

ARUP

Façade Engineering and Building Physics

examples of current best practice and recent innovations

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PhD MSc CEng MCIBSE FSFE
Chairman, Society of Façade Engineering

ARUP



Overview

- Introduction
- Arup
- Facade Engineering
- Two Case Studies
- Innovation Example





Designing for Climate

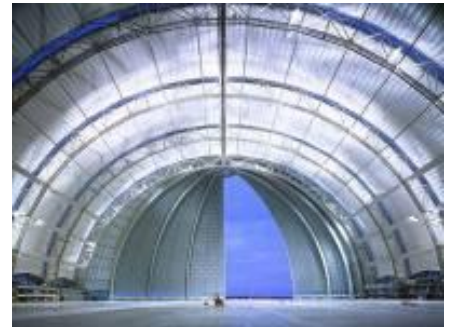
“The first American house built in war-time Java completely bewildered natives there. Instead of building walls of local bamboo, which is closely spaced to keep out rain while admitting light and air, the white man put up solid walls to keep out light and air, and then cut windows in the walls to admit the light and air. Next, he put glass panes in the windows to admit light but keep out the air. Then, he covered the panes with blinds and curtains to keep out the light too.”

Ken Kerr, 1978



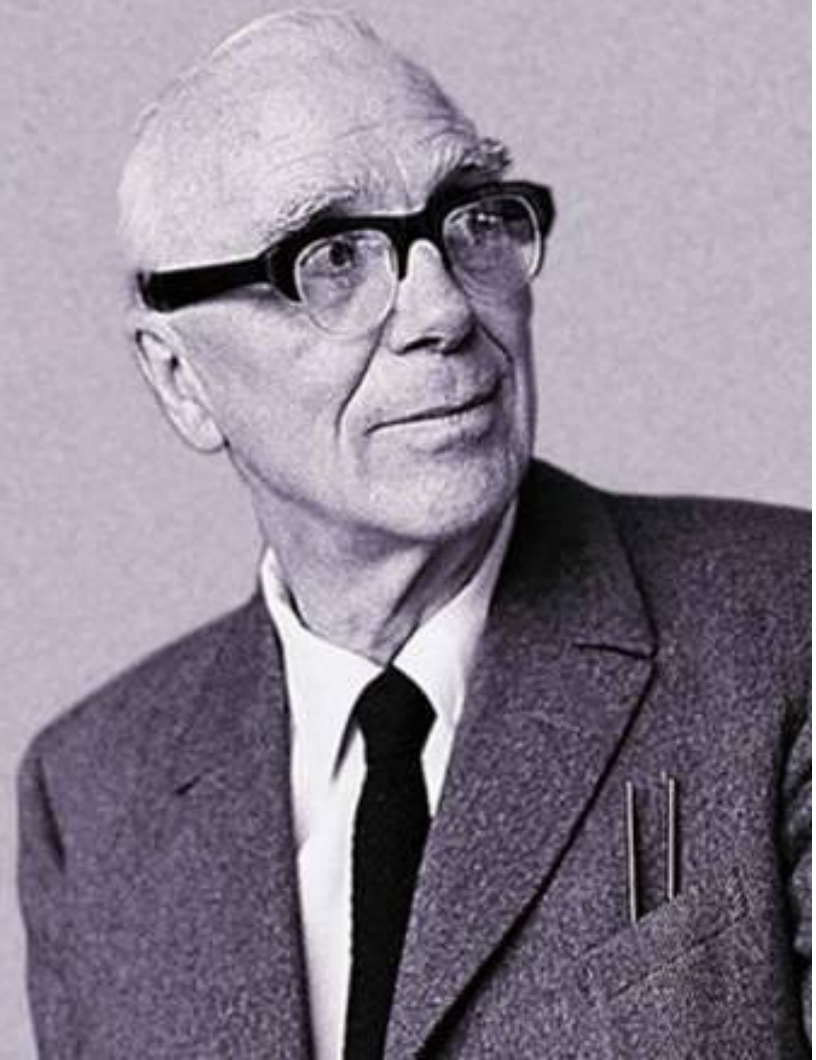
Arup was established in 1946 in the United Kingdom
to provide a completely independent
professional consulting engineering service

ARUP



“A design team which produces a total, balanced, efficient design can help to produce a better environment”

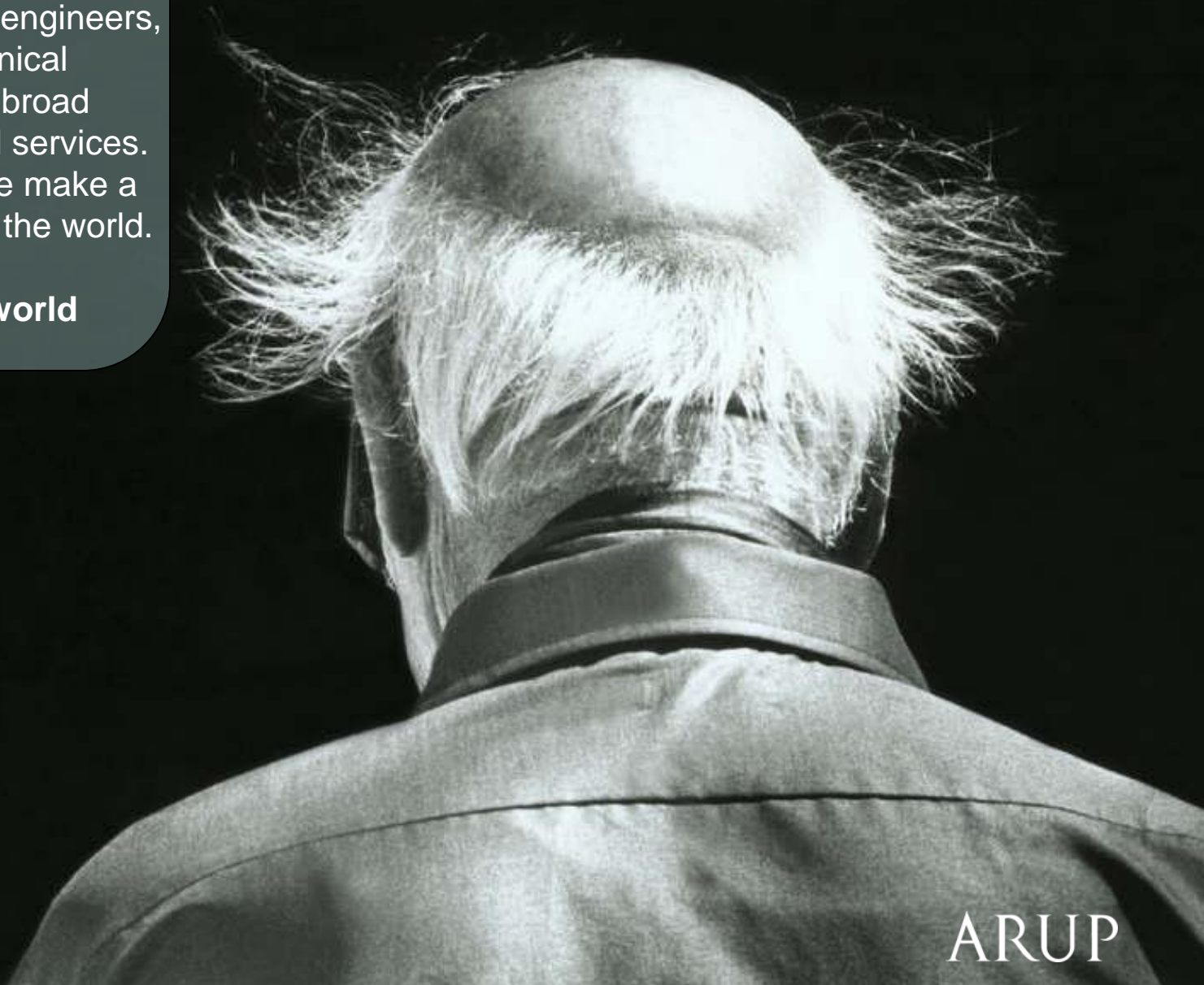
Sir Ove Arup



Arup is no ordinary firm

We are an independent firm of designers, planners, engineers, consultants and technical specialists offering a broad range of professional services. Through our work, we make a positive difference in the world.

We shape a better world



ARUP



facade engineering

Architecture

Services

Structure

The 'Impact' of Building Envelopes

- 15% - 25%+ of construction costs
- Interfaces *"It's where the problems always arise..."*
- Appearance of building
- Filter inside/outside
- Added value
- Reduced risk
- Control costs

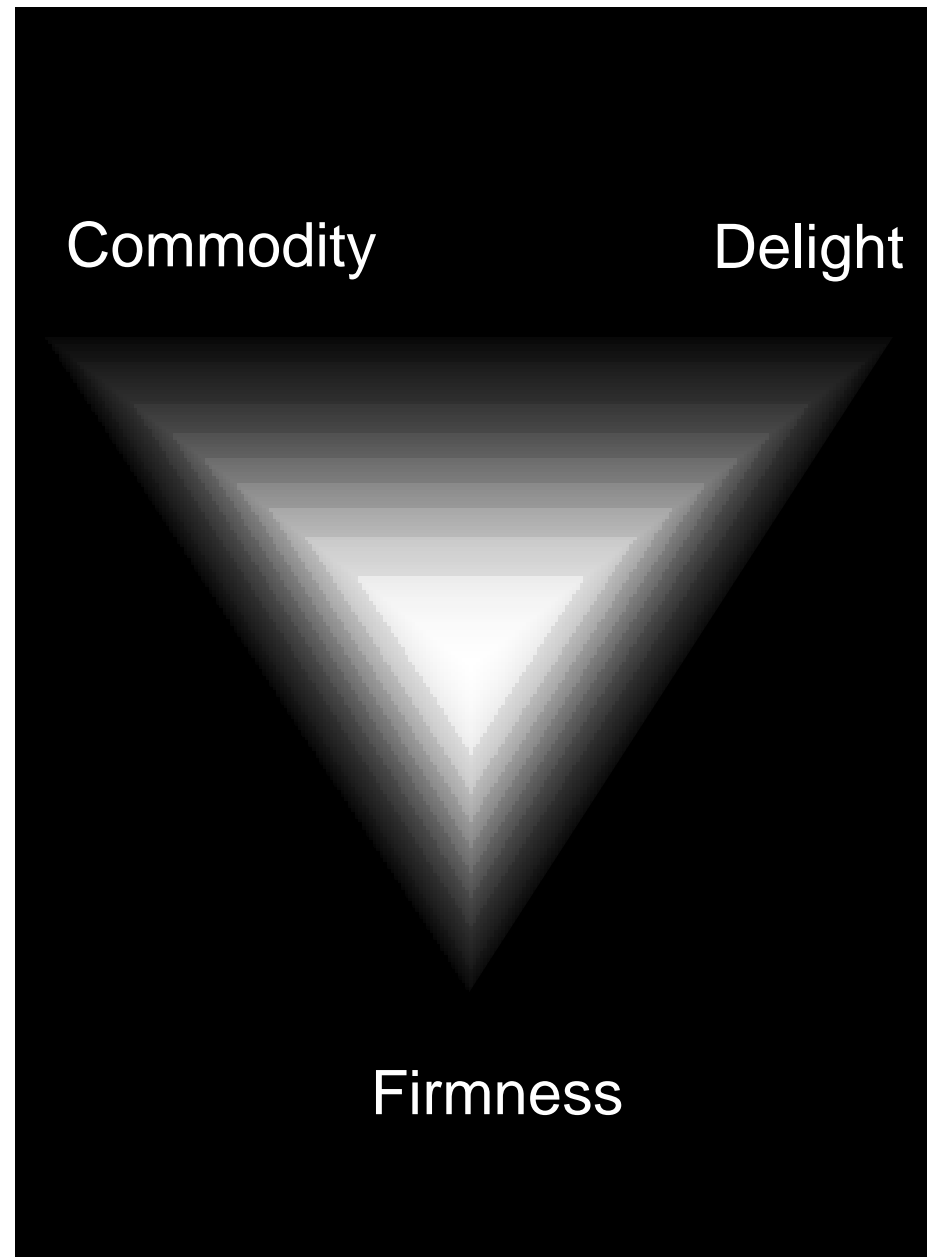
Architecture

Commodity

Firmness

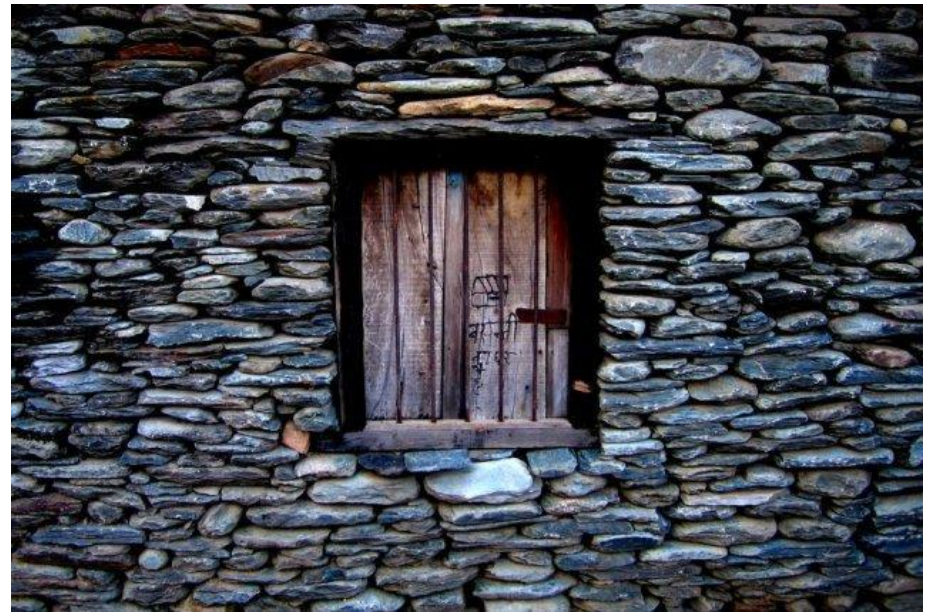
Delight

[Vitruvius]



Façade Engineering

- ‘Grey area’
- From traditional to non-traditional methods and technologies
- Multitude of specialist skills, knowledge, and intelligence about industry
- Emerging specialist ‘discipline’
- Qualifications?




Society of Facade Engineering

FACTS: Established in 2003. CIBSE Society. Supported by RIBA and IStructE. Growing membership across industry and regions. Currently around 250 members (Affiliate / Associate / Member / Fellow).

BENEFITS: Recognised professional status and FSFE / MSFE designation. Enhancement of career opportunities. Networking. Events. Magazine. Technical forum.

www.FacadeEngineeringSociety.org





a couple of projects

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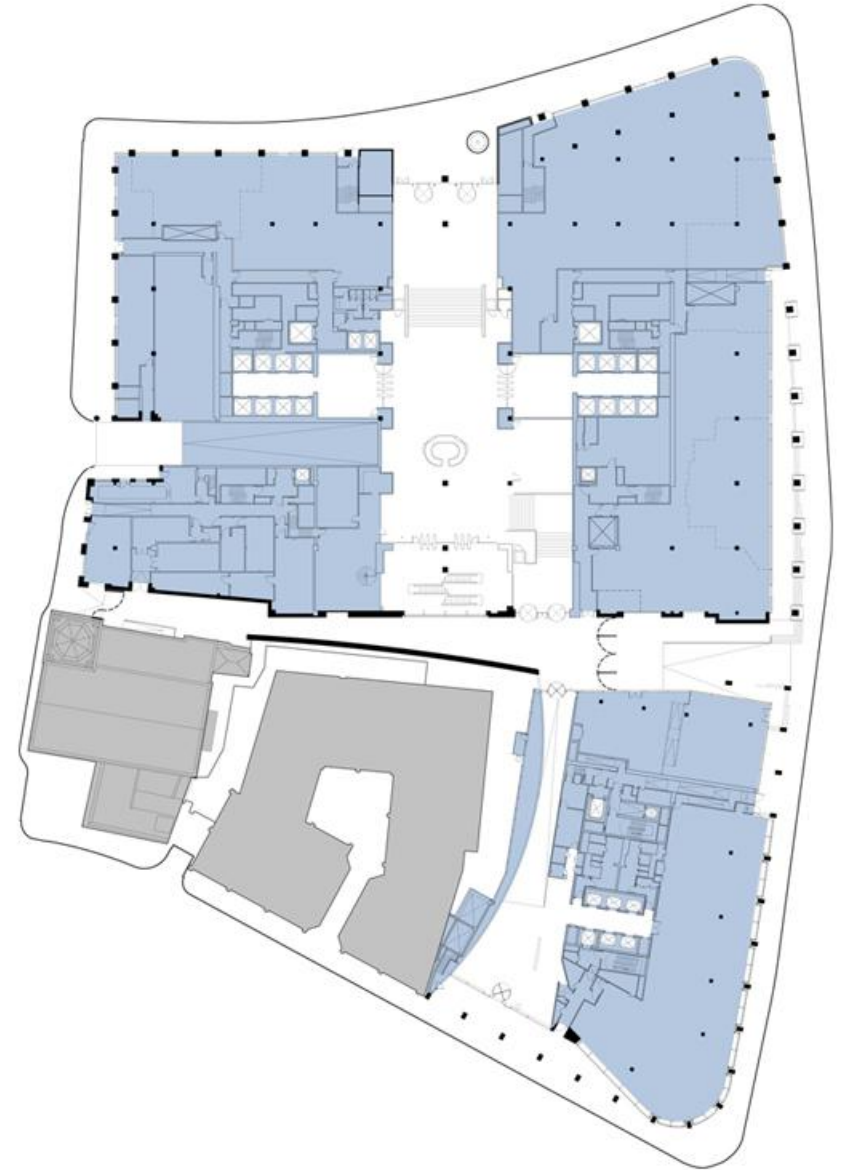
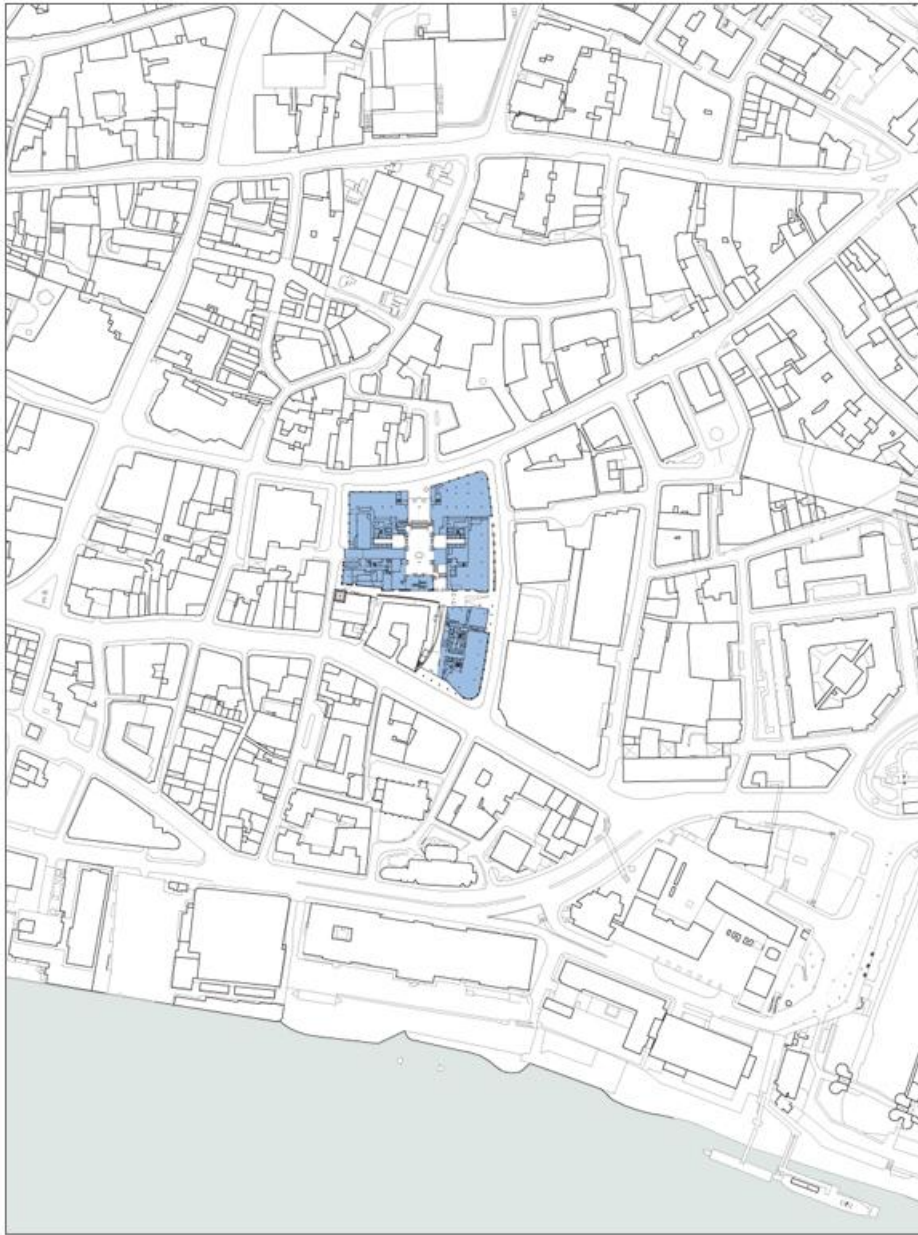
A low-angle, upward-looking photograph of a modern skyscraper with a glass curtain wall. The building's structure is composed of a grid of dark metal frames holding large glass panels. The perspective creates a sense of height and scale, with the building's edges converging towards the top of the frame. The sky is a clear, deep blue, and the lighting suggests a bright, sunny day.

