


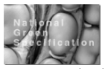

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Air movement in & about buildings 1 of 9 + Q&As

© NGS 2007 CPD in 10 parts

- Principles of Element Design
- Climate Change
- Wind
- Wind Tunnel Testing
- Wind Turbines
- Natural Ventilation
- Moisture Vapour & Condensation
- Thermal Insulation
- Breathing Construction
- Airtightness
- Wind & Airtightness Testing
- Building Elements

- Passive Ventilation
- Active Ventilation
- Stack Effect
- Atrium
- Solar Orientation & Solar Gain
- Conservatories
- Thermal mass
- Conduction, Convection, Radiation
- Solar Shading
- Thermal mass, Passive and active cooling
- Fluid dynamics
- Mechanical Ventilation
- Air-Conditioning

NGS CPD Seminar Series

- Educational Objective:
  - Comprehensive introduction to subject: from tornadoes to air-conditioning and a lot more in between
  - emphasis on environmentally sustainable solutions
  - design primer: addressing principles and solutions
  - technically rich: materials, construction, services & testing
  - Related NGS CPD Seminars indicated
  - Questions and answers for each subtopic in file 10
- Audience:
  - Architecture Students Part 1 Year 2
  - CPD update for all levels of experience & knowledge
- Delivery:
  - 3 to 4 hours depending upon audience participation
  - Reading 1 hour
  - 26 subject breaks to enable subdivision

Air Movement in Buildings Sub-topics in 10 separate files

- Principles of Element Design
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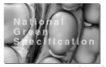
- Questions and Answers

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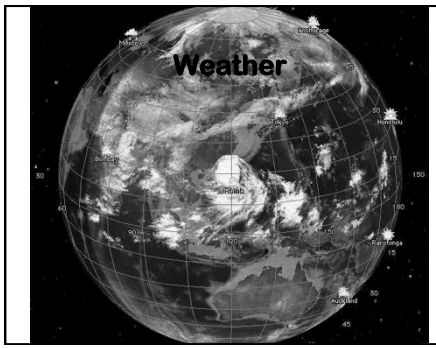
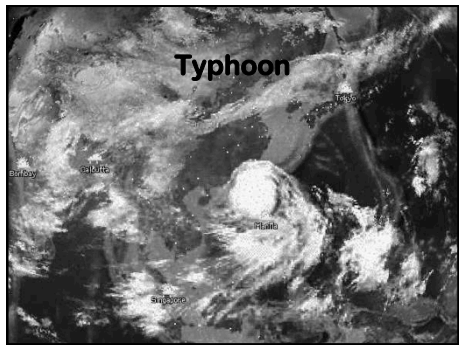
Climate is Changing





Climate Change

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- As the climate changes it is anticipated that all natures forces we are familiar with will become more extreme:
- Stronger winds, dryer summers, wetter winters, more intense rainfall, etc.
- We need to design accordingly but also to try to mitigate the changes

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Global Warming

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- The consequences are already showing up on a regular basis, not just across the world, but increasingly in Europe and the UK.

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Future Proofing

- Reliance on fossil fuels which release carbon dioxide and other green house gasses is futile
- Multi-fuelled boilers that can change over to biomass and bio-diesel fuels as they become available is okay
- Making provision for the addition of renewable heat and energy generation will make their addition feasible and economical
- Not being reliant on the need for heating and cooling at all is better still

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Wind

Affects on buildings

Wind

- Wind can be very destructive
- Wind can be beneficial if we know how
- Wind brings clouds, rain and fresh cooling air
- We can use wind to dry crops and clothes
- Rain is good for crops, washing and a source for drinking water
- Wind can drive mills, water pumps and turbines (electricity generators)

Barn doors opposite for wind to separate threshing from seed
Threshold holds thresh at door

Grain Barn

perforated walls let wind dry grain

Outskirts of Sandy Bedfordshire

Listed Grade I Barn
slot windows ventilate cattle stalls

Wiltshire

Untreated Unseasoned Unfinished Durable Timber

Wind & Sun dries Species Boarding.

Tall plinth protects timber from ground water.

Irregular pavement protects from rain splash.

Wind & air dries timber

Aberystwyth Arts Centre: Architect: Smith Roberts: Peter N Roberts

Timber as Biomass Fuel

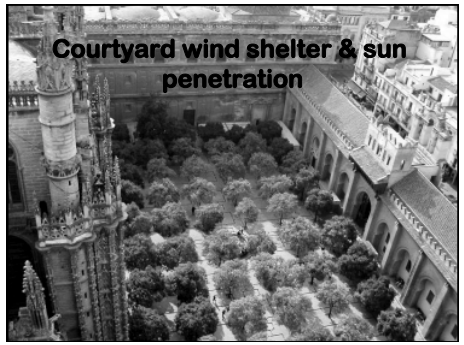
Fuel store ventilated to allow wood to dry without adding energy

Wind shelter: Buildings

- Buildings create some shelter on the leeward side away from the wind
- But create strong winds around sides and down alleyways between
- Wind direction changes: sheltered spot moves
- Prevailing wind usually from SW in UK means shelter is usually on the NE
- Ensuring solar penetration into the sheltered spot is not always easy

Wind shelter: Courtyards

- Courtyards create shelter most of the time from most directions
- Courtyards need views out and they can provide routes for fresh air if too sheltered
- Air could become stagnant if too sheltered, too deep or two narrow
- Tall, small area courtyards are light wells used for light and ventilation



Wind shelter: Towers

- Smaller buildings on the windward side of nearby Towers push the air flow up so it hits the tower and spreads in all directions
- The down drafts can be considerable stronger than the original wind
- Edie currents are set up around the edges of the tower
- Creating a hostile environment that can be dangerous for pedestrians
- Podium, Shelf, Skirts around the towers above pedestrian level will deflect much of the wind and create a comfortable place to walk and linger.

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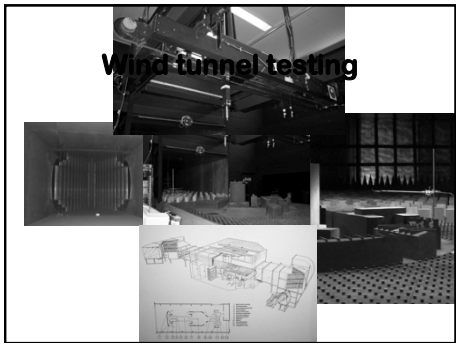
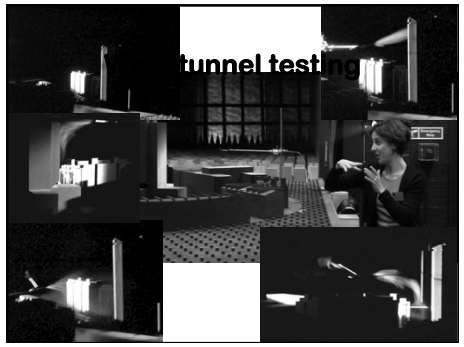
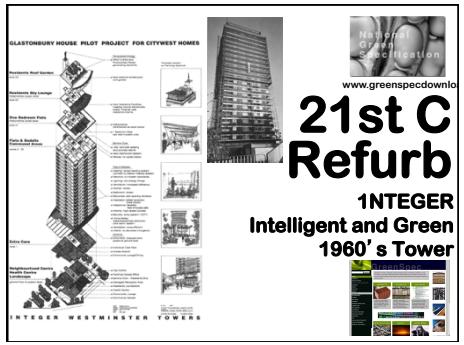
Wind Tunnel Testing

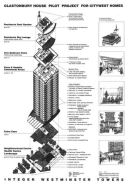
Renewable Energy: Wind





Towers: turbulence at ground level





Another NGS CPD seminar to consider

Wind Orientation: UK

- SW prevailing wind from Atlantic Gulf Stream warm and/or wet, mild in winter
- Northerly cold winds in winter
- Easterly from Mainland Europe very cold and snow-bearing in winter
- Southerly warm dry, occasionally sand-bearing in summer

Wind orientation: Buildings

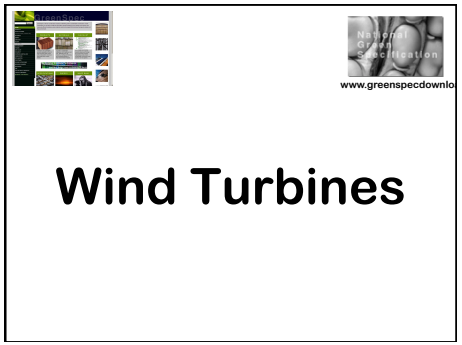
- Turn the building away from the northerly cold winds
- Less windows, doors and air bricks on the northerly side
- Well insulated and airtight walls to the northerly winds
- Courtyard buildings protect from the winds

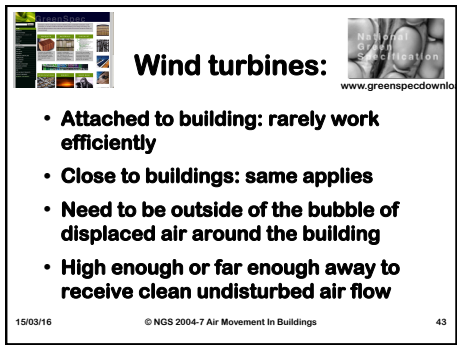
Wind shelter: Landscape Trees

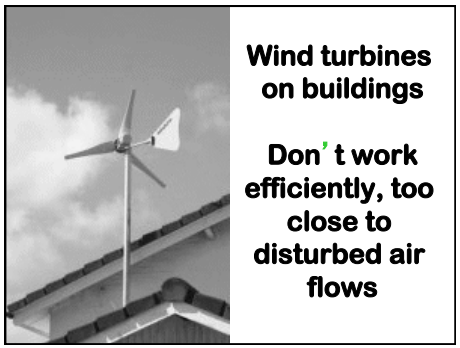
- Local trees, hedges and bushes have a sheltering effect on a building
- They are permeable so most wind passes through and some goes over and around
- It takes some of the pressure out of the wind without too much disturbance
- Deciduous trees to the east, south and west, coniferous to the north
- Fences being solid disturb the air flow

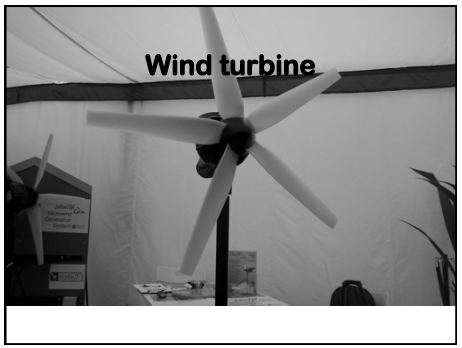
Wind shelter: Creepers & Vines

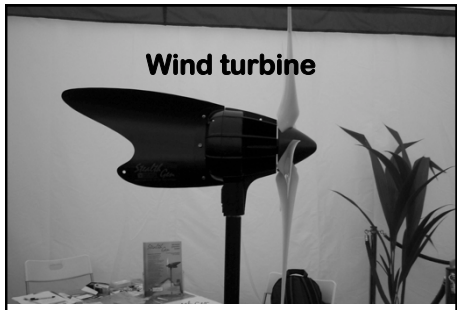
- Offer little effect on wind loading
- But create a micro-climate sheltering the wall
- Shelter from rain, wind and sun
- Haven for insects, spiders, bugs, birds

