Innovative Roof Design for Passive Low-Income Housing in Western India

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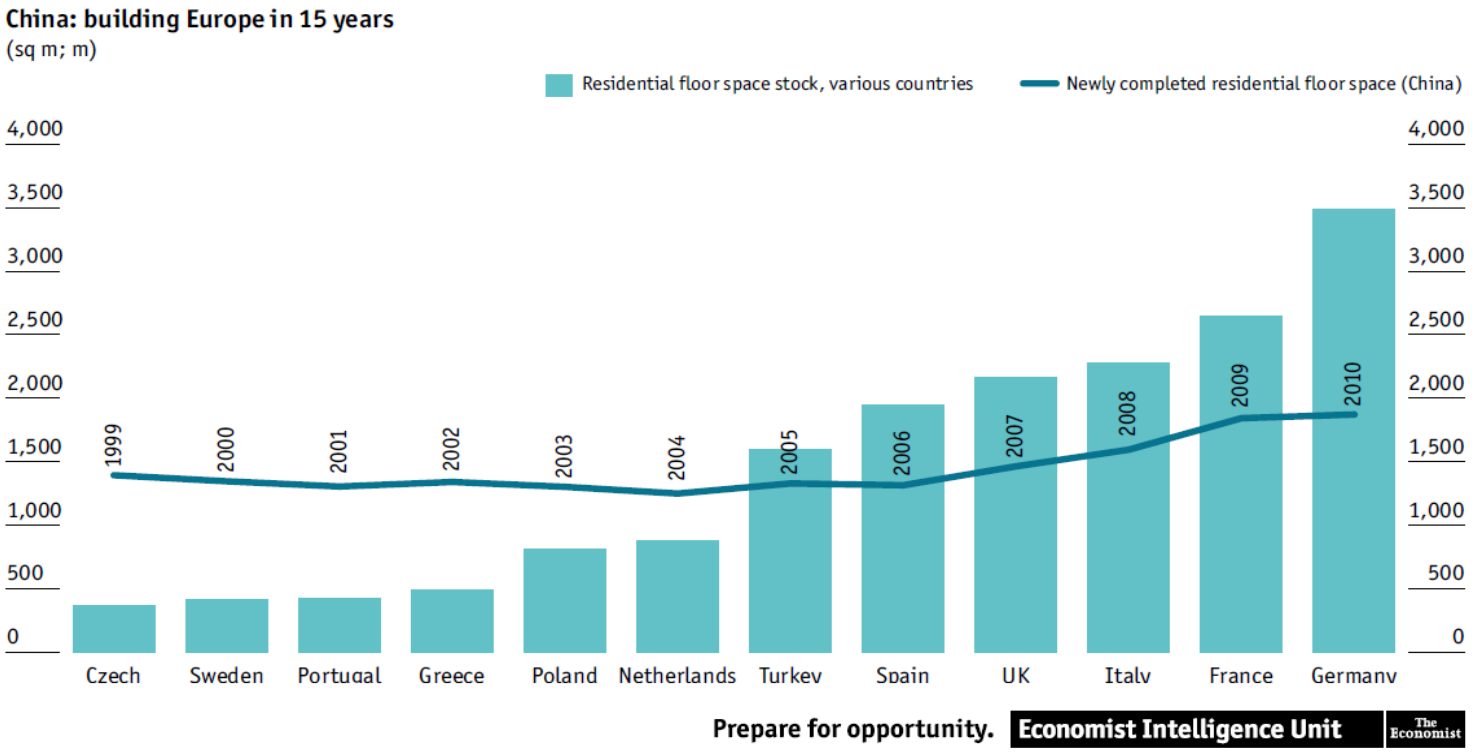
Developing World:

Perhaps Rome cannot be built in a day. But at China's current rates of construction, it would take roughly two weeks. It took the Asian hyper-economy roughly a decade to build the equivalent of Europe



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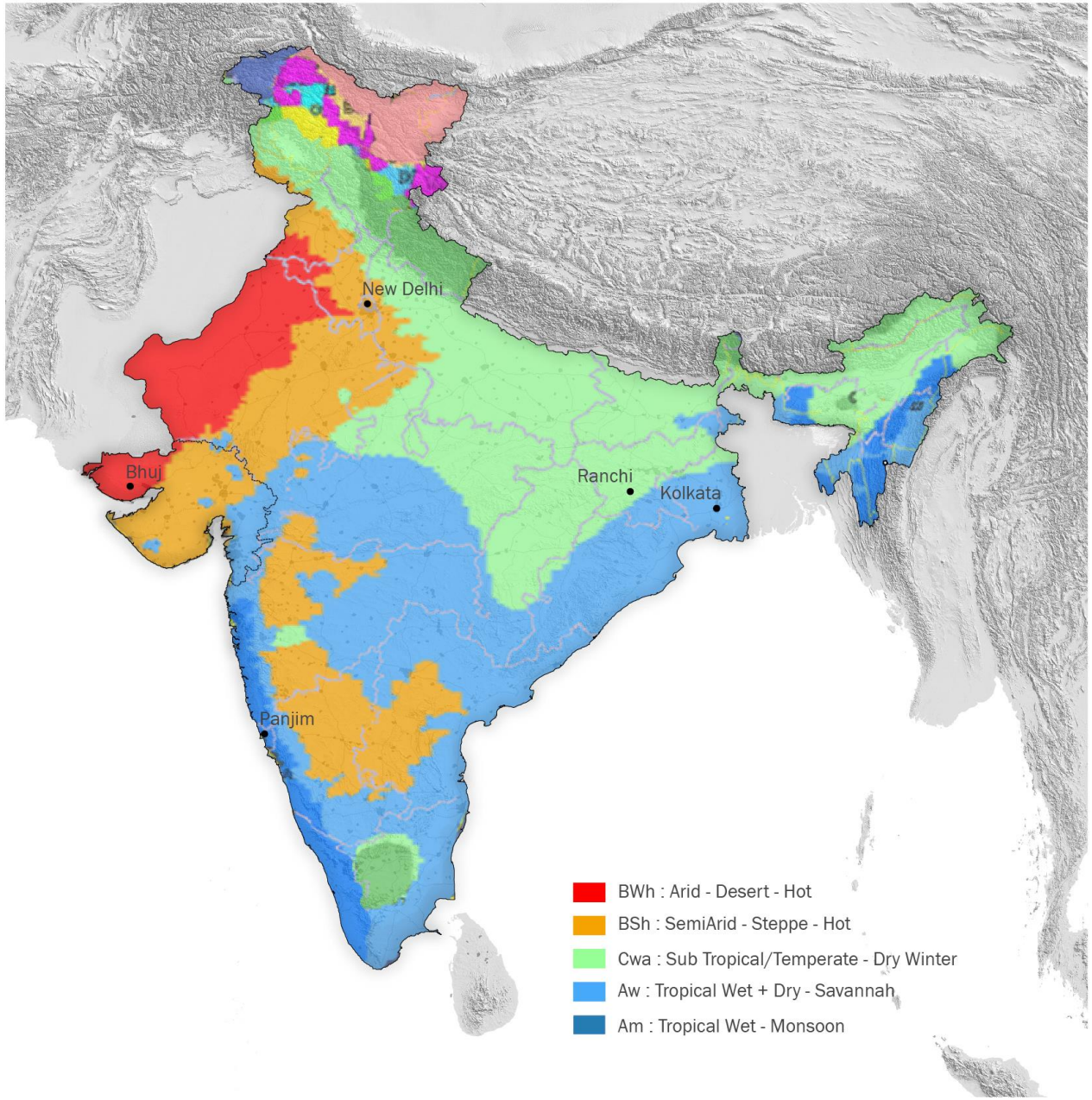
Housing for All
Program by Central Indian Government

