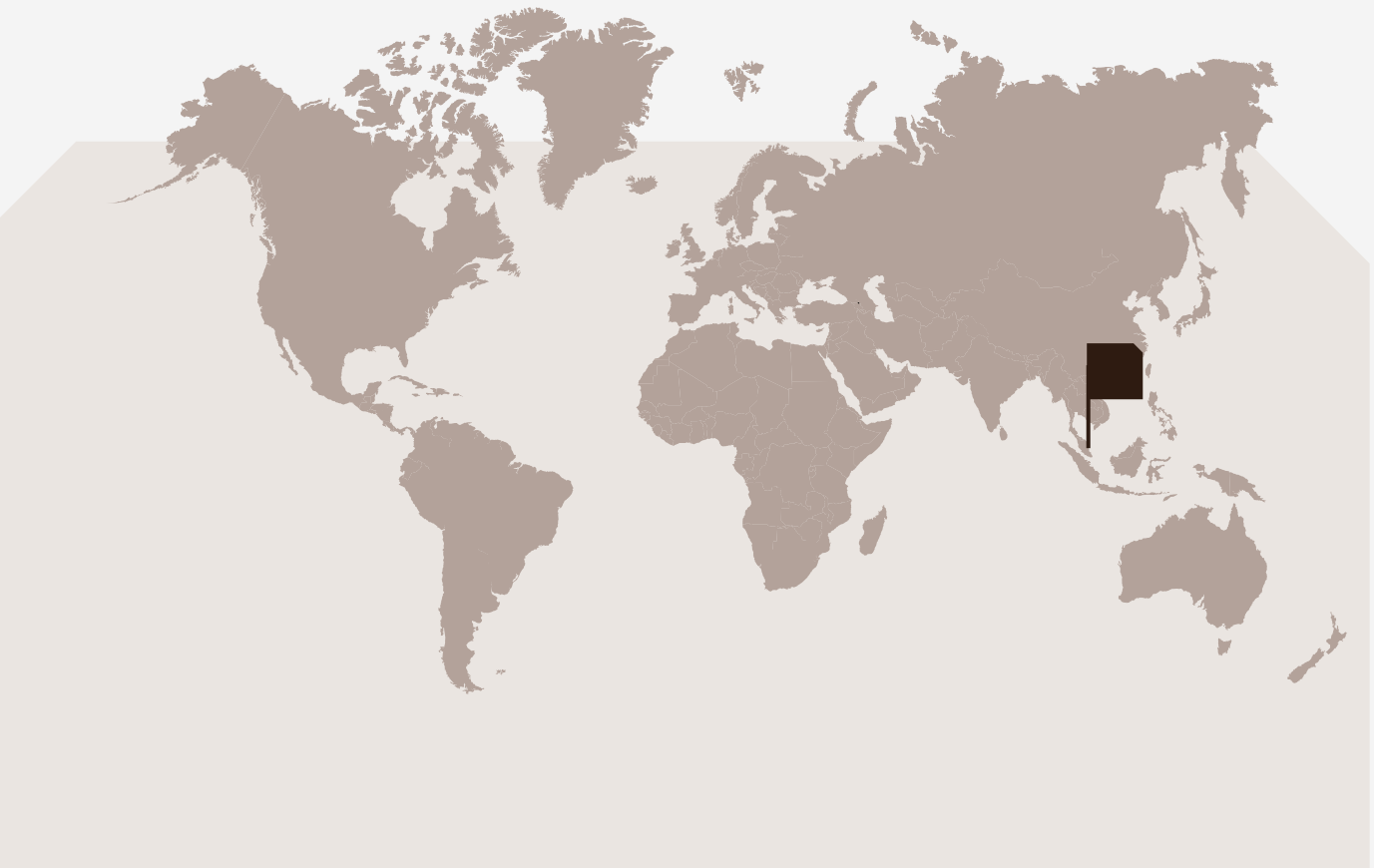
P5

Designing for Comfort: a computational design framework and its application

Ghazel Masah

OVERVIEW

CONTEXT

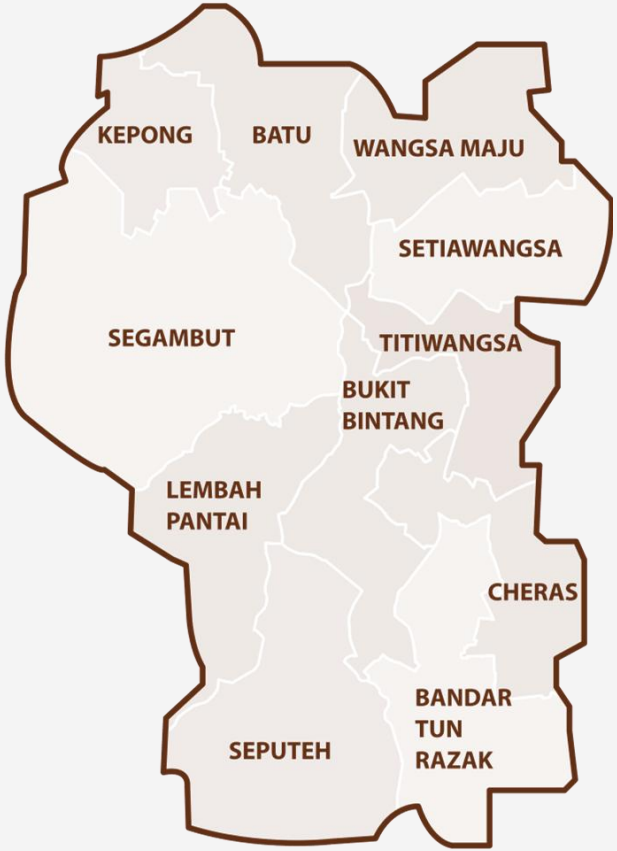


Malaysia, KL

Approx 36 mln.
[2025] in MY

Approx 2 mln.
[2025] in KL

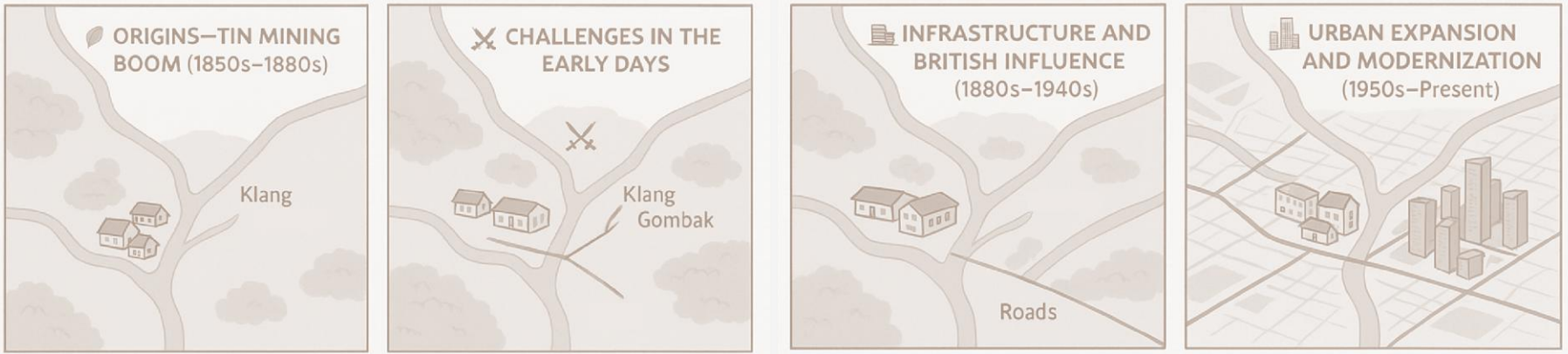
Approx 9 mln.
in Greater KL



Kuala Lumpur
“where the rivers meet in the mud”

“Kuala” = the confluence (where two rivers meet)

“Lumpur” = mud or muddy


ORIGINS—TIN MINING BOOM (1850s–1880s)
Klang
CHALLENGES IN THE EARLY DAYS
Klang
Gombak
INFRASTRUCTURE AND BRITISH INFLUENCE
(1880s–1940s)
Roads
URBAN EXPANSION AND MODERNIZATION
(1950s–Present)

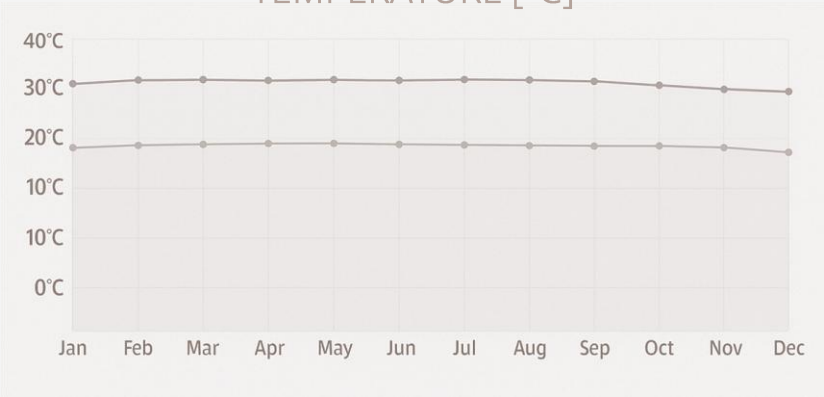
MALAY
47.7% in KL

CHINESE
41.6% in KL

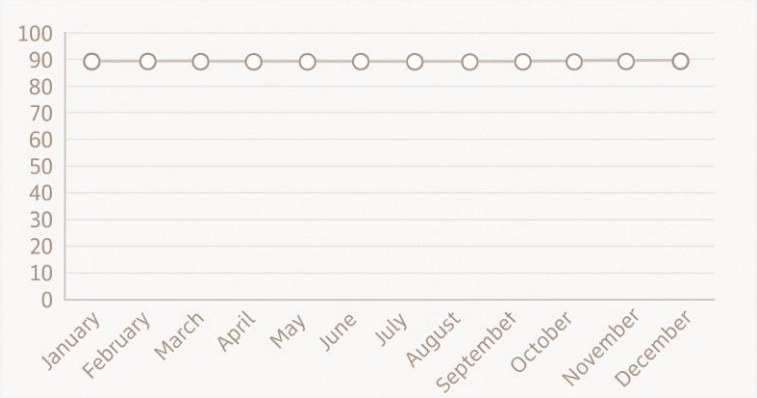
INDIAN
10.0% in KL


STRAITS TIMES

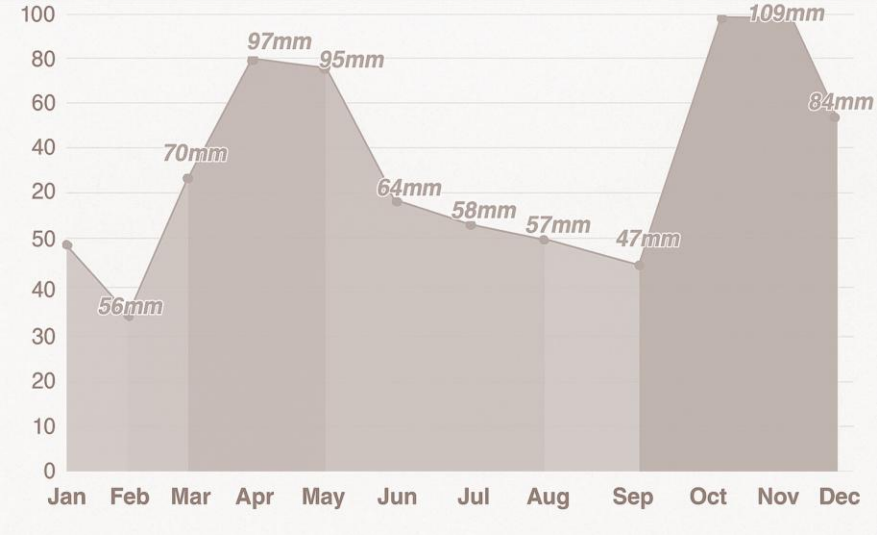
TEMPERATURE [°C]



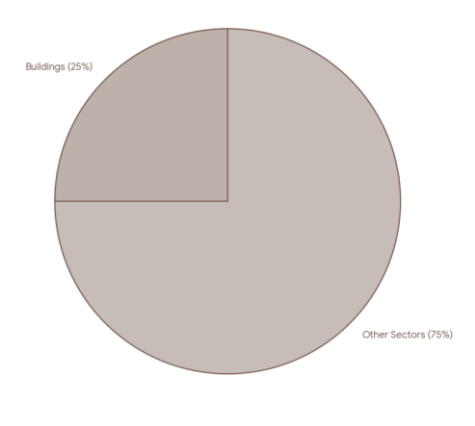
RELATIVE HUMDITY [%]



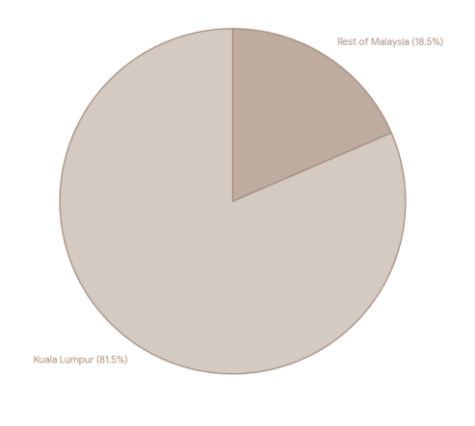
RAINFALL [mm]



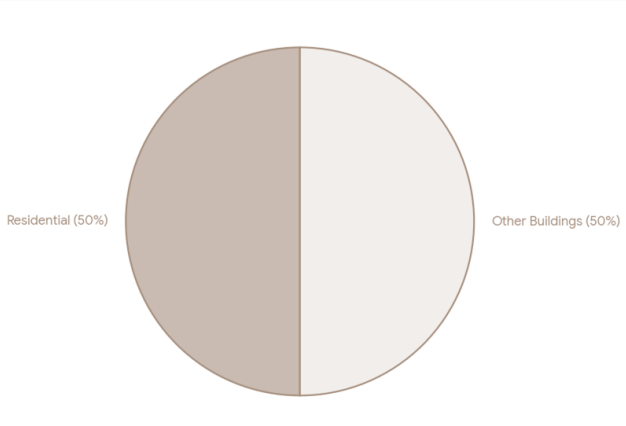
CO2 emissions Malaysia



High-rise in Malaysia



Building types in KL



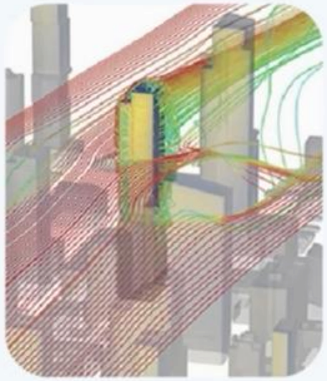
Knowledge Gap

Despite the availability of computational tools, their integration into tropical architectural design is limited.

Research Question	Design Question
How can computational design methods be systematically applied to evaluate and optimize **passive strategies** for thermal comfort of buildings in the tropics?	How can computational design be used to improve the thermal comfort of residents while decreasing energy use in high-rise residential buildings in Malaysia?

COMPUTERIZION OF DESIGN

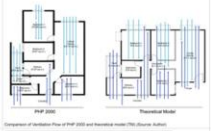
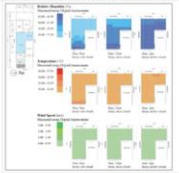
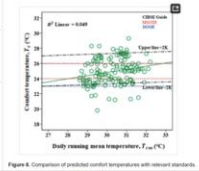
PARAMETRIC DESIGN



PERFORMATIVE DESIGN

GENERATIVE DESIGN

MACHINE LEARNING/AI

	A	B	C	D	E	F
1	**What design element is used to improve thermal comfort?**	**Strategy**	**Design Implication**	**Computational Design Method**	**References**	**Example from paper**
2	Facade and Elevation design	**Improving thermal comfort in social housing whilst incorporating traditonal Malay values**	Incorporate design elements such as large exposed surfaces, full-height openings, and raised floor levels to enhance cross-ventilation and promote natural airflow, as demonstrated in the 'Air House' concept.	Use of IES <VE> simulation in combination with MacroFlo & Microflow to analyze airflow and thermal comfort.	Sahabuddin & Gonzalez-Longo (2015)	
3	Building facade	**Optimizing Building Materials and Operative Conditions**	Material selection and spatial configuration should prioritize thermal performance to passively maintain indoor comfort and reduce cooling energy demands.	Thermal analysis using energy simulation software (e.g., DesignBuilder, EnergyPlus). Also see email Feras named *Psychrometric chart*.	Zulkeply, Sidik & Chuen (2023)	
4	No design element -> Indoor temperature is optimized through simulation	**Adaptive Thermal Comfort Standards**	Indoor temperature setpoints should align with adaptive comfort levels in tropical climates to reduce reliance on mechanical cooling and improve energy efficiency	Gather real-life data on how people feel in different temperatures, then use simulations to better understand and predict what makes indoor spaces comfortable.	Izzati, N., Zaki, S. A., & Rijal, H. B. (2023). Investigation of Thermal Adaptation and Development of an Adaptive Model under Various Cooling Temperature Settings	
5	Greenery (parks, green roofs, trees), building orientation, height, density, and parcel layout	**Generative Urban Design Parameters**	Design strategies should consider adjusting building and urban densities, land parcel sizes, and integrating green spaces to reduce urban heat island effects and enhance local microclimates	Parametric urban modeling with sensitivity analysis and generative design (e.g., Rhino/Grasshopper, Ladybug/Honeybee).	Climate-Responsive Urban Planning Through Generative Models (2024)	
6	No design element	**Climate-Responsive Adaptation Strategies**	Integrate local climate risk assessments into the design process and draw on vernacular architectural strategies to develop climate-adaptive buildings	Multi-criteria analysis and climate scenario simulations.	Saifudeen & Mani (2023)	

definitions and metrics | Computational design methods | Tools | Metrics case studies | Metric targets | Ladybug tools

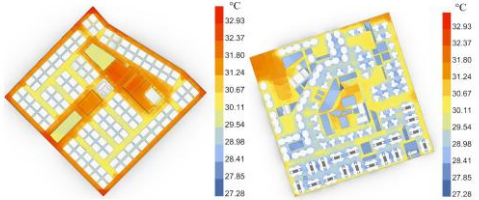


Fig. 12: The average UTCI values of the extremely hot week of the year [Author].
Left: Sheraton residences neighborhood in Cairo (from July 20 to July 26)
Right: The 5th district neighborhood in New Damietta (from August 1 to August 7)

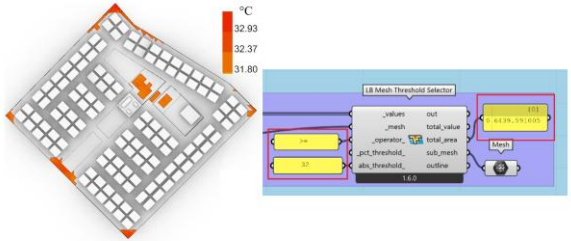


Fig. 13: The generated sub-mesh by "LB Mesh Threshold Selector" component [Author].

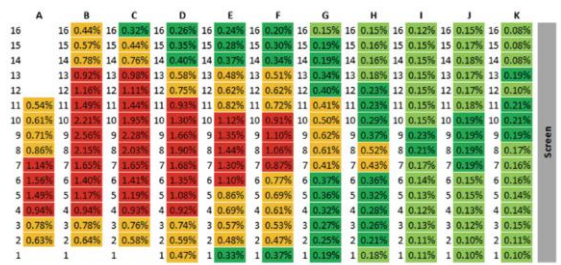


Fig. 1. Occupation and distribution in the cinema room. (Color figure online)

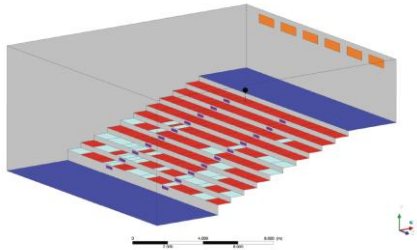


Fig. 2. Representation of the modelated cinema room and its boundary conditions. The black point represents the location of the experimental measurements. (Color figure online)

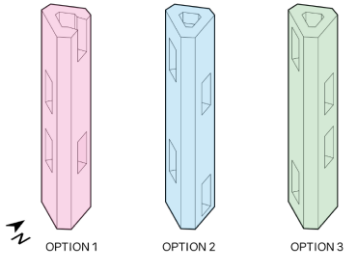


Figure 4. First three best options' sky gardens locations.

