Effect of Residential Tower Geometries on Urban Wind Environment

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Pedestrian Ventilation Challenges in Hong Kong

- Extremely high density in urban areas has led to a number of urban thermal comfort issues: stagnant wind, air pollution concentration and urban heat island effect

- The study investigates
  - the impacts created by podium type residential developments on pedestrian level air ventilation speed
  - impact from residential tower geometries on urban wind environment

Research design

Correlation between building typologies & pedestrian wind performance

Correlation between design modifications to podium developments & pedestrian wind performance

Correlation between building geometries & urban wind performance

Development of 3D digital urban models for Tsuen Wan

Development of historic wind profiles based on air ventilation simulation platform ANSYS Fluent

Wind profiles: 1960 – 2015 ten year interval study

Wind profiles: 1997- 2015 three year interval study

Onsite measurements for simulation results verification & setting parameters

Factory estate A
Factory estate B

Methodology

- Establishment of cell resolution appropriate for city scale AVA study adhering to AVA guidelines
- Verifying results with on-site measurements
- Development of historical wind profiles from 1960-2015
- Correlational analysis of development trends and building typologies on pedestrian wind environment
- Testing impacts from podium & towers residential typology on pedestrian wind
- Testing the influence from voids created on the podium on wind speed
- Testing effects of tower geometries on urban wind speed

Boundary layer conditions

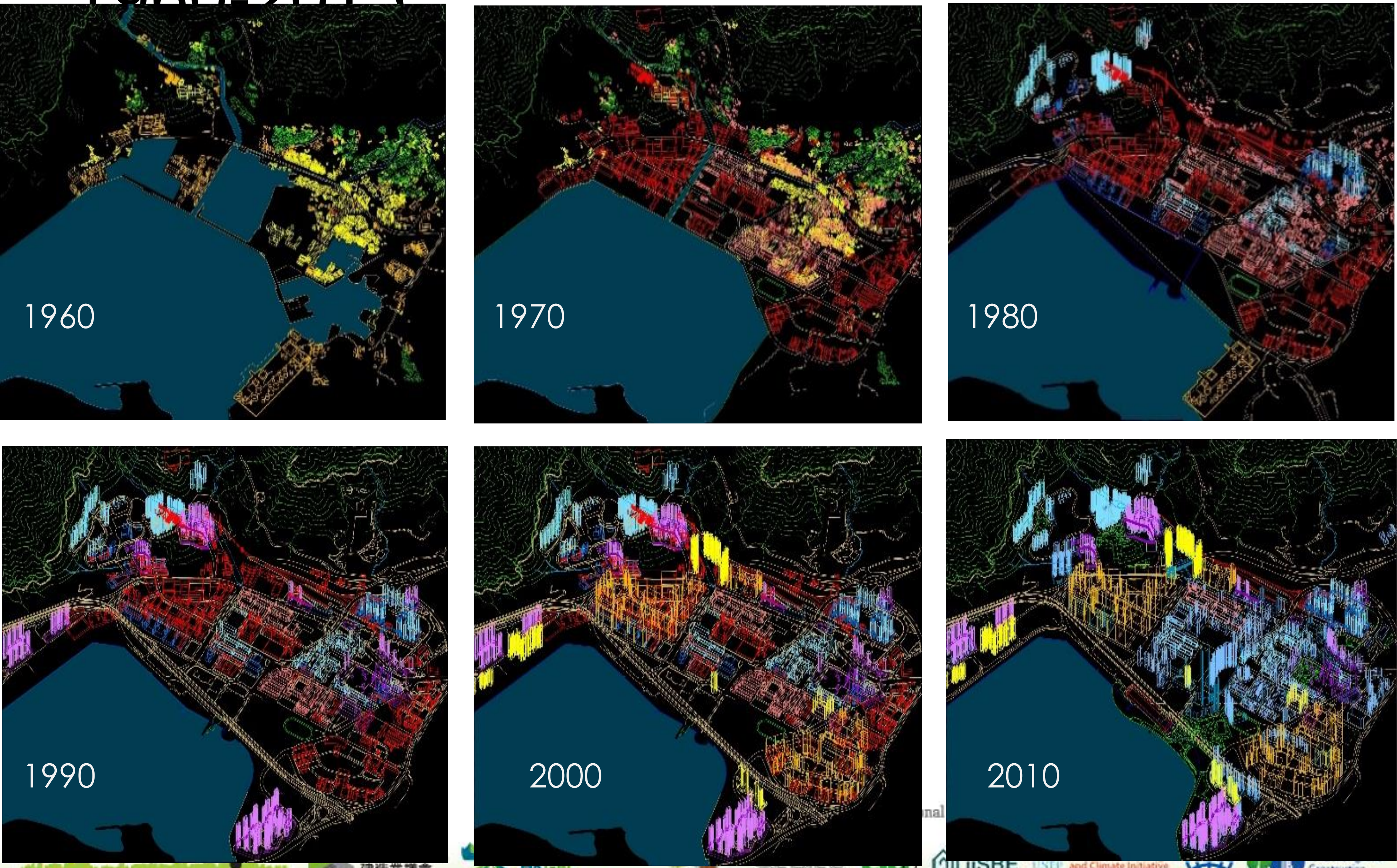
	FLUENT CFD Model
Computational Domain Size	5H inflow buffer and 5H for lateral region
	15H downstream region, 6H in vertical region
Grid Expansion Ratio	At most 1.3 in both horizontal and vertical direction
Prism Layers	4 layers of prism layers with each 0.5m
Boundary Conditions	Symmetric condition for two side boundaries and the ceiling
	Wall boundary condition for the ground and buildings
	Velocity inlet condition for inflow boundaries
	Zero gradient condition for outlet boundary
Turbulence Model	Realizable $k - \varepsilon$ Model
Numerical Scheme	High Order Schemes
Convergence Criteria	Scaled Residuals dropped to below 1×10^{-4} (Casey and Wintergerste, 2000)

