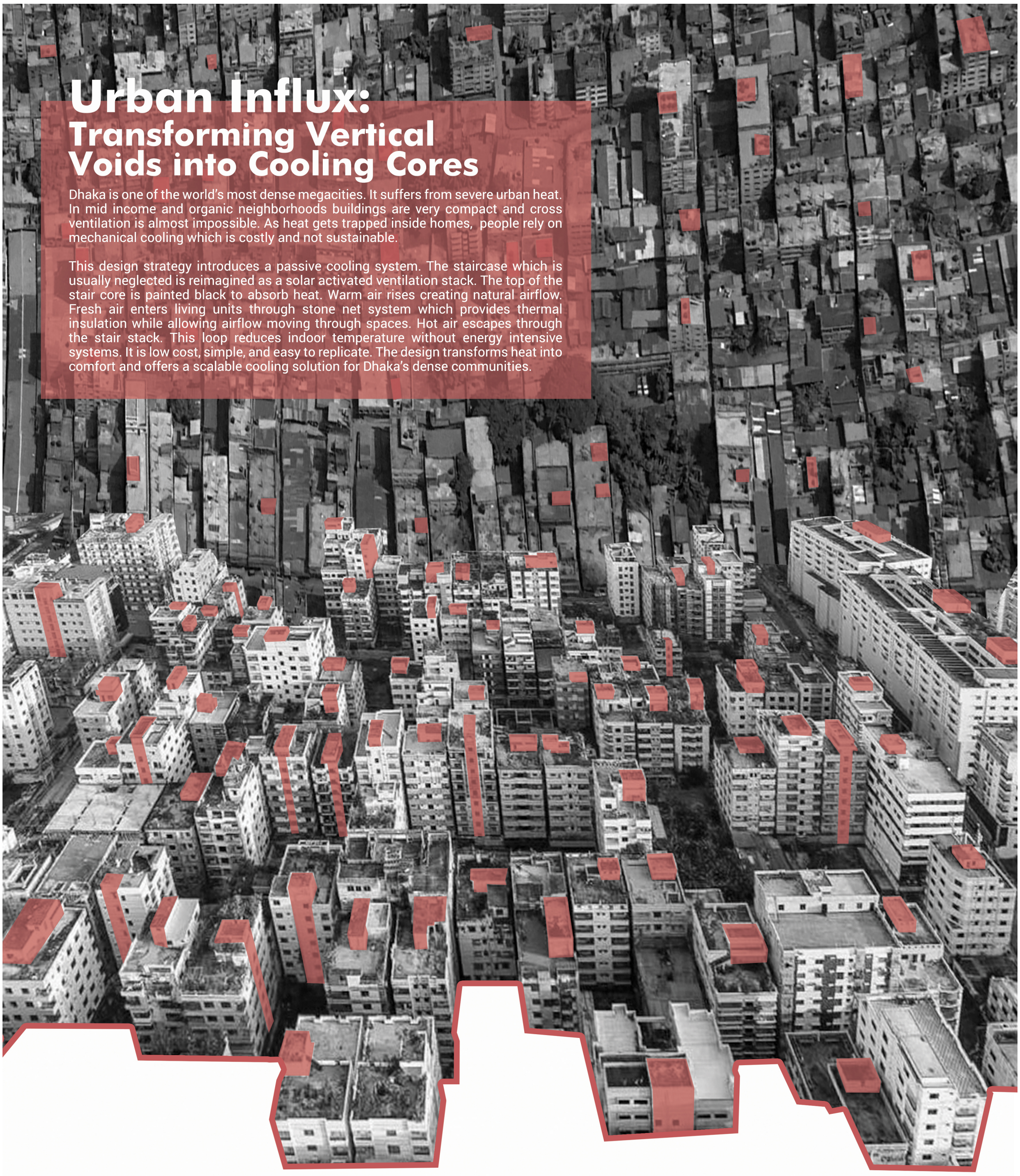
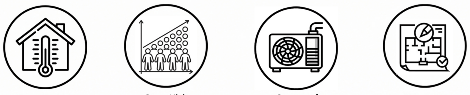
Urban Influx:
Transforming Vertical Voids into Cooling Cores

Dhaka is one of the world's most dense megacities. It suffers from severe urban heat. In mid income and organic neighborhoods buildings are very compact and cross ventilation is almost impossible. As heat gets trapped inside homes, people rely on mechanical cooling which is costly and not sustainable.

