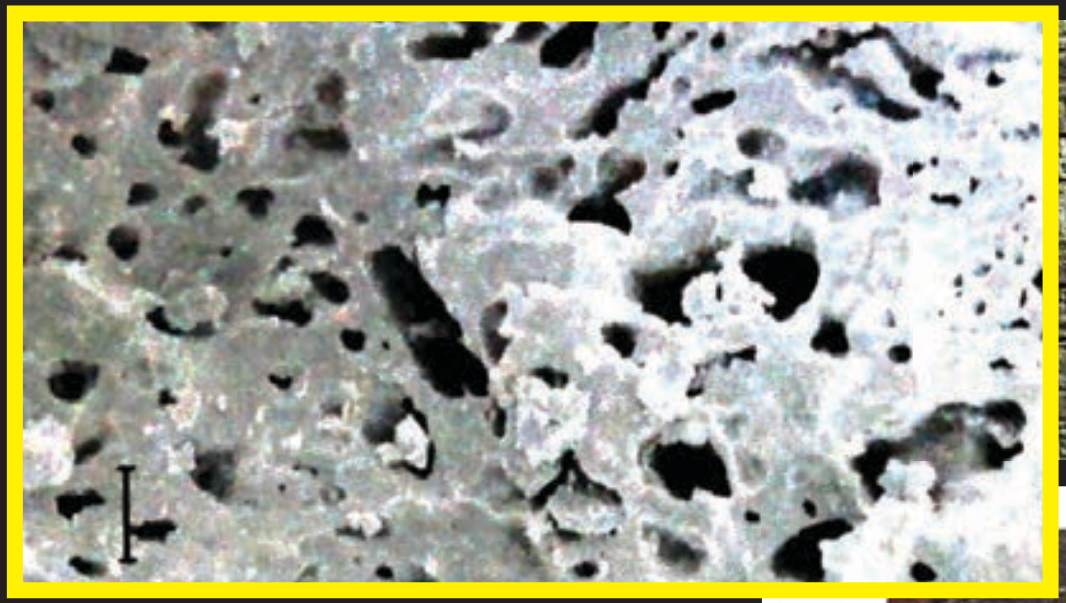


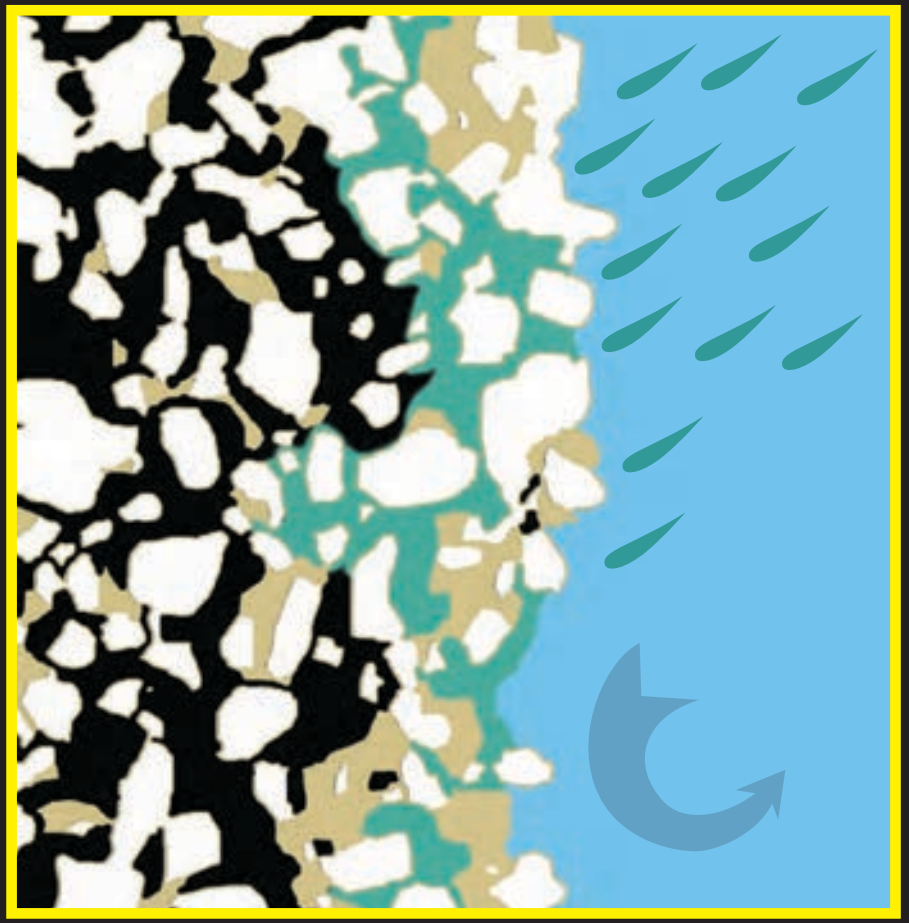
Darcy's equation and definition of permeability

$$\vec{k} = -\mu \frac{\vec{U}}{\nabla P}$$

Permeability, Flux, Pressure head


PERMEABLE





TRADITIONAL = GREATCOAT

DRY
SPONGE

WET
SPONGE

WATER TRANSPORT IN BRICK, STONE AND CONCRETE

SECOND EDITION

CHRISTOPHER HALL
AND WILLIAM D. HOFF

113 kPa = 1.13 Bar = 16psi

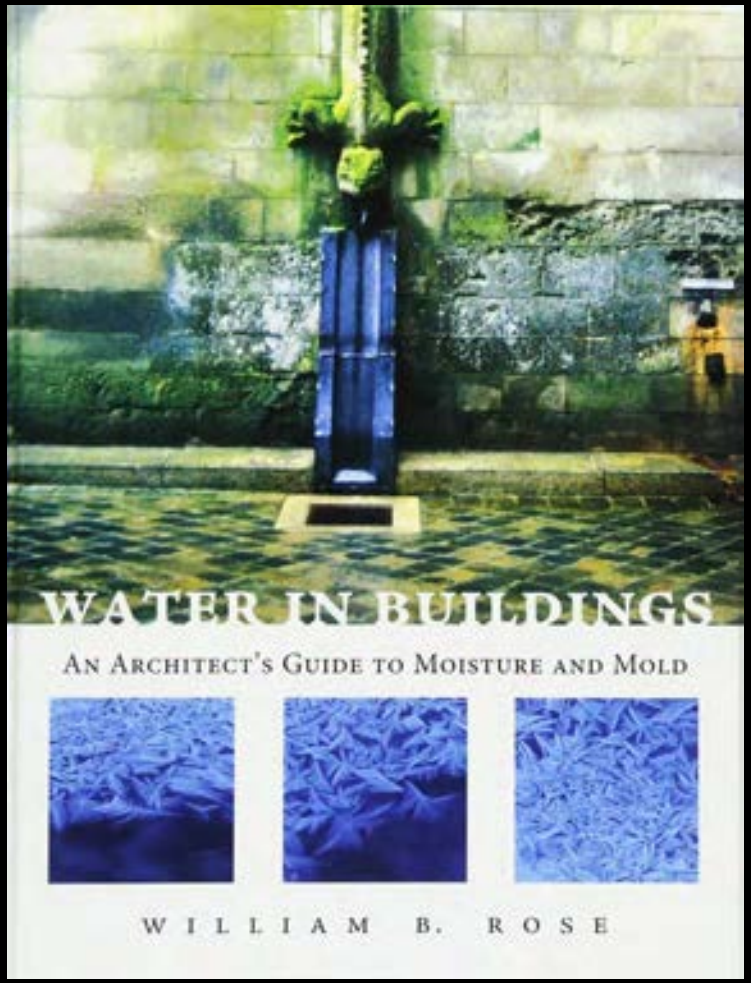
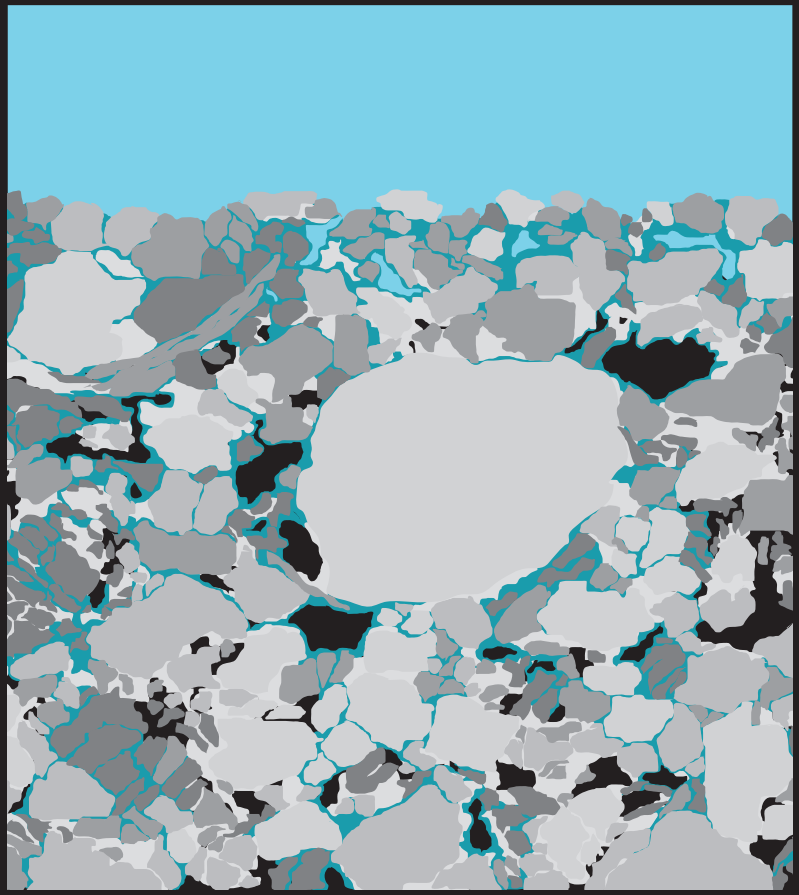

WATER IN BUILDINGS
An Architect's Guide to Moisture and Mold
WILLIAM B. ROSE

Figure 2 Collyweston, Northamptonshire: stone laid out for splitting by winter frost (Photograph: Daniel Martin)



Imperial College London

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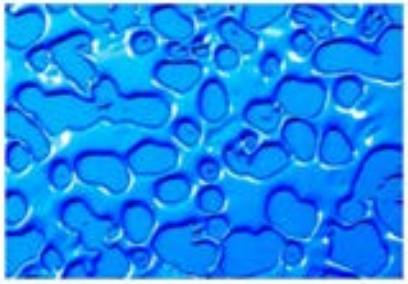
Hundred-year-old law on fluid flow overturned by Imperial research

by Colin Smith
17 July 2017



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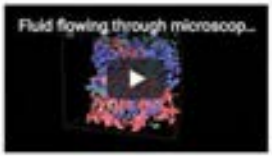
Engineers from Imperial College London have dispelled a 100-year-old scientific law used to describe how fluid flows through rocks.

The three 3D models below show fluid flowing through rocks at different microscopic scales.



The discovery by researchers from Imperial could lead to a range of improvements including advances in Carbon Capture and Storage (CCS). This is where industrial emissions will be captured by CCS technology, before reaching the atmosphere, and safely stored in rock deep underground.