Tsuen Wan district now and then

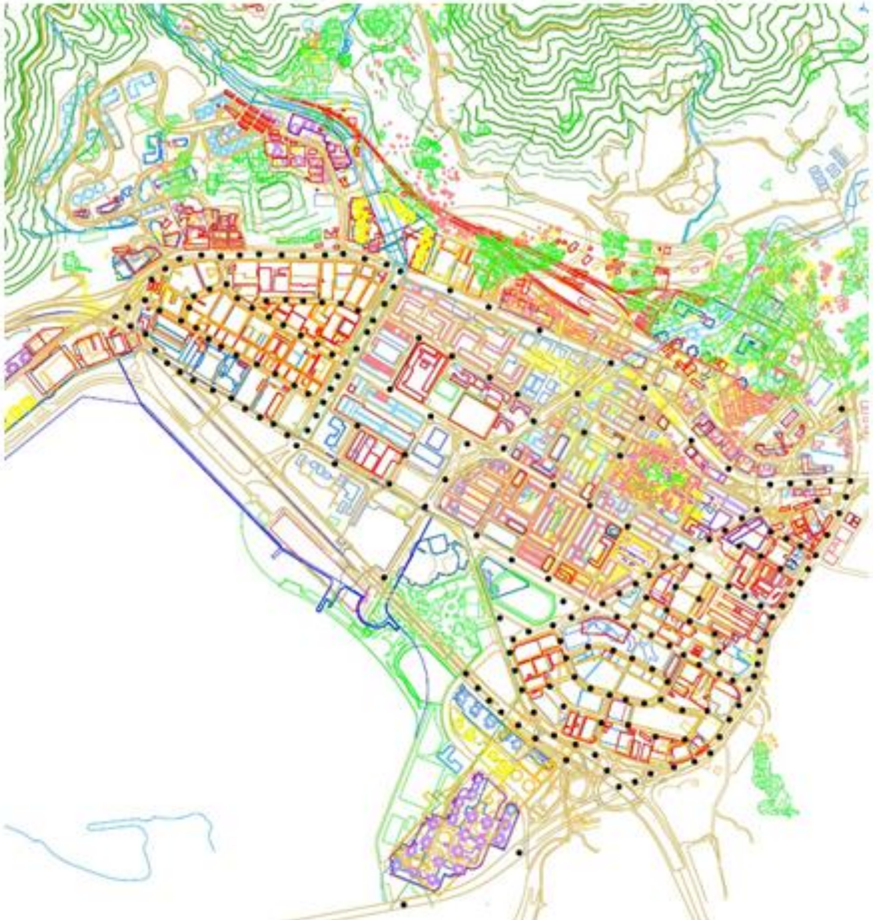
1960s

2015

Tsuen Wan development profile 1960-2015



SIMULATION RESULTS CAPTURE POINTS



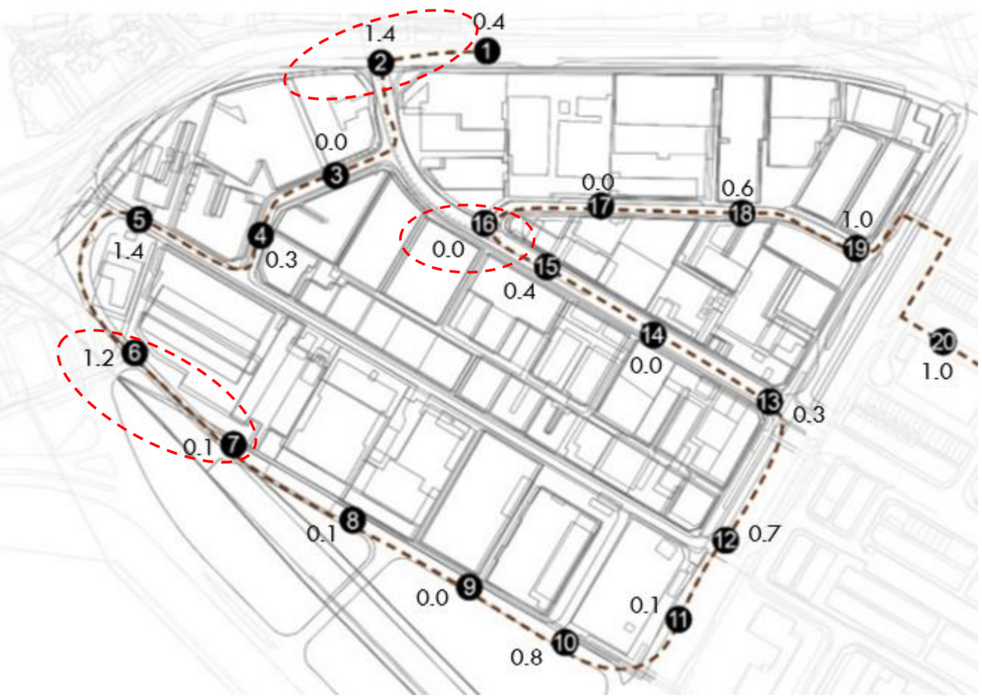
200 test points for calculating weighted average; every 50m

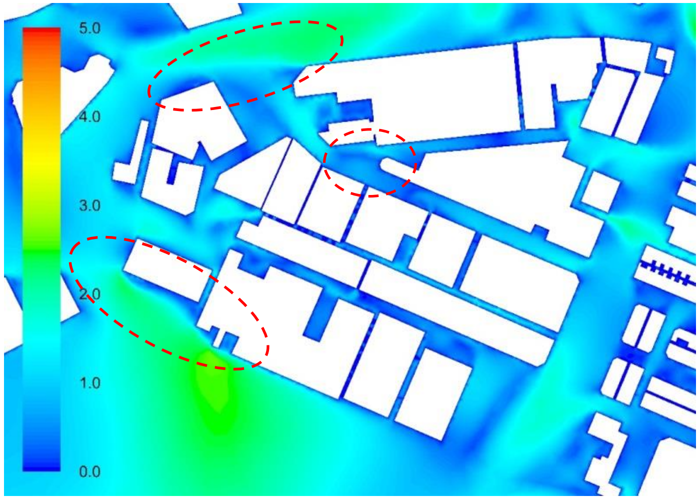
ON-SITE MEASUREMENTS FOR DATA VERIFICATION