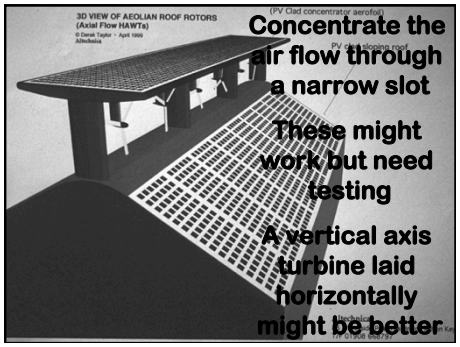


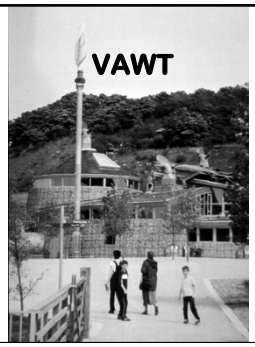


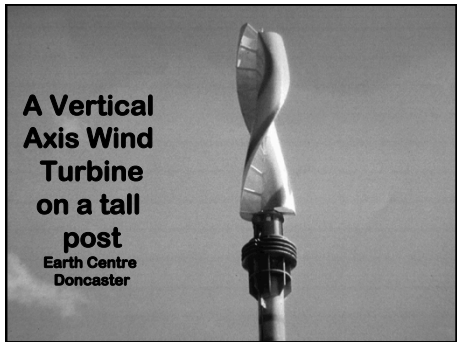


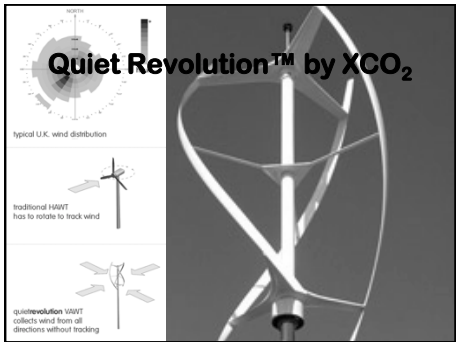












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Natural Ventilation

using wind & air movement

External Wind loading

- Prevailing wind direction and magnitude
- Wind driven rain index (rain carried in wind)
- External pressures on elevations:
  - +ve & -ve
- For every action there is an equal and opposite reaction
- Internal suction correspond to external pressures and visa versa

Internal Wind Pressure Buffeting

- Internal pressures on walls and partitions
- Doors shutting in breeze, bang into frame, force held by walls
- Stability posts in tall slender walls
- Wind posts in internal and external walls
- Air leaky joints around posts
- Waste of cut blockwork either side

Deliberate Ventilation to rooms

- UK By-Laws (in the past)
- To Control humidity
  - Airbricks & hit/miss grilles (close/open)
  - Into Larders (food stores)
  - Into habitable (living and bed) rooms
  - Into Kitchens, WCs, lobbies and Bathrooms
- To supply combustion air to fires
  - Airbricks

Ventilated cavities

- Traditionally construction ventilated to avoid condensation
- Flat Roof void
- Attic space
- Ground floor voids under timber floor
- Cavity walls: Weep holes and Air Bricks
- Control humidity and moisture content of materials around the cavity

Layered Construction: Simplifies details and avoids interfaces: Ventilation zone above insulation.
Don' t puncture Damp proof membrane, Gas proof membrane, Vapour barrier, Breather membrane & Air tightness layer.
Add services zones to avoid complications

Aberystwyth Arts Centre: Architect: Smith Roberts: Peter N Roberts

Moisture in materials

- The air is full of spores and pollen from fungi and plants
- They land on surfaces or materials
- If the Relative Humidity (RH) of the air is high the moisture content of those materials may rise
- Timber above 20 % moisture content is at risk of the spores growing on the surfaces
- Once growing the spores turn to fruiting bodies feeding off the timber
- Timber in buildings is not vigorously living, nature does not like waste so it tries to reduce the dead timber and return it to nutrients for nature

Moisture and Health

- Those same spores create mould on surfaces of absorbent materials that are kept moist
- Mould releases more spores which can affect the respiratory system in humans
- Unventilated bathrooms, showers and bedrooms are prone
- Ventilation is important and it can solve many ills

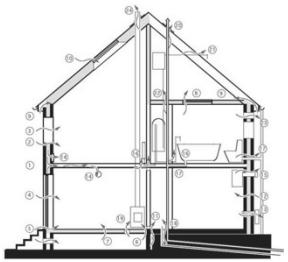
Ventilation today

- In addition to ventilating moisture today we have other issues
- We use so many synthetic materials, adhesives, finishes and cleaning agents in buildings today
- They off-gas chemicals into the air which can affect air quality and health
- Sick Building Syndrome is one result.

Leaky construction

- Cavity wall construction (open perpends)
- Plasterboard dry-linings to walls and ceilings with cavities behind
- Plasterboard and metal or timber stud partitions
- Decorative linings to walls
- Cladding to external walls
- Tiled and slated roofs (but sarking boards in Scotland, sarking felt in England)

Leaky Buildings



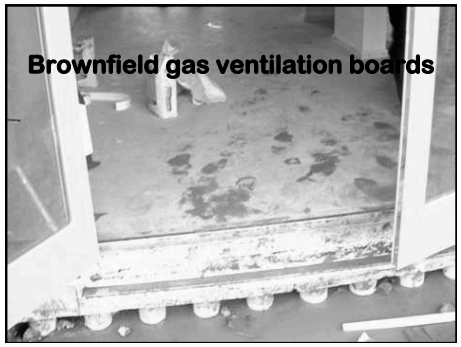
Leaky paths round buildings

Surface mounted service ducts:
Use hollow skirting, dado & services cover
But form a pathway for air leakage.

Traditional method may be more airtight but:
Avoid chasing masonry
Avoid noise
Avoid masonry dust
Avoid exclusion zones
Avoid waste materials
Avoid conduits
Avoid Rendering-in
Avoid Plastering over

Brownfield site ventilation

- Methane from biodegrading organic waste in backfill
- Petro-chemicals from prior use
- Hydro-carbons from prior use
- Ventilated cavity below buildings allow removal before entry into building
- Gas Proof Membrane in floors
- Often combination Damp Proof Membrane
- Cigarette smokers must take care with stubs
- Methane is combustible



Radon Ventilation

- Radio-active granite e.g. in west country
- Releases radioactivity into air
- Ventilated cavity below buildings allow removal before entry into building
- Radon Barrier: Gas Proof Membrane in floors
- Often combination Damp Proof Membrane

Combustion Air: Fire Places

- Victorians designed leaky buildings to provide combustion air to open fires
- The heat of the fire draws air up chimney and draws fresh cold air in through doors, windows and airbricks
- Chimneys include a throat, a narrowing of the flue above the fire which causes the warm air to pass through the narrowing at higher speed than the flue above
- Know as the Venturi effect it is an effective measure to prevent back draft pushing smoke back into the room

Combustion Air: Boilers

- Air demand is known from boiler manufacturer data
- Air bricks or louvres or gap under doors
- Additional air bricks to ventilate the room, inefficient boilers loose heat to the room
- Some flues radiate heat to the room
- Walls between Plant room and other room are effectively external walls, insulate accordingly

Build-tight ventilate-right

- Do not build leaky buildings to prevent humidity build up and condensation
- This will only squander heat energy uncontrollably as well
- Do build airtight buildings and then purposefully ventilate them in a controlled way
- Choose passive or active ventilation over mechanical and air-conditioning

Design of Barriers

- We design Damp proof membranes (DPM), Damp proof courses (DPC) & their junctions
- We specify vapour barriers (VB) but fail to detail them and fail to police them on site
- We fail to design airtightness layers (ATL) and its many contributing materials, layers and junctions
- We need to red line the VB/ATL on drawings
- We expect our inadequacies to be corrected by the builder
- Actually don't think about it

Workmanship: often poor

- Buttered, tip and tailed joints in masonry
- Inaccurate cutting of insulation materials
- Inaccurate fitting of insulation materials
- Gaps in insulation, around edges and abutments
- Unsealed laps in barrier sheets
- Incomplete seals in laps
- Missing barrier sheets
- Wind damaged barrier sheets
- Punctured barrier sheets
- Service penetrations not resealed

Locational Assembly: oversized compress, offer up & release

- If rafter spacing and insulation size correspond
- No waste
- Do they?

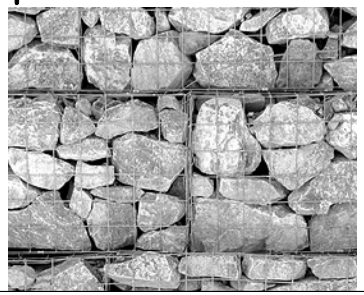
Airtight construction

- Wet trades often are
- External Render
- Internal Plaster or plaster skim on board
- Parge Coat (British Gypsum Ltd. have one)
- Insitu Concrete
- Sprayed Insitu Hemp-lime
- Vapour Barriers in timber construction (can be)
- Airtightness layers (new to industry)

Open Materials

- Open cell glass and rock mineral fibre insulation
- No fines concrete blockwork (open interstices)
- Rainscreen Cladding (open joints)
- Gabion walls & Dry stone walling (linked interstices)
- Straw bale walls (high-setting on harvester)
- Permeable pavement (oxygen for microbes)
- Butted floor boards and loose T&G boards
- Micro-porous paints and stains
- Breather Membranes
- Breathing sheathing boards

Open materials/construction



Rainscreen

- Rainscreen cladding works on the principle that the outer layer of cladding catches most of the wind and rain
- The open joints permit some air and rain to pass through
- a second line of defence a Damp Proof Membrane over the wall surface
- Stops the rain and wind wetting the wall

Pressure Equalisation

- Rainscreen cladding benefits from the principle that air passing through the joints will fill the void behind, build up pressure and then bounce back out
- Following air and rain will meet the air bouncing back out through the joints
- Less air and rain will pass through the joints and reach the rear wall

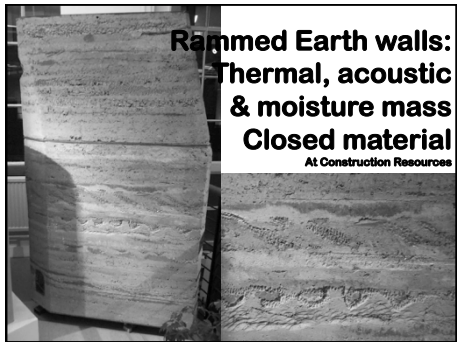
Pressure Equalisation

- Curtain walling can adopt the same principle where it has open drain holes to remove rain and condensation
- Pressure equalisation will occur when air entering one hole will push air out through other holes
- Some window manufacturers rely on air pressure entering the deep recess around the window to bounce air back to deflect further air entering the recess, avoiding the use of sealants

Pressure equalised doors invented for towers with high pressure winds at ground level

Closed Materials (potentially airtight)

- Structural Glass Assembly sealant jointed
- Metal sheet cladding
- Aircrete concrete blockwork (Closed cell matrix)
- Hemp-lime (but micro-porous fibres)
- Rammed earth walls
- Tongue & Groove Jointed boards
- Oil Paints (skin forming)
- Vapour barriers
  - Polyethylene e.g. polythene
  - Aluminium

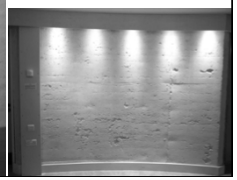


Rammed Earth walls: Thermal, acoustic & moisture mass Closed material

At Construction Resources

Rammed Earth walls: Chalk & Flint

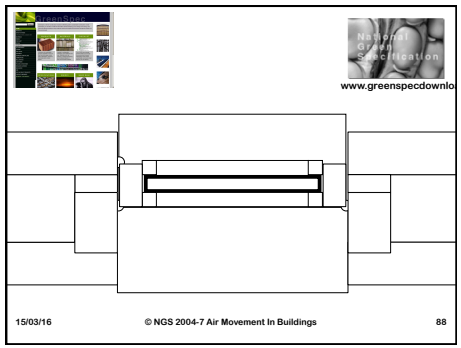
Pines Caryx Conference Centre Dover



Closed glass balustrade Offers view and wind shelter.

