
CMHC Healthy House, Toronto

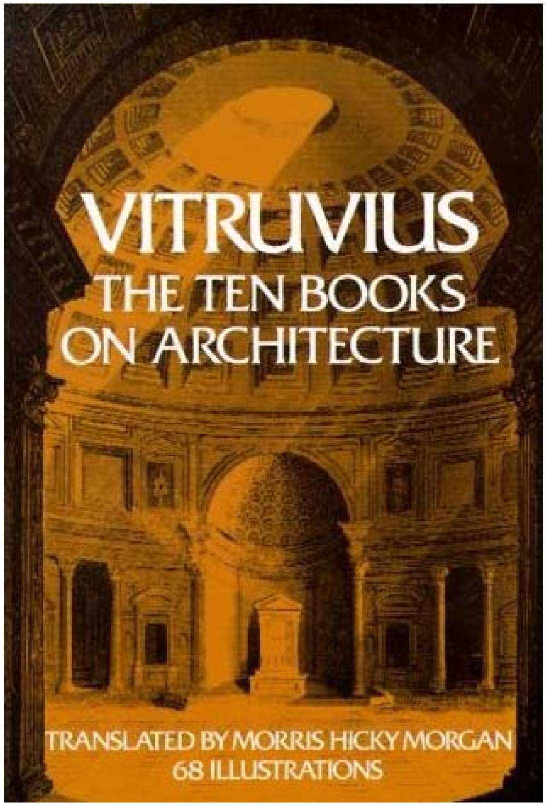
Introduction to Building Science

Arch 172: Building Construction 1

From Vitruvius to the present:

A building must satisfy several general requirements. It must be:

- **safe** in respect of structure, fire and health
- **economical** in initial cost and operating cost
- **aesthetically** pleasing,
- **inoffensive** to the senses and an aid in sensory tasks.



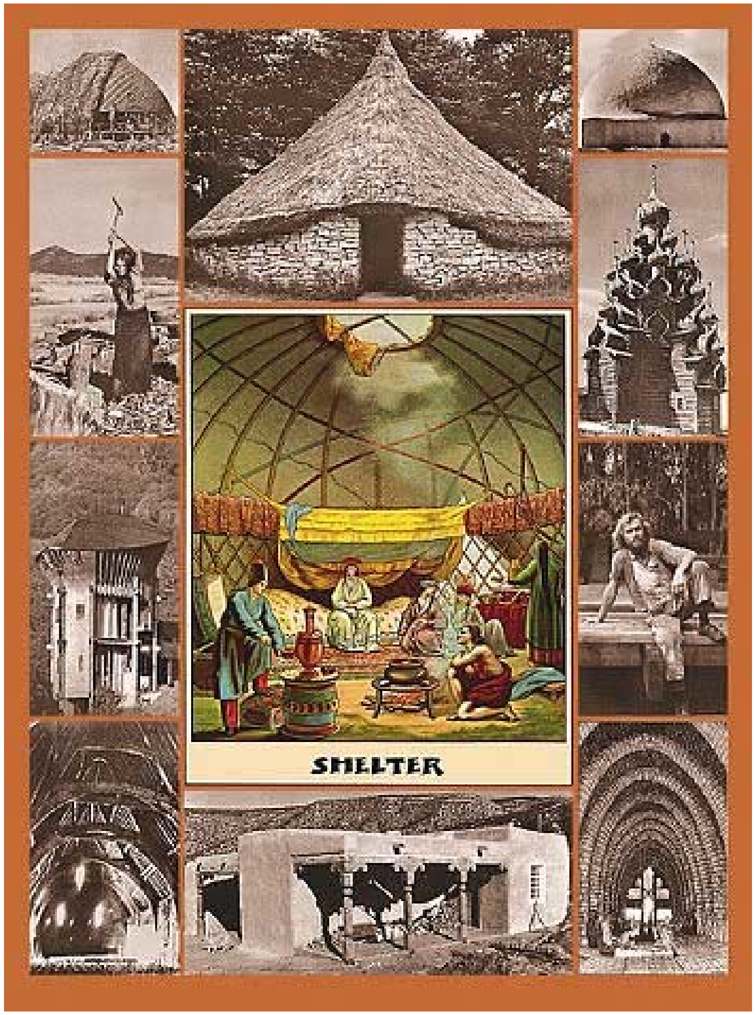
Vitruvius' version was
"strength, utility and aesthetic effect"

Building as shelter…

From the beginning of time, people have created buildings to give them shelter from the elements.

Buildings used "vernacular" climate responsive methods to protect from sun, wind and precipitation using natural materials and simple construction methods.

Even in 2013, the basic objective of building construction remains essentially the same.



Low technology shelters

Simply put. In Western “civilized” culture, providing *shelter* is no longer enough. Modern buildings must endure the contemporary person’s needs for comfort, separation from outside elements, and accommodation of more demanding daily activities.

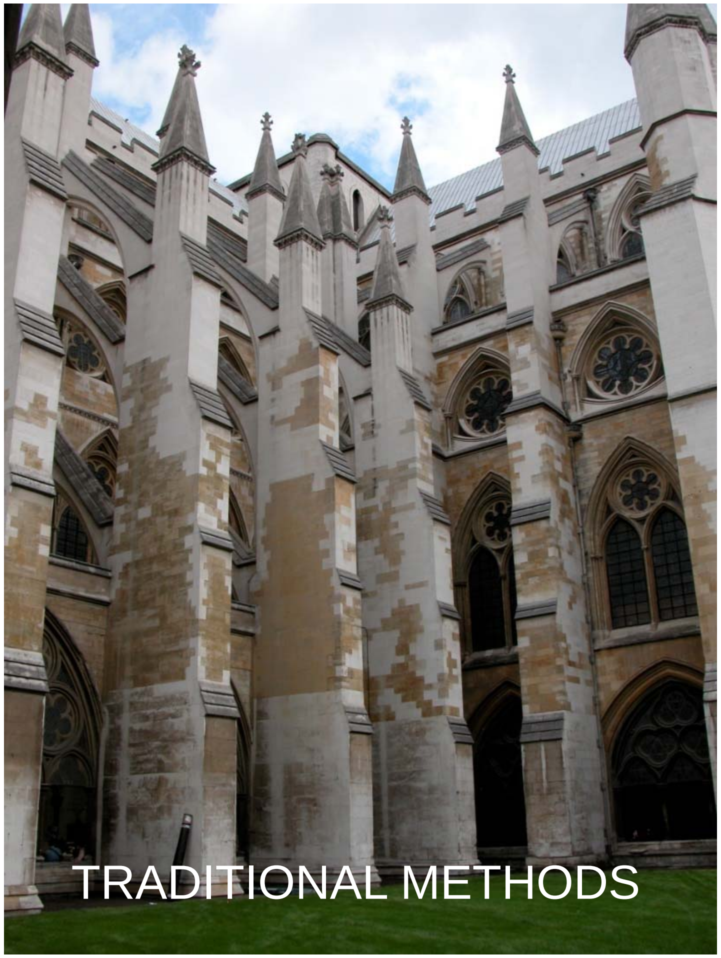
High Performance Buildings

Greater London Authority, Norman Foster

These buildings also have “thin skins”. But nowadays, people expect an awful lot MORE PERFORMANCE from their buildings – as technological symbols and cultural icons. *Shelter is just not enough.*

Channel 4 News, London, Richard Rogers

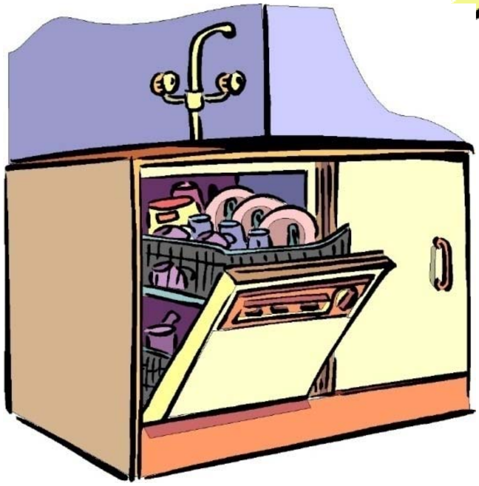
Technique vs. Technology



Old stone buildings relied on their massive nature to withstand the weather. New buildings are comprised of thinner layers, that are individually less able to withstand the elements.

Additional pressures on modern buildings

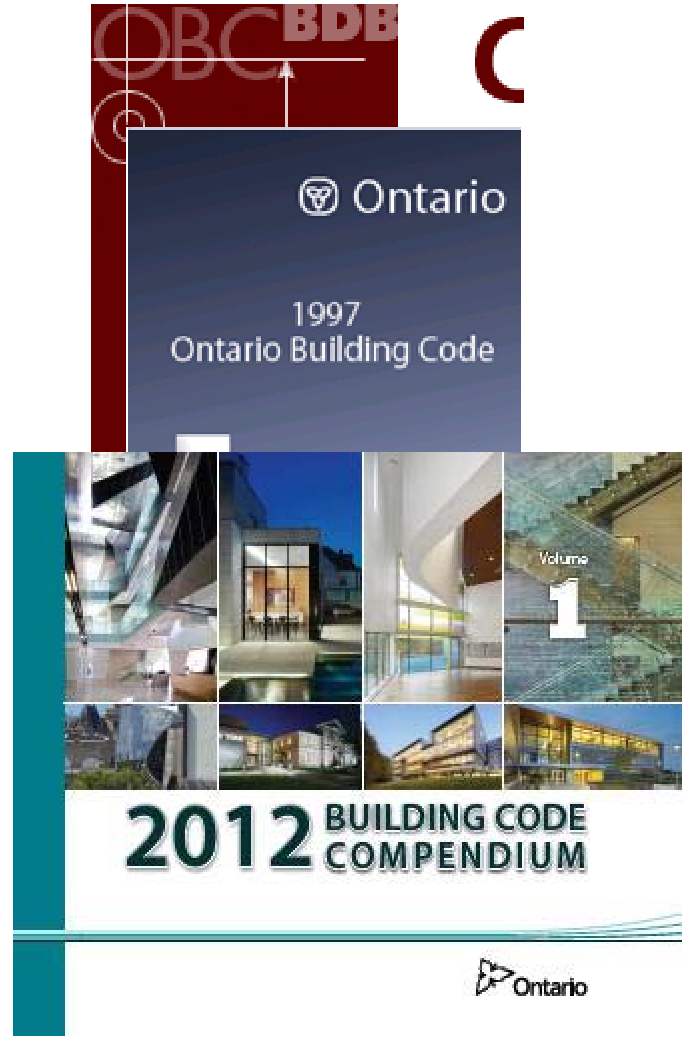
The “*clean”* lifestyle puts high amounts of moisture into our interior environments that are pressure fed through the walls by high temperatures and deteriorate the envelope on their way through.



Safety:

To achieve safety it must provide:

1. structural strength and rigidity
2. resistance to initiation and spread of fire
3. control of air and water quality and means for waste disposal



Economy:

To achieve economy it must:

1. be well matched to its purpose
2. have durable materials and components
3. have reasonable maintenance and operating costs

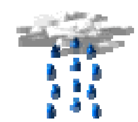
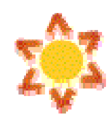
Inoffensive:

To be inoffensive and an aid in sensory tasks it must provide control of:

1. odors
2. light
3. sound vibrations

Environmental Moderator:

To function as a moderator of the environment and to satisfy all other requirements, it must provide control of:

1. heat flow 
2. air flow 
3. movement of water as vapour and as liquid 
4. solar and other radiation 

Building envelopes are like balloons…

Building envelopes are like balloons… very thin but their performance is critical!

Performance failure…

Just like the balloon, if the envelope is compromised or punctured, it does not work very well.

Balloons and (cold climate pressurized) buildings both have high pressure on the inside that DRIVES the air inside the building to ESCAPE to the outside.

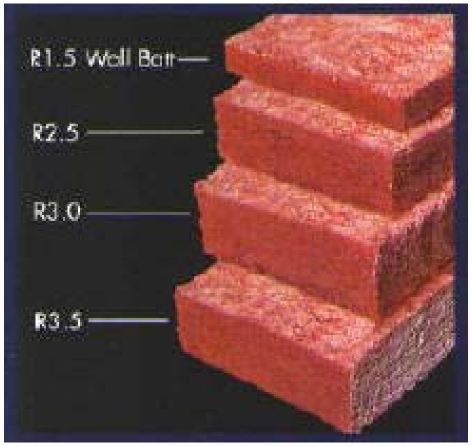
The building envelope is like a fur coat…

Fur was one of the first materials used to provide protection from extreme cold.

It works because it traps air between the hair, providing "insulation" from heat loss to the cold outside.

Insulation is the "fur coat" for buildings…

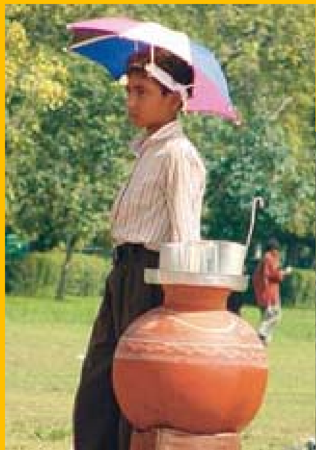
Different types perform different ways, as a function of their materiality and thickness. *More is more…*



Buildings must provide shelter from rain

A roof is like an umbrella...

And we like BIG umbrellas as they provide better protection against rain because they overhang our body more.

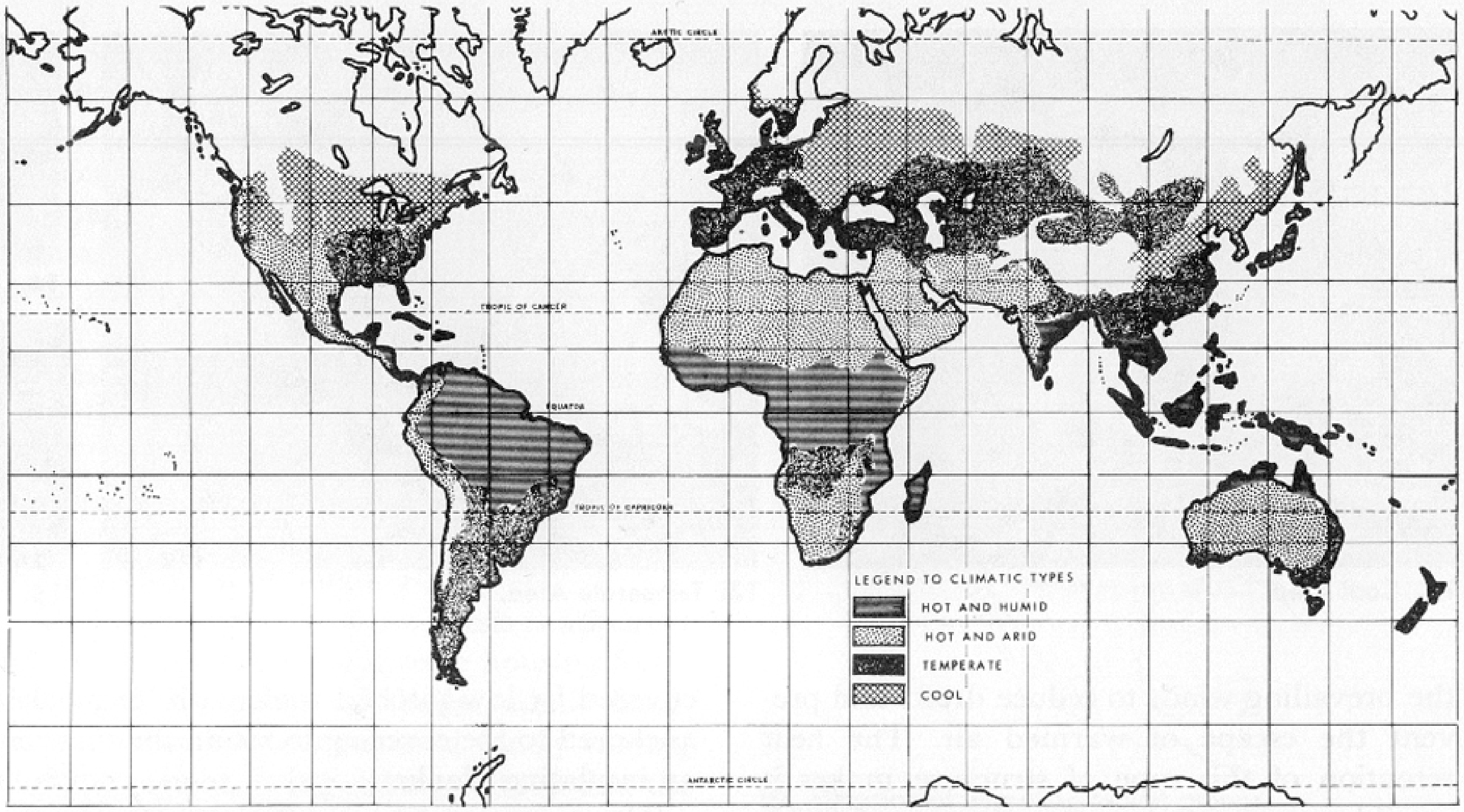


Why does this man look happy? Because he has a BIG umbrella!

The size of a roof overhang…

The purpose of the roof overhang is to shed rain / snow from the roof. If it does not project adequately beyond the face of the building, water will drain down the face of the building, bounce in the dirt around the foundation, and cause wetting issues. *Flat roofs normally provide NO overhang so offer NO protection for the walls of a building.*

Different climates around the world

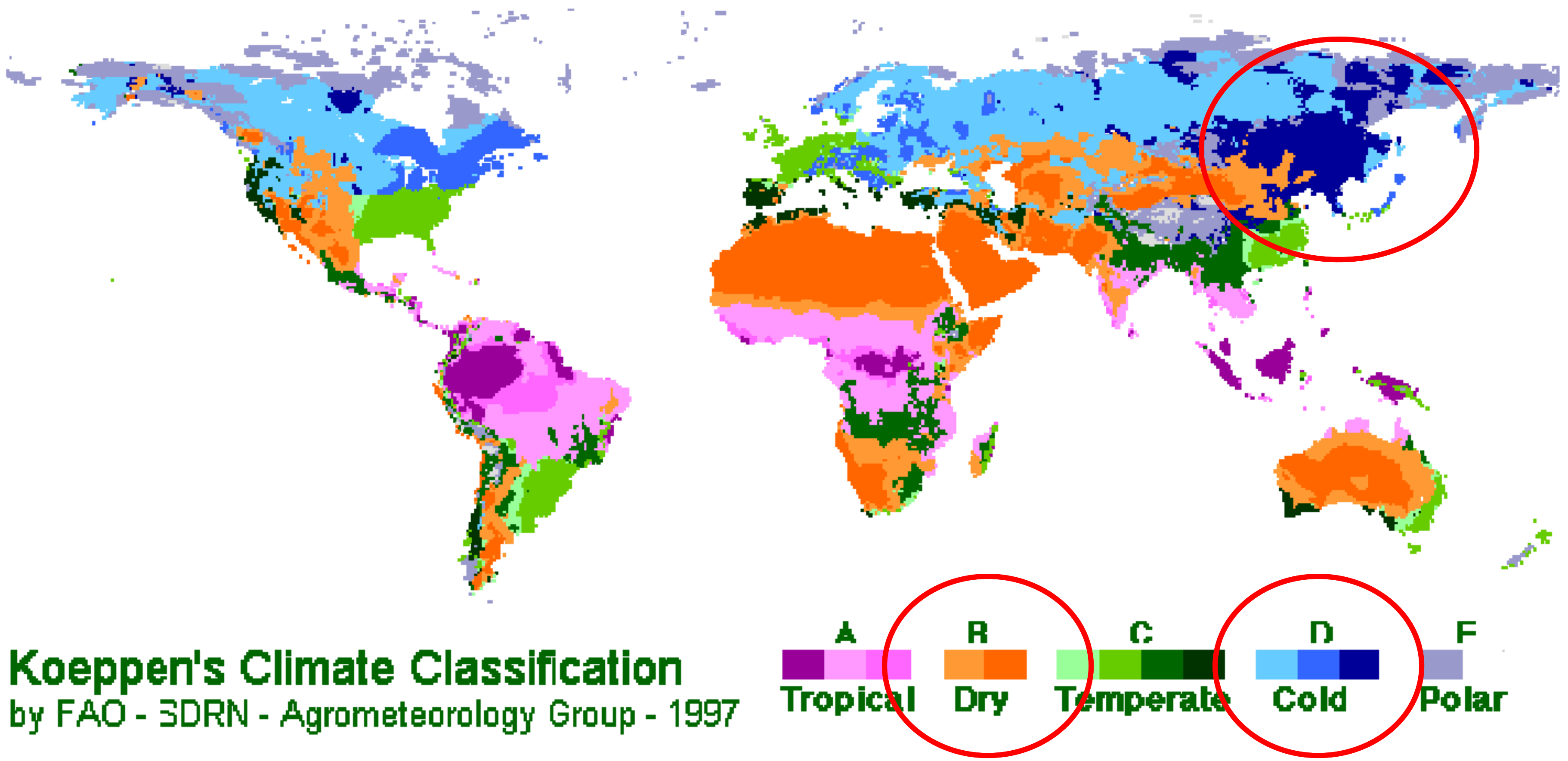


16. Climatic zones.

Operating Energy

Global Bio-climatic Design:

•Envelope design must first acknowledge regional, local and microclimate impacts on the building and site.