On site measurements conditions

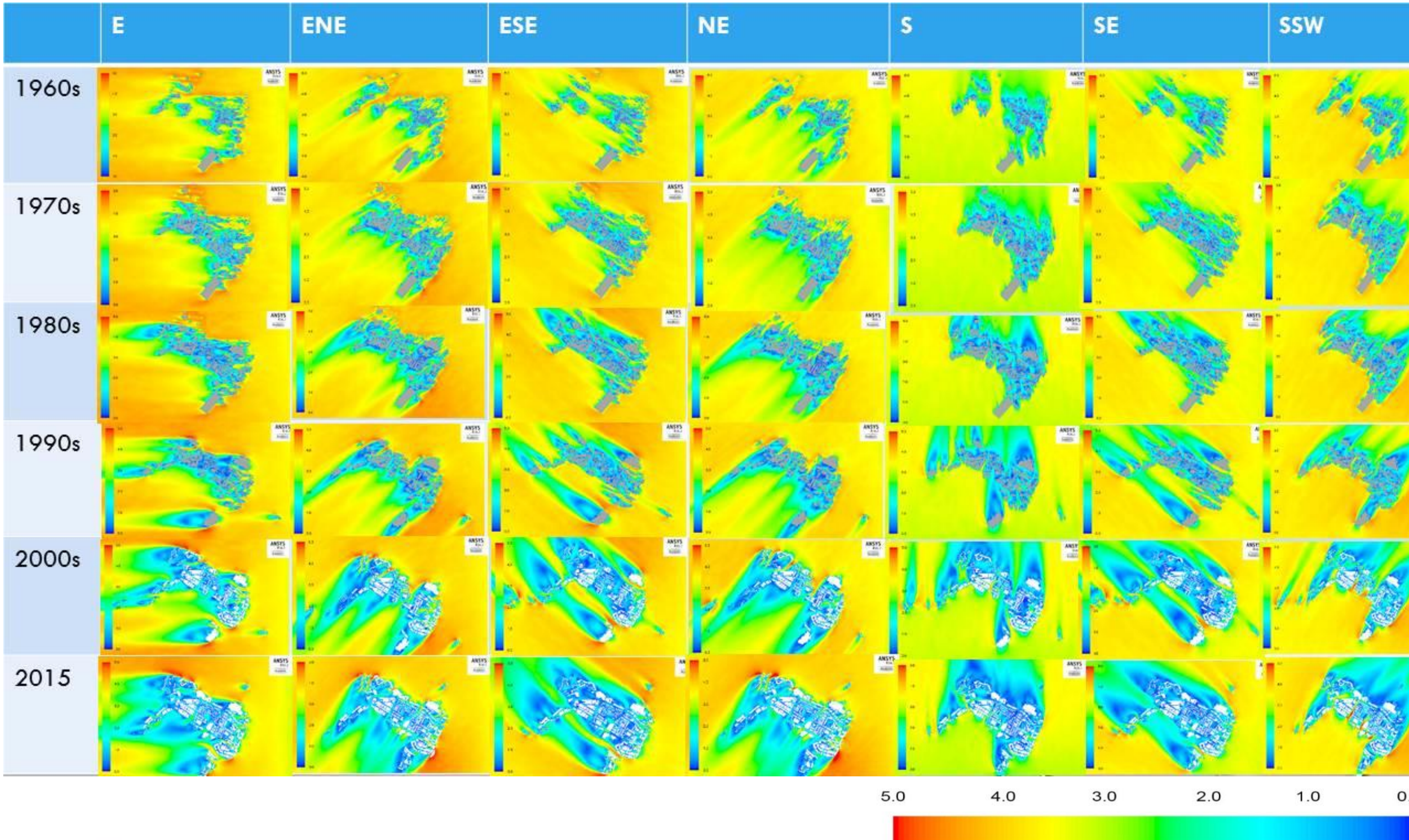
- Measured on stable wind condition in the following location
- Measured both experimental sites and representative development areas within the site
- Measured wind data on major pedestrian areas every 100m