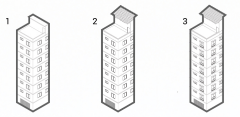
This design strategy introduces a passive cooling system. The staircase which is usually neglected is reimagined as a solar activated ventilation stack. The top of the stair core is painted black to absorb heat. Warm air rises creating natural airflow. Fresh air enters living units through stone net system which provides thermal insulation while allowing airflow moving through spaces. Hot air escapes through the stair stack. This loop reduces indoor temperature without energy intensive systems. It is low cost, simple, and easy to replicate. The design transforms heat into comfort and offers a scalable cooling solution for Dhaka's dense communities.

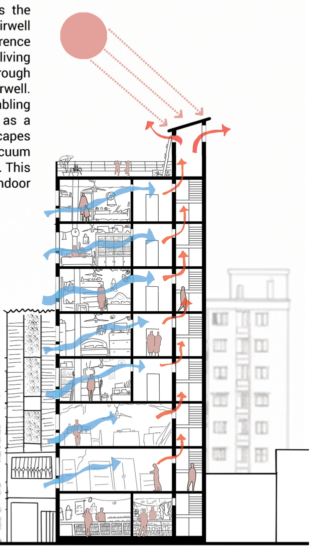


In dense urban areas the thermal comfort of people is getting worse day by day. Dhaka suffers from severe urban heat island effect. In mid income and organic settlements buildings stand very close with little space between them. Cross ventilation becomes almost impossible. Heat gets trapped inside living spaces. As temperatures rise people face uncomfortable indoor environments. Many rely on mechanical HVAC systems to stay cool. Overuse of these systems adds more heat to the city. They are expensive and not environmentally sustainable for most people. High population density makes the problem worse. Living spaces remain hot and uncomfortable throughout the day.



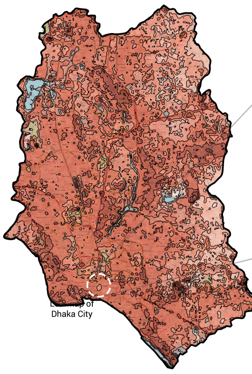
The vertical void is reimagined as a solar activated ventilation stack. The top surface of the stair core is painted black to absorb heat during the day. As the surface warms the air inside the enclosed stairwell becomes lighter and rises, creating a pressure difference that drives natural exhaust. Fresh air enters the living units through ventilators and openings, moves through interior spaces and is drawn upward into the stairwell. Each unit connects to the stairwell via a window enabling continuous airflow. The staircase chamber acts as a vertical ventilation stack where heated air escapes through an aperture at the roof, producing a vacuum effect that pulls cooler outdoor air into the building. This stack effect provides passive ventilation reducing indoor temperatures without mechanical systems.

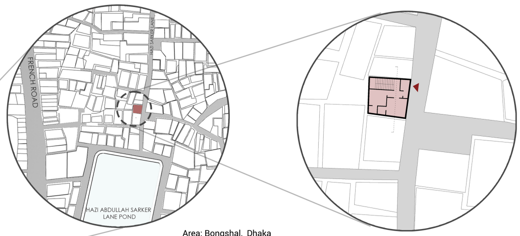




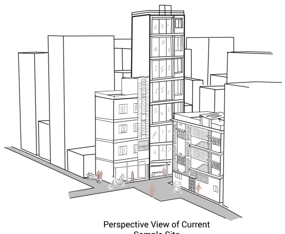
Conceptual Diagram of Stack Ventilation

Site Analysis





Area: Bongshal, Dhaka
(23.7181° N, 90.4007° E)



Perspective View of Current Sample Site

The project focuses on the Bongshal area of Dhaka, one of the city's most densely populated neighborhoods. The compact urban fabric, limited open space, and pronounced urban heat island effect significantly restrict natural airflow. High building density and closely spaced structures make effective cross ventilation difficult, resulting in heat accumulation and reduced indoor thermal comfort. These conditions highlight the need for architectural interventions to improve airflow and indoor

To develop a solution, we followed a clear and structured process. First, we studied the site context to identify core problems and formulate a possible design strategy. Next, we adopted a participatory approach, engaging with residents to evaluate feasibility and refine the design based on their feedback. Finally, the combined strategies were tested through simulation to validate performance, ensuring the system enhances thermal comfort while remaining scalable, practical, and cost-effective.