Open Mesh offers view but little protection from wind

Greenwich Millennium Village and Oxford Science Park Architect: Proctor Matthews



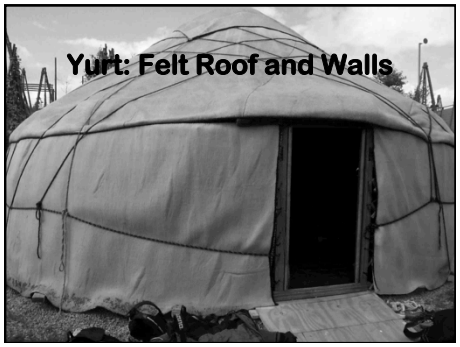
Moisture Vapour and Condensation

Moist air under pressure

- Occupation of buildings
- Breathing, perspiring, bathing and boiling (clothes, water, food, bodies)
- Adds moisture to air, raising humidity
- When less humid outside, moisture laden air moves outwards through building fabric
- The moisture can be deposited in the fabric by interstitial condensation

Moisture Permeable Materials

- Traditional methods
- Lime: mortar, render, plaster, paints, crete
- Bricks, Blocks, mortar (not all)
- Earth: walls, mortar, plaster, render, paints
- Felt: Yurt roof and wall sheeting
- Micro-porous paints (but water repellent)
- New methods:
- Hemp-lime: insitu: walls, floors, roofs, insulation; blocks, screed,
- Moisture Mass (like thermal mass but for moisture)



Wick Effect

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- Building-in moisture absorbent materials can help to control moisture deposited from the air
- E.g. Straw bale above a shower
- Unfired clay bricks, blocks,
- Clay plaster, paint
- Moisture Mass

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Condensation Eradication

- Don't let the temperature in the construction drop below the temperature at which the air can no longer hold moisture
- If it does it will deposit the moisture
- Vapour resistance inside ideally 5 times more resistant than outside
  - Vapour Barriers (VB):5 - Breather Membrane (BM):1
- VB & BM used in timber frame constructions
- With hydrophobic materials that do not perform well when wet (above 3% MC)

Vapour Barriers (VB)

- Often polyethylene or aluminium
- High moisture vapour resistance
- 5 times more resistant than Breather Membrane
- Inside of the insulation
- Lapped and continuous sealed at joints
- Joints supported on members and battened
- Penetrations sealed: lights, switches, sockets, etc.
- Stops moist air getting into construction and into hydrophobic insulation

Vapour Check (VC)

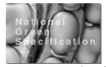
- In reality because of compromised construction, incomplete Vapour Barriers, leaky services penetration
- It is generally accepted that Vapour Barriers are not barriers
- We call them vapour checks because they slop down vapour entry not prevent it
- But they are likely to concentrate vapour passage into small spaces between frames with higher risk of problems

Air as insulation

- Air trapped in the spaces in the insulation
- Closed or open cells of foamed plastics or glass
- Air spaces between fibres
- Spaces between layers of multi-layer reflective insulation
- But fibre quilts act like a filter: air passes through, particulates may be held
- Needs a sheet on one or both sides to stop warm air passing through

Breather Membranes (BM)

- Often felt or brown building paper
- Low moisture vapour resistance
- 5 (or more) times less resistant than vapour barrier
- Outside of the insulation
- Lapped at joints over supports and battened
- Joints fastened on members
- Stops warm air being sucked out of open cell insulation into ventilation air stream



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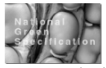
Thermal Insulation

CO_2 and Carbon reduction

- Do not limit to complying with Building Regulations Approved Document L1A, L1B, L2A, L2B
- Set out to exceed Kyoto, EU or UK CO_2 targets
- Strive for Zero Carbon buildings now not 2016
- Insulation costs less than plant
- Reduce heating, cooling, ventilation and air-conditioning demands towards zero
- Windows: U value of 1.0 W/m2.K or better
- Walls: U value of 0.1 W/m2.K or better
- Airtightness: less than 1, not 10 of Building Regulations

Insulation



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- Insulation Insulation Insulation
- Spend money on cheap insulation
- Save money on heating and cooling plant
- Save money on heating and cooling bills

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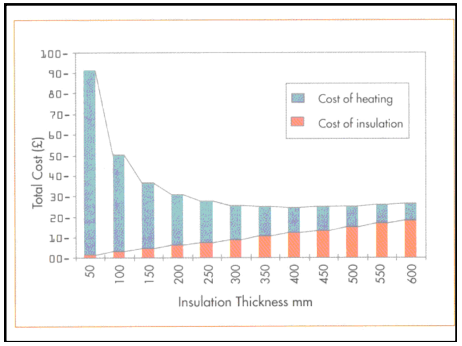


50 mm. cavity is history

300 mm. is optimum

Ties and tie spacings may change

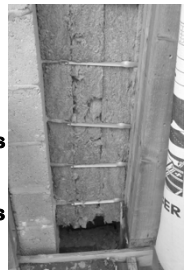
BedZED Beddington Sutton Architect: Dr Bill Dunster

Long ties and deep reveals For 300 mm. insulation

Hydrophobic Insulation in timber frame

- Glass and rock mineral wool thermal and acoustic insulation
- If used in dry construction e.g. timber frame wall the moisture content of the wall is expected to be low
- However compromised vapour barriers (VB) are only a Vapour check (VC) and some moisture will enter the construction
- Hydrophobic materials in these conditions will absorb moist air and water
- The moisture will occupy the air spaces and prevent the insulation from acting as insulation
- Its performance drops off unless it can loose the moisture
- High resin content and non absorbent materials offer resistance to moisture uptake into the fibre so it remains in the airspaces.
- 1:5 ration is critical to the moisture passing through driven by warm air
- If the insulation holds the water it can hold the water against timber sections

Zero Fossil Fuel Energy Development
High thermal mass cavity walls and floors
Low U values
Rock Mineral Fibre
Long 2 part cavity ties



BedZED Beddington Sutton Architect: Dr Bill Dunster

Zero Fossil Fuel Energy Development

High thermal mass cavity walls, roofs and floors

Low U values
300 mm.
Rock Mineral Fibre
Long 2 part cavity ties

BedZED Beddington Sutton Architect: Bill Dunster

Hydrophobic Insulation in masonry

- Glass and rock mineral wool thermal and acoustic insulation
- If used in wet construction e.g. masonry cavity wall the moisture content of the wall is expected to be 3% MC
- Rainwater can pour down the inside face of the external leaf
- Hydrophobic materials in these conditions will absorb moist air and water
- The water will occupy the air spaces and prevent the insulation from acting as insulation
- Its performance drops off unless it can loose the water
- High resin content can offer some resistance to water uptake
- Fibre orientation or disorientation can discourage capillary attraction into the depth of the insulation
- Allegedly the insulation keeps the moisture close to the exposed surface

Other Topics

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- r and k values
- U values
- Thermal Mass
- G values
- Decrement (heat passage over time through insulation and thermal mass)
- When NGS know enough: another CPD

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Breathing Construction

Breathing Construction (BC)

- Breathing Walls: well known for some time
- BRE recently accepted roofs as well
- Opposite to traditional timber frame with VB and BM which prevent moisture entry and passage
- BC permits moisture into and through construction
- No vapour barrier
- Rock and glass mineral wool not suitable
- Requires airtightness layer (ATL), hygroscopic insulation and breathing sheathing board (BSB)
- 1:5 rule is less important moisture passes both ways

Compromised Breathing Construction (CBC)

- Blurring of the boundaries between Breathing Walls and traditional timber frame
- Uses polyethylene Vapour Barrier VB or Vapour Check VC inside
- It resists moisture entry and passage
- Rock and glass mineral wool are used
- Breather membrane BM outside
- 1:5 rule applies

EVT Enhanced Vapour Transfer ™

Enhanced Vapour Transfer (EVT) and rainscreen

Hygroscopic insulation maintain their performance even when wet
Vapour and water released when conditions permit
No need for Vapour Barrier
Use vapour permeable construction
5:1 ratio VR inside:outside and an air tightness layer

Construction Resources Showrooms Southwark London

Airtightness layer (ATL)

- Usually recycled paper sheet e.g. Pro Clima DB+
- High resistance to air passage
- Low resistance to moisture passage
- Can absorb moisture on one face & release it on the other
- Inside of thermal insulation
- Lapped and sealed at joints over supports
- Joints fastened on supports and battened
- Stops warm air leakage out of the building
- Allows moisture through into hygroscopic insulation which can tolerate it and then out of the building
- Used in Breathing construction

Enhanced Airtightness layer (ATL)

- All of the characteristics and applications of ATL
- Variable resistance to moisture passage
- Size of micro-pores varies with the seasons
- Material: _____
- E.g. Pro Clima Intello
- Study:
  - Study Calculating Potential Freedom From Structural Damage Of Thermal Insulation Structure in Timber Built systems

Hygroscopic Insulation

- Any natural plant based material: hemp, straw, flax, coconut husk, cellulose, sheep's wool, grass, etc.
- Air trapped in material is what makes insulation work
- Water does not work in the same way
- Moisture laden air or interstitial condensation occupies the space that air would
- Stops hydrophobic insulation from insulating
- Hygroscopic insulation absorbs the moisture into the fibre leaving the air spaces to insulate
- Releases the moisture when conditions are right and it leaves the construction and building

Hygroscopic Thermal Insulation

Newspaper
Flax
Hemp
Sheep's wool
Cellulose

Construction Resources Showroom Southwark London

Hygroscopic Insulation: Sheep's Wool

Sheep's wool

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- When on the sheep's back they are kept warm
- Hygroscopicity absorbs moisture and the insulating effect is maintained
- Sheep's wool has other characteristics whereby it warms up when wet
- But I do not know enough to explain

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Breathing Sheathing Boards (BSB)

- Usually cellulose fibre board
  - some with bitumen impregnation
  - some with cellulose's own natural resins
- E.g. Panelvent
- Low moisture resistance
- Airtight: stops warm air being dragged out of insulation into ventilation air stream
- Moisture permeable: Breathing
- Some with racking strength, some not
- Fixed butt jointed to timber framing sections

Breathing Sheathing Boards (BSB)

- Wheat Straw fibre board
- e.g. invotek strawboard www.invotek.co.uk
- Bound with fibre's own natural resins
- Low moisture resistance
- Airtight: stops warm air being dragged out of insulation into ventilation air stream
- Moisture permeable: Breathing
- Racking strength: _____
- Fixed butt jointed to timber framing sections

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Airtight & Permeable finishes

Paints & Stains

- Oil based paints form skins and usually act like vapour barriers in both directions
- Once paint fails say on an edge or corner it will let wet in, which will them travel inside the pores of the timber
- If the moisture is warmed the vapour tries to move to outside but the paint film traps the moisture inside
- The wood can start to rot and the paint film is likely to be compromised and fail early
- Consider micro-porous paints and high build stains which resist water intake but allow any moisture out
- Consider more resistant finish inside, less resistant finish outside to encourage moisture outwards

Materials Protection:

Full hbmpp scheme
No absorbent surfaces
Pallet
Stability bracing
Corner & edge Protection
Moisture control
But:
Rain Cover needed
Not Remote storage
Not off the ground
Not JIT but JIC
How many doors to push over the windows?

