Air Flow Assisting Systems in Hot-Humid Urban Context

New Chautauqua Institute // Singapore.

Arch_754 // Performance Design Workshop

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Design Problem

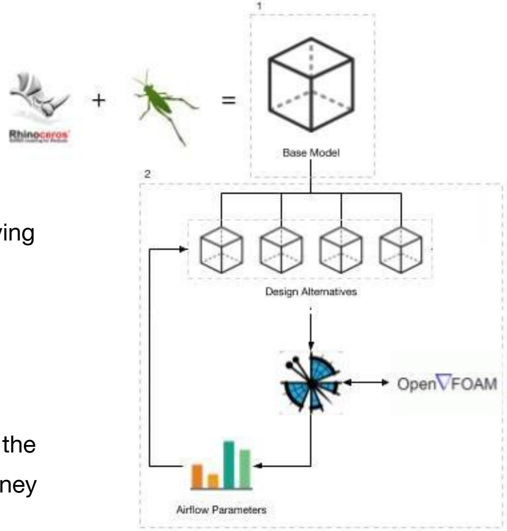
What are we trying to solve? Why is it an interesting problem?

Singapore has a particular climate featuring high dry bulb temperatures (20-35ºC) and high relative humidity (60-100%) constantly throughout the year. This results in high and frequent thermal stress due to heat. Studying previous examples and solutions to fit such a challenging climate brought us to two main solutions: *shading and ventilation*. We ran several iterations with a “shoebox” model in attempts to understanding how different technique made different levels of improvement. The greatest improvement was introducing air movement. According to PMV models, the climate is simply unbearable. However, when viewing through the Adaptive Comfort “lens”, we find that it is possible to achieve high comfort levels throughout the year (mainly thanks to ventilation). It is not only a technical but a cultural challenge.

Although it is the technique with the most leverage in this climate, natural ventilation is quite difficult to model, predict and even achieve. Designing mid-high rise buildings with natural ventilation in mind is challenging, especially in urban contexts. This is because of wind shadows all around the city, as well as other buildings slowing down the predominant winds. Because of that, we must look for systems that will passively (or else) aid in air movement for both supplying and distributing air throughout our building.

Analytical Approach

Looking for case studies and different techniques used to aid in natural ventilation, we found solar chimneys. The principle is to heat up a vertical void that will provide continuous and uniform circulation of air along with minimum speed using thermal buoyancy and pressure difference. While our site is not too exposed to direct radiation (Singapore has high sky coverage), we must look for different solutions. For example, stacking up all mechanical systems (such as outdoor side splits) that eject heat, can serve to create a sort of "Thermal Chimney". We also added atria in the building to provide fresh air to circulation spaces and those rooms which are not having any share of the external wall or the breathing facade.



Our different alternatives to study are as follow:

1. On site air flow – Considering major wind directions
2. Diagonal Atria with various openings – In a completely conditioned building
3. Wind driven ventilation in a naturally ventilated building – Stack and cross ventilation as driving strategies
4. Thermal Chimney in a naturally ventilated building – Thermal buoyancy as the driving strategy

The tools we need to use to solve the problem are the following:

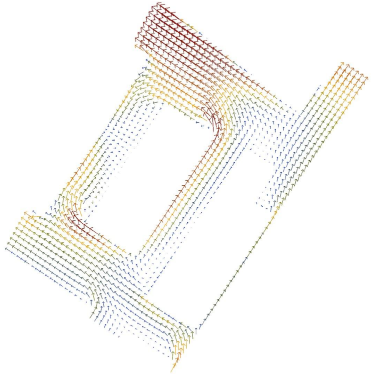
1. CFD - To understand airflow in different conditions. With these results we will be able to size the inlets and outlets in our facade, as well as having a rough estimate of the size of our thermal chimney (and its supporting systems).