Community Participation

Dense Urban Fabric of Bongshal, Dhaka

Gathering Resident Feedback on Thermal Comfort and Ventilation

Collecting Community Feedback on the Proposed Intervention

Field Data Collection from local people

Personal Information

1. Name (Optional): ____________________
2. Age: ______
3. Gender: ☐ Male ☐ Female ☐ Other
4. Occupation: ____________________
5. Floor Number: ______
6. Number of family members: ______
7. How many hours per day do you stay at home?
   ☐ 0–4 hrs ☐ 4–8 hrs ☐ 8–16 hrs ☐ 16+ hrs

Existing Thermal Comfort Condition

8. During summer (April–September), how do you feel inside your apartment?
   ☐ Very Hot ☐ Hot ☐ Slightly Uncomfortable ☐ Comfortable
9. At which time is your apartment hottest?
   ☐ Morning ☐ Afternoon ☐ Evening ☐ Night
10. How would you rate air movement inside your apartment?
    ☐ No airflow ☐ Weak airflow ☐ Moderate airflow ☐ Good airflow
11. What cooling method do you currently use?
    ☐ Ceiling fan ☐ Stand fan ☐ AC ☐ None
12. On a scale of 1–5, how satisfied are you with current ventilation?
    1 (Very dissatisfied) — 5 (Very satisfied)
    ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Perception, Acceptance & Feedback

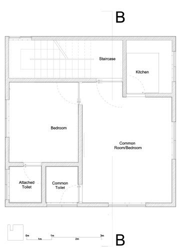
13. Do you believe natural ventilation can reduce indoor heat?
    ☐ Yes ☐ No ☐ Not sure
14. If airflow increases naturally, would you reduce AC/fan use?
    ☐ Yes ☐ Maybe ☐ No
15. If this system improves airflow and reduces indoor temperature, would you support it?
    ☐ Strongly support ☐ Support ☐ Neutral ☐ Do not support
16. Are you willing to contribute financially for construction?
    ☐ Yes ☐ Maybe ☐ No
17. Are you willing to help maintain the water-cooled inlet (pour water during summer)?
    ☐ Yes ☐ Sometimes ☐ No
18. Do you have concerns about:
    ☐ Maintenance ☐ Mosquitoes ☐ Cost ☐ Fire safety
    ☐ No concerns
19. What changes would make your apartment more comfortable in summer?

20. Any suggestions regarding the proposed ventilation system?

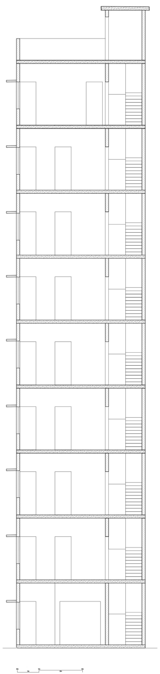
A structured questionnaire was developed to evaluate residents' thermal comfort, ventilation conditions, and acceptance of the proposed passive cooling strategy.

Existing Condition (Case Building)

During the initial site survey for problem identification and assessment of existing conditions, measured drawings including plans and sections were documented through field observation. The analysis revealed that cross ventilation within the building is significantly inadequate. The positioning and proportion of openings do not effectively facilitate airflow, resulting in limited air movement across interior spaces. Additionally, the openings lack proper shading devices, leading to excessive solar heat gain and reduced indoor thermal comfort. These factors collectively reduce thermal comfort and increase dependency on mechanical cooling methods. Therefore, the need for a passive ventilation enhancement strategy becomes essential.



