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Heat Management in Housing under Extreme Summer

(অত্যধিক গ্রীষ্মে আবাসনের তাপ নিয়ন্ত্রণ)

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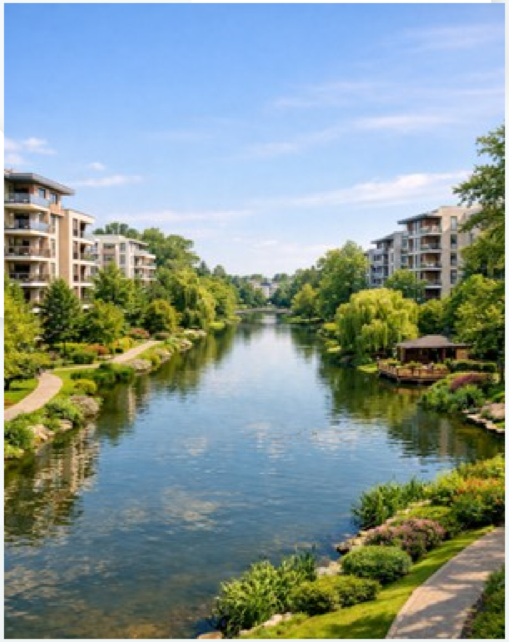
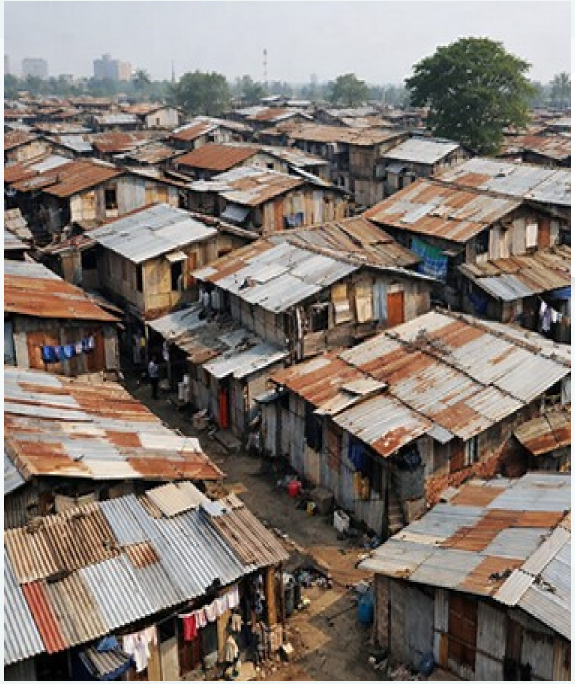
- For millions of households across South-East Asia and similarly placed tropical or arid regions in the Global South, “staying cool" during extreme heatwaves is a matter of survival.
- With air conditioning remaining economically inaccessible for a vast segment of the population, a range of low-cost, innovative, and passive strategies are being proposed to cool homes without incurring prohibitive electricity costs.
- Unfortunately, such strategies are rarely implemented, and each year many people suffer from heat-related illnesses. Tragically, numerous lives are lost during the summer due to extreme heat.
- In this discussion, a few known strategies for temperature moderation in housing and apartments, along with the underlying reasons, will be addressed.





- A residential complex with many trees and a long lake or a few ponds provides a substantially cooler environment compared to one without such features.
- Such environments are rare in South-East Asia, and middle- and lower-income families cannot imagine having these facilities in their residential complexes.

Well-Established Strategies of reduction of temperature

- Cool Roofs and Surface Treatments (the First Line of Defense)
  - In dense urban areas, corrugated iron sheets or concrete rooftops absorb massive amounts of solar radiation and turn homes into ovens.
  - Solar Reflective White Paint (Cool Roofs)
  - Green Roofs and Thatch Layering
- Modular Evaporative Cooling
  - Traditional "Desert" Coolers , Clay and Terracotta Passive Innovations
- Vernacular Ventilation and Solar Shading
  - Keeping windows tightly shut and shaded during the scorching peak hours (10 AM to 5 PM) stops heat ingress. At night, opening windows at opposite ends of the home creates cross-ventilation, flushing out trapped daytime heat using cooler night air.
- Microclimate and Localized Cooling

Cooling Solution	Upfront Cost	Electricity Usage	Best Suited For
Solar Reflective Paint	Very Low	0 Watts	Flat concrete or metal roofs
Wetted Bamboo Screens	Extremely Low	0 Watts	South/West facing windows
Evaporative/Desert Cooler	Low	60 – 150 Watts	Hot, dry climates
Micro-AC Bed Tents	Moderate	150 – 300 Watts	Humid or dry climates (Sleep comfort)
Standard Split AC (Baseline)	High	1,500+ Watts	Requires enclosed, insulated space

Physical Causes of Hot Rooms

- Solar heating & Exterior temperature
  - solar intensity during summer – 5000 -7500 W/m^2/day.
  - sunlight heats roof and walls,
  - roof and walls conduct heat inward
  - room temperature evolves from energy balance
- Suppose sunlight falls on a roof/west-facing concrete wall during summer afternoon
- solar power absorbed per unit area

$$q_{abs} = \alpha S$$

- $\alpha\, is\, the$ absorptivity and S is the solar intensity

- The wall loses heat through
- Convection to ambient air
  - $q_{conv}=h(T_w-T_{out}), h=convective\,coefficient$
- Thermal radiation
  - $q_{rad}=\epsilon\sigma(T_w^4-T_{sky}^4)$, • $\epsilon\approx0.9$
- Conduction inward
  - $q_{cond}=(T_w-T_{in})/R$
- At equilibrium
  - $q_{abs}=q_{conv}+q_{rad}+q_{cond}$