- Proposed to build 20 x 10^6 houses for slum dwellers by 2022 in India
- 305 cities in program

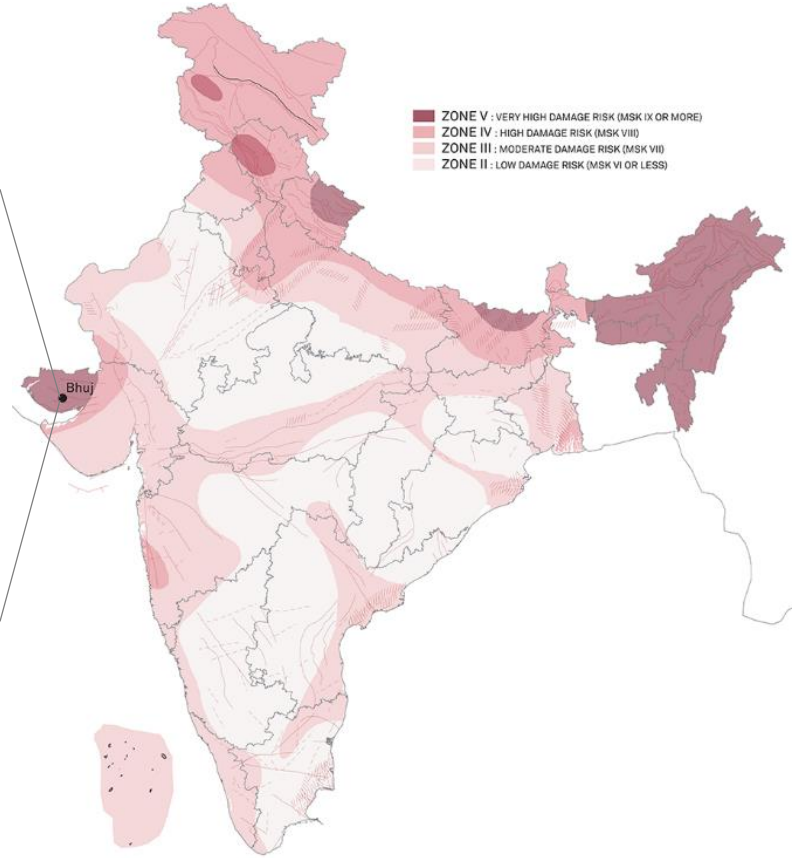

New Delhi
Bhuj
Ranchi
Kolkata
Panjim
BWh : Arid - Desert - Hot
BSh : SemiArid - Steppe - Hot
Cwa : Sub Tropical/Temperate - Dry Winter
Aw : Tropical Wet + Dry - Savannah
Am : Tropical Wet - Monsoon

Context

Bhuj Earthquake : January 26, 2001

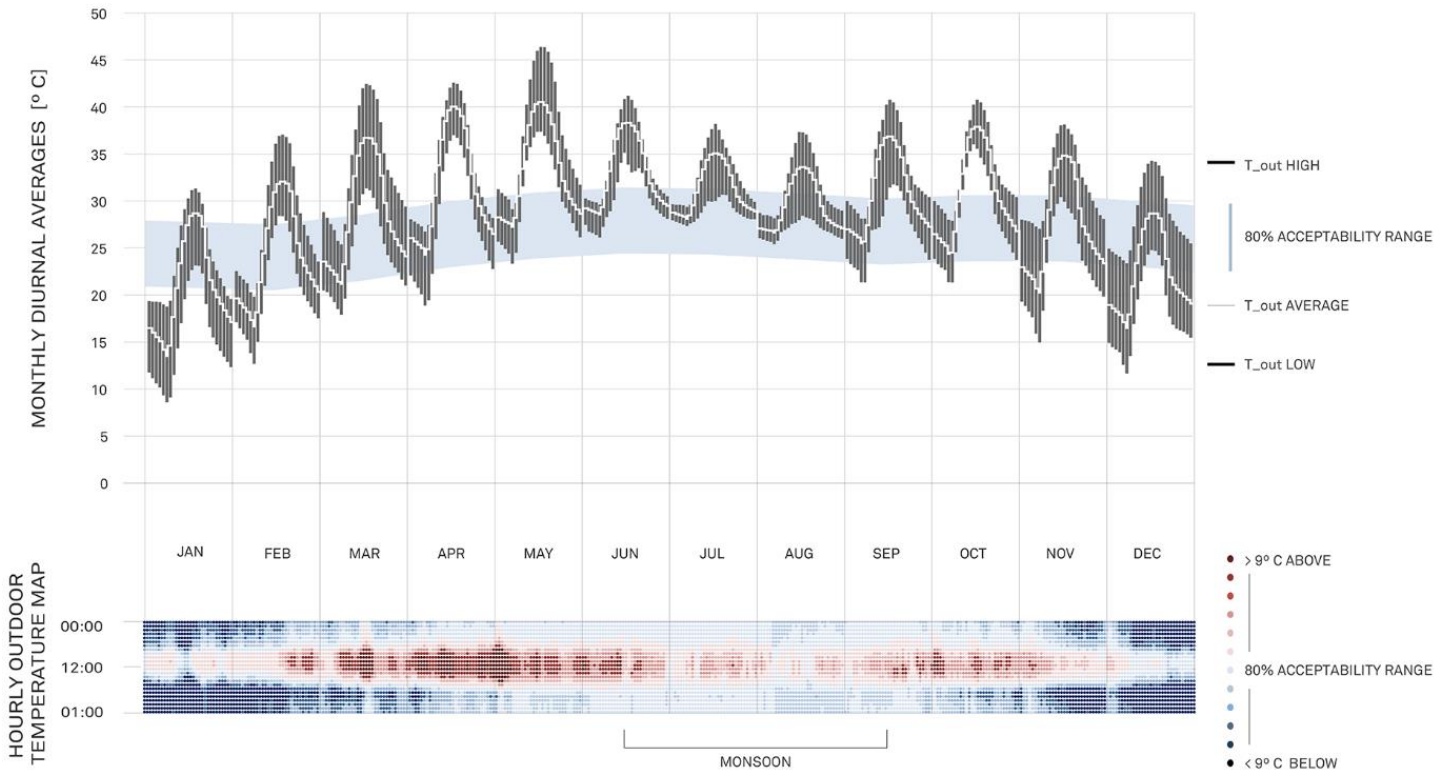
source: http://listotop.com/top-10-deadliest-natural-disaster-in-india/