Existing Simplified Plan

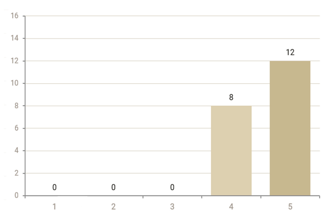


Existing Simplified Section BB

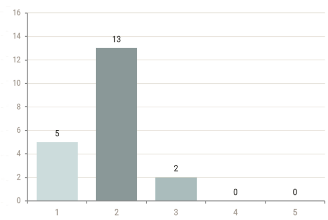
Occupant Response and Passive Intervention Acceptance

Based on a survey conducted among 20 residents of the relevent area, the data reveals significant thermal discomfort during the summer season. On a scale of 1 to 5, where 5 represents the highest level of discomfort, the majority of respondents rated 4 and 5, indicating severe overheating conditions indoors. Furthermore, when asked about their satisfaction with the existing ventilation system (5 being highly satisfied), none of the participants rated 4 or 5, demonstrating general dissatisfaction with current airflow conditions.

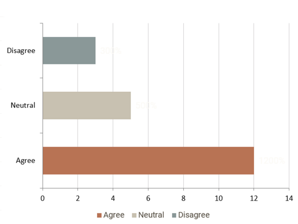
After presenting the proposed passive design interventions, including a stack chimney system to enhance natural ventilation through the stack effect and a water-cooled inlet system utilizing evaporative cooling , residents were asked about their acceptance of these strategies. Among the 20 respondents, 12 expressed agreement and 5 remained neutral regarding the water-cooled inlet system, reflecting a largely positive response. Similarly, 8 respondents agreed to implement the stack chimney system, while 7 indicated conditional acceptance. The findings suggest both a clear need for improved thermal comfort and a favorable community attitude toward passive cooling solutions.



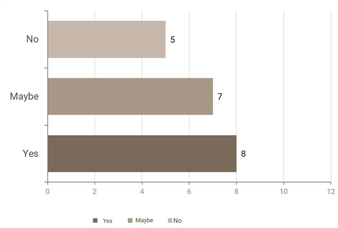
Summer Discomfort Level (1- 5 Scale)



Satisfaction with Current Ventilation (1- 5 Scale)



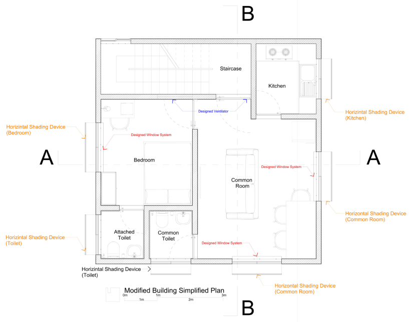
Preference for Water- Cooled Inlet System



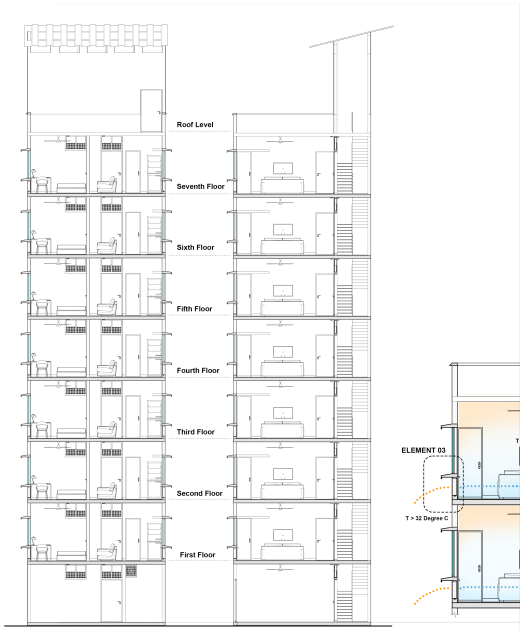
Willingness to Implement Stack Chiemney System

DESIGN INTERVENTIONS

In this building design, a black-painted tin roof maximizes solar heat absorption, warming the air beneath it. The heated air rises naturally through a traditional Bangladeshi Z-shaped ventilator connecting the indoor space to the stair shaft. The Z-shaped channel ensures privacy and reduces noise, enhanced further by acoustic insulation inside the ventilator. This continuous upward airflow, driven by the stack effect, promotes natural ventilation and thermal comfort. A stone pebble wall is incorporated for evaporative cooling, with an overhanging shade protecting it from direct sunlight to reduce heat gain and enhance the cooling effect. Together, these interventions create an integrated passive system that improves indoor air quality and thermal comfort in a regular building.