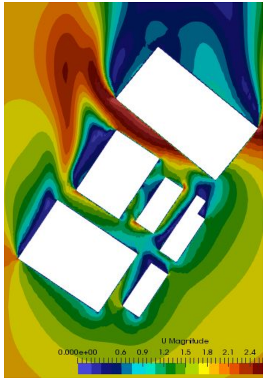
STAGE 1

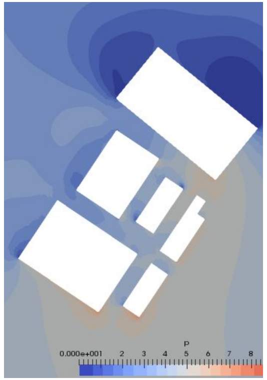
On site air flow – Considering major wind directions

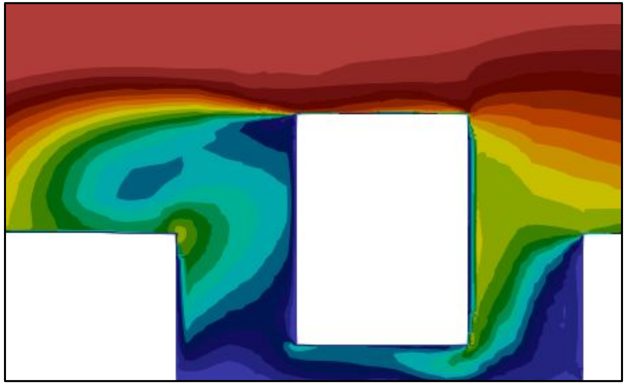
Wind directions and speeds are considered as per Green Mark standards

2.2m/s

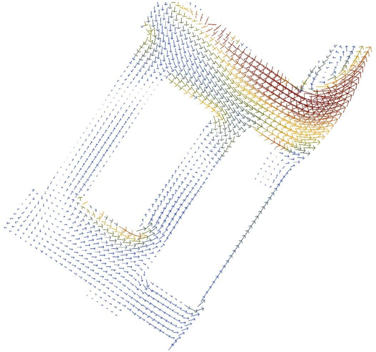


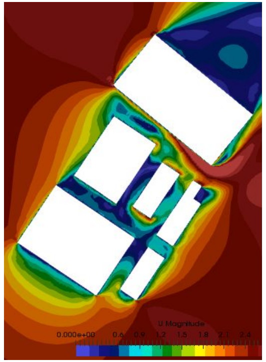


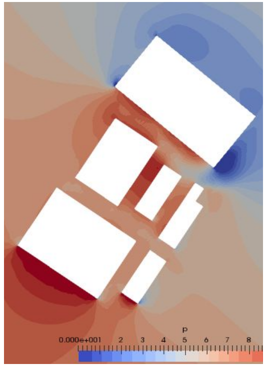


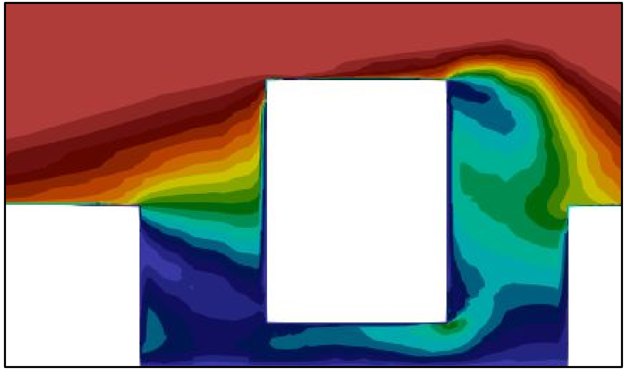


2.8m/s



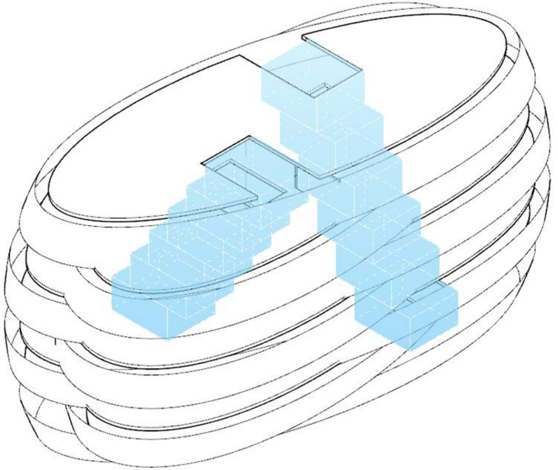






Atria

(Wind driven)