20,000 deaths | 167,000 injuries | 400,000 homes destroyed



Bhuj, India

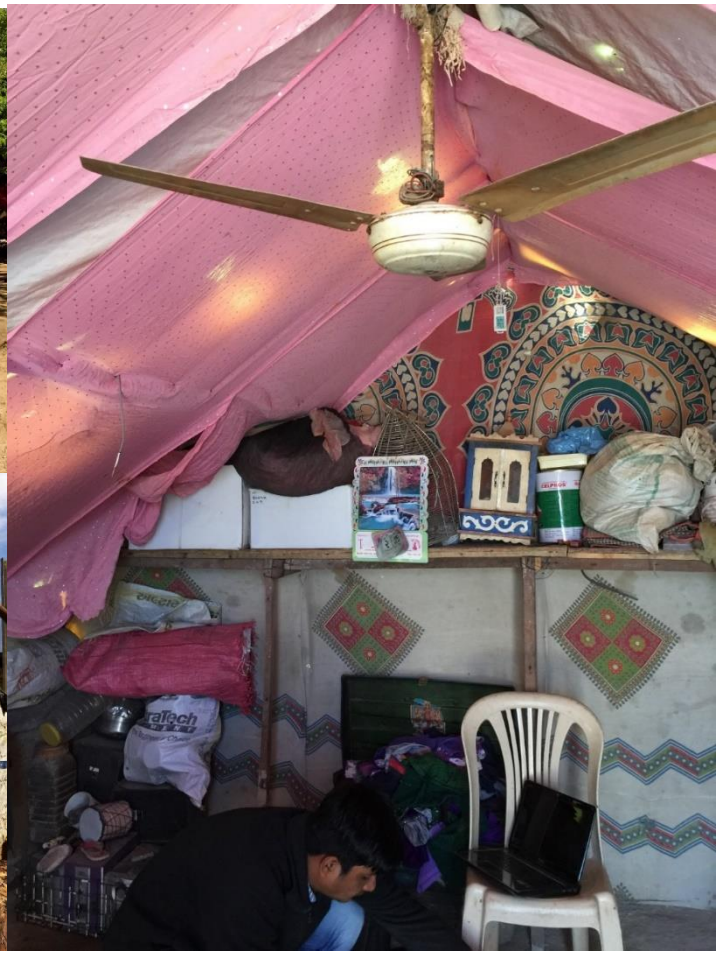
23.2500° N, 69.6700° E | Arid | Hot



Examples of temporary housing

The Challenge

- Inadequate housing is a primary cause of poor health in developing countries
- Urban population projected to rise from 28% to **50%** by 2030
- About **65.5 million** Indians live in slums
- Real-estate contributed to **6.3%** of the GDP in 2013–14
- To promote sustainable construction and energy consumption practices.



Context

Slums and informal housing often provide inadequate shelter from extreme temperatures