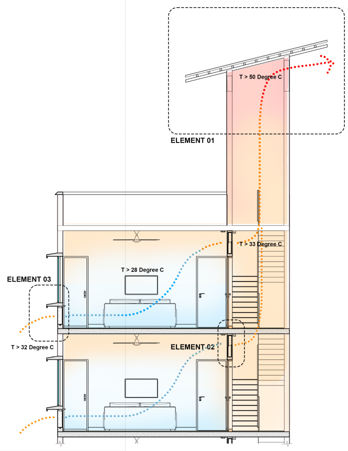


Modified Plan



Section AA

Section BB



Blow Up

1 Black Tin Roof Shade

A black-painted tin roof absorbs maximum solar radiation, increasing the air temperature beneath it. The heated air becomes lighter and rises through the shaft, creating negative pressure. This draws indoor air upward, enhancing natural ventilation through the **stack effect.**

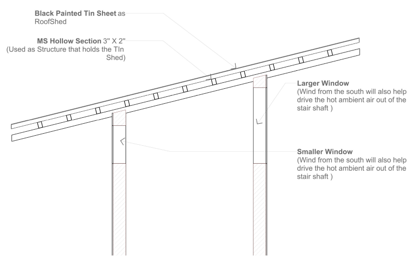
2 Wall Top Ventilator

Indoor air is drawn upward through a traditional Bangladeshi Z-shaped ventilator that connects the room to the stair shaft. The zigzag channel prevents direct visual connection, ensuring privacy, while also minimizing noise transmission between spaces. Acoustic insulation is integrated within the ventilator to further enhance sound control, allowing airflow without compromising comfort.

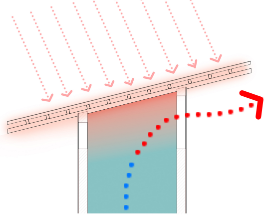
3 Stone Windows

Indoor air is drawn upward through a traditional Bangladeshi Z-shaped ventilator that connects the room to the stair shaft. The zigzag channel prevents direct visual connection, ensuring privacy, while also minimizing noise transmission between spaces. Acoustic insulation is integrated within the ventilator to further enhance sound control, allowing airflow without compromising comfort.

Detail Section

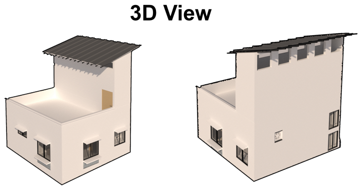


Work Process

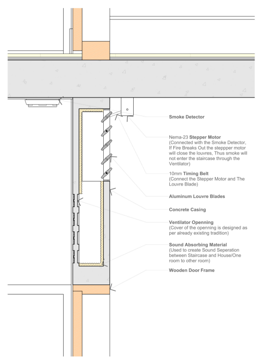


A black-painted tin roof is used to maximize solar heat absorption. Due to its dark surface, the tin sheet absorbs a higher amount of solar radiation, causing its temperature to rise significantly. This heat is then transferred to the surrounding air within the roof cavity or shaft. As the air temperature increases, its density decreases, making it lighter. The warmer air rises naturally and escapes through the vertical shaft or designated openings at the top. This upward movement creates a pressure difference (negative pressure) within the space below. Consequently, cooler air from the indoor environment is drawn upward to replace the rising hot air.This continuous process establishes a passive ventilation system based on the stack effect, enhancing natural airflow and improving indoor thermal comfort without mechanical assistance.

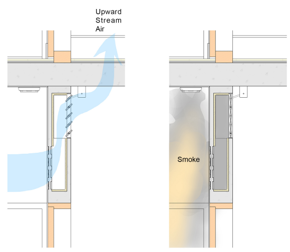
3D View



Detail Section



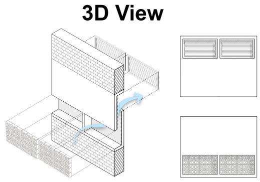
Work Process



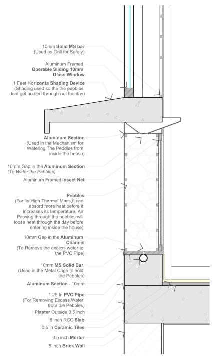
Hot air accumulated at the ceiling level passes through the ventilator and rises into the stair shaft, facilitating continuous upward airflow

During a fire, the smoke detector activates the external louvre blades, allowing smoke and hot gases to exhaust through the shaft for safer evacuation.