ENVELOPES FOR DIFFERENT CLIMATES ARE DIFFERENT!

Bio-climatic Design: HOT-ARID

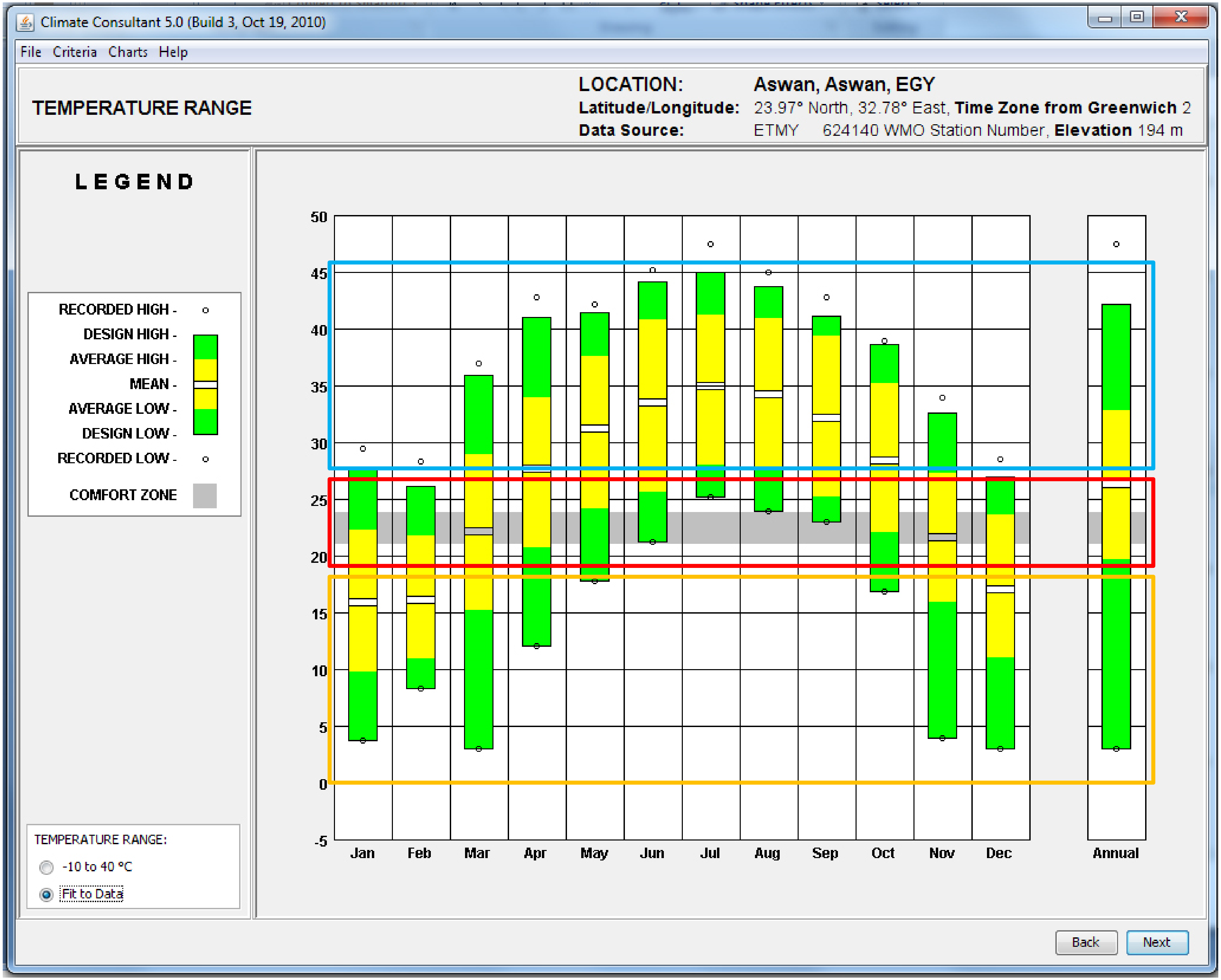
• Where **very high summer temperatures** with great fluctuation predominate with **dry conditions** throughout the year. **Cooling degrees days greatly exceed heating degree days.**

•

RULES:

- SOLAR AVOIDANCE: keep DIRECT SOLAR GAIN out of the building
- avoid daytime ventilation
- promote nighttime flushing with cool evening air
- achieve daylighting by reflectance and use of LIGHT non-heat absorbing colours
- create a cooler MICROCLIMATE by using light / lightweight materials
- respect the DIURNAL CYCLE
- use heavy mass for walls and DO NOT INSULATE

Traditional House in Egypt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TEMPERATURE RANGE
LOCATION: Aswan, Aswan, EGY
Latitude/Longitude: 23.97° North, 32.78° East, Time Zone from Greenwich 2
Data Source: ETMY 624140 WMO Station Number, Elevation 194 m
LEGEND
RECORDED HIGH -
DESIGN HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
DESIGN LOW -
RECORDED LOW -
COMFORT ZONE
TEMPERATURE RANGE:
-10 to 40 °C
Fit to Data
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Traditional hot climate design:

In hot dry (arid) climates windows are kept to a minimum to prevent the sun from entering the building. Bright stucco finishes are used to reflect light and keep the environment bright.

Courtyard buildings:

Courtyards are used in hot arid climates and work well because sun can warm these spaces in cooler months.

Courtyards do NOT work well in cold climates because of low winter sun angles.

Hot climate cathedrals:

Gothic cathedrals in hot climates did not use buttress systems to increase their window areas as they did not want more windows to allow heat into the buildings.

Bio-climatic Design: HOT-HUMID

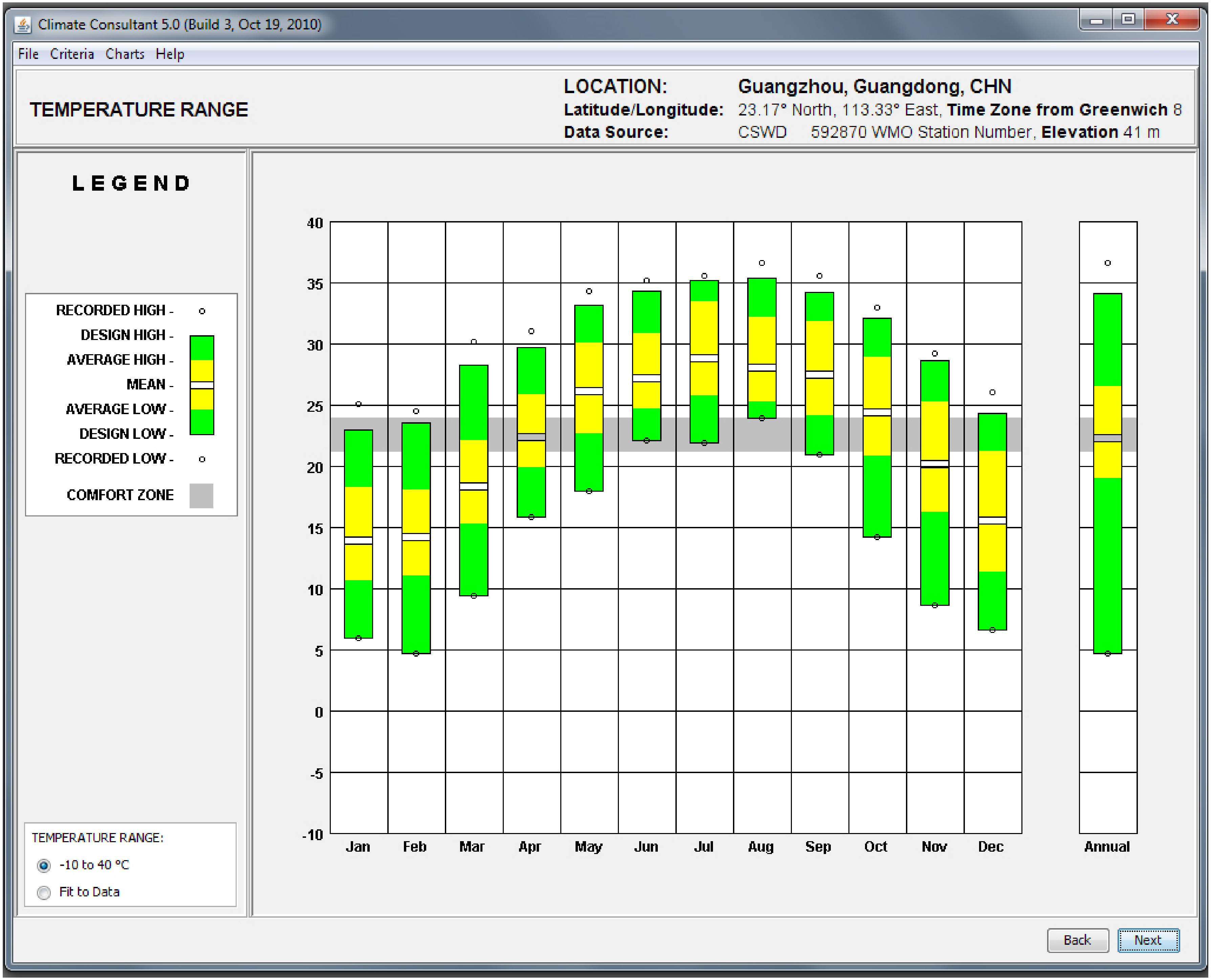
•Where **warm to hot** stable conditions predominate with **high humidity** throughout the year. **Cooling degrees days greatly exceed heating degree days.**

•

RULES:

- **SOLAR AVOIDANCE** : large roofs with overhangs that shade walls and to allow windows open at all times
- **PROMOTE VENTILATION**
- **USE LIGHTWEIGHT MATERIALS** that do not hold heat and that will not promote condensation and dampness (mold/mildew)
- *eliminate basements and concrete*
- use STACK EFFECT to ventilate through high spaces
- use of COURTYARDS and semi-enclosed outside spaces
- use WATER FEATURES for cooling

House in Seaside, Florida



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LOCATION: Guangzhou, Guangdong, CHN
Latitude/Longitude: 23.17° North, 113.33° East, Time Zone from Greenwich 8
Data Source: CSWD 592870 WMO Station Number, Elevation 41 m
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DESIGN HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
DESIGN LOW -
RECORDED LOW -
COMFORT ZONE
TEMPERATURE RANGE:
-10 to 40 °C
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Humid climate cathedrals?

And hot humid climates take a completely different approach to creating “comfortable” spaces for worship. Shelter from the sun and completely open up the walls to promote natural ventilation.

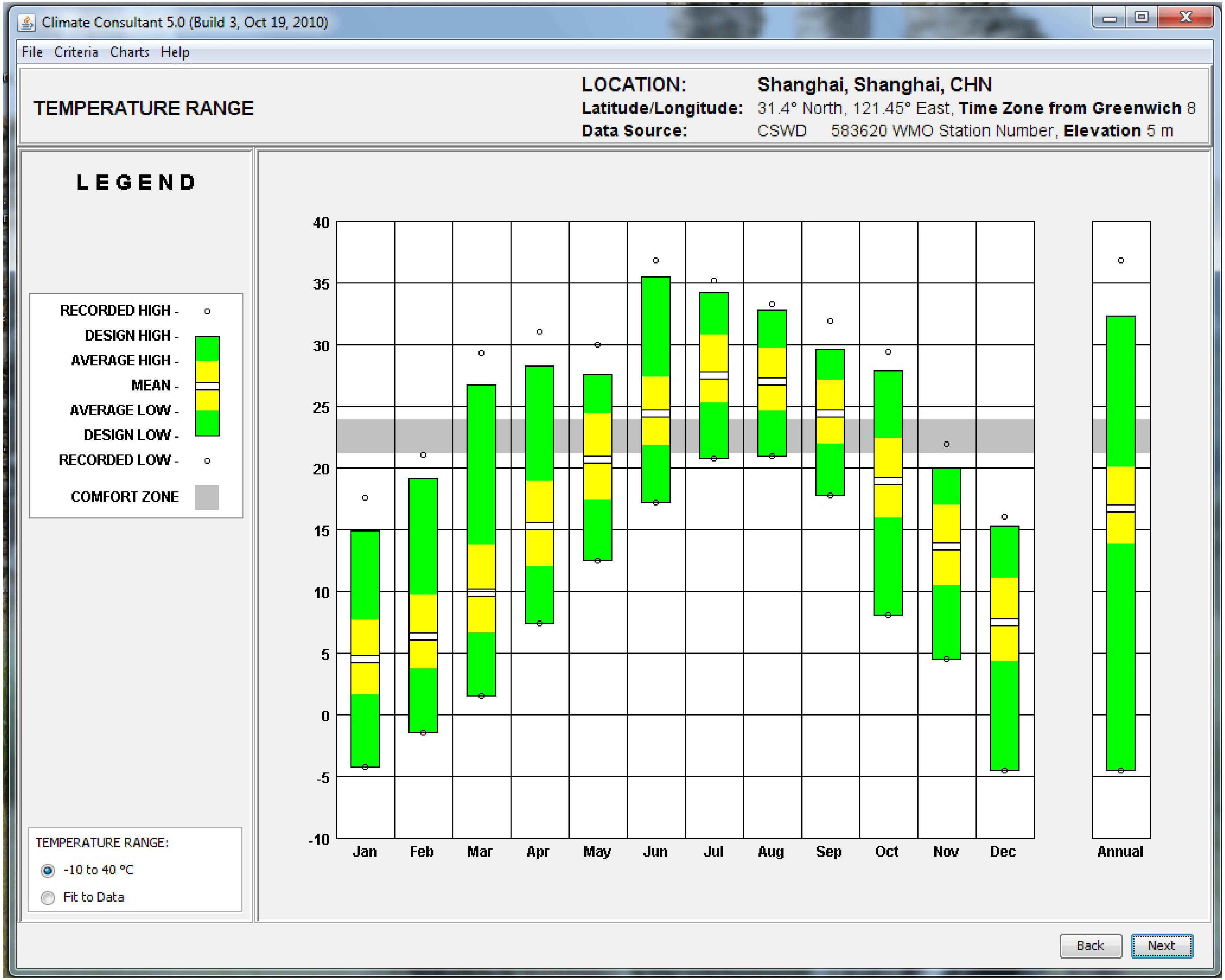
Bio-climatic Design: TEMPERATE

•The summers are hot and humid, and the winters are cold. In much of the region the topography is generally flat, allowing cold winter winds to come in form the northwest and cool summer breezes to flow in from the southwest. **The four seasons are almost equally long.**

IslandWood Residence, Seattle, WA

•**RULES:**

- BALANCE strategies between COLD and HOT-HUMID
- maximize flexibility in order to be able to modify the envelope for varying climatic conditions
- understand the natural benefits of SOLAR ANGLES that shade during the warm months and allow for heating during the cool months



Climate Consultant 5.0 (Build 3, Oct 19, 2010)
File Criteria Charts Help
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LOCATION: Shanghai, Shanghai, CHN
Latitude/Longitude: 31.4° North, 121.45° East, Time Zone from Greenwich 8
Data Source: CSWD 583620 WMO Station Number, Elevation 5 m
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DESIGN HIGH -
AVERAGE HIGH -
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AVERAGE LOW -
DESIGN LOW -
RECORDED LOW -
COMFORT ZONE
TEMPERATURE RANGE:
-10 to 40 °C
Fit to Data
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Bio-climatic Design: COLD

•Where **winter** is the dominant season and concerns for conserving heat predominate all other concerns. **Heating degree days greatly exceed cooling degree days**.

•

RULES:

- First **INSULATE**

- *exceed* CODE requirements (DOUBLE??)

- minimize infiltration (build tight to reduce air changes)

- Then **INSOLATE**

- ORIENT AND SITE THE BUILDING PROPERLY FOR THE SUN

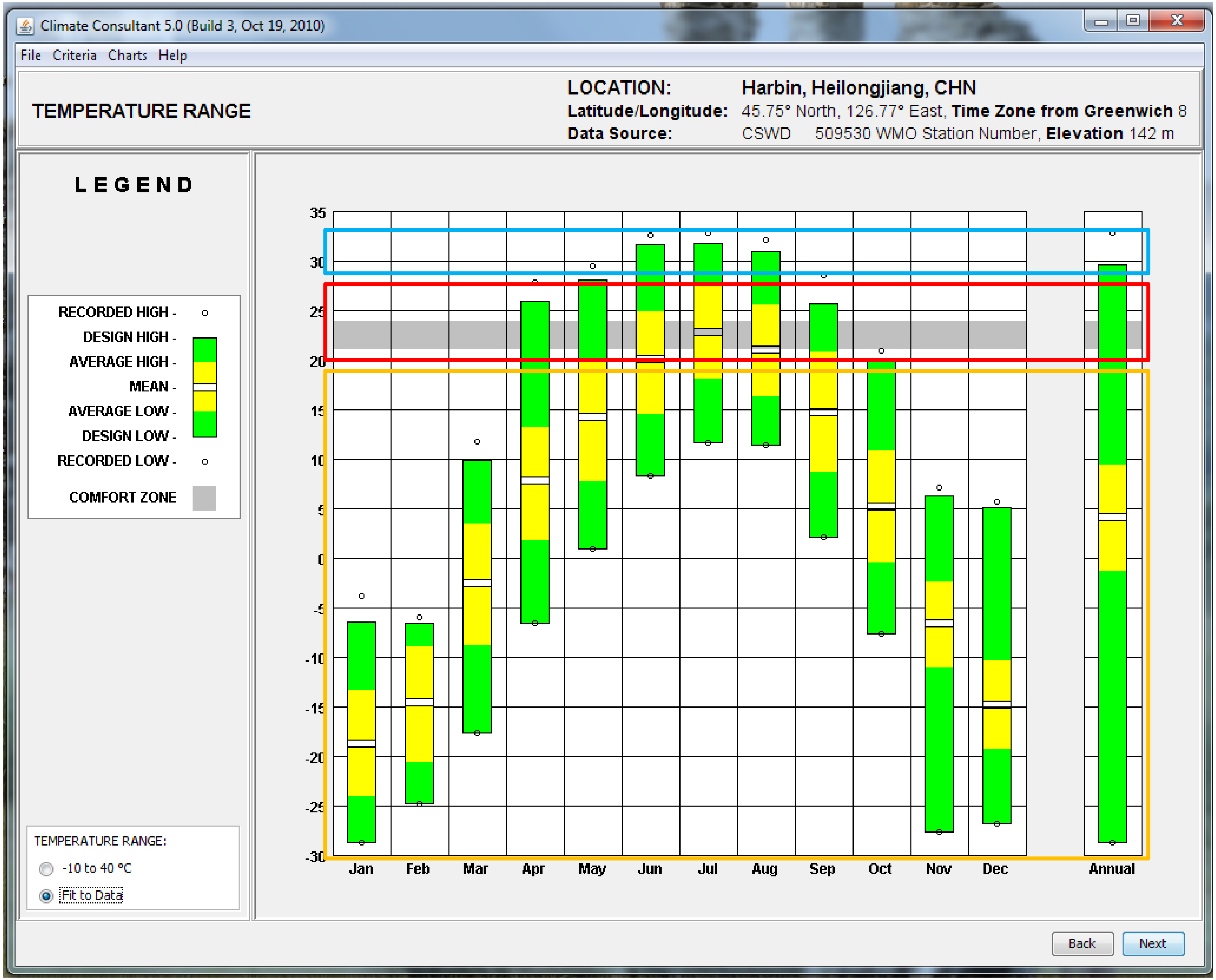
- maximize south facing windows for easier control

- fenestrate for **DIRECT GAIN**

- apply **THERMAL MASS** inside the building envelope to store the FREE SOLAR HEAT

- create a sheltered MICROCLIMATE to make it LESS cold

YMCA Environmental Learning Centre, Paradise Lake, Ontario



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Data Source: CSWD 509530 WMO Station Number, Elevation 142 m
LEGEND
RECORDED HIGH -
DESIGN HIGH -
AVERAGE HIGH -
MEAN -
AVERAGE LOW -
DESIGN LOW -
RECORDED LOW -
COMFORT ZONE
TEMPERATURE RANGE:
-10 to 40 °C
Fit to Data
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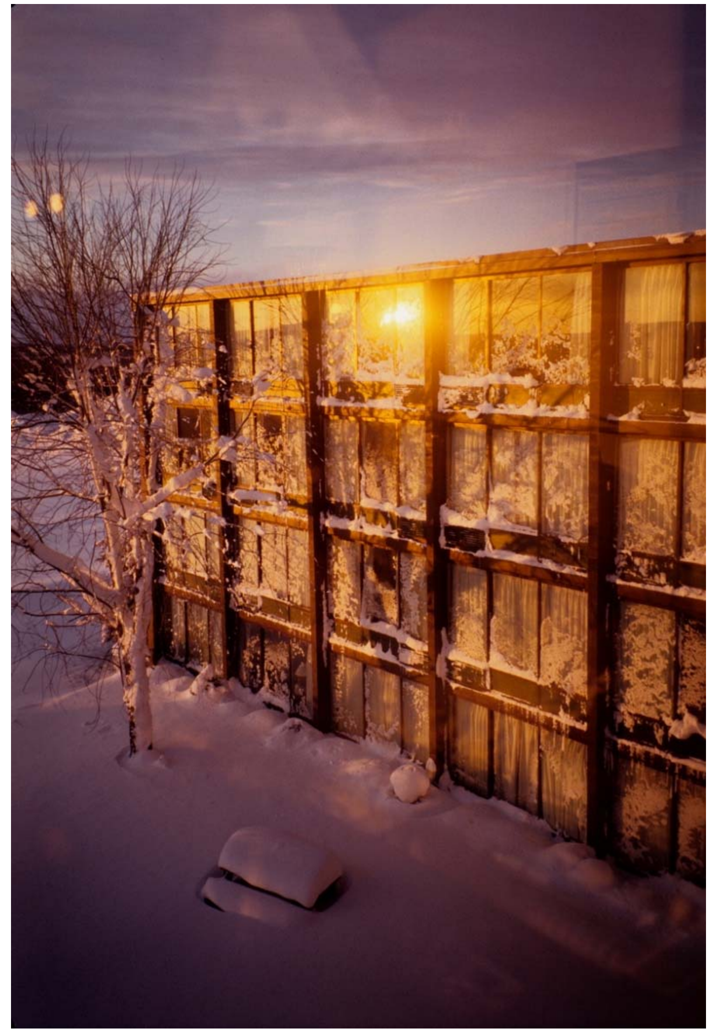
…designing for a cold climate…

Designing for a cold climate requires a completely different approach to and respect for the weather. Buildings must be designed with an environmental barrier.