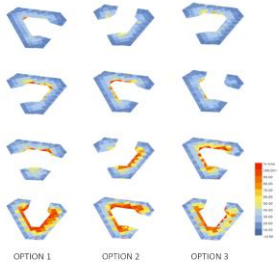


Figure 5. UDI<300lux evaluated at the four selected floors in three best sky gardens configurations.

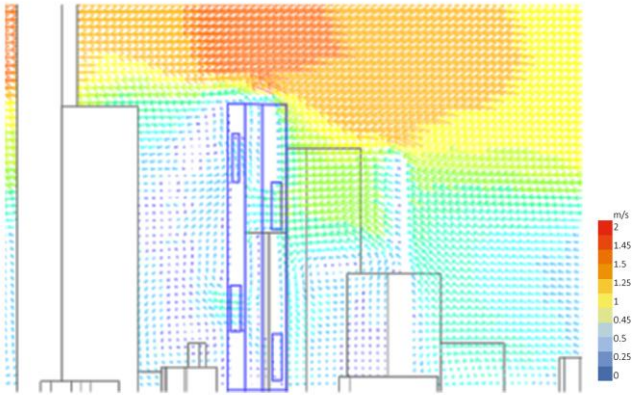


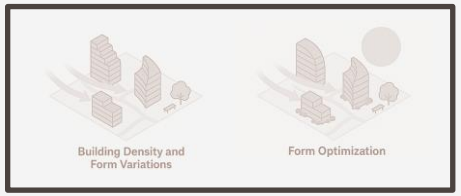
Figure 6. CFD analysis along the main wind direction plane.

DESIGN PRINCIPLES

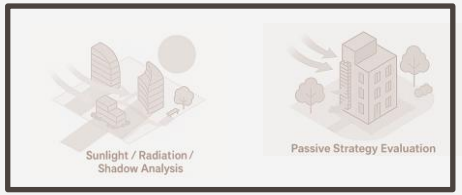
5 Phases
Macro to Micro

DESIGN PRINCIPLES AND PHASES

phase 1



phase 2



phase 3

phase 4

phase 5

Nr	Metric	Target for Residential, KL Malaysia	Target for Commercial, KL Malaysia	Reference
1	Urban Heat Island (UHI) Reduction	1 - 2°C reduction compared to surrounding urban areas	1 - 2°C reduction compared to surrounding urban areas	Elsayed, I. S. (2012). A study on the urban heat island of the city of Kuala Lumpur, Malaysia. Journal of King Abdulaziz University,23(2), 121. and Harun, Z., Reda, E., Abdulrazzaq, A., Abbas, A. A., Yusup, Y., & Zaki, S. A. (2020). Urban heat island in the modern tropical Kuala Lumpur: Comparative weight of the different parameters. Alexandria Engineering Journal, 59(6), 4475-4489.
2	Universal Thermal Climate Index (UTCI)	26 - 32°C (outdoor spaces) (Comfortable to Moderate Heat Stress)	26 - 32°C (outdoor spaces) (Comfortable to Moderate Heat Stress)	Błażejczyk, K., Kuchcik, M., Błażejczyk, A., Milewski, P., & Szmyd, J. (2014). Assessment of urban thermal stress by UTCI–experimental and modelling studies: an example from Poland. DIE ERDE-Journal of the Geographical Society of Berlin,145(1-2), 16-33.
3	Wind Speed Pedestrian Level	≥1.5 m/s at pedestrian level, 50% of time	≥1.5 m/s at pedestrian level, 50% of time	Du, Y., & Mak, C. M. (2018). Improving pedestrian level low wind velocity environment in high-density cities: A general framework and case study. Sustainable cities and society, 42, 314-324.
4	Relative Humidity Indoor	50-70% indoor RH (55% recommended)	55% – 70%	MS 1525:2007 (Commercial), MS 2680:2017 (Residential)
5	Solar Radiation Exposure	~1,500–1,600 kWh/m²/year	~1,500–1,600 kWh/m²/year	Qahtan, A. M. (2019). Thermal performance of a double-skin façade exposed to direct solar radiation in the tropical climate of Malaysia: A case study. Case Studies in Thermal Engineering, 14, 100419.
6	Air Changes per Hour (ACH)	≥ 6 ACH in naturally ventilated areas	≥ 6 ACH in naturally ventilated areas	MS 1525, ASHRAE Standard 62.1 (2019)
7	Surface Temperature Reduction	≥ 3°C reduction compared to standard façades	≥ 3°C reduction compared to standard façades	Santamouris, M. (2012). Advances in Building Energy Research: Volume 1 (Vol. 3). Earthscan.
8	CFD Airflow Performance (Velocity)	0.5 - 2.0 m/s (optimal natural ventilation range)	0.5 - 2.0 m/s (optimal natural ventilation range)	Aynsley, R., & Shiel, J. J. (2017). Ventilation strategies for a warming world. Architectural Science Review, 60(3), 249-254.
9	Energy Use Intensity (EUI)	≤120 kWh/m²/year	≤100 kWh/m²/year	MS 1525 (Commercial), MS 2680 (Residential)
10	PMV (Predicted Mean Vote)	-0.5 to +0.5 (Neutral thermal sensation)	-0.5 to +0.5 (Neutral thermal sensation)	Fanger, P. O. (1970). Thermal comfort: Analysis and applications in environmental engineering. Copenhagen: Danish Technical Press.
11	Airflow Distribution Uniformity	Uniformity ≥ 75% across ventilation paths	Uniformity ≥ 75% across ventilation paths	Awbi, H. B. (2003). Ventilation of buildings (2nd ed.). London: Spon Press.
12	Facade U-value	≤ 1.8 W/m²K for opaque, ≤ 3.0 W/m²K for glazing	≤ 1.8 W/m²K for opaque, ≤ 3.0 W/m²K for glazing	MS 1525 (Commercial), MS 2680 (Residential)
13	Reduction in Direct Solar Radiation	≥ 25% compared to baseline conditions	≥ 25% compared to baseline conditions	Littlefair, P. (1998). Solar shading of buildings. Garston: Building Research Establishment (BRE).
14	Daylight Factor Indoor	2% - 5%	2% - 5%	MS 1525 (Commercial), MS 2680 (Residential)
15	Recommended dry bulb temperature indoor	24°C	23°C – 26°C	Malaysian Standard MS 1525:2007 (commercial), MS 2680:2017 (Residential)
16	Recommended air movement indoor	not specified; can use 0.15 m/s to 0.5 m/s (max 0.7 m/s)	0.15 m/s to 0.5 m/s (max 0.7 m/s)	Malaysian Standard MS 1525:2007
17	Minimum dry bulb temperature indoor	24°C	22°C	Malaysian Standard MS 1525:2007 (commercial), MS 2680:2017 (residential)

FOCUS FOR DESIGN

Phase 1: Urban Thermal Comfort
Phase 2: Form optimization
Phase 3: Passive strategy evaluation

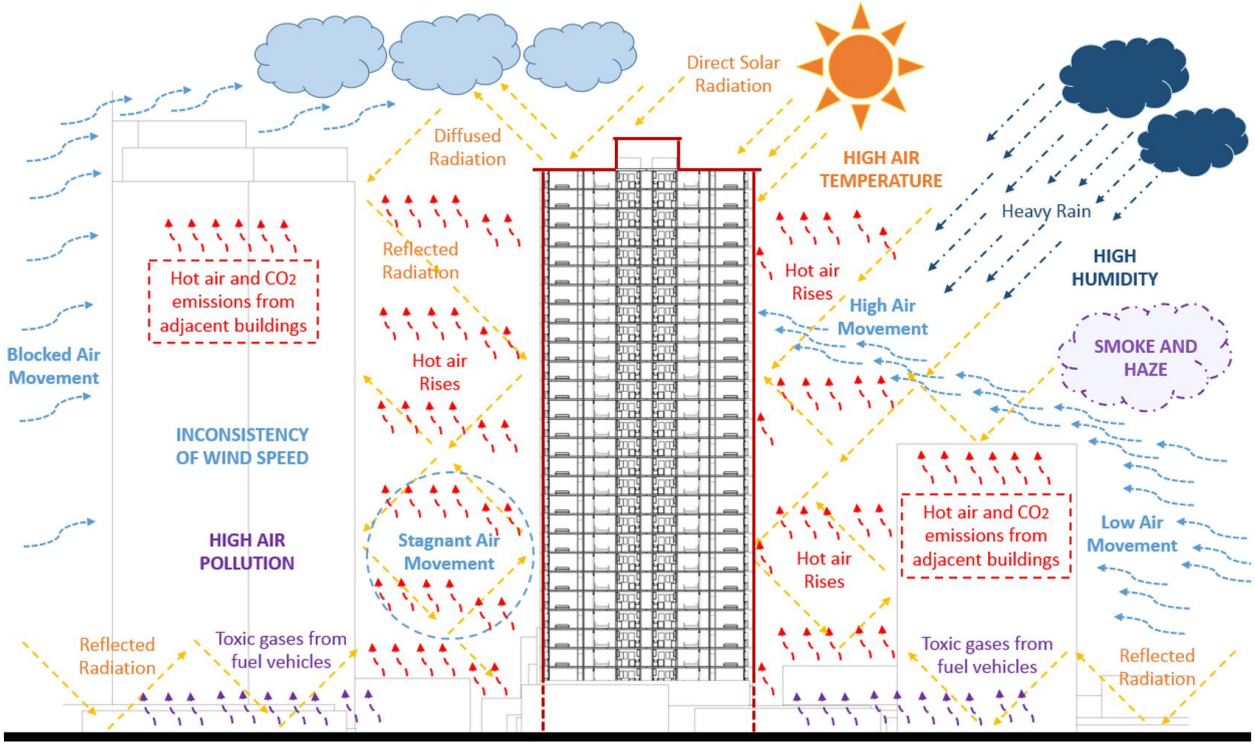


Figure 1: Factors affecting natural ventilation in a typical high-rise building within an urban area in hot-humid climate

Source: Sahabuddin, M. F. B. M., & Gonzalez-Longo, C. (2017, July). Natural ventilation potential in Kuala Lumpur: Assumptions, realities and future. In 33rd international conference on passive and low energy architecture: design to thrive.

FOCUS FOR DESIGN

High rise residential

KLCC

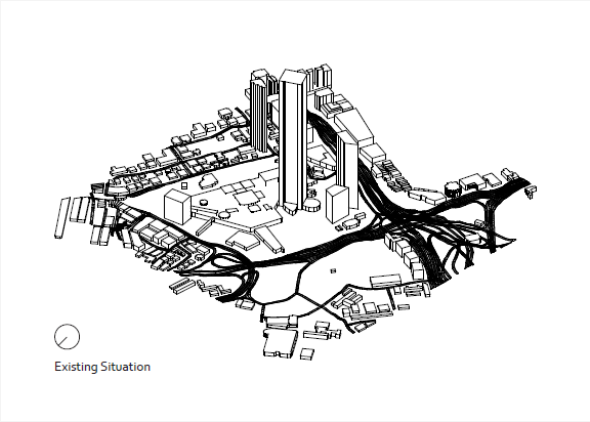
ntang

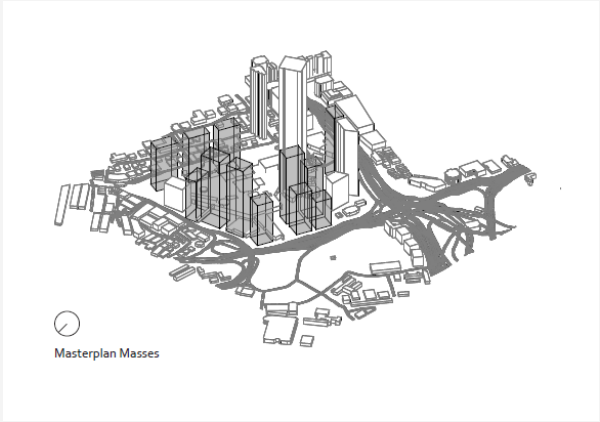
TRX Exchange

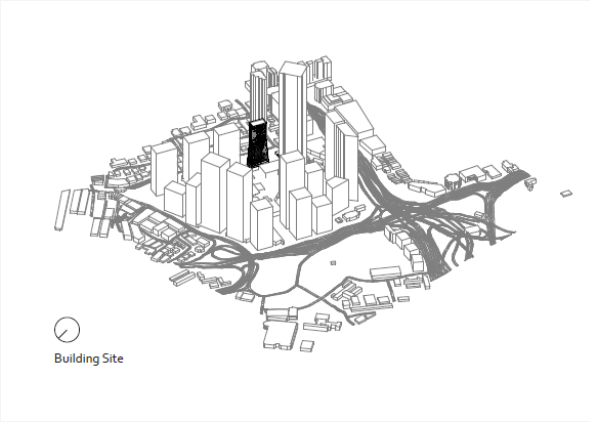
Merdeka 118 (679m)

Exchange 106 (453m)

Designing here means intervening in the skyline that will define the city's next century.

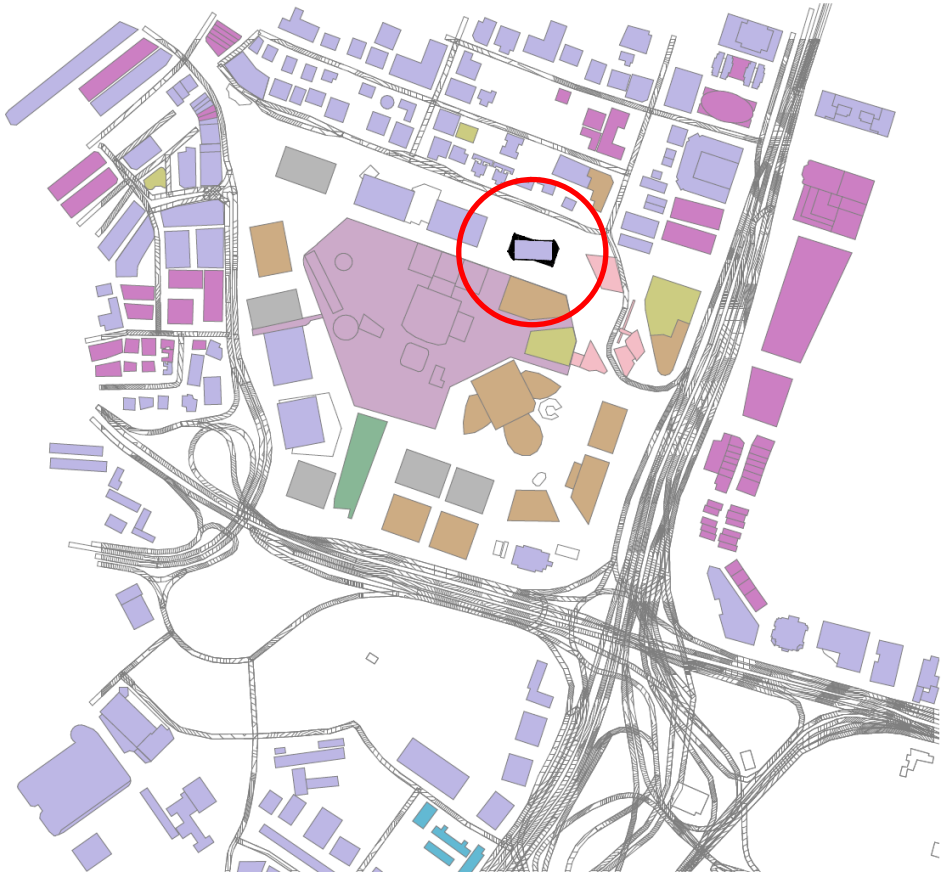






time

EXISTING SITUATION AND MASTER PLAN



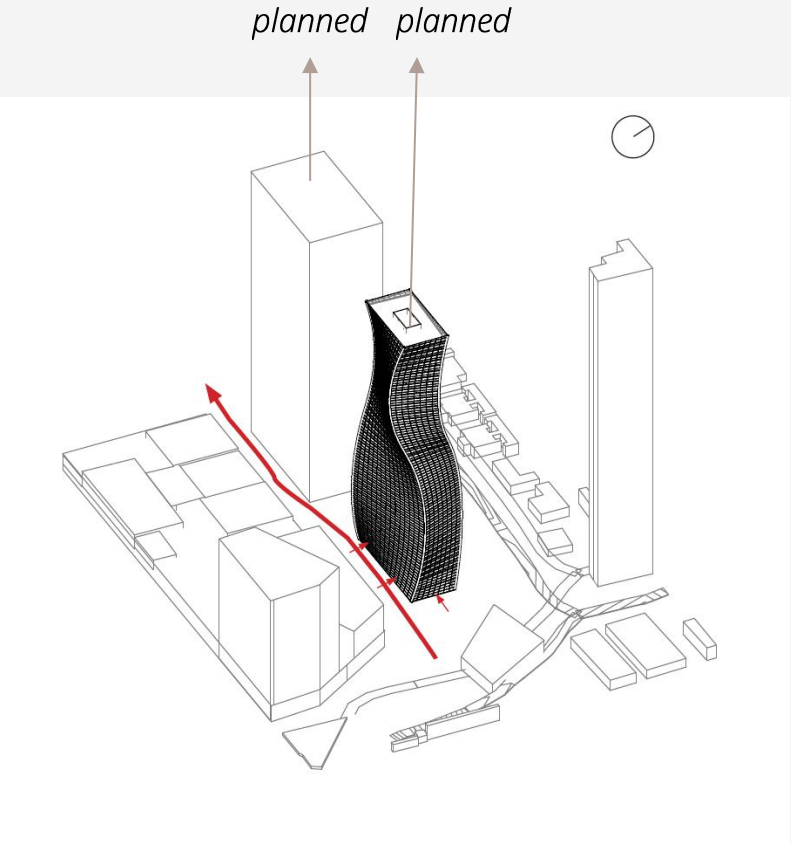
SITE PLAN
1:5000

residential
commercial
hotel
office

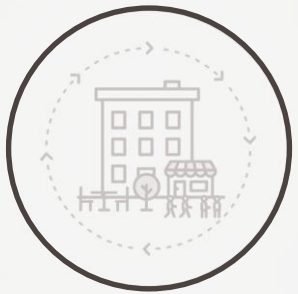
school
water treatment plant
parking
metro station