Plantation Place

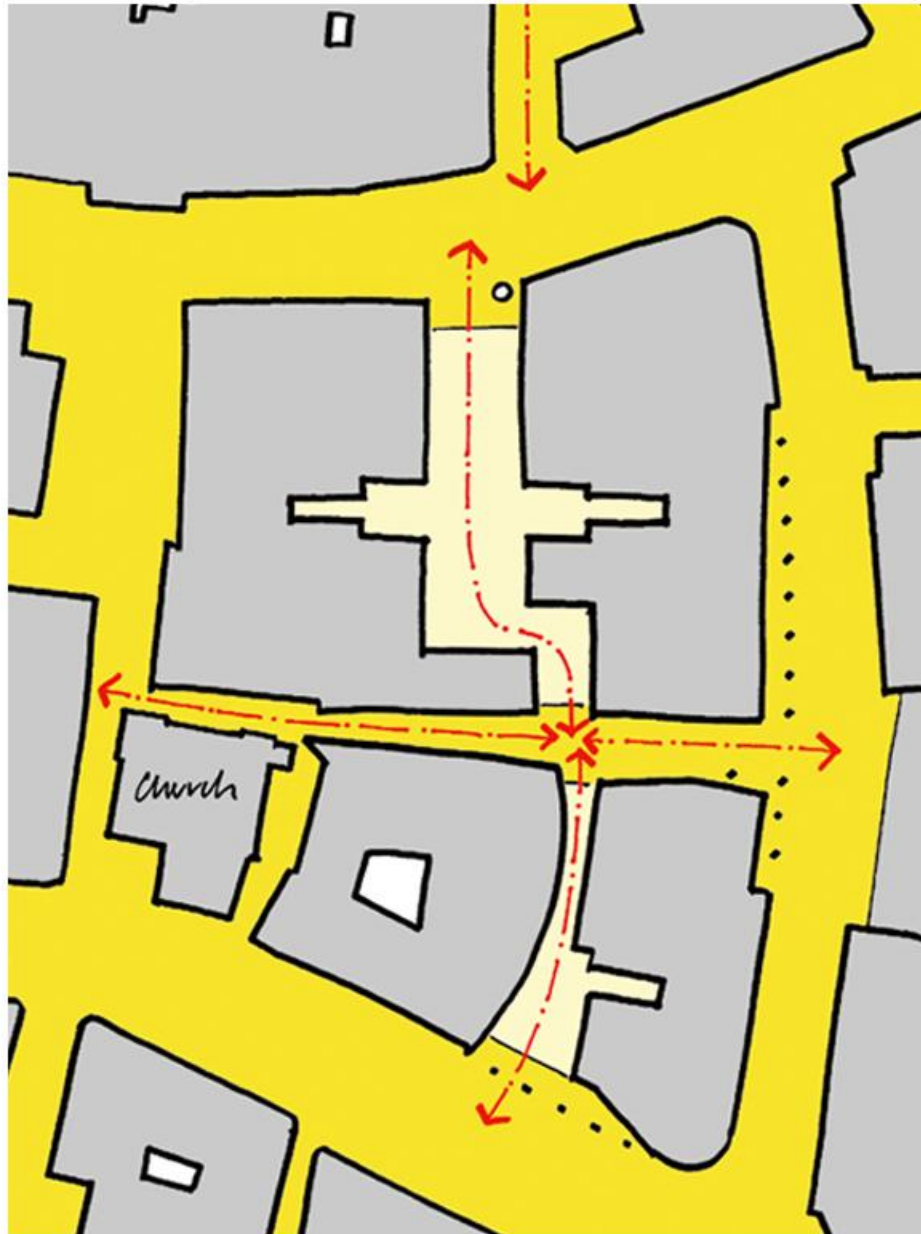
Arup Associates

Plantation Place:
An exemplar of the versatility of glass
in 21st Century architecture

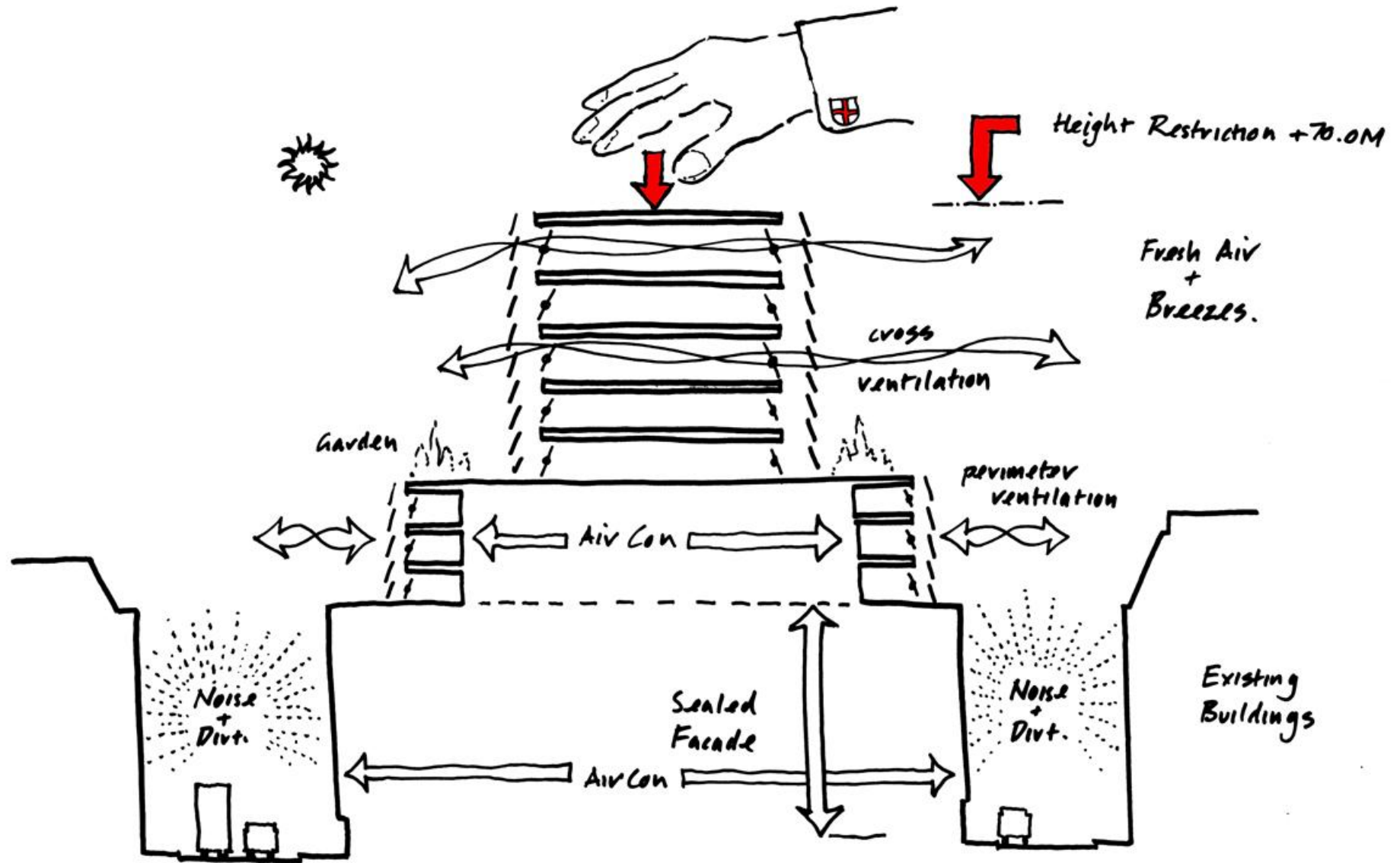
Plantation Place, London EC3



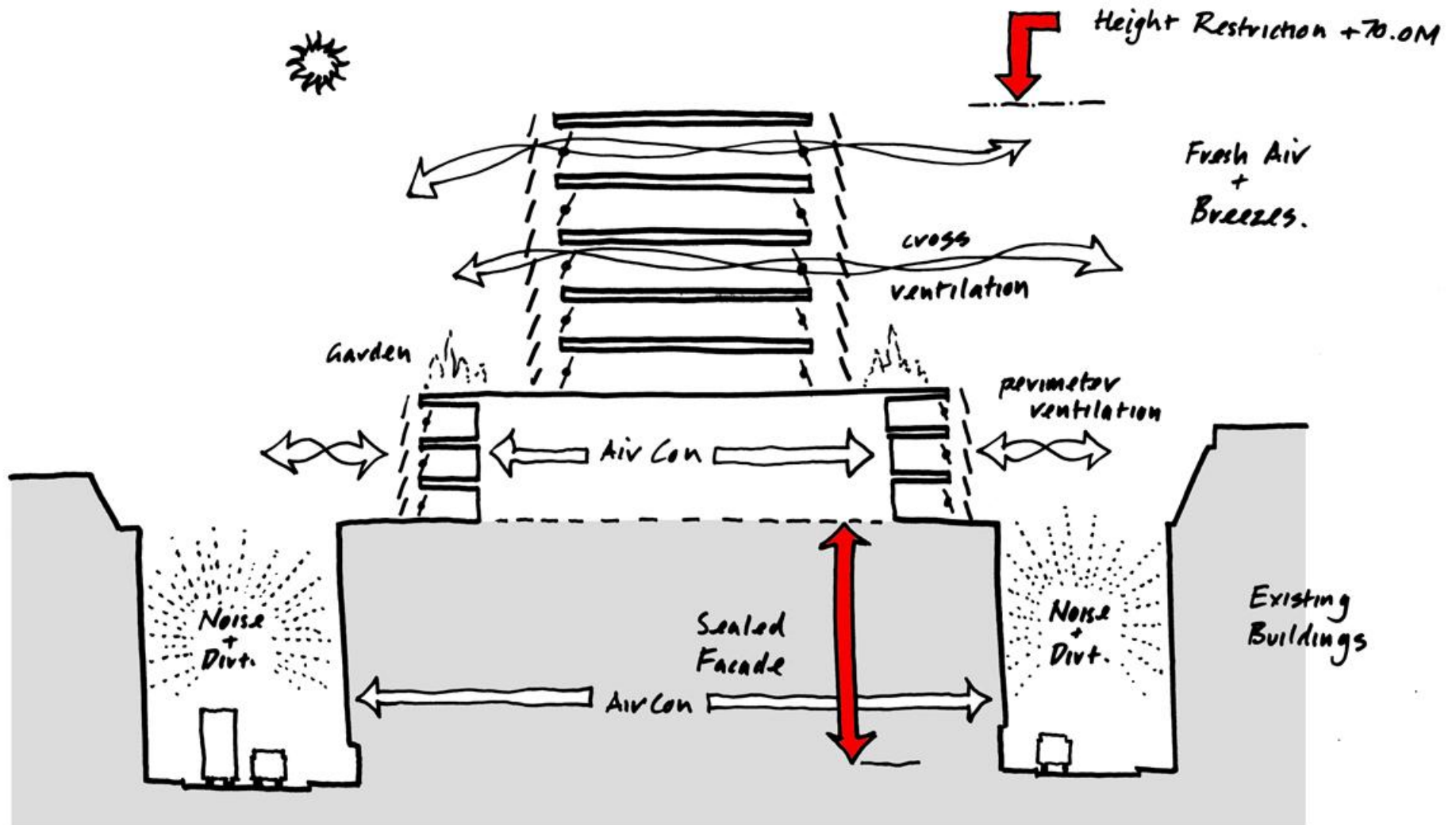
Plantation Place, London EC3



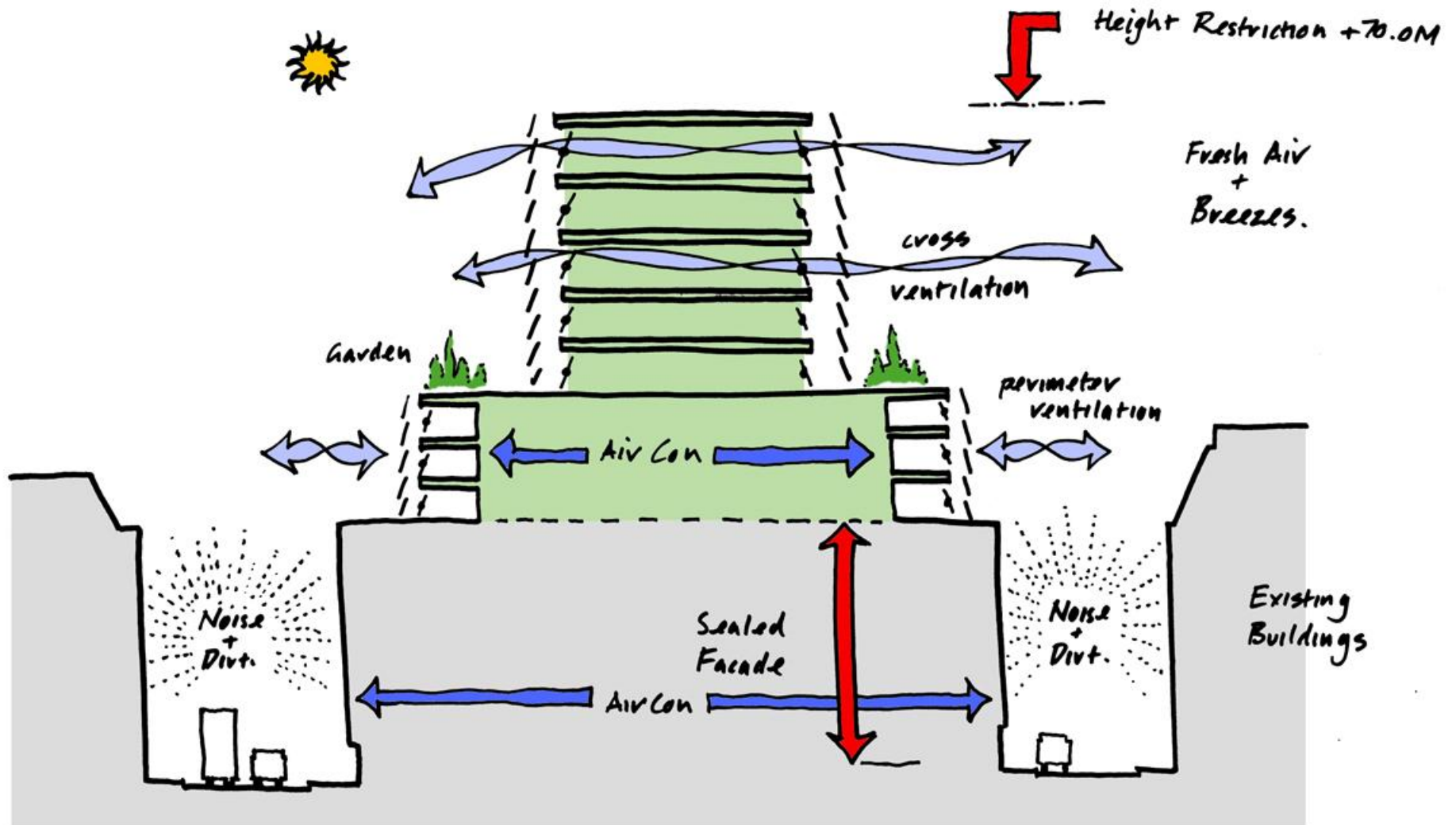
Massing



Massing



Massing

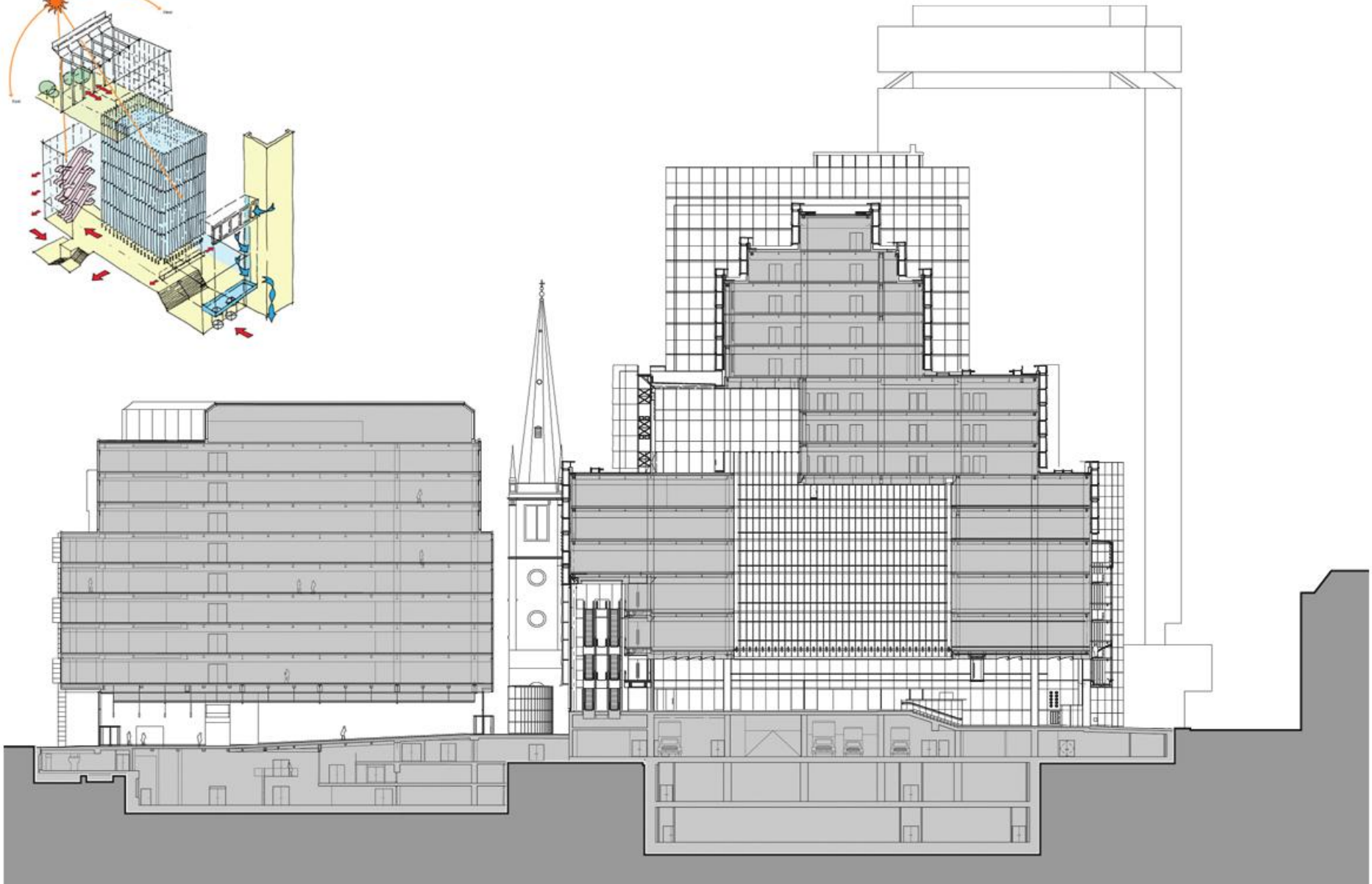
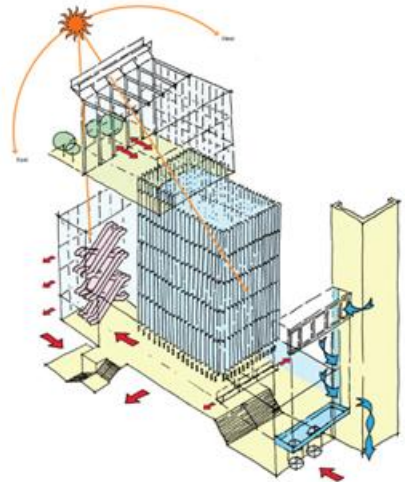