For: $40^{\circ}C$ **ambient air, strong afternoon sunlight, dark concrete wall** $(\alpha\simeq0.7)$, **the exterior wall temperature naturally rises to about** $\mathbf{53}^{\circ}C$–$\mathbf{55}^{\circ}C$ and Dark roofs can become even hotter 60$^{\circ}C$–$70^{\circ}C$

Effect of White Paint

- $Absorptivity\, \alpha: 0.7 \rightarrow 0.3$
- Then absorbed solar power becomes 180 W/m^2
- The equilibrium wall temperature drops dramatically to roughly: 44^o C to 46^o C (for T_{out} – 40^o)
- sunlight contains: Visible light - ~ 45%, Near infrared ~ 50%, UV small
- White lime leads $\alpha: 0.3\text{-}0.15$
- modern coatings may reduce wall temperature by about another 2^o - 3^o

Room temperature

- The thermal energy of air is $E=MC_pT_{in}$, M – mass of air, C_p is the specific heat, and T_{in} the room temperature.
- The thermal energy stored in room air changes according to
  - $MC_p(dT_{in}/dt)=Q_{in}-Q_{out}$
- Heat conduction through wall
- $Q_{in}=A(T_w-T_{in})/R$, A = wall area, R = thermal resistance.
- Ventilation exchanges air with outside
- $Q_{vent}=\rho\, c_p\, dV/dt\,(T_{in}-T_{out})$

Numerical calculation (typical values)

- Room – 4 x 4 x 3 m^3, A=10 m^2 .
- Air mass - $M_{air} \approx 58\,kg$
- $Cp=$ 1000 J kg^{-1} K^{-1}
- However, furniture/walls also store heat, effective thermal mass is much larger.
- Mc_p ~ 5 x 10^5 J K^{-1} .
- Bare concrete wall R= 0.15 m^2 K/W
- Modest ventilation dV/dt= 0.05 m^3/s
- For T_{out} 40^o C, T_{in} ~ 44^o - 45^o C. The thermal time scale of thick concrete is roughly 8 hours, a building experiences a massive thermal lag.

Advanced Internal Thermal Barriers

- When one cannot paint the exterior wall, a barrier on the inside of the walls that face the direct afternoon sun (usually South or West-facing walls) may be created.
- Thermocol Sheets -
- With 2 cm thermocol sheet, thermal resistance R~ 0.72.
- Room temperature reduces by about 3^{o} - 5^{o} .
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Window engineering

- Up to 75% of the heat entering a middle-floor apartment comes directly through the glass windows via solar radiation. Managing your windows is the single most effective passive strategy available.
- High-Reflective or Low-E Window Films: Applying reflective, mirror-finish, or low-emissivity (Low-E) film to the inside of window glass is highly effective. These films reflect infrared solar rays away before they can heat up room's air. They are cheap, completely removable (renter-friendly), and can reduce indoor temperatures by 2°C to 4°C.
- Internal Thermal Blackout Curtains: Standard cotton curtains let heat pass right through. Switching to heavy, multi-layered thermal curtains with a light-colored or reflective backing facing the window will trap heat in the small pocket of air between the curtain and the glass.
- Traditional Bamboo Chicks

A room with an unpainted/painted tin roof

- $\alpha \approx 0.5$
- The roof reaches a temperature where absorbed solar power balances convection and radiation
- $q_{abs}=h(T_r-T_{out})+\epsilon\sigma(T_r^4-T_{sky}^4)$
- For T_{out} = 40^o C, $T_r \approx 65^\circ C - 75^\circ C$
- A typical tin sheet thickness is 0.5 mm with conductivity k≈50 W/(m K).
- T^{in} ~ 50^o C -53^o C.
- a solar-reflective white coating reduces absorptivity from 0.5 to 0.15. This leads $T_r \approx 45^\circ C - 50^\circ C$ and Tin ~ 43^o C.

A ceiling below the tin roof

- 10–20 cm ventilated air gap,
- lightweight ceiling below
- The air gap dramatically reduces heat transfer.
- this often lowers indoor peak temperature by another
- 4^{o} – 8^{o} C.

Cooling load

- Aged straw thatch 30 cm thick
- absorptivity – 0.7, thermal resistance inverse – 1/R ~ 0.15 W/(m^2 K) (highly insulator)
- Unpainted concrete 15 cm thick
- absorptivity – 0.7, thermal resistance inverse – 1/R ~ 3.2 W/(m^2 K)
- $Q_{in}=A(T_w-T_{in})/R$
- Q_{in} (concrete)/Q_{in} (aged straw) ~ 21.3

Heat retention

- Specific heat -
- Straw ~1800 – 2000 J/Kg/K
- Concrete/brick ~ 800-1000 J/Kg/K
- While straw has roughly double the specific heat capacity of concrete per kilogram, it is incredibly lightweight (low density). Concrete is dense and heavy, meaning a concrete slab contains far more total kilograms of material than a straw roof of the same volume. Therefore, concrete stores significantly more total heat energy over time. In summer, they absorb daytime heat and radiate it indoors late at night.

The future

- The physics is well understood. The challenge is implementation, coordination, and demonstrating local benefits clearly enough that communities and policymakers act on them. Small, well-documented local experiments can be surprisingly influential in that process.

Thank you.