Podium of cars deadens the street edge and cuts people off from the city


TEA
茶岩
茶岩


planned
planned

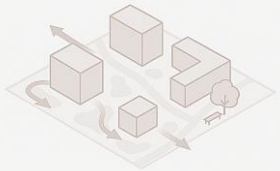
heals urban fabric



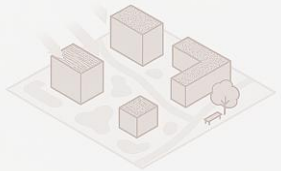
enhances livability

centers people, not cars

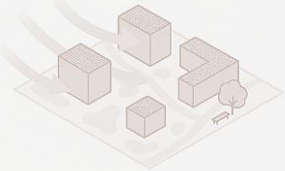
phase 1: urban thermal comfort



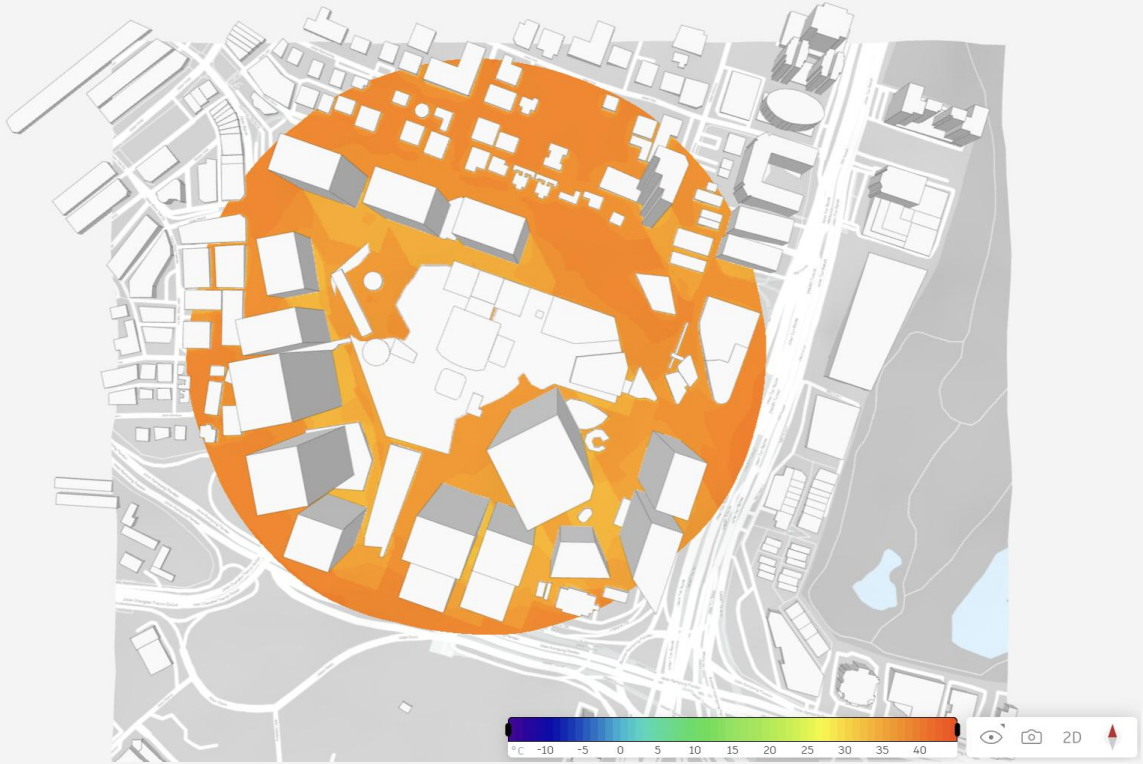
Site Planning

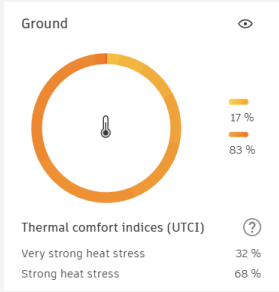


Urban Heat Island Mitigation

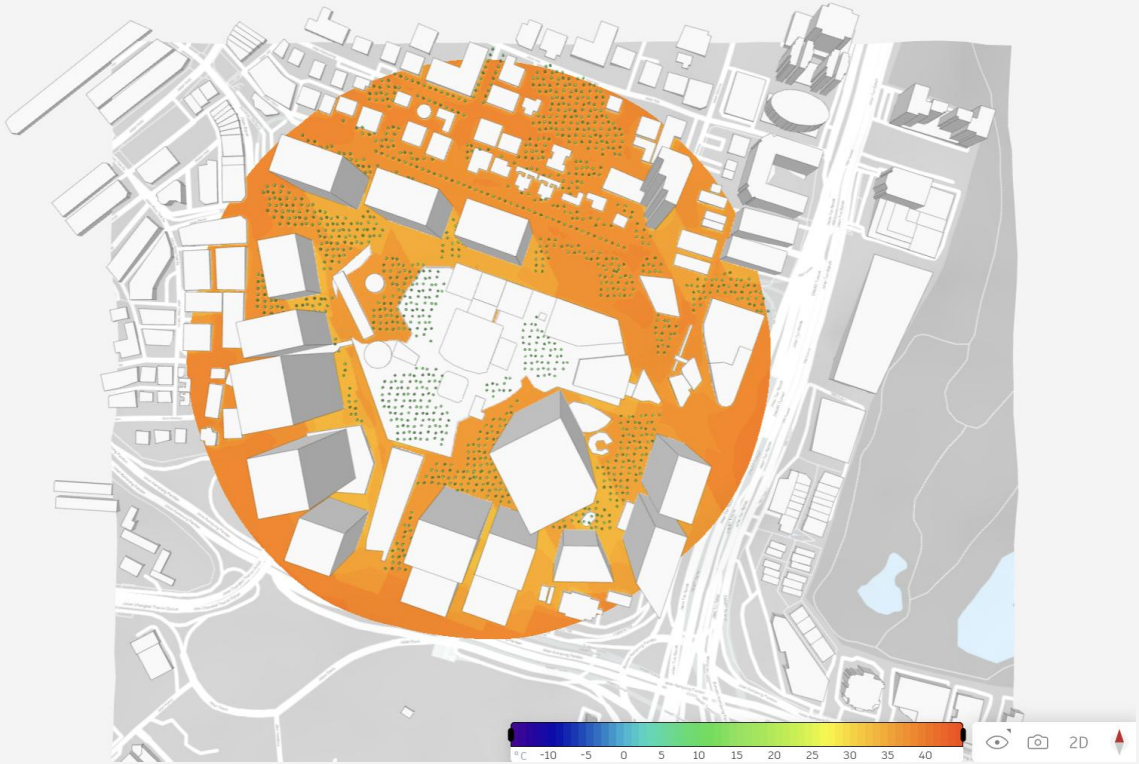


Microclimate Analysis





Target: 26 - 32°C (outdoor spaces) (Comfortable to Moderate Heat Stress)
Target adjusted: 30-35 °C



Ground

17 %
83 %

Thermal comfort indices (UTCI)

Very strong heat stress	32 %
Strong heat stress	68 %

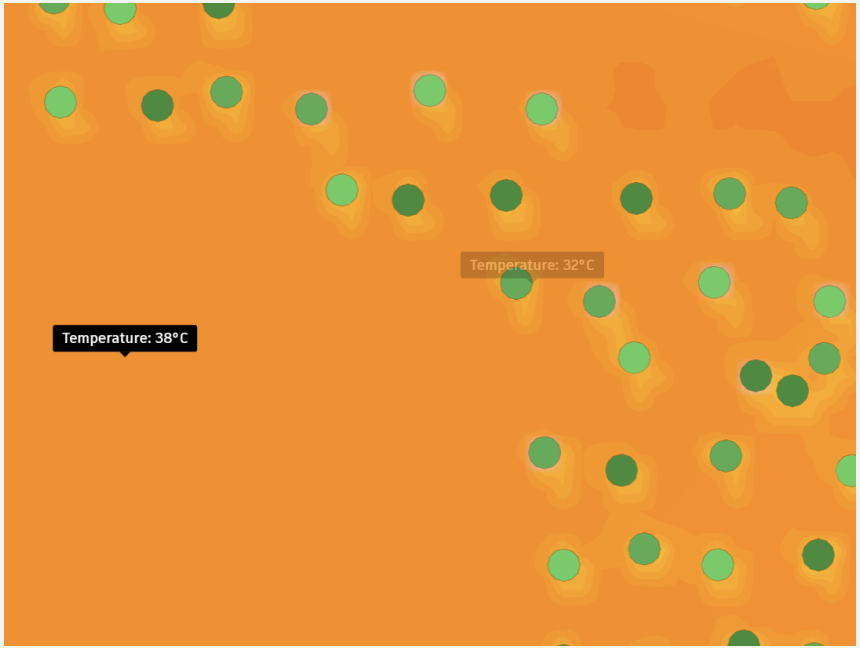
Ground

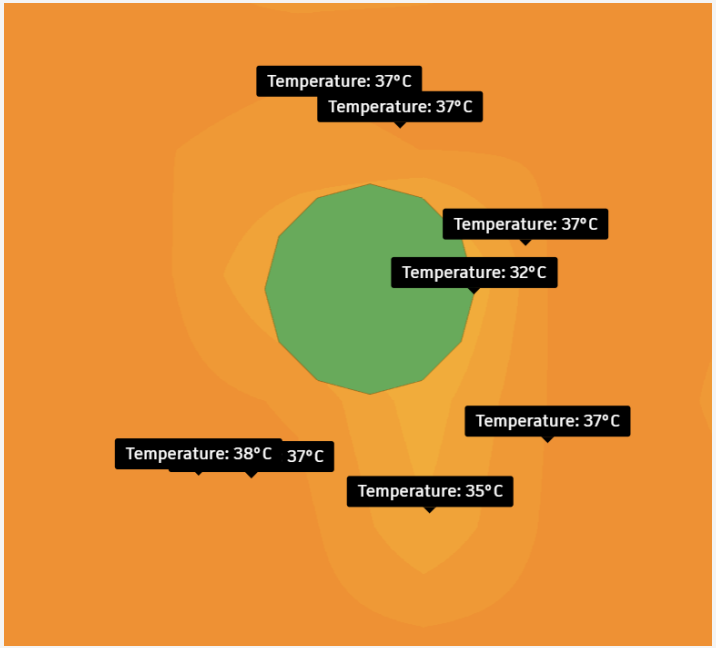
26 %
74 %

Thermal comfort indices (UTCI)

Very strong heat stress	11 %
Strong heat stress	86 %
Moderate heat stress	2 %

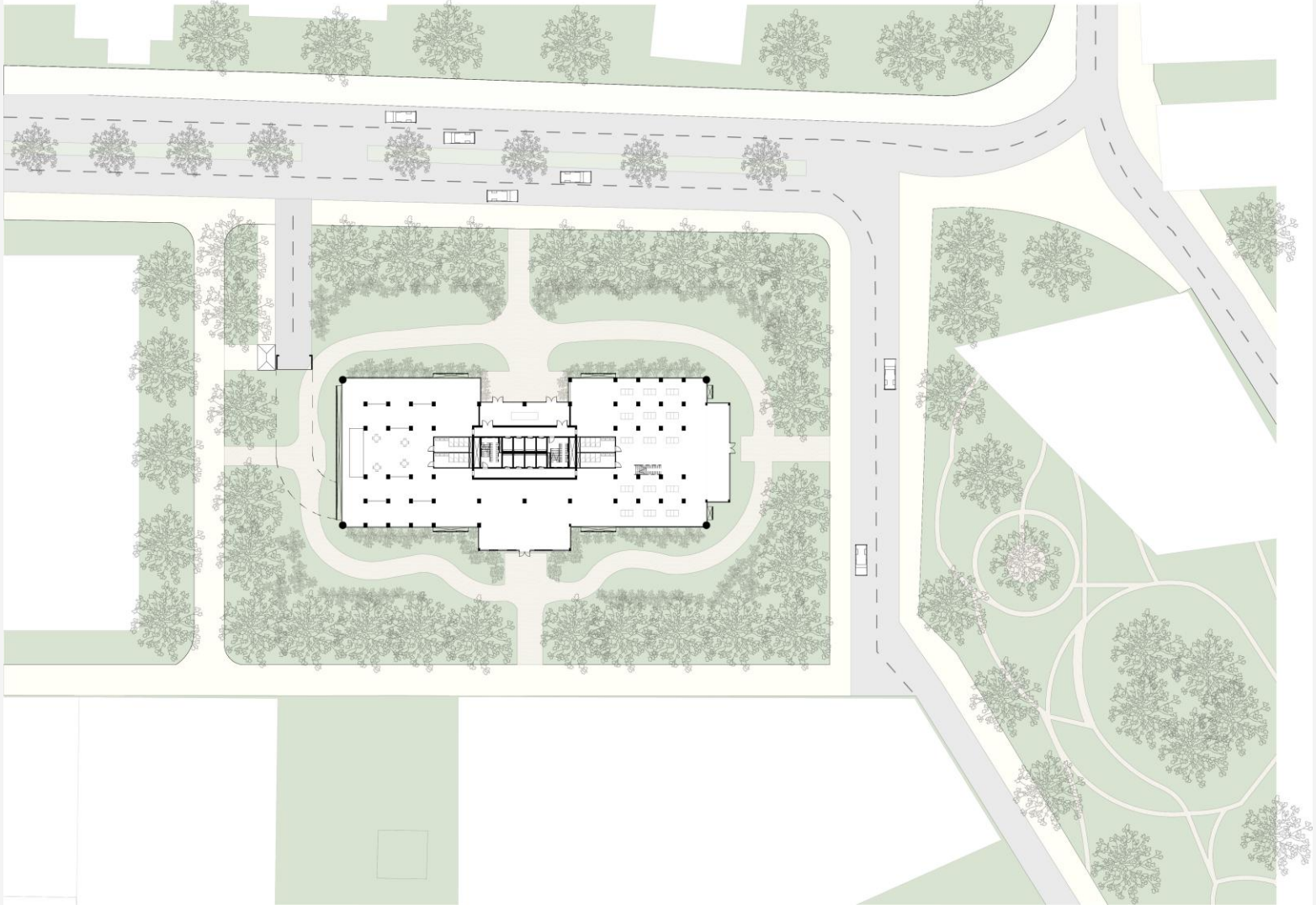
Roof


Temperature: 32°C
Temperature: 38°C


Temperature: 37°C
Temperature: 37°C
Temperature: 37°C
Temperature: 32°C
Temperature: 37°C
Temperature: 38°C
37°C
Temperature: 35°C

drain moisture, regulate heat, redirect air, lowers MRT

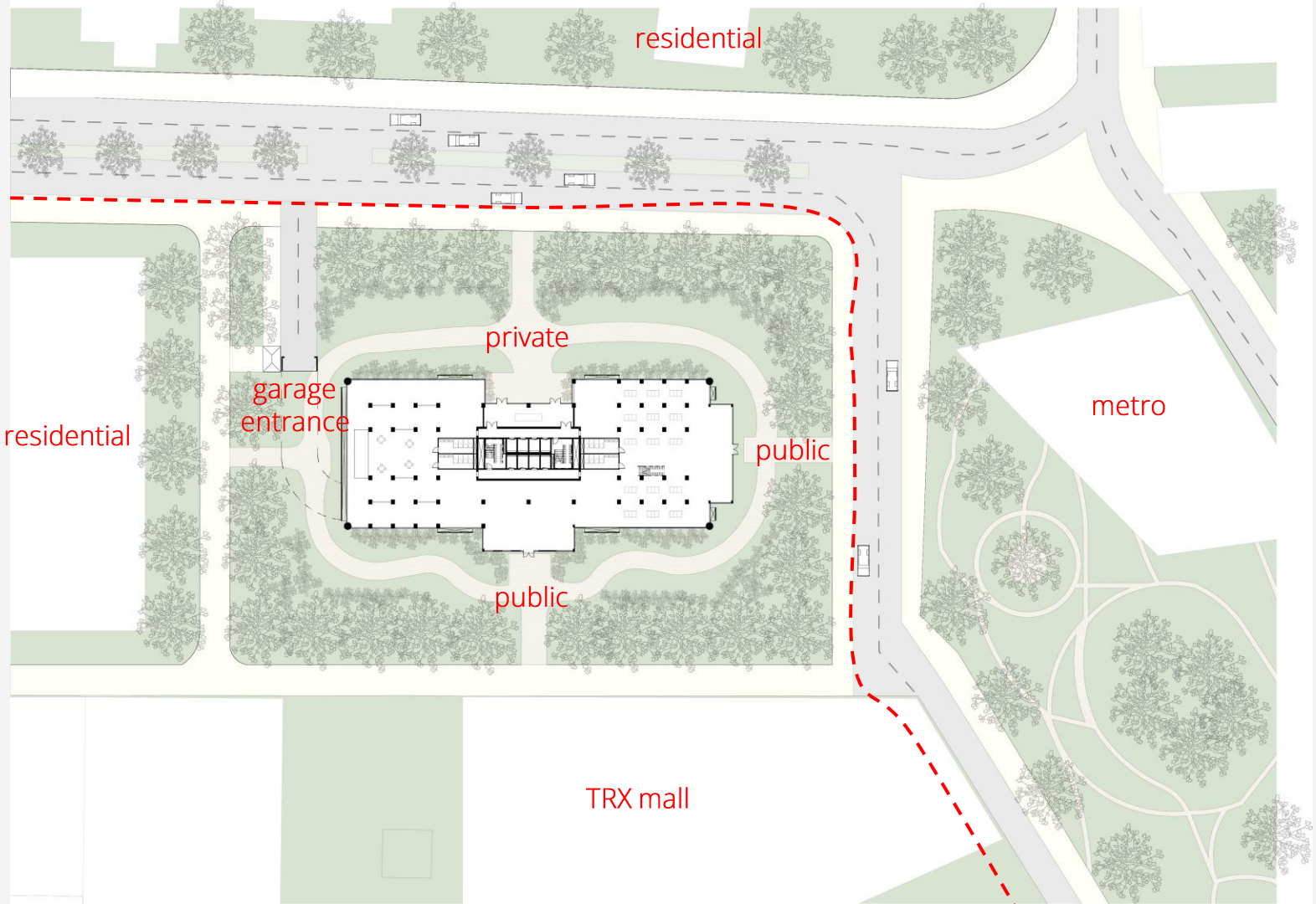
absorps solar energy, re-radiates as heat, raises MRT



reduces radiant heat

manages humidity

enhanced air movement

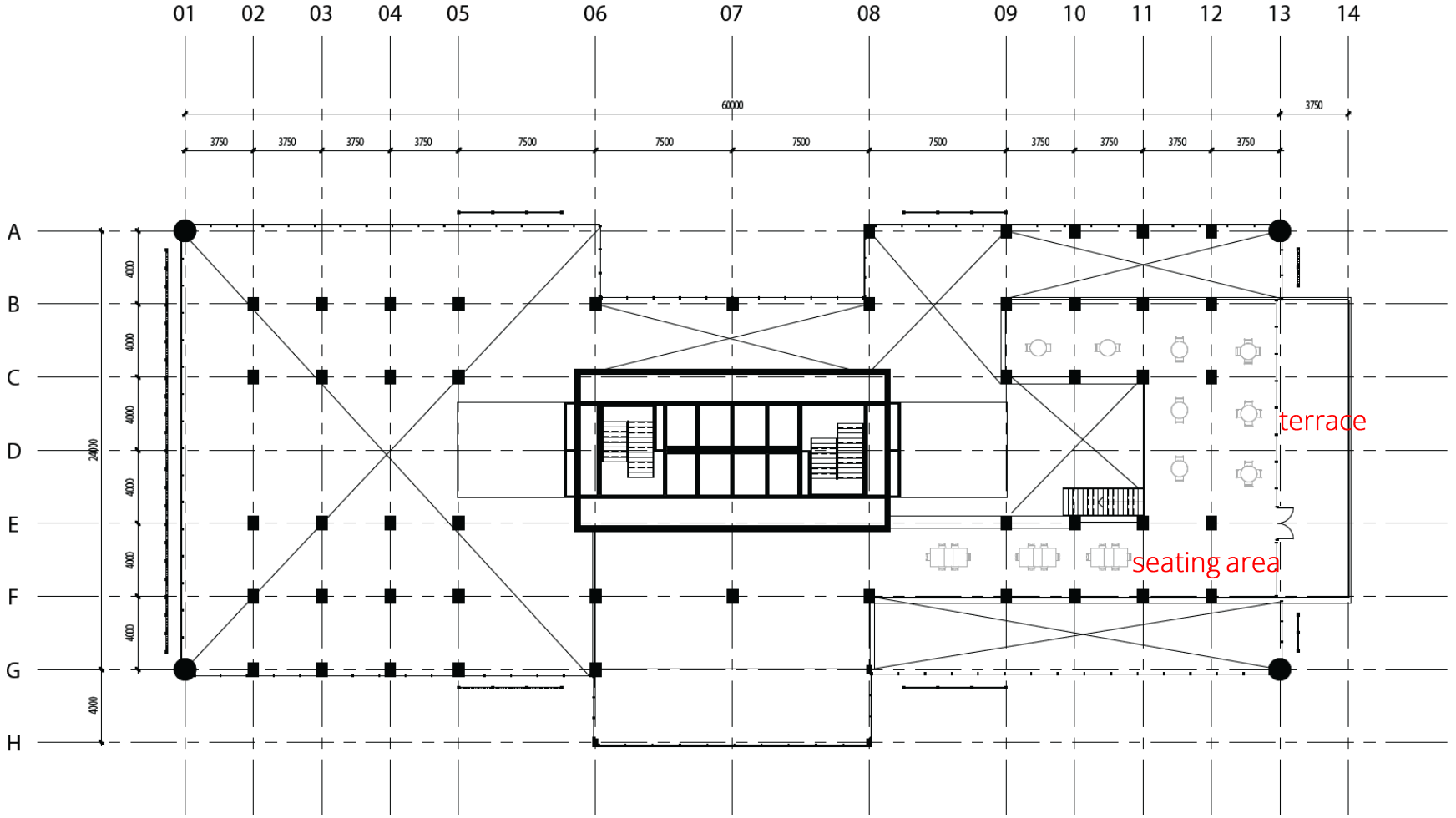

residential
private
garage
entrance
residential
public
metro
public
TRX mall

guard post

residents entrance

exhibition hall/cafe

pop-up market


01
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14
60000
3750
3750
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7500
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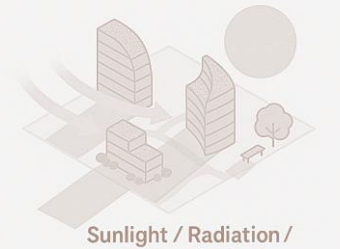
7500
3750
3750
3750
3750
A
B
C
D
E
F
G
H
4000
4000
4000
4000
4000
4000
4000
24000
terrace
seating area

Building Density and Form Variations

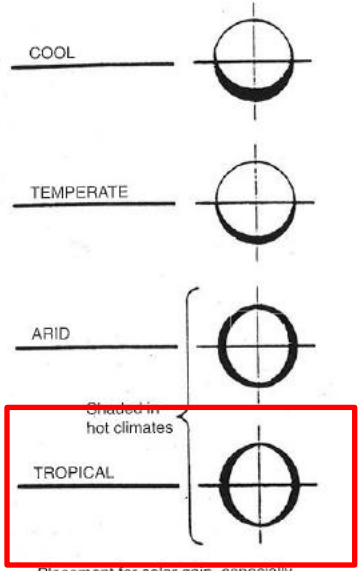
Form Optimization



Sunlight / Radiation / Shadow Analysis

Passive Strategy Evaluation

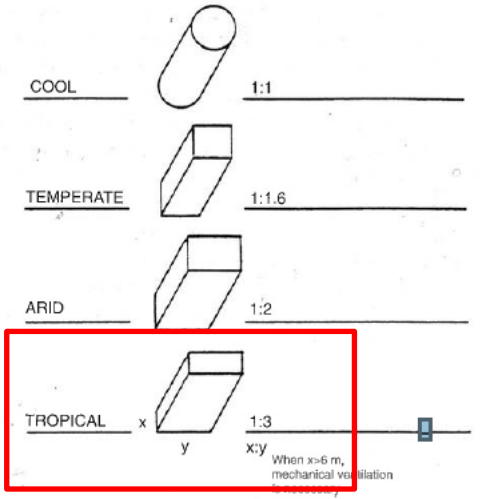
Designing in TRX means intervening in the skyline



Placement for solar gain, especially in arid and tropical zones; these areas must be shaded.