Plantation Place, London EC3



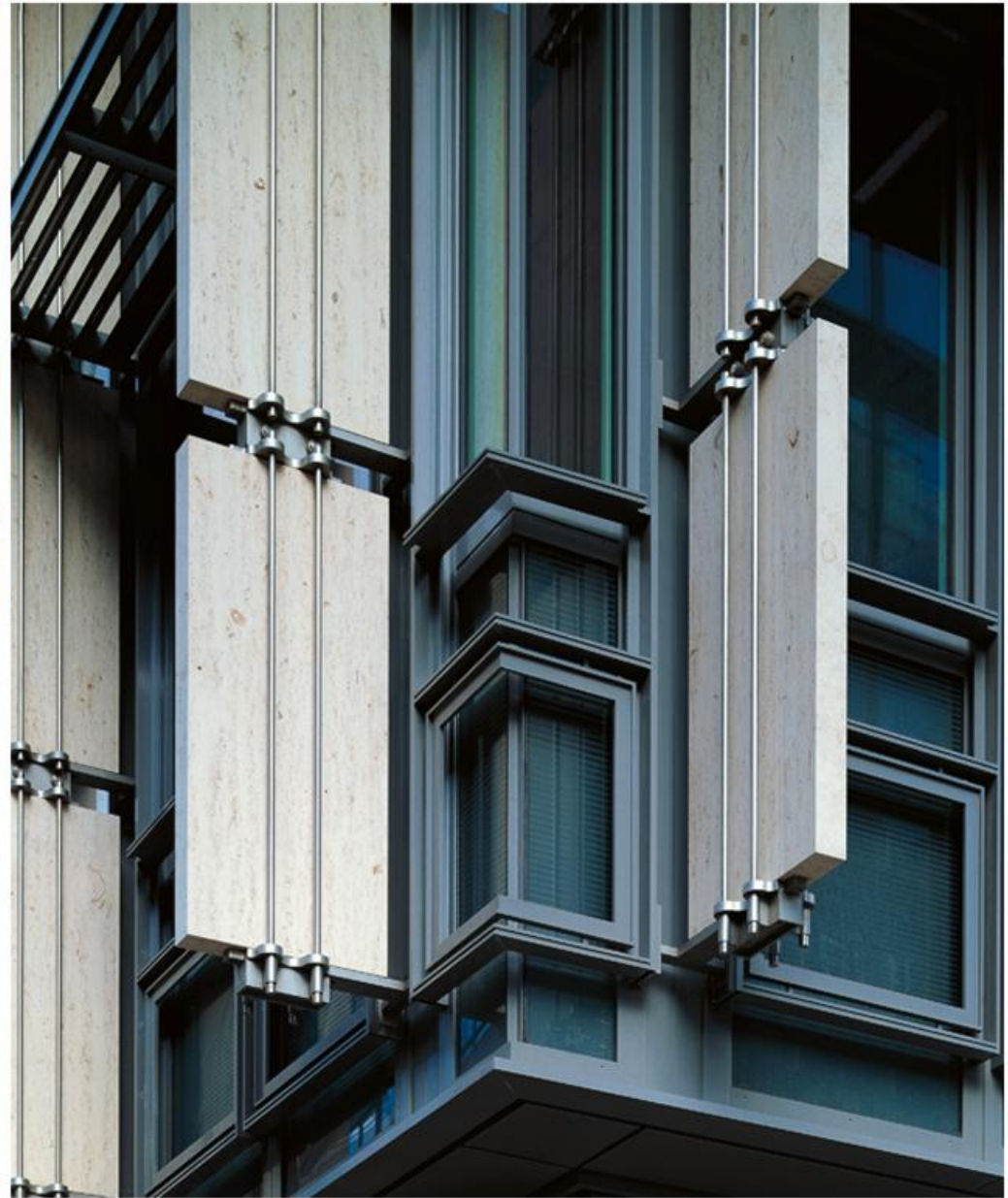
Arup Associates

Internal Anatomy



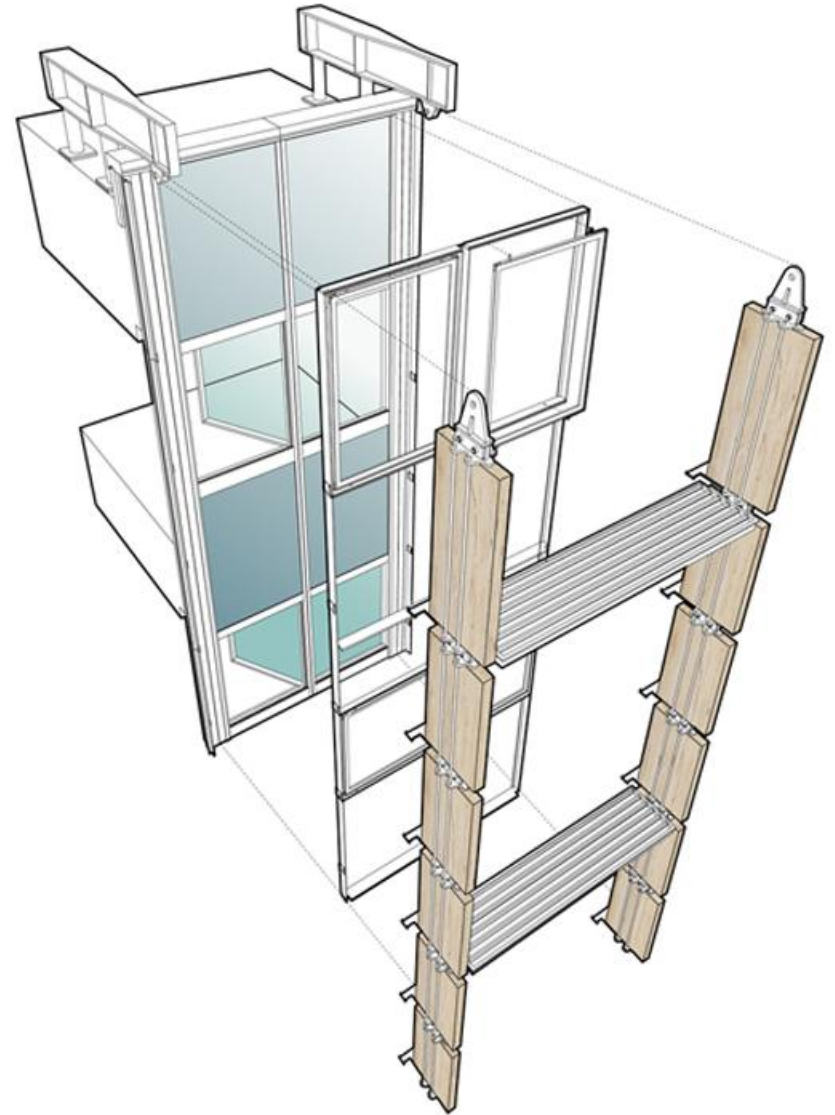
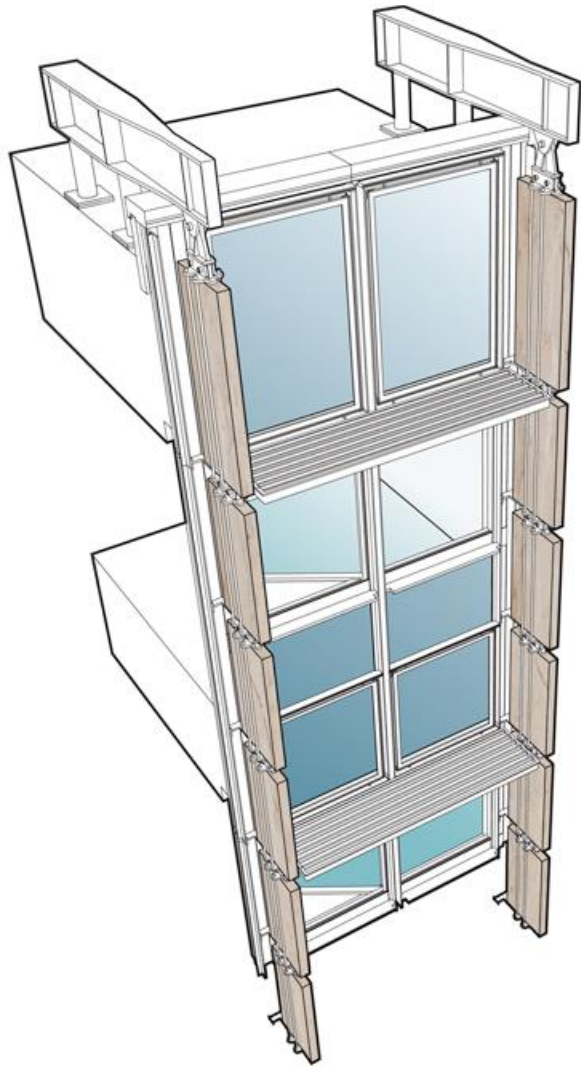


The Lower Levels



Arup Associates

Lower Levels cladding system



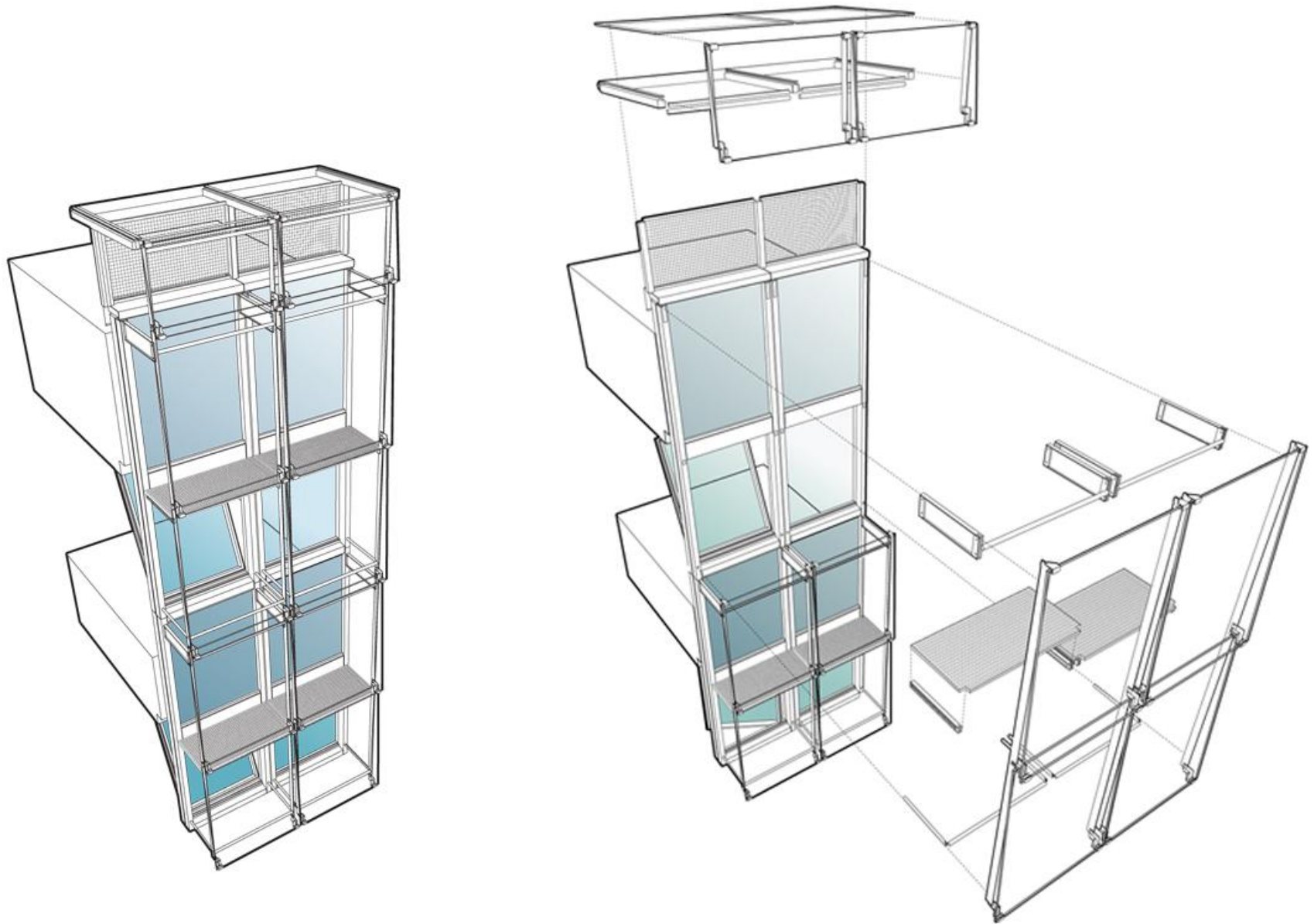
Lower Levels cladding system



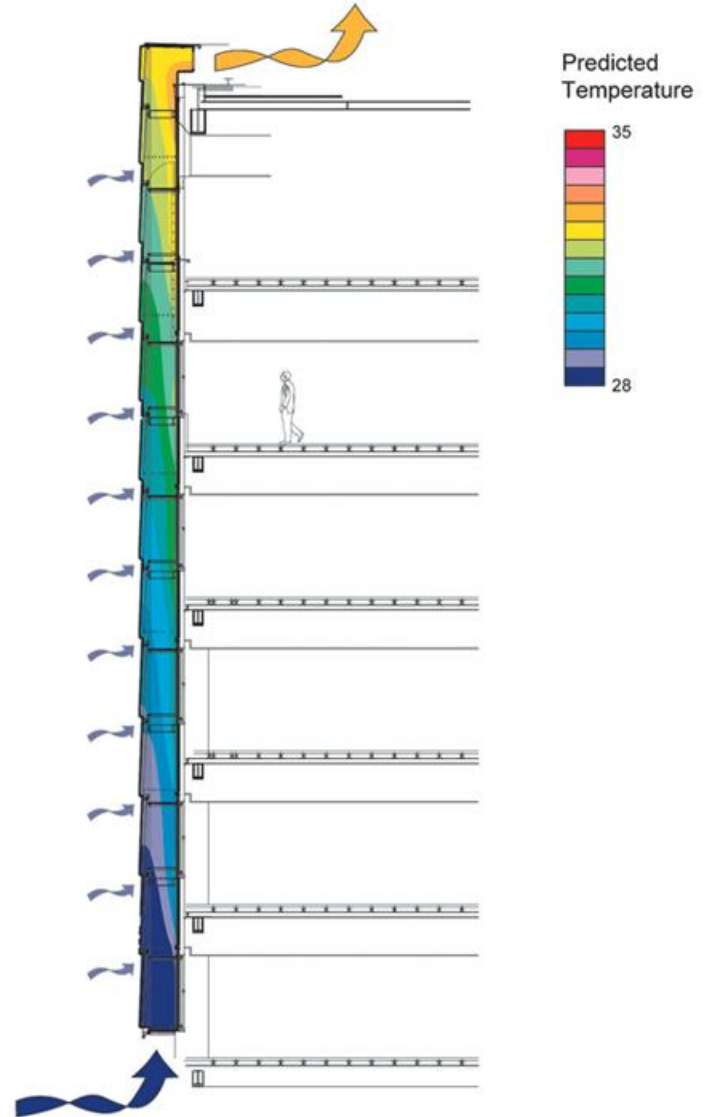
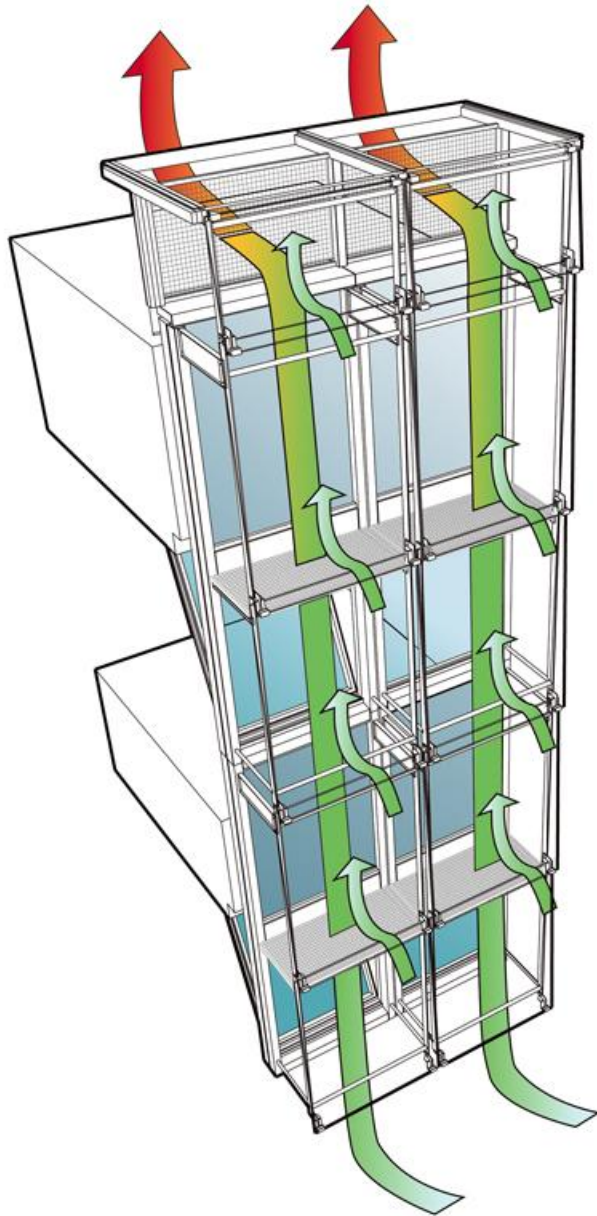
Upper Levels cladding system