BedZED Beddington Sutton Architect: Bill Dunster

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Airtightness & Testing

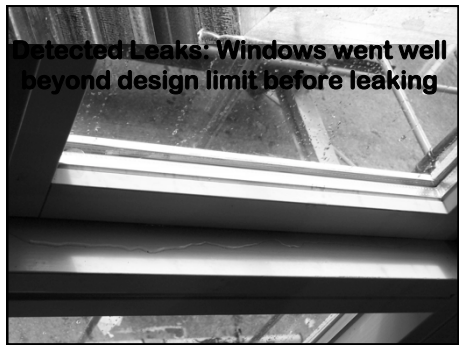
Minimising uncontrolled air leakage

Airtightness Testing

- Off-site:
  - Full scale mock-up
  - Weather, wind and structural distortion
- On-site:
  - Air leakage testing

Off-site full scale mock-up testing

- Test the design for appearance
- Test method & sequence of assembly and interfaces
- Test weather resistance of construction
- Sprague pipes: rain simulation
- WWII Merlin engine: wind simulation
- Air suction: to pull air and water in through leaky joints

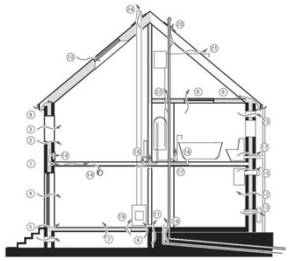


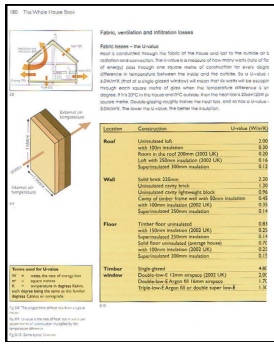
Feedback into design/workmanship

- Observe, analyse, resolve
- Propose solutions, record
- Communicate, inform,
- Redesign if required
- Commit to improve workmanship where weak

Another CPD seminar to consider

Leaky Buildings





50% of heat loss is through the insulating building fabric and 50% through air leakage

% heat loss

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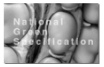
- As Insulation Standards rise
- The % heat loss through the fabric reduces
- The corresponding % of heat loss through air leakage increases
- All the more important to fix air leakage

Air Tightness



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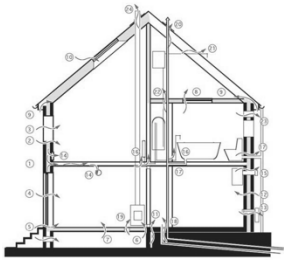
- In past related to:
  - Windows and doors
  - Ground Floor Floorboards
  - Roof spaces (except Scotland, boarded)
- Now relates to:
  - Inadequately designed buildings
  - Badly built building fabric
  - Due to lack of understanding or training

On-site Airtightness Testing

- Seal up the building openings
- Pump air in
- Reach a preset +ve pressure
- How much air is needed to maintain the pressure?
- = Air leakage rate
- Building Regulations permit 10 we struggle to achieve it
- 8 is a leaky building unusable in windy weather, due to air noise and drafts
- Europeans aim for 3, 2, 1 and better down to 0.3-0.1

Leaky Buildings



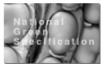
Vulnerable details

- Skirting:
  - Where are the slip layers and vapour barriers?
  - Do they lap and are they bonded?
- Floor level:
  - Do joists bear in walls how are they sealed?
  - mortar shrinks, consider joist hangers
- Light fittings:
  - Are they sealed or just a hole?

Timing of testing

- Has an impact on construction sequence and programme
- Test building structure and building fabric
- Envelop substantially complete
- No finishes yet
- No cavities behind linings to complicate leak finding
- Test and fix leaks in the structure and fabric
- Then complete the finishes
- All sealants hidden behind finishes

Sealants?



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- Use to seal the leaks?
- Benign type of sealant?
- Linseed oil putty is natural plant extract but not appropriate
- Oils will leach out into absorbent materials

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Foamed insulation?

- Use to seal the leaks?
- Petrochemical: non-renewable
- Blowing agent: ZODP Zero Ozone Depletion Potential essential
- Many HCFC blowing agent, bad news
- Evidence suggests they shrink after a short period of time and fail

Cold bridges

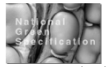
- Not normally an air passage out through construction but a thermal conduction route
- Usually solid materials with low insulation performance in contact with each other
- Forming a chain from inside to outside
- Usually load-bearing elements

Cold bridge solutions

- Plastics in aluminium extrusions in windows and curtain walling
- recycled glass load-bearing thermal insulation into base of load-bearing walls
- E.g. Foamglas Perinsul

Air leakage

- Building Regulations Approved Document:
  - L1A, L1B, L2A, L2B Thermal Insulation
    - Robust Details
    - Thermal insulation avoiding Cold bridging
    - Airtightness? Possibly
  - E Acoustic Insulation
    - Robust Details
    - Acoustic detailing
    - (contributes to airtightness if addressing external walls)



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Acoustics

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Airtightness of Building Elements

Doors

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- Victorian buildings: leaky including doors
- 10 air changes per hour (1ac every 6 minutes)
- Trickle venting and no control
- Can be upgraded or refurbished
- Modern doors are higher performance
- Door with 10,000 mm2 opening e.g. letter flap = Window (B Regs)

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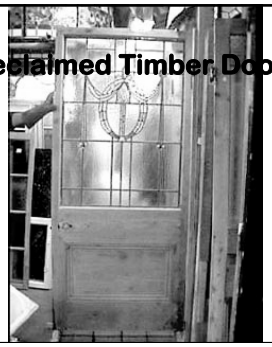
Reclaimed Timber Doors



L20 Doors/sets
BWF-Certifire
& FIRAS
Warrington Fire

Another NGS CPD seminar to consider

Lobby or Porch

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- A second line of defence at doors
- External Porch of Internal Lobby
- Wind shelter, airlock (rarely effective) solar trap,
- Retrofit to buildings

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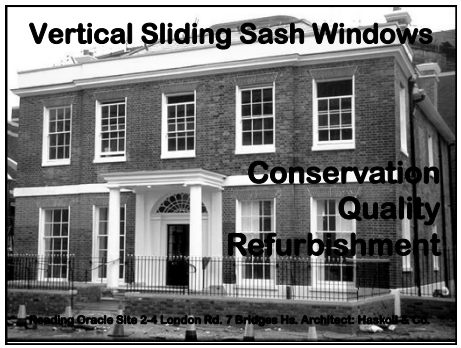
Windows

- Victorian Buildings: leaky including windows
- 10 air changes per hour (1ac every 6 minutes)
- Trickle venting and no control
- Vertical sliding sash (unique to UK)
- Le Corbusier was impressed by them
- Heat out at top
- Cool in at bottom
- Half open at top or bottom
- Can be upgraded or refurbished

Vertical Sliding Sash Windows



Conservation
Quality
Refurbishment

Reading Oracle Site 2-4 London Rd. 7 Bridges Ha. Architect: Haskoll & Co.

Window and door refurbishment

- Victorian timber windows and doors 100 years old, why stop now?
- If in good state of repair consider upgrading with new DGSU and modify beads or frame
- If the Conservation Officer permits it
- Companies specialise in timber window refurbishment/upgrade
- Insitu or at factory
- Phased working to suit programme

Draft proofing VS Sash

Modern alternative

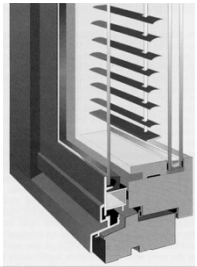
- Timber: 60 years with maintenance regime
- Timber/Aluminium composite:
- Vulnerable bottom bead and sills or outer casement in aluminium
- 60 years with maintenance regime
- Usually Scandinavian manufacture

High performance windows (and doors):

- < 1.0 W/m2K
- Low E coatings
- Gas filled DGSU & TGSU
- Double casement
- Solar shading blinds in cavity
- Trickle ventilation
- Controllable by occupant

High Performance Windows

- Aluminium outer casement
- Timber inner casement
- Treble glazed
- Dust free sun blinds



Reduce demand for all resources used by building

- Envelope Airtightness (build tight)
  - < 1 ach @ 50 Pa
- Appropriate ventilation (ventilate right)
  - 0.5 – 1.0 ac/h air change per hour
  - Heat recovery
  - Wind driven
  - Well controlled

Finishes:

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- Consider High Performance Micro-porous finish to all faces
- Full build up to all faces especially face in contact with masonry
- Coat before installing or reinstalling
- Forest Stewardship Council (FSC) certified wood and ply

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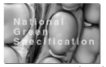
Trickle vents



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- Usually associated with windows and roof windows, can be in doors too.
- Must be within reach to ensure they can be used easily and controllable
- Not permanently open and out of reach
- Windows without them have great potential to loose considerable energy when left ajar.
- And could be less secure in this state

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Cat Flaps

- 20,000 mm2 or more, hole in the wall
- Air leakage excessively high
- Destroy all efforts to make an airtight building if flapping in wind
- Consider:
- cat collar electronic key releases otherwise held-closed flap to control leakage
- lobby with two flaps, cat occupies space blocking air flow, but would cats use them?