Traditional cold climate design:

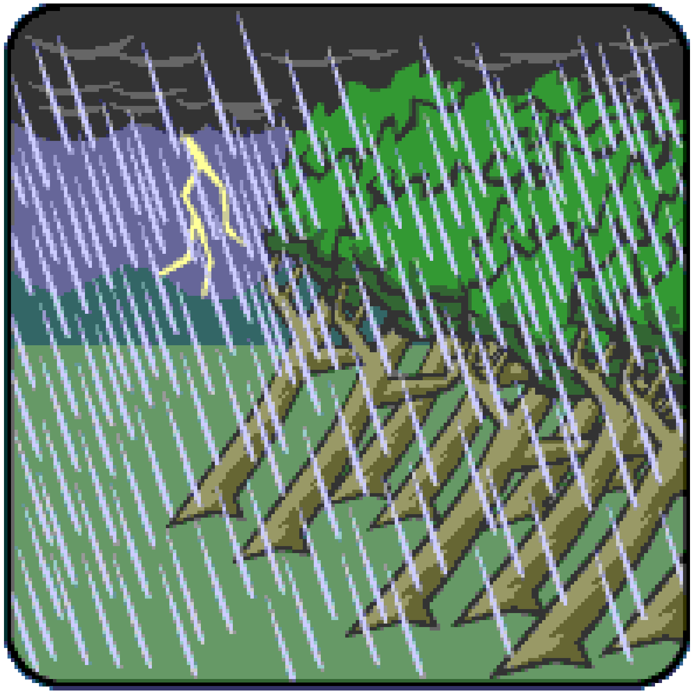
At this time heating costs were low, nobody was concerned about CO_2 emissions and global warming, so fossil fuels were burned.

Traditional cold climate design in Canada took to task the shedding of snow from roofs and used minimal windows in the walls to try to keep heat inside the building.

Cold climate cathedrals:

Buttressing systems in stone allowed for the enlargement of glazing systems that were once hindered by the limitations of the wall – giving more light and heat to the interior of cold, draughty cathedrals.

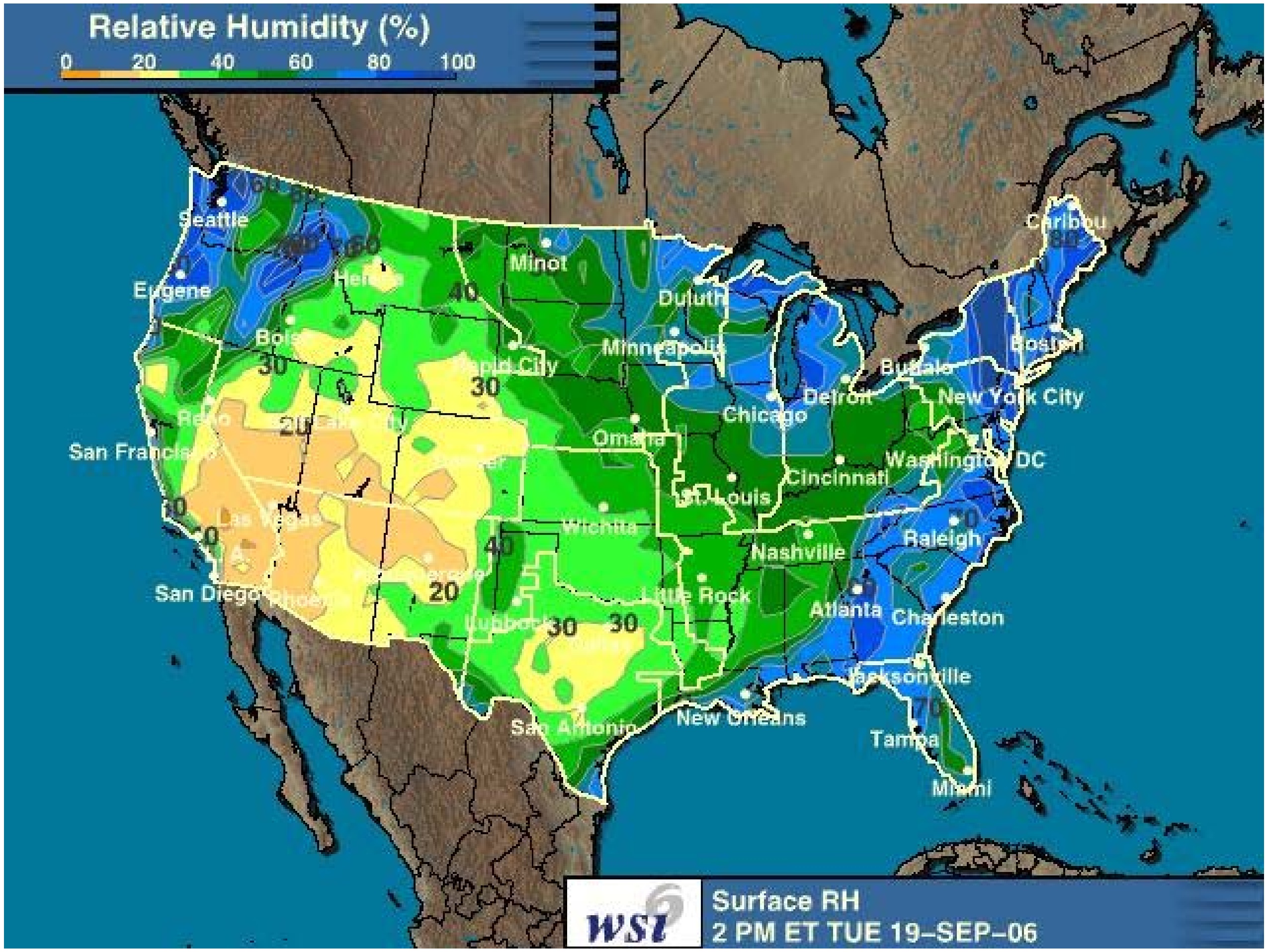
Identifying "the enemy"



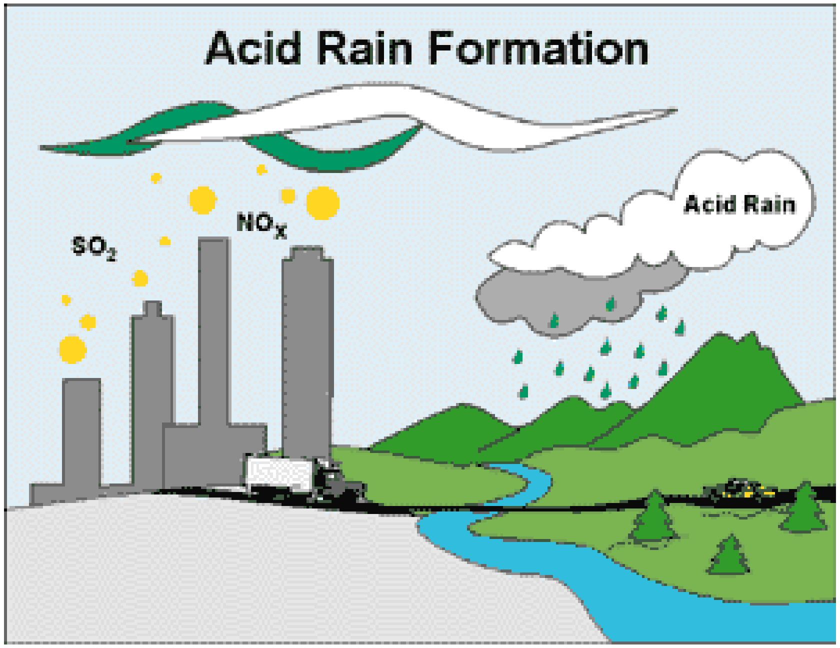
Rain is likely the largest enemy of both the Architect and the Building Envelope. Moisture damage to the building envelope is one of our key concerns when looking at GOOD building envelope design.

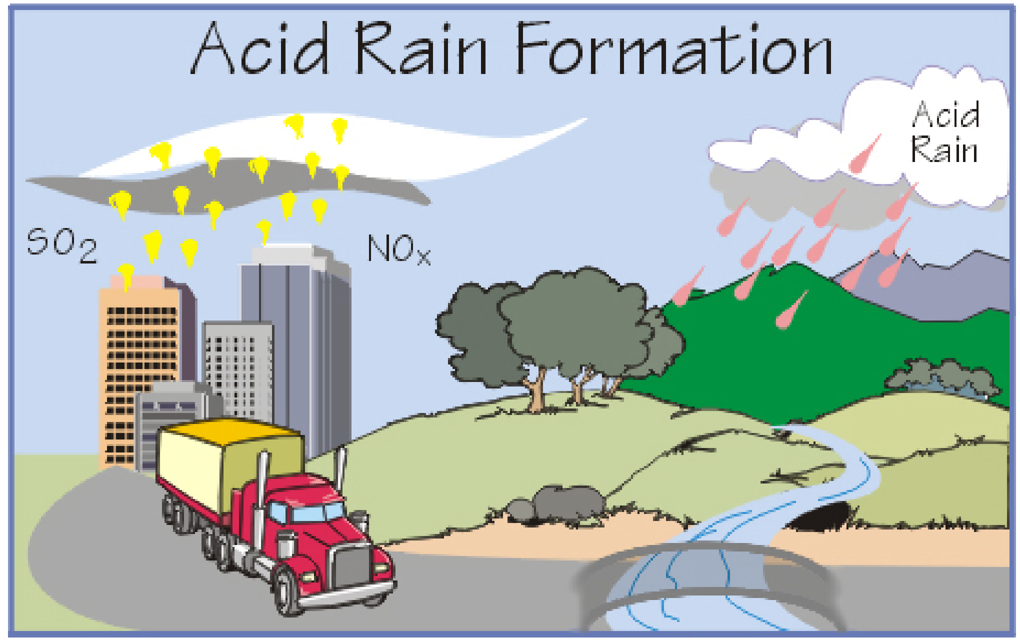
Humidity:

Whether in a cold or warmer climate, humidity remains one of the most potentially devastating forces that can cause degradation to the building envelope.



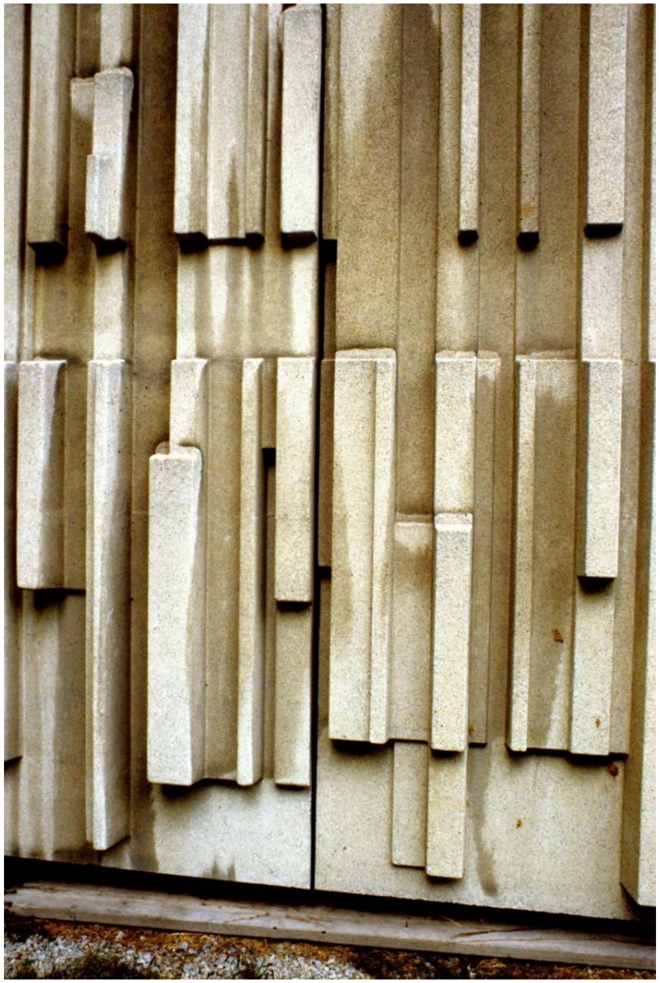
Acid rain



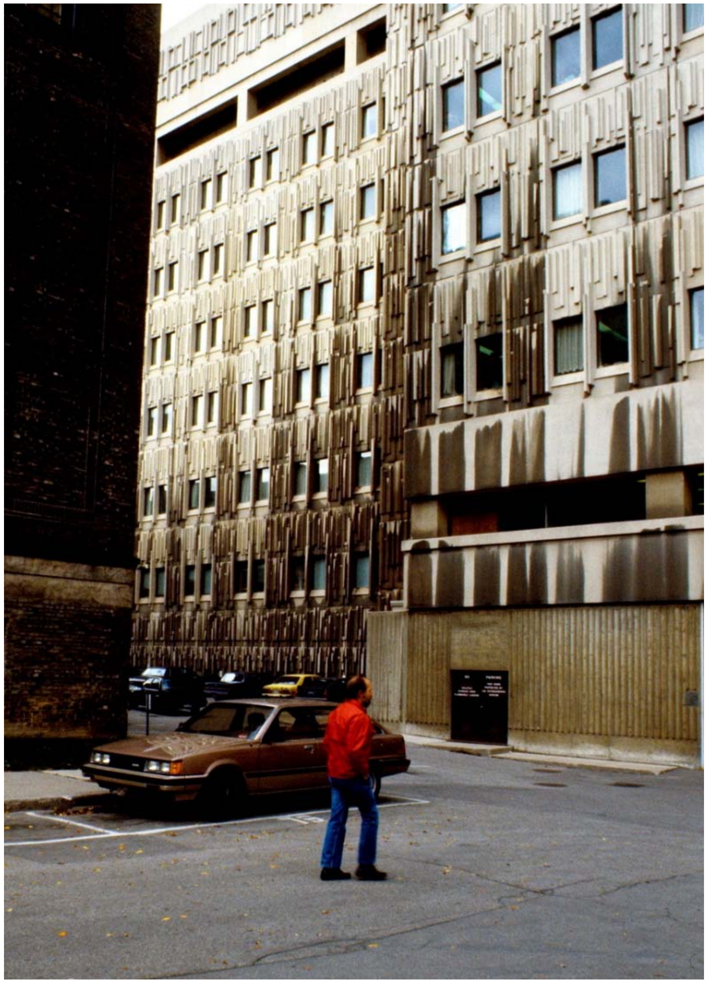


Acid rain not only affects the integrity and functionality of our rivers, lakes and streams, but also can degrade our building envelopes, causing either deterioration or unsightly staining. The sculptural elements on many old cathedrals in Europe are losing their detail due to acid rain erosion.

Staining of buildings

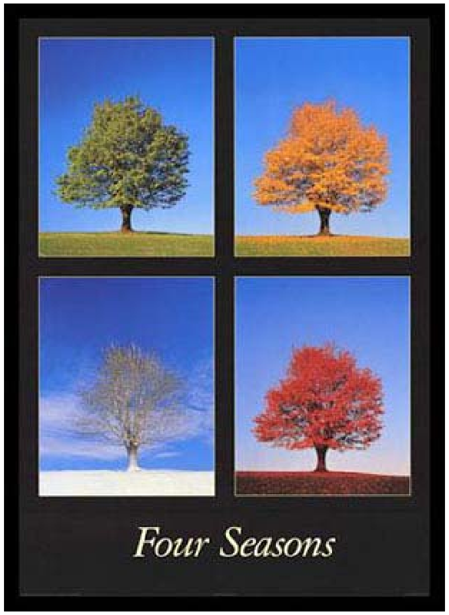


The Medical Arts Building at University of Toronto – showing the effects of acid rain/ polluted air on the precast concrete cladding.



The four seasons…

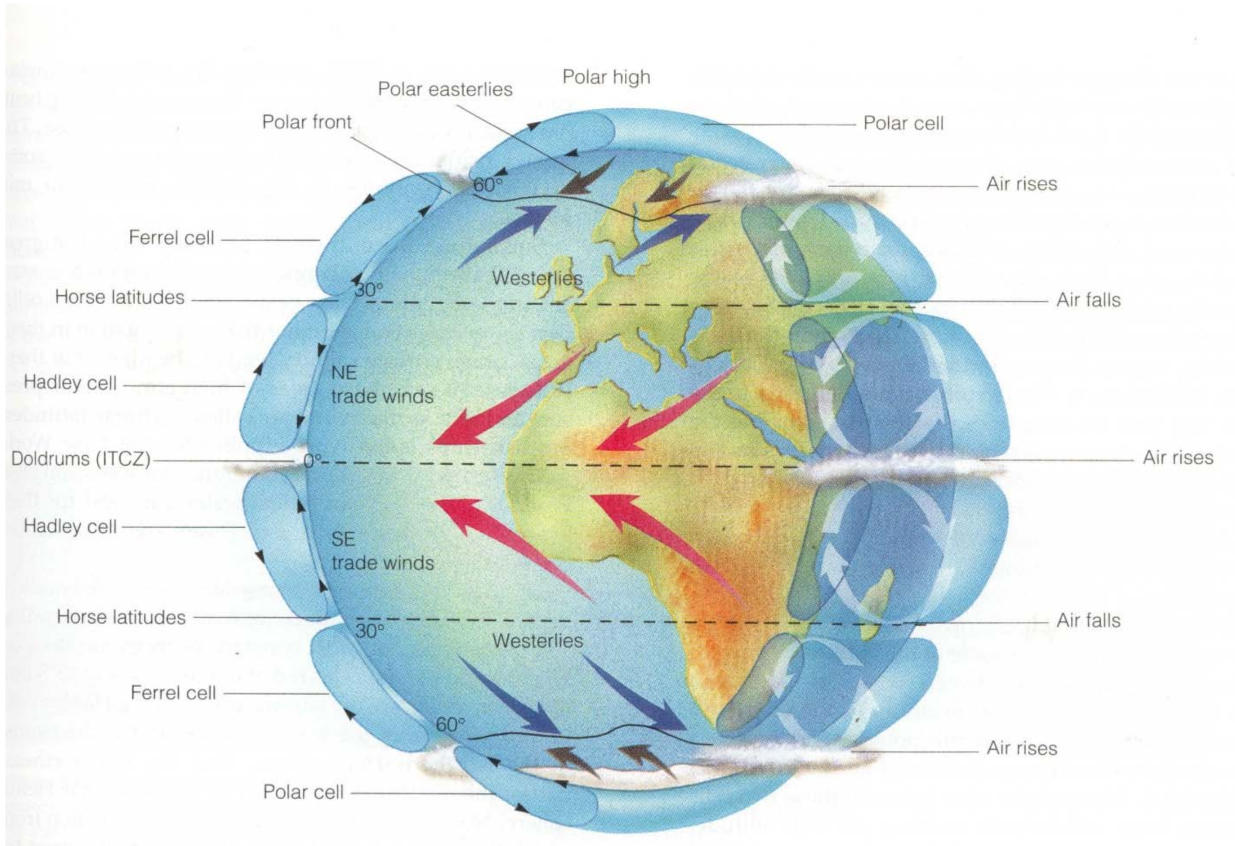
…ask for variance in the performance of our buildings – either in keeping the cold OUT or letting the cool IN.