OR

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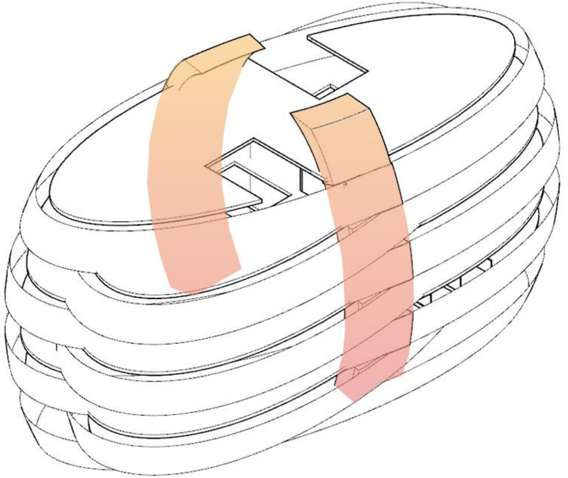
Thermal Chimney

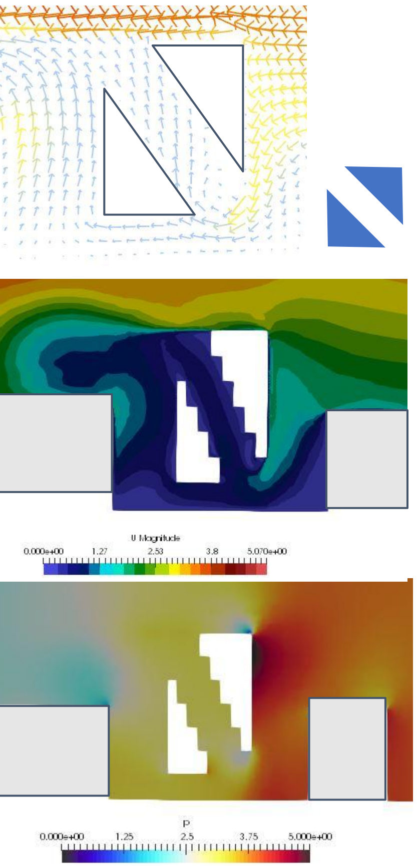
(Thermal Buoyancy driven)