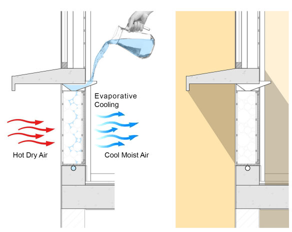
3D View



Detail Section



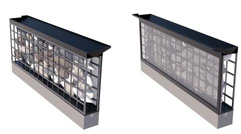
Work Process



A stone pebble wall provides evaporative cooling when water flows over or seeps through it, lowering the surrounding air temperature as the water evaporates.

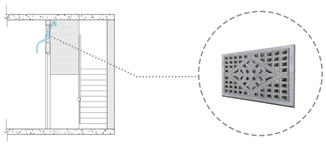
A shade is used to protect the stone wall from direct sunlight, reducing heat gain and enhancing the wall's evaporative cooling effect. This combination helps maintain cooler ambient temperatures and improves thermal comfort in the adjacent space.

3D View



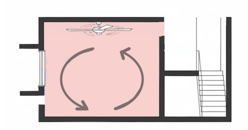
Cultural Reinstatment by Using Ventilator

The inclusion of a ventilator draws inspiration from traditional buildings of Bangladesh, where ventilators were essential for natural airflow and thermal comfort in the hot-humid climate. Before mechanical cooling, they played a crucial role in passive environmental control. Reintroducing this element revives a valuable vernacular feature, reconnecting the design with Bangladesh's architectural heritage while enhancing climate responsiveness.

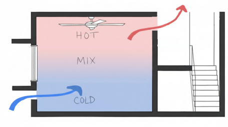


Energy Efficiency and Impact of Ceiling Fans

Since ceiling fans are very common here, we also considered their impact. Ceiling fans disturb the natural vertical air movement and weaken the stack effect. During the day, keeping only the lower window open can reduce indoor temperature by 2–3°C. At this cooler condition, occupants may use ceiling fans for comfort; however, as they are not required all the time, the proposed stack effect will significantly contribute to energy savings. If many buildings adopt this strategy, the cumulative energy reduction would have a meaningful impact for a country like ours.



When ceiling fan is off



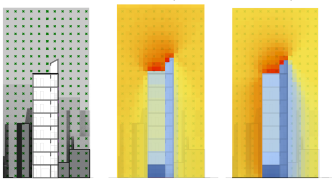
When ceiling fan is on

Thermal Simulation (Existing Building)

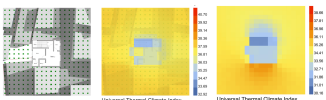
Due to the lack of cross ventilation and inadequate shading devices, the airflow within the room is minimal, resulting in reduced indoor comfort.

During Hot Summer From April - July
From 9am to 6pm

Annual Thermal UTCI
From 9am to 6pm



Indoor temperature surges from 33°C to 36°C, which is above comfort level of people living living in Bangladesh.
(Comfort Level 26°C and 33°C.)



Universal Thermal Climate Index
4/1 to 6/30 between 9 and 18 @1

Universal Thermal Climate Index
1/1 to 12/31 between 9 and 18 @1

AirFlow Calculation

Using the stack ventilation formula with an opening area of 0.195 m², a height of 1.6 m, and a 3°C temperature difference, the calculated airflow is 0.06 m³/s (60 L/s).

Each floor requires about 50 L/s (10 L/s per person × 5 people), so the system meets the minimum ventilation requirement under these conditions. If the stairwell temperature increases by around 5°C, for example through a heated black roof, the airflow would become more stable and reliable.

Furthermore, analysis using the CBE comfort graph indicates that the resulting indoor temperatures and airflow conditions remain within the comfort zone, confirming that the proposed passive ventilation strategy effectively enhances thermal comfort without mechanical cooling.