RELATED STORIES

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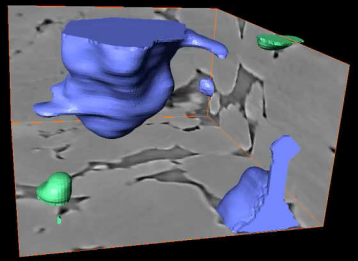
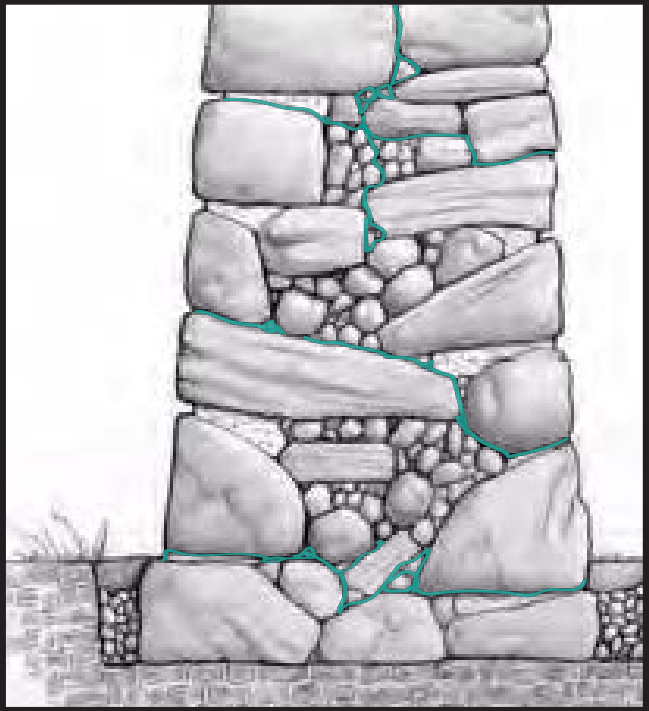
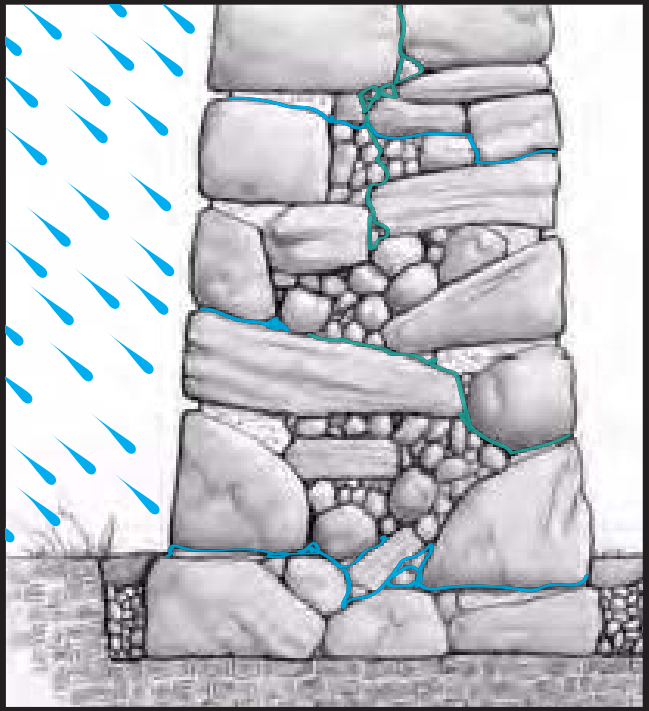
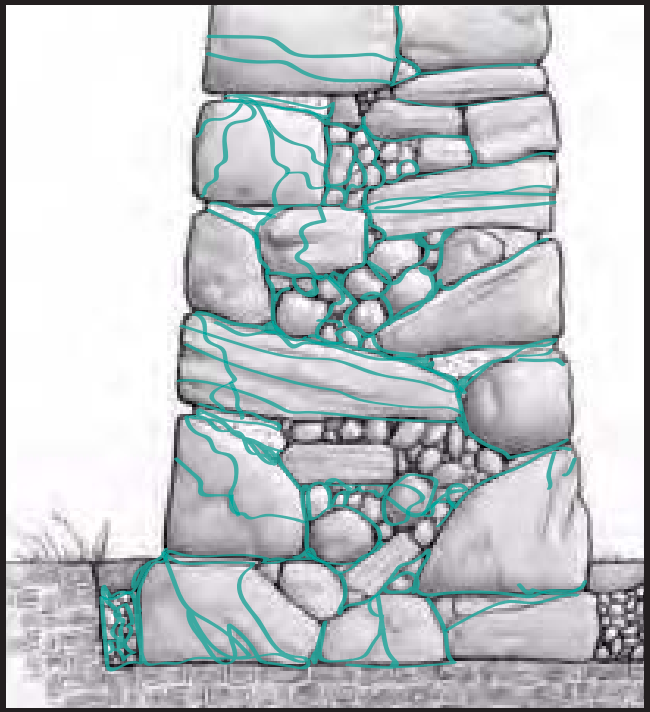
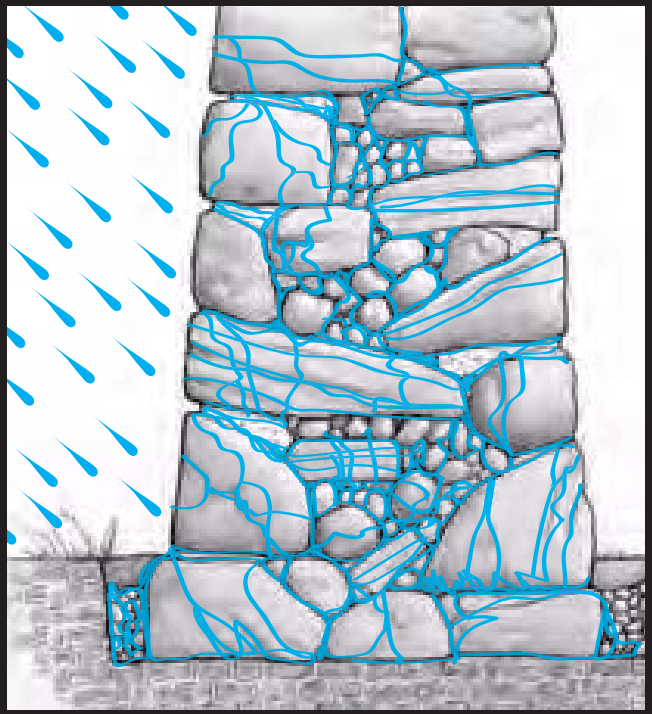
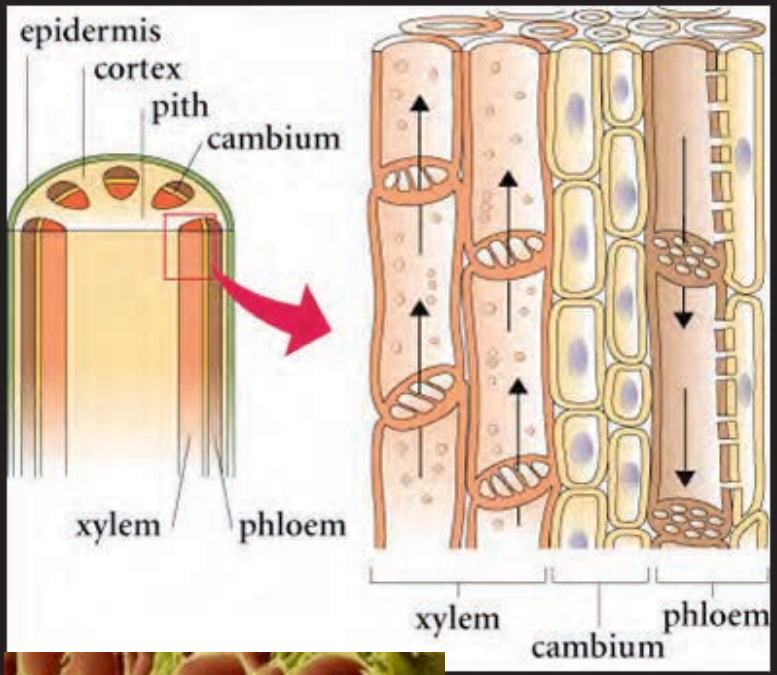