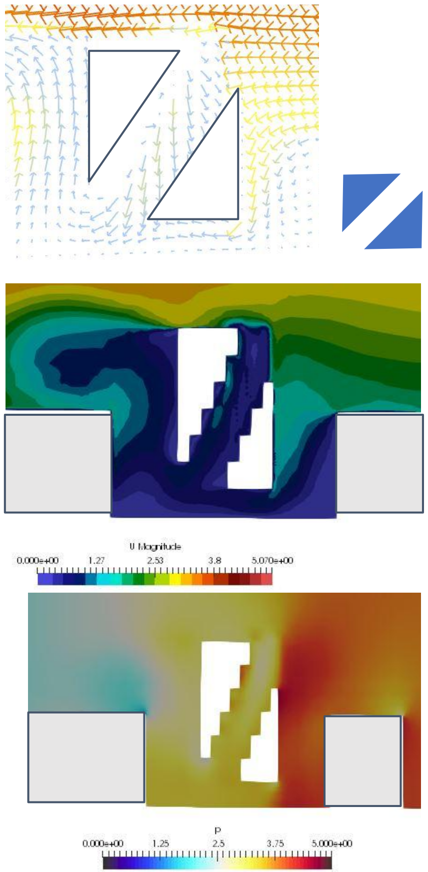
STAGE 2

Diagonal Atria with various openings – In a completely conditioned building

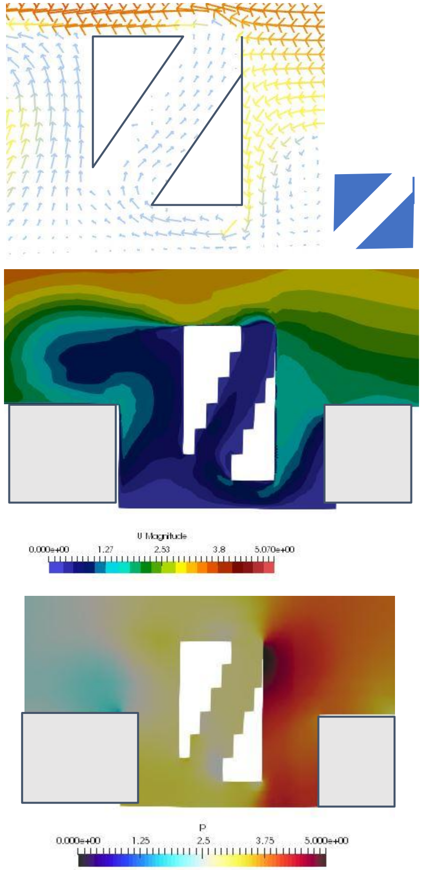
Atrium 1



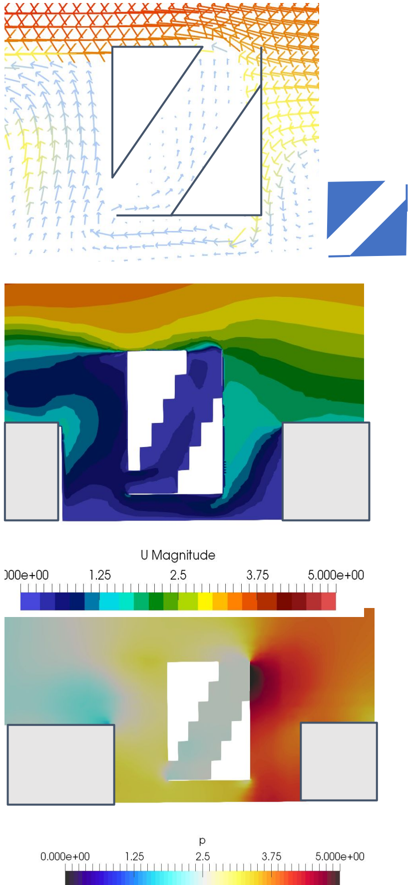
Atrium 2 (Reverse)



Atrium 2 (Top Outlet single side open)



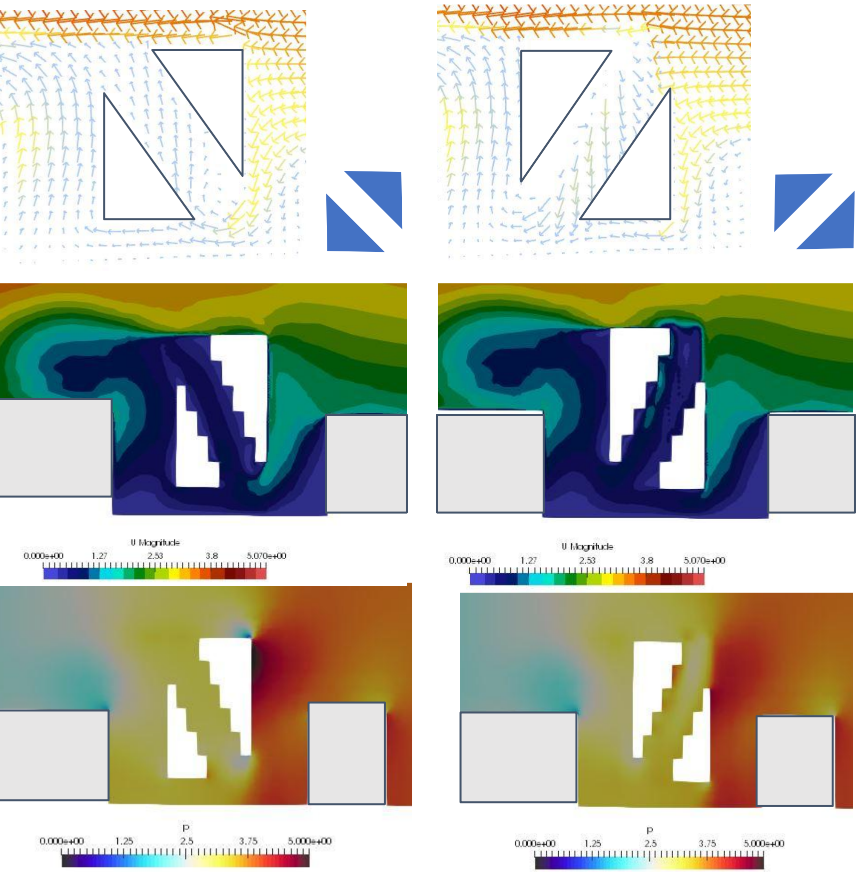
Atrium 2 (Top & Bottom Outlet single side open)