$$Q = C_d A \sqrt{2gH\frac{\Delta T}{T}}$$

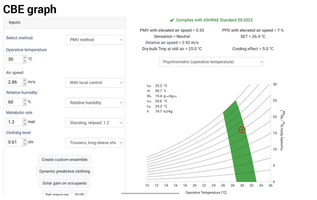
here

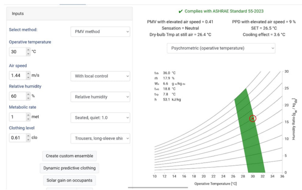
- **Q** = airflow (m³/s)
- C_d = discharge coefficient (≈ 0.6 for rough openings)
- **A** = area of opening (m²) = 0.195 m²
- **g** = 9.81 m/s²
- **H** = height between lower and upper openings (m) =1. 6 m
- **ΔT** = indoor–outdoor temperature difference (K or °C) =3
- **T** = absolute temperature (K) ≈ 305 K for 32°C = 305

$$Q = .6 * 0.198 * \sqrt{2 * 9.8 * 1.6 * \frac{3}{305}}$$

=0.06 m³/s

CBE graph



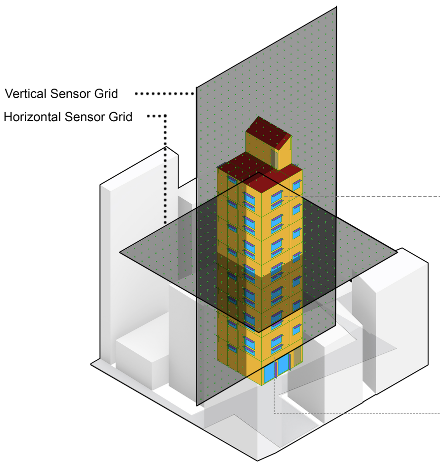


Ref: https://comfort.cbe.berkeley.edu/

Thermal Comfort Simulation and Wind Simulation (Modified Building)

THERMAL AND WIND SIMULATION AFTER DESIGN INTERVENTION

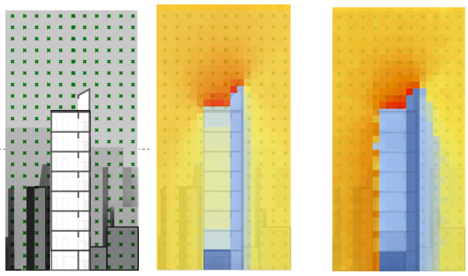
Stack effect and cross-ventilation strategies are introduced. Shading devices along with window apertures are redesigned to enhance airflow throughout the room, allowing heat to escape through the vertical staircase stack. As a result, excess heat is dissipated, improving indoor thermal comfort. This simulation shows better results compared to the existing situation simulation, demonstrating the clear effectiveness of the proposed interventions.



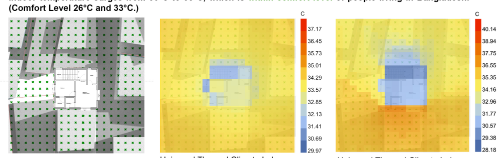
Modified Building & Surroundings

During Hot Summer From April - July
From 9am to 6pm

Annual Thermal UTCI
From 9am to 6pm



Indoor temperature surges from 30°C to 33°C, which is within comfort level of people living in Bangladesh. (Comfort Level 26°C and 33°C.)



Universal Thermal Climate Index
4/1 to 6/30 between 9 and 18 @1

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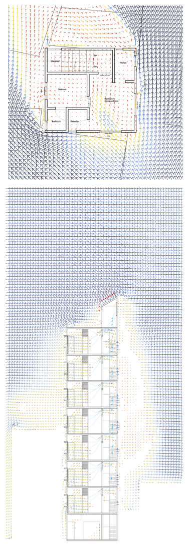
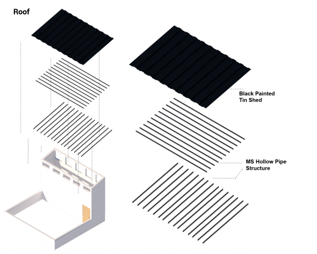
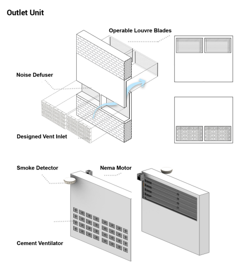
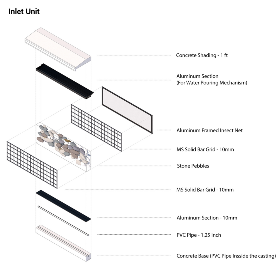