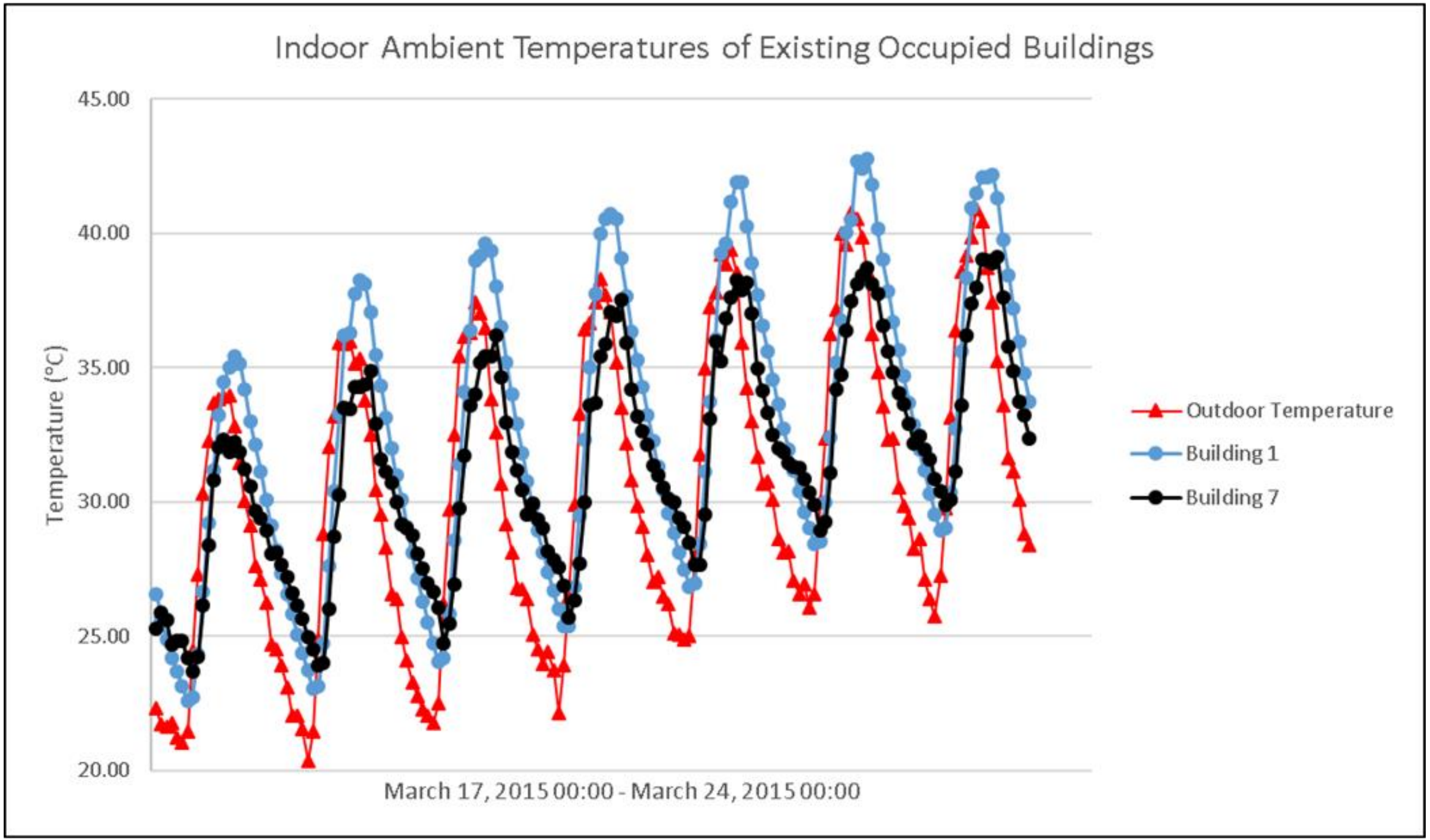
- Air conditioners too expensive
- Massive energy consumption for air conditioning
- Need for passive solutions
- Use solutions for upscale housing as well

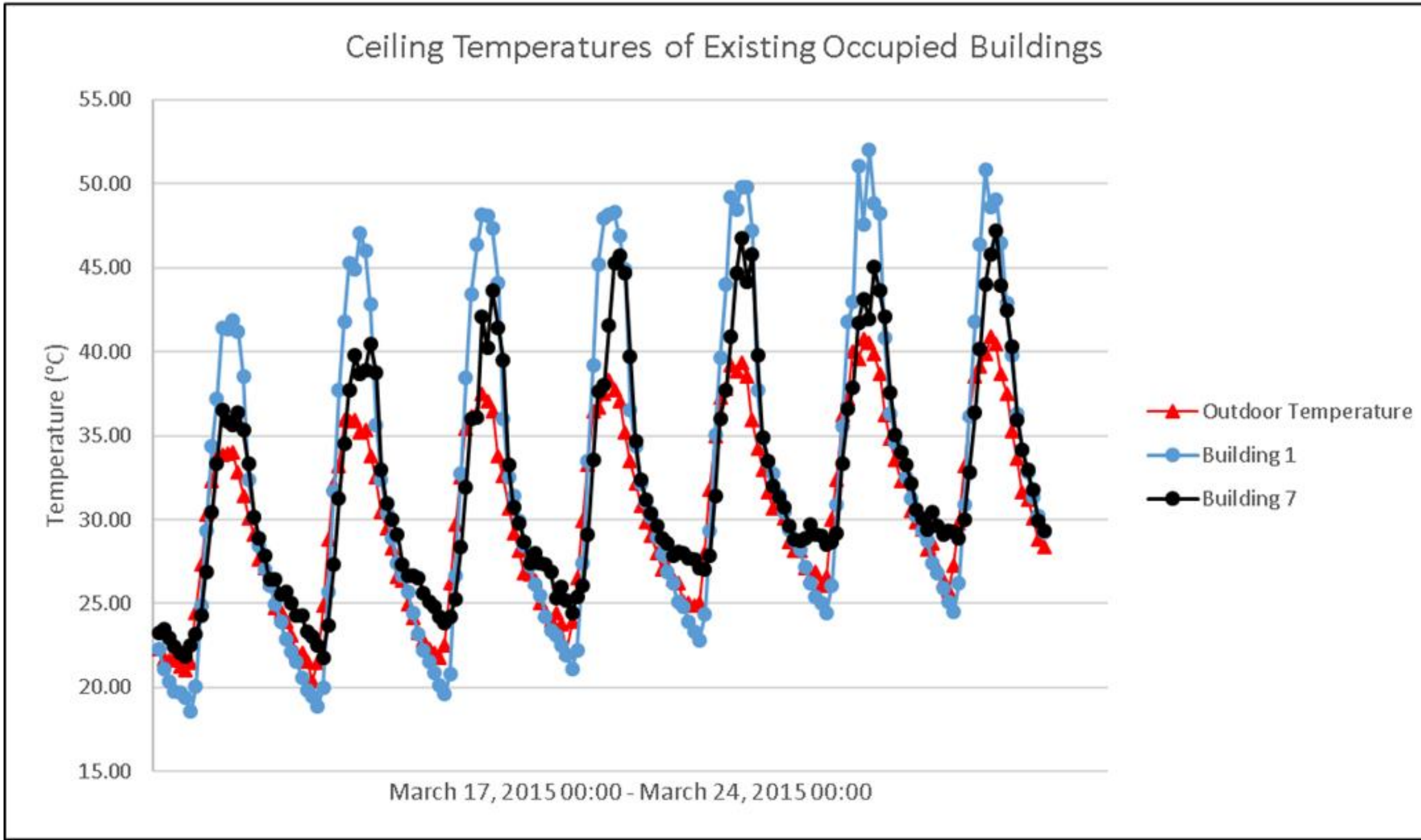
Research Program Sponsored by MIT Tata Center in Cooperation with Hunnarshala Foundation in Bhuj-Kutch Gujarat, India

- Tests of Existing Housing
- New Design Concepts
- CFD Simulations
- Construct Test Huts
- Monitor Huts under different operating conditions
- Apply to new house construction

Building 1: single-room dwelling with 15 cm thick solid CMU walls and an uninsulated asbestos cement corrugated sheet roof.

Building 7 One room dwelling with 23 cm thick uninsulated CSEB walls and 12 cm RCC slab roof.