STAGE 2

Diagonal Atria with various openings – In a completely conditioned building

Atrium 1 Atrium 2 (Reverse)



Observations:

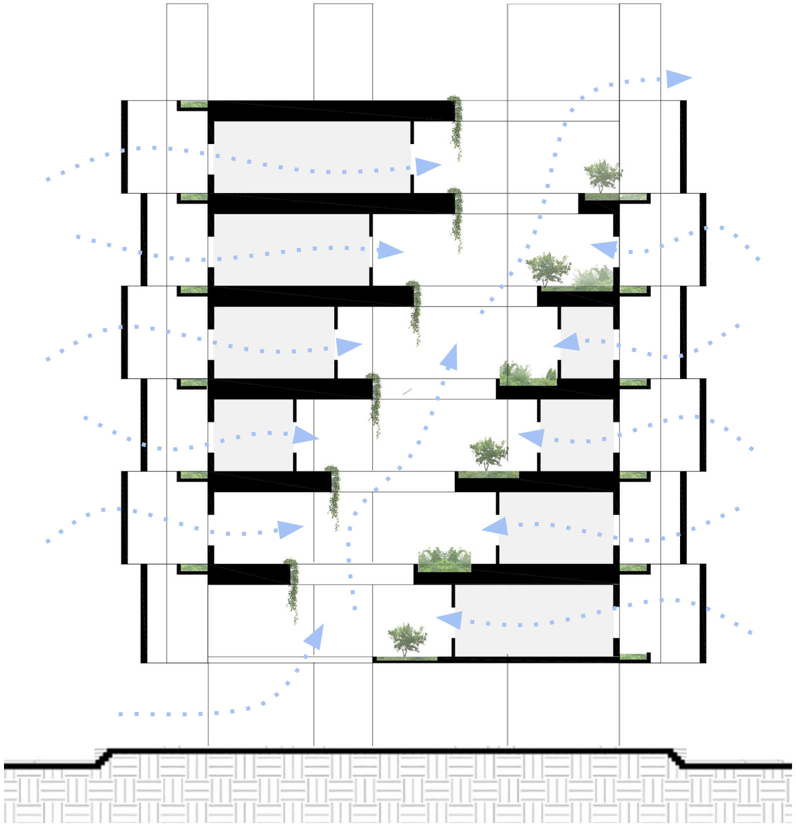
The reversal in the direction of diagonal atrium might also reverse the direction of wind flow, which made us think about having 2 atria with opposite diagonal profiles

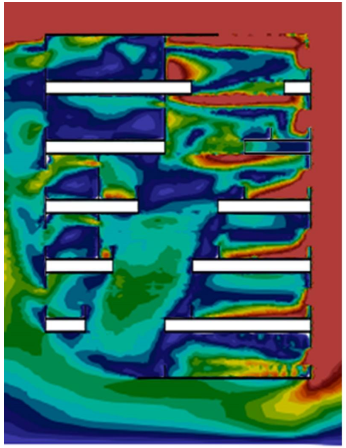
From this study it is visible that atria with maximum opening size have airflow at a greater speed