Wind Simulation

Cost Estimations and Breakdown of the Design Elements







Roof

Sl.	Item Description	Specification / Content	Qty	Unit	Material (BDT)	Labour (BDT)	Total (BDT)
1	Corrugated GI Sheet	26-28 gauge, black painted finish	165	SFT	21,450	-	21,450
2	Black Paint	Synthetic enamel, approx. 1.5 gallons	1.5	Gallon	4,200	-	4,200
3	MS Structural Frame	MS angle/box section (~214.5 kg)	214.5	KG	30,030	-	30,030
4	Fasteners & Sealant	Bolts, screws, washers, sealant	L.S.	-	5,000	-	5,000
5	Fabrication Labour	Frame fabrication work	L.S.	-	-	8,000	8,000
6	Installation Labour	8th floor installation work	L.S.	-	-	10,000	10,000
7	Lifting & Transport	Material lifting to roof level	L.S.	-	-	6,000	6,000
						Grand Total	84,680 BDT

Outlet Unit

Sl.	Item Description	Specification / Content	Qty	Unit	Material (BDT)	Labour (BDT)	Total (BDT)
1	Concrete Vent Body	Non-RCC concrete, 0.925 cft	0.925	CFT	1,000	400	1,400
2	Aluminum Louvers	3 SFT, 4 blades, motor compatible	1.5	SFT	2,100	750	2,850
3	Motorized Mechanism	NEMA 23 stepper motor with timing belt & brackets	0.5	Unit	3,100	1,750	4,850
4	Smoke Detector System	Photoelectric smoke detector with wiring & relay	0.5	Unit	1,500	600	2,100
						Grand Total	11,200 BDT

Inlet Unit

Sl.	Item Description	Specification / Content	Qty	Unit	Material (BDT)	Labour (BDT)	Total (BDT)
1	Concrete Shading	1:2:4 mix (Cement, Sand, Aggregate)	2.2	CFT	2,335	600	2,935
2	MS Rod	10mm solid mild steel (~21 kg)	0.094755	CFT	2,940	150	3,090
3	Aluminum	Solid aluminum section (~23.5 kg)	0.31	CFT	3,100	400	3,500
4	Stone Pebbles	Natural thermal pebbles (~70 kg)	1.5	CFT	4,200	150	4,350
5	PVC Pipe	1.25 inch dia uPVC pipe (5 ft) + fittings	5	FT	480	400	880
						Grand Total	14,755 BDT

Assumption for One Family (Passive Cooling System)

Stone Windows: 3 units per family

Each full stone window = 14,755 BDT (includes concrete, MS rod, aluminum 0.31 CFT @ 7,000 BDT, pebbles, and labour)
Total stone windows = 3 × 14,755 = 44,265 BDT

Ventilators: 2 units per family

Each ventilator = 11,200 BDT
Total ventilators = 2 × 11,200 = 22,400 BDT

Tin Shade (shared roof):

Total tin shade = 84,680 BDT
Shared among 7 families : 84,680 ÷ 7 = 12,098 BDT

Assumption for One Family

Stone Windows + Ventilators + Tin Shade (shared roof):

44,265 + 22,400 + 12,098 = **78,763 BDT**

Assumption for One Family (Air Conditioned System)

House size : 380sft (≈35.3m²)
Occupants : 5 people
AC system : Standard split AC unit

Typical Sizing for Bangladesh Climate
Cooling load ≈ 1 ton AC per 120–150sft
For 380sft → 380 ÷ 150 ≈ 2.5 ton → round to 3 ton

AC units: Could be 1 × 3 ton unit or 2 × 1.5 ton units (common setup)

Cost of AC (2026 Bangladesh market):

Unit Price (BDT)

1.5 ton split AC 55,000–65,000
3 ton split AC 110,000–120,000

Installation & labour: ≈ 10,000–12,000 BDT

Total AC cost ≈ 132,000 BDT

Comparing Passive Heat / Ventilation System

From previous calculation:

- Cost per family: 78,763 BDT (stone windows + 2 ventilators + shared tin shade)
- One-time investment, no running electricity cost except occasional fan for ventilators if needed
- AC system (material + installation): 132,000 BDT——>slightly cheaper upfront

Observation:

- The passive system costs almost half, with almost no operational cahrge. So its very affordable compared to AC.
- Passive system has no electricity dependency and provides natural ventilation + thermal comfort, plus environmental benefits.