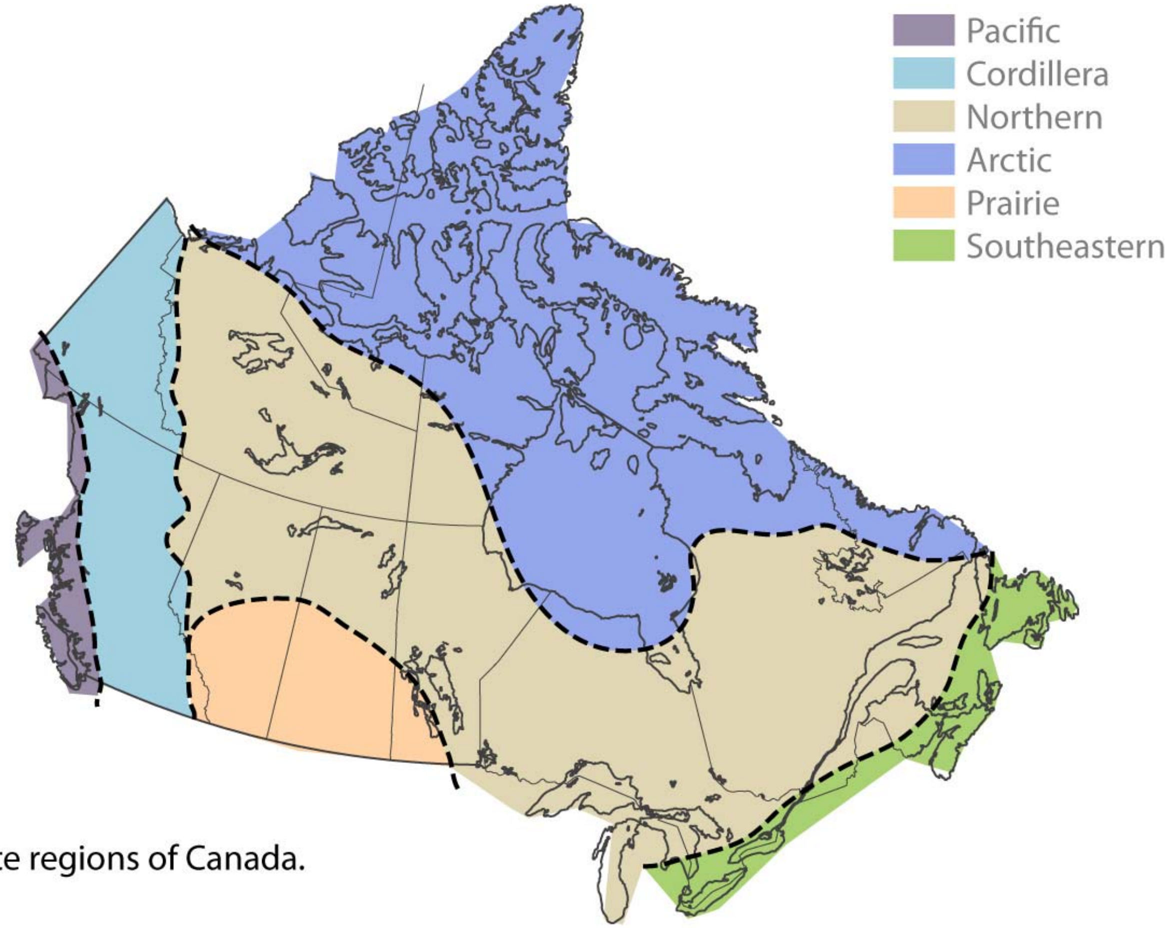
Weather and Climate:

The weather of the world varies by location as relates to the distance from the equator and as influenced by aspects of geography such as the trade winds, adjacency to bodies of water, elevation, etc.

The earth's atmosphere helps to moderate the climate to prevent radical shifts in temperature from season to season and day to night.



The climate regions of Canada



Climate regions of Canada.

Even within Canada, there exist variations in climate, enough to require very different envelope design practices and regulations. This mostly concerns insulation and water penetration, as well as humidity concerns.

The Sun

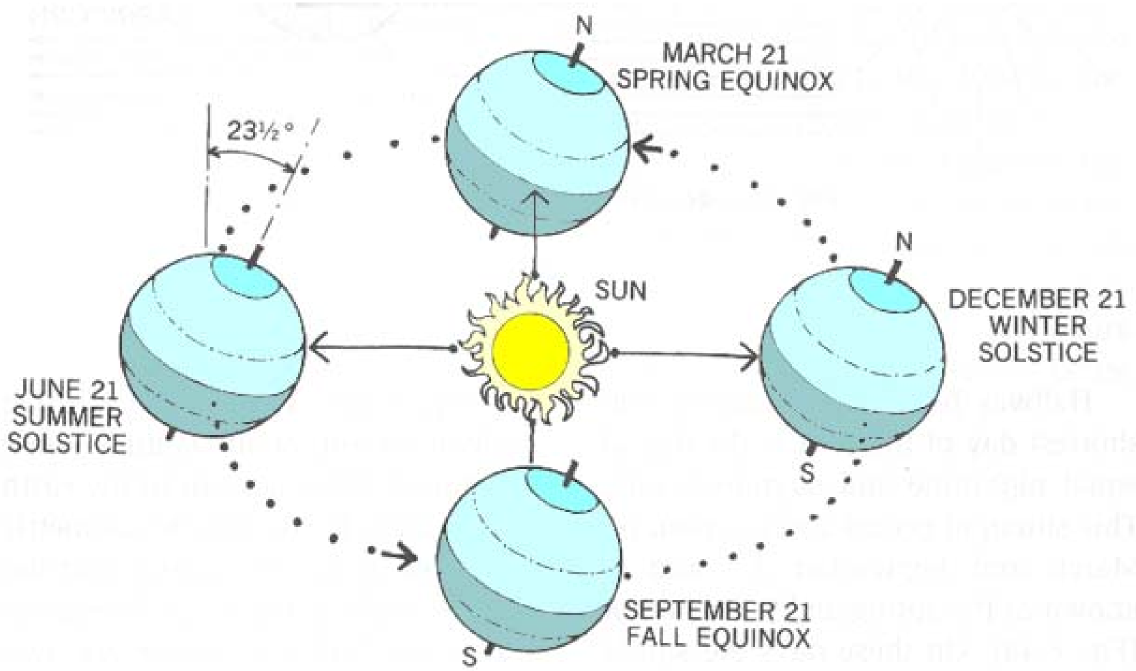


Figure 6.4a The seasons are a consequence of the tilt of the earth's axis of rotation. [From *Solar Dwelling Design Concepts* by AIA Research Corporation. U.S. Dept. Housing and Urban Development, 1976. HUD-PDR-154(4).]

The impact of the sun on our buildings is a direct result of our distance from the equator.

This affects amounts of solar radiation as well as solar geometry.

Thermal mass is the “container” for free heat…

If you “pour” the sun on wood, it is like having no container at all.

Just like water, free solar energy needs to be stored somewhere to be useful!

Thermal mass in buildings

The sun gives away FREE heat and light.

Massive building materials such as concrete and brick can absorb and hold in the heat from the sun.

This heat can be reradiated out to the building when the sun goes down, to assist in keeping the building warm.

This only works if the THERMAL MASS is on the INSIDE of the building!

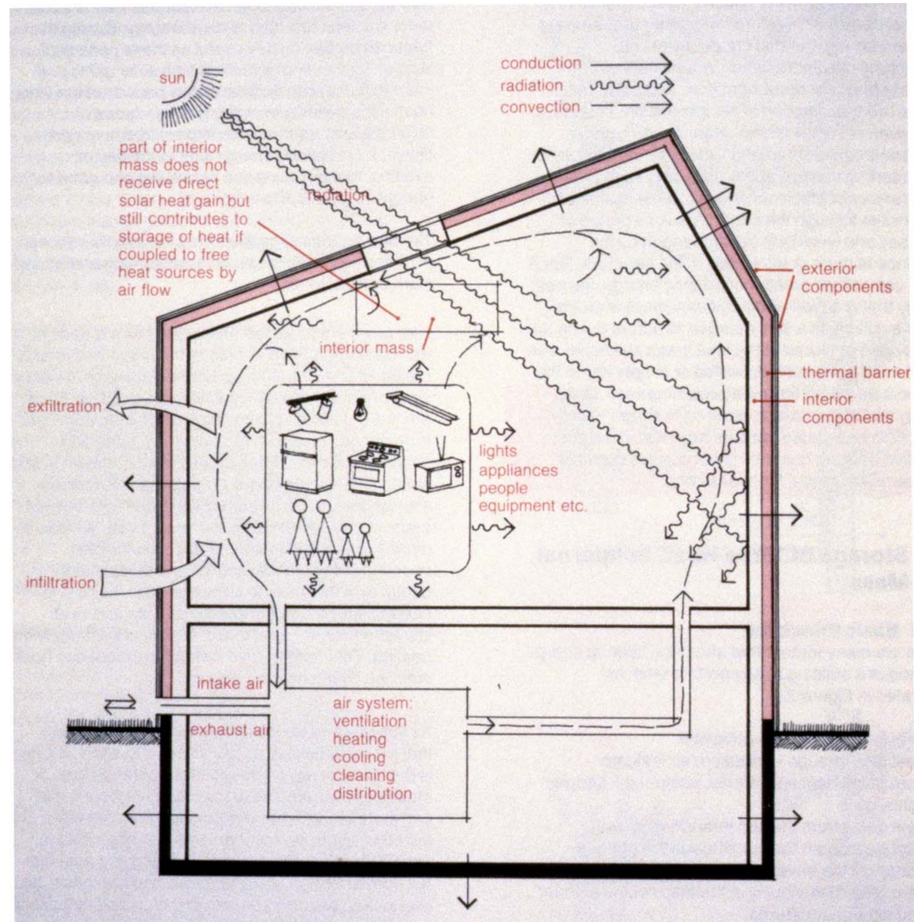
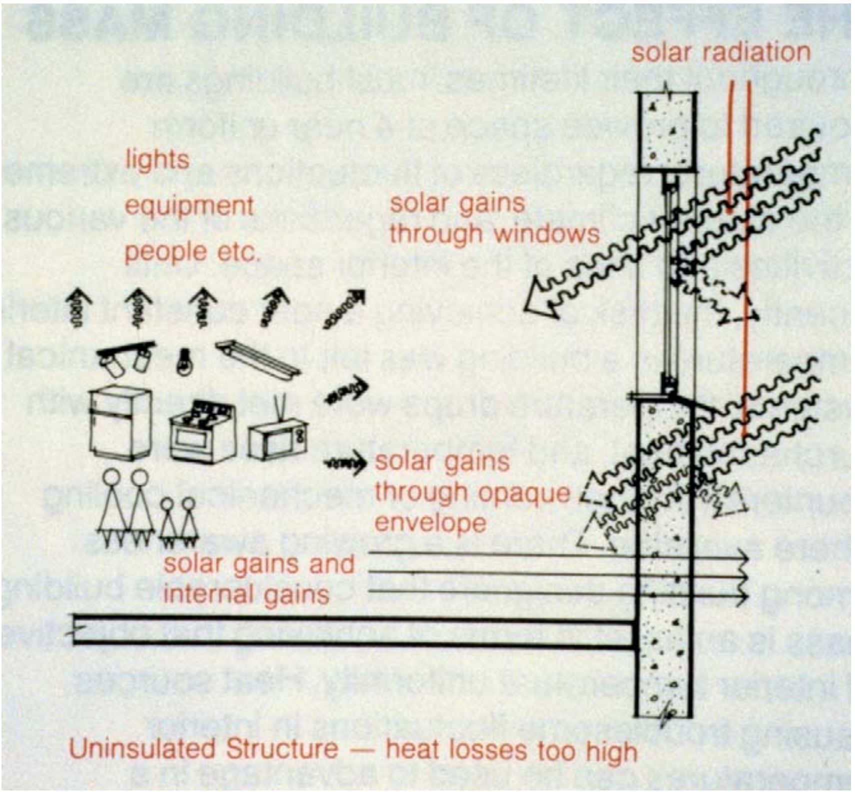
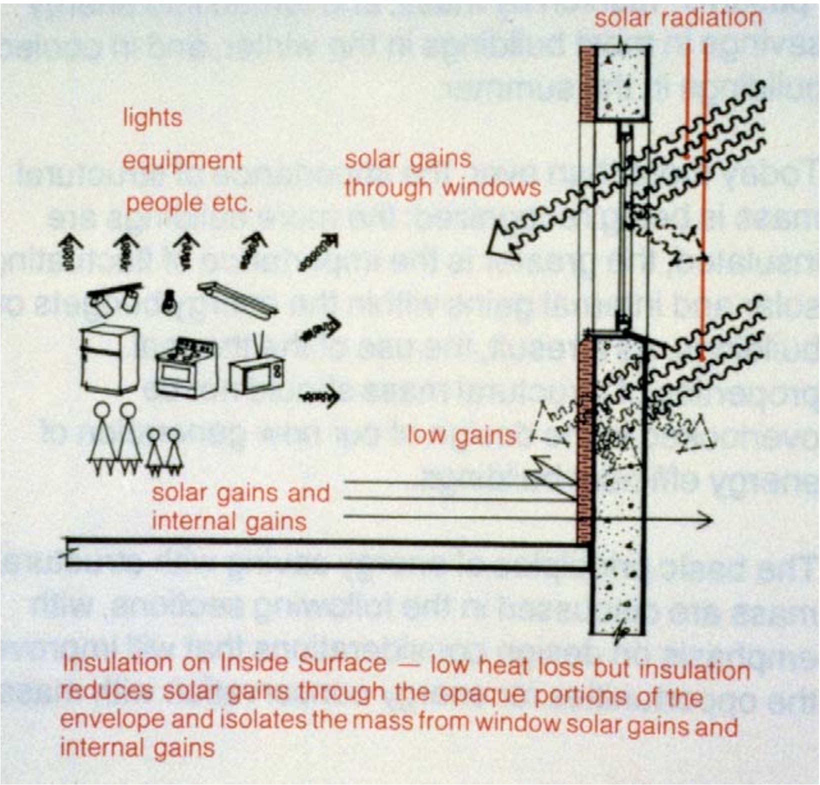


Figure 3.2 Storage of Free Heat in Internal Mass.

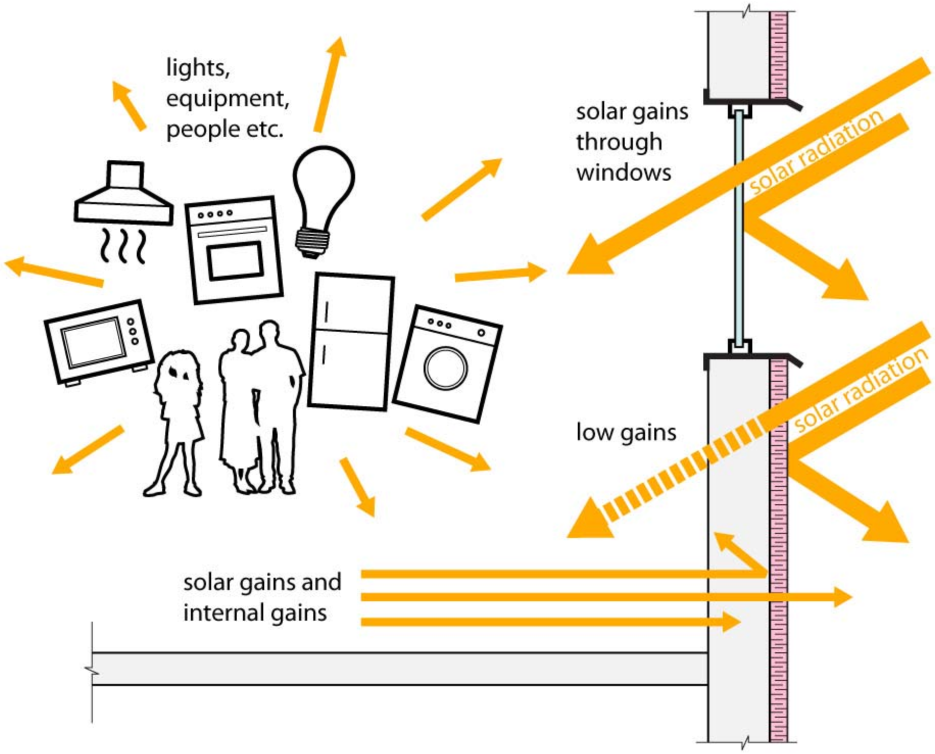
Thermal mass and insulation





If you have NO insulation, the heat will not be retained.
If the insulation is on the INSIDE of the envelope, the heat cannot get in.

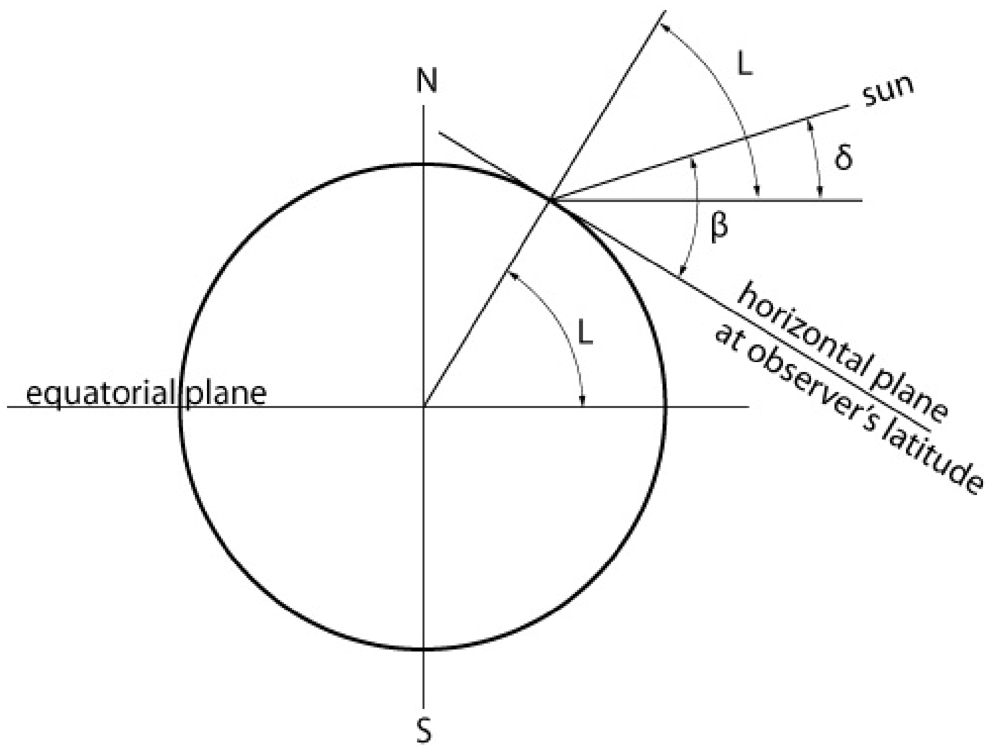
Thermal mass and exterior insulation



If the insulation is on the OUTSIDE of the building envelope (and thermal mass element), the heat that gets in STAYS in.

As windows/glass elements are good at allowing solar radiation to pass through, this configuration is the best solution.

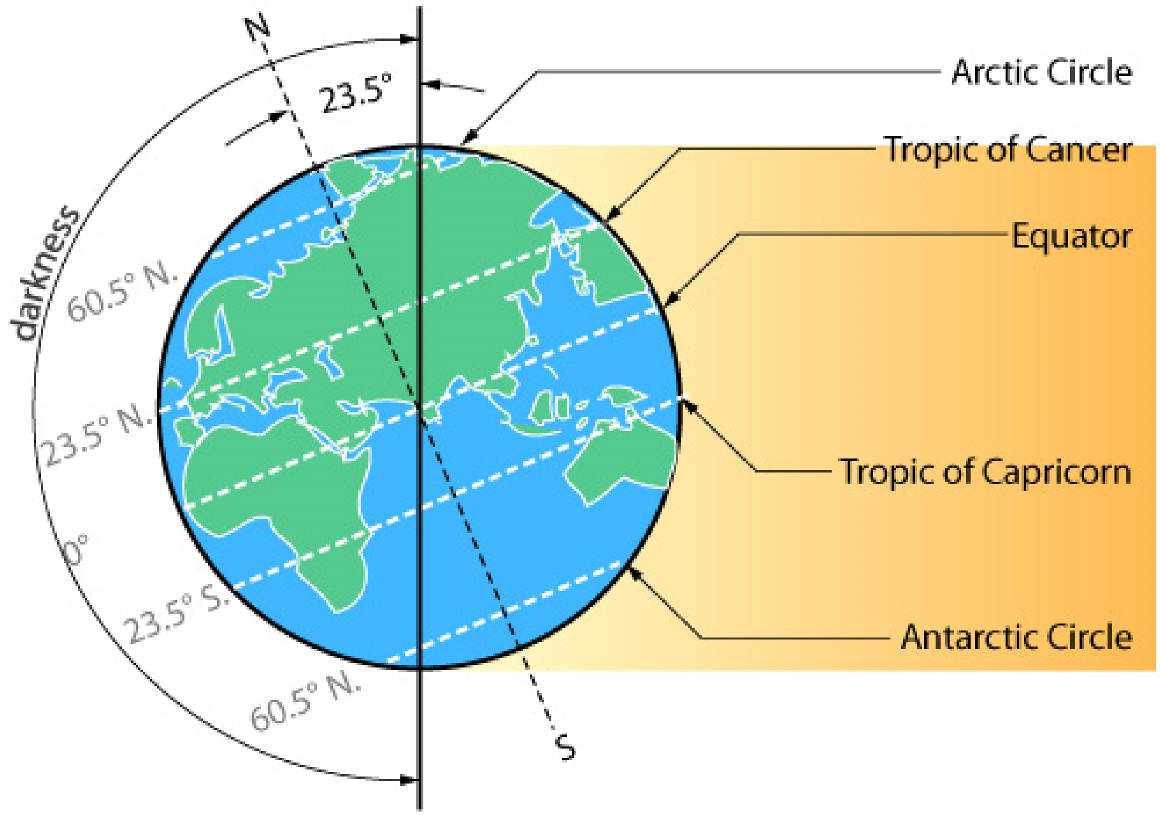
Solar Geometry



Relation between declination, attitude angle, and latitude.

Understanding solar geometry can help us to better control the FREE HEAT AND LIGHT from the sun.

Solar Geometry



Earth relative to sun at winter solstice.

The sun is highest in the sky at NOON at summer solstice (Jun 21) and lowest at winter solstice (Dec 21).