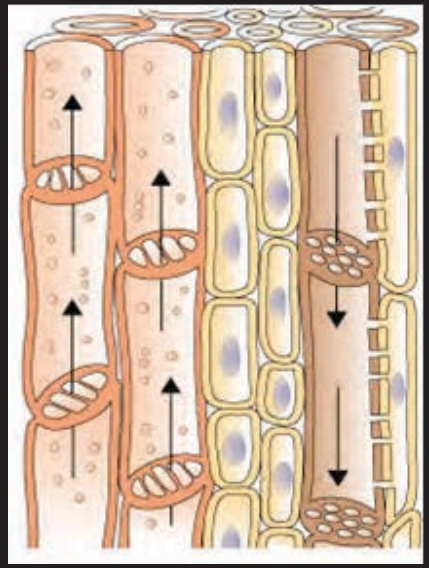


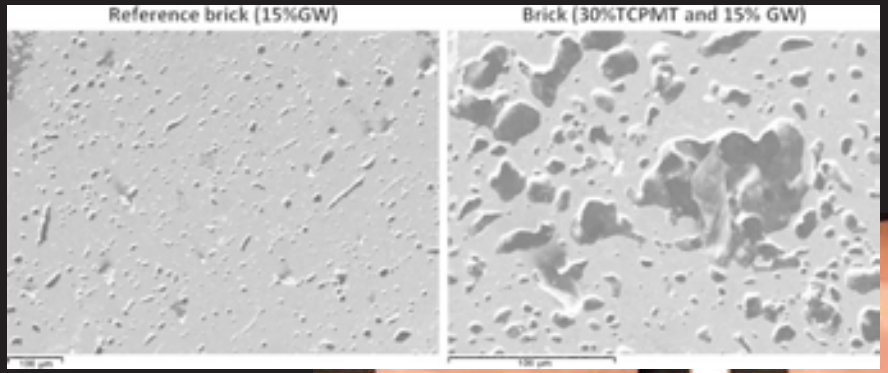


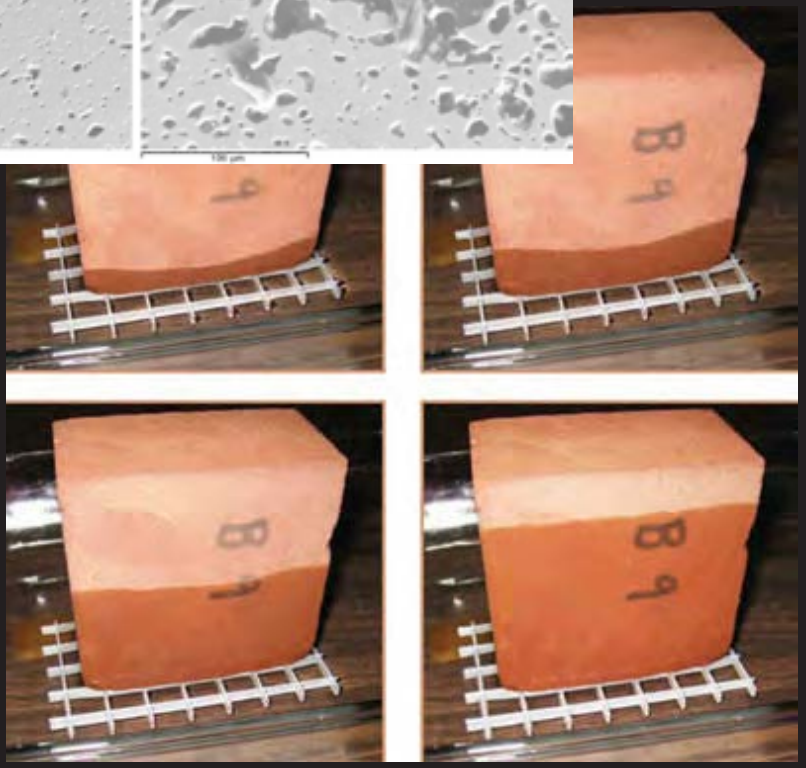

epidermis
cortex
pith
cambium
xylem
phloem
xylem
cambium
phloem

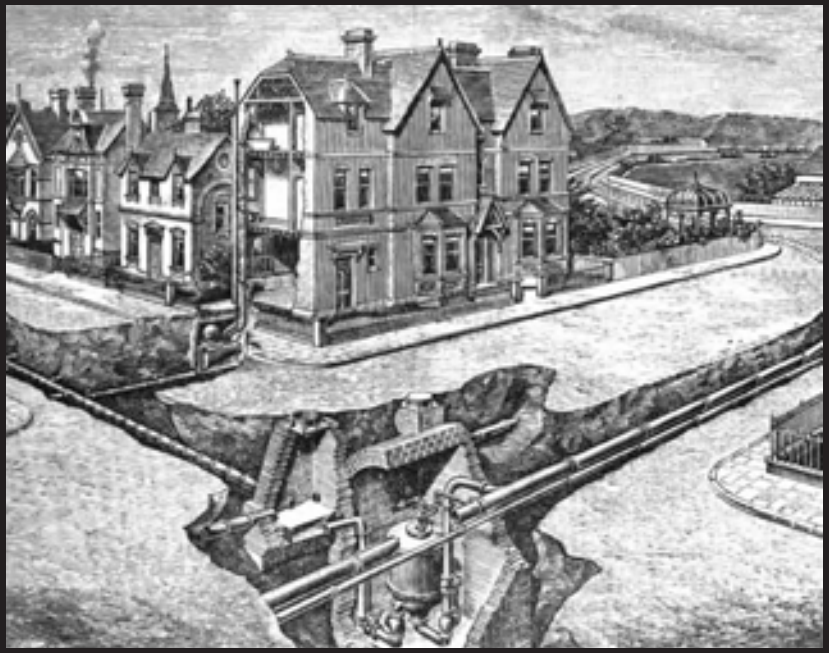

Leeds


TRATTORI
SEMPIONE



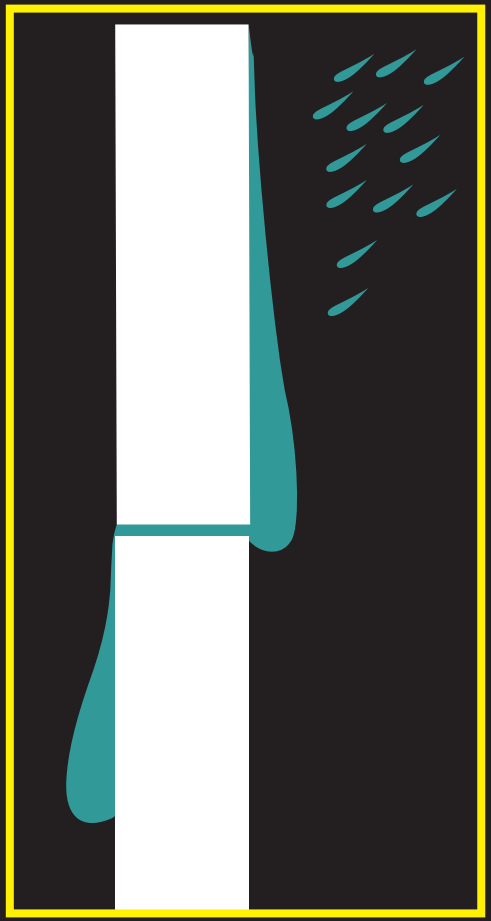

Reference brick (15%GW)
Brick (30%TCPMT and 15% GW)


B 9
B 9
B 9
B 9

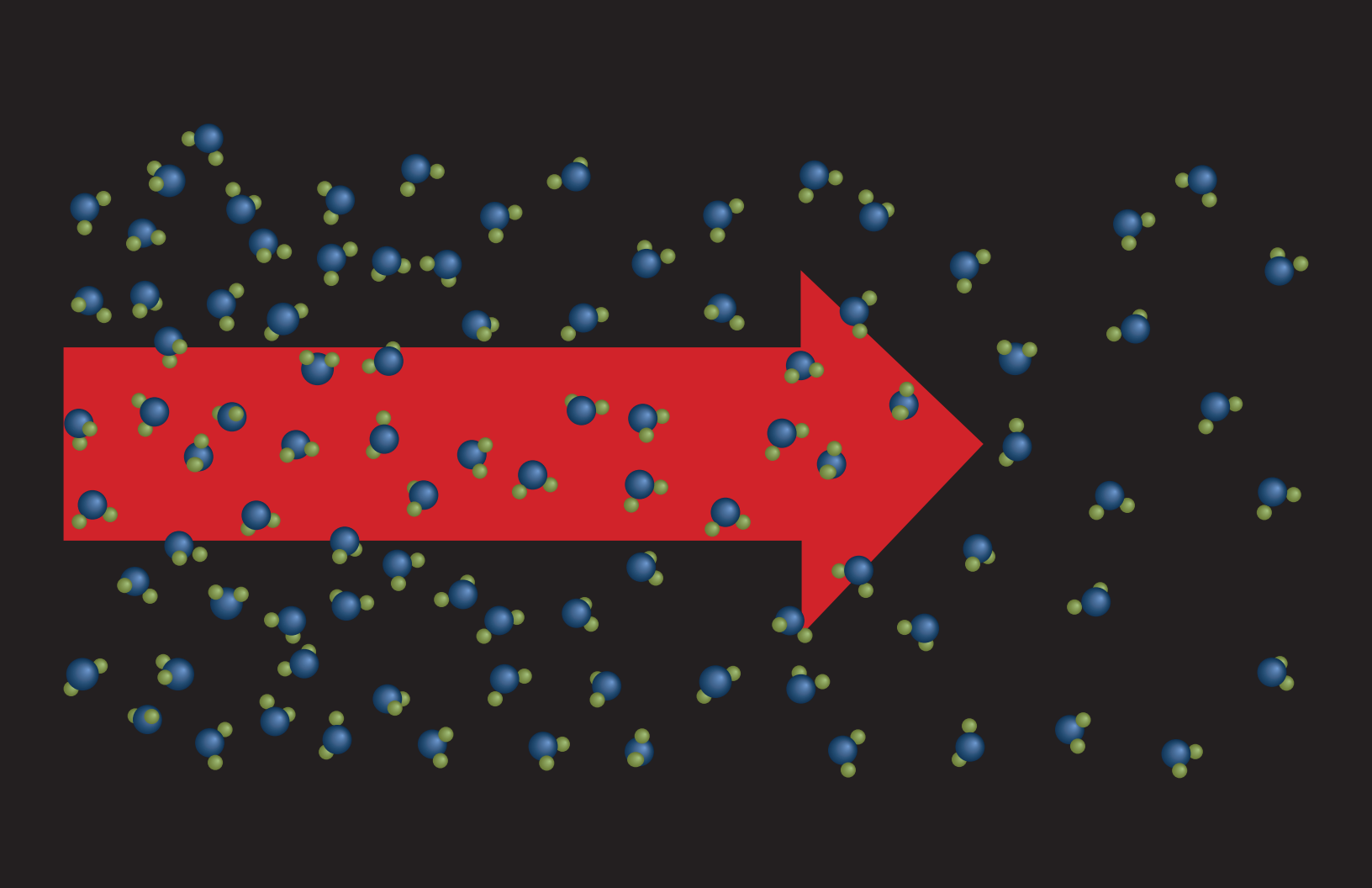


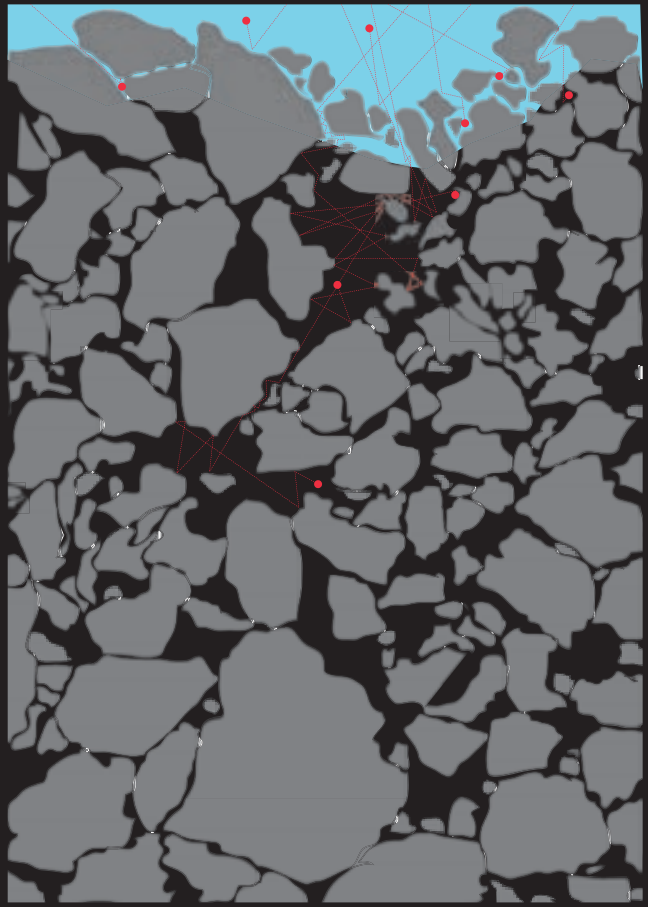

CROWN COURT
SERVICES

MODERN =
RAINCOAT



WATERPROOFING SEALANTS





1 RAINDROP =

1 390 000 000 000 000 000 000
WATER MOLECULES

DRYING OF PERMEABLE MATERIALS

STAGE I :

WATER MOVEMENT VIA LIQUID FLOW

DRIVEN BY EVAPORATION; DEPENDS ON EXTERIOR CONDITIONS

VERY FAST

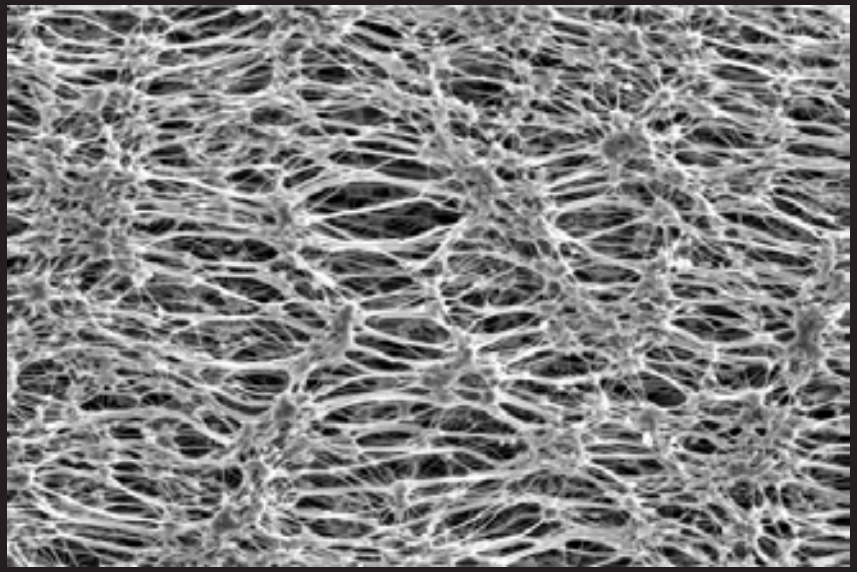
STAGE II :