Simulation vs. real-time data validation





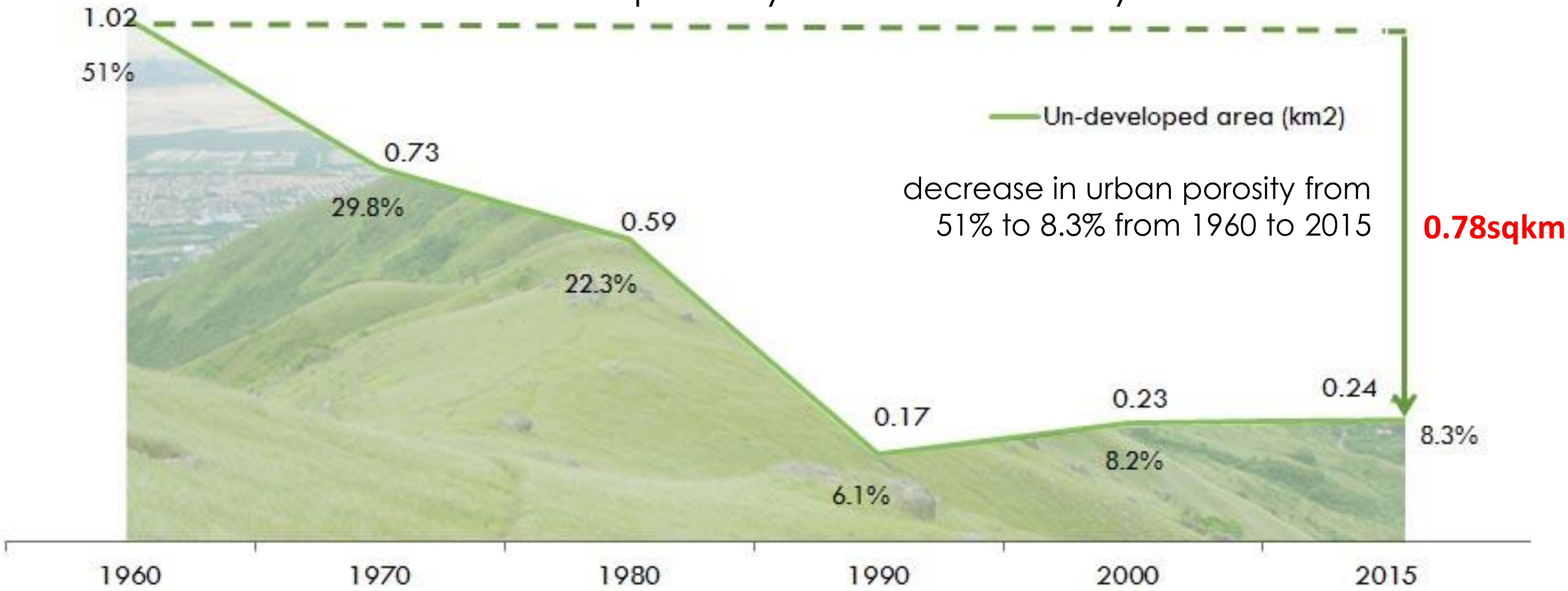
1960- 2015 historical wind profiles



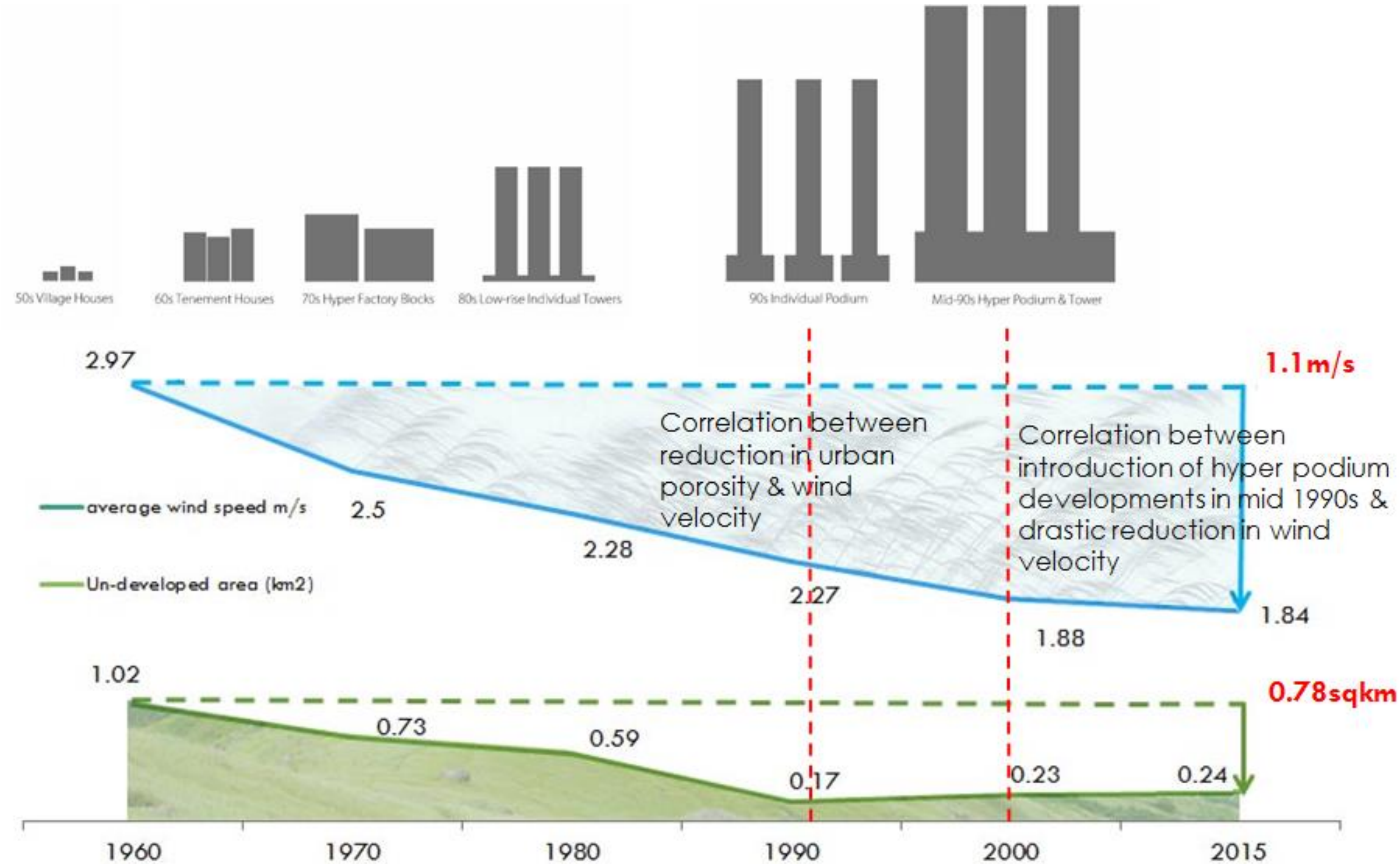
Development trends impact on pedestrian wind

	1960	1970	1980	1990	2000	2010	2015
Tsuen Wan City centre area	2.00	2.45	2.65	2.79	2.79	2.87	2.87
Un-developed area (km^2)	1.02	0.73	0.59	0.17	0.23	0.24	0.24
% undeveloped land	51%	29.8%	22.3%	6.1%	8.2%	8.3%	8.3%
average wind speed	2.97	2.50	2.28	2.27	1.88	1.93	1.84

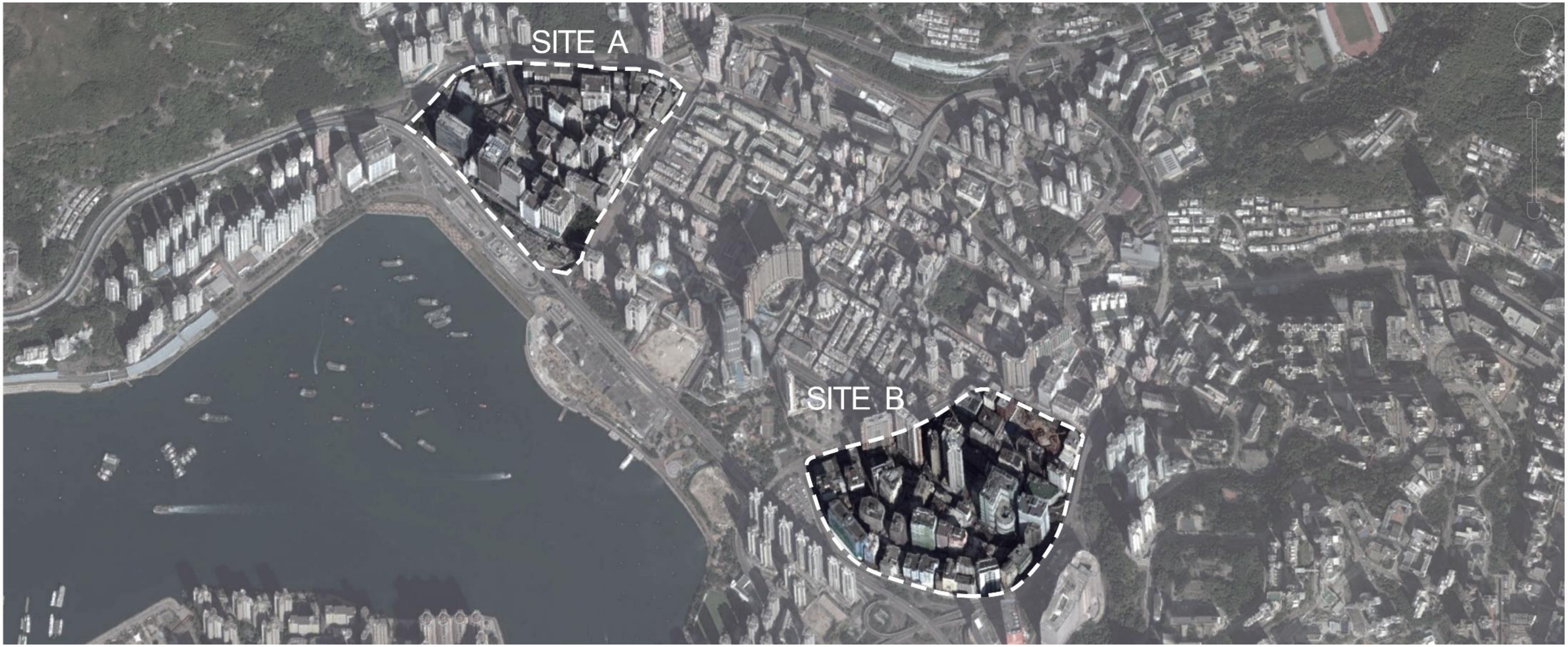
Reduction in urban porosity in Tsuen Wan city centre