At the equinoxes, we have equal times of day and night.

Designing shading devices

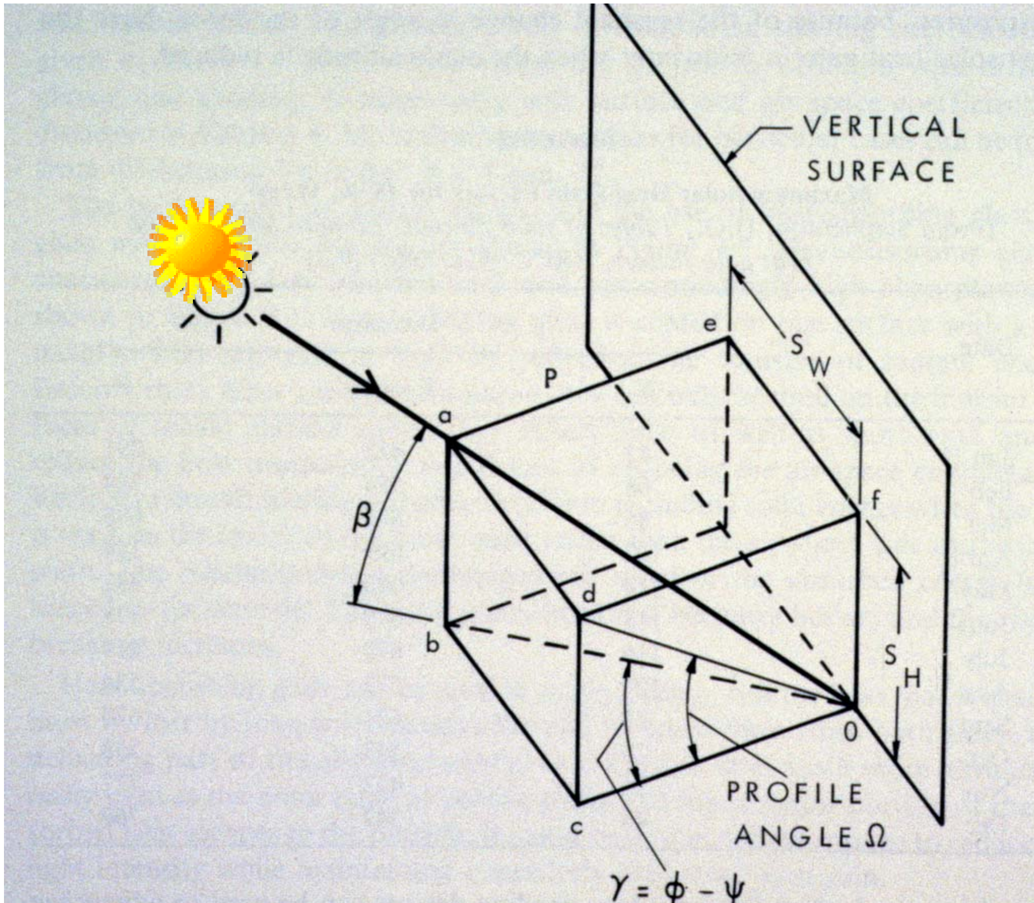
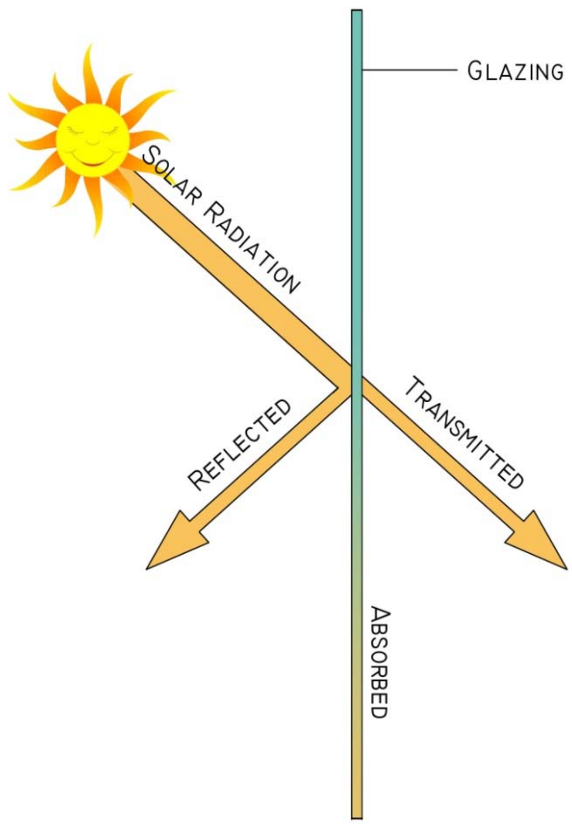


FIGURE 9.6 Geometry of exterior shading.

By mapping out the path of the sun we can design shading devices at window openings that can shade unwanted hot sun in the summer, and allow desired sun in the cold winter months.

We will spend significant time looking at this in Arch 125 next term.

Sun and glass



Glass type and orientation affects the amount of solar radiation that enters our buildings.

The more obliquely hit by the sun, the more the rays bounce off the glass.

Solar transmission and glass type

Solar Transmission of Flat Glass

Type	Thickness, mm (in)	Solar transmittance, %
Clear	2.5-6 (0.1-0.25)	78-87
Heavy-duty clear	8-22 (0.3-0.87)	67-74
Tinted	6-12 (0.25-0.5)	47-68
Heavy-duty tinted	10-12 (0.39-0.5)	24-33
Reflective	6-12 (0.25-0.5)	3-29
Insulating	15-18 (0.59-0.7)*	†
Solar	6-30 (0.25-1.18)	90-93
Architectural laminated	6-30 (0.25-1.18)	†
Spandrel	6- (0.25)	
Figured	3-4 (0.12-0.15)	78-80
Wired	6 (0.25)	78-80
Heat-resisting	3-12 (0.12-0.5)	80-92

*Thickness listed is total thickness, made up of lights 3 to 6 mm (1/8 to 1/4 in) thick separated by a 12-mm (1/2-in) air space.

†Transmittance of insulating and laminated glass varies widely depending on whether or not one or more surfaces are treated with reflective films.

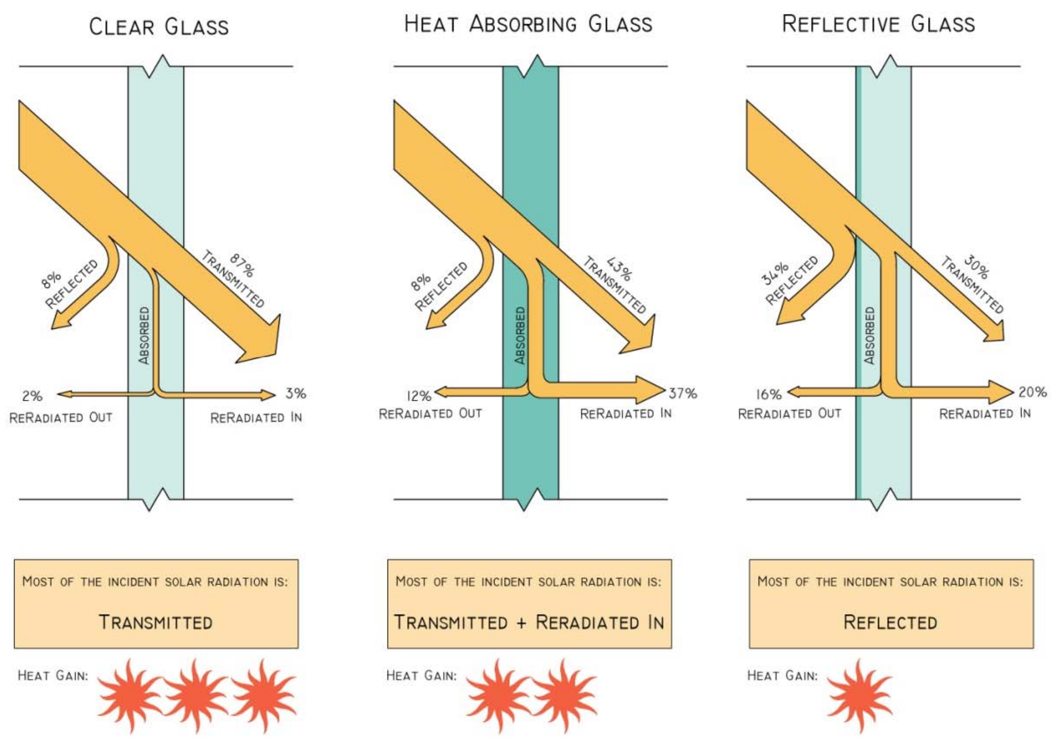
Layers of glazing

Multiple layers of glazing, alter the flow of solar rays through the glass.

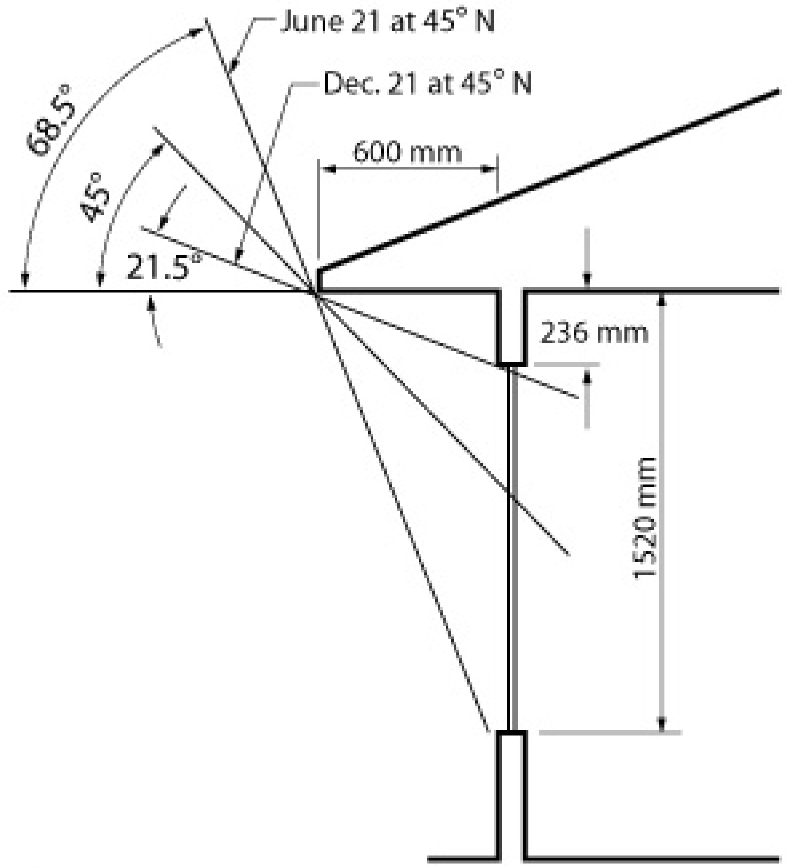
Double glazing is the “norm” in cold climates as it insulates better.

If coloured or protective films are used, the coloured glass goes on the outside, and the protective film in the cavity.

The air space is either “empty/vacuum” or filled with argon gas.



Shading with overhangs



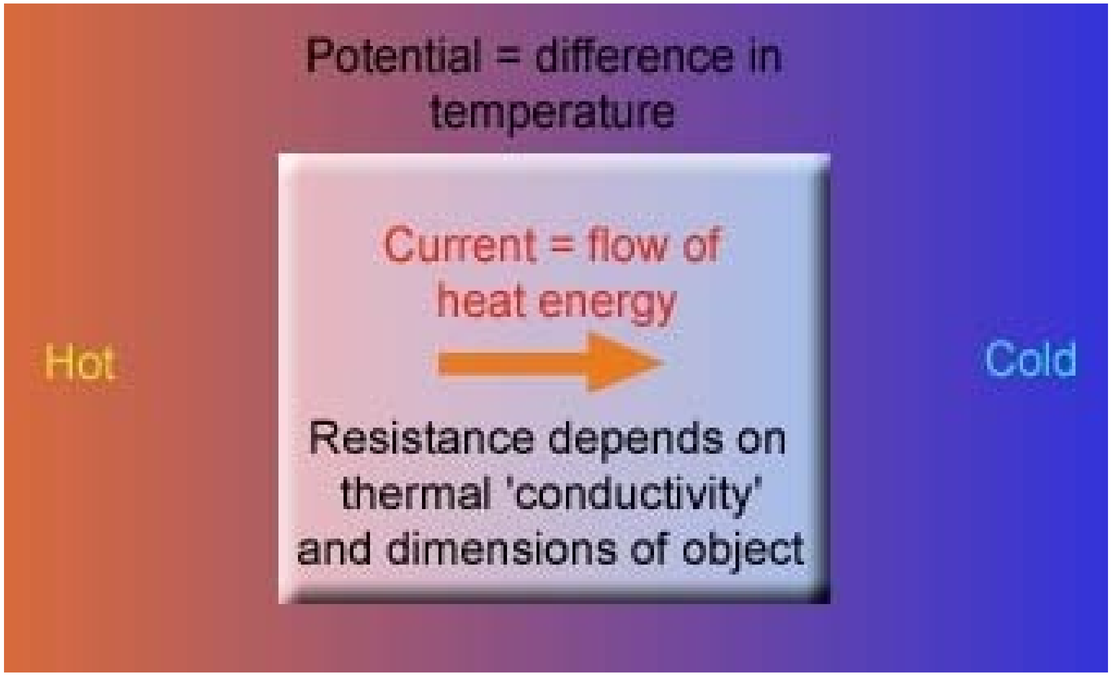
Shading angles for a south wall at 45°N

Roof overhangs are not only useful in protecting the exterior wall from rain wetting (like a good umbrella), but they shade the windows from sun during the summer and allow sun to enter during the winter, just by using the natural geometry of the sun. *(**much** more on this in Arch 125 next term!!)*

More complex shading devices

Building design can also employ more complex shading devices.

Heat flow



The heat that flows through the building envelope follows the "rules of science" – migrating from HOT to COLD. This is true in winter and summer – meaning the flow reverses as a function of the season and temperature.

The R-Value and U-Value

The **R-VALUE** is the measure of the ability of a material to RESIST HEAT FLOW. The bigger the number, the better the material.

In buildings we want these numbers to be BIG.

The **U-VALUE** is the measure of the ability of a material to CONDUCT HEAT FLOW. In buildings we want these numbers to be SMALL.

The U-Value is the INVERSE of the R-Value…

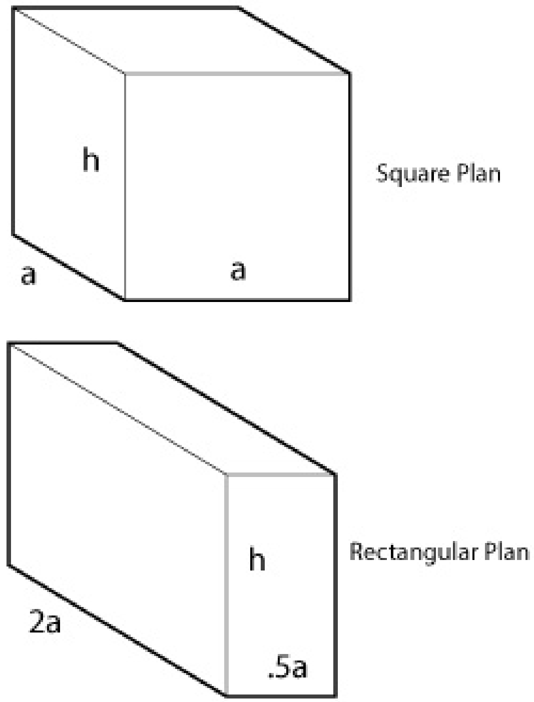
R = 1/U and conversely, U = 1/R

Units of R = $m^2 * {}^oC$ / Watts

Units of U = Watts / (m^2 x ${}^oC$)

Buildings are like radiators

The more surface area a building has, the more envelope to build and the more heat can escape through the walls. Not that we should only design “efficient boxes”, but something to be kept in mind…



	square bldg	rectangular bldg
floor area	a^2	a^2
surface area	4*ah + a^2	5*ah + a^2

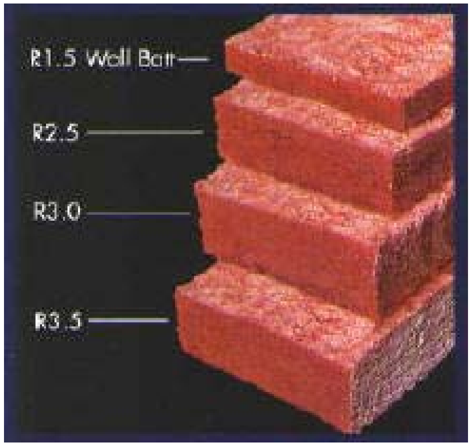
Square Plan vs. Rectangular Plan Buildings, with same floor areas and height.

Surface Area of the Envelope

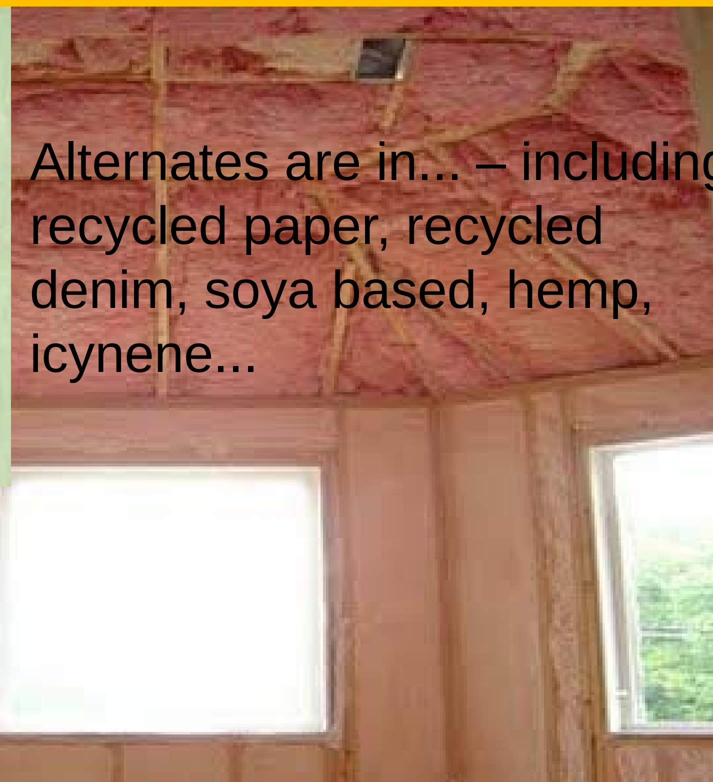
The sawtooth surface of the Royal Bank Building in Toronto greatly increases its area for heat loss.

Insulation…

Different types perform different ways, as a function of their materiality and thickness. *More is more…*



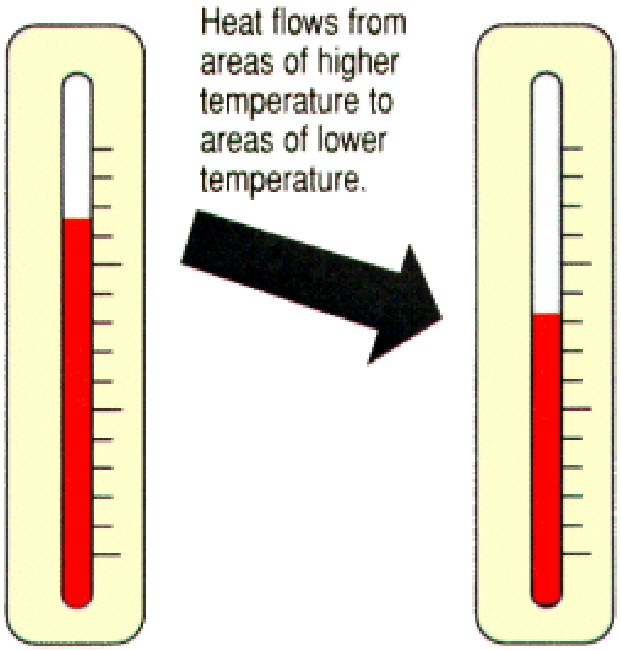
Sustainable Insulation



Alternates are in... – including, recycled paper, recycled denim, soya based, hemp, icynene...

Fibreglass is out!