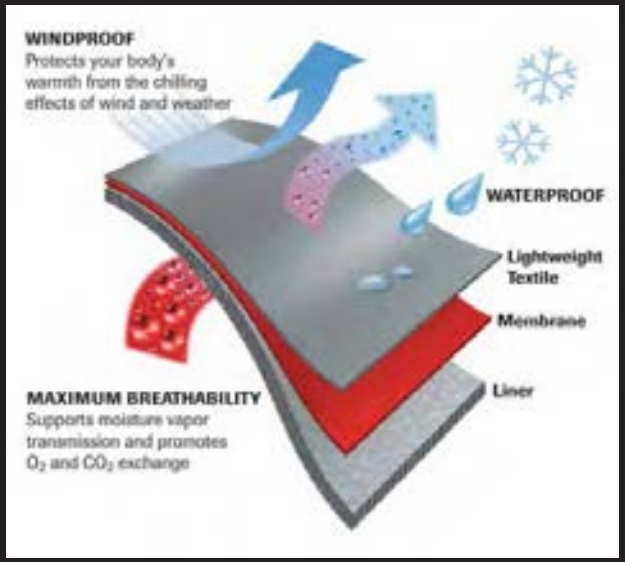
WATER MOVEMENT VIA VAPOUR MOVEMENT

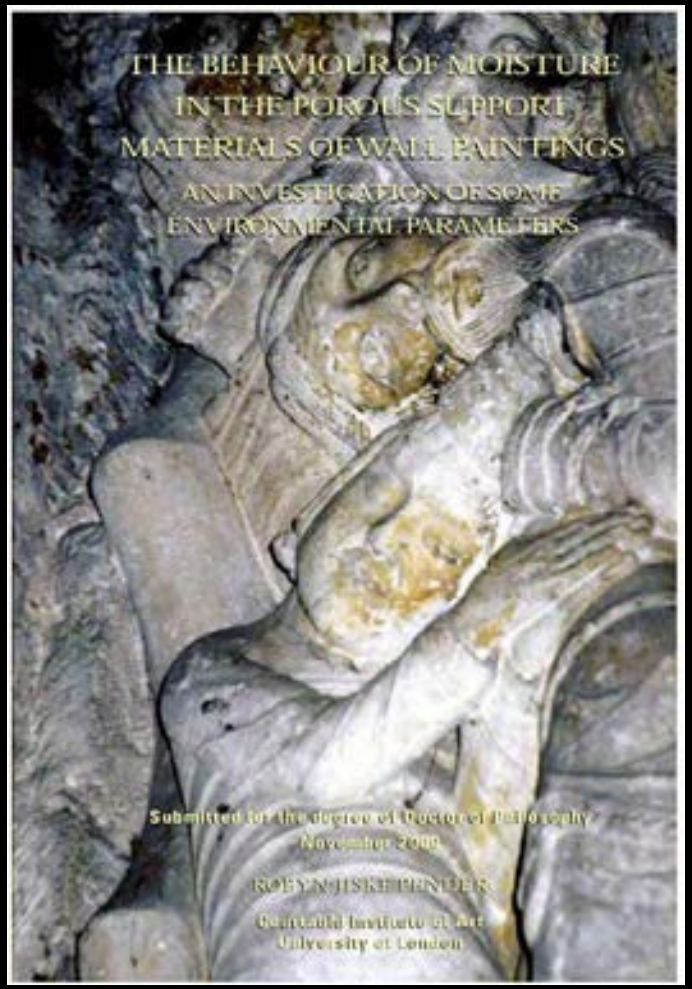
RANDOM; INDEPENDENT OF EXTERIOR CONDITIONS

EXTREMELY SLOW

THEREFORE, FOR EFFECTIVE DRYING,
KEEP IN STAGE I AS LONG AS POSSIBLE




WINDPROOF
Protects your body's warmth from the chilling effects of wind and weather
WATERPROOF
Lightweight Textile
Membrane
Liner
MAXIMUM BREATHABILITY
Supports moisture vapor transmission and promotes O_2 and CO_2 exchange


THE BEHAVIOUR OF MOISTURE
IN THE POROUS SUPPORT
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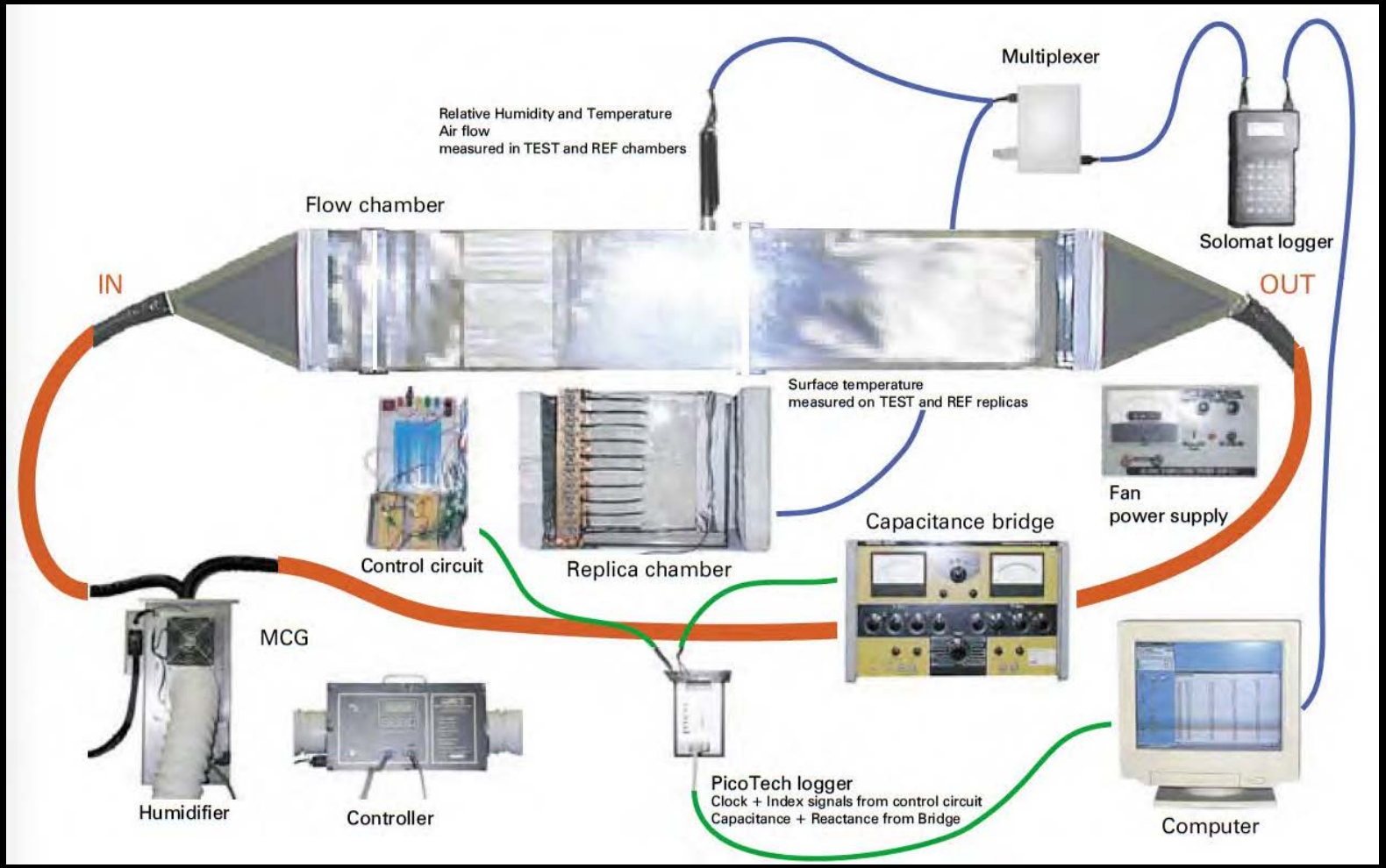
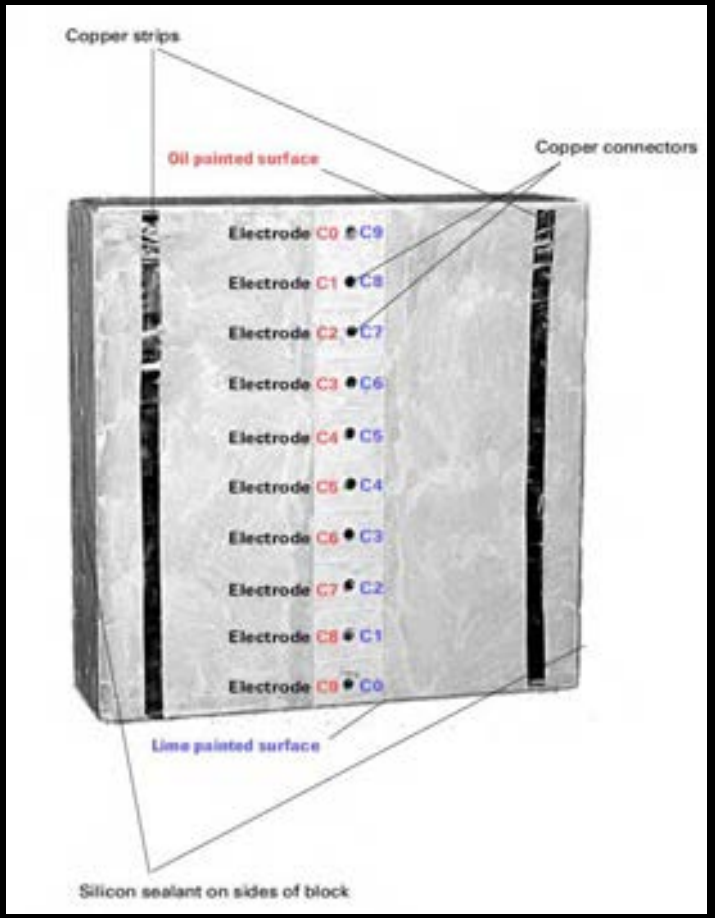
AN INVESTIGATION OF SOME
ENVIRONMENTAL PARAMETERS
Submitted for the degree of Doctor of Philosophy
November 2000
ROEY N. HISKE PENDER
Courtauld Institute of Art
University of London


Multiplexer
Relative Humidity and Temperature
Air flow
measured in TEST and REF chambers
Flow chamber
Solomat logger
IN
OUT
Surface temperature
measured on TEST and REF replicas
Fan
power supply
Capacitance bridge
Control circuit
Replica chamber
MCG
Humidifier
Controller
PicoTech logger
Clock + Index signals from control circuit
Capacitance + Reactance from Bridge
Computer