Upper Levels cladding system



Upper Levels cladding system

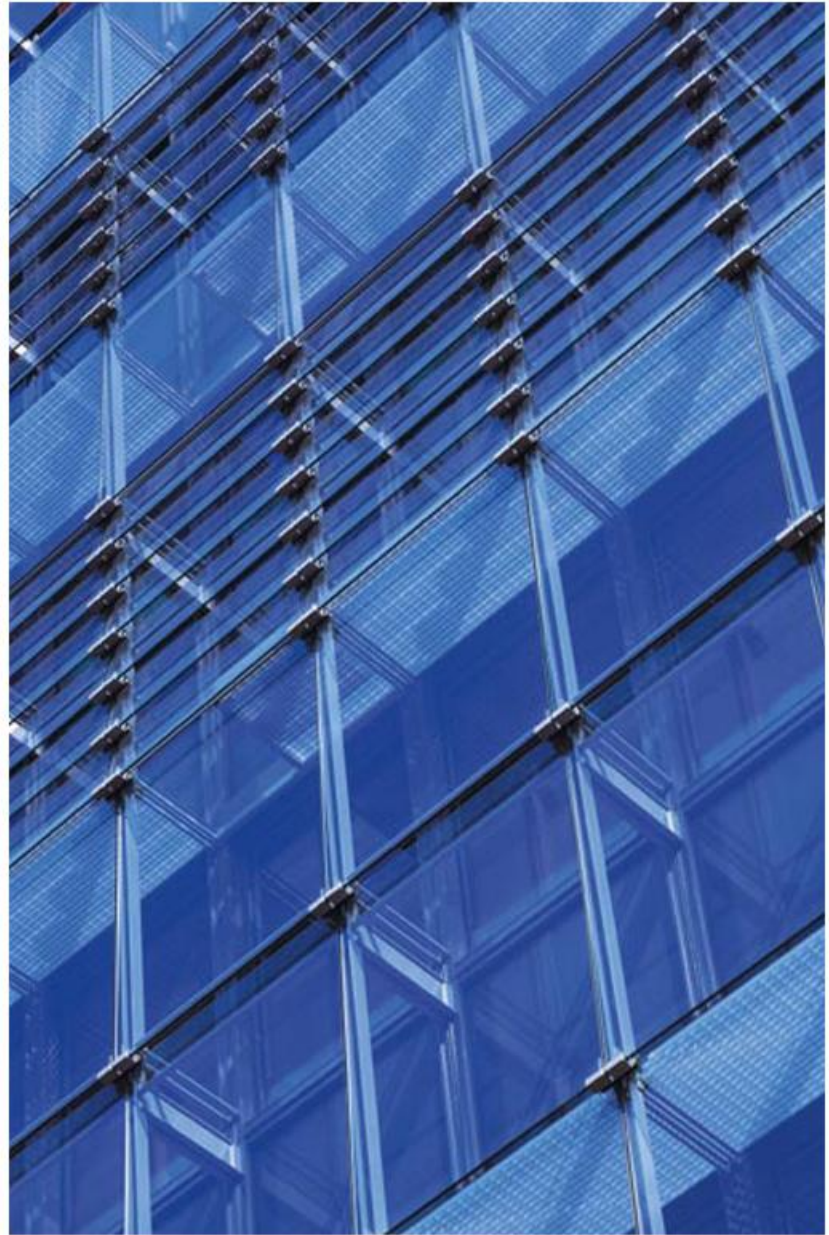


Computational Fluid Dynamics Study :
Upper cladding in hot summer

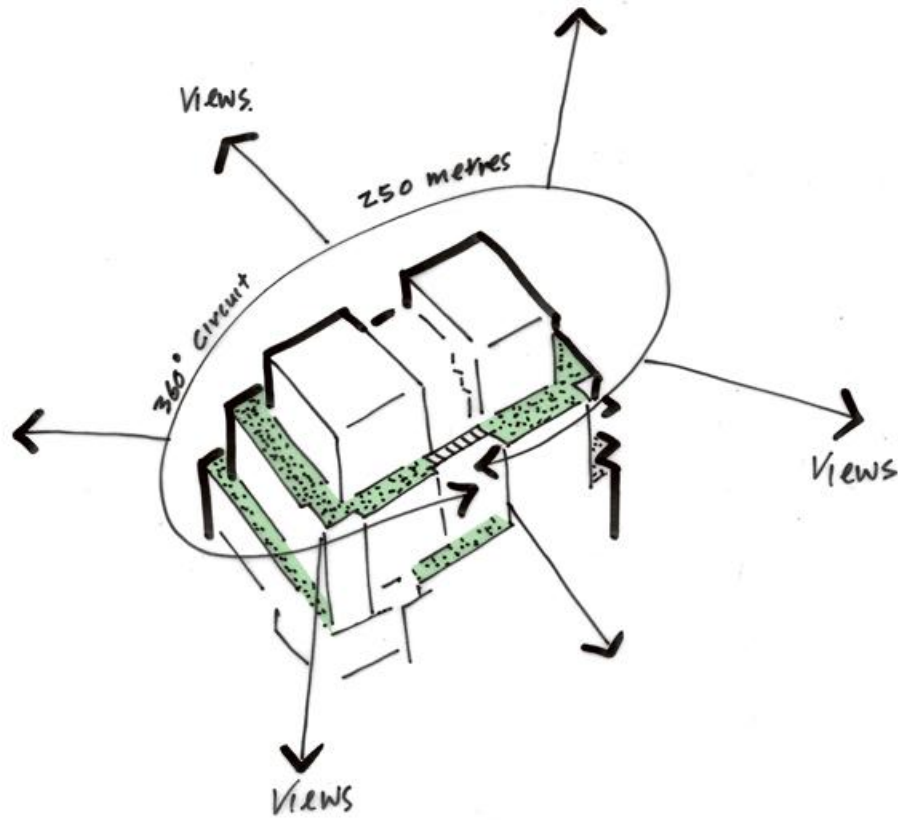
Upper Levels cladding system



Upper Levels cladding system

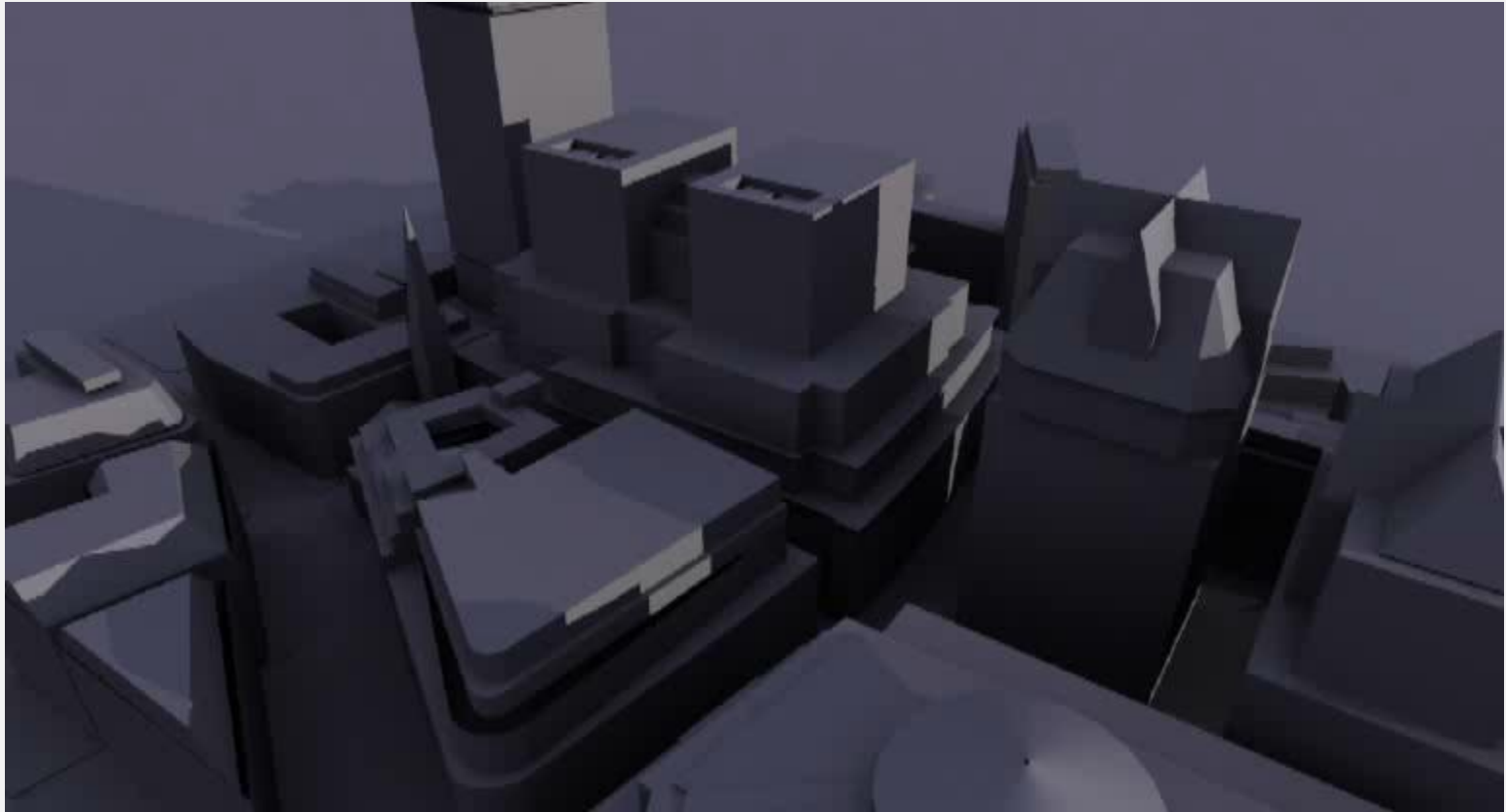


The Garden in the Sky

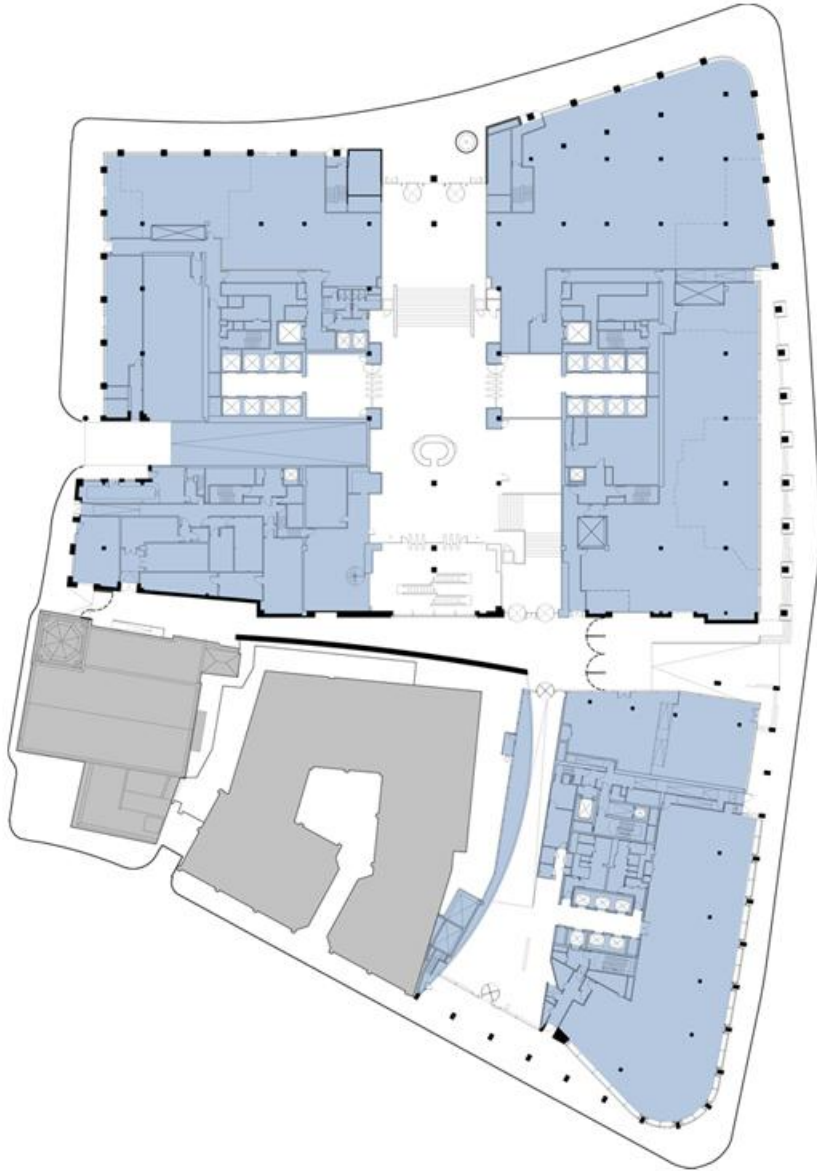


Upper Levels cladding system

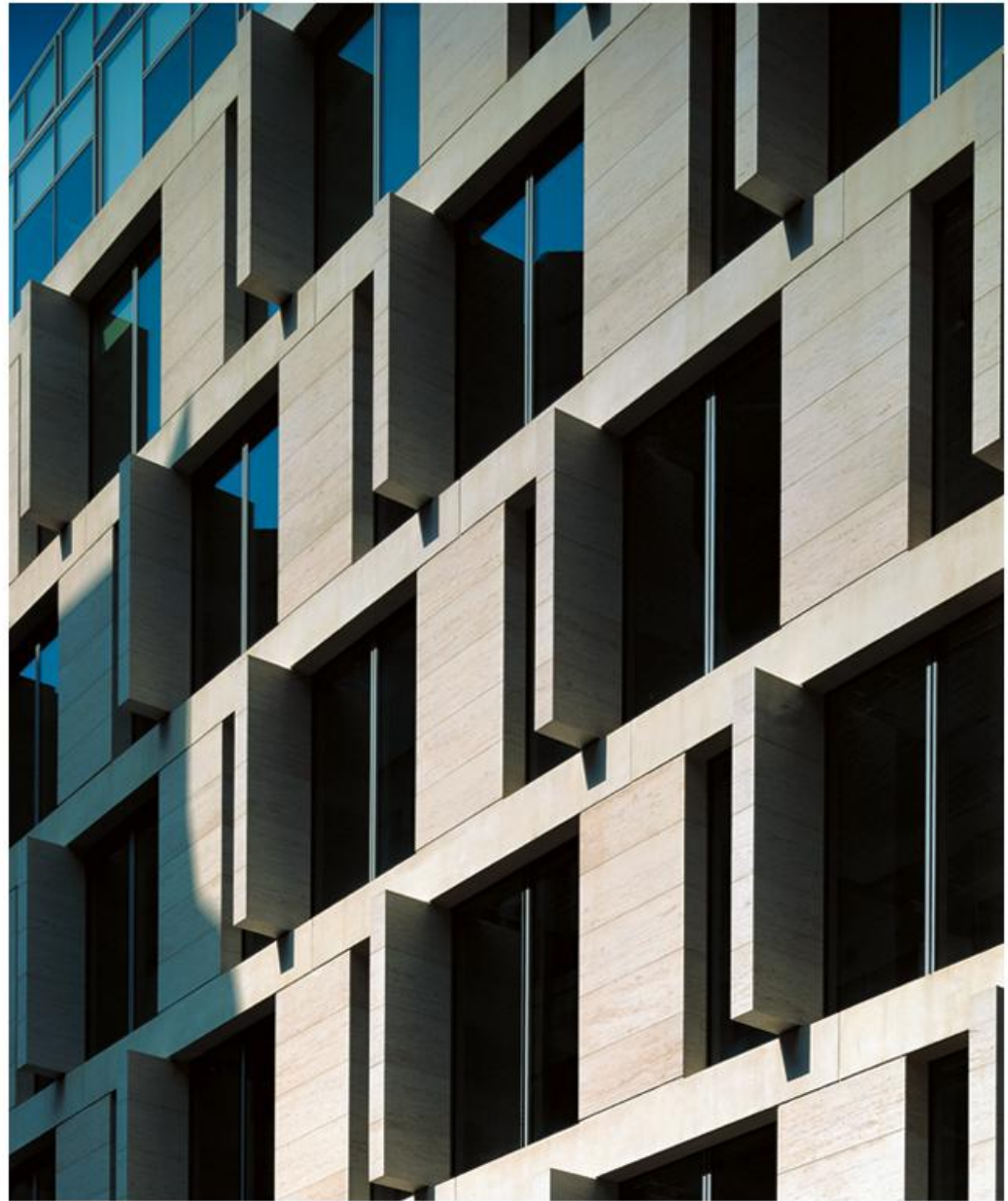
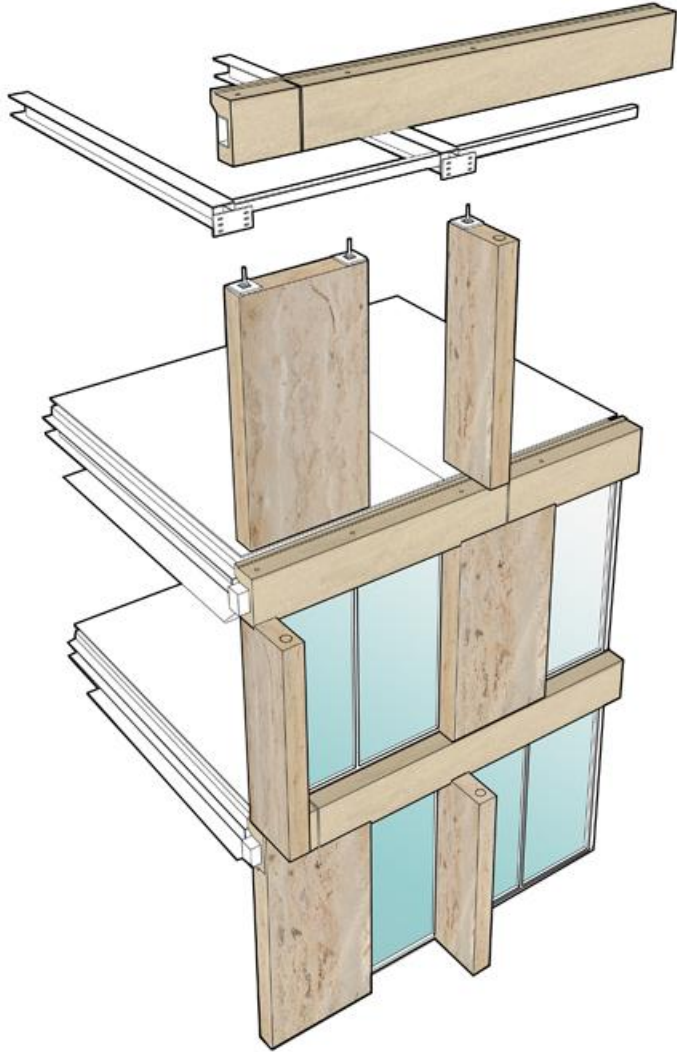




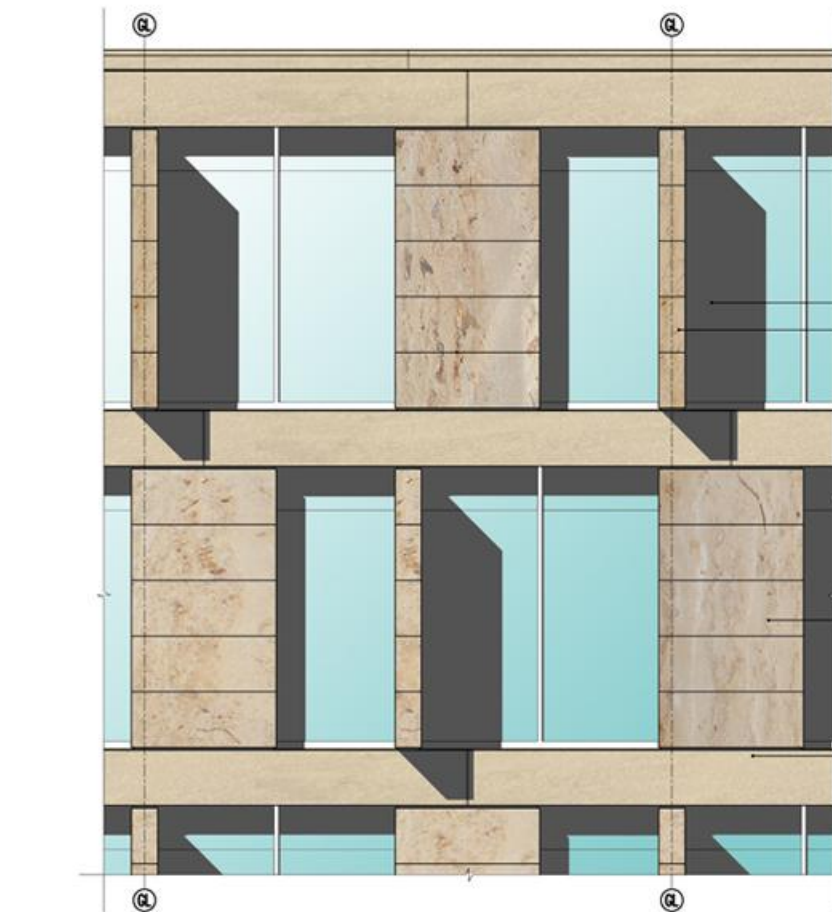
Plantation Place South



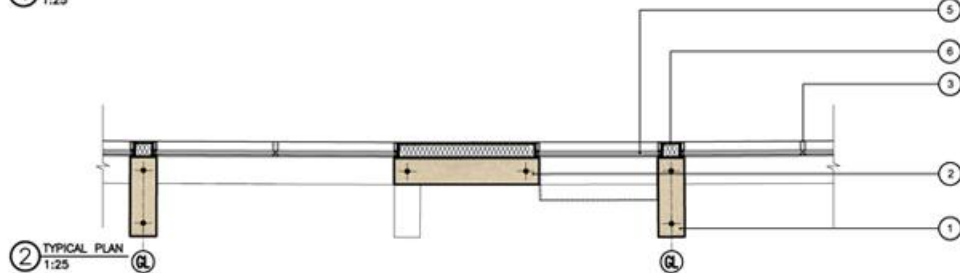
Plantation Place South



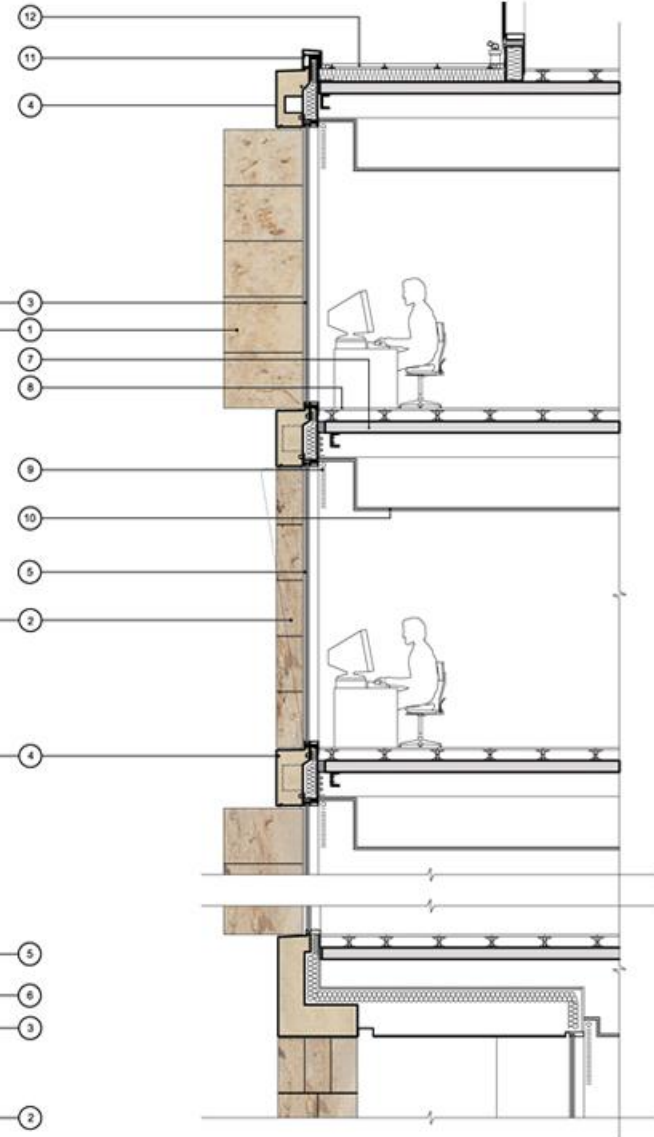
Plantation Place South



① TYPICAL ELEVATION
1:25



② TYPICAL PLAN
1:25



③ TYPICAL SECTION
1:25

- Materials Key
- ① Stone Panel: Jura Limestone
 - ② Stone Panel: Jura Limestone
 - ③ PPC aluminium framed DOU
 - ④ PPC aluminium framed DOU
 - ⑤ To open as smoke vent, Remountable Stone Spanel Unit
 - ⑥ Plasterboard on Rigid Insulation
 - ⑦ 100mm Concrete Floor Slab
 - ⑧ Ramped Floor
 - ⑨ Blind (Tenant Fit Out)
 - ⑩ Suspended Ceiling (Tenant Fit Out)
 - ⑪ PPC extruded aluminium coping to its reconstructed stone spandrel
 - ⑫ Precast Concrete Perimeter on Rigid Insulated Deck