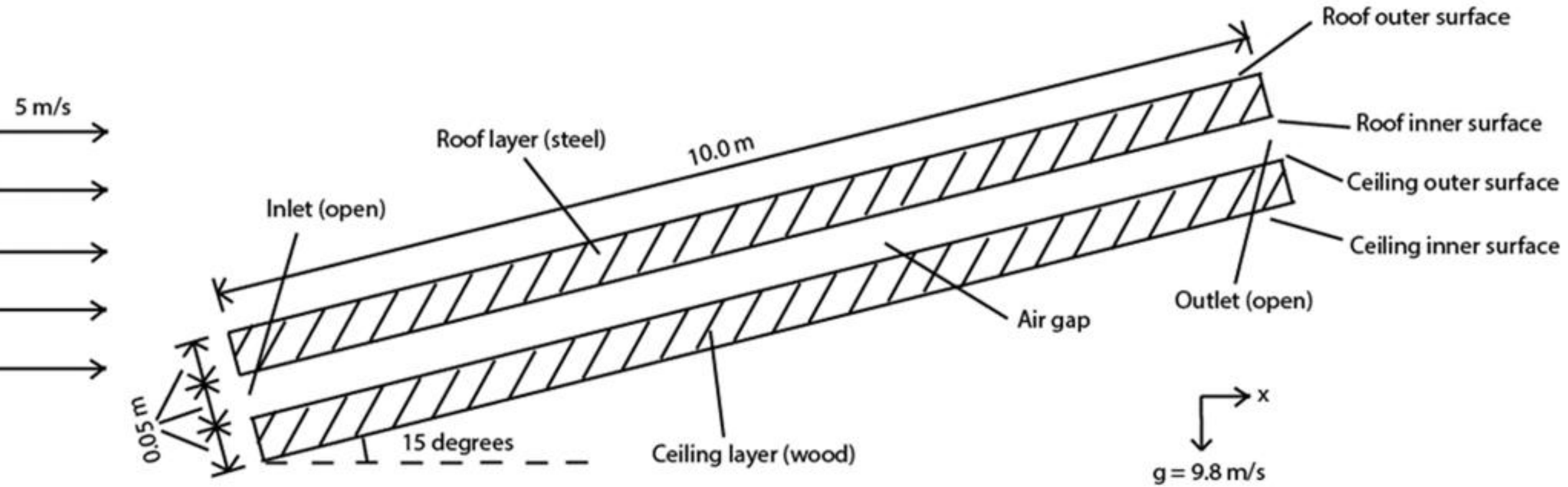

Indoor Ambient Temperatures of Existing Occupied Buildings
45.00
40.00
35.00
30.00
25.00
20.00
Temperature (°C)
March 17, 2015 00:00 - March 24, 2015 00:00
Outdoor Temperature
Building 1
Building 7


Ceiling Temperatures of Existing Occupied Buildings
55.00
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
Temperature (°C)
March 17, 2015 00:00 - March 24, 2015 00:00
Outdoor Temperature
Building 1
Building 7

Ventilated Double Layer Roof Concept

- CFD Simulations
- Test with small scale buildings
- Application to new construction

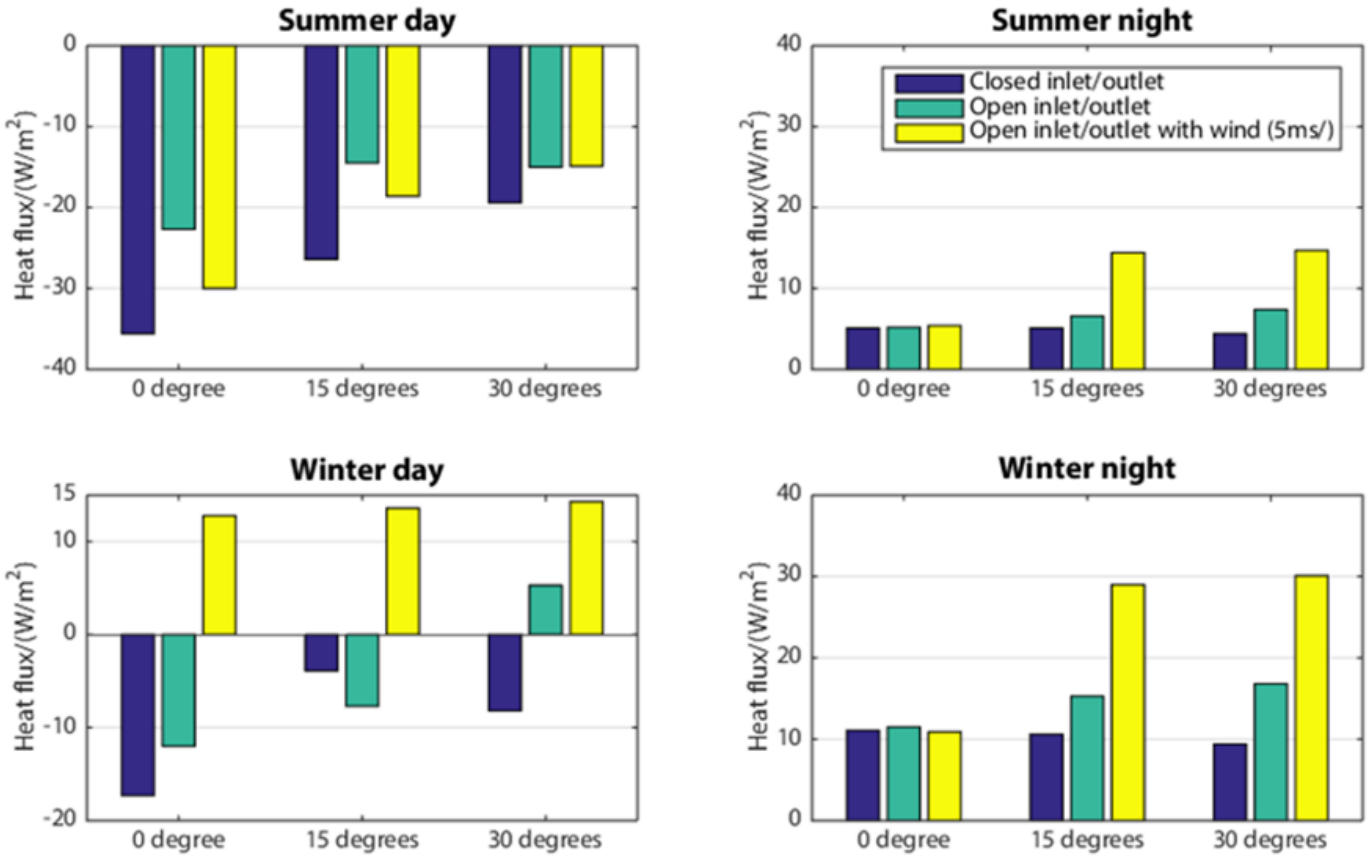
Domain of CFD Model with 15 degree inclination and wind velocity of 5 m/s