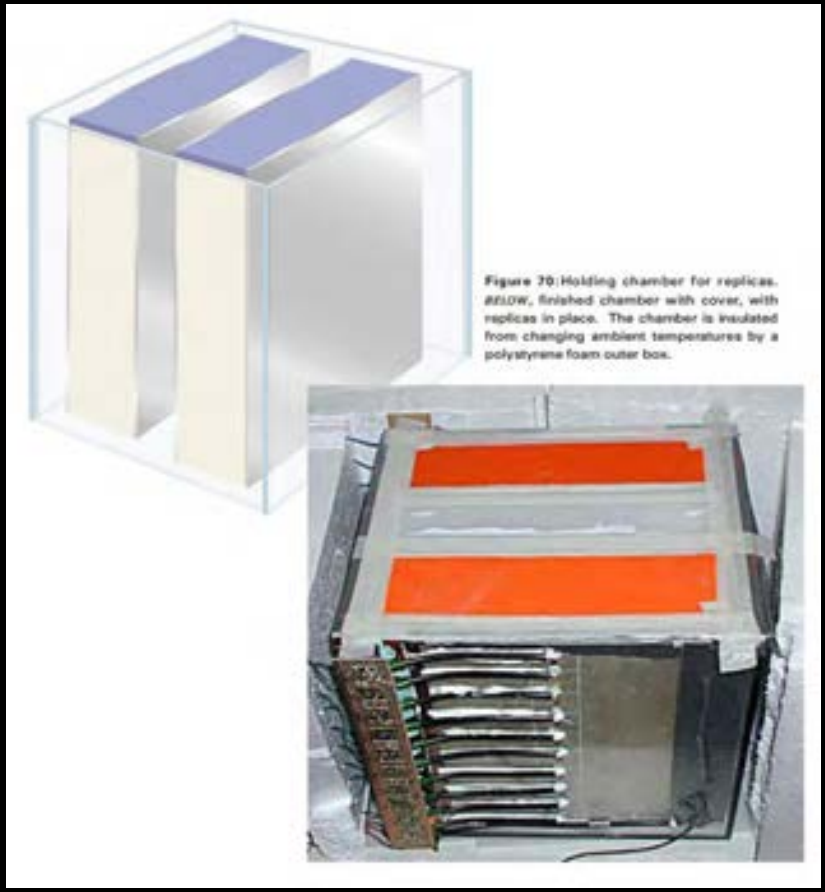
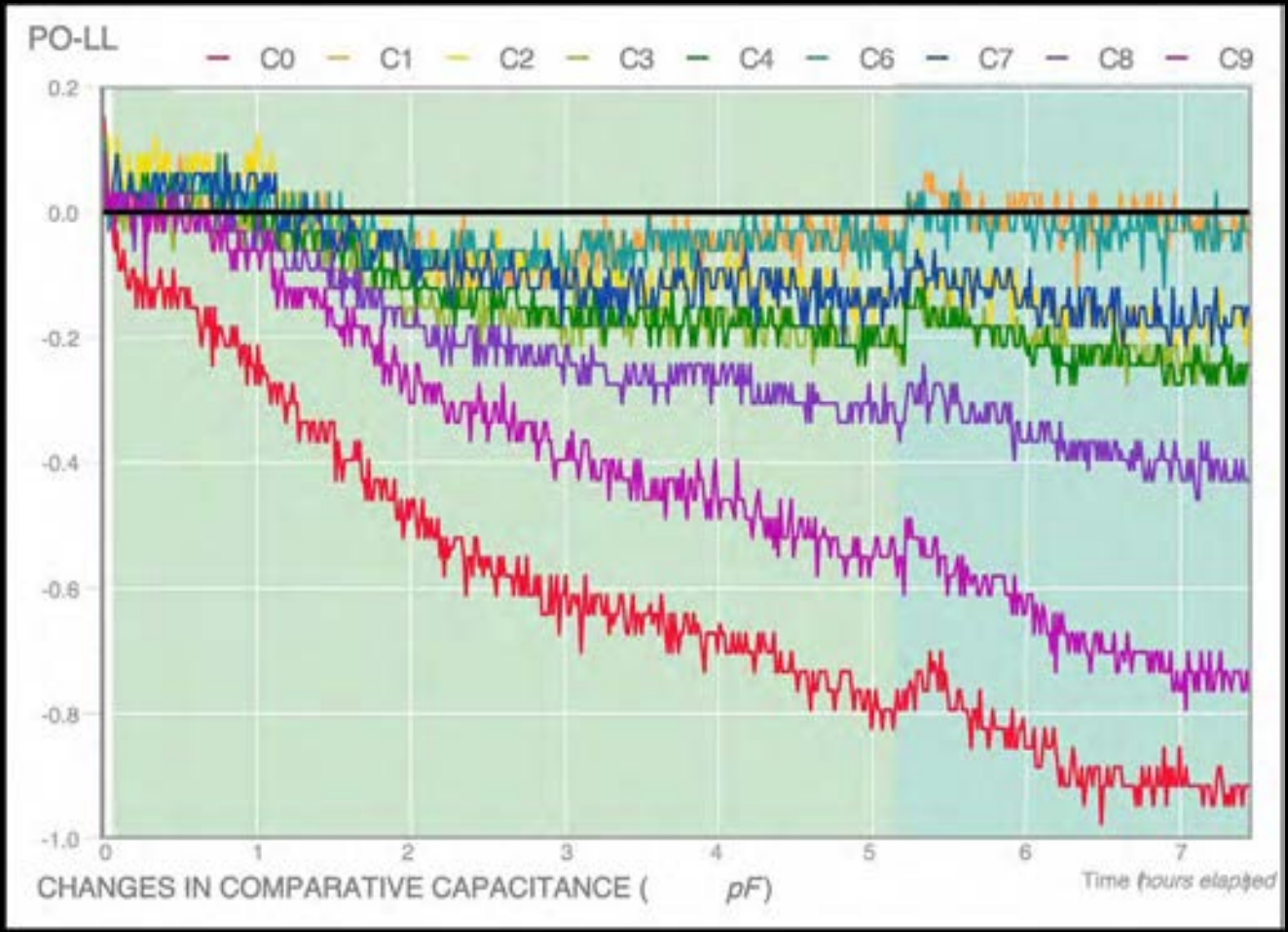
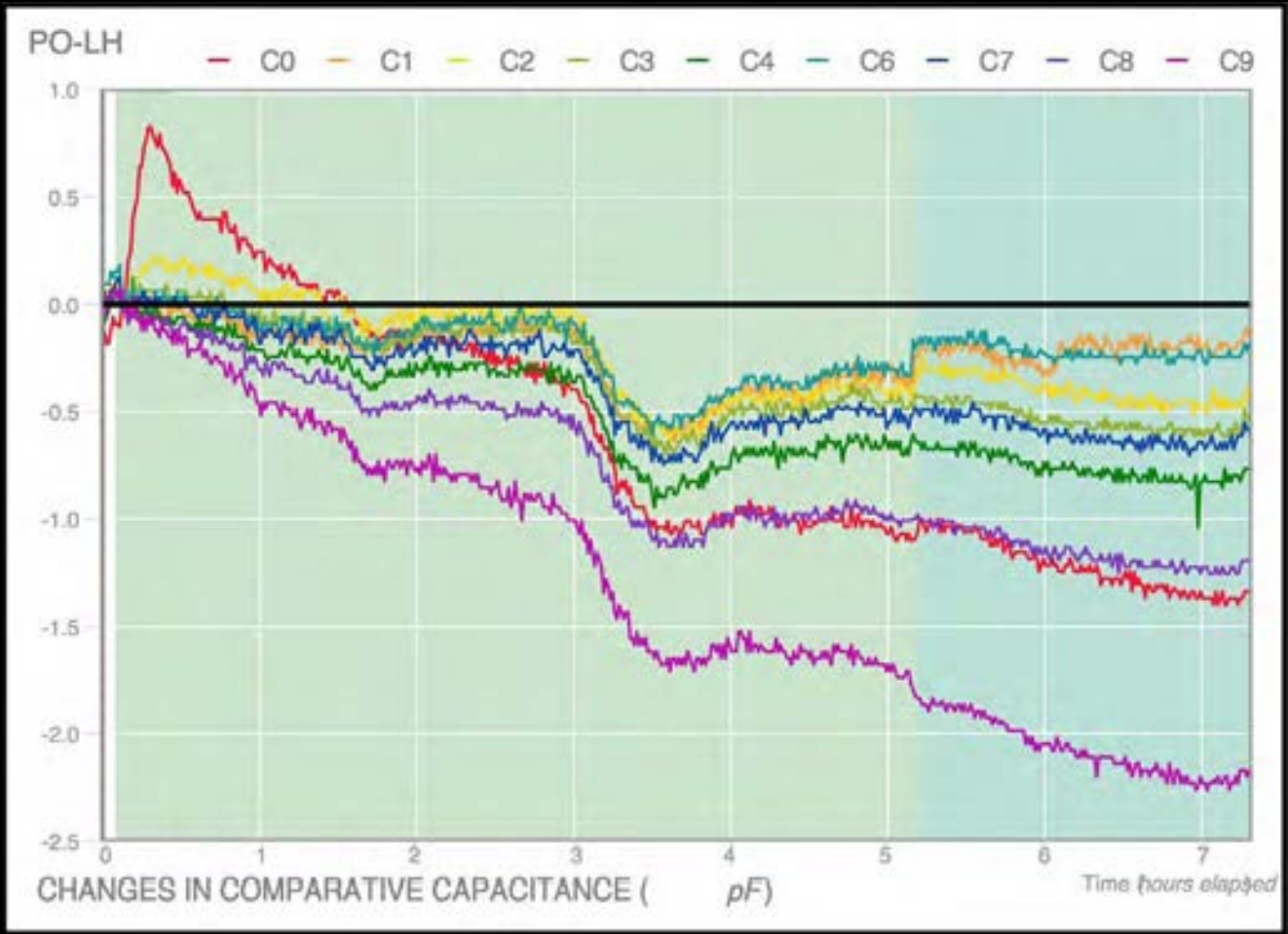
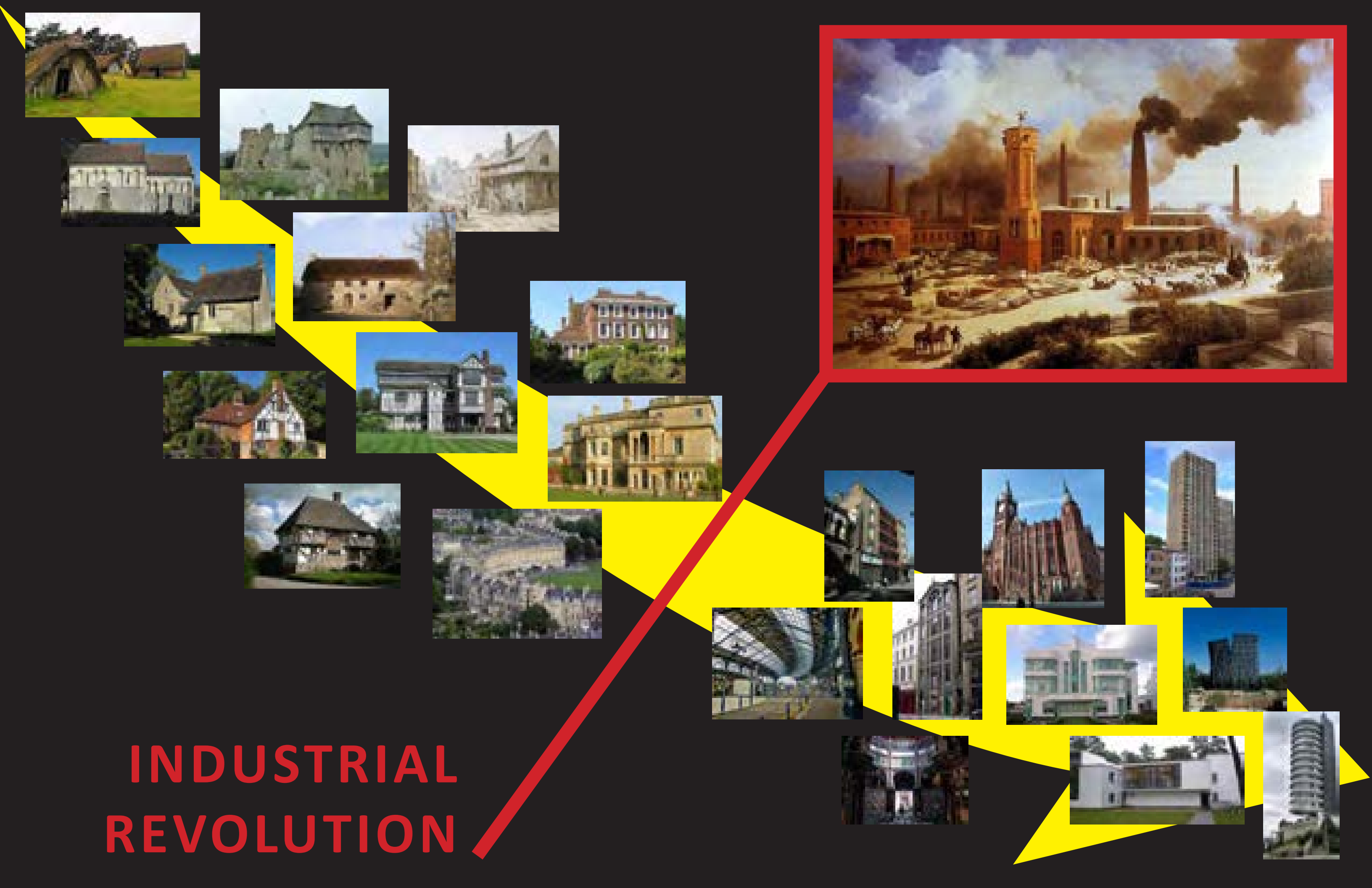


Figure 70: Holding chamber for replicas. *BELOW*, finished chamber with cover, with replicas in place. The chamber is insulated from changing ambient temperatures by a polystyrene foam outer box.