Temperature



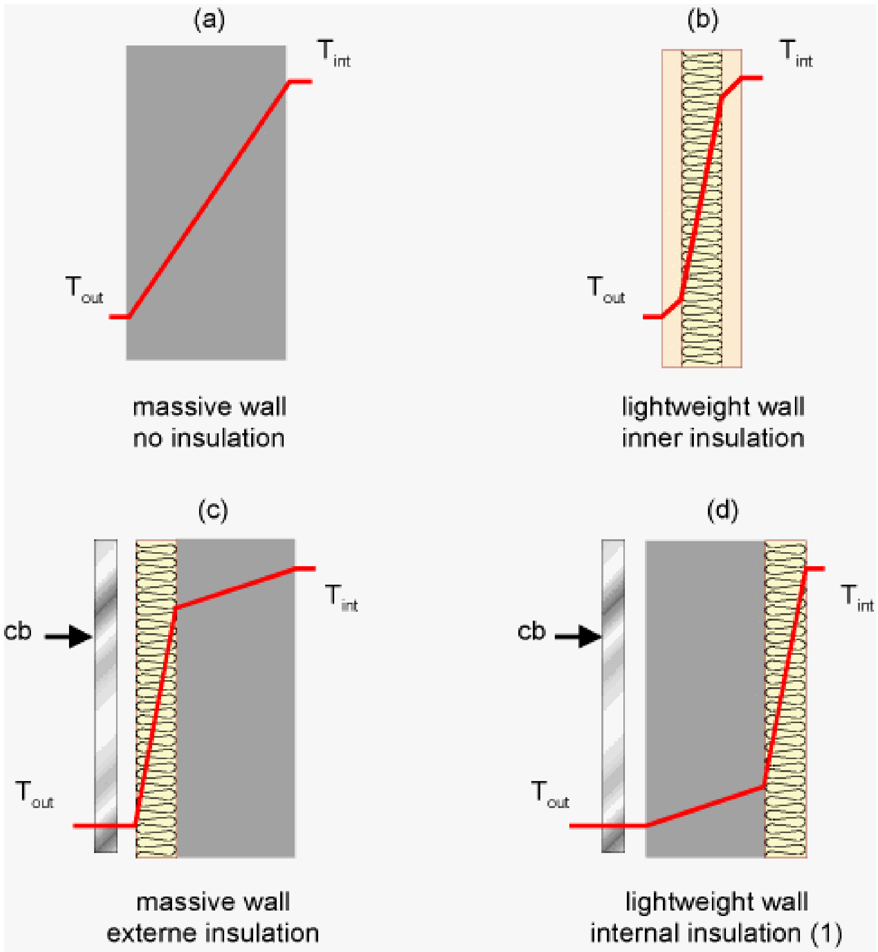
The BIGGER the temperature difference from Inside to Outside (or vice versa) the greater the PUSH for heat flow.

If it is -23C outside and +23C inside, the temperature difference is 46C! *Big PUSH*.

If it is 18C outside and 23C inside, the temperature difference is only 5C.
Not much push.

Hence MORE important to have a fantastic building envelope in a harsh climate.

Temperature differential

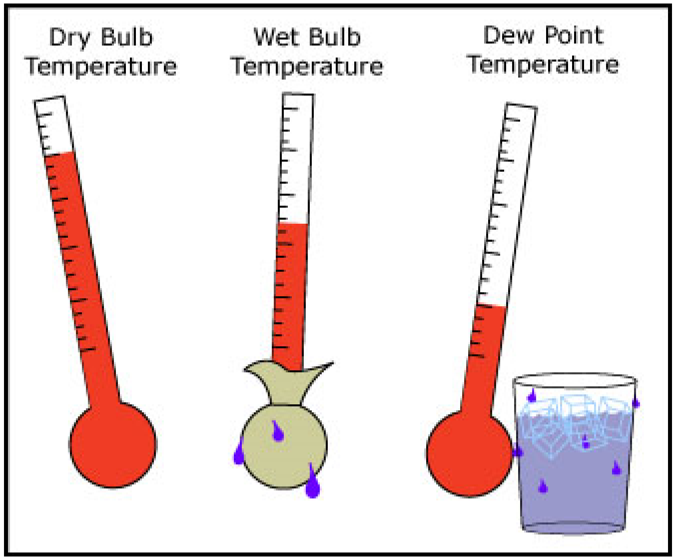


We use insulation to **slow the transfer of heat** across the building envelope.

The placement of the insulation is important as we want to keep the structure (support system) WARM so that it does not expand and contract too much.

We also want our inside surfaces WARM so that we don't have condensation occurring on the inside surfaces which will cause mold…

Dew point



The DEW POINT is the temperature at which air of a certain level of Relative Humidity will cool and the water vapour will condense into a liquid form (100% RH).

Condensation can lead to mold.

Thermal Bridges!!! - BAD

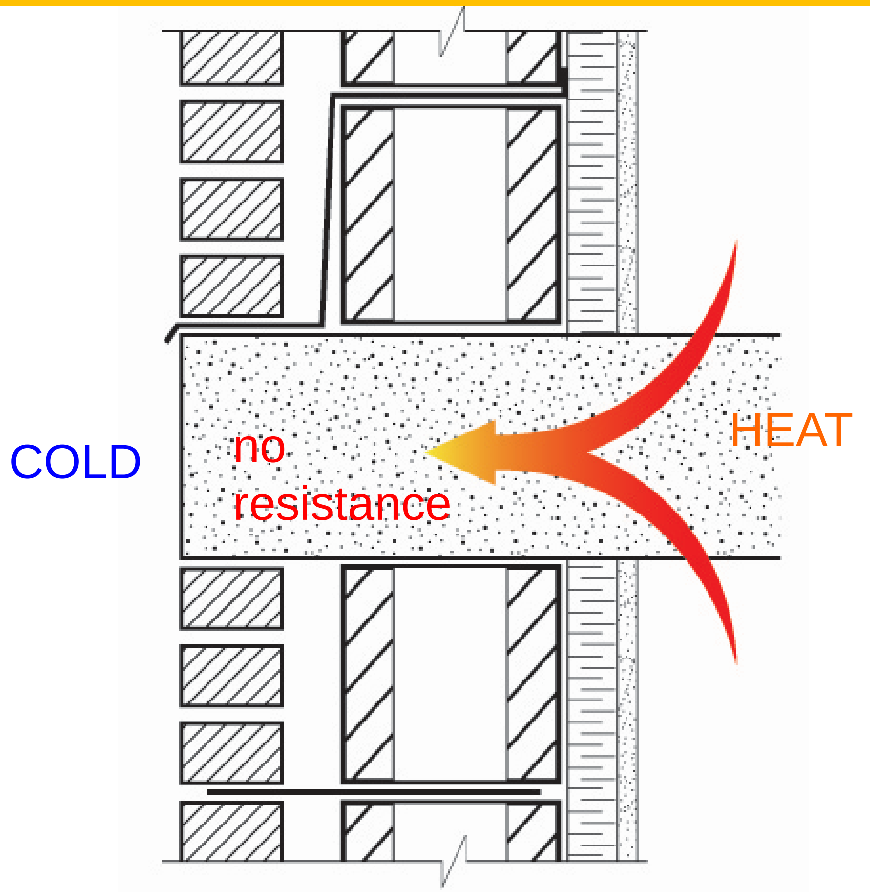
THERMAL BRIDGES are places in the building envelope where there is no insulation.

This allows the heat from inside to flow to the exterior without any “delay”.

This means that someone is paying for heat that is being wasted.

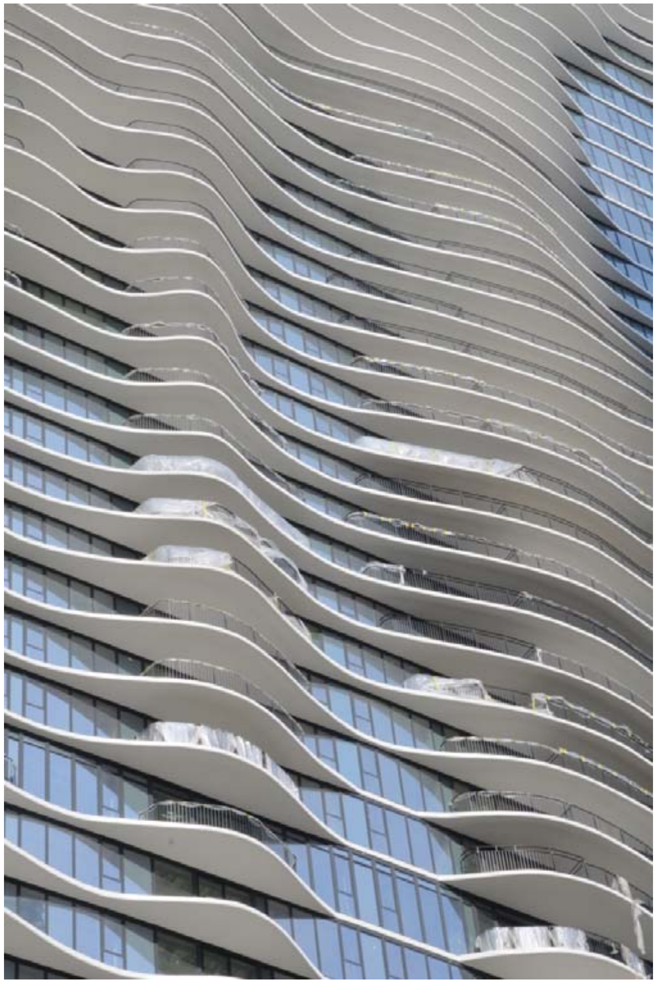
Such points in the envelope also “feel cold” on the inside, so can cause condensation, mold and mildew problems.

With few exceptions, THERMAL BRIDGES SHOULD BE AVOIDED AT ALL COSTS!

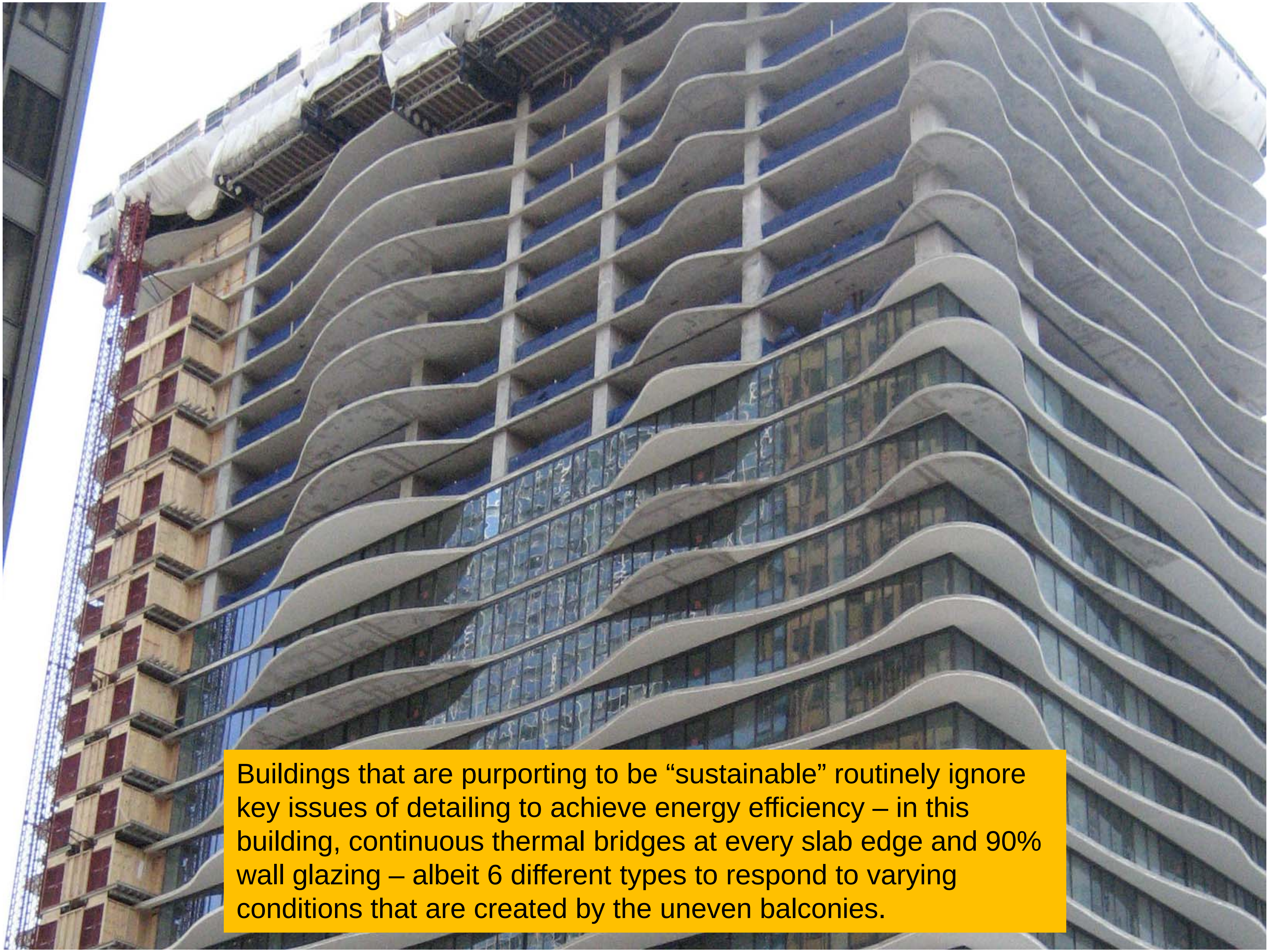


Thermal bridge at floor slab.

The Controversial “Cover” of Greensource Magazine

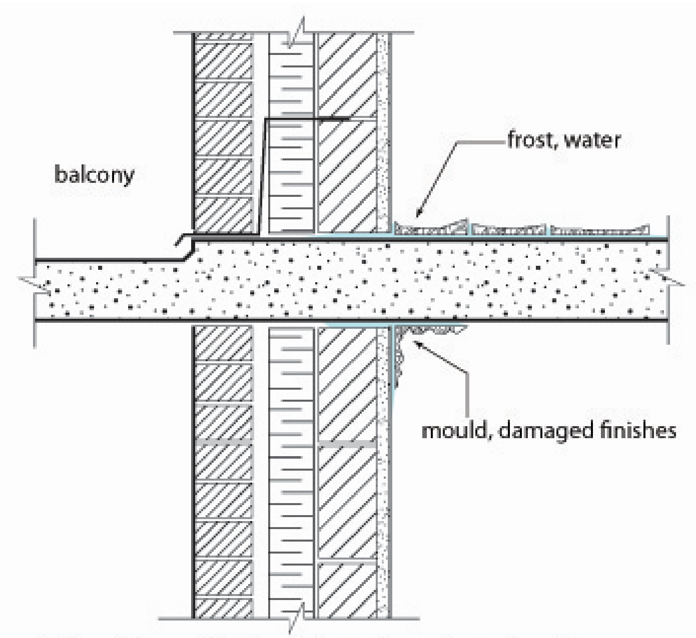


A “sustainable” Chicago residential skyscraper – going for LEED

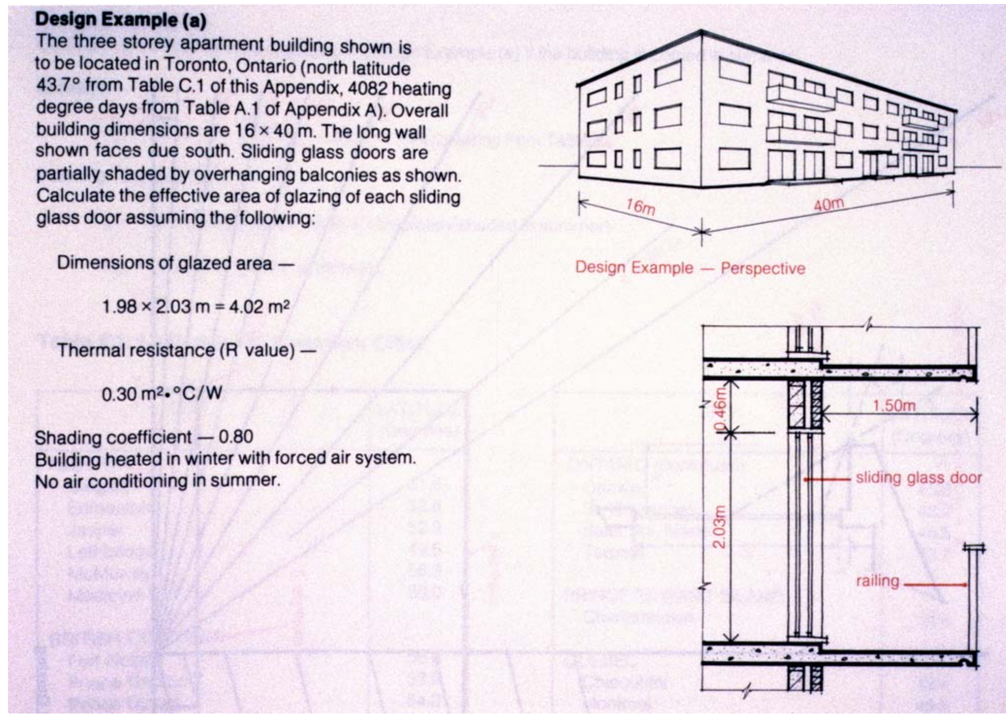


Buildings that are purporting to be "sustainable" routinely ignore key issues of detailing to achieve energy efficiency – in this building, continuous thermal bridges at every slab edge and 90% wall glazing – albeit 6 different types to respond to varying conditions that are created by the uneven balconies.

The “classic” bad balcony detail



Effect of thermal bridge when indoor relative humidity is appreciable (above 20% RH in midwinter)



Design Example (a)

The three storey apartment building shown is to be located in Toronto, Ontario (north latitude 43.7° from Table C.1 of this Appendix, 4082 heating degree days from Table A.1 of Appendix A). Overall building dimensions are 16 × 40 m. The long wall shown faces due south. Sliding glass doors are partially shaded by overhanging balconies as shown. Calculate the effective area of glazing of each sliding glass door assuming the following:

Dimensions of glazed area —

1.98 × 2.03 m = 4.02 m²

Thermal resistance (R value) —

0.30 m²•°C/W

Shading coefficient — 0.80
Building heated in winter with forced air system.
No air conditioning in summer.

Structurally this has been the *easiest* way to make balconies on apartment buildings – just cantilever the slab out over the walls. But it is also one of the **WORST** building envelope failure conditions.

Exfiltration / Air Leakage

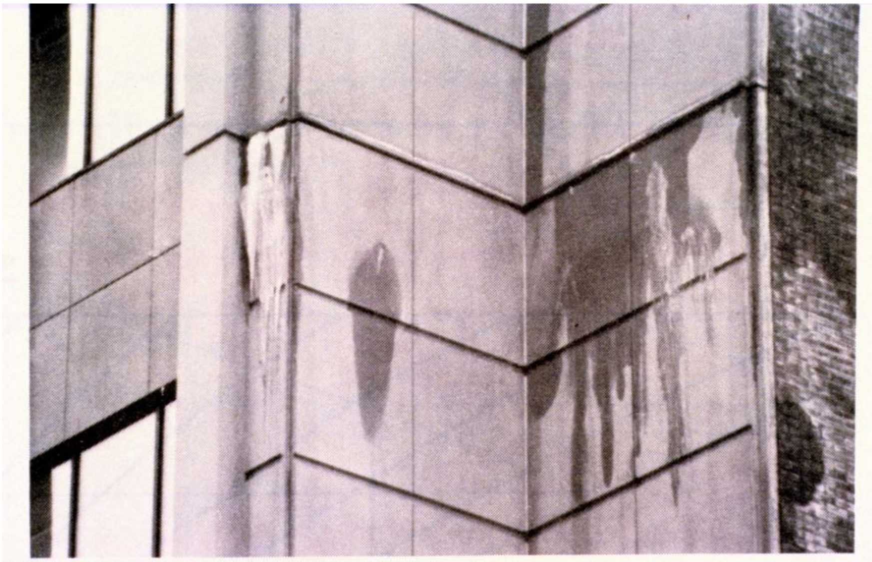
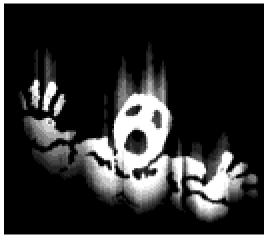


Figure 2.10 Exfiltration/Condensation

Fig. 15 Example of air leakage on the side of a building

In addition to heat flowing out of our buildings, we also need to make sure that air and moisture vapour do not make their way through the building envelope as when the temperature drops, air vapour reaches its DEW POINT and condenses, damaging the wall.

Through WALLS vs. through cracks

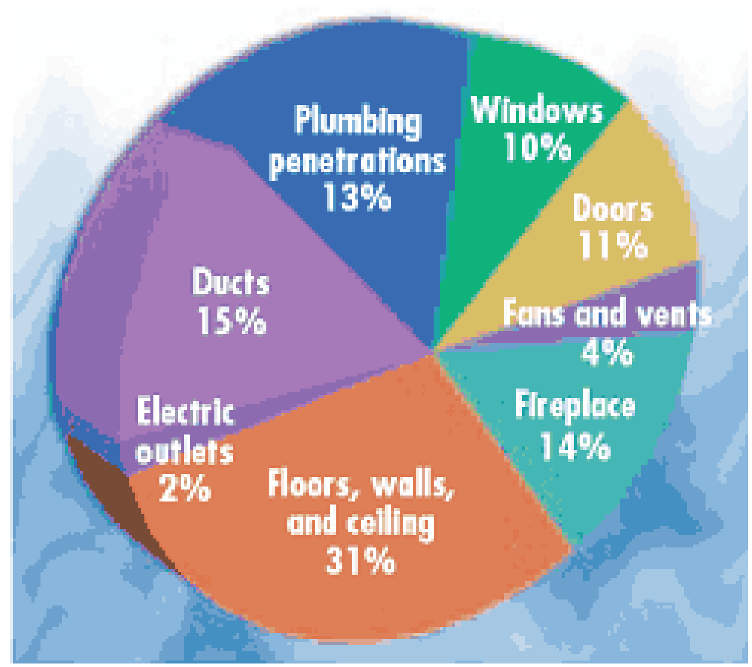


Water VAPOUR can be carried THROUGH the walls, like a GHOST.

This is called **VAPOUR DIFFUSION**.

Evidenced sometimes by EFFLUORESCENCE (the white salty stuff on the brick above).