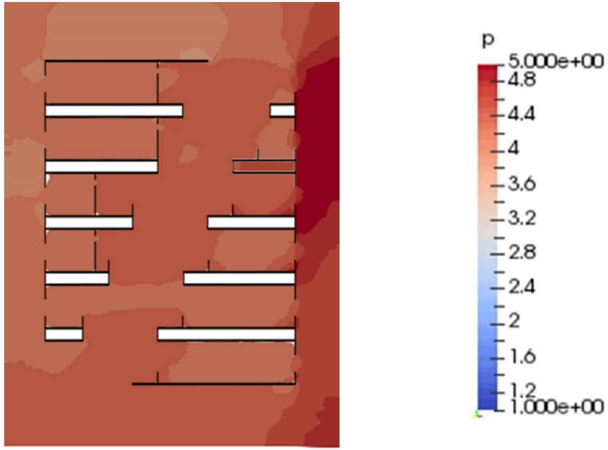
STAGE 3

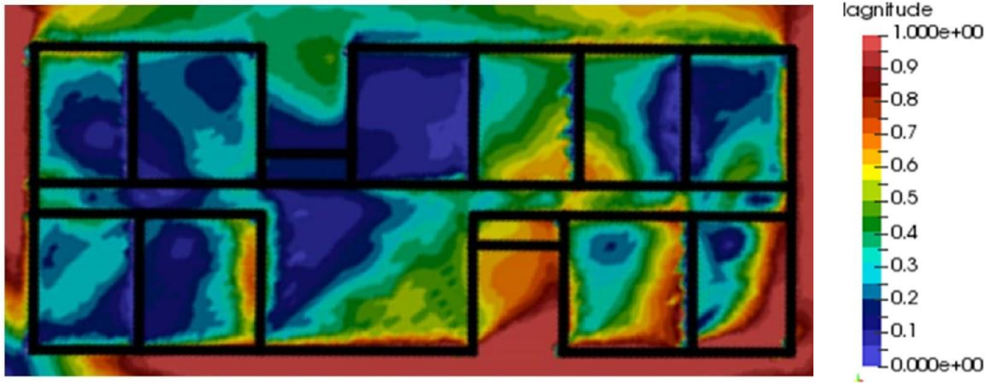
Wind driven ventilation in a naturally ventilated building