Fig. 64 Influences on built form (Source: Yeang, K., *Bioclimatic Skyscrapers*, Ellipsis, 1994)

Fig. 57 Optimum aspect ratios of buildings (Source: Yeang, K., 'Bioclimatic Skyscrapers', Ellipsis, 1994)



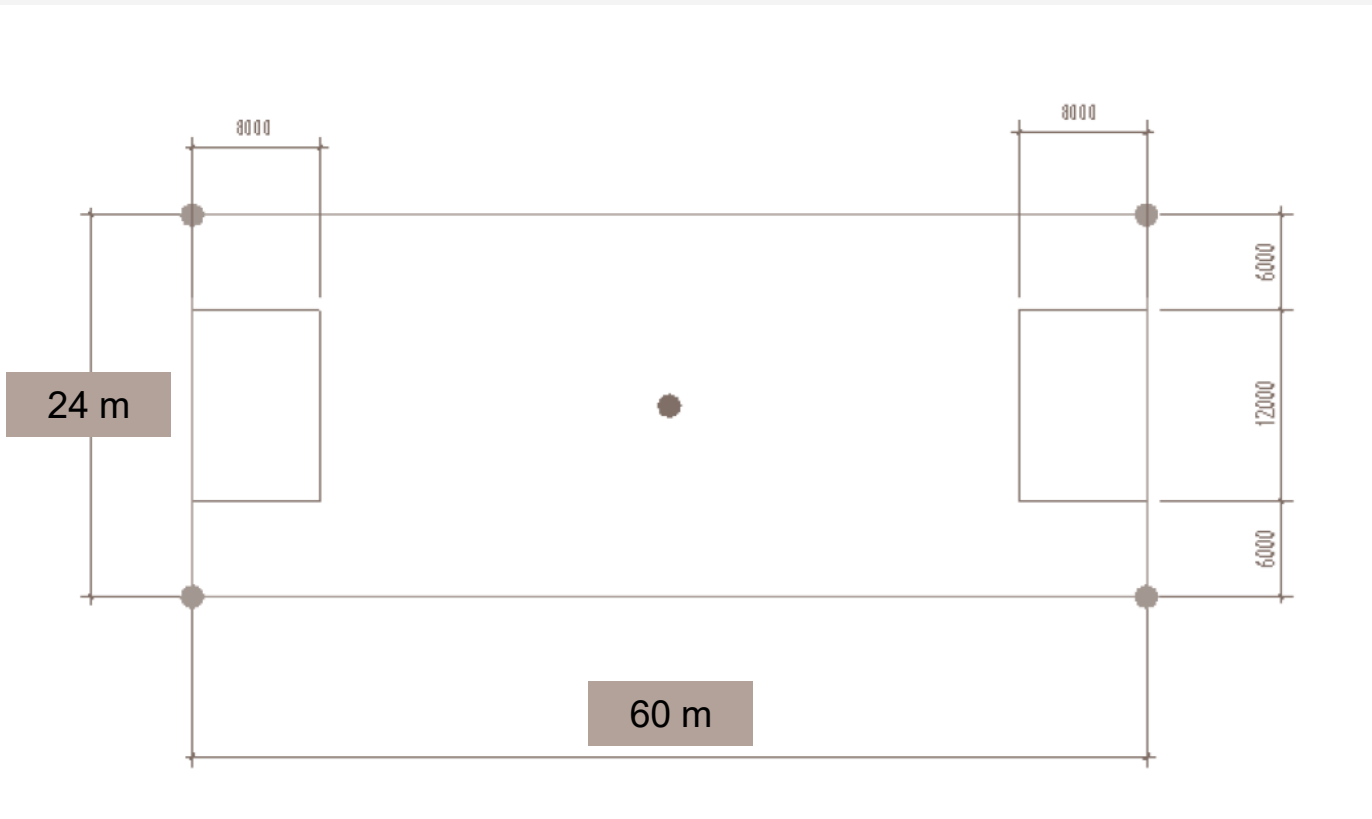
FORM

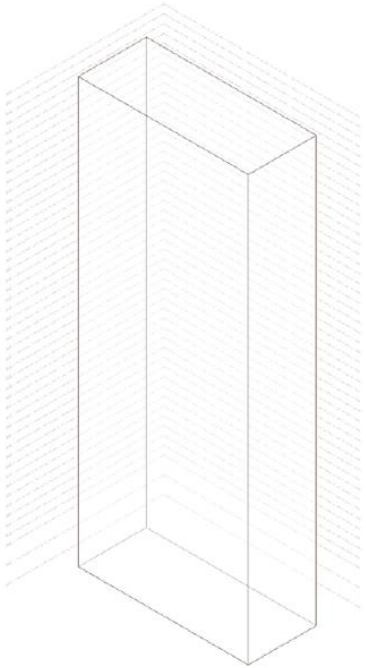
Diagram shows the optimum aspect ratios of buildings in each climate zone, the best orientation of main facades, and the distribution of primary mass to achieve maximum solar shading or solar gain respectively. Research has shown that the preferred length of the sides of the building, where the sides are of length x:y, is:

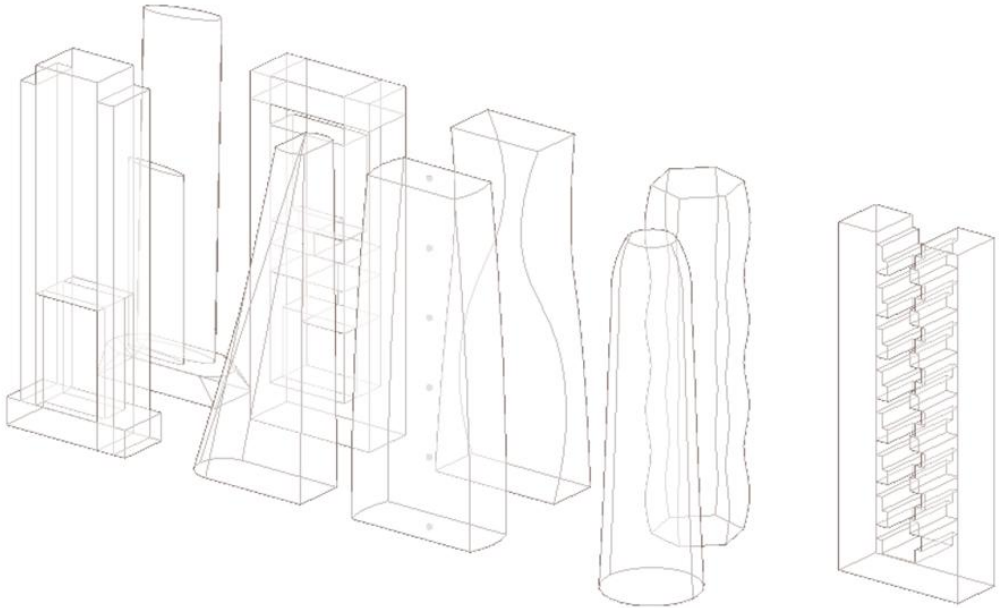
- Cool zone 1:1
- Temperate zone 1:1.6
- Arid zone 1:2
- Tropical zone 1:3

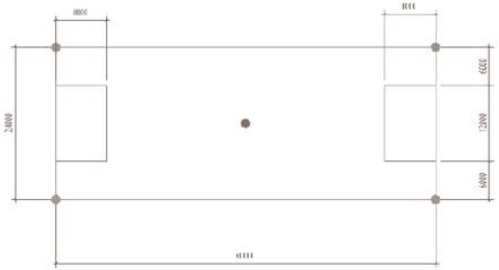
Looking at the aspect ratios, we see that lower latitudes require an elongated from, to minimize the east and west exposure. This form gradually evolves into a 1:1 ratio, i.e. to a cylindrical form, as we reach the higher latitudes in the north, where the surface capable of utilizing solar gain should be as large as possible.

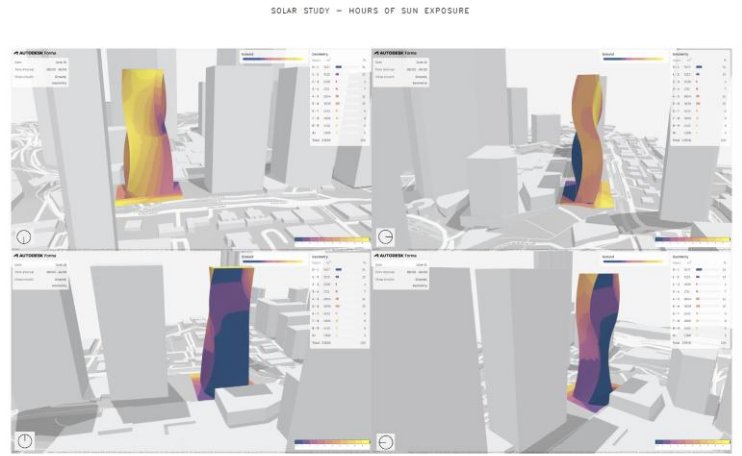
The building's aspect ratio (its length-to-width proportion) is not arbitrary. It is a direct response to latitude and climate.

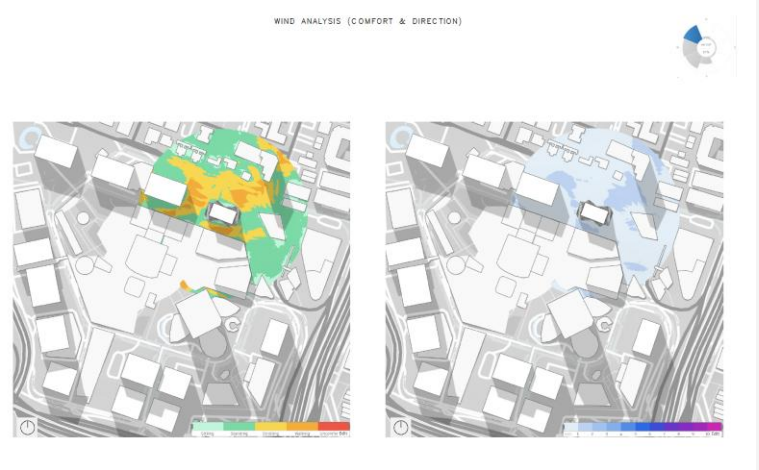

8000
8000
6000
12000
6000
24 m
60 m

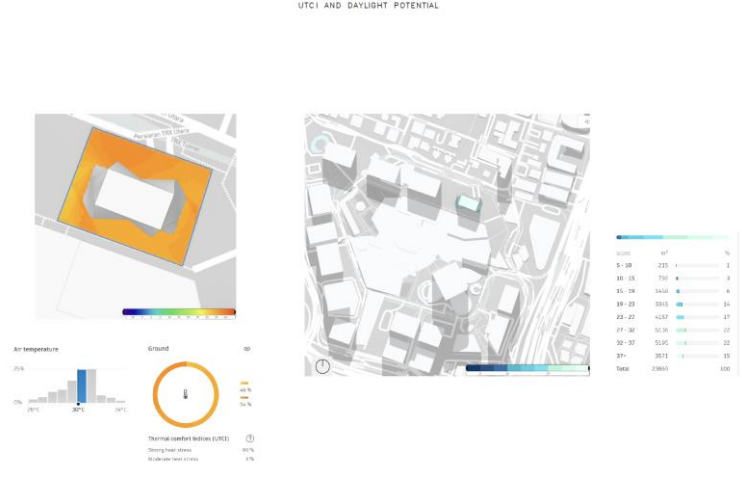












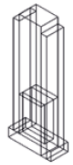
1. Sun hours (<5 hours)
2. Wind (0,5-2m/s)
3. UTCI (<33 celsius)
4. Daylight potential

variant 1		--	-	+	++
sun hours	60,0%		■		
wind	11,0%				■
UTCI	22,5%			■	
daylight potentia	59,0%			■	

variant 2		--	-	+	++
sun hours	59,0%		■		
wind	10,0%			■	
UTCI	17,9%		■		
daylight potentia	59,0%			■	

variant 3		--	-	+	++
sun hours	70,0%			■	
wind	8,0%		■		
UTCI	17,0%		■		
daylight potentia	66,0%				■

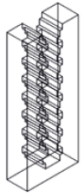
variant 4		--	-	+	++
sun hours	69,0%			■	
wind	9,0%		■		
UTCI	16,9%		■		
daylight potentia	44,0%	■			



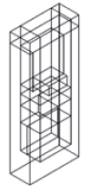
variant 5		--	-	+	++
sun hours	65,0%			■	
wind	9,0%		■		
UTCI	18,8%		■		
daylight potentia	51,0%		■		

variant 6		--	-	+	++
sun hours	51,0%	■			
wind	10,0%			■	
UTCI	20,5%			■	
daylight potentia	72,0%				■

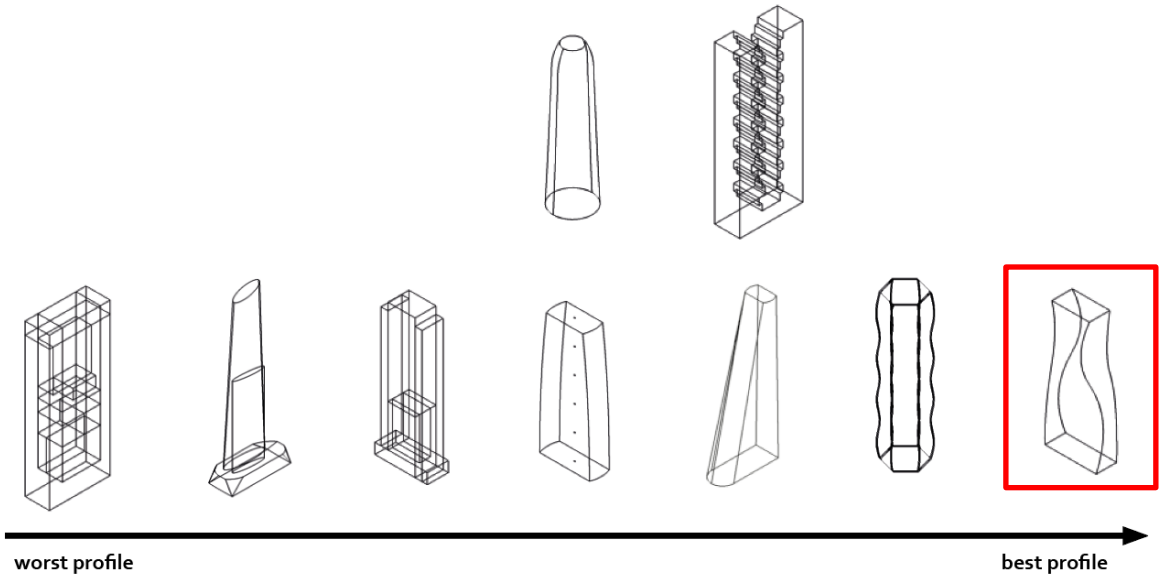
variant 7		--	-	+	++
sun hours	67,0%			■	
wind	9,0%		■		
UTCI	29,2%				■
daylight potentia	55,0%			■	

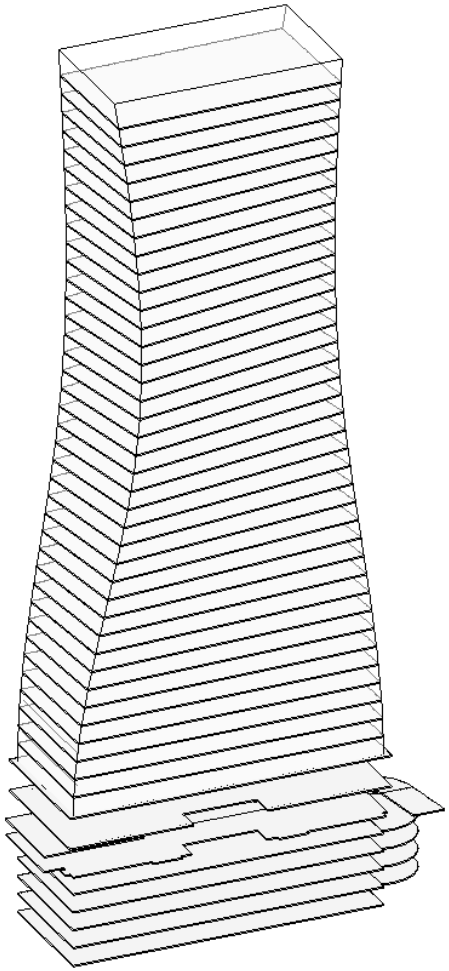


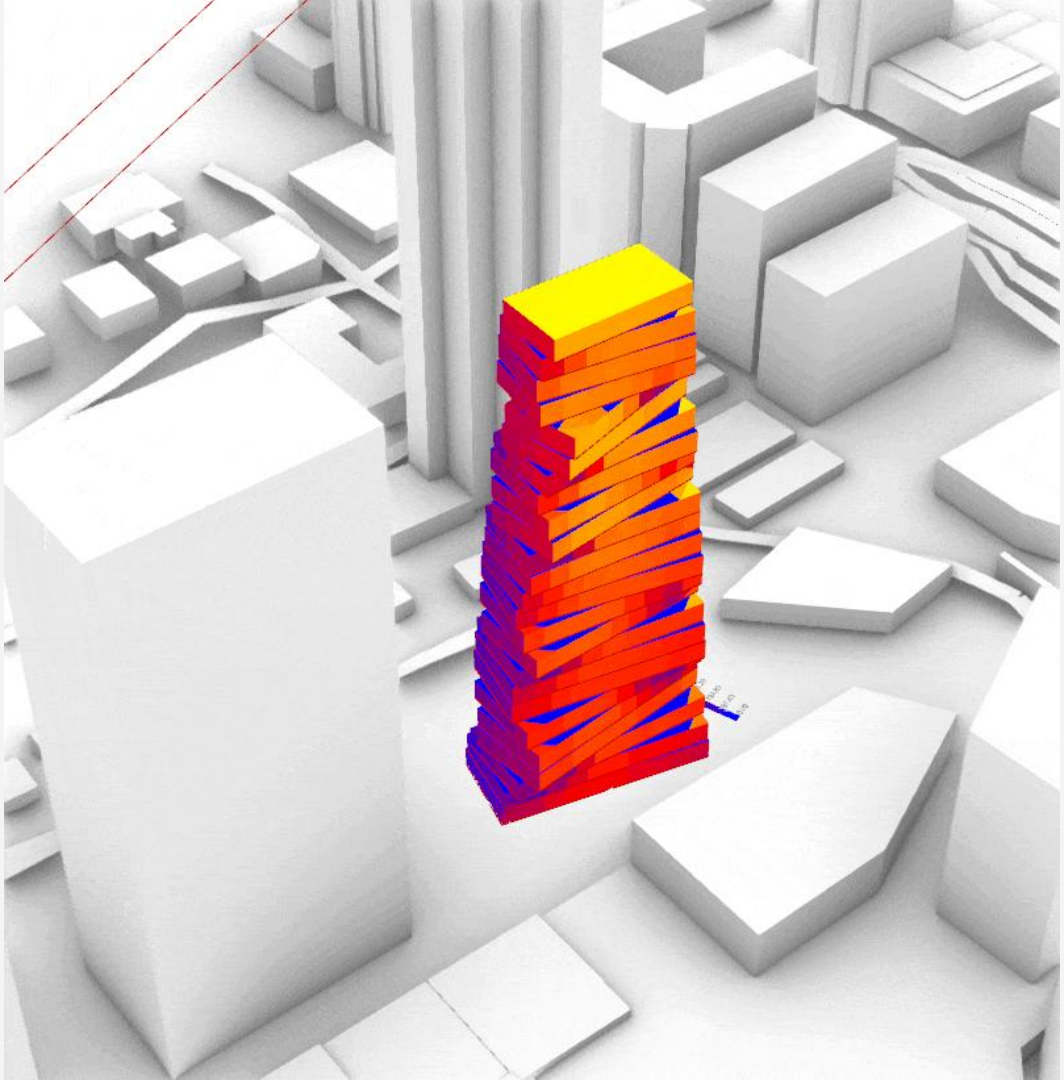
variant 8		--	-	+	++
sun hours	72,0%				■
wind	10,0%			■	
UTCI	21,7%			■	
daylight potentia	43,0%	■			