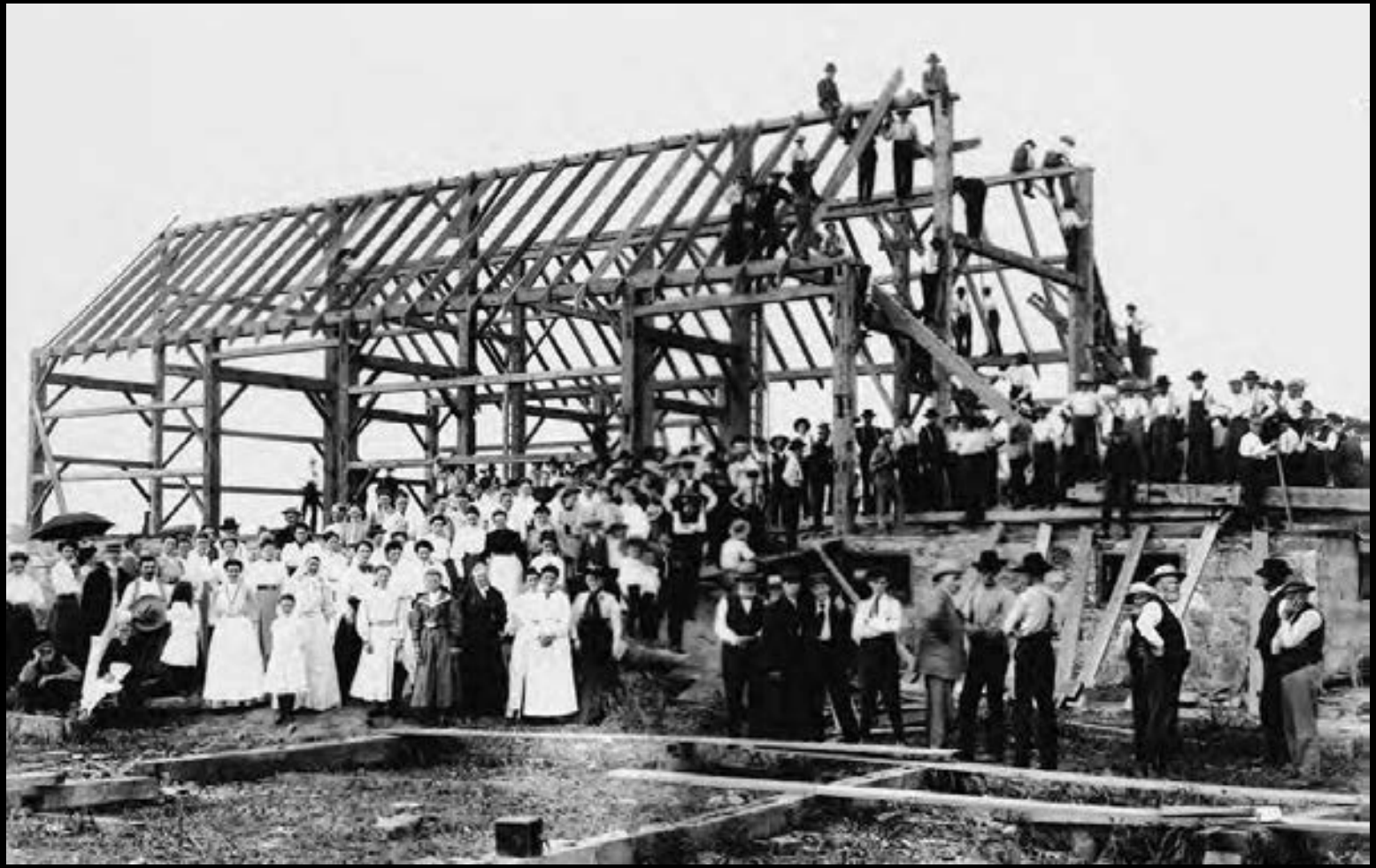

PO-LL
C0
C1
C2
C3
C4
C6
C7
C8
C9
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
0
1
2
3
4
5
6
7
CHANGES IN COMPARATIVE CAPACITANCE (pF)
Time hours elapsed


PO-LH
C0
C1
C2
C3
C4
C6
C7
C8
C9
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
0
1
2
3
4
5
6
7
CHANGES IN COMPARATIVE CAPACITANCE (pF)
Time (hours elapsed


MAGNA CARTA

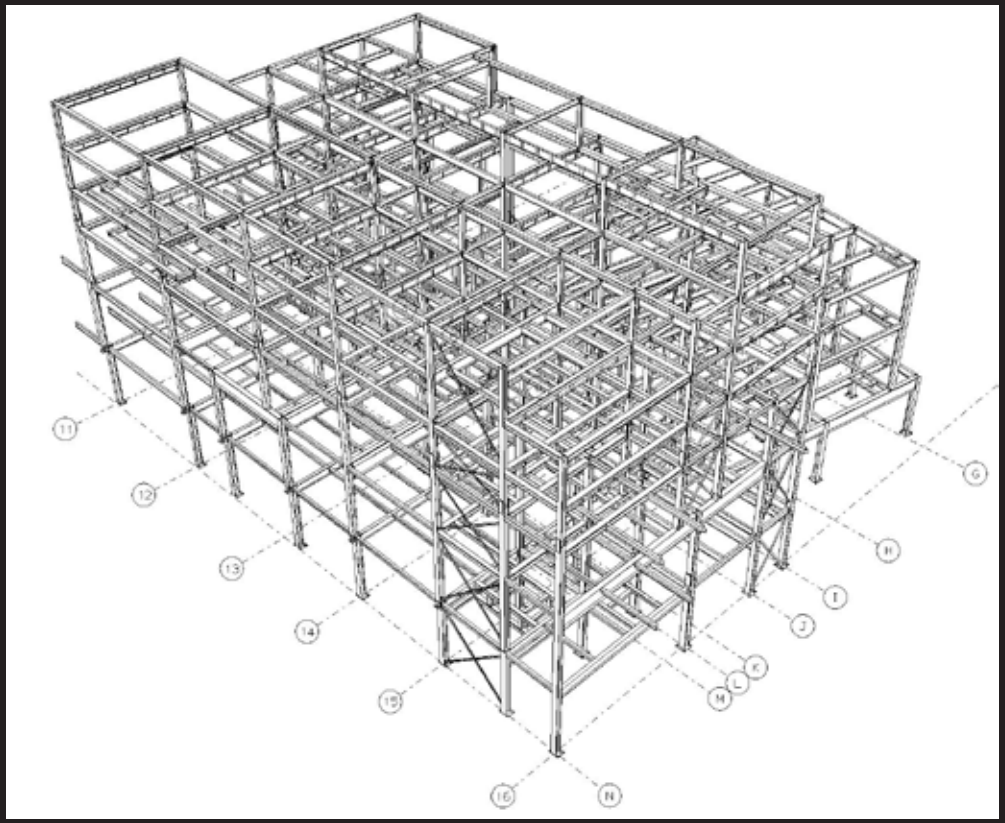

INDUSTRIAL
REVOLUTION


WILLINGTON
Willington Station
215



ARCHITECTS

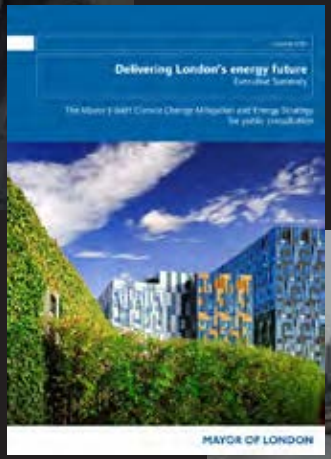
ENGINEERS



PLANNERS

ECONOMISTS


King Sturg
No5
Across the UK
Raising the Bar


Delivering London's energy future
Executive Summary
MAYOR OF LONDON

ENERGY INPUTS INTO A BUILDING

TRADITIONAL VERNACULAR

ENERGY IS EXPENSIVE

OBTAINING RAW MATERIALS (GROWING, MINING, HARVESTING)

TRANSPORTING RAW MATERIALS FOR PROCESSING

MAKING USABLE BUILDING MATERIALS

TRANSPORTING THE FINISHED BUILDING MATERIALS TO SITE

CONSTRUCTING THE BUILDING

KEEPING THE BUILDING IN SERVICE:
DAY-TO-DAY MAINTENANCE

KEEPING THE BUILDING IN SERVICE:
OTHER RUNNING COSTS

KEEPING THE BUILDING IN SERVICE:
UPDATING & REFURBISHING


OBTAINING RAW MATERIALS
TRANSPORTING RAW MATERIALS
MAKING BUILDING MATERIALS
TRANSPORTING FINISHED MATERIALS TO SITE
CONSTRUCTING
DAY-TO-DAY MAINTENANCE
OTHER RUNNING COSTS
UPDATING & REFURBISHING

INTENDED LIFETIME OF BUILDING?

INTENDED LIFETIME OF BUILDING:

500 YEARS?

POTENTIALLY INDEFINITE

DAY-TO-DAY MAINTENANCE

OTHER RUNNING COSTS

UPDATING & REFURBISHING

ENERGY INPUTS INTO A BUILDING

MODERN

ENERGY IS CHEAP & EASILY AVAILABLE

OBTAINING RAW MATERIALS (GROWING, MINING, HARVESTING)

TRANSPORTING RAW MATERIALS FOR PROCESSING

MAKING USABLE BUILDING MATERIALS:

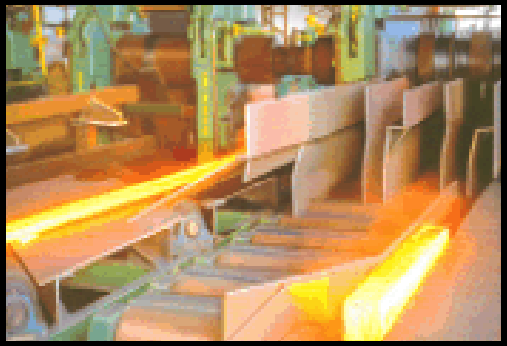
PRIMARY PROCESSING

MAKING USABLE BUILDING MATERIALS:

TRANSPORT

MAKING USABLE BUILDING MATERIALS:

SECONDARY PROCESSING



MAKING USABLE BUILDING MATERIALS:

TERTIARY PROCESSING

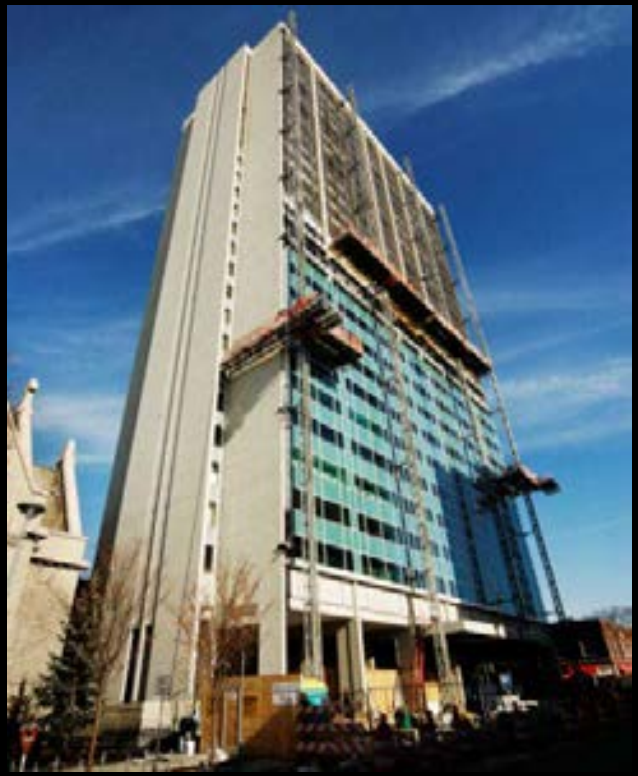
TRANSPORTING THE FINISHED BUILDING MATERIALS TO SITE