Correlation between building typologies & wind speed



Existing factory estates as prospective redevelopment areas




1
2
3
4
5

Revitalization of the factory estates

Modifications to podiums & comparative scenarios

CASE 1

existing factory sites

CASE 2

Replace the factory buildings with 15m tall podium and tower type residential buildings; plot ratio 6.5 for 2015 model

CASE 3

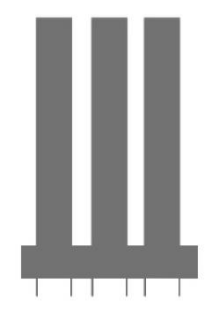
6m high 20 % void area was introduced to the podium block in Case 2

CASE 4

6m high 30% void area was introduced to the podium block in Case 2

CASE 5

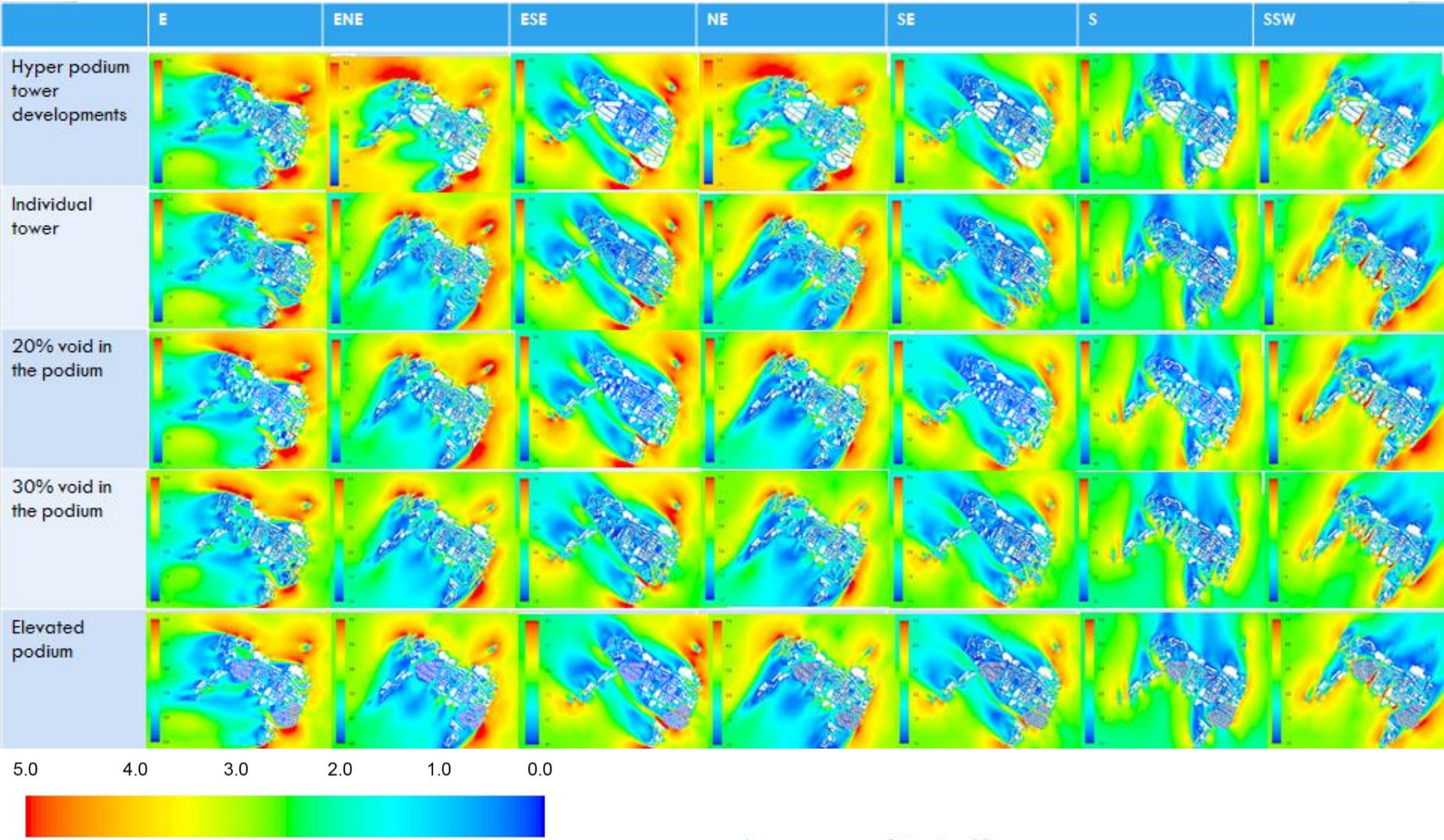
Individual towers with a linked podium



CASE 6

9m podium elevated 6m above ground

Testing with modifications to the podium



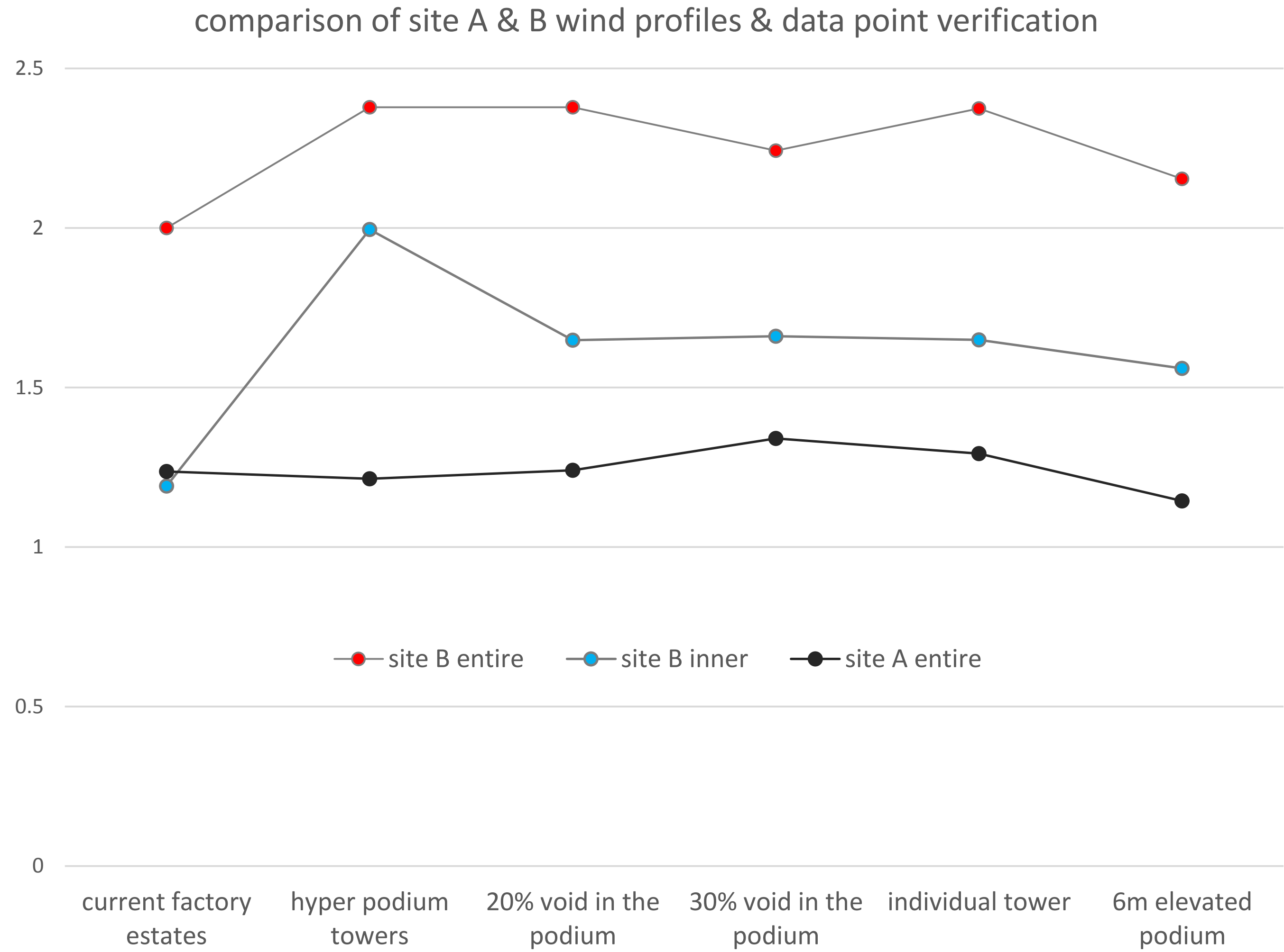
Wind profiles in the two test sites

Site A is surrounded by buildings particularly on the East, South East and North East wind directions

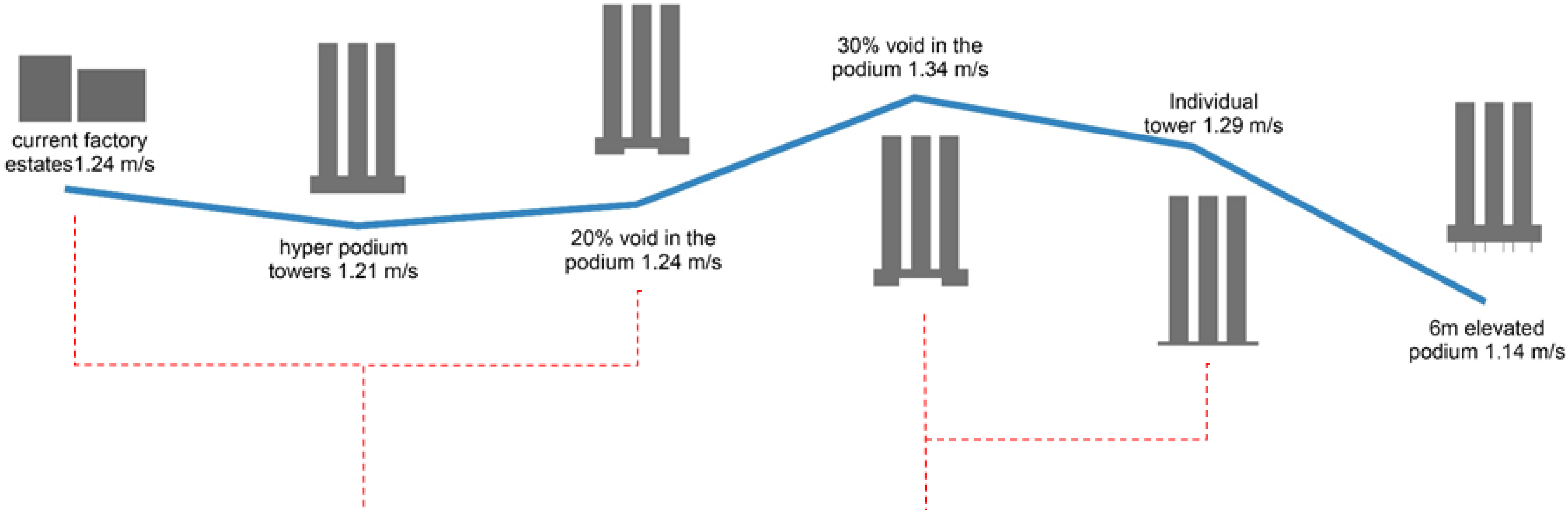
Site B is relatively exposed to wind from these directions

Site B indicated better wind levels compares to site A

Therefore inner core of the site B was considered for assessment in order to make it comparable to site A



