Climate-responsive buildings in India & US Laboratory and field studies

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Background: What is CBERD?

Objective

Promote energy efficiency in both India and the

U.S. through collaborative research, with a focus on commercial and multi-family residential buildings

Background

- Part of larger initiative: U.S.-India Partnership to Advance Clean Energy (PACE)
- 5-year project: 2012-2017
- R&D Partners:
 - Five in U.S., led by LBNL
 - Six in India, led by CEPT University

Funding

US DOE and Government of India







CBERD organization



Task 1: Simulation and Modeling LBNL, UCB, IIIT, CEPT

Task 2: Monitoring & Benchmarking LBNL, CEPT

Task 3: Integrated Sensors & Controls LBNL, RPI, IIIT, IIM

> Task 4: Advanced HVAC ORNL, MNIT, IIT

Task 5: Building Envelopes LBNL,ORNL, CEPT, IIIT

Task 6: Climate Responsive Bldgs UCB, CMU, MNIT, CSR, CEPT

> Cross Cutting Integration CMU, LBNL, CEPT

Blue = US; Red = India

Task 6: Climate responsive buildings

Objective

Better understand performance of well designed passive buildings; focus on:

- Natural ventilation & mixed-mode
- Thermal mass & nighttime ventilation
- Role of air movement

Activities

- 1. Physical Performance
 - a) Earth air heat exchangers (monitoring & simulation
 - b) Mixed-mode case studies
 - c) Building monitoring (India & US)
- 2. Thermal Comfort
 - a) Climate analysis & new bioclimatic chart
 - b) Field-based IEQ surveys
 - c) Laboratory studies





Monitoring in India

Passive design strategies in different regions in India

Daylighting	ing Shading Natural venti & air movem		Insulation & high thermal mass	Low-energy				
Courtyards	Overhangs	Cross ventilation	Wall systems	Humidifiers				
Skylights	Vertical fins	Stack ventilation	Wattle & daub	Evaporative				
				cooling				
North light	Louvers	Solar chimney	Hollow clay blocks	Radiant cooling				
	Internal &	Courtyards	Cement stabilized					
	external		compressed earth					
	blinds		blocks					
	Ceiling fans		Rammed earth					
			Cavity					
			Roof systems					
		and the second se	Precast RCC rafters &					
			insulated tile roof					
			Vaulted roof with					
			terracotta pots					
	A REAL		Roof gardens					

Monitoring in India

- Completed year-long monitoring of indoor/outdoor thermal conditions:
 - Air temperature
 - Humidity
 - Globe & surface temperature
- Instrumentation
 - Long term monitoring: Hobo data loggers
 - Instantaneous measurements: Testo 410 & Extech HT 30
- Currently conducting comfort & performance analysis



HOBO data loggers – temperature & humidity & radiant



Test 410-2 compact vane

- temperature, humidity

anemometer

& air velocity



Extech HT30 Heat Stress meter - radiant temperature (from globe & air temp)

Monitoring in India - Auroville

- 7 naturally ventilated buildings in a hot & humid climate, small commercial & some residential
 - Thermal mass
 - Ventilated cavity walls & roof
 - Dome (stack effect)
 - Courtyard
 - Insulation



Annual air temperature profile of building using thermal mass and night ventilation scheme



Monitoring in India – Mixed Mode

- 6 mixed mode buildings across India's climate zones, larger commercial bldgs
 - External shading
 - Operable windows
 - Evaporative cooling
 - Radiant cooling
 - Thermal chimneys







Evaluation of instantaneous indoor operative temperature based on the IMAC and ASHRAE-55 adaptive models

90% acceptability - ASHRAE Ada

80% acceptability - ASHRAE Adaptive

- Coordinated study in "thermally controlled chamber"
- Impact of air movement on thermal comfort in hot & humid environment
- Personally controlled fans
- 8 different thermal conditions



Chamber HVAC rendering



Chamber furniture layout



Airmate S35113R Pedestal Fan

Developed work plan and experiment schedule



Experiment schedule

					Α					В	
		15min	1 hr 20 min (15+30+5+30)								
Dt	Time	8:45- 9:00	9:00- 9:15 9:15-9:45				9:50-10:20				
dd/mm/yyyy	Day 1- 26°C/60%			session 1A				session 1B			
	Session	acclimatize		26°C/60%			26°C/60%				
	Survey	prep.		Y/N Y/]	N Y/N	Y/N		Y/N	Y/N	Y/N	Y/N
	Subject No		1+2	1		2		1		2	

Example of work plan

- Calibrated all equipment
- Measured air velocity and fan power



Fan power and air velocity

TESTO 480 for air velocity measurement

- 20 subjects acclimated to hot Indian climate
- Typical Indian summer clothing
- Administered experiments with human subjects



Subject in chamber experiment



Survey questions

People prefer a wide range of air speeds

 \rightarrow Important to give people individual control



To what extent does air movement compensate for hot & humid conditions?

At least 90% thermal acceptability up to 32°C (89.6°F), 60% RH

Thermal acceptability at each test condition



Air movement allowed people to stay thermally neutral up to 32°C (89.6°F), 60% RH



Thermal sensation at each test condition

Over 25% of subjects still prefer to feel cooler at 28°C (82.4°F), increasing as it gets hotter

Temperature preference at each test condition



Chamber study in India – Next steps

Compare with other studies using SET



Questions?