Boundary Conditions for CFD Simulations of Ventilated Roof Concept, Summer and Winter Conditions

Season	Time	Boundary Conditions		
		Solar Heat Gain at Roof Outer Surface, W/m^2	Ceiling Inner Surface Temperature, K	Ambient Temperature, K
Summer	Day	120	302.15	302.15
	Night	0	298.15	293.15

CFD Results Heat flow through ceiling Negative: Heat flow Into room with Open and Closed Double Layer Roof



The Solution: Thermal Autonomous Housing

- Ventilated Roof
- Night Flush Ventilation
- Use of Thermal Mass
- Proper Insulation

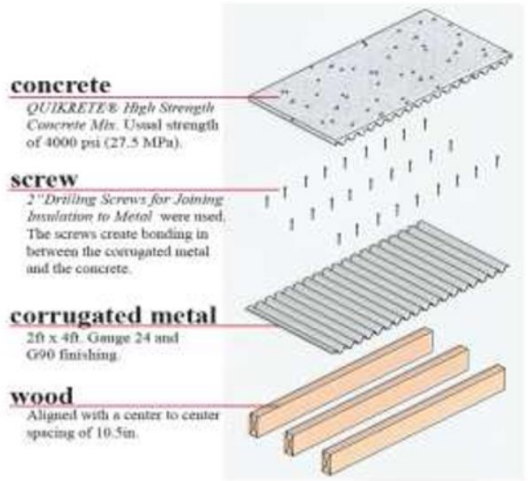
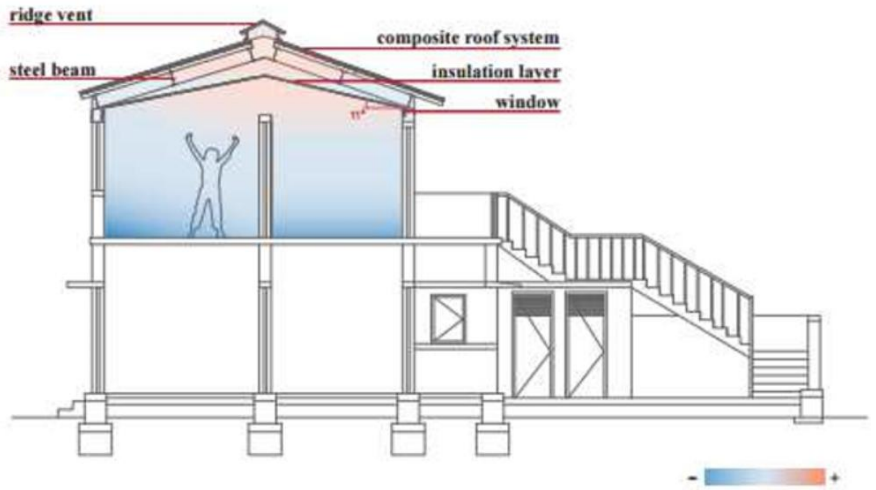
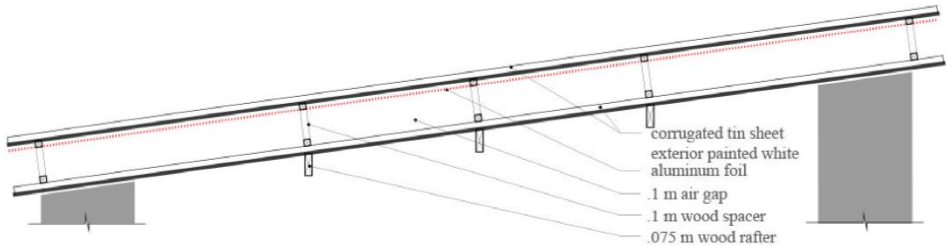