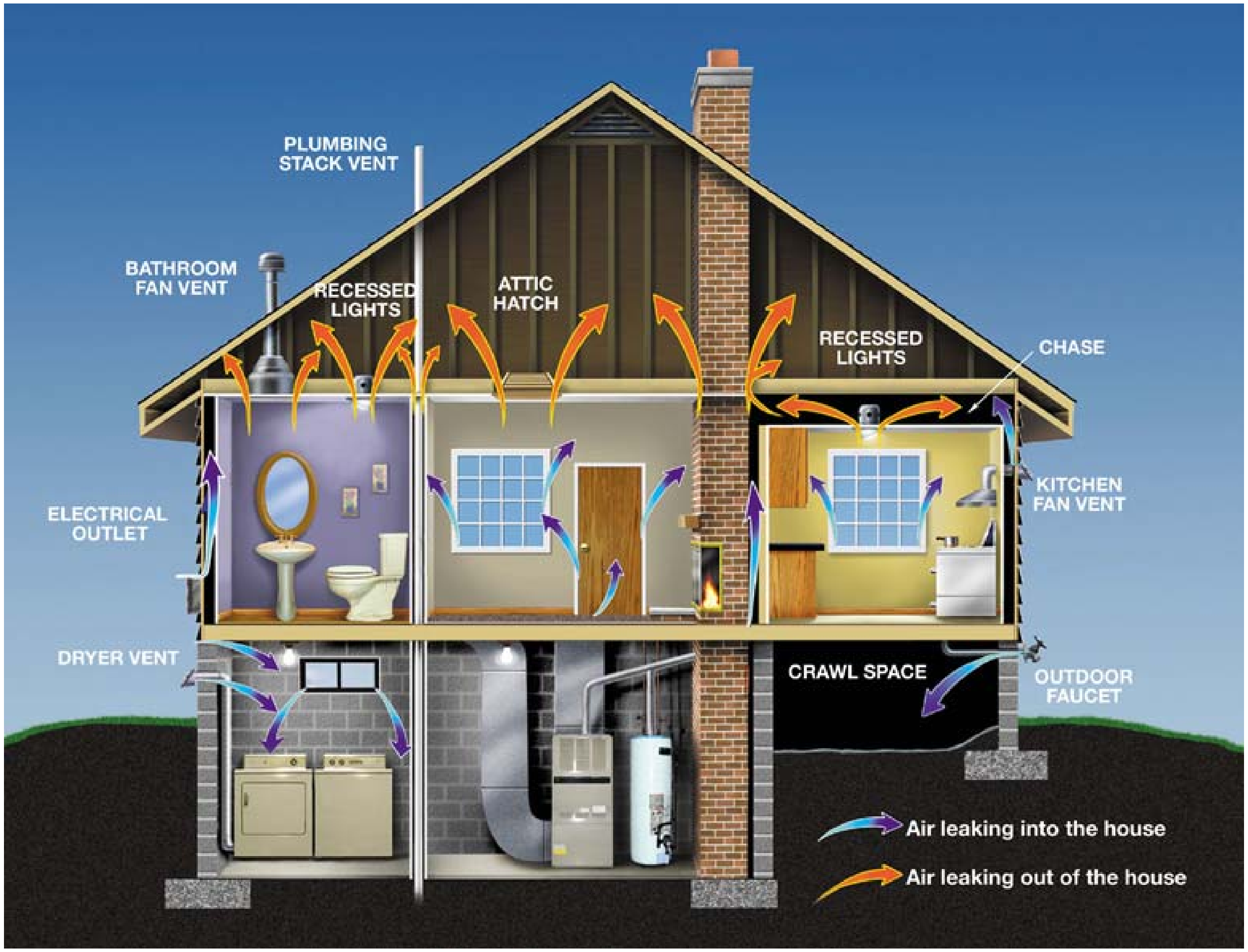
…vs. through CRACKS



How Does the Air Escape?
Air infiltrates in and out of your home through every hole, nook, and cranny. About one-third of this air infiltrates through openings in your ceilings, walls, and floors.

When water vapour is carried in the AIR and escapes THROUGH THE CRACKS this is termed **AIR LEAKAGE**.

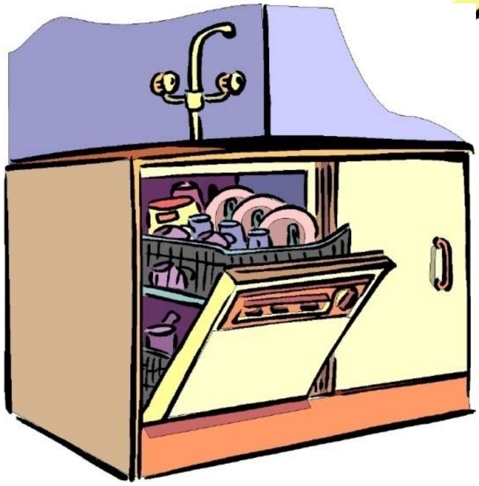
Air leakage paths in houses



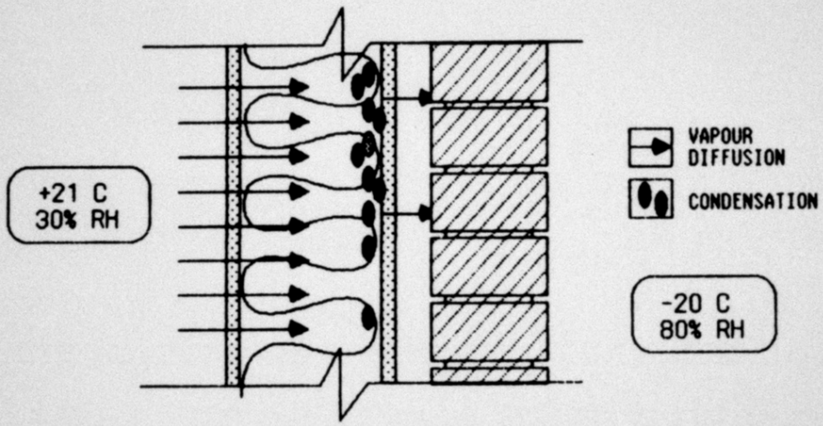
A moist interior environment

All of these factors put moisture into the air that is trying to escape via **Diffusion** or **Exfiltration (ghosts** and **cracks)**.

The moisture ends up condensing IN the building envelope…

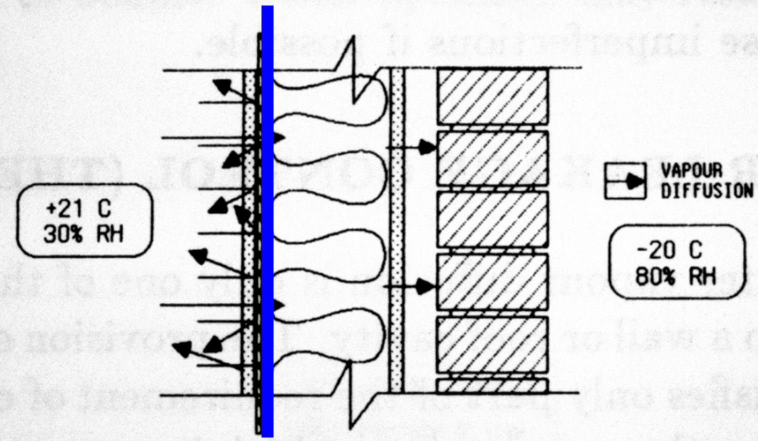


Vapour barriers



WALL WITHOUT A VAPOUR BARRIER

FIG. 1A



WALL WITH A VAPOUR BARRIER

FIG. 1B

The vapour barrier (in this instance made from 4mil polyethylene film) is placed on the WARM SIDE OF THE INSULATION. It stops the GHOST-like vapour from passing THROUGH THE WALL.

Only about 10% of vapour escapes through the wall in this manner. 90% of the problem is as a result of AIR LEAKAGE through the cracks.

Problems with vapour barriers

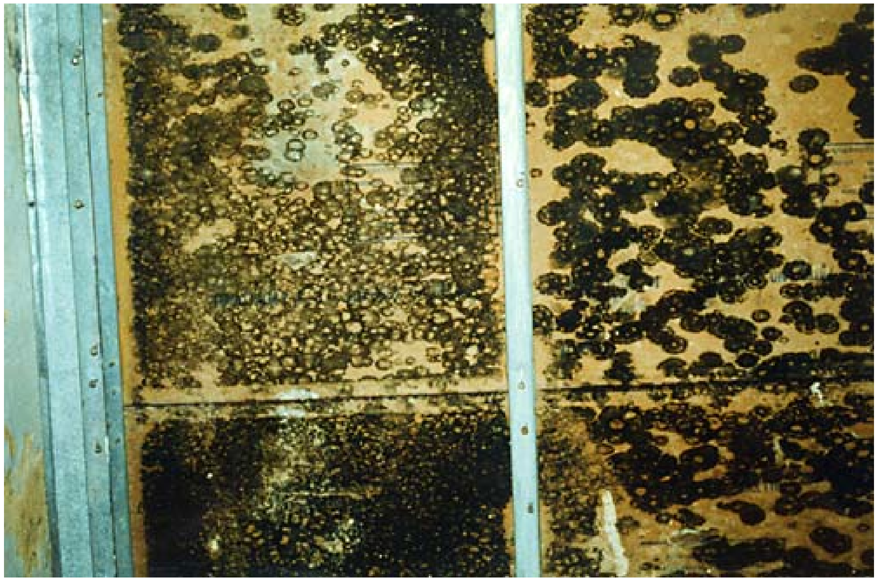
Polyethylene film that is used as a vapour barrier has some inherent problems arising from its fragility. It is easy to puncture and is not very durable.

There are studies being done at present that might indicate that it should not be used as widely as it is in walls for humid situations, as in some cases it is trapping moisture in the wall and CAUSING rot.

The jury is still out…

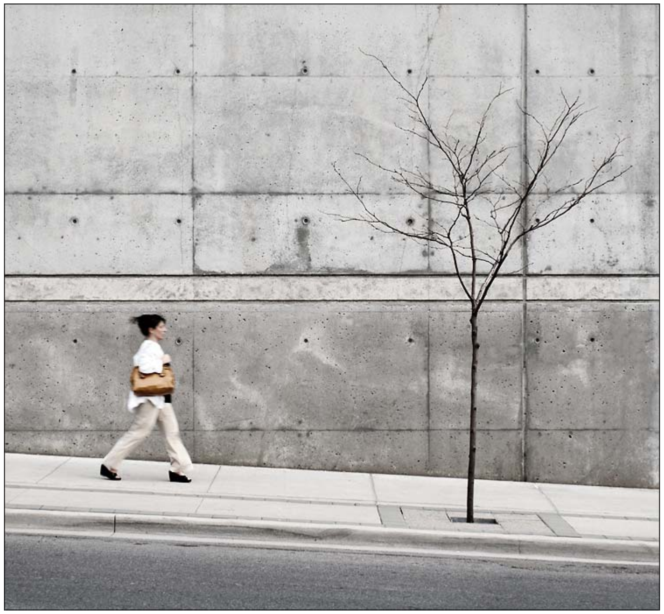
Ask Dr. John Straube when you have him in Arch 364…

Mold!!



Mold is TOXIC and very expensive to remediate.

Air barriers



Air barriers are products or systems of products that keep AIR from passing through them (not vapour).

A concrete wall is a good **air barrier** – but it does allow (some) vapour to pass through…

Much better than concrete block which is quite porous.

Controlling air leakage

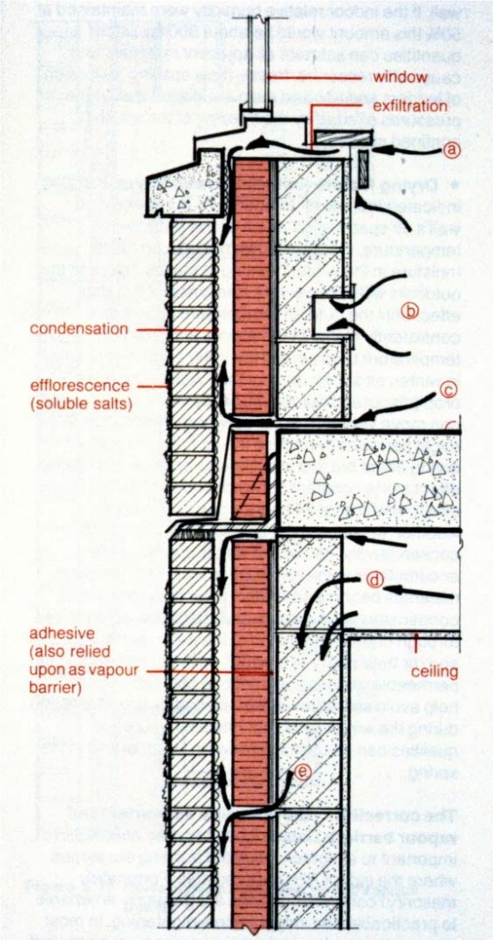


Figure 2.15 Exfiltration/Condensation Example Pattern (leakages ⓐ to ⓔ are discussed in the text)

Building envelopes must be designed and detailed to prevent **VAPOUR DIFFUSION** as well as **AIR LEAKAGE**.

This means sealing up all of the CRACKS between elements of the building envelope system.

You seal CRACKS with an AIR BARRIER.

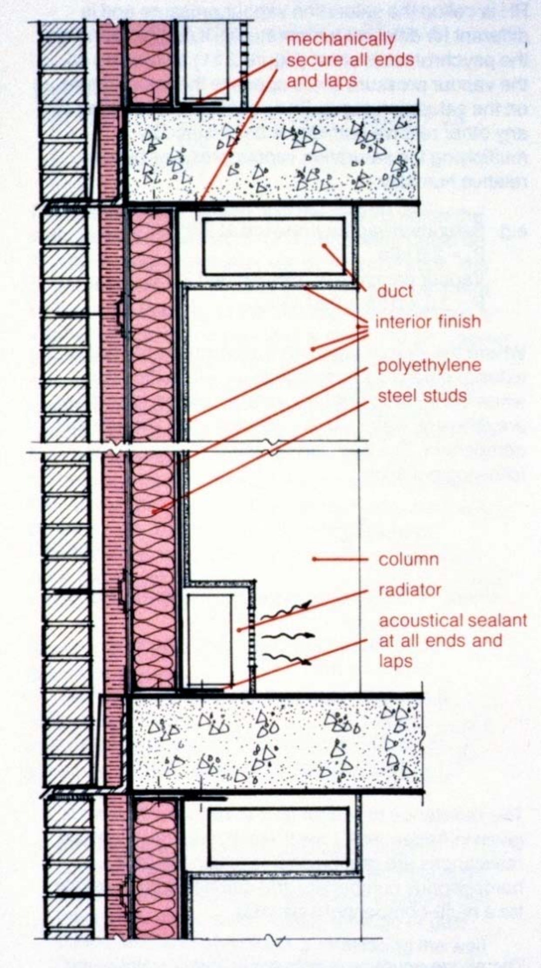
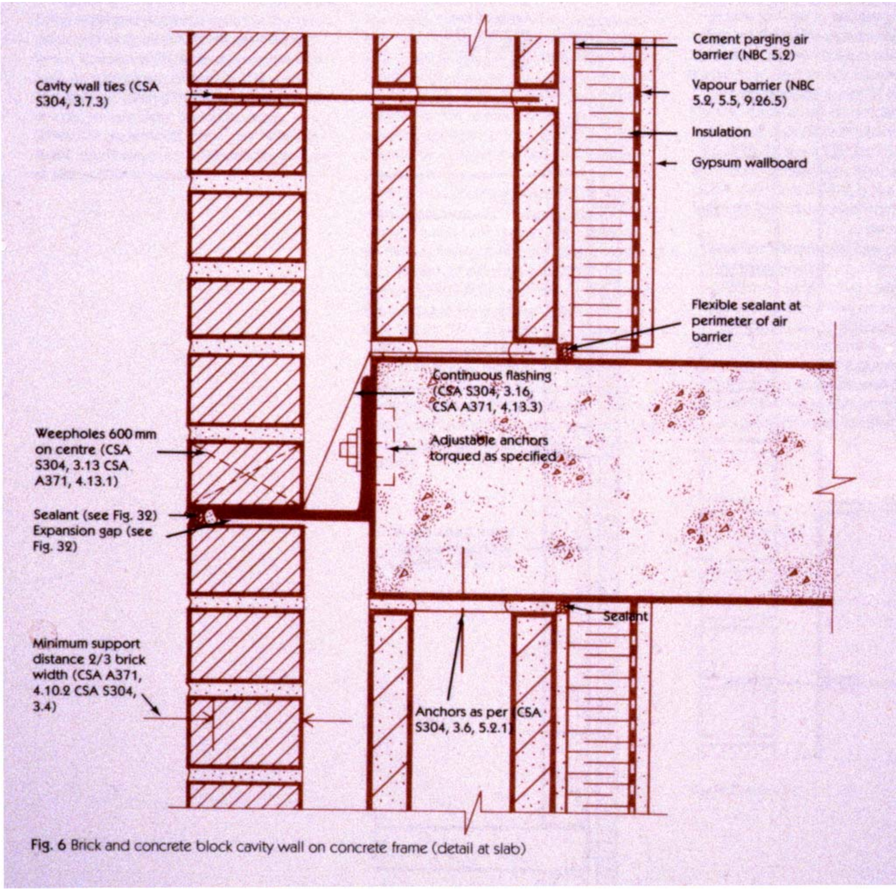


Figure 2.16 Polyethylene Film Used as Air/Vapour Barrier

Fixing the thermal bridge



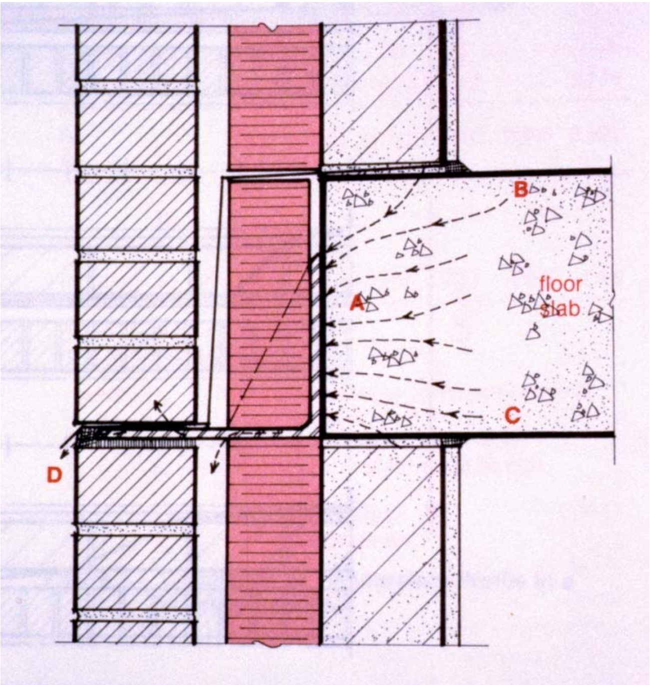
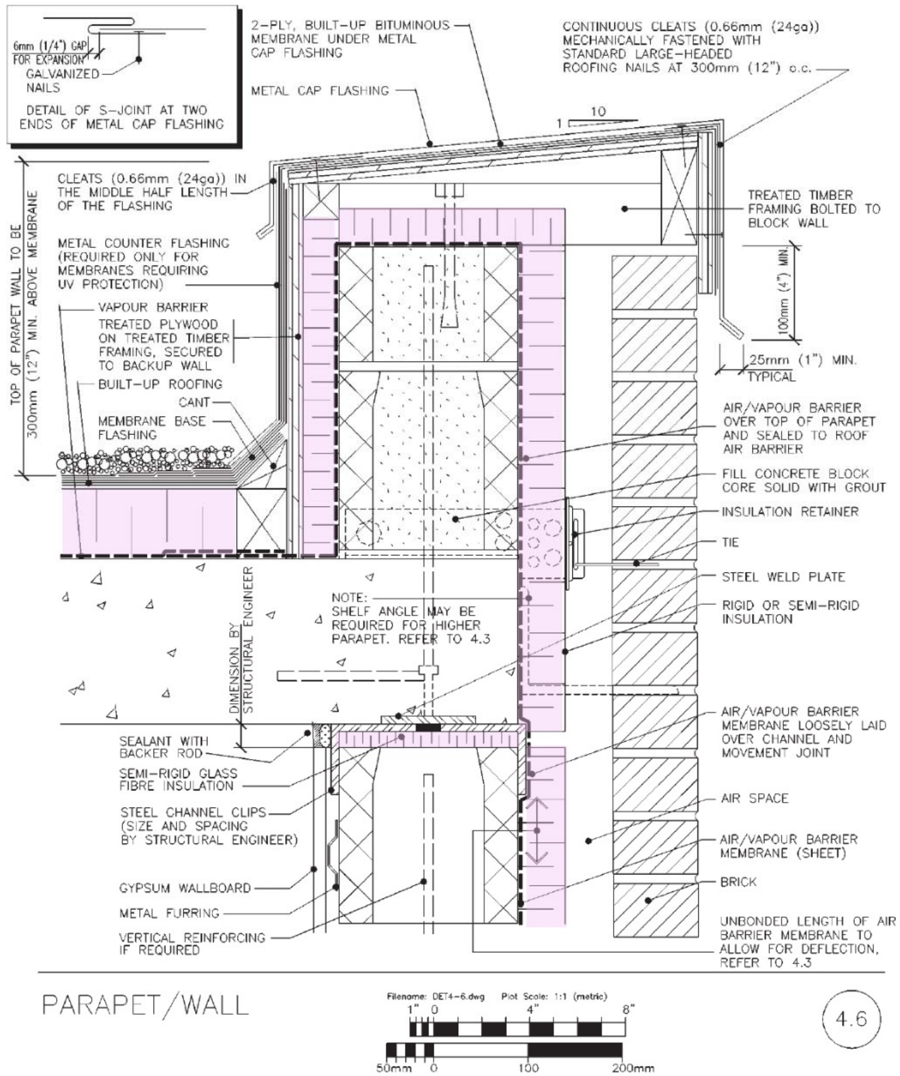


Figure 2.7 **An Unavoidable Thermal Bridge Properly Designed and Treated (temperatures at A, B, and C remain warm because the steel angle's pickup area A is large and conductive while its heat releasing area D is relatively restricted)**

With some intelligent detailing, pretty well all thermal bridges can be avoided.