Bin Chutes

- In Australia they have a chute over the kitchen sink
- straight to the bins fixed to the wall outside
- Okay in a warm climate assuming there is smell seal
- BedZED planned to have them but too complicated and abandoned

Soil, Waste and Vent pipes

- Small amounts of Air from bathrooms and kitchens is drawn into waste pipes
- Air admittance valves draw air into Soils stacks with no vent to roof level
- Sewer gas is prevented from leaking back into the room

Hot or cold air hand dryers

- Move air around and add heat
- They squander electricity made at 25% efficiency
- They fail to dry your hands unless you have all day and no queues behind you
- Avoid specifying them if you can
- Don't position over radiators (convectors) avoid rust
- Dyson's Blade uses unheated blade of 400 mph air to blast water from hands
- Much better energy efficiency
- Will be on the market soon

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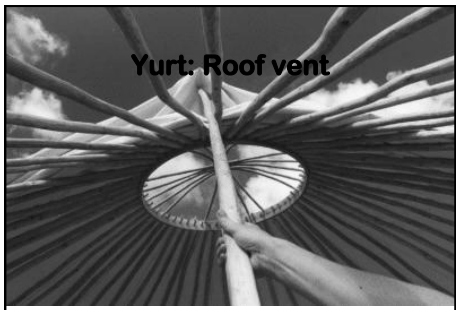
Passive Ventilation

Passive & Stack Effect

Passive Ventilation

- Passive ventilation can be in numerous forms
- Cross ventilations using open windows and doors on both sides of a building and prevailing winds driving fresh air through
- Venetians use windows close to and either side of the corners of buildings to catch air currents in a tight urban environment
- Stack effect to draw air from warm interiors and draw cooler air in to replace it
- Lift and stair shafts have ventilation at their heads to release smoke this can add to the ventilation but probably is uncontrolled



Passive stack ventilation

Passive Stack Ventilation

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Active Ventilation

Air pressure driving passive ventilation

Active ventilation

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- **Using Passive ventilation principles**
- **Adding controls and actuators to open and close valves, flaps and vents**
- **Harnessing the power of nature (wind pressure) to drive the passive systems**

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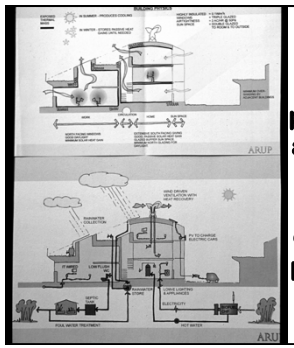


Wind pressure pushes fresh air in driving stale air out, with heat exchange to prevent heat loss

BedZED

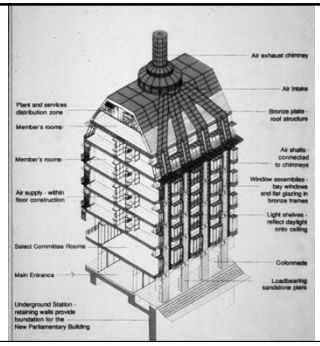
Active ventilation:

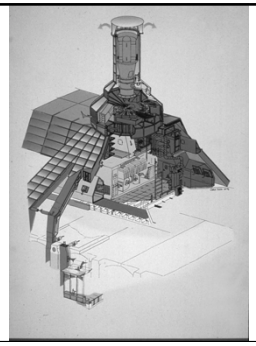
wind captured pushed into building, driving air out,

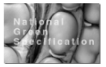
heat transferred where they pass

BedZED

Jubilee Campus Nottingham Uni







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Stack Effect

Stack effect

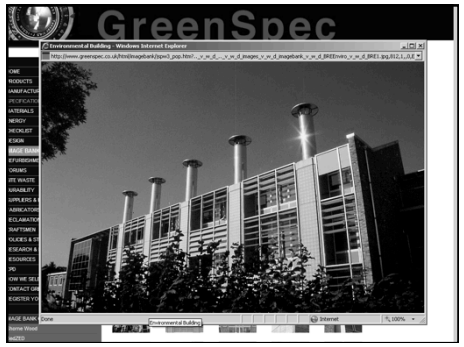
- Chimney stacks are a route from the building interior to exterior at high level
- With a source of heat at the base the warmed less dense air will be buoyant and rise to high level
- Cooler air will be drawn in to replace the warmed air leaving by the chimney
- Once the flow is started this effect is self propelling
- A venturi throating makes this irresistible
- This is called the stack effect and it can be exploited in designs to ventilate buildings

Stack effect Brick Kilns: Often lime making in widespread cottage industry

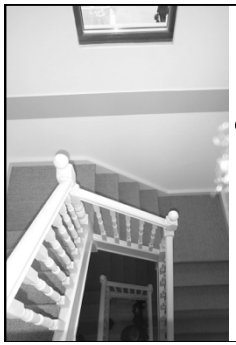
Chimneys use stack effect

Cooling Towers: stack effect but not to be confused with building ventilation

Chimneys are part of UK history and a part of our culture



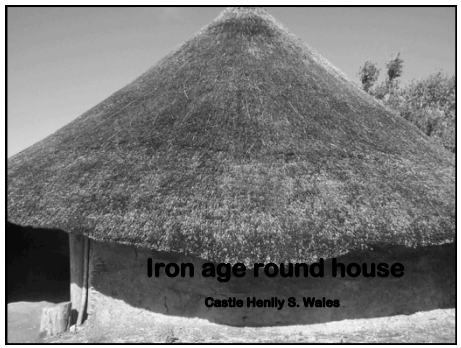
Stack Vents to car parking



Staircase void can play its part in the stack effect
Need air in at bottom and air out at top

Roof lights, windows & vents

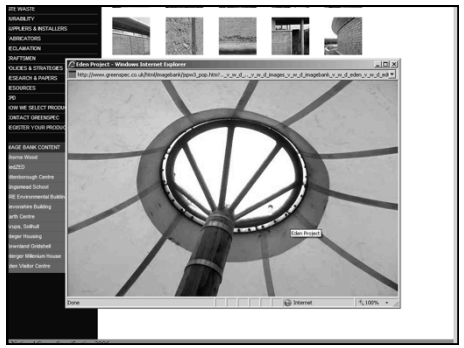
- High level rooflights are an essential part of passive ventilation using the stack effect without the chimney
- They need to be well insulated to minimise winter heat loss
- They are best controlled to ensure optimum performance: i.e. once a temperature is reached then open to get the stack effect off to a good start

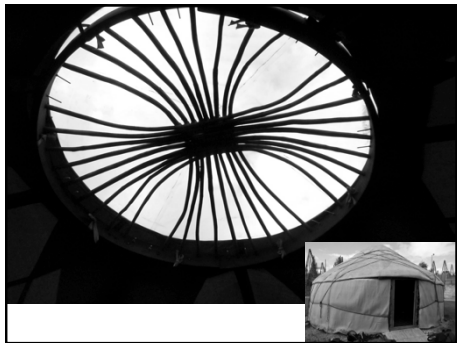


Iron age round house

Castle Henlly S. Wales

Perimeter ventilation, cooking and heating fire and vented apex



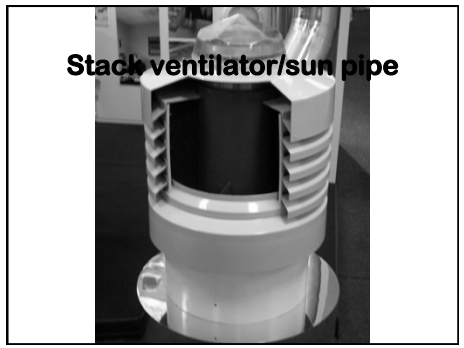


Humidity Actuated Vents

- Passivent closed normally
- Humidity sets off vent to open and release air
- Using stack effect the humid hot air rises up the vent pipe to evaculate at high level externally

Sun Pipes & Passive Vents

- Sunpipes bring daylight and sunlight to the interior of building with no windows
- Add concentric ventilation duct
- Include valves
- But heat recovery from ventilation not normally available
- Modern substitute for the light well and chimney



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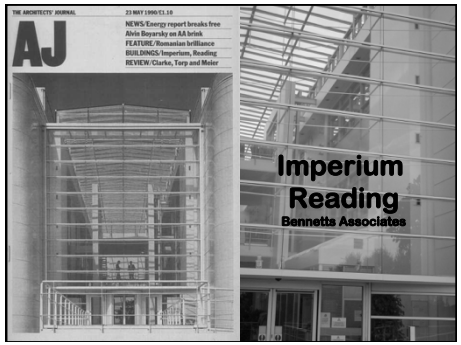
Atrium & Atria

Atrium

- Atrium could be described as Courtyard with roof
- They provide the usual wind shelter, some sun penetration and added opportunities:
- The help to minimise the heat loss from walls that face the courtyard by preventing the rising heat being lost to the sky
- They allow those walls to be open to the atrium
- The Atrium may also include walkways and balconies adjacent to the atrium
- There will be implications for fire strategy of building
- They may have smoke vents at high level and replacement air vents at low level
- These may act as cooling vents in hot weather



Imperium Reading
Bennetts Associates

Atrium, Left: offices, Right: Open Plan
Devonshire Building Newcastle

Sometimes Lift Cars add to air movement

or lift shafts lose heat via permanent vents

Atria in 3 parts
helix at the edge of the building
In 3 zones
7 stories each.
Casements in façade or in pavement

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Solar Orientation & Solar Gain

Face the sun and capture free energy

Solar Orientation: Northern Hemisphere

- Easterly early morning sun rise
- Southern sun at the peak of the day
- Westerly evening setting sun
- Northerly sky is source of good daylight in the day

Solar orientation: Buildings

- Face Housing at sun to collect the heat
- Morning sun for waking
- Avoid sleeping rooms heating in afternoon and evening
- Offices generate heat so do not need to face the sun

Solar shelter: Landscape Trees

- Local trees, hedges and bushes can have a solar shading effect on a building
- Deciduous trees to the east, south and west, coniferous to the north
- In winter with leaves dropped sun passes through trees and low angle penetrates deep into the building
- In summer the high angle of the sun offers some shelter if solar shading is available

Wind shelter: Creepers & Vines

- Offer some protection form heat of sun
- Create a micro-climate sheltering the wall
- Shelter from rain, wind and sun
- Haven for insects, spiders, bugs, birds

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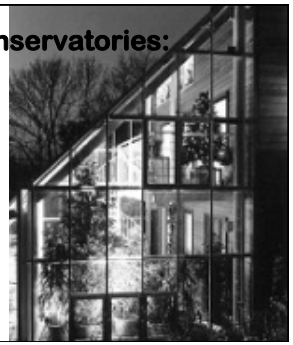
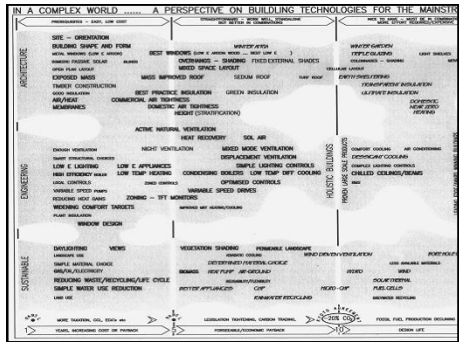
Conservatories

B12 Conservatories

Source of free heat

Conservatories:





Green Houses & Conservatories: Summer

- Glass permit the passage of the rays from the sun to warm the interior
- This can be released in summer by ventilation
- Victorians understood the need for opening vents in the roofs to release the heat in the summer, high enough to exploit the stack effect, catch any breeze and ensure heads do not cook.
- Most PVC conservatories only have windows in the sides, a real problem

Zero Energy Development

Reduce demand for artificial light and heating: Outdoor living Conservatory life sunny warm cave to retreat to in the cold of night