Plantation Place South



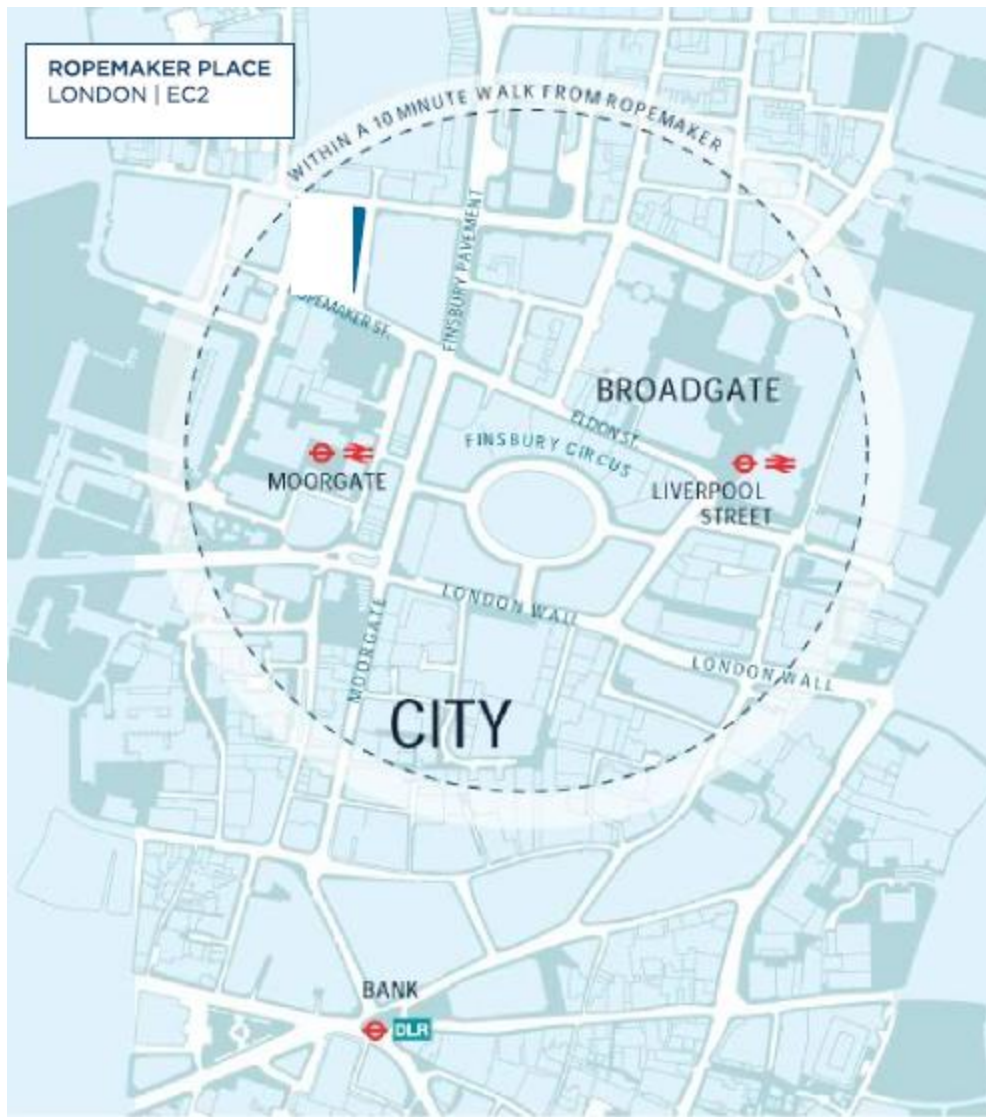
Arup Associates

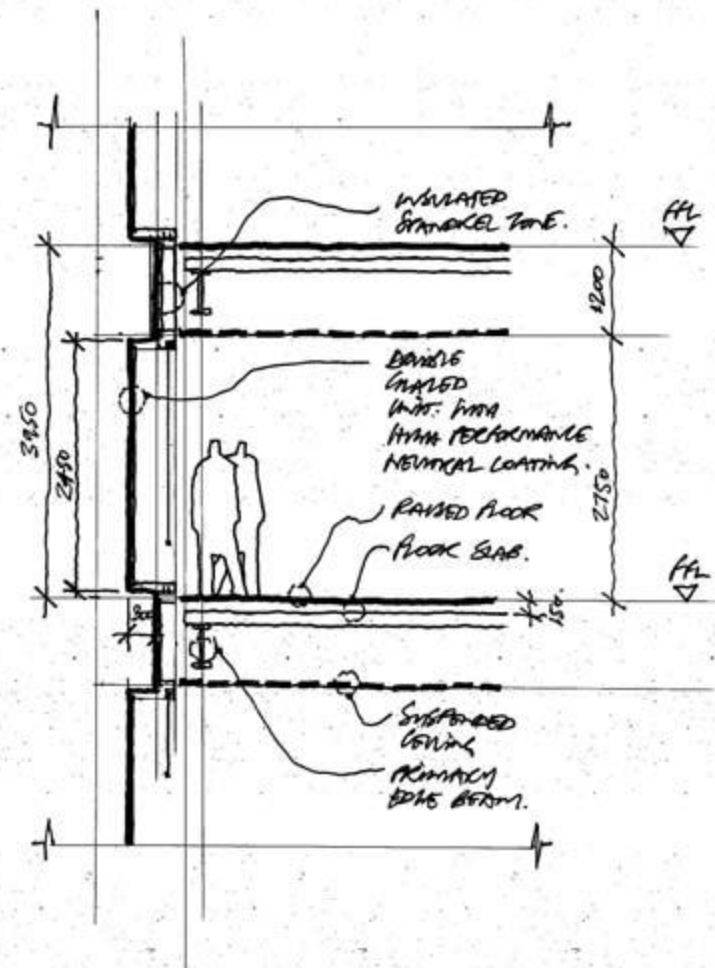
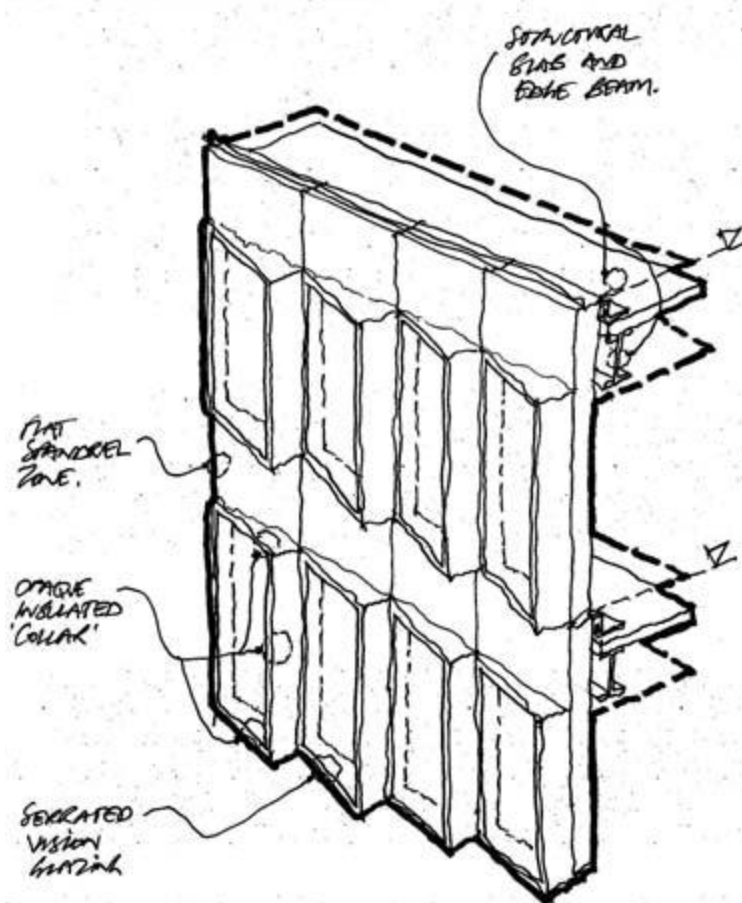


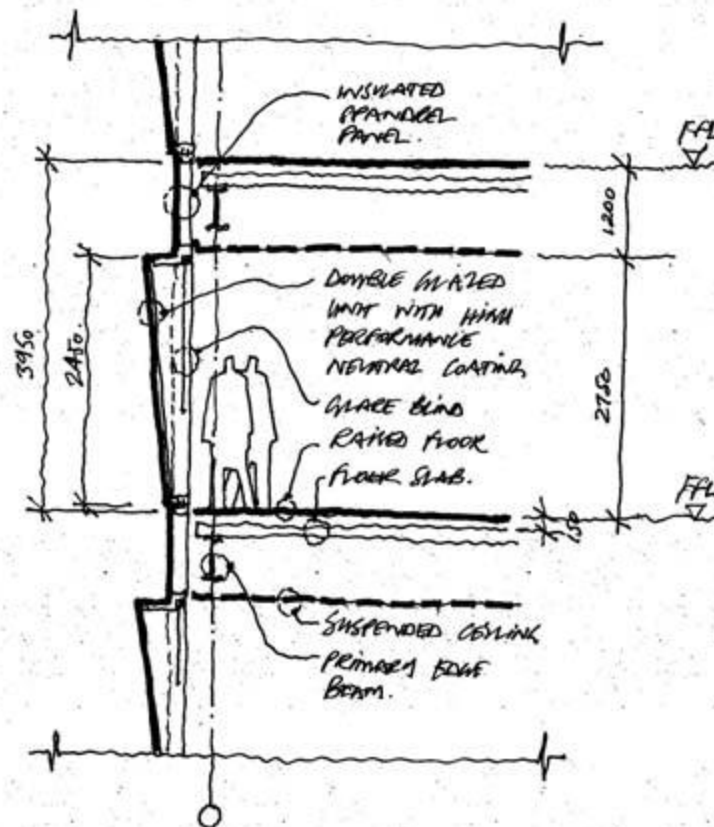
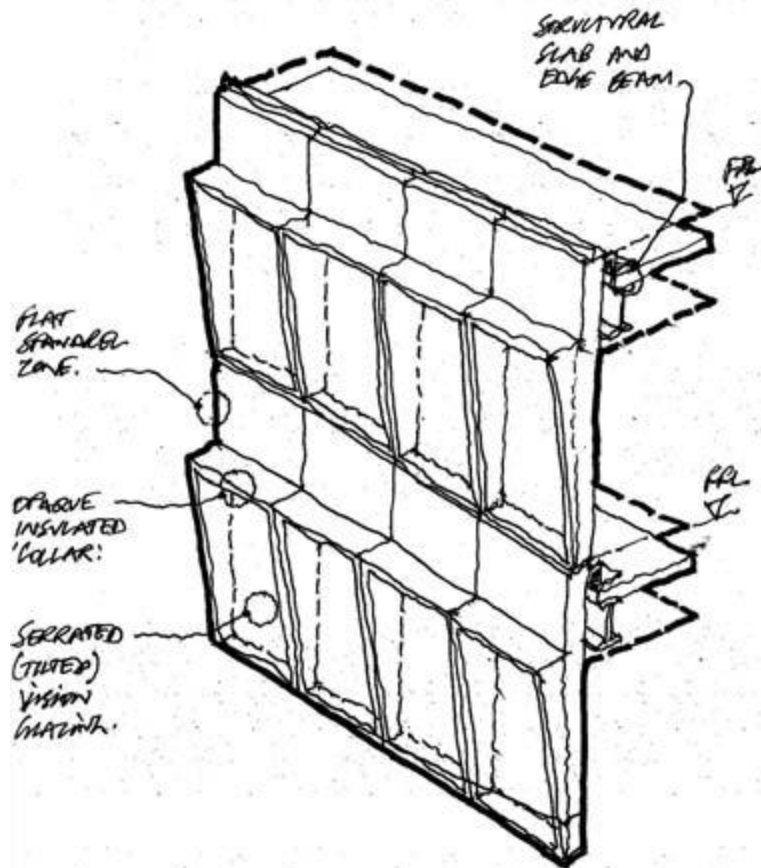
Ropemaker Place

Arup Associates

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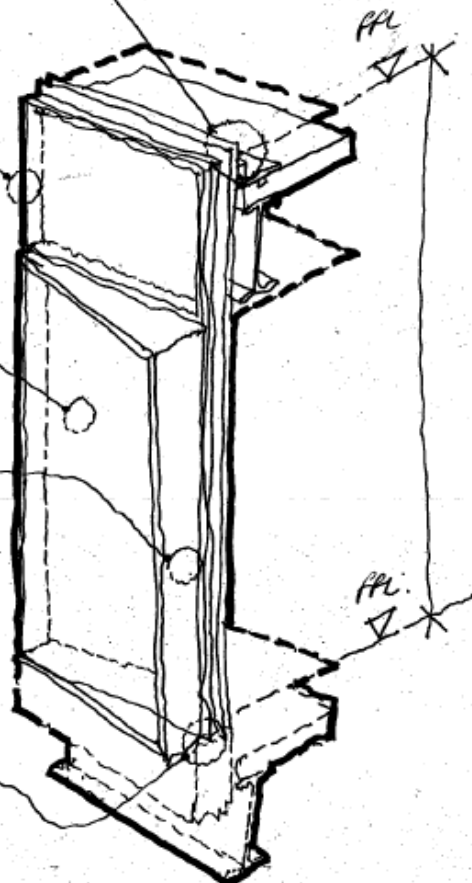
PANEL TO BE
DEAD LOAD SUPPORTED
AT HEAD OF PANEL
OFF SLAB EDGE

TYPICAL
STOREY-HEIGHT
UNITISED CLADDING
PANEL AT ~1.5m STOREY
HEIGHT.

PROJECTING WINDOW INTEGRATED
INTO UNITISED PANEL

INSULATED APL
ALUMINIUM 'COLLAR'
AROUND PROJECTING
WINDOW GLAZING.

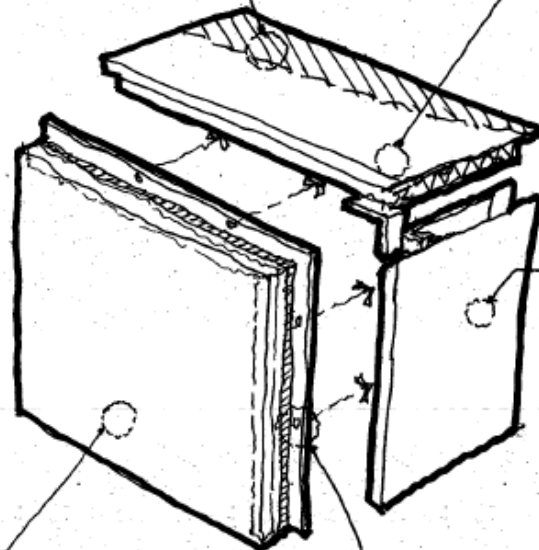
PANEL RESTRAINT
PROVIDED AT HORIZONTAL
JOINT BETWEEN ADJACENT
PANELS.



'COLLAR' TO BE
TRIMMED AT REAR
TO SUIT OVERALL
TILT OF PROJECTING
WINDOW GLASS.

THERMALLY
BROKEN
FRAME TO
FORM PROJECTING
COLLAR ALLOWING
GLAZING TO 'TILT'
RELATIVE TO
UNITISED FRAME.

VERTICAL EDGE
OF FRAME PROVIDES
STRUCTURAL
CAPACITY TO
SUPPORT GLAZING.



DOUBLE GLAZED
UNIT WITH STRUCTURALLY
BONDED CARRIER
FRAME TO BE GLUED
INTO 'COLLAR' FRAME.

CARRIER FRAME TO
BE MECHANICALLY
FIXED TO PROJECTING
'COLLAR'

Job Title
ROBINA KEX
PLC.

Drawing Title
EAST/WEST
SEPARATED CLADDING
TYPICAL PANEL.

Drawing Status
PROLIMINARY

ARUP

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London W1T 4SD
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Scales

Dim. 68 Date 07/06/06 66 Passed

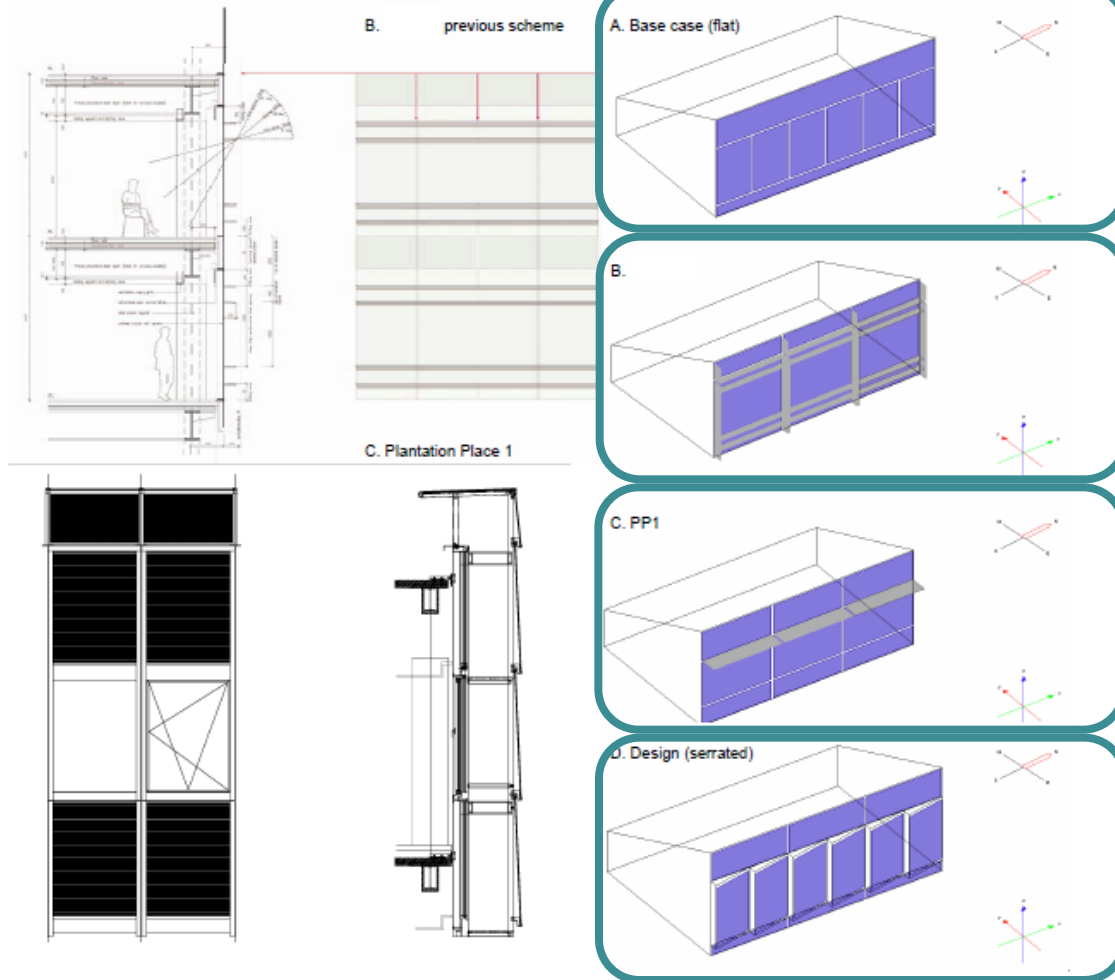
Job No.