CONSTRUCTING THE BUILDING

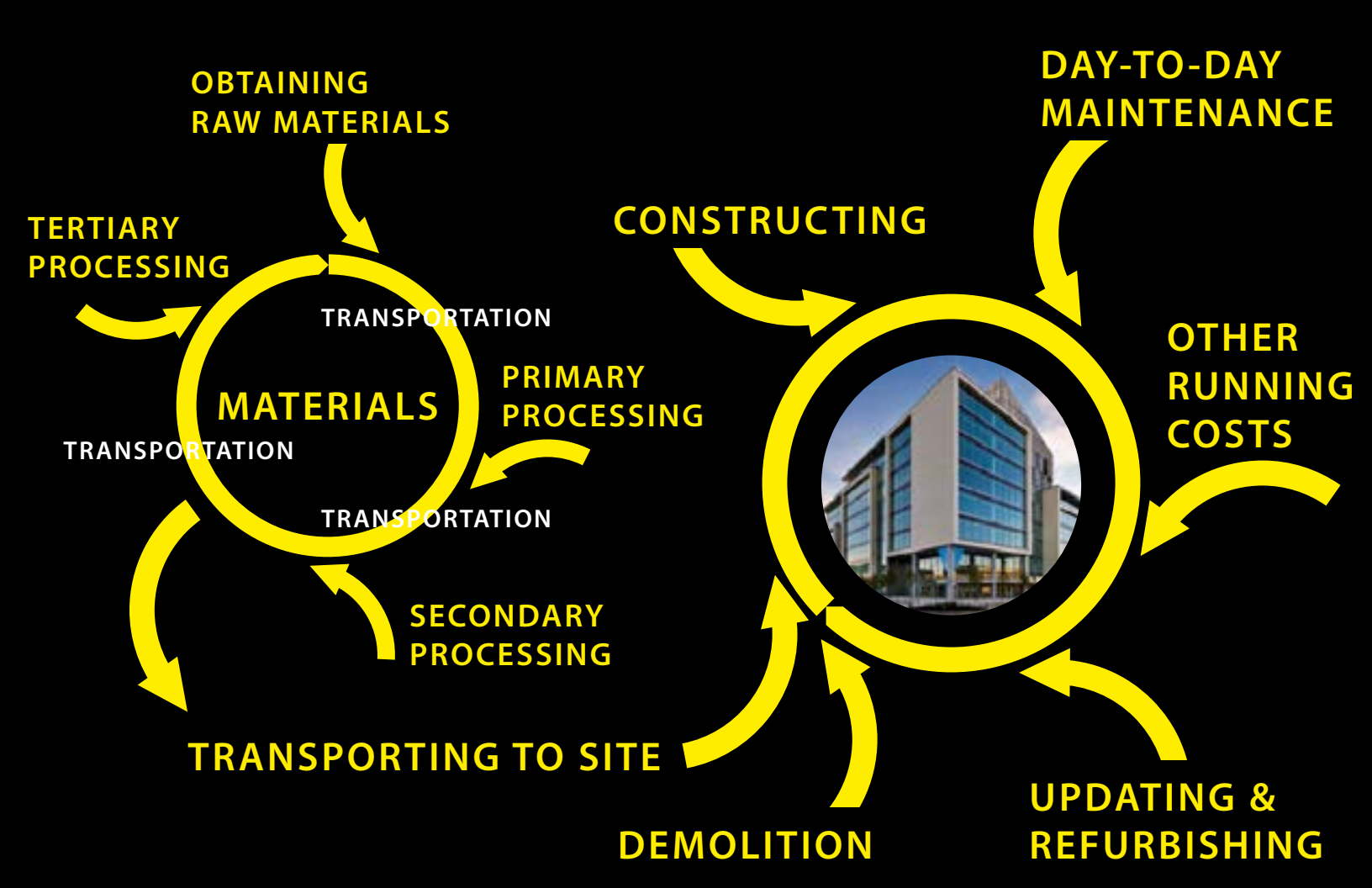
KEEPING THE BUILDING IN SERVICE:
DAY-TO-DAY MAINTENANCE

KEEPING THE BUILDING IN SERVICE:
OTHER RUNNING COSTS

KEEPING THE BUILDING IN SERVICE:
UPDATING & REFURBISHING



DEMOLITION, DISPOSAL & REPLACEMENT


OBTAINING
RAW MATERIALS
TERTIARY
PROCESSING
TRANSPORTATION
MATERIALS
PRIMARY
PROCESSING
TRANSPORTATION
TRANSPORTATION
SECONDARY
PROCESSING
TRANSPORTING TO SITE
CONSTRUCTING
DAY-TO-DAY
MAINTENANCE
OTHER
RUNNING
COSTS
UPDATING &
REFURBISHING
DEMOLITION

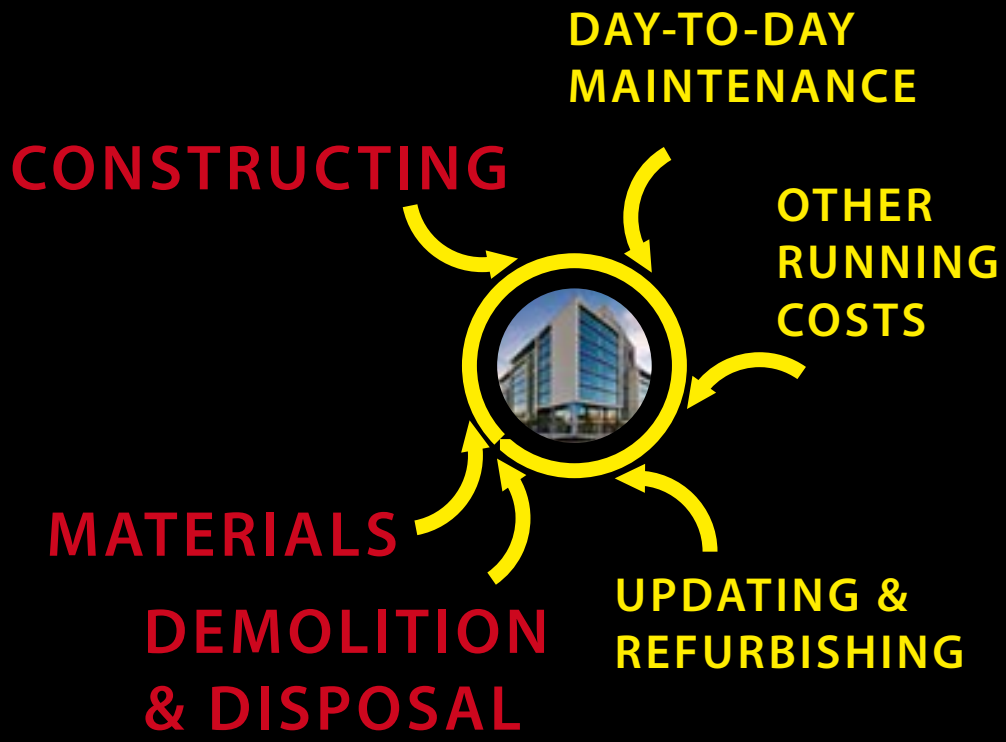
INTENDED LIFETIME OF BUILDING?

ENERGY INPUTS INTO A BUILDING

INTENDED LIFETIME OF BUILDING:

IN CITY OF LONDON

AVERAGE 16 YEARS



TIMELINE FOR SERVICES

1500s

SMOKE BAYS

1600s

GLASS FOR WINDOWS IN LARGE HOUSES

CHIMNEYS IN ORDINARY HOUSES

1670

SLIDING SASH WINDOWS

INDUSTRIAL REVOLUTION

1760

FIRST PRACTICAL WCs

SEWERS

WATER MAINS

1840

GAS LIGHTING

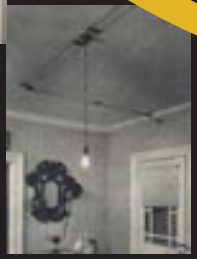
COAL-FIRED RANGES

ARTIFICIAL VENTILATION

1870

HOT WATER CYLINDERS

1900

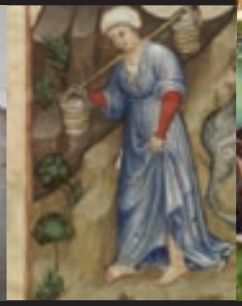


ELECTRIC POWER

AIR CONDITIONING

CONNECTIVITY

2020

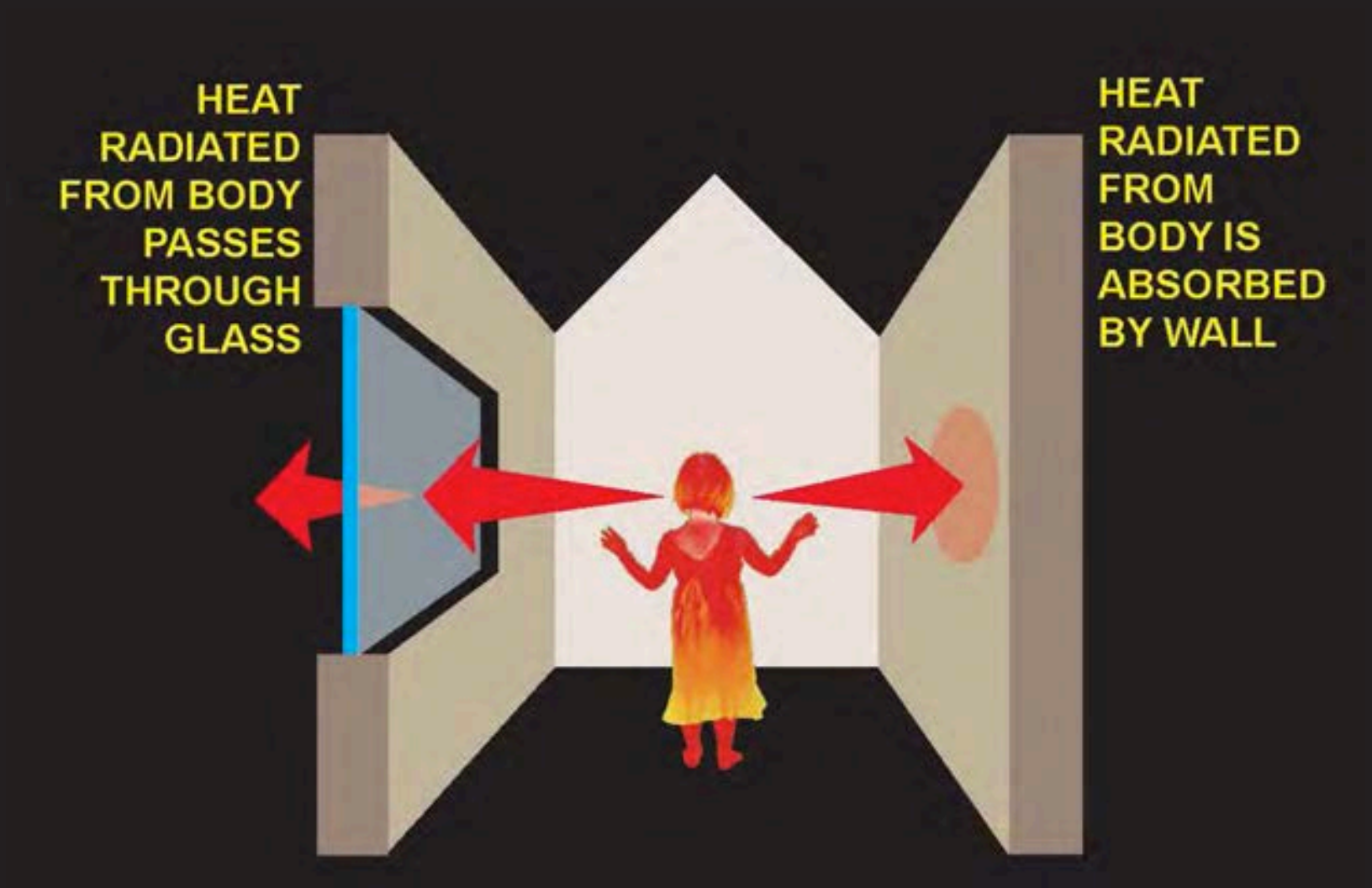


FIRE PITS
HANGINGS + CURTAINS
ANIMAL HEAT

UP UNTIL 1600s

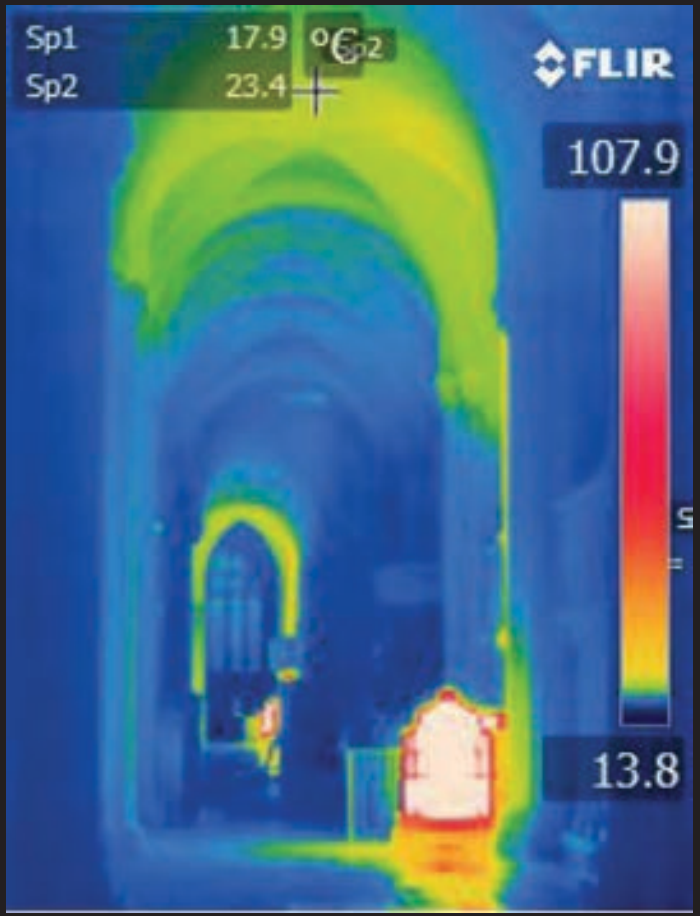
SUNLIGHT
RUSH LIGHTS
LAMPS
CANDLES
SHUTTERS