HHP Hockerton Housing Project, Newark, Nottinghamshire

Hot house
in the middle
of winter
Ventilation
for summer
No heating
Solar gain
Exposed
thermal mass
Windows and
Doors to house

Hockerton & BedZED

- Conservatories are double glazed and Low Emissivity coated to allow the heat in, prevent it escaping and trap the heat for use
- Doors and windows from conservatory to house are triple glazed Low E for the same reason
- The doors and windows are closed not letting any heat from building out into conservatory
- Until the conservatory is hot enough then windows and doors are opened to let a burst of heat into the building to heat up the fabric

Green Houses & Conservatories: Winter

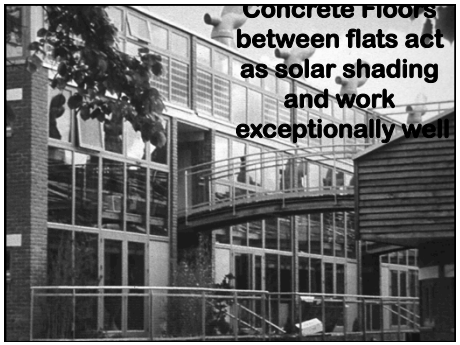
- Glass permit the passage of the rays from the sun to warm the interior
- Close all opening vents, doors and windows capture the heat
- This can be exploited in winter
- Grow plants that would otherwise perish

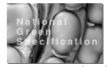
Green Houses and Conservatories: Winter

- Thermal mass is where the construction materials are usually dense, close to the surface have large surface area, can absorb and store heat
- Conservatories can capture heat in sunny but cold weather
- Intelligent use of thermal mass in floors and rear walls can exploit the captured heat by storing it and saving it until the sun has disappeared and release it to warm the occupants of the conservatory.

Lean-to Conservatories: warm the house

- Once a conservatory attached to a building is warmed
- it can than be used to heat the interior of the attached building by opening doors and windows between them to let the heat into the building
- The building' s thermal mass can be warned and heat stored for release into the building later after the sun has gone





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Hockerton HHP

Conservatories

Zero Energy Development

Reduce demand for artificial light and heating:

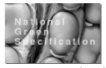
Outdoor living

Conservatory life

Sunny warm cave to retreat into From the cold of night

Hockerton Newark Nottinghamshire

Hot house
in the middle
of winter



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BedZED

Conservatories

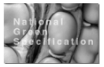
Zero (Fossil Fuel) Energy Development

BedZED Beddington Sutton Architect: Dr Bill Dunster

Profile:
to ensure sun penetration
over roofs reaches sill
of office space windows
Sun rooms on south side
thermally massive floors walls
and roofs store heat until required

Sunroom on
South face
captures the sun

Heavy
building
elements
store the heat
and release it
later



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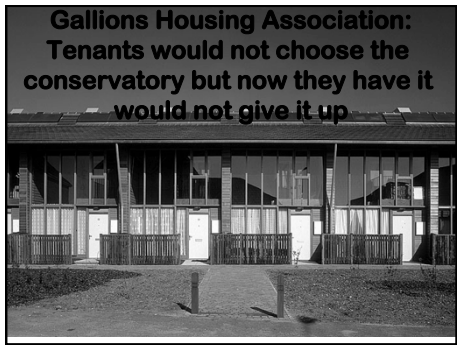
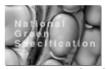
Gallions HA

Conservatories



Gallions Housing Association:
Tenants would not choose the
conservatory but now they have it
would not give it up



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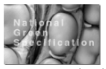
National Botanic Gardens of Wales

Glass roof

Glass Roof: gain & loose heat

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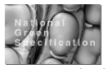
In the real world

Conservatories gone wrong

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Conservatories Gone Wrong

In the real world

Conservatories gone wrong

- **Heated Conservatories (why not Solar?)**
- **Radiant Heated Conservatories (under floor heating) radiates heat out of glass**
- **Electrically Heated Conservatories (++ +CO_2)**
- **Conservatories open to remainder of building (Heat gain or heat loss)**
- **Conservatories without ventilation (over-heating)**

No hope then

- 90% of UK conservatories have heating installed
- In terms of fuel use they are like a gushing tap over a gulley
- Significant number have no doors or windows to separate from the rest of the house
- Despite the Building Regulations


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GLA Head Quarters

North Facing Conservatory

North facing conservatory

Conservatory Gone Wrong

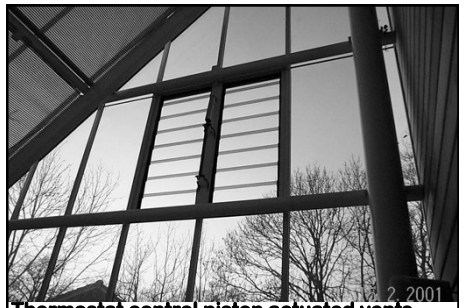
- **No boundary between conservatory and accommodation beyond**
- **No thermal mass wall or floor to hold the heat**
- **No entry or exit ventilation in glazed roof**
- **No Solar shading (externally is best)**
- **Tenant fitted Air Conditioning**

1NTEGER @ BRE Intelligent & green

Not very intelligent Conservatory:
Secure all-weather garden
single glazed and double to house but open at top floor
Some solar shading, some planting

1NTEGER house conservatory at BRE is not all that it could be
Single glazed
No thermal mass back wall, open to living accommodation on top floor.
Just sheltered out door space

Opening vents in side walls of conservatory but only half way up the height of the conservatory



Thermostat control piston actuated vents
Thermostat at high level? Vents at mid level

Doors: provide low level ventilation
Windows: none at top
Internal solar shading: internal radiant heating & thermal stress

Solar Thermal ET for Hot Water
Roof window & minimal PV

Rainwater: collection and disposal?
Any Harvesting and reusing?

Internal Solar shading
No Thermal Mass on rear wall
Some thermal mass on floor

Top floor open to hottest part of conservatory

Internal solar shading: catches solar radiation heats up and re-radiates heat inwards. Energy efficient light fittings?

Top floor open to conservatory and no ventilation at high level

Bedrooms face South
& open onto the warm conservatory

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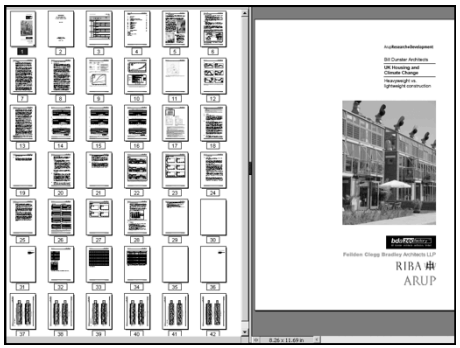
Thermal Mass

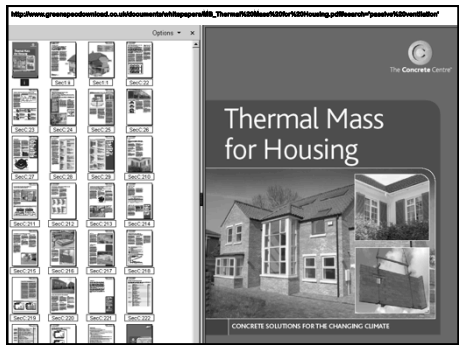
Ventilation, warmth and coolth

High Thermal Mass at surfaces
fairfaced brick, block and plank

Heat movement in buildings

- ARUP/B Dunster Report on need for Thermal mass in buildings to cope with climate change global warming
- Recommend internal doors are self closing to hold heat energy where it is created or collected
- All partitions to be insulated
- Then actively move heat wherever you may want it or leave it where it is





Exploiting thermal mass

- If the building has high thermal mass and its surfaces are exposed
- they can be exploited in both heating and cooling
- In winter the mass can be heated in the day the heat stored for exploitation in the night
- In summer the mass can be cooled in the night and exploited in the day

Thermal mass

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- Large surface areas are best
- Thickness closest to surface is used in daily cycles,
- Full thicknesses and more used over annual cycles
- Higher density material is best
- Exposed to the space not hidden above ceilings or below floors
- Exposed to the sun's rays is good
- Embedded pipes can be exploited to move warmth and coolth around building or into storage

15/03/16 © NGS 2004-7 Air Movement In Buildings 281

Hollow core floors

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- Product Reference: Termadeck
- Precast concrete plank floors with hollow cores and pathway through cores
- Connected to ventilation system
- Cooling from the inside out

15/03/16 © NGS 2004-7 Air Movement In Buildings 282

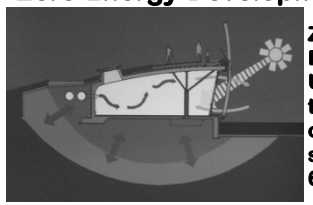
Overnight Purge Cooling

- By passively cross ventilating a building during the summer nights
- the exposed building mass can be purged the of its heat and cooled
- This allows the occupants arriving in the morning to benefit from the added coolth
- As the day warms the mass will absorb heat given off by the people and computers, etc.
- Helping keep the building lower than ambient temperature to the benefit of occupants

Inter seasonal thermal storage

- Remove collect solar energy and store it over year cycled
- Remotely in rock or salt thermal stores
- Transferred by piped liquid
- Or remove thermal insulation under and behind building and sun will heat floor and then earth below
- The heat will store for 6 months and then warm the building for 6 months

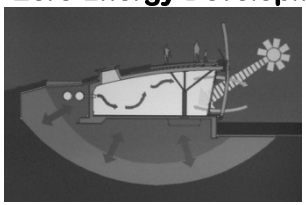
Zero Energy Development



Zero Energy Development Use of thermal mass of earth to store heat for 6 months

Mile End Road Park

Zero Energy Development

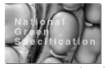


Heat transfer in soil 1m/mth 6m insulation boards at perimeter 6 months of heat storage

Mile End Road Park

ZED Z[illegible]ments

Another NGS CPD seminar to consider



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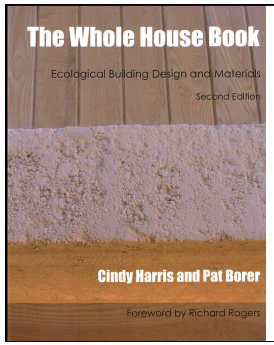
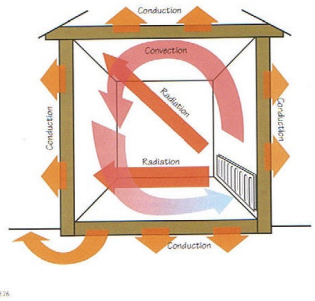
Conduction
Convection
Radiation
Conduction



Publisher: CAT Centre for Alternative Technology Publications
2nd edition
ISBN: 1-90217-522-0
£35 (worth it)



Rammed Earth @ CAT

Convection 'Radiators'

- Radiators use conduction to bring the heat to the surface,
- Radiation to push some of the heat into the surrounding air
- Convection to push the warmed air upwards to circulate and warm the room
- Matt black radiators radiate more but still convect most of that heat
- Hot air rises, cool air displaces it

Losses behind Convection 'Radiators'