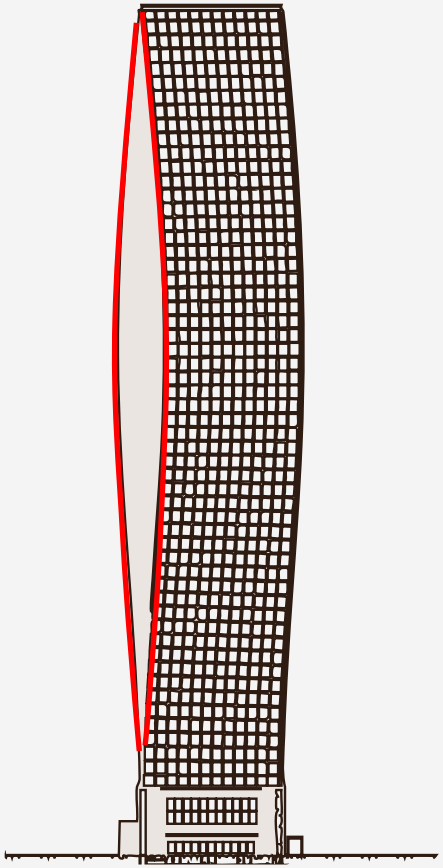


variant 9		--	-	+	++
sun hours	63,0%		■		
wind	10,0%			■	
UTCI	15,6%	■			
daylight potentia	47,0%		■		


worst profile
best profile







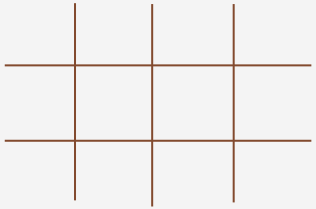
curvature makes it self- shading

Principle: The curved surfaces self-shade various parts of the façade throughout the day, reducing direct solar radiation exposure.

Thermal Comfort Benefit: Significantly lowers the solar heat gain on the building envelope, decreasing cooling loads and maintaining stable internal temperatures.

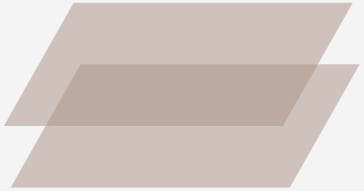
How can a complex form be made (somewhat) cost-effective?

Find regularity in irregularity

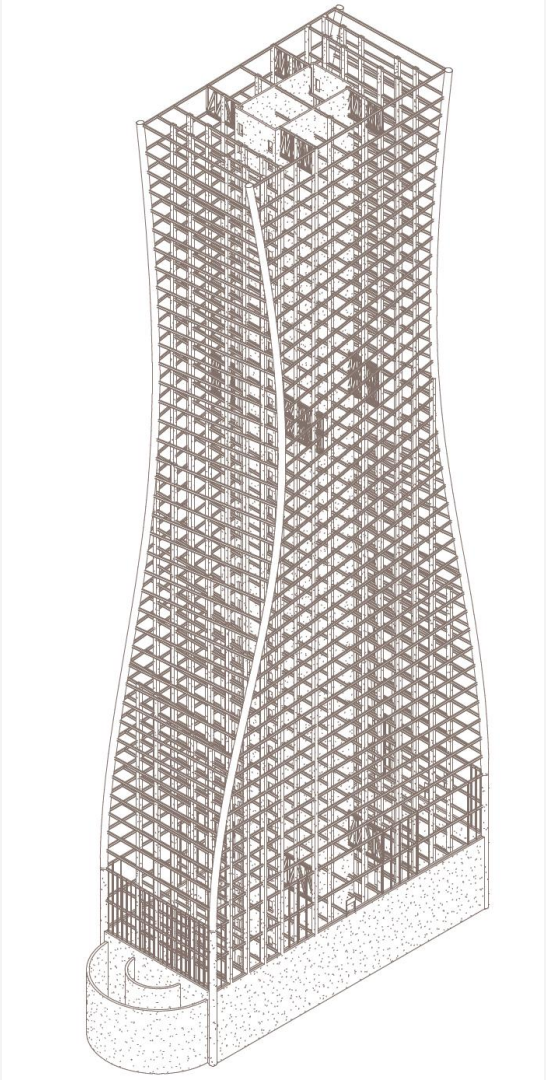


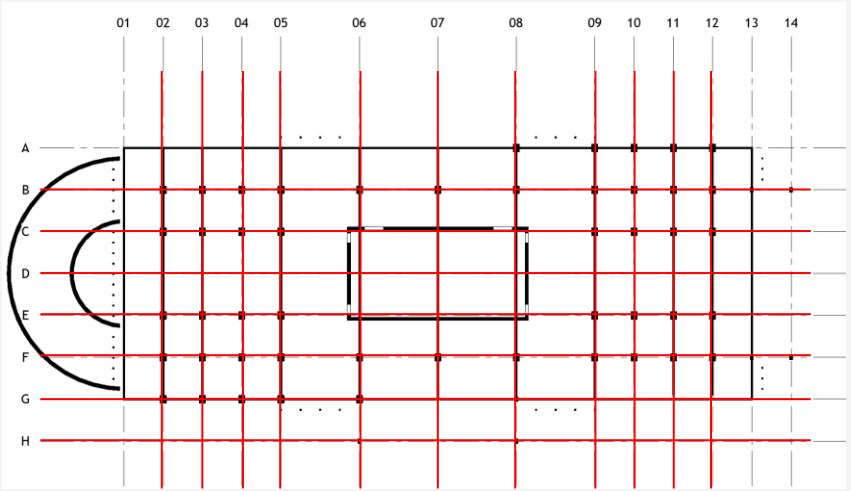
grid

cantilevered floors



material




01 02 03 04 05 06 07 08 09 10 11 12 13 14
A
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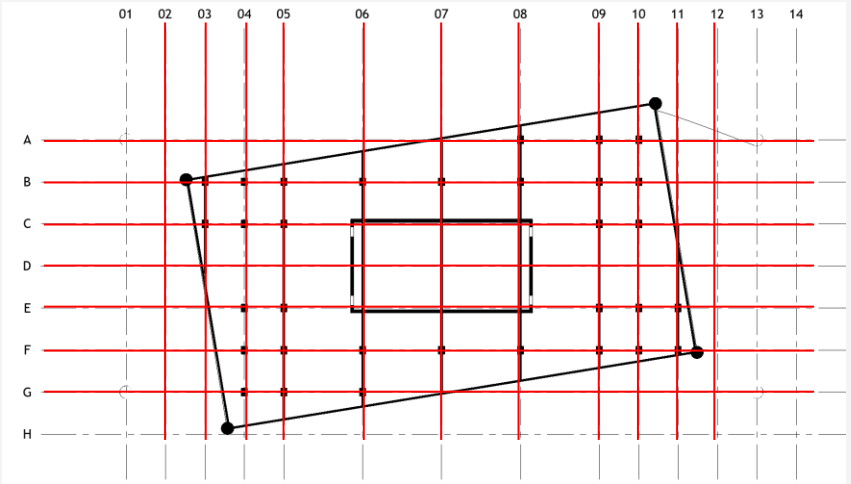
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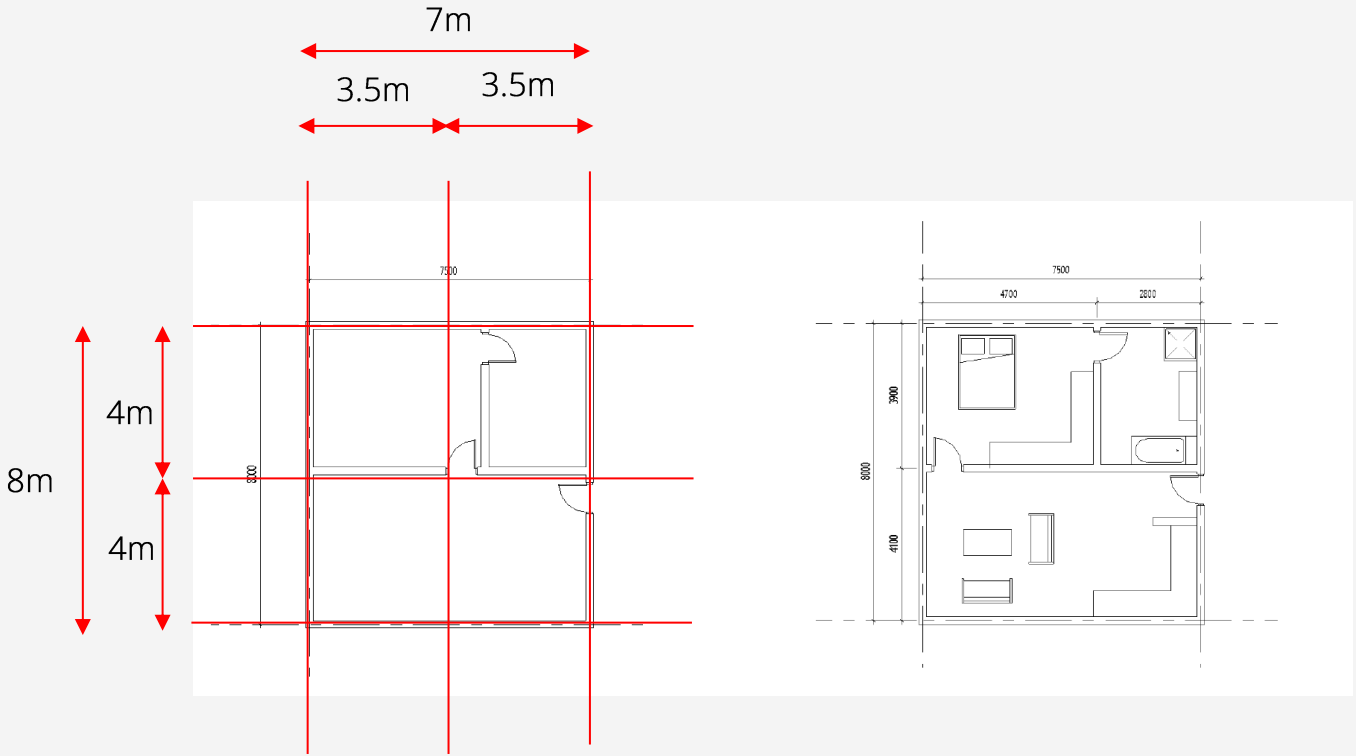
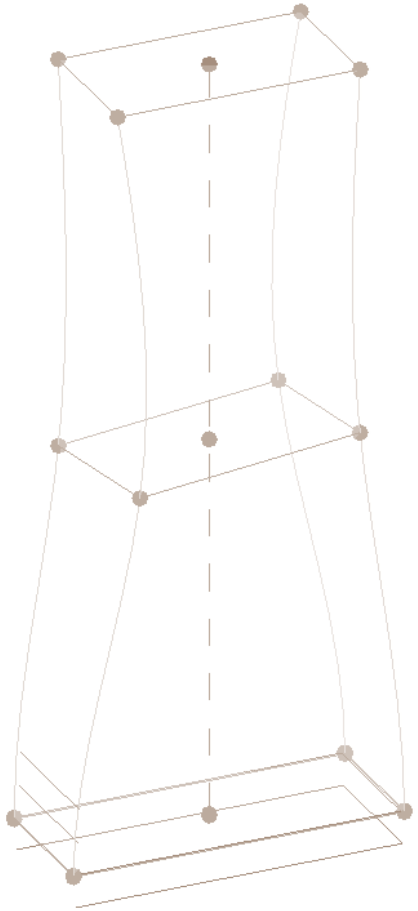
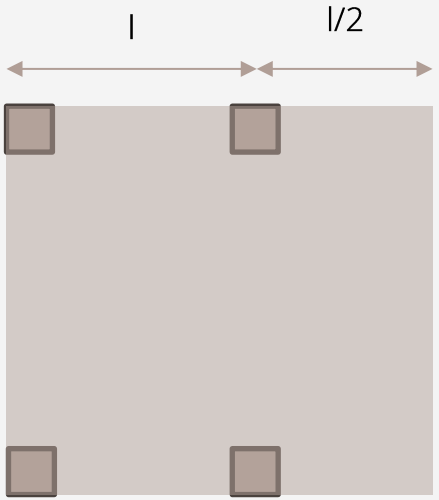

7m
3.5m
3.5m
8m
4m
4m
7000
8000
7500
4700
2800
3900
8000
4100

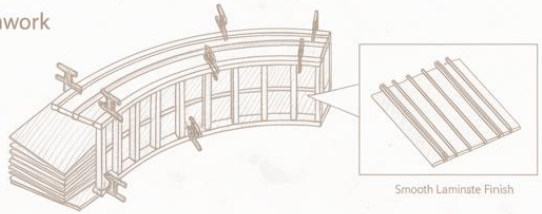




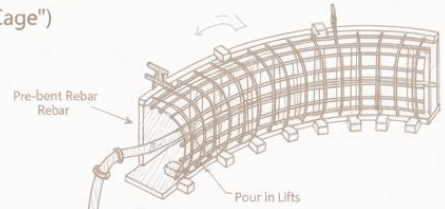
Equivalent to a rotation angle of 10°

1. Design & Engineering

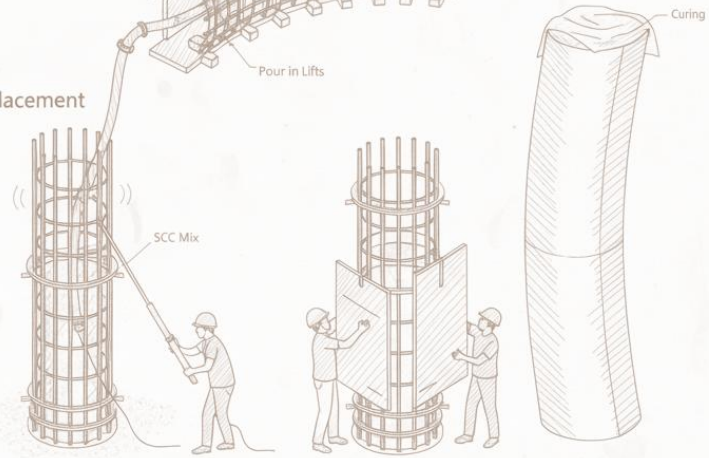
2. Building the Curved Formwork



3. Reinrorcement ('Rebar Cage")



4. Concrete Pouring & Placement



5. Curing & Stripping

This isn’t a “free-form” tower.
This is a disciplined structure wearing a fluid dress.

Zeljic, A. S. (2010, June). Shanghai Tower Façade Design Process. In *International Conference of Building Envelope Systems. Retrieved from: http://www. gensler. com/uploads/documents/Shanghai_Tower_Faca de_Design_Process_11_10_2011. pdf*.

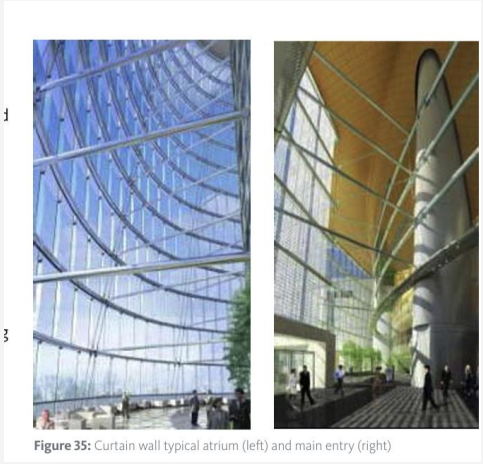
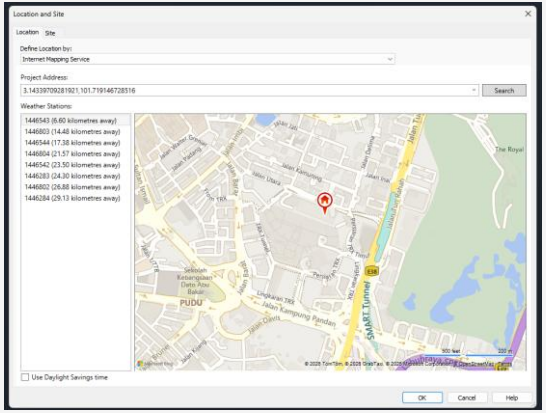


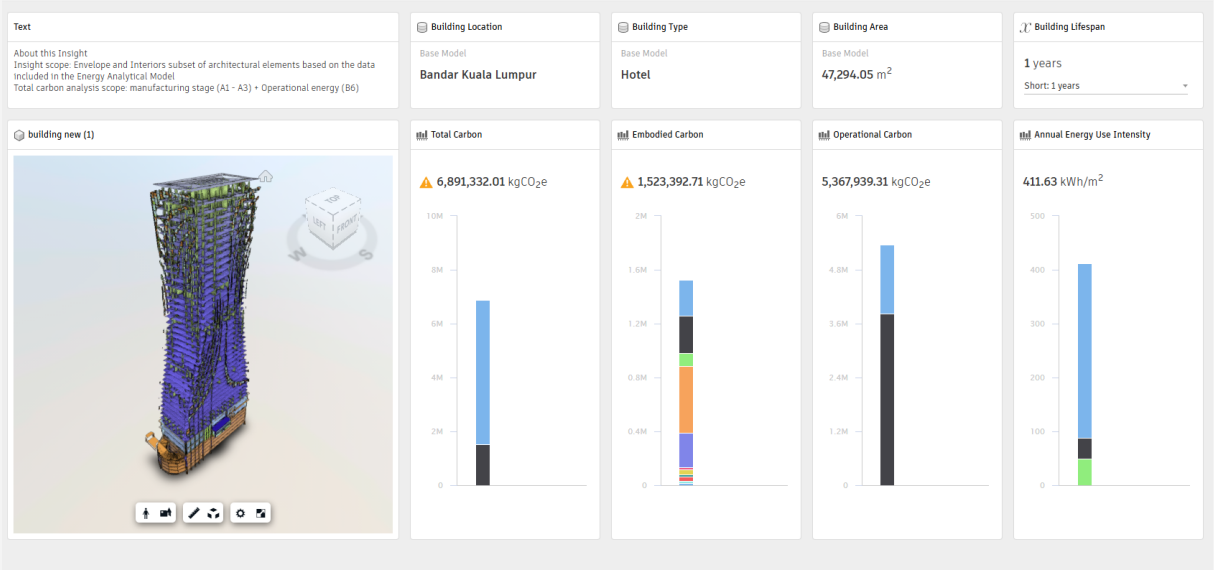
Figure 35: Curtain wall typical atrium (left) and main entry (right)