Continuity of Insulation in Details

Insulation wraps around the parapet to prevent heat loss in this vulnerable position (because hot air rises)

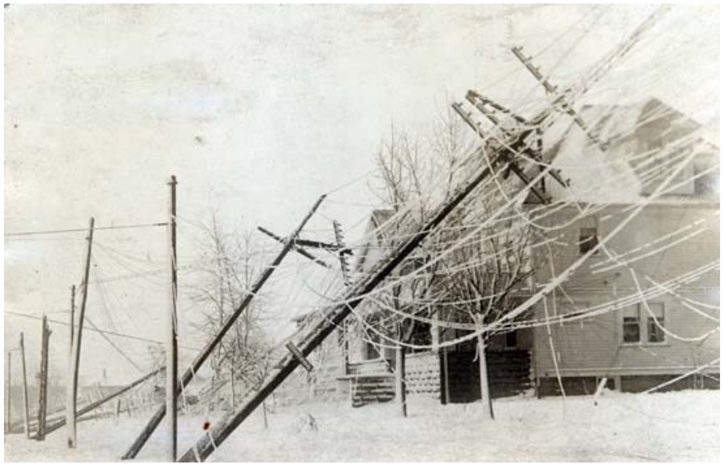


Wind

Wind can be a very positive force in the built environment, giving us natural ventilation and energy for our buildings.

Wind damage

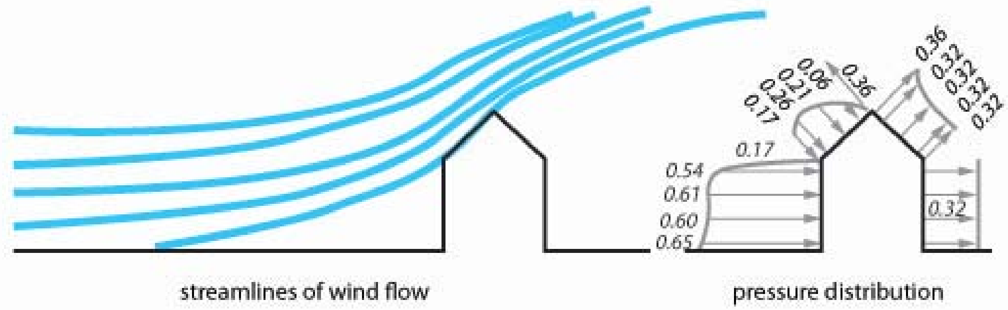
However building envelopes must be designed to resist extreme wind forces, particularly in hurricane and tornado prone areas.



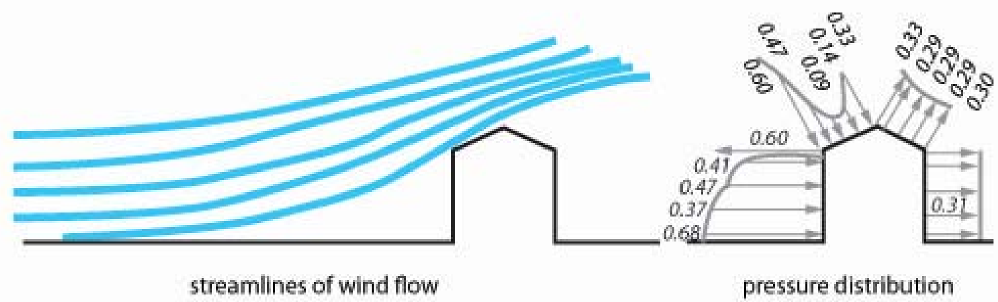
Wind over a small building

The effects of wind on low rise buildings will have ramifications on the design of roofs (and selection of roofing materials to prevent uplift), as well as ventilation patterns through openings/windows.

Recognize positive pressure on the windward side and negative/suction pressure on the leeward side of the building.

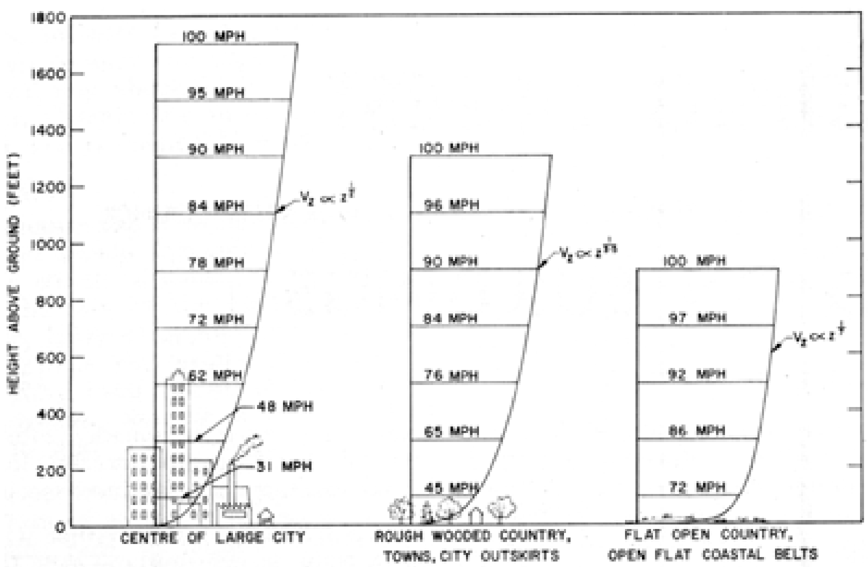


two-dimensional wind flow over a building.



separation of wind flow at eave causing high suction.

Wind speeds

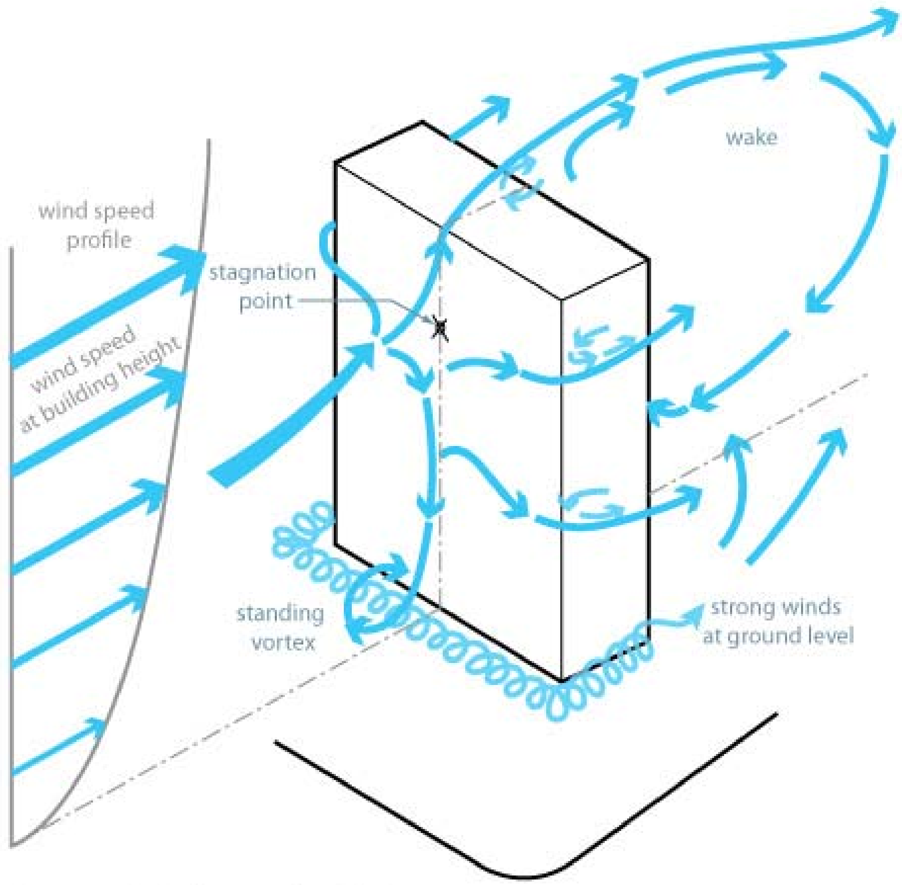


Wind speeds vary as a function of the “openness” of the space.

Ground level winds speeds are higher in open country, but tall buildings experience severe wind loads on their upper stories that can put extra pressure on the building envelope.

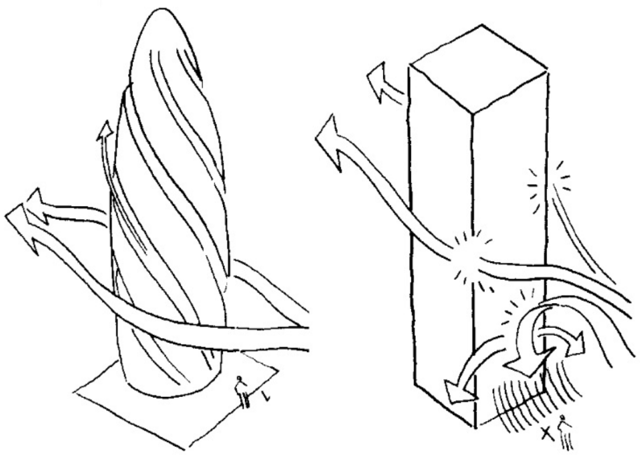
Wind around a tall building

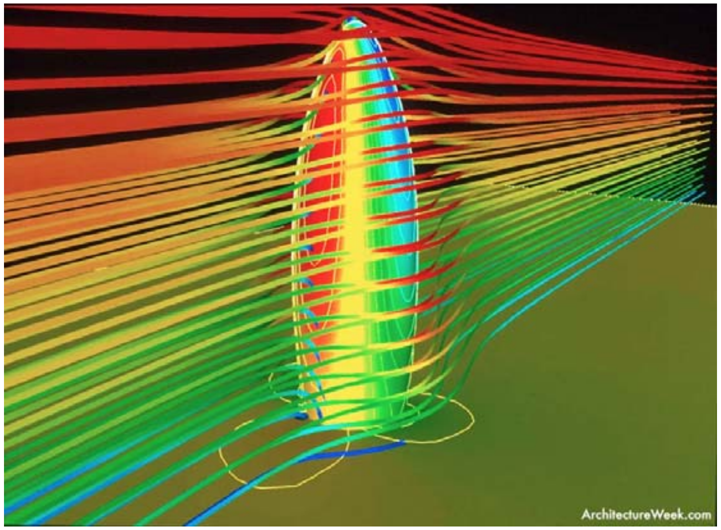
Wind forces around very tall buildings can be severe. There is upward wind flow at the top of the building and downward flow at the base. Turbulence at ground level can make it difficult to open and close doors.



Flow around a building in a boundary layer.

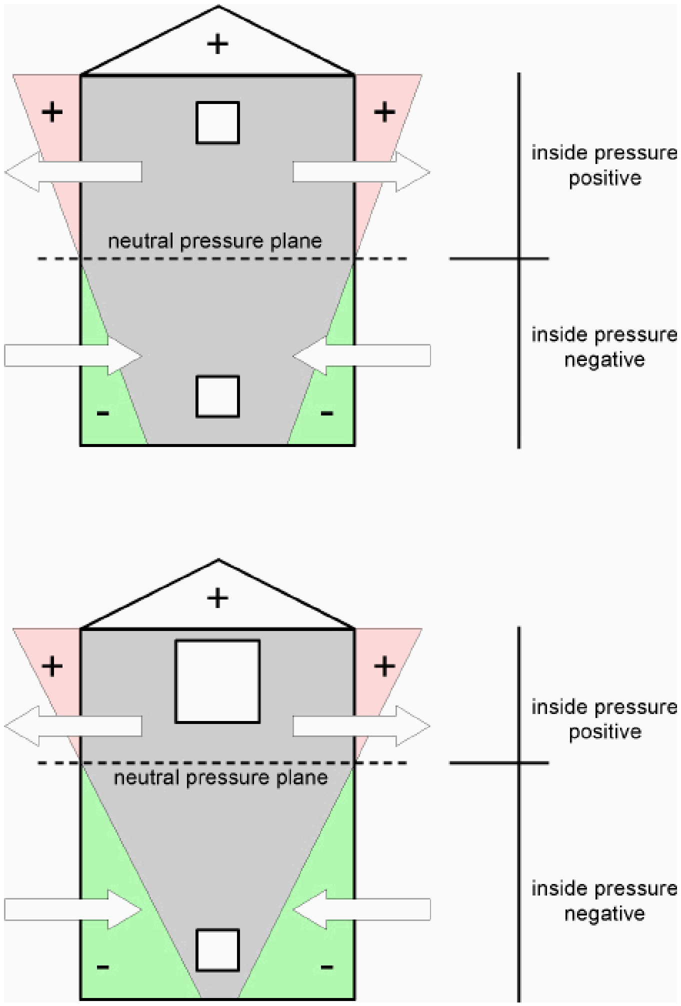
Swiss Re by Foster + Partners





Building designed as a round tower to make for a less hostile wind regime at the base.

Stack effect



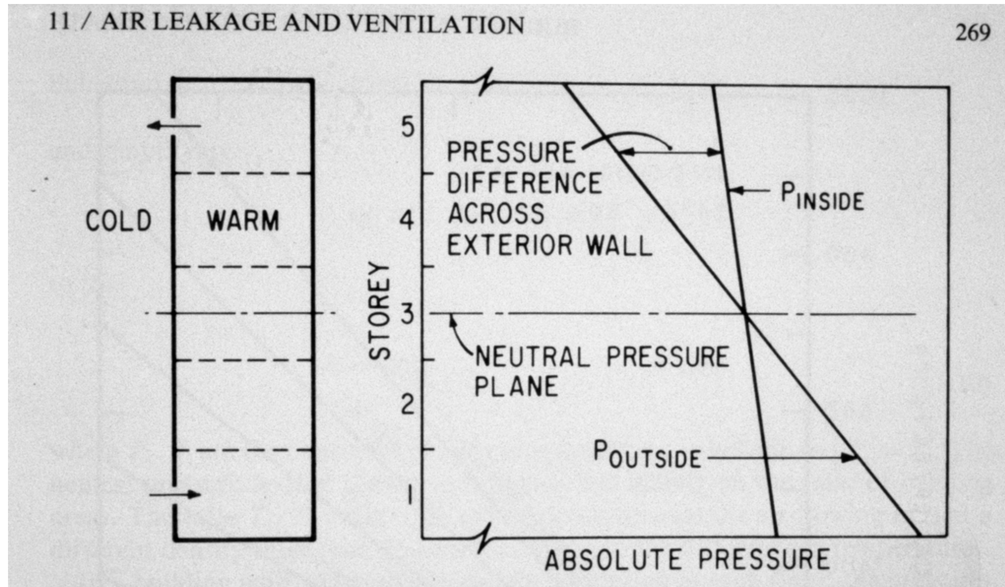
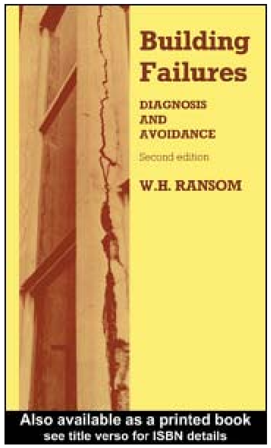
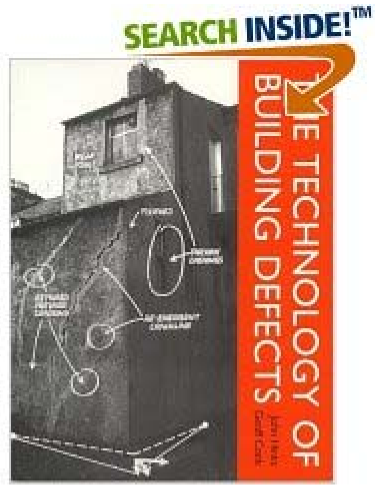


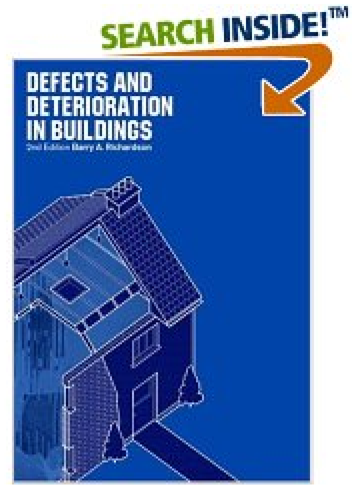
FIGURE 11.2 Stack effect in a building with no internal partitions. (From Wilson, A.G., and Tamura, G.T., Canadian Building Digest 104, DBR/NRCC, 1968, Fig. 1(b))

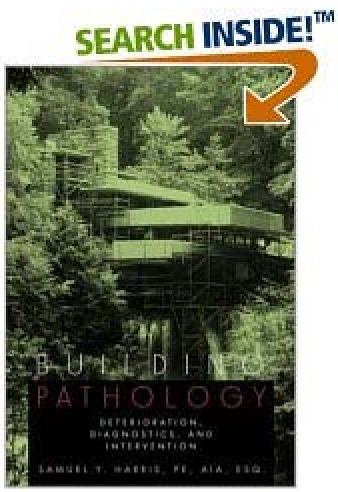
Stack effect is caused by the nature of hot air to rise. It puts upward/outward pressure at the top of a building and suction/inward pressure at the base.

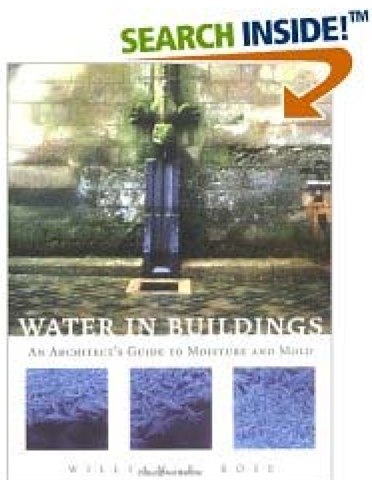
The study of building failures…

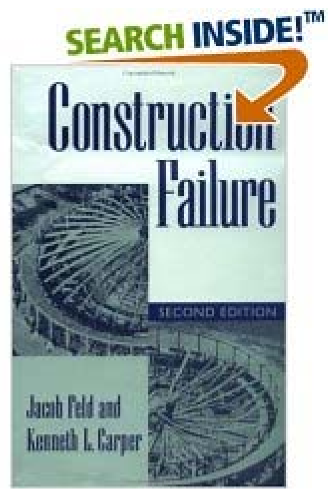


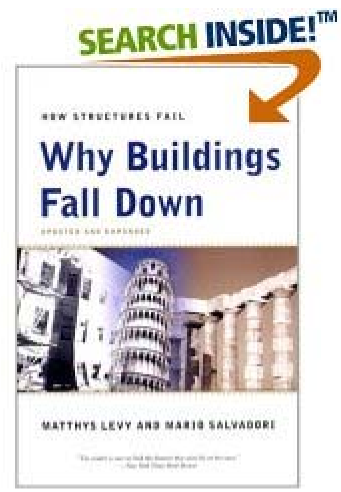




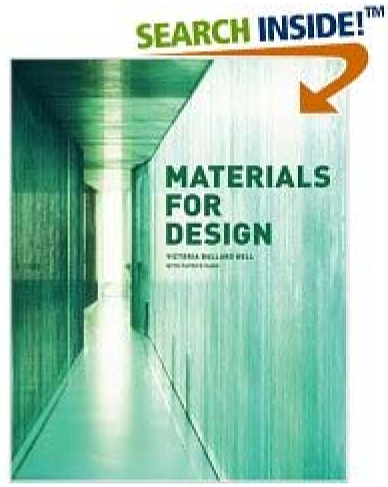


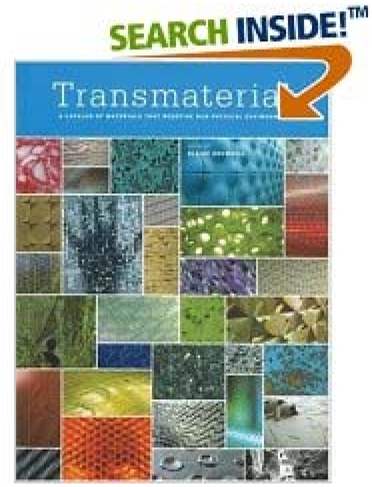






The question of so many new materials?





Adding to the complexity of the issue, there are a great many NEW materials that are now being used in buildings. Some of these have not been properly tested for all climates and weathering locations, and therefore might not work well. Research and investigation is necessary…