39203-72

Drawing No.

SK-003

Rev.



Ropemaker Place **DRAFT**

Building Physics Report—Stage C Rev 02

The adjacent sketches show how the proposed geometry will increase the surface area of the building significantly. This increased surface area will result in more heat loss through the building envelope than with an equivalent flat building façade.

In order for the energy model to be able to compare the two scenarios of a flat façade and a serrated one, the serrated façade has been given an equivalent U-value for the flat projected area of the façade.

For simplicity and in order to facilitate comparison and further processing of the results, the increased transmission area of the proposed design has been translated into a corrected (or a 'projected') U-value in the plane of the façade. These performances are as follows:

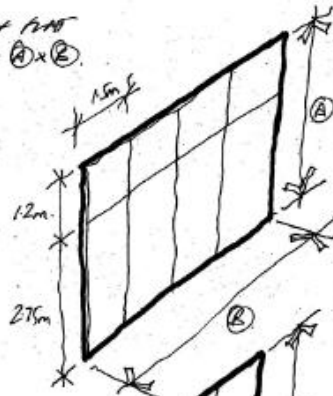
1. Flat Façade, Base Case $U_{cw,ref} = 1.7W/m^2K$
2. Serrated Façade, Design Target $U_{cw,design} = 2.0W/m^2K$

The target U-value is based on estimates of likely component performance and area weighting. Subsequent studies will focus on the detailing of the curtain wall and the target will be adjusted as required.

A description of the energy modelling carried out to date and the assumptions made to date follows on the next pages, along with our preliminary results which suggest significant reductions in the annual cooling energy load on the East, South and West elevations.

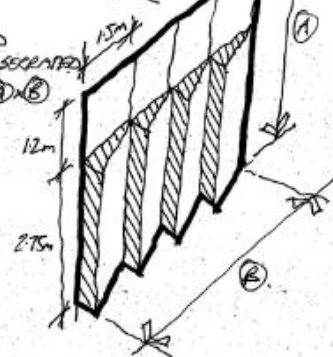
Comparative Façade Area for Energy Model

AREA OF FLAT
FAÇADE = (A) x (B)



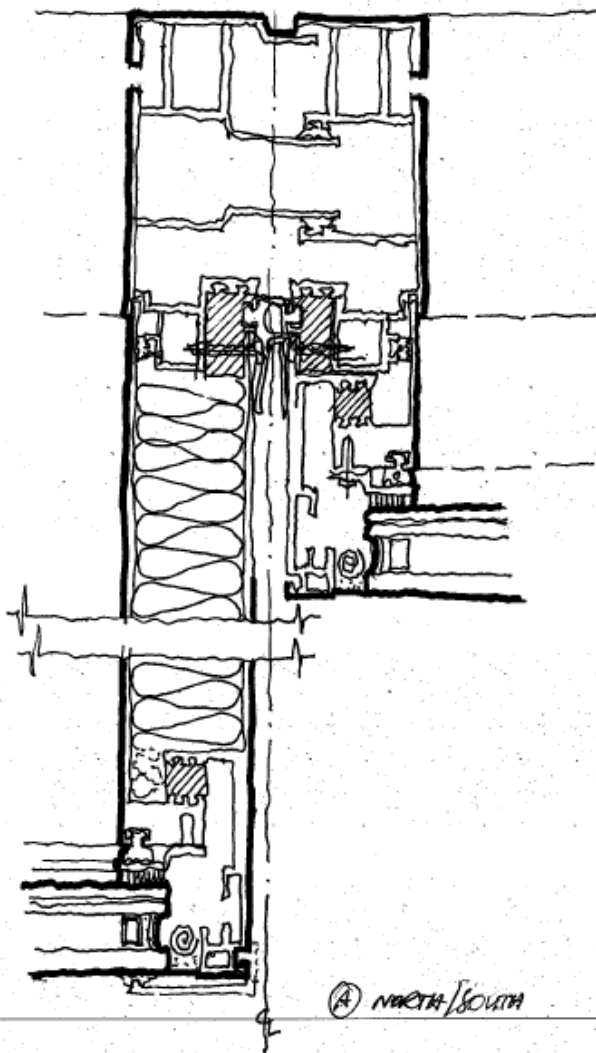
ASSUMED U-VALUE = $1.7W/m^2K$

* PROJECTED
AREA OF SERRATED
FAÇADE = (A) x (B)

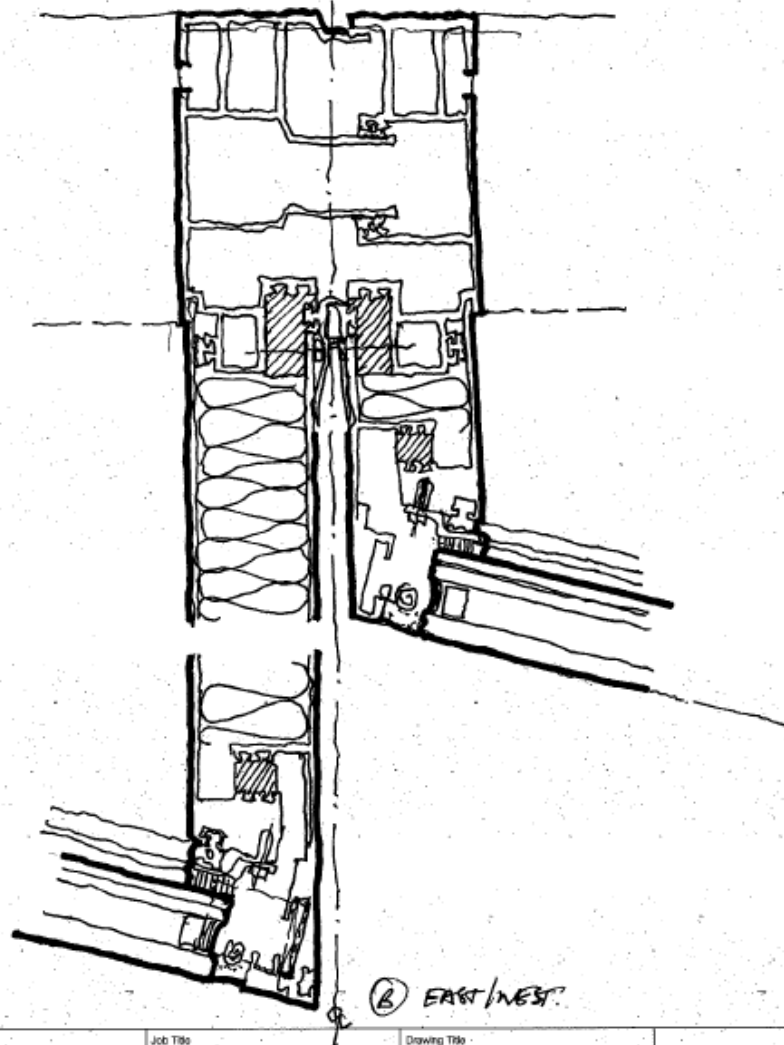


ASSUMED U-VALUE = $2.0W/m^2K$

* ACTUAL AREA OF SERRATED FAÇADE IS GREATER
THAN PROJECTED AREA. \Rightarrow U-VALUE FOR COMPARISON WILL BE WORSE THAN THE 'FLAT'



(A) NORTH/SOUTH



(B) EAST/WEST

Job Title

REPAIR/REPLACE
GLASS

Drawing Title

TYPICAL GLAZING
DETAILS THROUGH
ROBOTIC COLLAR ①

Drawing Status

PRELIMINARY

ARUP

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London EC2A 3BH
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F +44 (0)20 7190 1001

Scales

Dim. 8B Date 07/06 Chd 8B Passed

Job No.

39203-72

Drawing No.

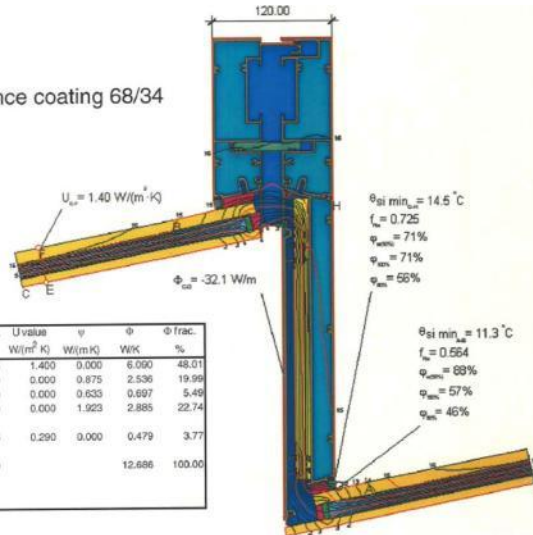
SK-005

Rev

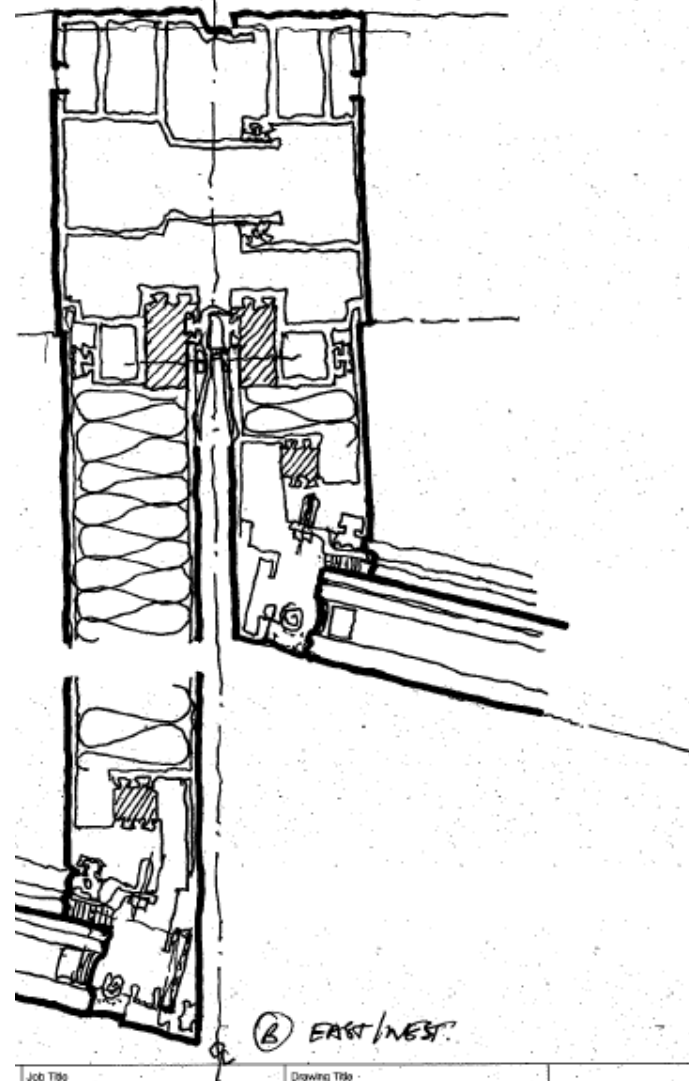
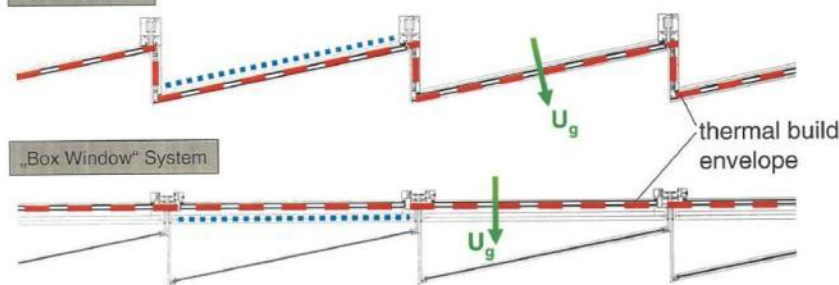
Basic assumptions

- $U_{\text{glass}} = 1.40 \text{ W/(m}^2\text{K)}$
- Air filled DGU, high performance coating 68/34
- Aluminium spacer tube

Section	Width m	Height m	Area m ²	Area frac. %	U value W/(m ² K)	ψ W/(mK)	Φ WK	Φ frac. %
Glazing	1.500	2.900	4.350	72.5	1.400	0.000	6.090	48.01
SD-0100	0.000	2.900	0.000	0.0	0.000	0.875	2.536	19.99
SD-0101	0.000	1.100	0.000	0.0	0.000	0.633	0.697	5.49
SD-0110	1.500	0.000	0.000	0.0	0.000	1.923	2.885	22.74
Panel/Shadow Box	1.500	1.100	1.650	27.5	0.290	0.000	0.479	3.77
Total			6.000	100.0			12.686	100.00
$U_{\text{CW}} \text{ value}^1$	2.11	W/(m ² K)						



Base System



Job Title ROPERMANEX PLATE	Drawing Title TYPICAL GLAZING DETAILS THROUGH PROJECTING COLLAR ①	ARUP <small>13 Finsbury Street London EC2A 1BB T +44 (0)20 7580 1500 F +44 (0)20 7580 3500</small>	
Scales		Dim. SB Date 07/12 Chk. SB Passed Drawing Status PRELIMINARY	
Job No. 39203-72		Drawing No. SK-005	Rev.

Ropemaker Place **DRAFT**

Building Physics Report—Stage C Rev 02

The adjacent diagrams illustrate the operational profiles assumed in the energy model for all of the three scenarios.

The basic assumptions can be summarised as follows.

1 The SBEM Standard scenario

Weather file: CIBSE London TRY 2006
Occupancy: 9m²/person
Lighting: 18.75W/m²
Equipment / small power: 15W/m²
Heating set point: 22°C
Cooling set point: 24°C
Infiltration: 0.15ac/h
Ventilation: 8l/s/person
Perimeter zone: 6.0m

2 The Client's Brief scenario

Weather file: CIBSE London TRY 2006
Occupancy: 10m²/person
Lighting: 12W/m²
Equipment / small power: 25W/m²
Heating set point: 21°C
Cooling set point: 22°C
Infiltration: 0.15ac/h
Ventilation: 16l/s/person
Perimeter zone: 4.5m

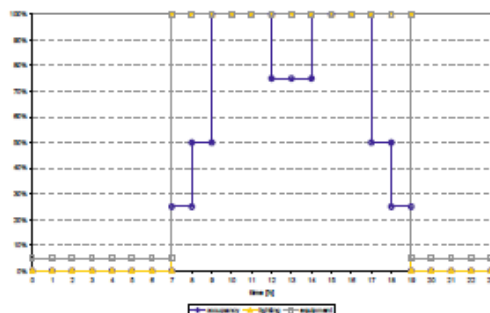
3 The Low Energy Tenant scenario

Weather file: CIBSE London TRY 2006
Occupancy: 9m²/person
Lighting: 8W/m²
Equipment / small power: 7.5W/m²
Heating set point: 22°C
Cooling set point: 24°C
Infiltration: 0.15ac/h
Ventilation: 8l/s/person
Perimeter zone: 4.5m

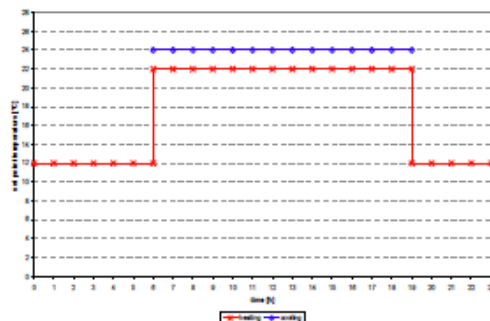
Limited cooling capacity: 89W/m² (assumed)

Energy Study — Assumptions

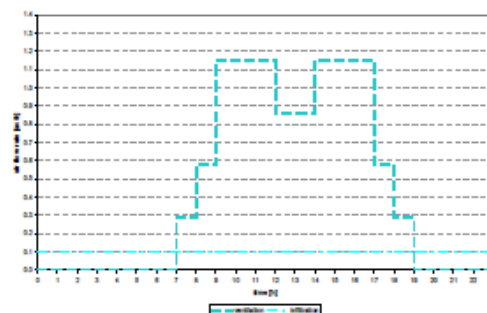
Profile 1 : Daily profile (weekdays) for internal gains



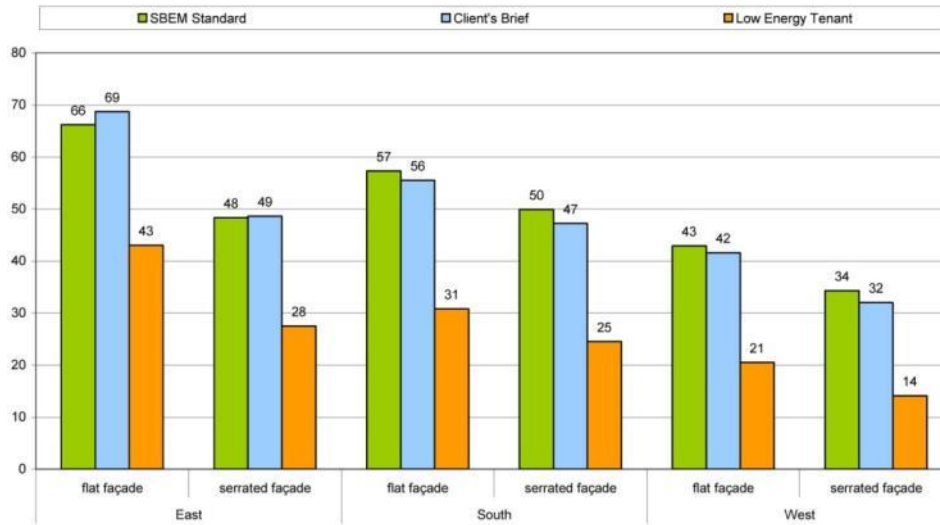
Profile 2 : Daily profile (weekdays) for Heating and Cooling Operation