– Stack and cross ventilation as driving strategies





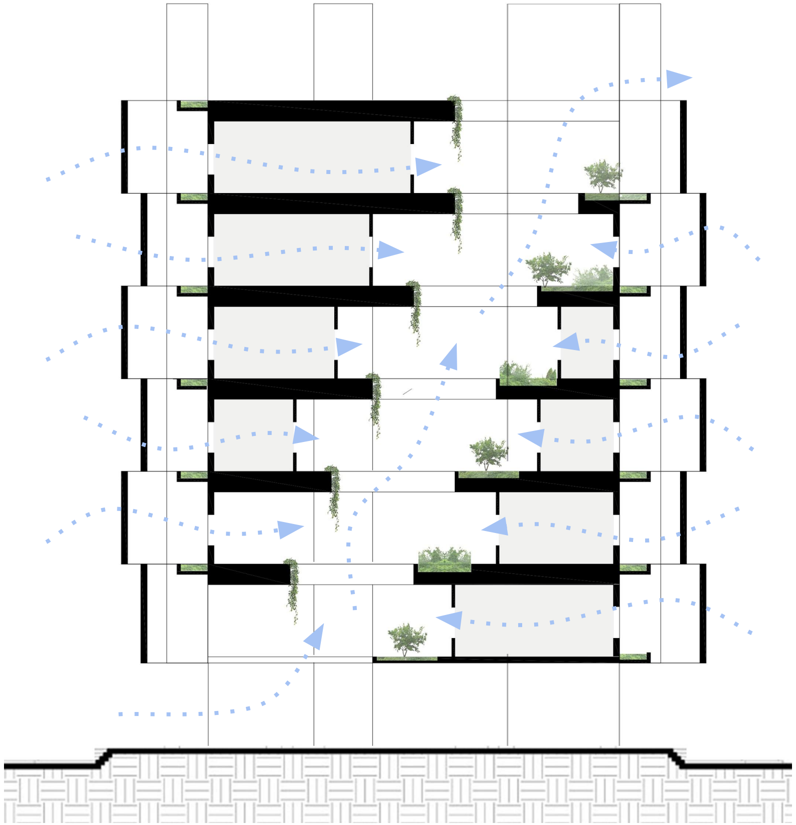




STAGE 3

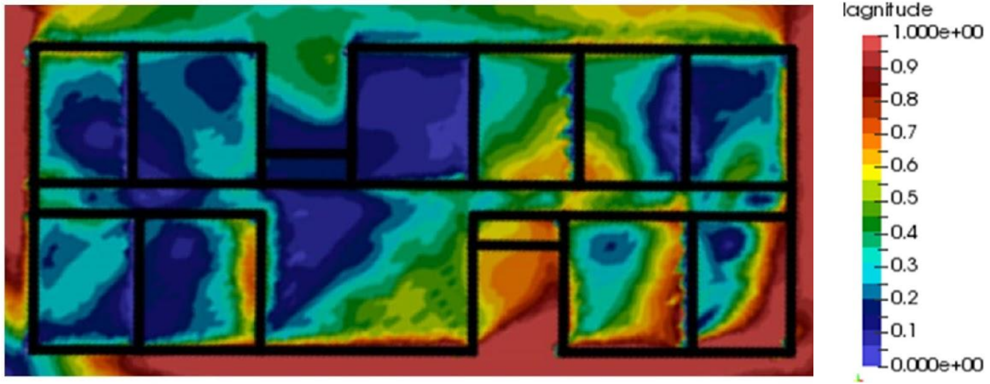
Wind driven ventilation in a naturally ventilated building

– Stack and cross ventilation as driving strategies



Observations:

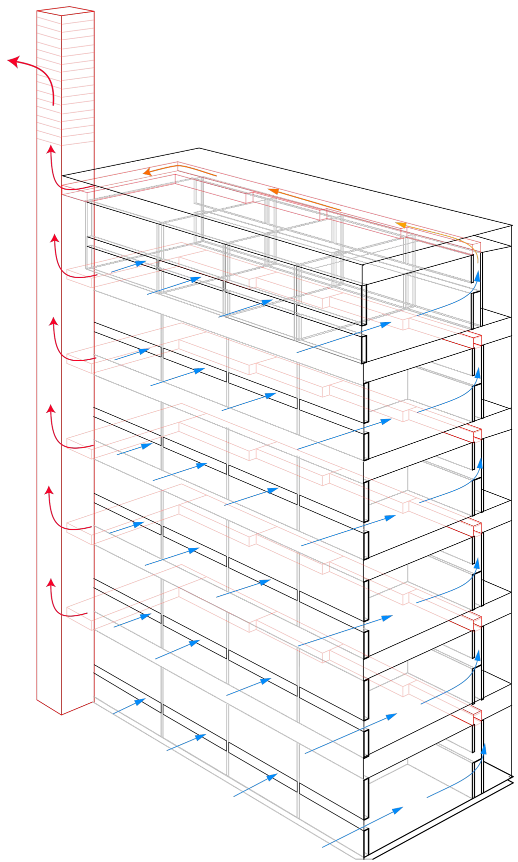
The non-uniform air-flow inside the spaces and low air velocities clearly show that wind driven ventilation can not be a solution ventilation in a climate and dense urban context like Singapore