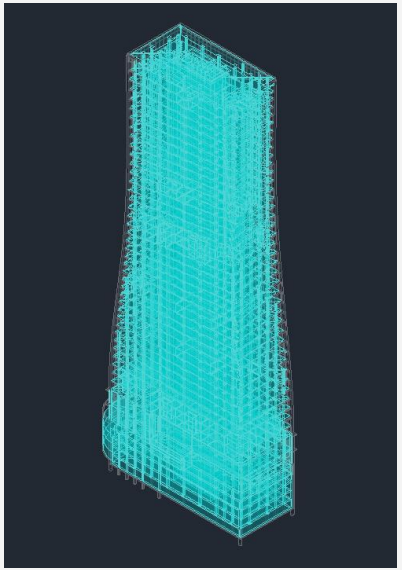
Figure 25b: Variations on "smooth" schemes with castings

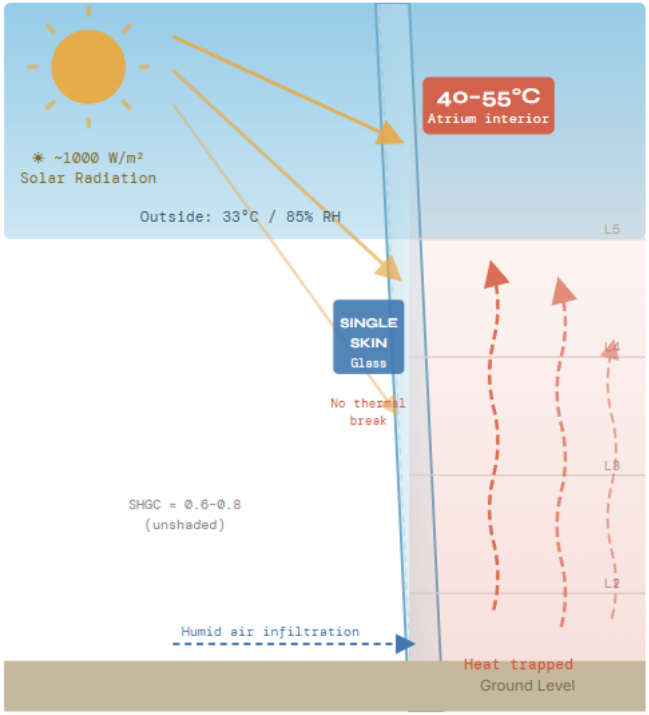
EUI Base = 411 kwh/m2/year using curtain wall facade

<u>Target = <120 kwh/m2/year</u>



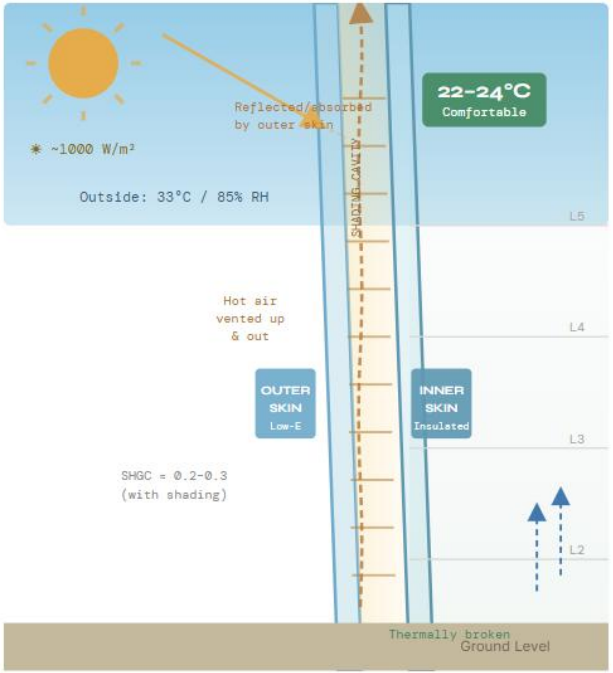






Solar radiation Trapped heat

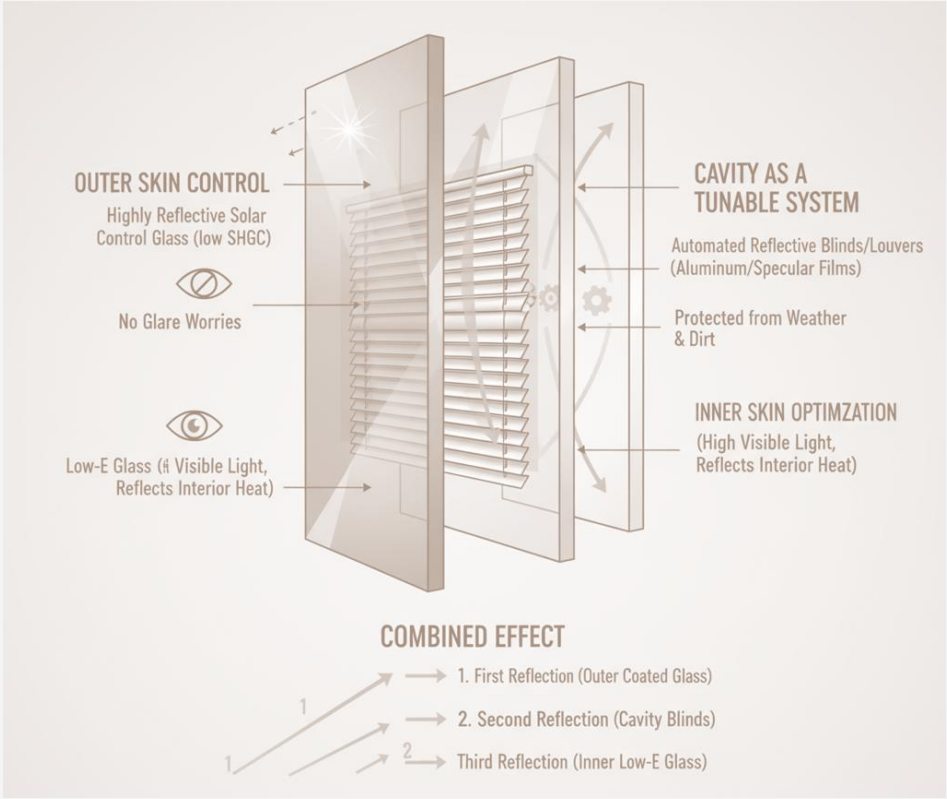
Humid air infiltration

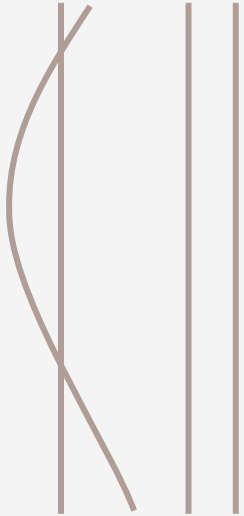


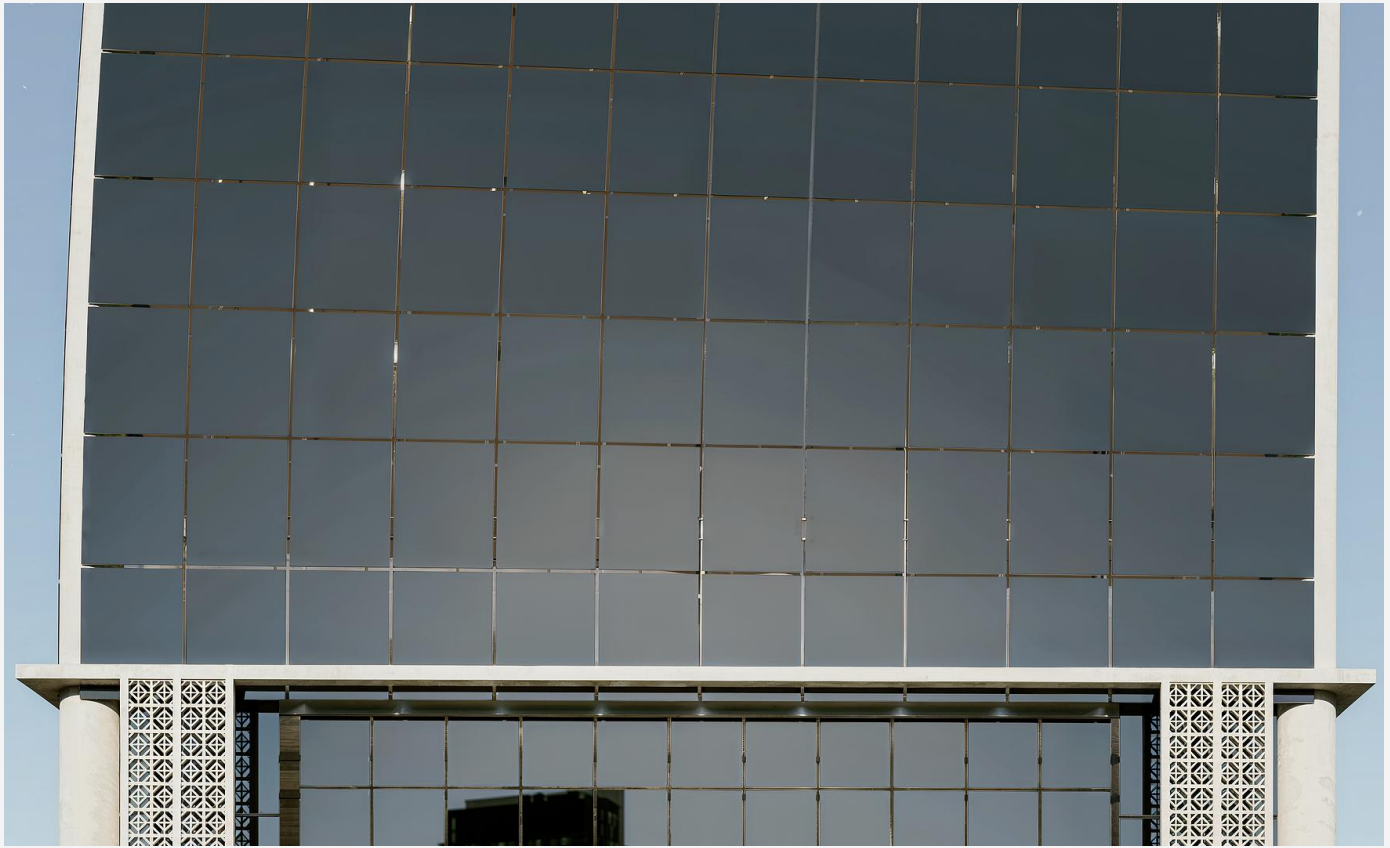
Solar radiation (blocked)

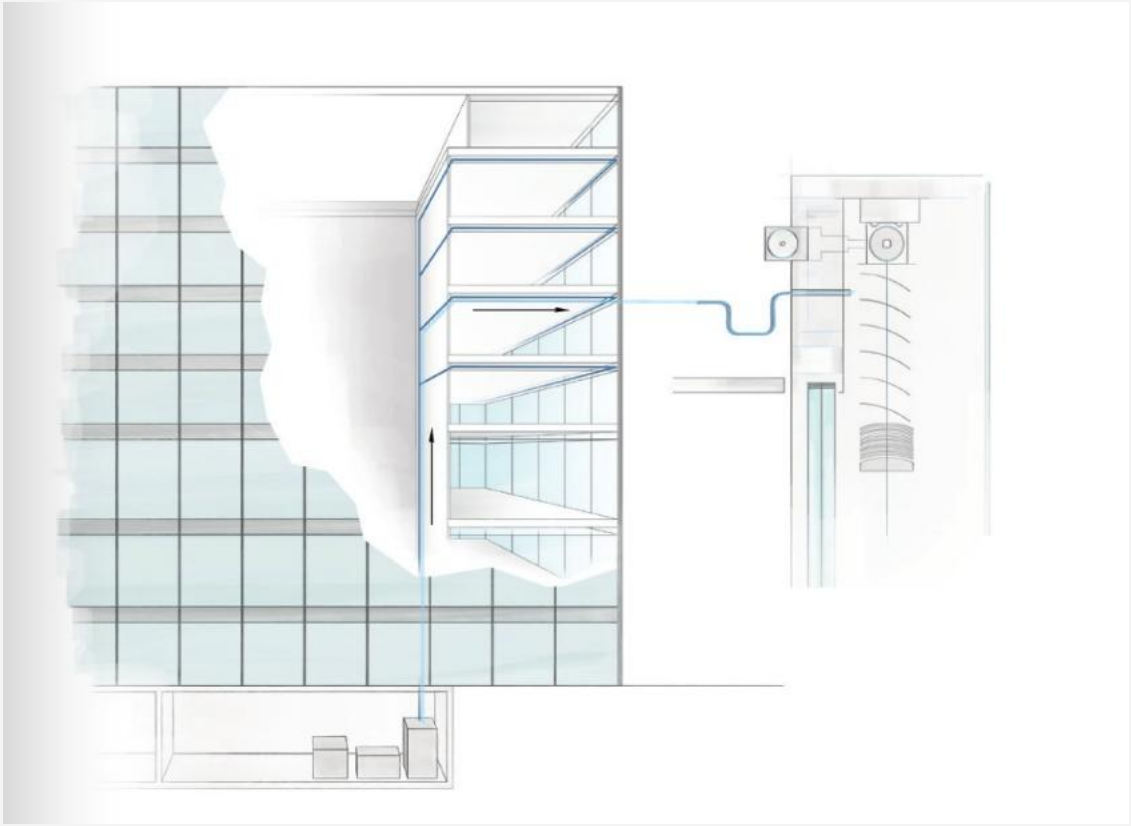
Heat vented from cavity

Conditioned interior air

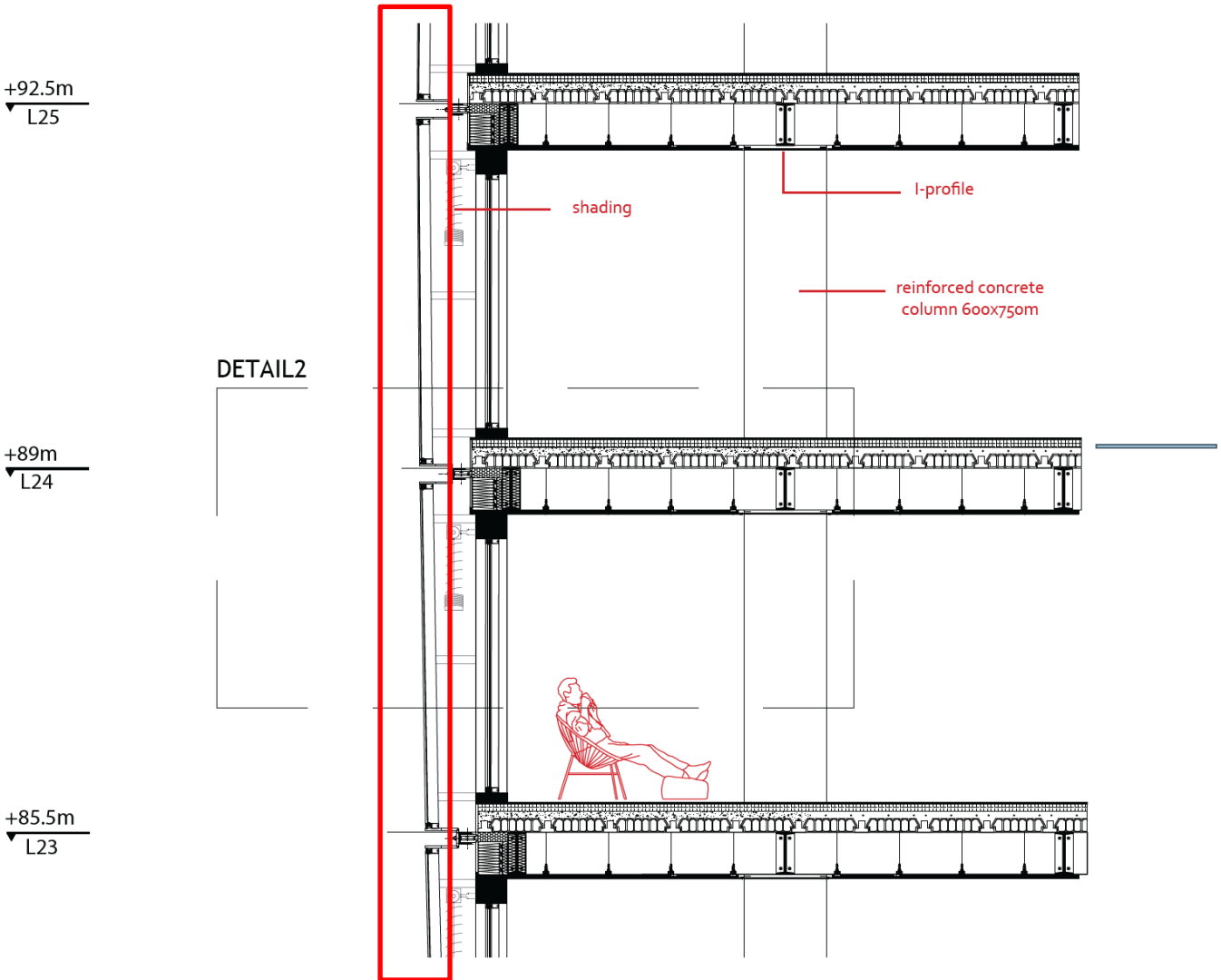

OUTER SKIN CONTROL
Highly Reflective Solar Control Glass (low SHGC)
No Glare Worries
Low-E Glass (↑ Visible Light, Reflects Interior Heat)
CAVITY AS A TUNABLE SYSTEM
Automated Reflective Blinds/Louvers (Aluminum/Specular Films)
Protected from Weather & Dirt
INNER SKIN OPTIMZATION
(High Visible Light, Reflects Interior Heat)
COMBINED EFFECT
1
2
1. First Reflection (Outer Coated Glass)
2. Second Reflection (Cavity Blinds)
Third Reflection (Inner Low-E Glass)

