Chapter 7: Passive Solar

- Collect, store, and redistribute energy without fans, pumps, or complex controls

7.1 History

A) Western Civilization (Mostly Europe)

i) Ancient Greeks (~600 BC to ~30 BC)

- People:
  - Mostly peaceful and philosophical (Socrates)
  - First Olympics
  - Introduced proportion
    - First in sculpture
    - Then in architecture

Architecture

- South-facing houses with overhangs
- Large windows
- Light shades on thick walls and floors (i.e., thermal mass)
- To store heat for nighttime heating of house

ii) Roman Empire (~700 BC to ~500 BC)

- People:
  - Great architects and engineers
  - Imperialistic
  - Republic

Architecture

- First glass windows (~AD 50)
  - Greenhouse effect
- Sun rooms
  - Fruits and vegetables all year
- Public baths
  - Faced southwest for sun
  - Plumbing
- "Sun rights"
  - Laws to ensure individuals had access to sunlight via homes and public buildings

Google Image: "Roman Empire Map"

Google Image: "Roman Baths"
iii) **DARK AGES** in Western Civilization (~500 AD to ~1400 AD)

- **People**
  - Fall of Roman Empire
  - Break-down of civilization
  - Feudal societies
    - People lived within walled cities and castles ruled by wealthy rulers with a private army

- **Architecture and Urban Design**
  - Organic venacular growth of buildings and cities
    - Ironically, beautiful crooked cobblestone streets and some architecture beautiful without "design" (formal)
    - Ironically, high-density cities during this time resulted in better mass transit later on (i.e., now)

  - People not spread out like in US and other more recently developed places
    - Cars → density

iv) **RENAISSANCE** (~1400 AD to 1600 AD)

- **People**
  - Civilization!
  - Art, science, etc.

- **Architecture**
  - First, big churches (cathedrals)
  - Conservatories (large green houses)
  - Summer rooms on north side
  - Winter rooms on south side

**Go to P. 14**

**Homepage**

**See all Italy pictures**

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B) Indigenous Old Western Civilizations

- Aztecs (Mexico)
  - Sun worshiped
  - Channeled sunlight
- Inca (Peru)
  - Sun angles and cities

C) Non-Western Civilizations

- Mesopotamia (5000 BC - First City)
- China (for 1000s of years, no dark ages)

- Ancient Egypt (3000 BC - 1300 BC)
- Thermal mass to compensate large ΔT from desert radiational cooling (see Ch 3)
  - Black pools of water heated during day
  - Water drained through pipes in floor to heat palace at night

Google Images:
- "Pueblo Bonito"
- "Mesopotamia"

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**Frank Lloyd Wright** (1867 to 1959) → U.S.A.

- **Early 1900's**
  - Optimized overhangs
  - Curved buildings to match sun paths "solar hemicycle"

- An Arts & Crafts and Victorian era architect who visited Japan and was influenced

- Invented **Prairie Style**

Also see Walter Gropius → came to U.S.

See Dr. W. "Mansions" PPT on his website

1800's, 1900's mostly

This lecture also has some architectural fundamentals

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PASSIVE ADVANTAGES OVER ACTIVE SOLAR

1. LESS INITIAL COST
2. LESS MAINTENANCE
3. MORE RELIABLE
   - Predictable
   - Longer life
4. Yields better overall architecture
   - Esthetics
   - Vegetation
   - Local materials
   - Local styles
   - Compliments surrounding
   - Human scale
5. LESS "EMBLINING" OF OUR EYES, INCREASING RELIANCE ON TECHNOLOGY

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7.6-11 DIRECT-GAIN SYSTEMS (INCLUDING TROMBE WALL)

LOW-MASS FLOOR + WALLS:

LOW-MASS FLOOR + WALLS:

HIGH-MASS FLOORS + WALLS

HIGH-MASS FLOORS + WALLS

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**Thermal Mass Choices**

**Concrete Floors and Walls (and columns) Good**

- **Floors Best:**
  1. Most sun directly
  2. Most comfortable as heat released
  3. Easier to construct
  4. Easier to penetrate maintain structural engineering
  5. Easier to surface
  6. More esthetic

- **Water:**
  1. Columns let light through
  2. Pools inside/outside
    - But maintenance and sanitation issues
    - Maybe a coy pond
  3. Egyptian type black pool outside
    - Pump water in at night
    - Semi passive
  4. Solar collectors with piping and pumps
    - This is not passive
    - "Active Solar"

*Google Image* "Thermal Mass Water"

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MORE ELABORATE TECHNIQUES

A. CLEARESTORY (HIGH WINDOW ABOVE EYE-LEVEL) ("CLEAN STOREY")

Also good for bringing in light
See Italy: Rome picture on Dr. W's website, Basilica St. Peter

Historically, clerestory meant upper level (second storey) of a Roman basilica

B. SOLAR HEMICYCLE BUILDING FOOTPRINT

"Google Image "Solar Hemicycle"
CHANNEL SUNLIGHT TO THERMAL Masses

- High-reflectance paints
- Polished metal
- Moveable reflectors on skylights = \( S(\theta_{\text{alt}}) \)