Figure 2: Visual Description of Panel # 1

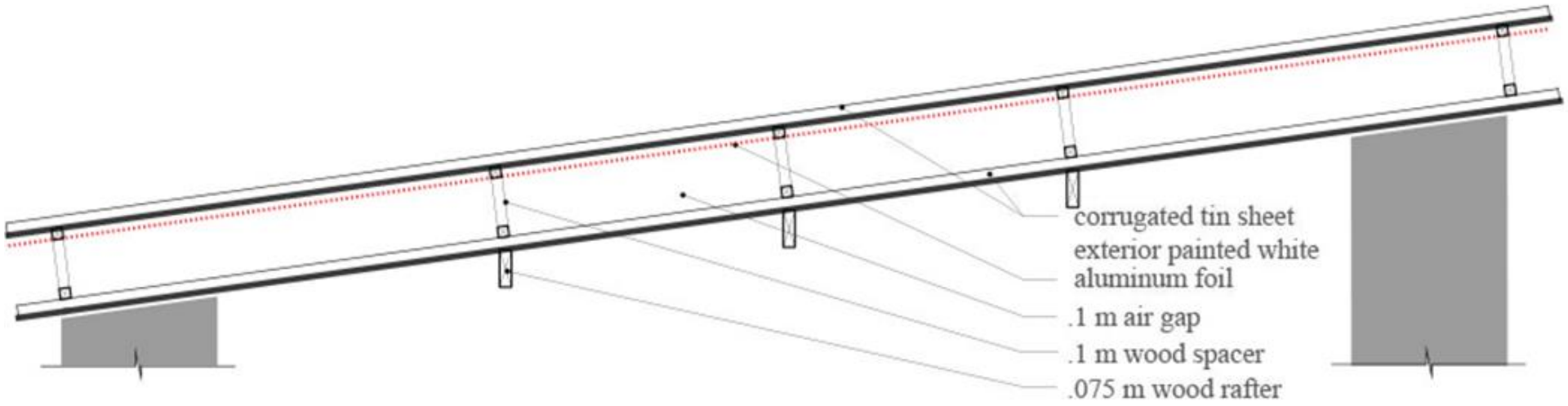




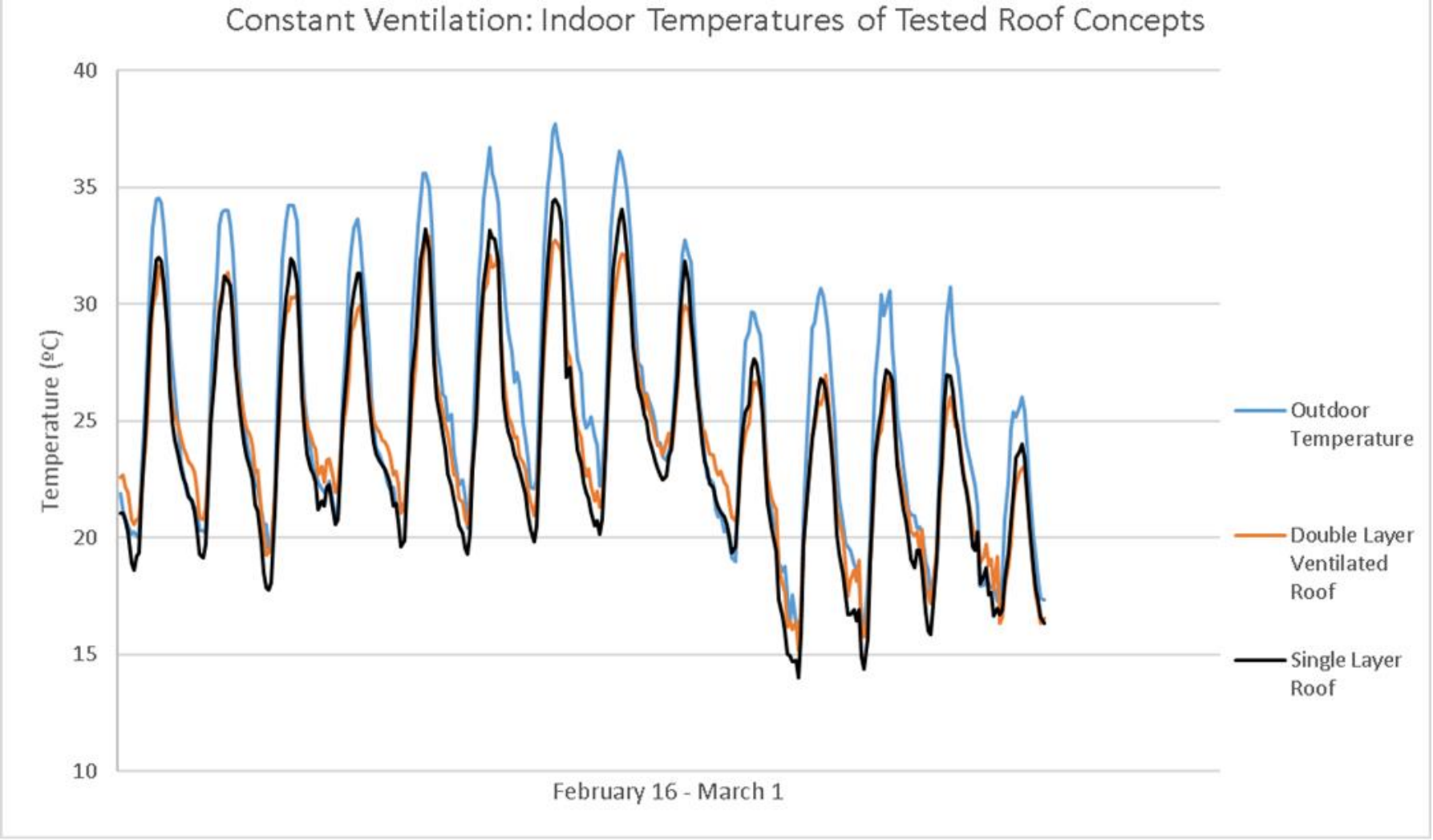
Night Flush Ventilation

Construction of 2.4 m square test chamber

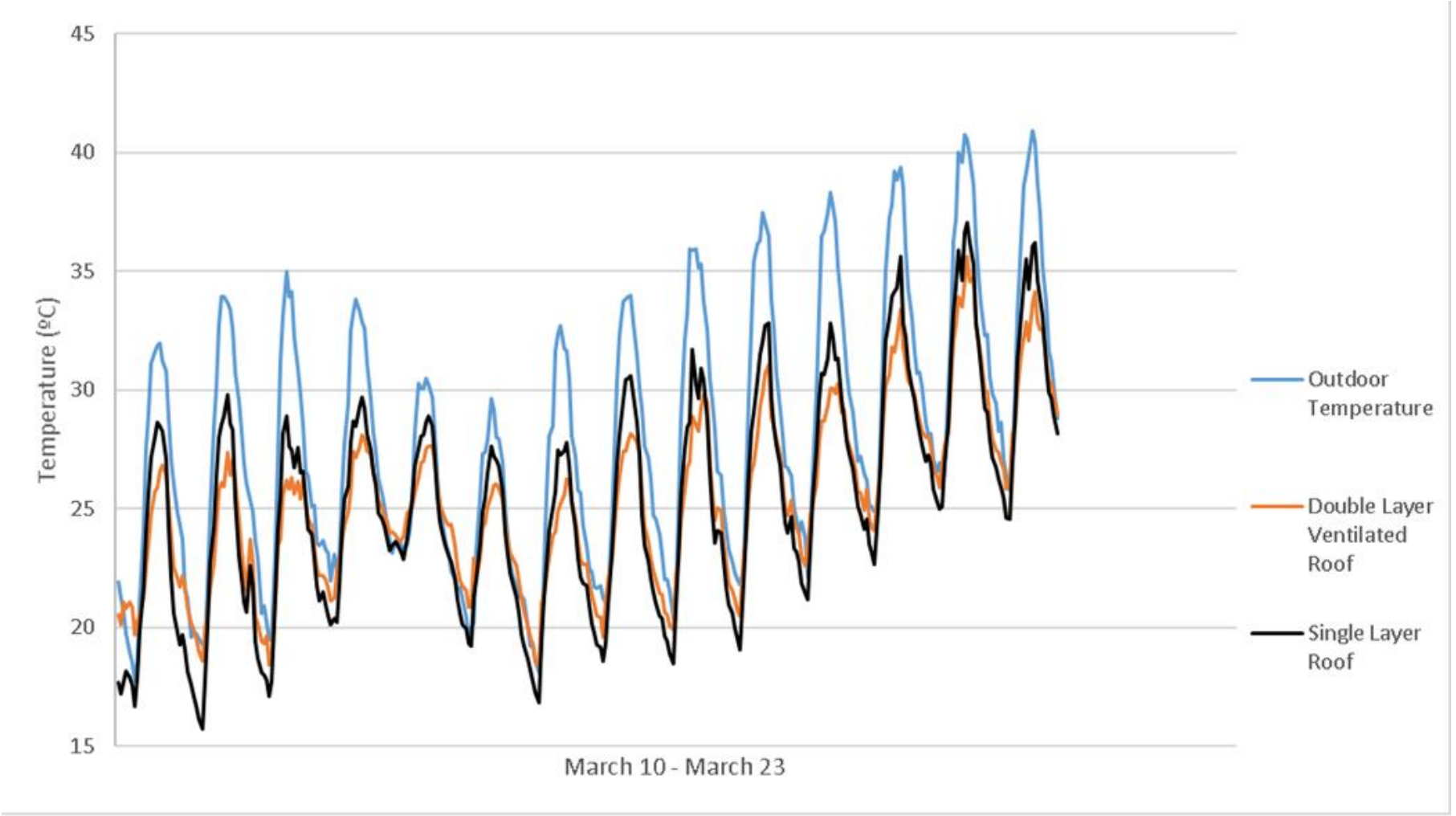
Double-layer ventilated roof with internal radiation shield