- Un-insulated solid external walls offer an easy way to heat the sky
- There are multilayer fabric insulation sheets and moulded plastic reflector sheets available
- install on the wall behind the 'radiator'
- Reflect more heat to allow convection to be more effective

'Radiators' in washrooms

- Never position radiators (convectors) under warm air hand dryers
- The combination of water droplets and warm air with break down the protective paint rapidly
- and the 'radiator' will rust easily

Radiators and Windows

- Traditionally we have fitted radiators under windows
- To warm the incoming cold air
- And warming the radiant coolth
- But we end up heating the external air and sky
- If hot air is escaping it wont be noticed
- Consider better insulated windows and trickle vents
- Position radiator away from windows
- If too much cold air is entering, it will be noticed and windows will be shut

Temperature Gradients

- Radiators use convection to warm air in spaces, warm air rises and cool air falls
- This creates temperature gradients in the spaces cool at your feet and warm at your head
- Cold feet may make you feel cold and hot head may make you feel hot
- Heat loss through high level windows and vents

Radiant Heating

- Available in ceiling, walls and floors
- Ceilings usually electric (avoid)
- Walls and floors usually piped hot water
- Low temperature compared to radiators (convectors)
- Radiate heat at objects in the space to warm them directly
- They in turn may radiate heat too
- No heat gradients

Underfloor Radiant Heating (URH) and GSHP or ST Panels

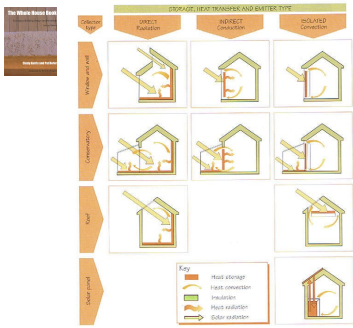
- Radiant heating uses low grade heat
- LG Heat available from Ground Source Heat Pumps (GSHP) and Solar Thermal (ST) panels.
- And from modulating boilers designed to work with URH
- Some under-floor heating pipes can also be used for cooling

Exploiting Solar Gain

- Thermal mass can be positioned to exploit solar gains
- It can then be exploited to use the stored heat to warm the building once the sun has gone
- Many configurations are possible using conduction, radiation and/or convection

Bill Dunster & Solar Penetration

BedZED Beddington Sutton



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Solar Shading

Used to shade or permit sun passage

Solar shading: Common in mainland Europe Will become more important in the UK if only we knew how

100% glazed façade requires 100% air conditioned office

Operational Energy

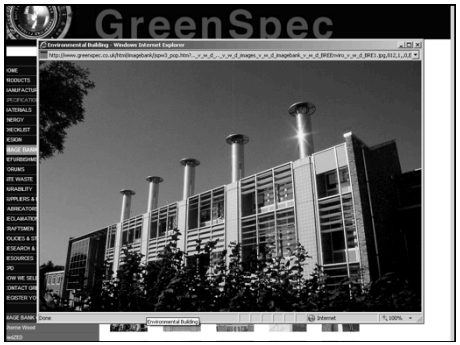
Passive solar control avoids mechanical ventilation and air-conditioning in summer

City Place, Gatwick

Wessex Water

Solar shading on west & north faces

just the same, but sun paths different



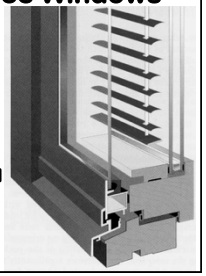
External Solar Shading: Roller Blinds

Internal solar shading: catches solar radiation heats up and reradiates heat inwards. Energy efficient light fittings?

Top-floor open to conservatory and no ventilation at high level

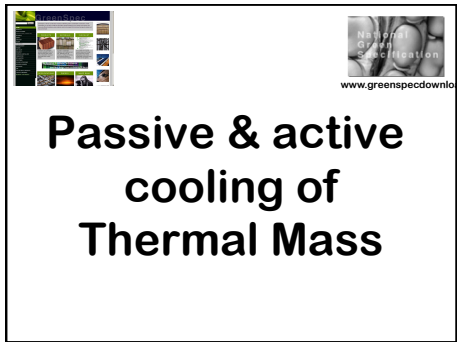
High Performance Windows

- Aluminium outer casement
- Timber inner casement
- Treble glazed
- Dust free sun blinds
- Can still absorb heat and radiate heat inwards
- Can also set up thermal stress in glass

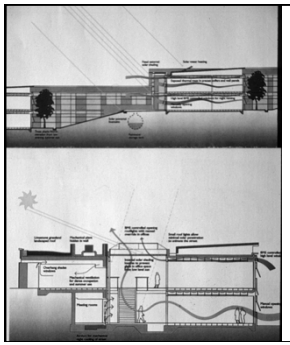


Solar Shading: Trees

- Trees also create shelter from the sun in the summer
- Deciduous trees drop leaves in autumn and allow sun to pass in the winter
- Trees can protect from summer solar gains and permit winter solar gains
- Solar gains can be manipulated to create internal air movement and exploited thermally

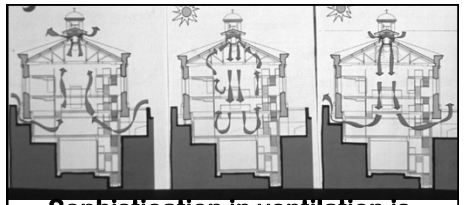


Passive & active cooling of Thermal Mass

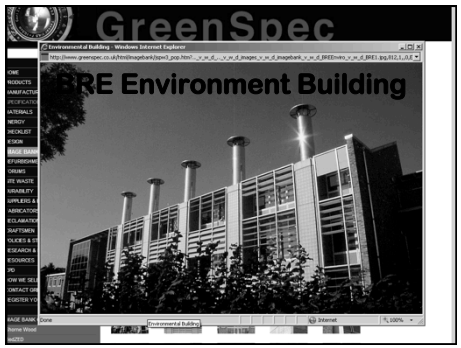


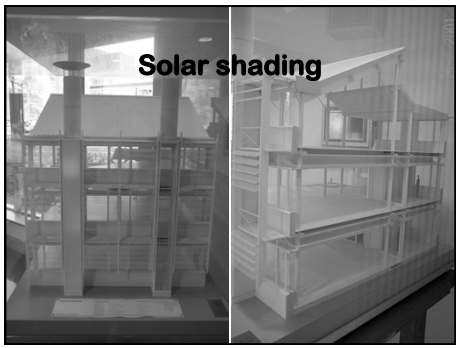
Wessex Water: Bennetts Associates

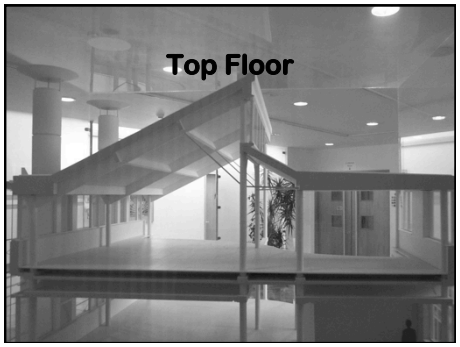
Cross ventilation or cooling via atrium

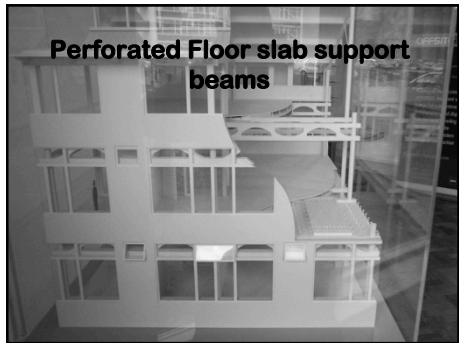


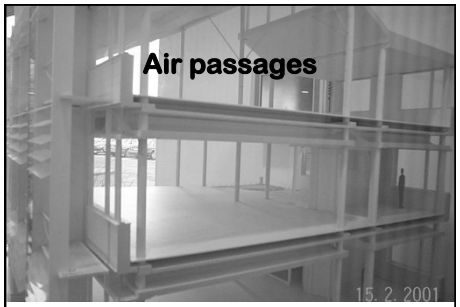
Sophistication in ventilation is possible with controlled vents

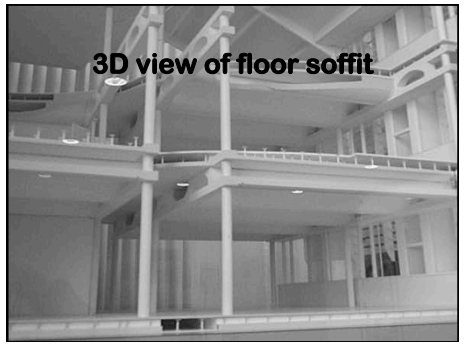


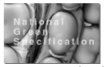












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Fluid Dynamics

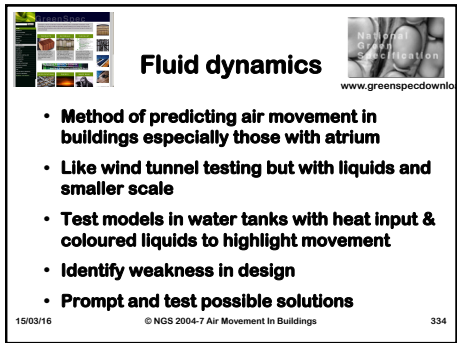
Understanding how a building works or solving problems that arise

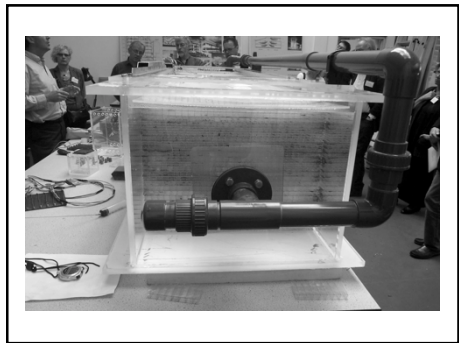
Conventional Mechanical Engineers

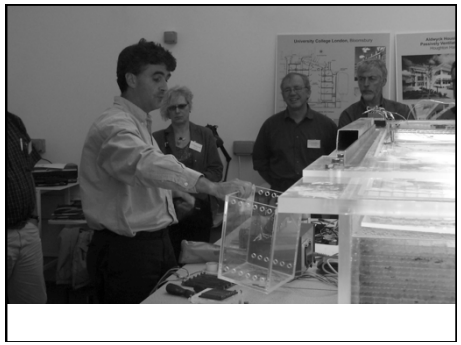
- Do not understand: passive ventilation stack effect and what can go wrong
- They are actively discouraging these techniques
- And opting for the safe understood mechanical ventilation, heating and cooling or air conditioning
- So prove the design first