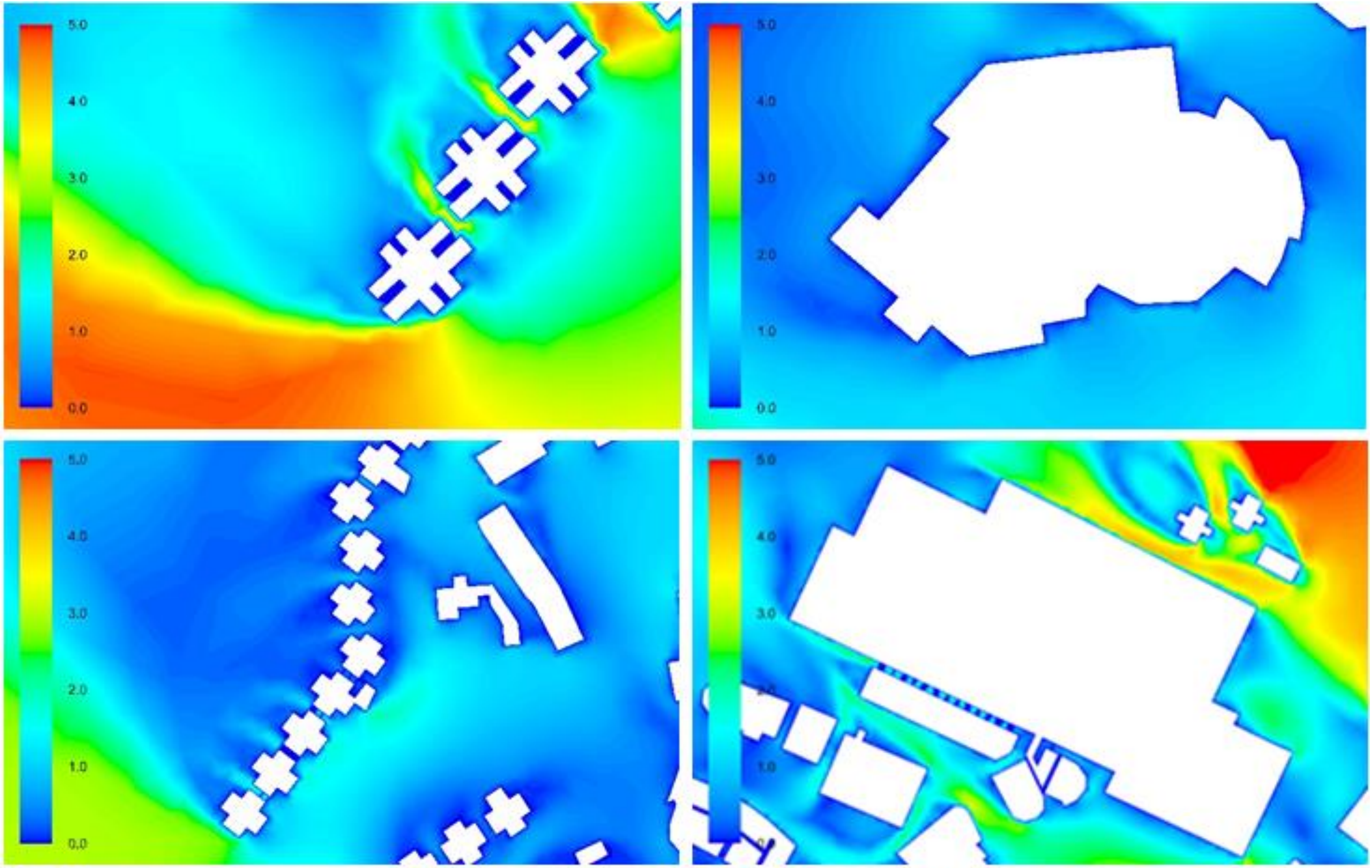
Modifications to podiums & wind profiles



Narrow building blocks and 20% void in the podium demonstrate similar improvement in wind velocity

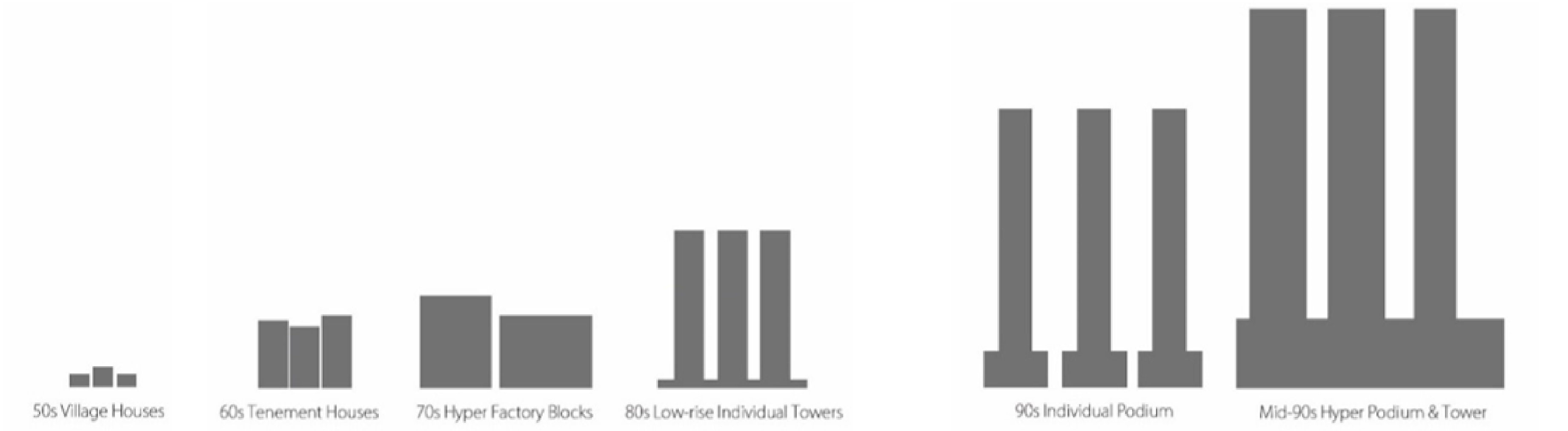
30% void in the podium & individual towers improve pedestrian wind velocity

Wind behavior around different masses

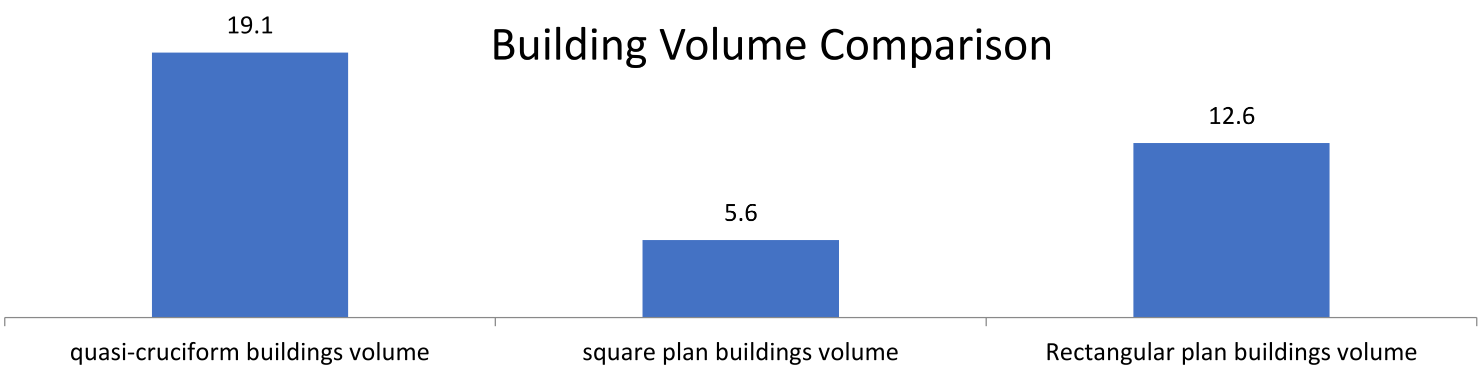


Individual towers indicate better wind behavior around the masses. However adequate spacing between buildings are important for better wind dispersion

Bulky masses may create Venturi effect on the windward side of the podium due to wind bouncing Nina tower podium results in stagnant wind in the surrounding