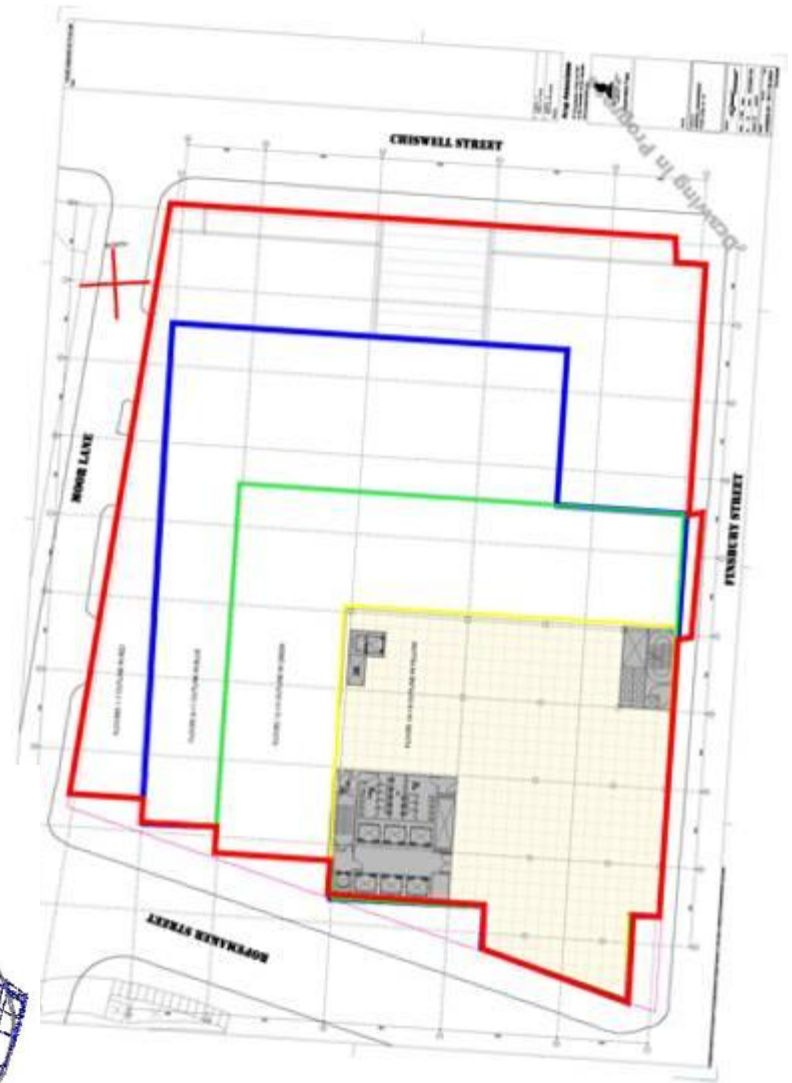
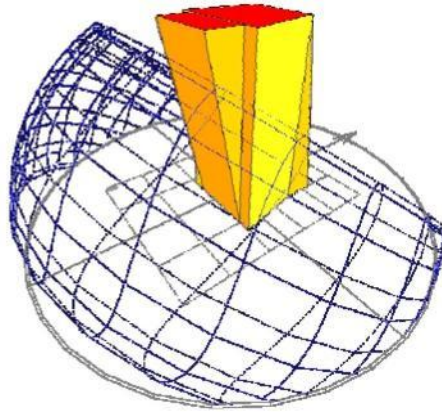
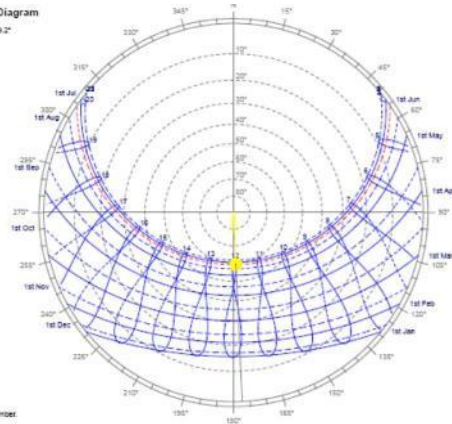
Profile 3 : Daily profile (weekdays) for Ventilation and Infiltration (SBEM Standard Scenario)

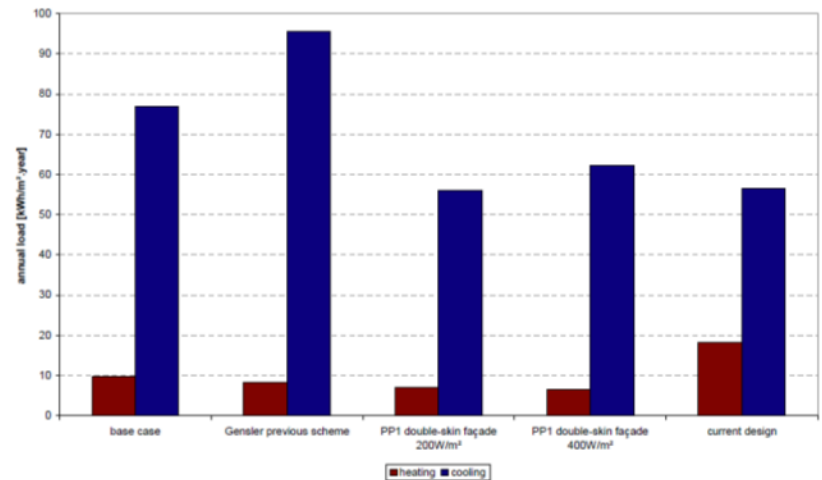
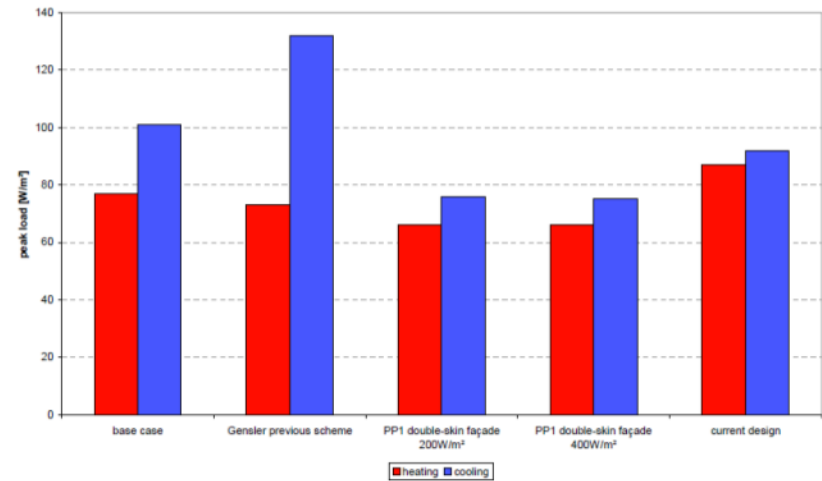
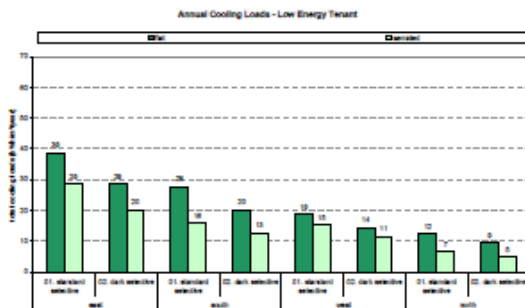
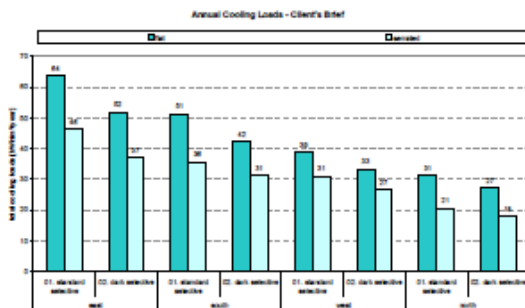
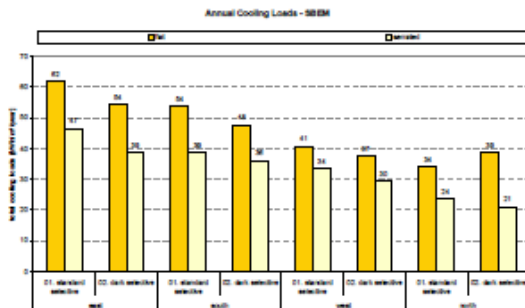


Cooling Loads



Stereographic Diagram
Location: 51° 41' 52"
Sun Position: 177.4°, 59.2°
NSM: 177.4°
NSA: 125.3°





Ropemaker

Our new development at Ropemaker, London EC2, has been designed to provide an attractive and sustainable building for occupiers, meeting their needs today and tomorrow.

With planning approved in April 2007, the 20 storey building will provide 593,000 sq ft (55,000m²) of office and retail space, including two trading floors of 42,500 sq ft (4,000m²).

It has been designed by Arup Associates for a range of occupiers and construction has begun with completion scheduled for mid 2009.

15% lower CO₂

Ropemaker is on target to achieve 15% lower predicted carbon emissions than set out in the Building Regulations.

BREEAM

The development is expected to achieve an 'Excellent' BREEAM rating. BREEAM is the most widely used environmental assessment method for buildings. For more information visit: www.breem.org

50% green roof

We are designating 50% of the available roof space as green roof. The green roof area will be partially covered with plants and soil over a waterproofing membrane to enhance biodiversity.



All energy used for heating water and space will come from renewable sources, generating enough power to run 7,000 washing machine cycles.



All wood will come from sustainably managed sources.



We will be collecting and re-using rainwater to reduce mains water usage, saving enough water each year to fill 10,000 bath tubs.



Materials from demolition have been used to form temporary works to construct the building.



30 local students have been given tours of the site, raising awareness of career opportunities within the construction industry.



Developing sustainable buildings

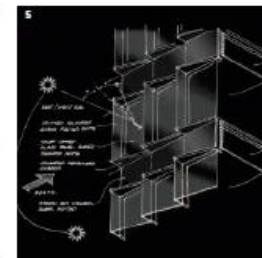
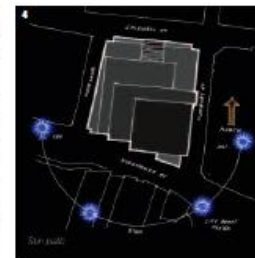
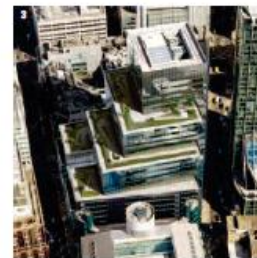
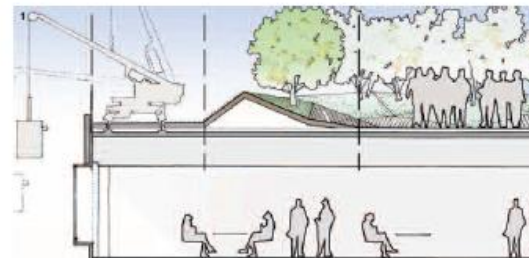
"We aim to lead the market in developing and managing buildings in a sustainable manner. By financing, developing and managing properties that responsibly utilise energy, water and waste, we conserve the world's resources and can also reduce our costs and those of our occupiers."

Stephen Hester Chief Executive

Since 2004 we have been working with our employees, consultants and contractors to implement the British Land Sustainability Brief on all our developments, including Ropemaker.

This Brief aims to ensure that our projects are designed and constructed sustainably, by establishing appropriate objectives and targets, defining the processes, standards, guidance and responsibilities for each stage and raising awareness of environmental issues and opportunities.

In 2006 we revised and improved the Brief following an independent review. We also developed a Sustainability Brief for Refurbishments and a Sustainability Guide for Acquisitions. You can download these documents from www.britishland.com/downloads



British Land's Ropemaker development incorporates a wide range of sustainability measures. These will enable occupiers to reduce energy and water use, cut down waste, decrease carbon emissions and lower associated costs.

Managing energy

Double glazed tilting facades will reduce the energy required for cooling by up to 27% compared to a flat facade. The facades are designed to allow occupiers to install low energy cooling systems and there will be fixed external shading for areas of vertical glazing to the south eastern facade. Air conditioning systems will use free cooling for as much of the year as possible and surplus heat generated by IT equipment, lights and occupiers will be recovered and reused. Associated carbon emissions will be reduced by a further 10% because all energy used for heating water and space will come from renewable sources, equivalent to 20% of the annual energy consumption.

Managing water use

Introducing water saving measures and harvesting rainwater will reduce mains water requirements and minimise Ropemaker's impact on local drainage systems. Mains water usage will be monitored through meters linked to the Building Management System. Rainwater will be collected and re-used to flush WCs.

Managing waste

Managing waste responsibly will help to safeguard the world's valuable resources and reduce the costs of transport, materials and disposal. Materials from demolition have been retained to form temporary works to construct the development and the existing buttress walls will be used to build the larger basement area. A target 15% of materials by value will have recycled or re-used content. There will also be large waste recycling accommodation to sort and store waste generated in offices.

Sustainable travel

Encouraging occupiers and visitors to use public transport and bicycles will reduce car use and associated emissions. Ropemaker is located close to excellent public transport links, including Moorgate and Liverpool Street stations. The development will also feature 270 secure, internal cycle spaces with high quality locker and shower facilities.

Enhancing biodiversity

Enhancing the local ecosystem at Ropemaker will add to its attractiveness as a place in which to do business. Designating 50% of the available roof space as green roof will enhance biodiversity, provide an attractive area for occupiers and improve the appearance of the building.

- 1 A cross section of one of the green roofs, showing garden terrace, green landscaping, eco-zones and amenities.
- 2 An artist's impression of one of the green roofs.
- 3 An aerial view showing the green roofs and the photovoltaic and solar panels.
- 4 A sketch showing how the orientation of Ropemaker helps to maximise solar control.
- 5 A sketch of the double glazed tilting facades that will reduce the energy required for cooling.

The development of Ropemaker is informed by guidance and best practice from sources including Arup, BREEAM, Islington Borough Council and the Mayor of London, as well as a range of British Land policies and plans.

British Land has a carefully timed 2.6 million sq ft (241,500m²) office development pipeline coming to fruition between now and 2011. Other developments include: 201 Bishopsgate and The Broadgate Tower (EC2), The Leadenhall Building (EC3), and Regent's Place (NW1).

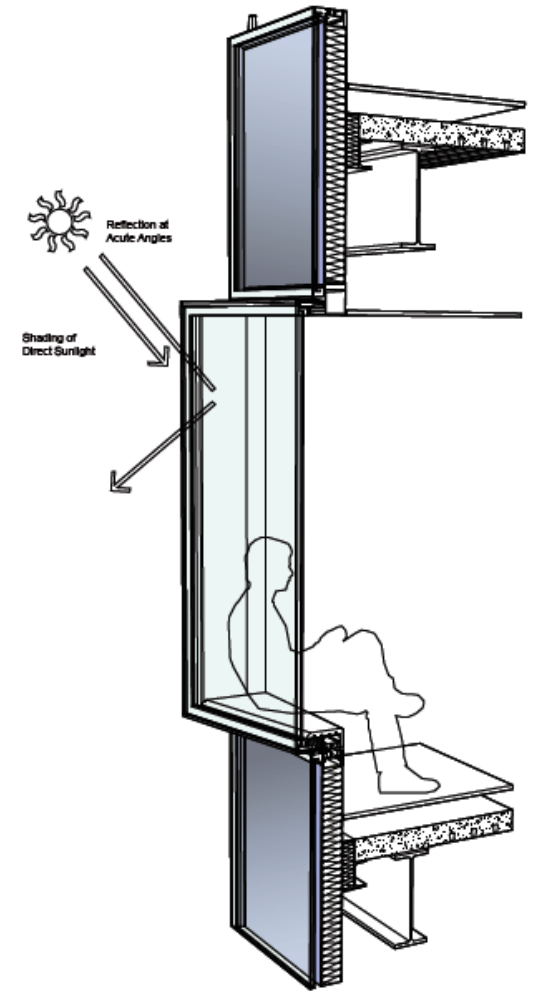
Printed on Flesch uncoated paper manufactured from 100% de-inked post consumer waste. Printed to ISO 14001 standards by Synergy using their environmental management system. The printing process uses vegetable based ink. No film or film processing chemicals were used. All electricity is supplied from renewable sources.

Arup Associates



ROPEMAKER FACADE

Arup Associates



Arup Associates

ARUP

Arup Associates





innovation example

ARUP



““He who innovates will have for his enemies all those who are well off under the existing order of things, and only lukewarm supporters in those who might be better off under the new.”

Niccolo Macchiavelli (adapted from Gordon Graham, 2008)



The Integrated Building Envelope

www.IntegratedBuildingEnvelope.com

BYGGERIETS/INNOVATION

BUILDING LAB DK



Innovation

- Curtain Walling
- Pultruded GFRP
- Consortium



Consortium

Arup

Permasteelisa

Fiberline

Art Andersen

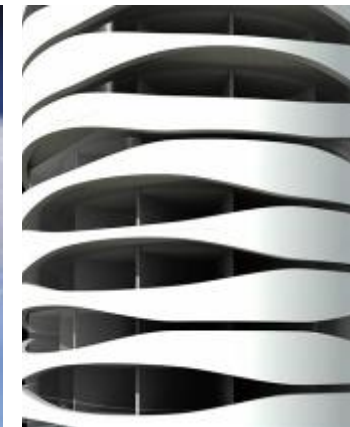
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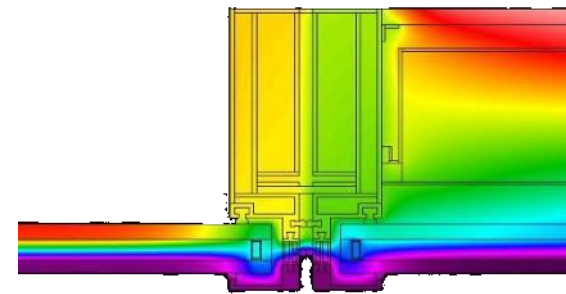
Make