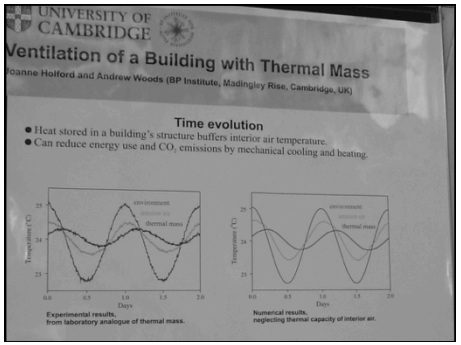
Computer simulation

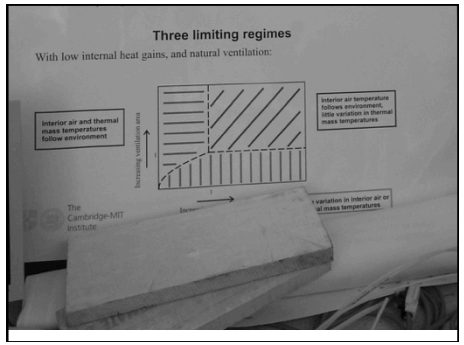
- This is possible
- but there have been examples of computer simulation not working in reality

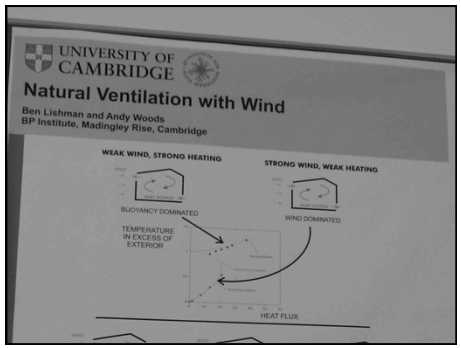

Fluid dynamics
www.greenspecdownlo
• Method of predicting air movement in buildings especially those with atrium
• Like wind tunnel testing but with liquids and smaller scale
• Test models in water tanks with heat input & coloured liquids to highlight movement
• Identify weakness in design
• Prompt and test possible solutions
15/03/16
© NGS 2004-7 Air Movement In Buildings
334

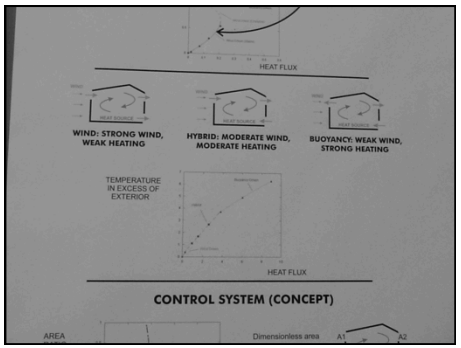


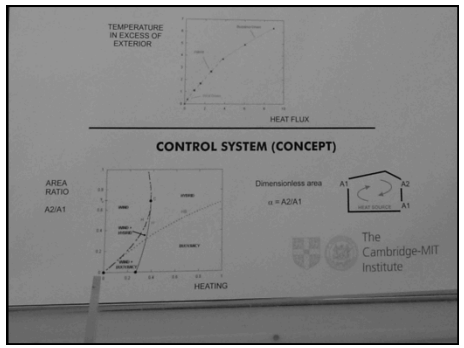


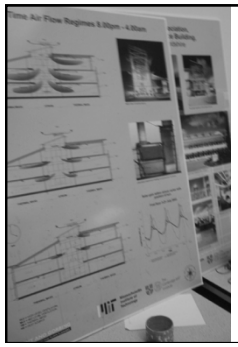

UNIVERSITY OF CAMBRIDGE
Ventilation of a Building with Thermal Mass
Joanne Holford and Andrew Woods (BP Institute, Madingley Rise, Cambridge, UK)
Time evolution
● Heat stored in a building's structure buffers interior air temperature.
● Can reduce energy use and CO2 emissions by mechanical cooling and heating.
Experimental results, from laboratory analogue of thermal mass.
Numerical results, neglecting thermal capacity of interior air.


Three limiting regimes
With low internal heat gains, and natural ventilation:
Interior air and thermal mass temperatures follow environment
Interior air temperature follows environment, little variation in thermal mass temperatures
The Cambridge-MIT Institute

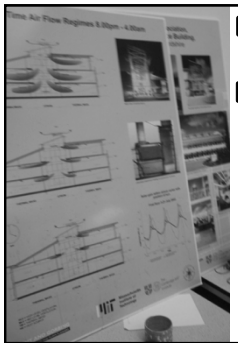

UNIVERSITY OF CAMBRIDGE
Natural Ventilation with Wind
Ben Lishman and Andy Woods
BP Institute, Madingley Rise, Cambridge
WEAK WIND, STRONG HEATING
STRONG WIND, WEAK HEATING
BUOYANCY DOMINATED
WIND DOMINATED
TEMPERATURE IN EXCESS OF EXTERIOR
HEAT FLUX


HEAT FLUX
WIND: STRONG WIND, WEAK HEATING
HYBRID: MODERATE WIND, MODERATE HEATING
BUOYANCY: WEAK WIND, STRONG HEATING
TEMPERATURE IN EXCESS OF EXTERIOR
HEAT FLUX
CONTROL SYSTEM (CONCEPT)
AREA
Dimensionless area

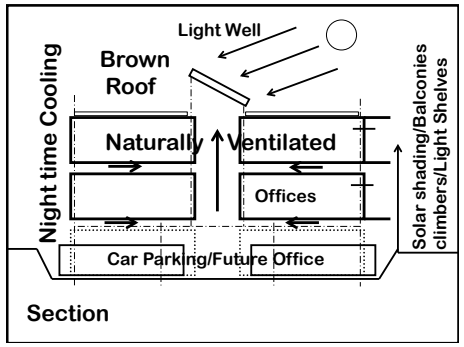

TEMPERATURE IN EXCESS OF EXTERIOR
HEAT FLUX
CONTROL SYSTEM (CONCEPT)
AREA RATIO
A2/A1
Dimensionless area
α = A2/A1
HEATING
The Cambridge-MIT Institute

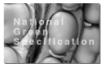


Lower floors can ventilate into atrium blocking upper floor air upper floor over heats.
More window ventilation on upper floor can over come this.



Lower floor can short circuit back into upper floor not into atrium, feeding hot stale air to an already hot stale space





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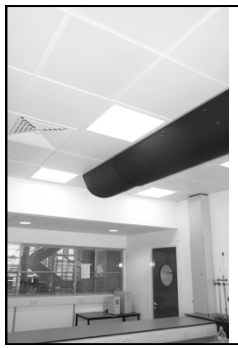
Mechanical Ventilation

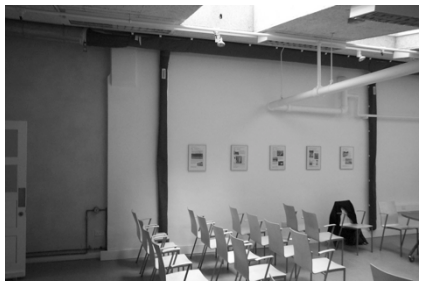
Mechanical Ventilation

- If open windows are not practical
- E.g. Urban traffic noise
- E.g. Agricultural smells
- E.g. Sea Breezes too strong
- Push cool fresh air in distribute at floor level
- Displaces hot air that moves up out of its way
- Draw hot stale air out

Atrium & Mechanical ventilation



Fabric Ducting
Air permeable
Distributed widely
No concentrated drafts

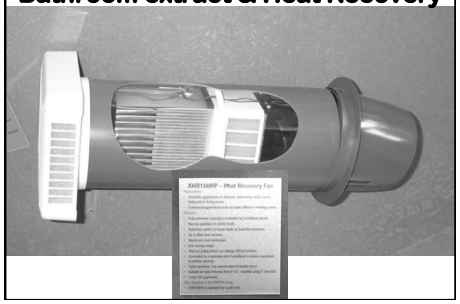


Laboratory Cabinet Extraction of hazardous chemical gases and products of combustion

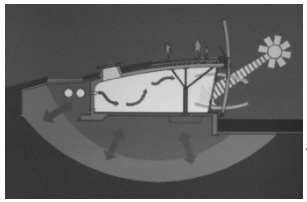
Mech Vent with Heat Recovery

- Hot stale air is pushed out of the building but that waste heat energy
- Cold fresh air is drawn in and it takes energy to warm it
- Steel the heat out of the outgoing air
- Transfer it to the incoming air
- Heat exchanger in a cross over chamber where the two air do not mix but pass through many thin walled ducts
- Duct walls are low insulating, transparent, conductive, plastic skins 1 – 2 mm. thick.

Bathroom extract & Heat Recovery



Zero Energy Development

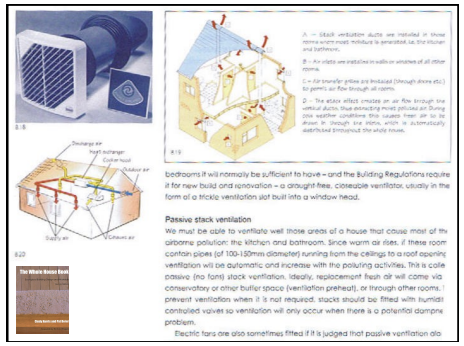


Mile End Road Park

Heat exchange into rear earth from pipes, air flow is reversed to draw the heat out again

Whole House Ventilation

- At Hockerton HHP bungalow
- one pipe in, one pipe out, valves along length to each space
- 225 mm. dia clay pipe, flexible joint, hung from soffit over corridor space
- 100 watt fan with heat recovery.
- Efficient fan essential,
- Airtight building essential
- Heat recovery essential
- More complicated in 2 storey house

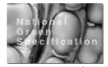


bedrooms it will normally be sufficient to have – and the Building Regulations require it for new build and renovation – a draught-free, closeable ventilator, usually in the form of a trickle ventilation slot built into a window head.

Passive stack ventilation

We must be able to ventilate well those areas of a house that cause most of the airborne pollution: the kitchen and bathroom. Since warm air rises, if these room contain pipes (of 100-150mm diameter) running from the ceilings to a roof opening ventilation will be automatic and increase with the polluting activities. This is calle passive (no fans) stack ventilation. Ideally, replacement fresh air will come via conservatory or other buffer space (ventilation preheat), or through other rooms. prevent ventilation when it is not required, stacks should be fitted with humidst controlled valves so ventilation will only occur when there is a potential dampne problem.

Electric fans are also sometimes fitted if it is judged that passive ventilation alo



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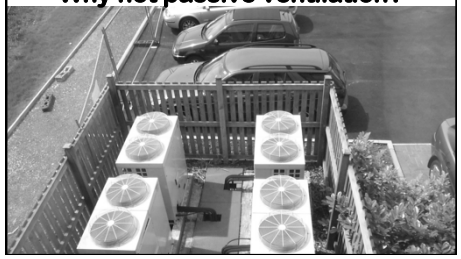
Air-conditioning

Avoid if possible

Air Conditioning

- Avoid at all costs (shoot the letting agent)
- Design walls, glazing, solar shading to not need air conditioning
- But if you have to have it (e.g. Art gallery)
- then use Green Tariff Electricity or PV
- link to Ground Source Coolth Pumps
- Switch from air-conditioning to ventilation when A-C is not needed.

Air conditioning of inadequately insulated buildings: Rural areas Why not passive ventilation?



Air conditioning of inadequately insulated buildings adding to the heat island effect of cities. push heat out below open windows!

Comfort conditions

- Bankers in the city on dealer floors
- 8 computers each emitting heat under desk
- Heat rooms then need air conditioning
- Cold head and hot legs
- Flaking by the end of the day
- Need Champaign showers to cool off