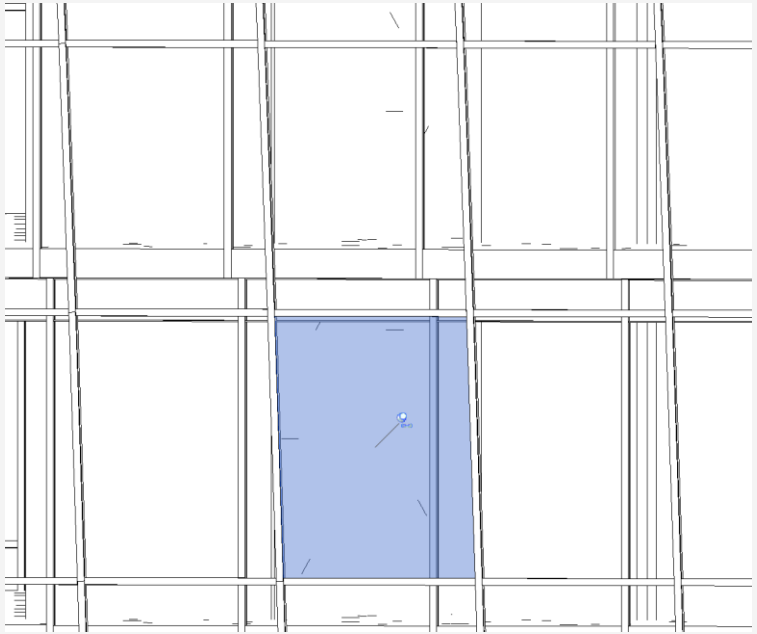


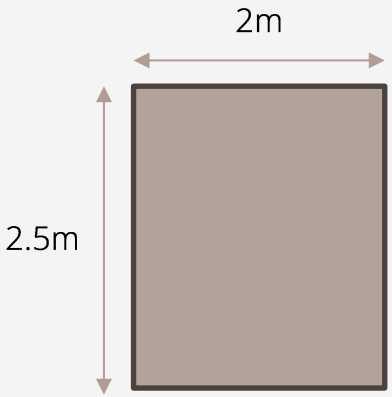


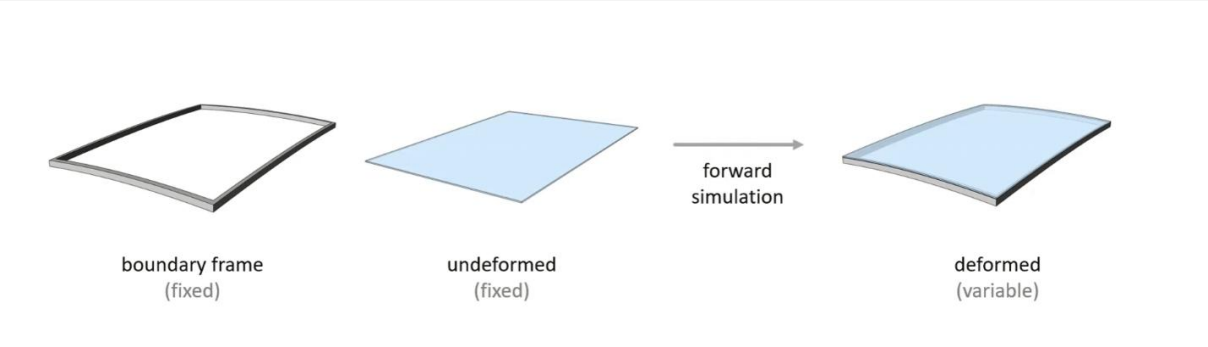


1. Draws in ambient air on mech. floors
2. Distributes this air-conditioned air through the network of pipes
3. Maintains positive pressure inside the cavity so no outside moisture or dirt can enter
4. Monitors and controls the environment continuously


+92.5m
L25
+89m
L24
+85.5m
L23
DETAIL2
shading
I-profile
reinforced concrete
column 600x750m



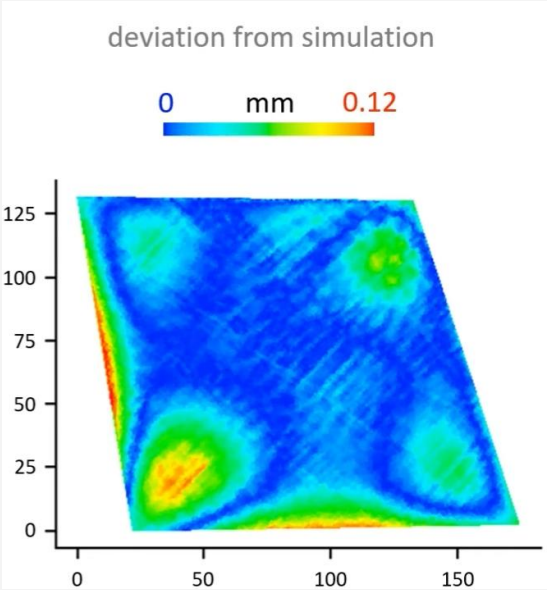

2m
2.5m



start flat

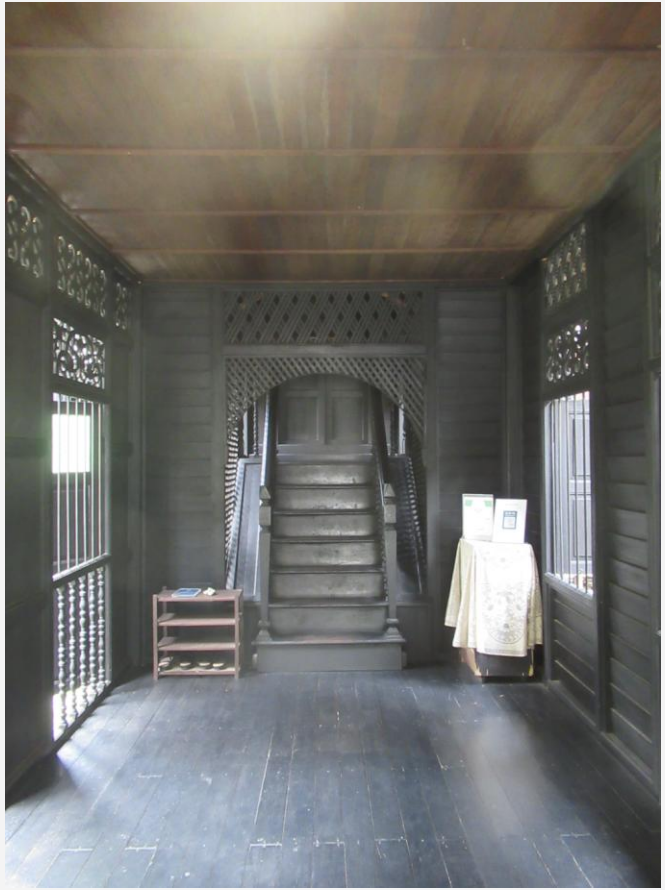
bend on site

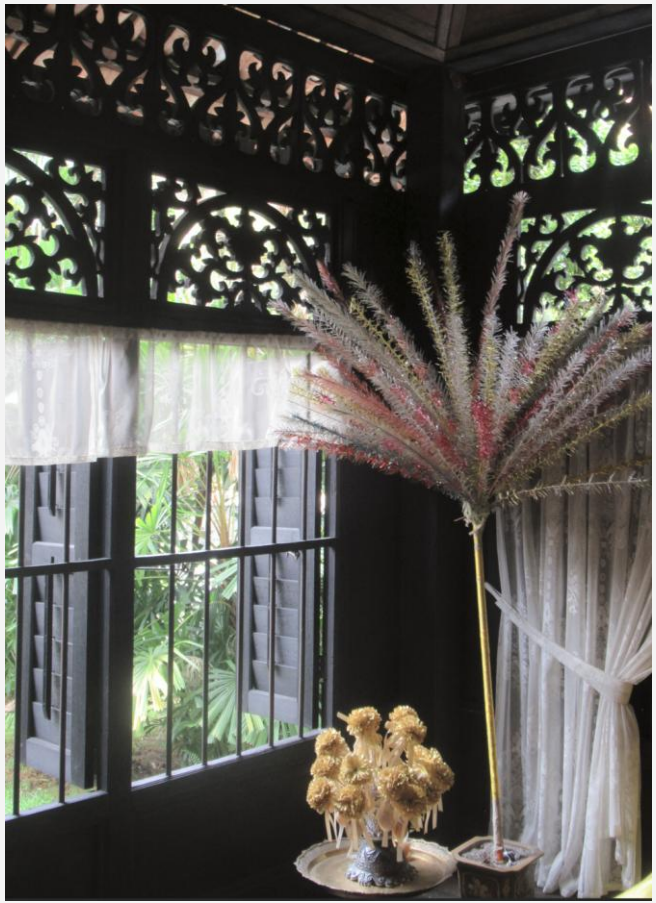
lock in place

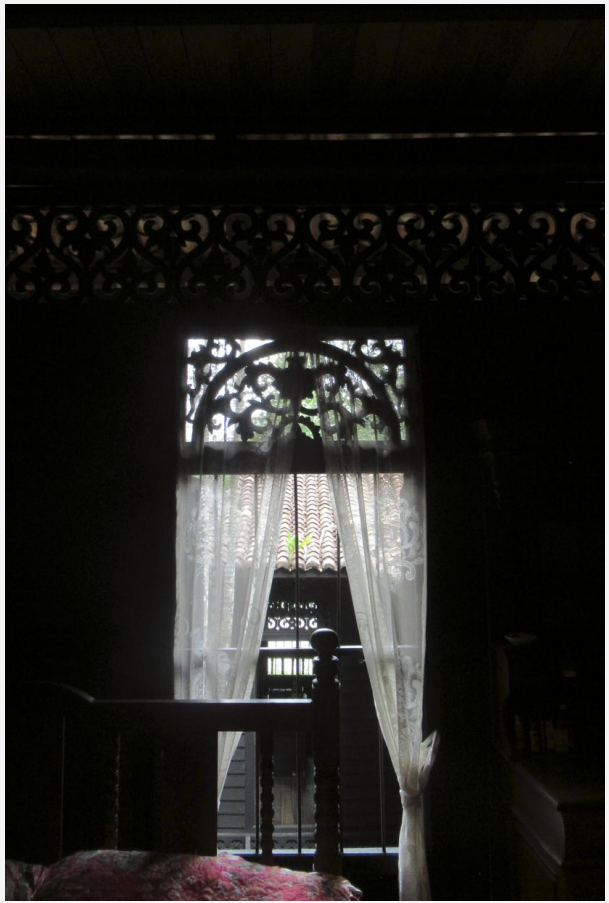


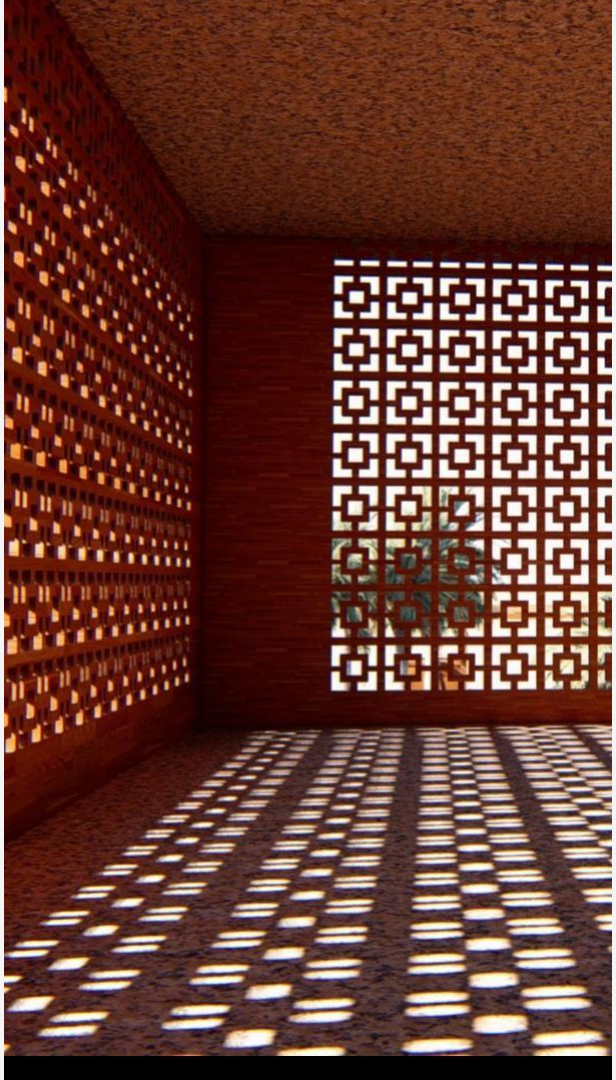
The cultural component

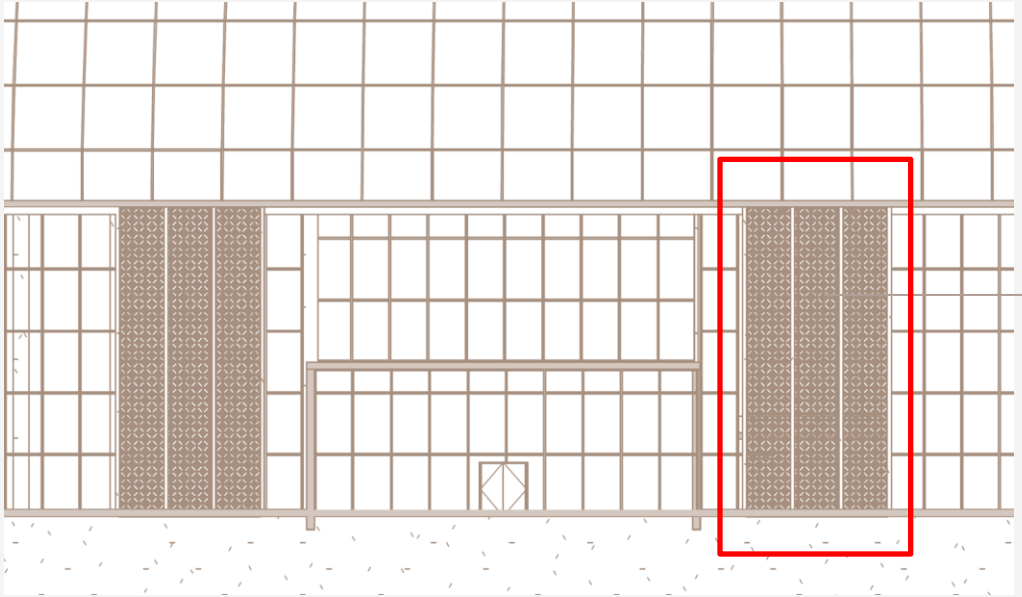

AIA

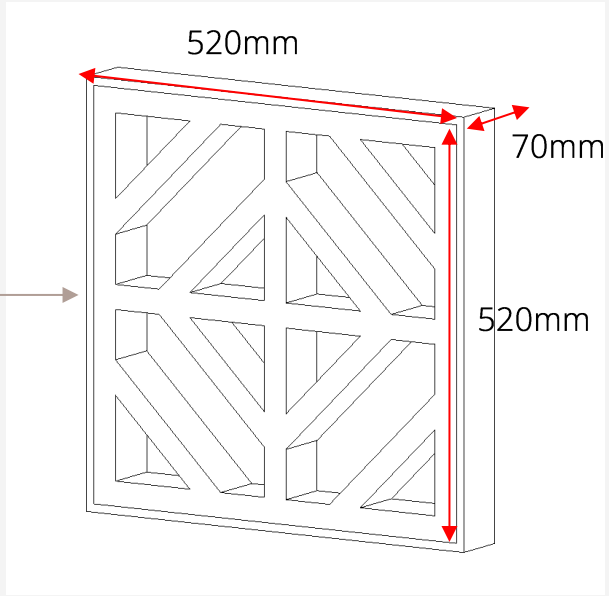


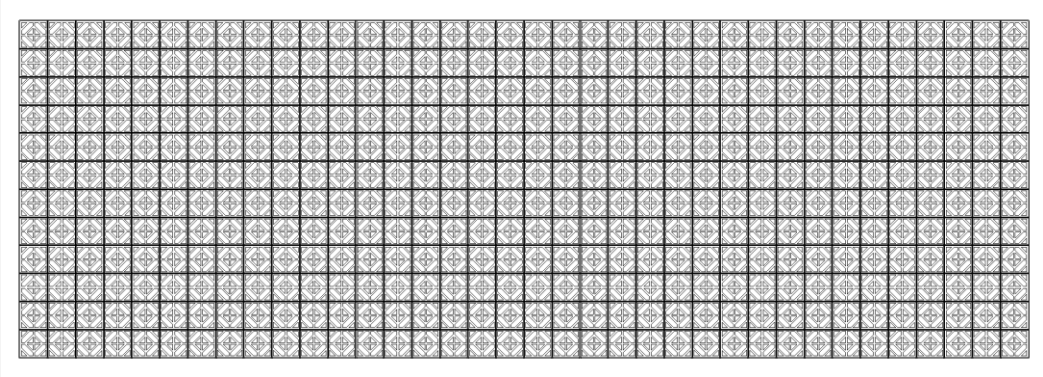




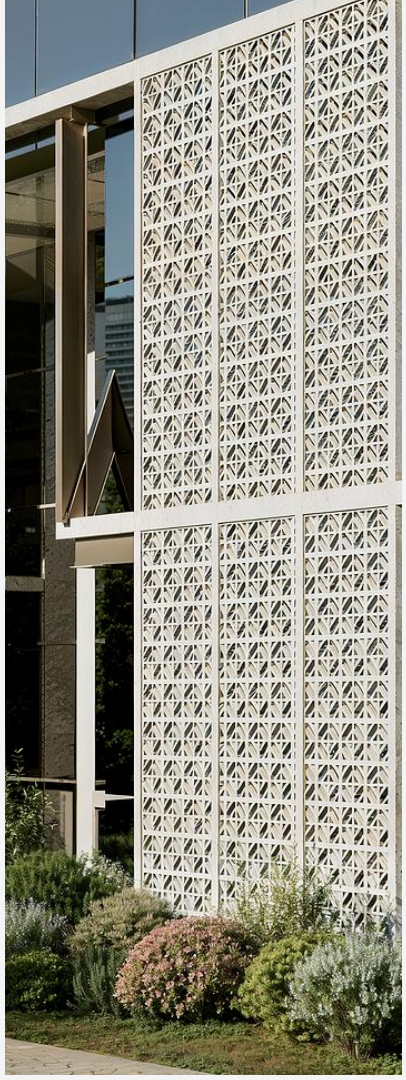




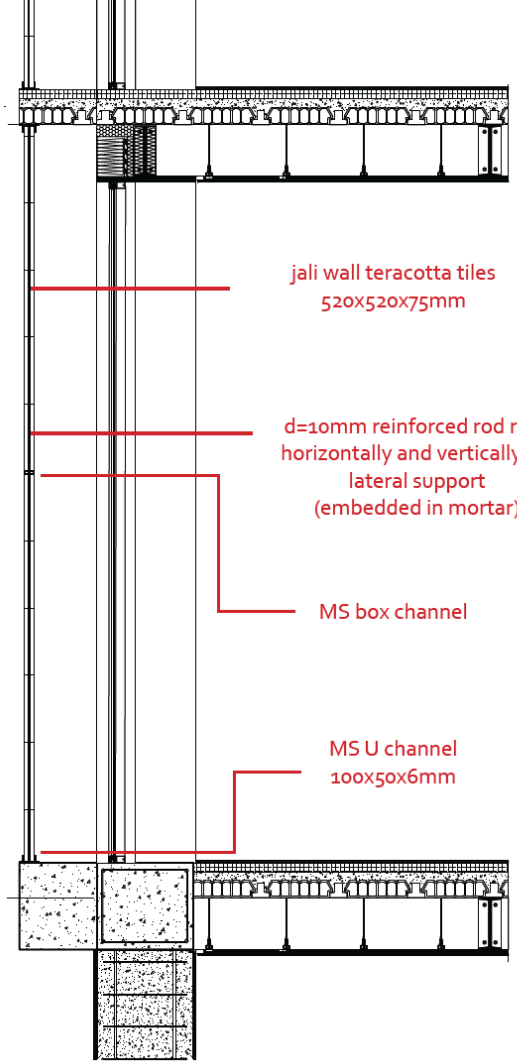

520mm
70mm
520mm



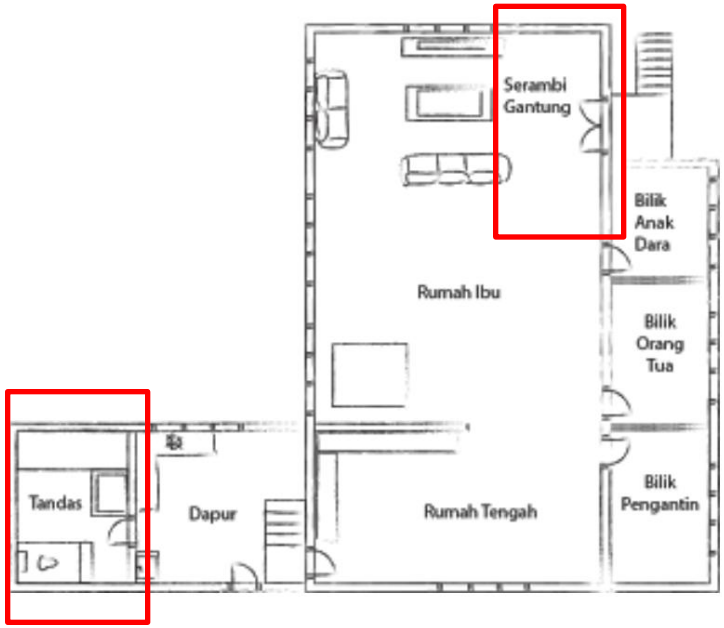
white terracotta = breathable, durable, naturally regulates moisture, can be formed into modular blocks