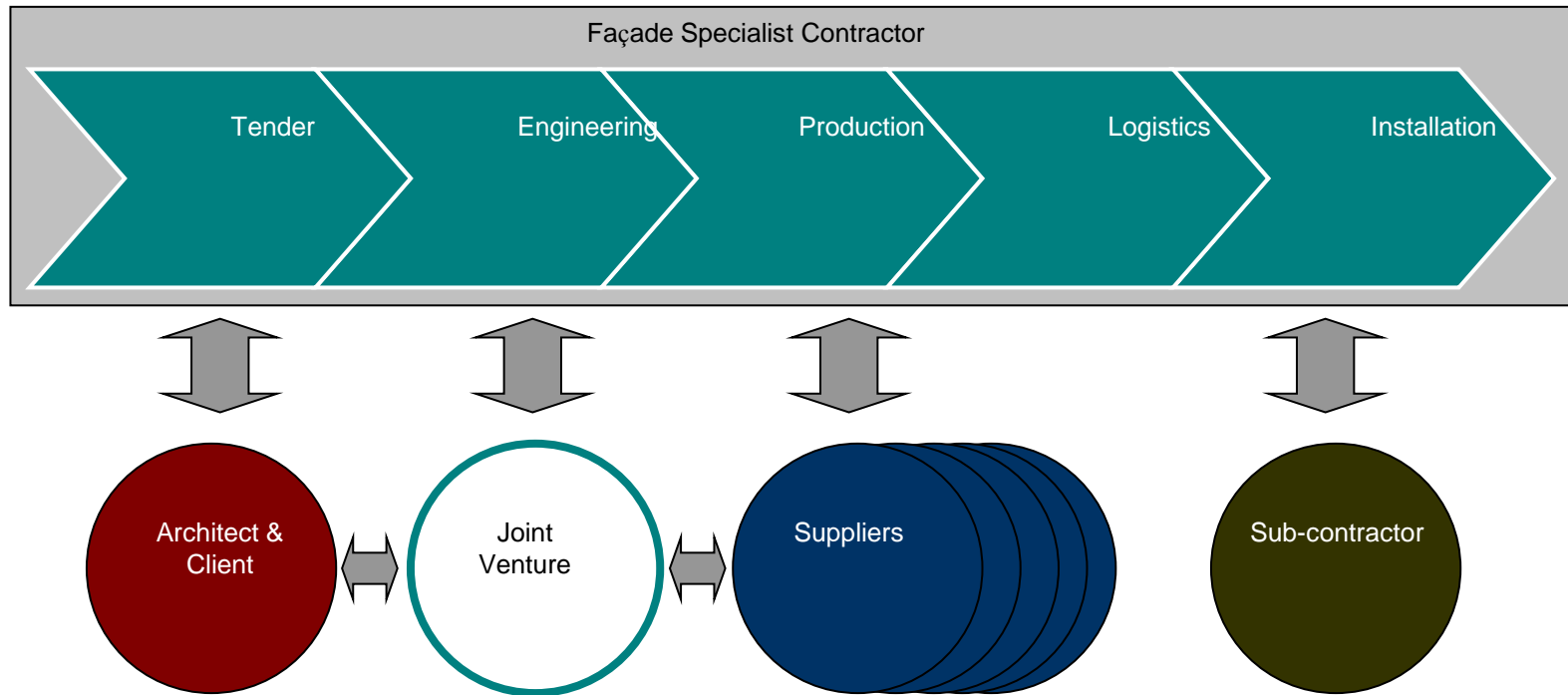
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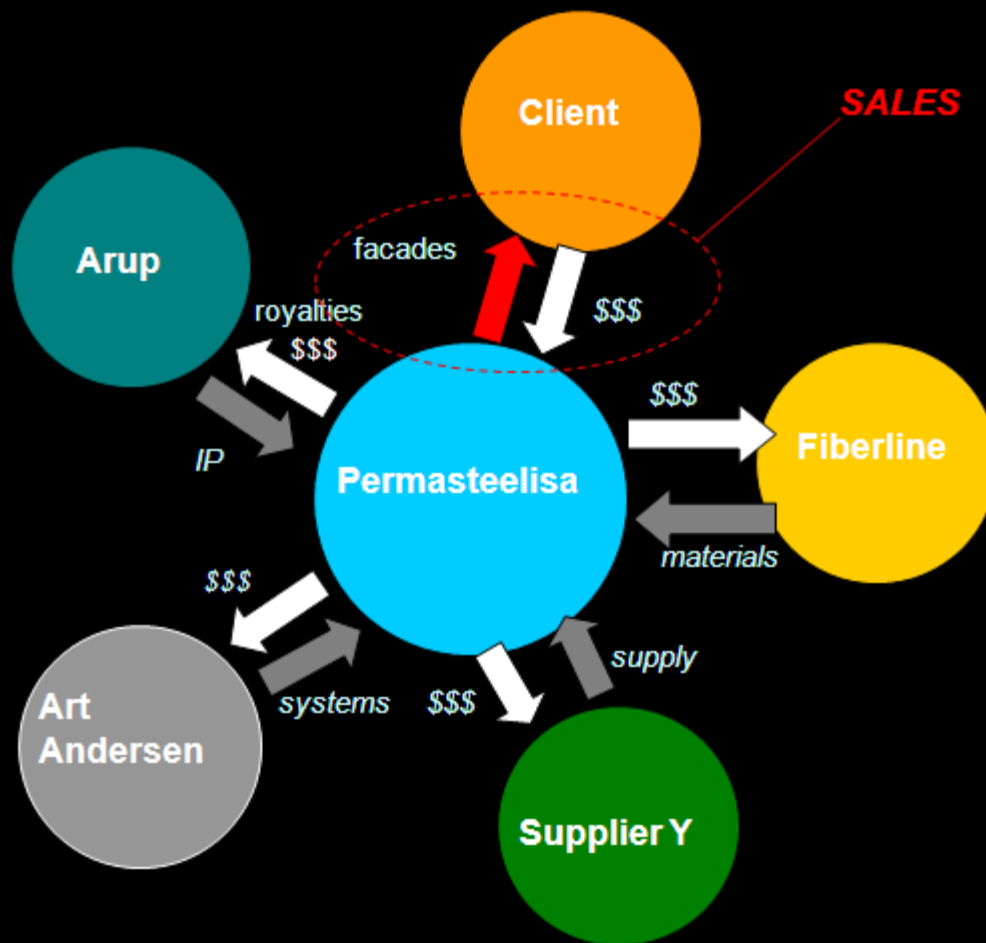
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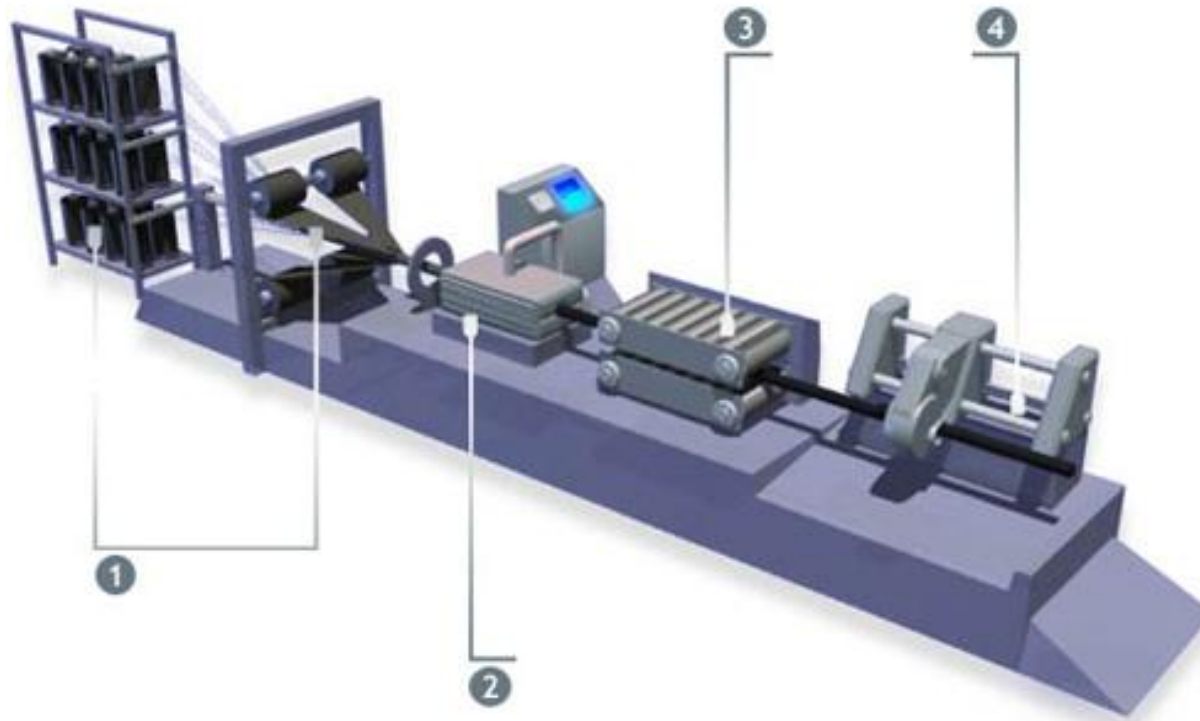
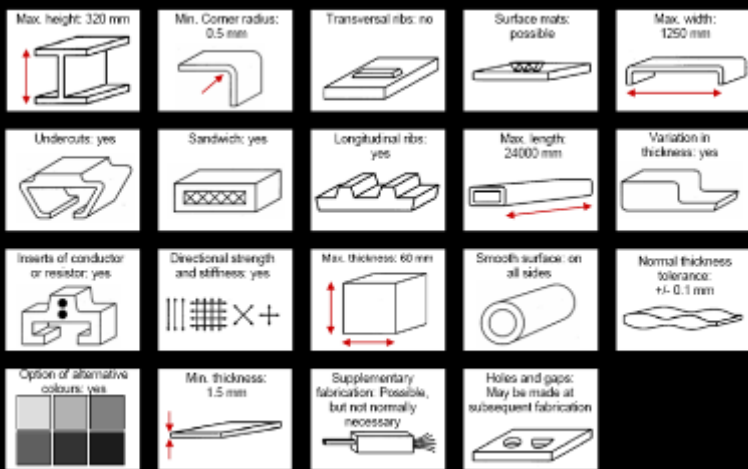
BUILDING LAB DK

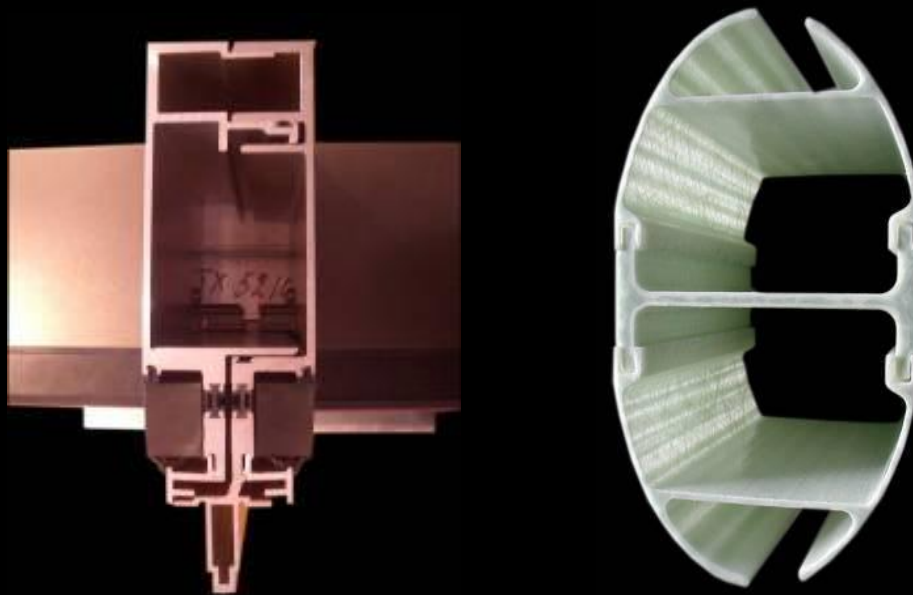














pushing the envelope

intelligence

media

dichromatic

natural ventilation

heating

blast resistant

mechanical ventilation

vacuum insulation

composite action

randomisation

photovoltaics

phase change

flexible

daylighting

switchable

translucency

reuse

fluidised

attenuation

cooling

dynamic insulation

recycle

double skin

solar thermal

louvres

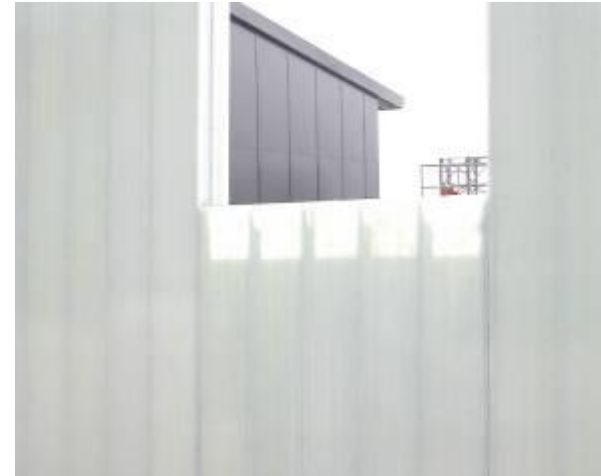
complex geometry

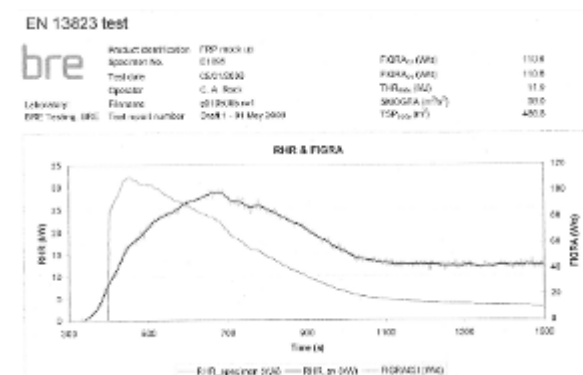
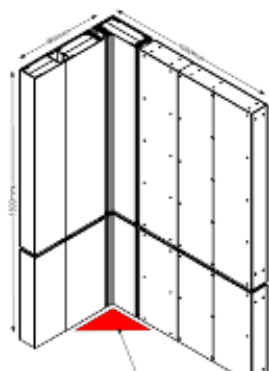
shutters

ARUP

Idea

- Low thermal conductivity
- Large pultruded sections
- Compact (slim) system
- Structurally bonded
- Lightweight
- Limited number of parts
- Appearance







GARTNER

page
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picture No. 1: GFK-panel



picture No. 2: GFK-panel with mineral wool filling

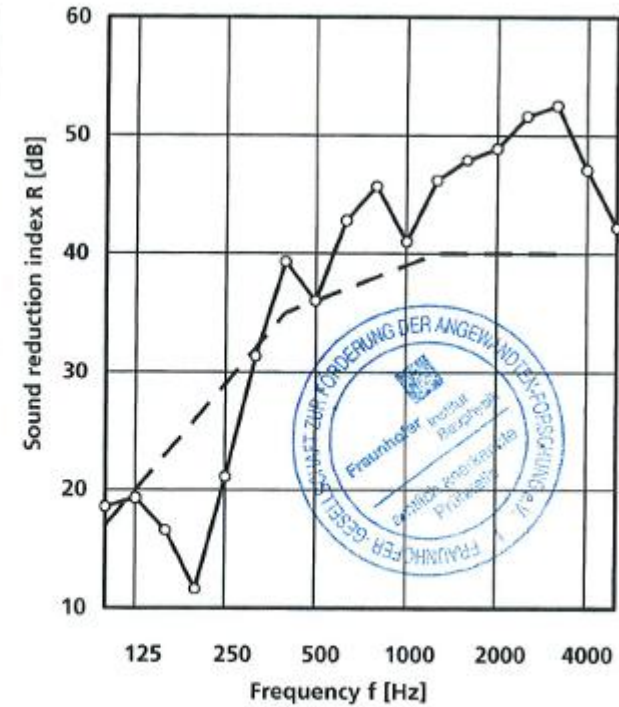


picture No. 3: GFK panel in test opening



picture No. 4: GFK panel with glass pane ahead

f [Hz]	R [dB]
100	18,6
125	19,3
160	16,6
200	11,6
250	21,1
315	31,3
400	39,3
500	36,0
630	42,8
800	45,7
1000	41,0
1250	46,2
1600	47,9
2000	48,9
2500	51,6
3150	52,5
4000	47,1
5000	42,2



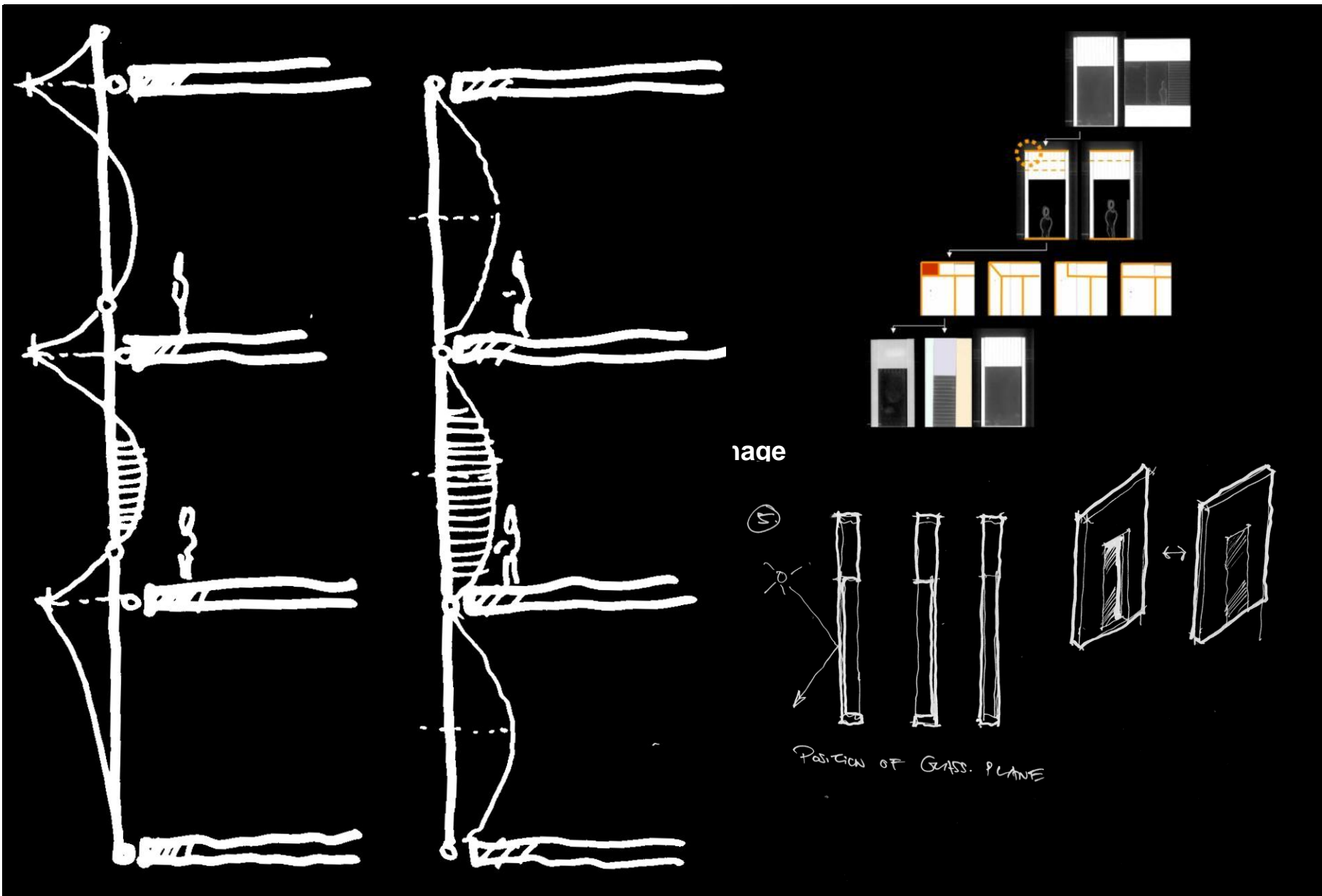


studies by **MAKE** architects

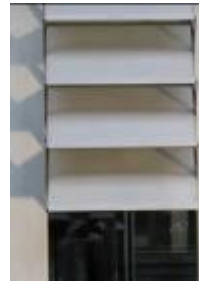


Collaboration





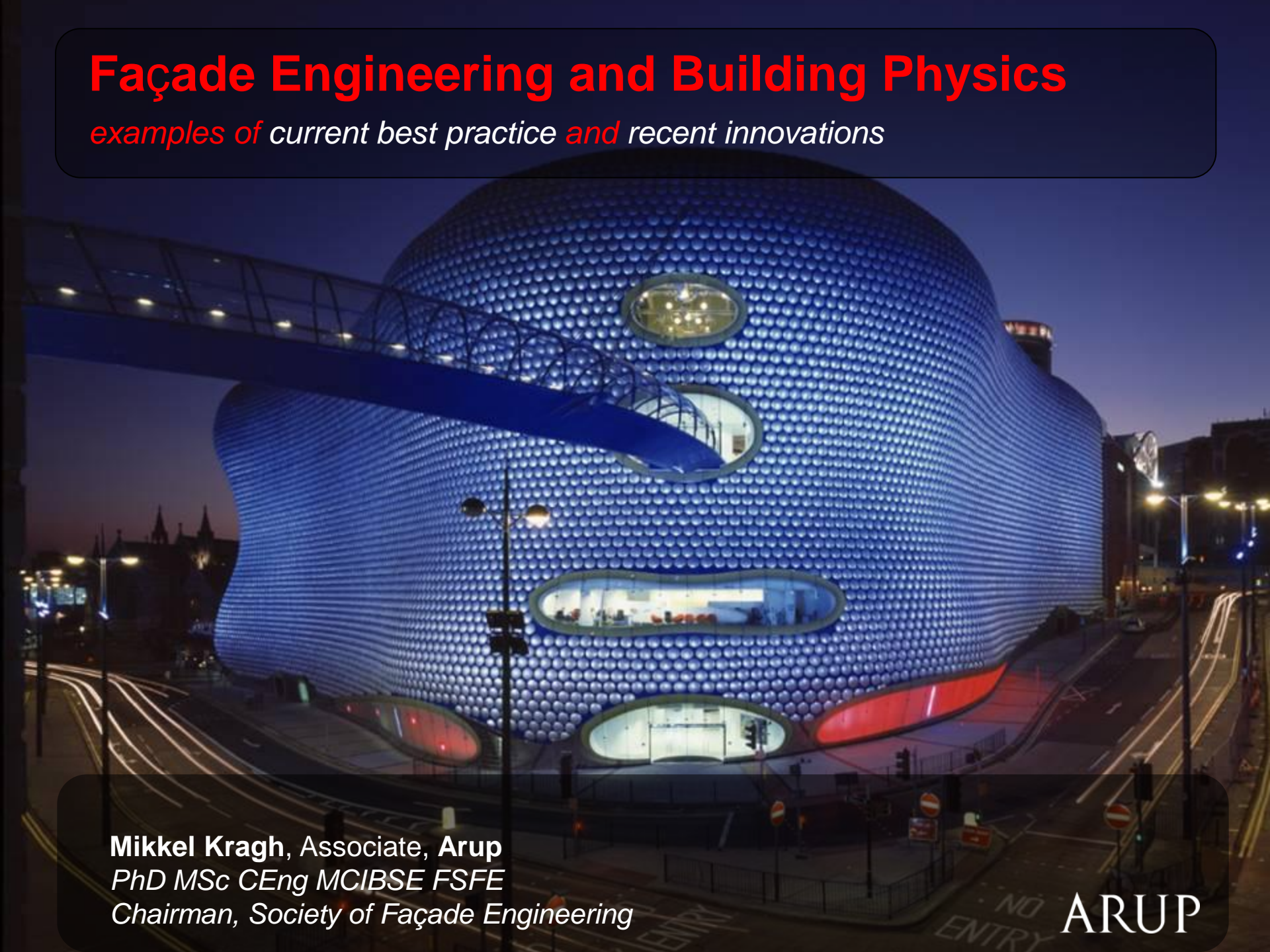




ARUP

Façade Engineering and Building Physics

examples of current best practice and recent innovations



Mikkel Kragh, Associate, **Arup**
PhD MSc CEng MCIBSE FSFE
Chairman, Society of Façade Engineering

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