TROMBEE WALL ("THERMAL STOREAGE WALL")

- Uses "greenhouse effect"
- Paint wall black
- Operable shutter over glass
- But not passive

BOOK SAYS:
- Avoid circulating air from gap
- Don't apply heating (old idea that doesn't work)
- More research needed

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**DESIGN OF DIRECT GAIN SYSTEMS**

- **Building MUST be well insulated**
- **Use thermal drapes at night in cold climates**
- **Optimum south-facing glazing** (from Table 7.9a)

| U.S. Climate Region | Glazing Area % of Floor Area | Heating Load Contributed by Solar (%)
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3 (Southeast PA)</td>
<td>28</td>
<td>No Night Insulation</td>
</tr>
<tr>
<td>11 (Phoenix, AZ)</td>
<td>12</td>
<td>With Night Insulation</td>
</tr>
<tr>
<td>16 (Miami, FL)</td>
<td>2</td>
<td>Thermal Drapes</td>
</tr>
</tbody>
</table>

- **Bigger than hotter places**
- **Windows should be high-performance**
  - Double glazed
  - Maybe special gas between glazings

- **Optimum thermal mass sizes** (not trombe wall)

<table>
<thead>
<tr>
<th>Type</th>
<th>Thickness</th>
<th>Surface Area / Glazing Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete or Masonry (Direct Sun)</td>
<td>4-6 in</td>
<td>3 Good!</td>
</tr>
<tr>
<td>1&quot; Reflective Sun</td>
<td>2-4 in</td>
<td>6</td>
</tr>
<tr>
<td>Water</td>
<td>6 in</td>
<td>1/2 Best</td>
</tr>
</tbody>
</table>

- Added thickness: Added insulation, comfort
- Use dark colors for thermal masses
- Use light colors for all else to reflect light to masses

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<table>
<thead>
<tr>
<th>Type</th>
<th>Thickness*</th>
<th>Surface Area/ Glazing Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adobe (Dry Earth)</td>
<td>6 - 10 in</td>
<td>1</td>
</tr>
<tr>
<td>Concrete/ Masonry</td>
<td>10 - 16 in</td>
<td>1</td>
</tr>
<tr>
<td>Water</td>
<td>8+</td>
<td>1</td>
</tr>
</tbody>
</table>

* Thicker yields better all-night heat

- Water works best in combination with other thermal mass systems for optimal
  ① ΔT Inside ② Views ③ Interior Lighting
  ④ No fencess of sun glare

- Water can be in vertical tubes of
  ① Plexiglass
  ② Steel

  → Half-Height Wall Combo-window + Trombe

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**7.12-16 Sunspaces ("Solvium")**

- Called "Conservatories" in US, 1700's, 1800's
- Can act as greenhouses (Romans did this)
- """
- Living space (but air to big sometimes)
- Collects heat for house!
- Isolate it at strategic times (assume sun will overheat)
- Doors & operable vents & fans (gives it)
- Acts as buffer to cold at night (gives it)

7.14

- Glazing: use thermal mass
  - Perpendicular to sun during coldest months
  - May choose vertical
  - Less leaky
  - Best when overhang shading design CH 9

- Include solar mass if space used most of year
  - But in very hot or cold climates
  - Just use as isolated heat collector

- Use trees, reflectors, and overhangs to control light (CH 9, 13)
- Use movable shades!

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But Exclusions:

1. Art/Architectural studios want mostly northern light
   - Despite worse thermodynamics
   - Consistent (cool and controlled)
   - Light with no glare important

2. "Uses" for mostly morning
   - Face south east
   - "Uses" for mostly morning

3. Microclimates with much morning fog or clouds
   - Face slightly west of south

4. Breakfast rooms
   - Face east for nice morning light
7.17 Heat Storage Materials

1. Concrete
   Masonry very good and structural

2. Water (phase change material)
   Water stores heat as water

3. PCM (Phase Change Material)
   PCM best for light through (phase change material) solid-liquid type
   - PCM stores as latent heat
   - PCM stores as sensible heat
   - PCM can store heat as T increases
   - When melting reached, material absorbs much heat for little ΔT
   - Until all material liquid
   - Then as T increases, PCM solidifies, heat released

Google Scholar:
"Phase Change Material Passive Solar"

Google:
"Sonneschiff" Solar City

- PCM's
- Better than net-zero energy
- Produces 4x what it needs
7.18 OTHER PASSIVE SOLAR

1. THERMOSIPHON (CONVEXIVE LOOP)
   - NEED SOUTH FACING SLOPE
   - COLLECTOR (FULL OF PIPES) (BLACK)
   - ROCKS FOR HEAT STORAGE
   - HOT COOL
   - CAN BE COSTLY
   - CAN USE AIR OR WATER
   - NO PUMP!

2. ROOF PONDS
   - BLACK PLASTIC BAGS OF WATER
   - INSULATED COVER

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Roof Radiation Trap

Open Shutter

Close Shutter

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