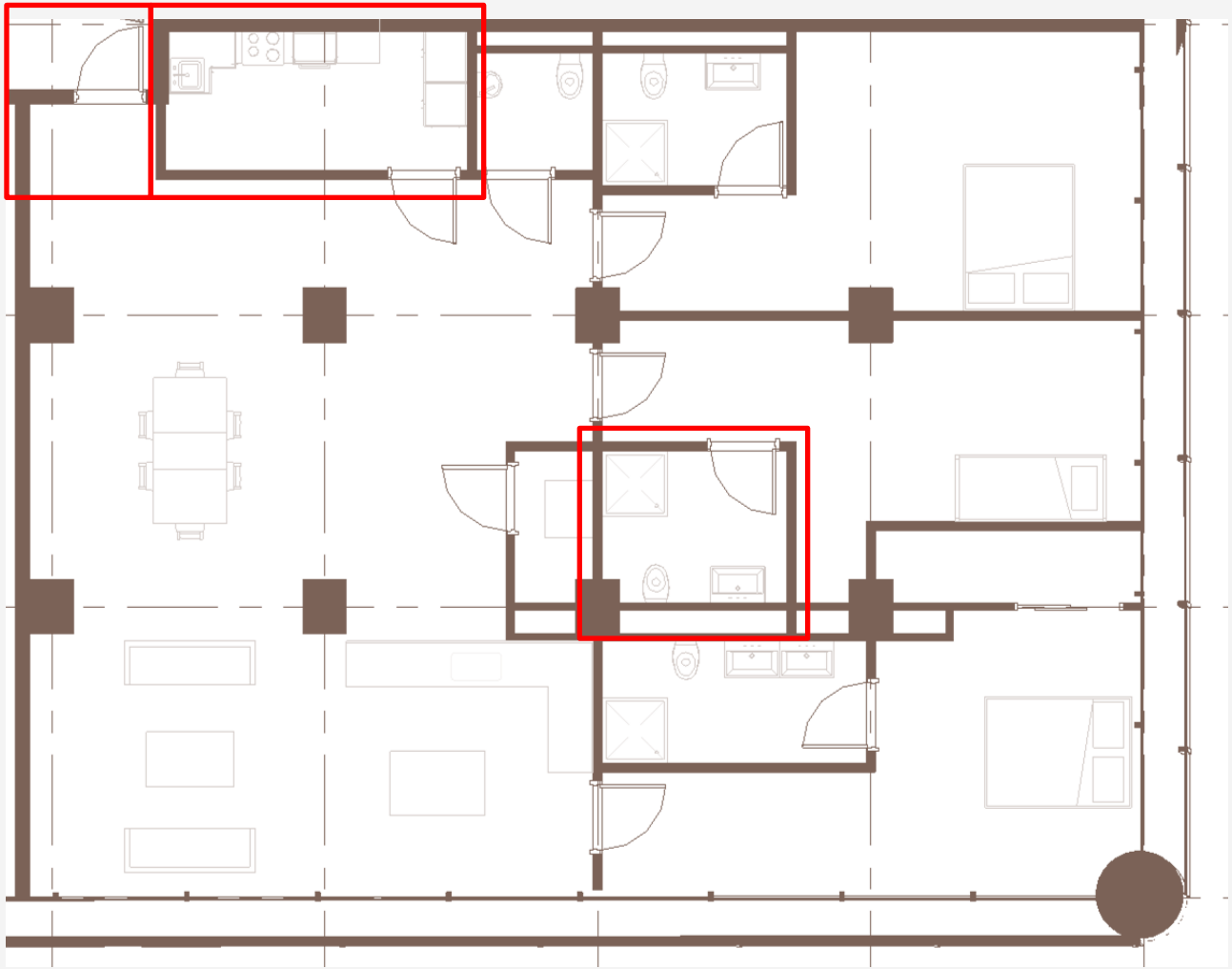
+6m
L1

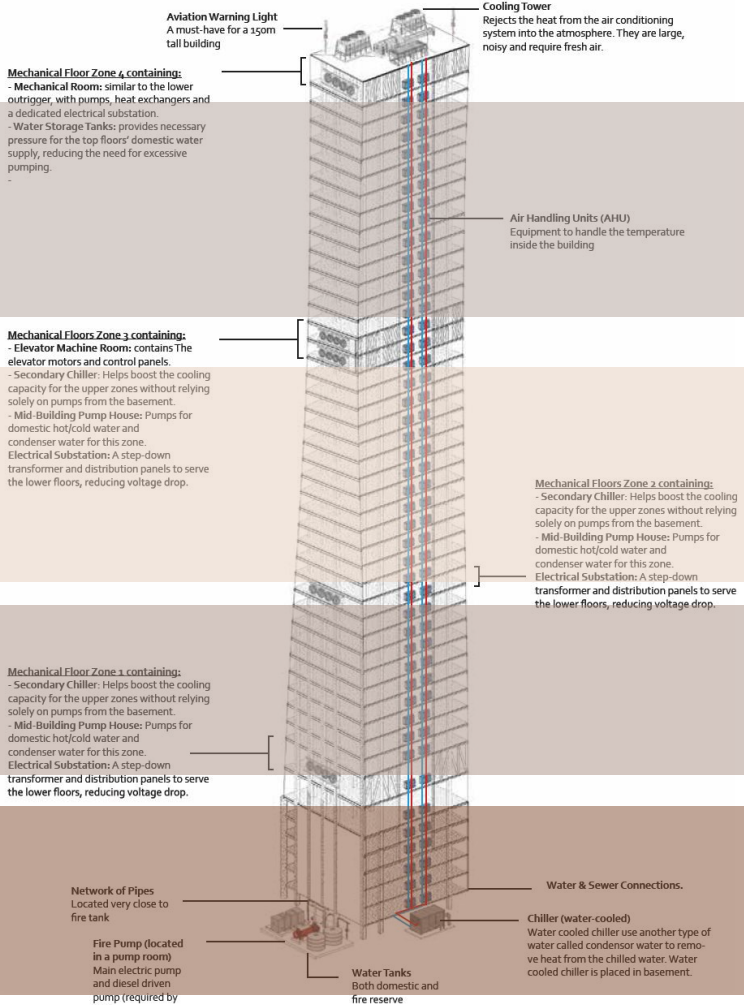

jali wall teracotta tiles
520x520x75mm
d=10mm reinforced rod runs horizontally and vertically for lateral support
(embedded in mortar)
MS box channel
MS U channel
100x50x6mm

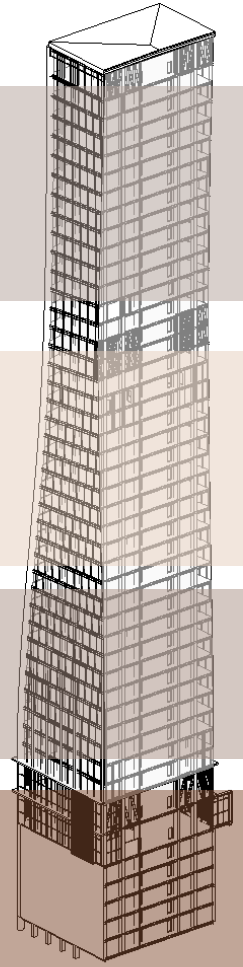
0
GF

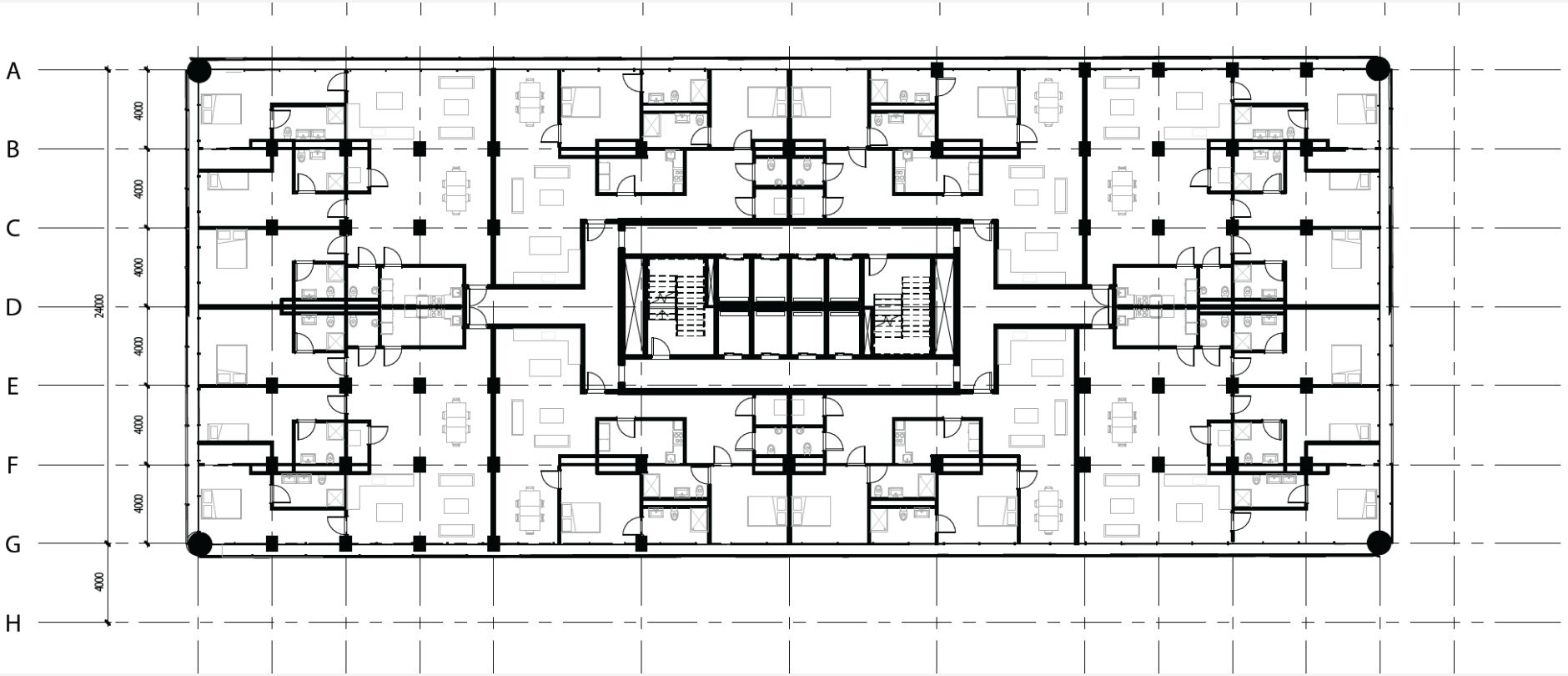


Floor plan of traditional Malay House (Lim et al, 2013)




Aviation Warning Light
A must-have for a 150m tall building
Cooling Tower
Rejects the heat from the air conditioning system into the atmosphere. They are large, noisy and require fresh air.
Mechanical Floor Zone 4 containing:
- Mechanical Room: similar to the lower outrigger, with pumps, heat exchangers and a dedicated electrical substation.
- Water Storage Tanks: provides necessary pressure for the top floors' domestic water supply, reducing the need for excessive pumping.
-
Air Handling Units (AHU)
Equipment to handle the temperature inside the building
Mechanical Floors Zone 3 containing:
- Elevator Machine Room: contains The elevator motors and control panels.
- Secondary Chiller: Helps boost the cooling capacity for the upper zones without relying solely on pumps from the basement.
- Mid-Building Pump House: Pumps for domestic hot/cold water and condenser water for this zone.
Electrical Substation: A step-down transformer and distribution panels to serve the lower floors, reducing voltage drop.
Mechanical Floors Zone 2 containing:
- Secondary Chiller: Helps boost the cooling capacity for the upper zones without relying solely on pumps from the basement.
- Mid-Building Pump House: Pumps for domestic hot/cold water and condenser water for this zone.
Electrical Substation: A step-down transformer and distribution panels to serve the lower floors, reducing voltage drop.
Mechanical Floor Zone 1 containing:
- Secondary Chiller: Helps boost the cooling capacity for the upper zones without relying solely on pumps from the basement.
- Mid-Building Pump House: Pumps for domestic hot/cold water and condenser water for this zone.
Electrical Substation: A step-down transformer and distribution panels to serve the lower floors, reducing voltage drop.
Network of Pipes
Located very close to fire tank
Water & Sewer Connections.
Chiller (water-cooled)
Water cooled chiller use another type of water called condensor water to remo-ve heat from the chilled water. Water cooled chiller is placed in basement.
Fire Pump (located in a pump room)
Main electric pump and diesel driven pump (required by law)
Water Tanks
Both domestic and fire reserve

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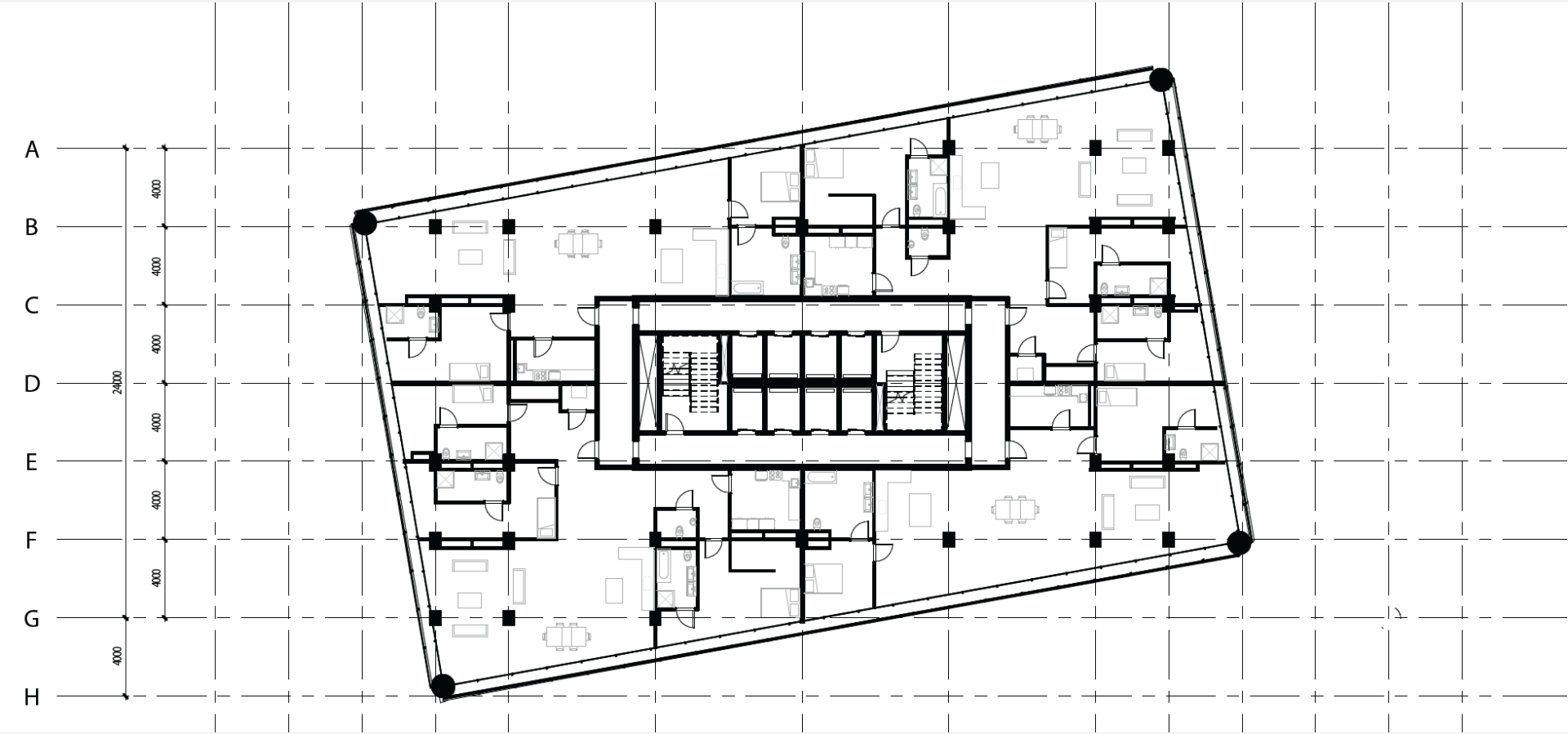
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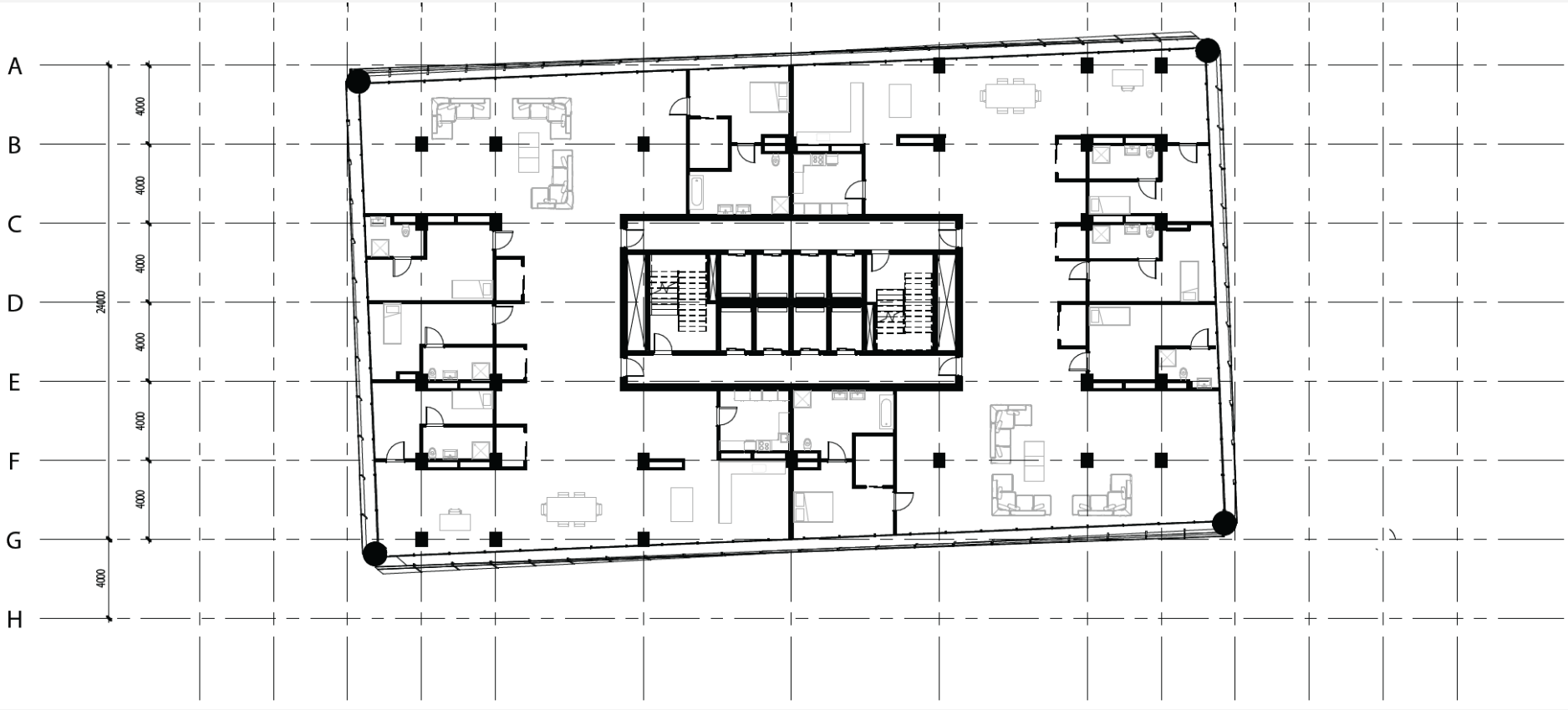
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Knowledge Gap

Despite the availability of computational tools, their integration into tropical architectural design is limited.

The knowledge gap can be verified by dr. Zaki (JKR) stating:

1. They don’t have staff with the right expertise or licenses,
2. There isn’t enough time to train people because of the steep learning curve
3. They lack the budget to expand the team.

Future research

1. Test all principles and derive rule of thumb per principle
2. Expand the framework