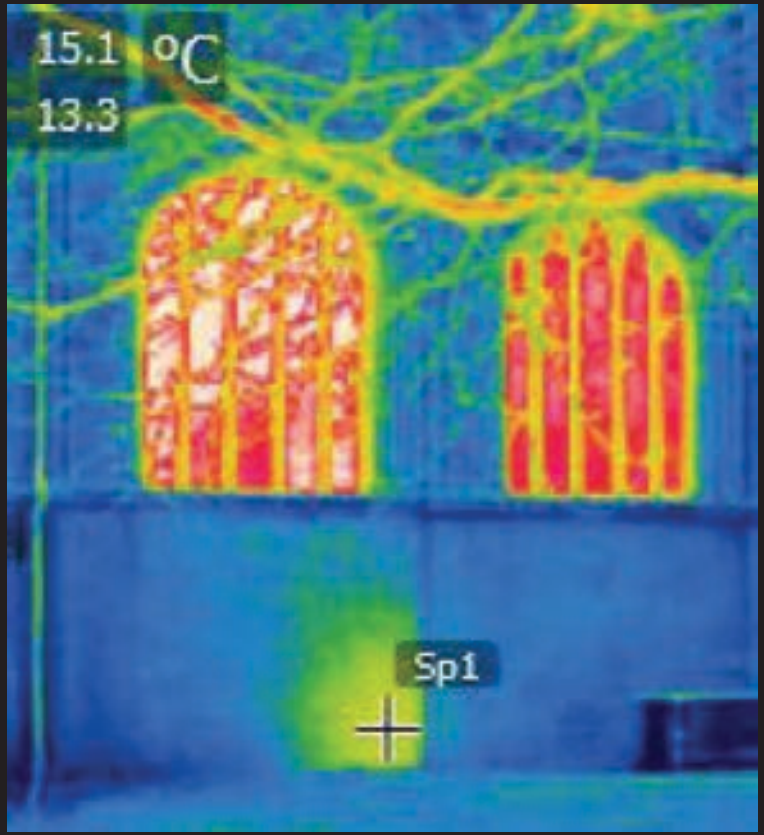
WELLS
PRIVIES

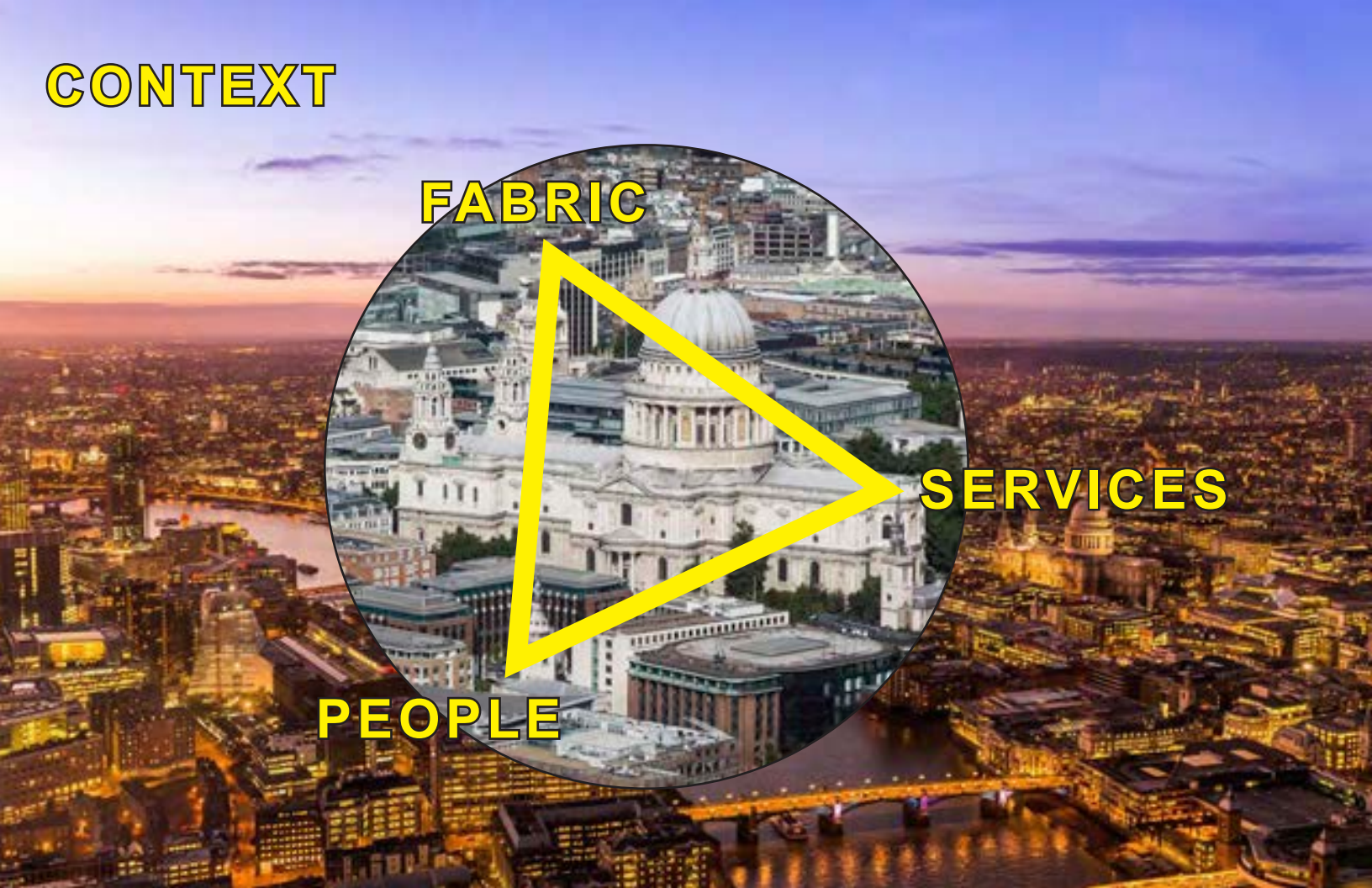

HEAT RADIATED FROM BODY PASSES THROUGH GLASS
HEAT RADIATED FROM BODY IS ABSORBED BY WALL

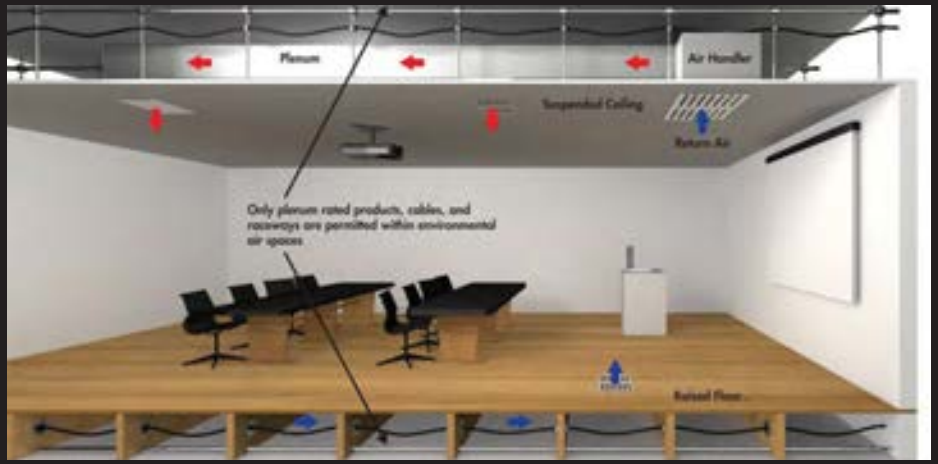

WHO PAINTE
SHAKESPEARE
GLOBE THEATRE!
108
HO MADE
ALLPAPER
POPULAR!

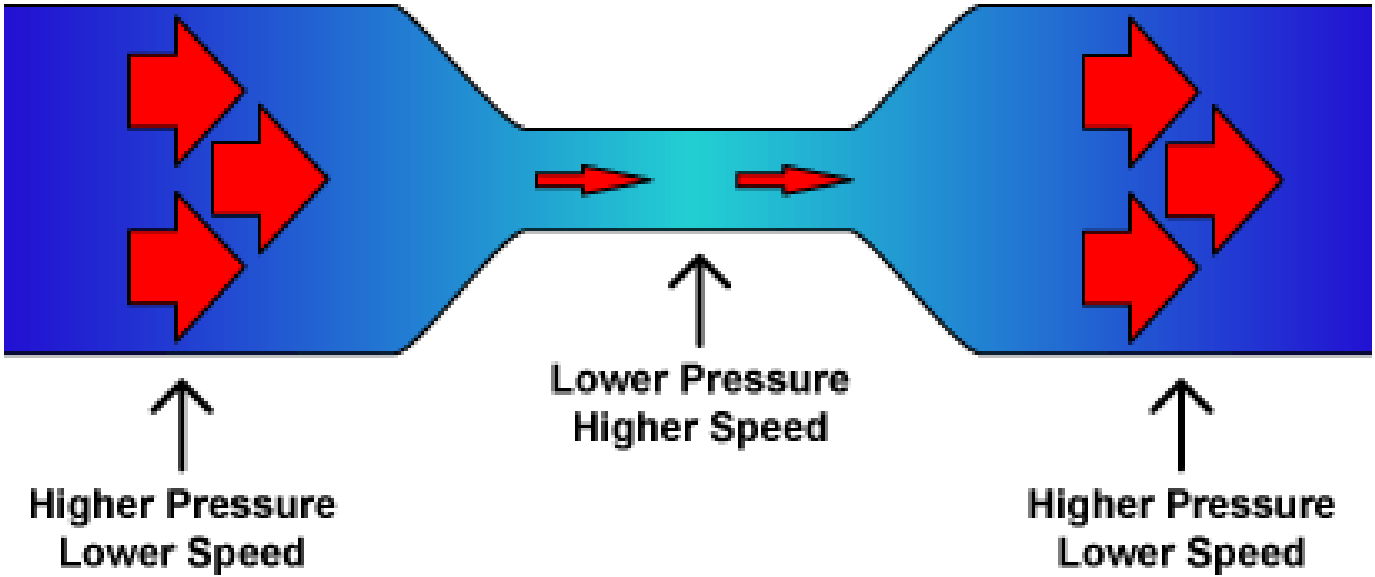

G. A. WILLIAMS & SON,
21 QUEEN'S ROAD, BAYSWATER.


Sp1 17.9 °C
Sp2 23.4
Sp2
FLIR
107.9
13.8


15.1 °C
13.3
Sp1


CONTEXT
FABRIC
SERVICES
PEOPLE


Plenum
Air Handler
Suspended Ceiling
Return Air
Only plenum rated products, cables, and raceways are permitted within environmental air spaces
Raised Floor


Lower Pressure
Higher Speed
Higher Pressure
Lower Speed
Higher Pressure
Lower Speed

GLOUCESTER CATHEDRAL LADY CHAPEL

FELIX THE BUILDING-SCIENCE SUPERHERO

THAT'S ALL FOLKS !