STAGE 4

Thermal Chimney in a naturally ventilated building

– Thermal buoyancy as the driving strategy



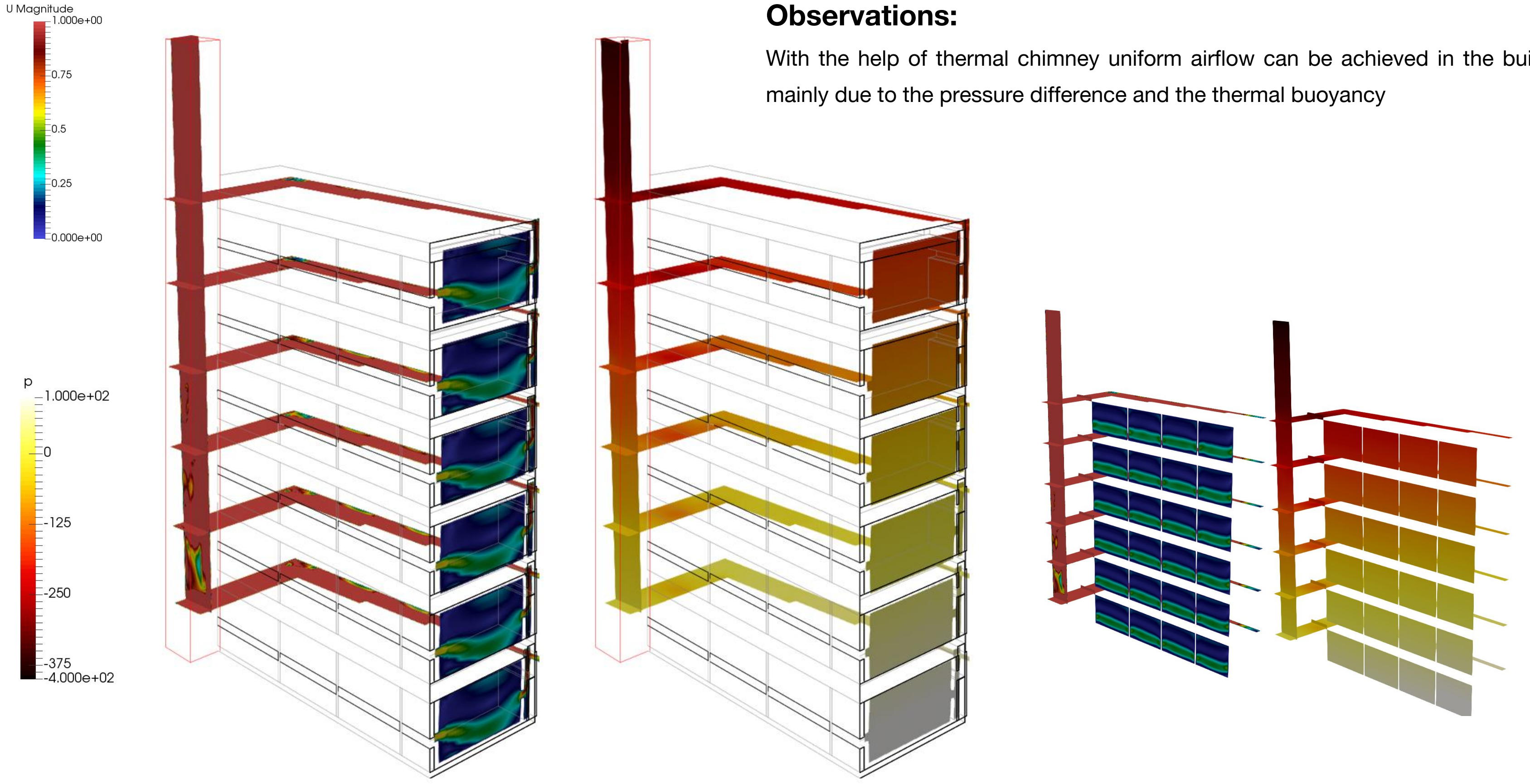
Prototype Model

This model is 1/4th the size of our building

STAGE 4

Thermal Chimney in a naturally ventilated building

– Thermal buoyancy as the driving strategy



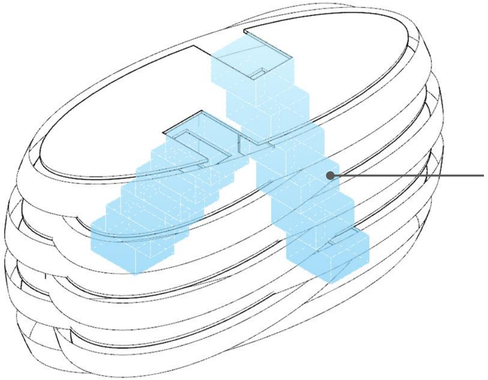
Observations:

With the help of thermal chimney uniform airflow can be achieved in the building mainly due to the pressure difference and the thermal buoyancy

Final Strategy

Atria

To deliver air to interior spaces and permit cross ventilation throughout, we added two diagonal atria.

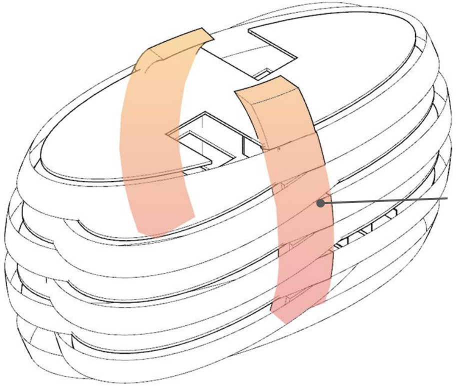


Subset Spaces:

Activity Rooms
Gymnasium
Conference Rooms
Open Space /
Circulation (All Floors)

Thermal Chimney

Due to the variability of local winds, and a dense urban context, accounting for natural wind-driven ventilation is not possible. Thermal chimneys will aid with air flow through thermal buoyancy.



Superset Spaces:

Research Offices
Classrooms
Directors Offices
Residences