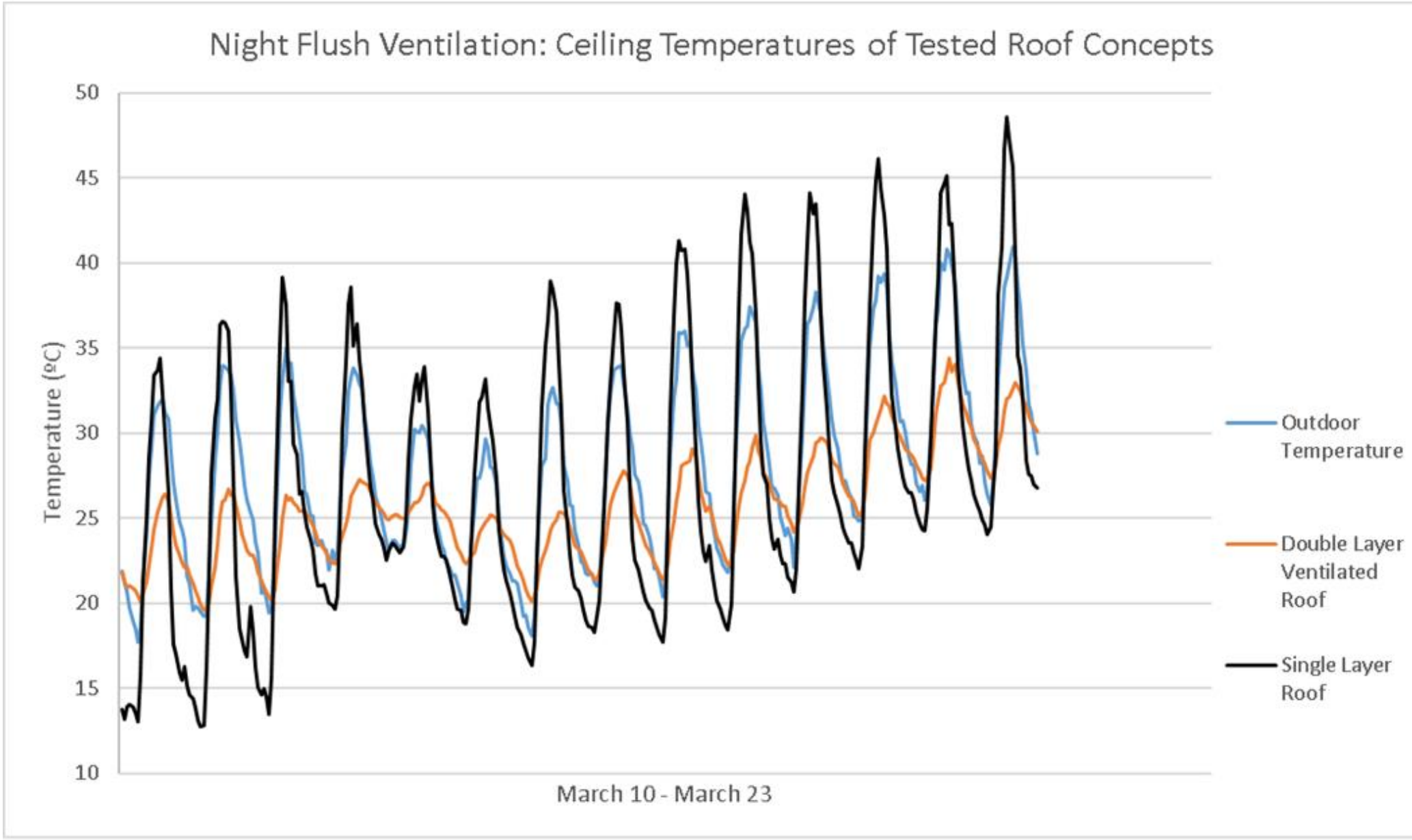


Indoor air temperatures for ventilated roof and single roof with windows open 24 hours per day.



Indoor air temperatures for ventilated roof and single roof with windows open only at night and night ventilation.




Night Flush Ventilation: Ceiling Temperatures of Tested Roof Concepts
Temperature (ºC)
50
45
40
35
30
25
20
15
10
March 10 - March 23
Outdoor Temperature
Double Layer Ventilated Roof
Single Layer Roof

Conclusions

Successful program:

- Work with local NGO
- Respect local building traditions
- Use test buildings to verify concepts and convince local workers

Conclusions

Proper performance requires:

- Thermal Mass in Walls
- Night flush ventilation
- Ventilated Roofs

Houses Under Construction in Bhuj Gujarat by Hunnarshala Foundation using Double Layer Roofs


Thank You