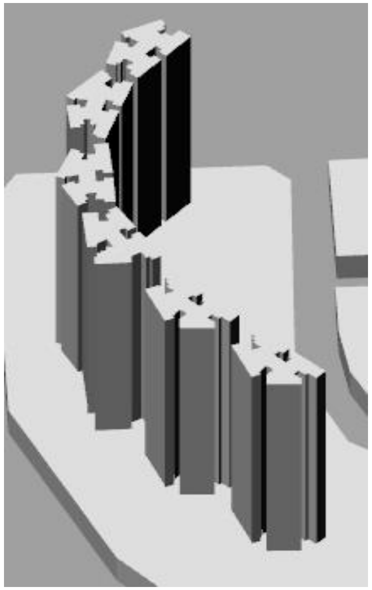


Evolution of building typologies in Tsuen Wan from 1950s to 2015

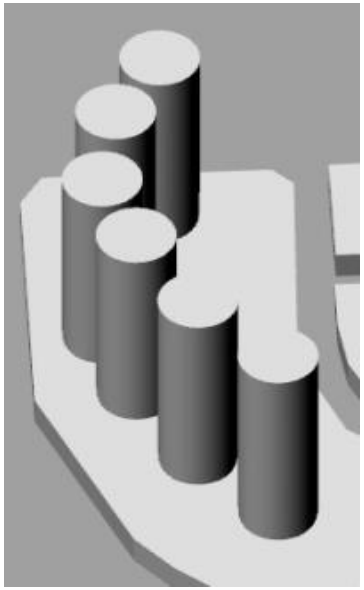


Building Volumes three different building geometry in Tsuen Wan in 2015 (million m3)

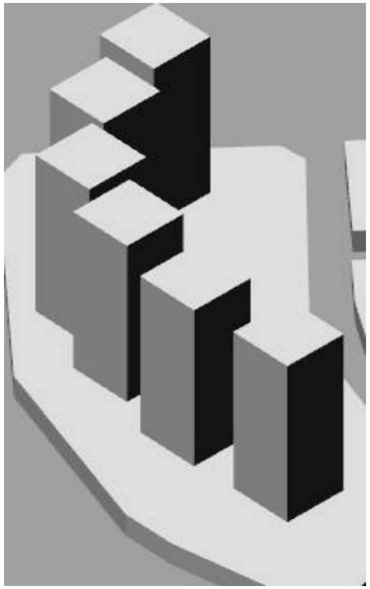
Modifications to tower geometries



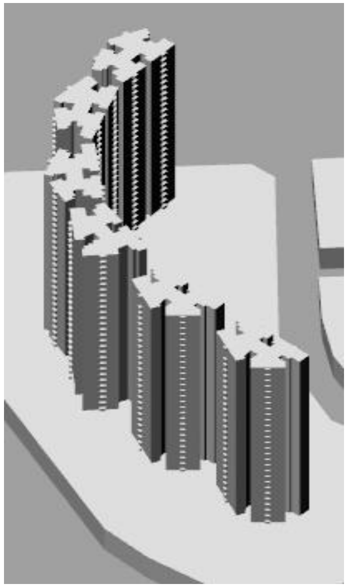
Quasi-cruciform plan towers



Cylindrical towers



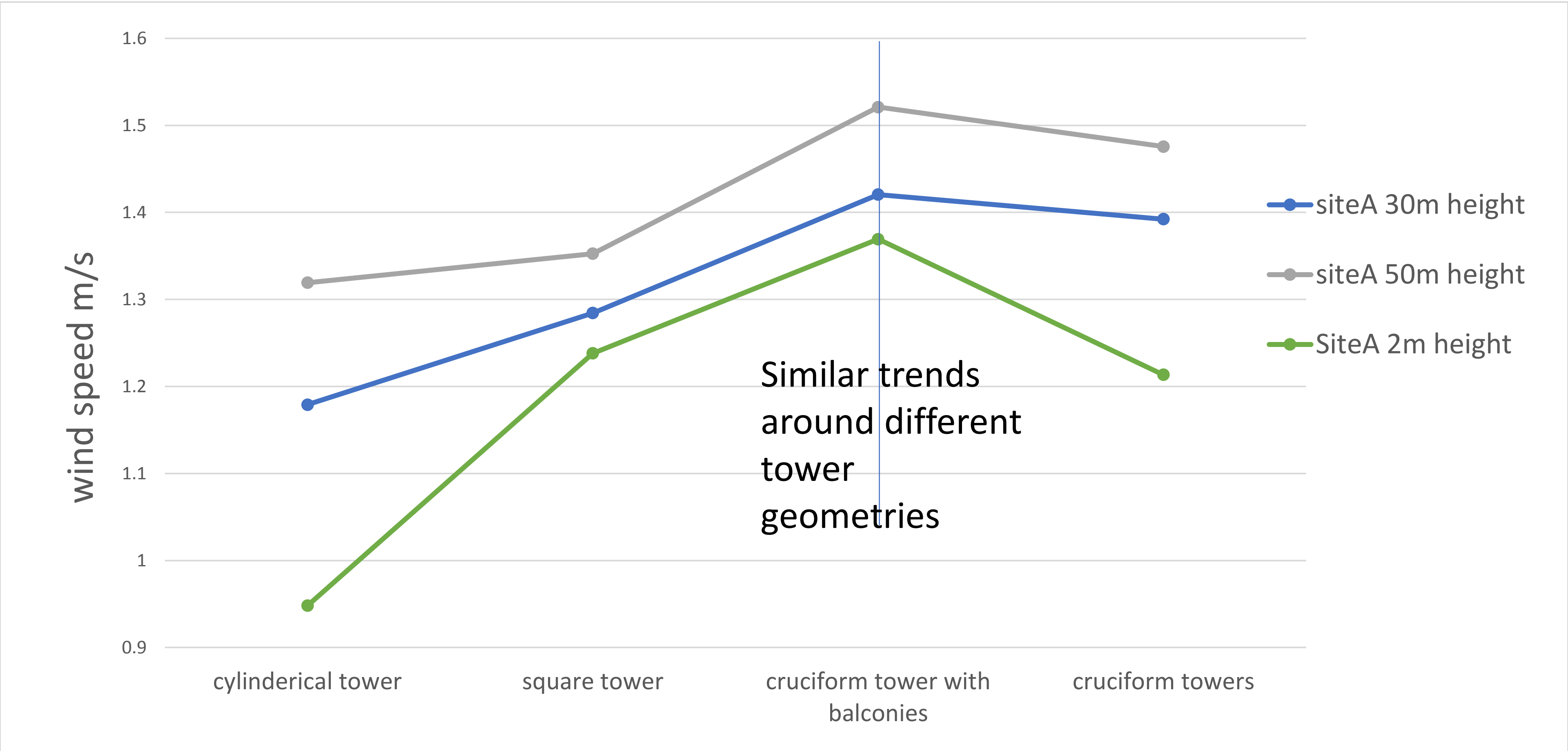
Square towers



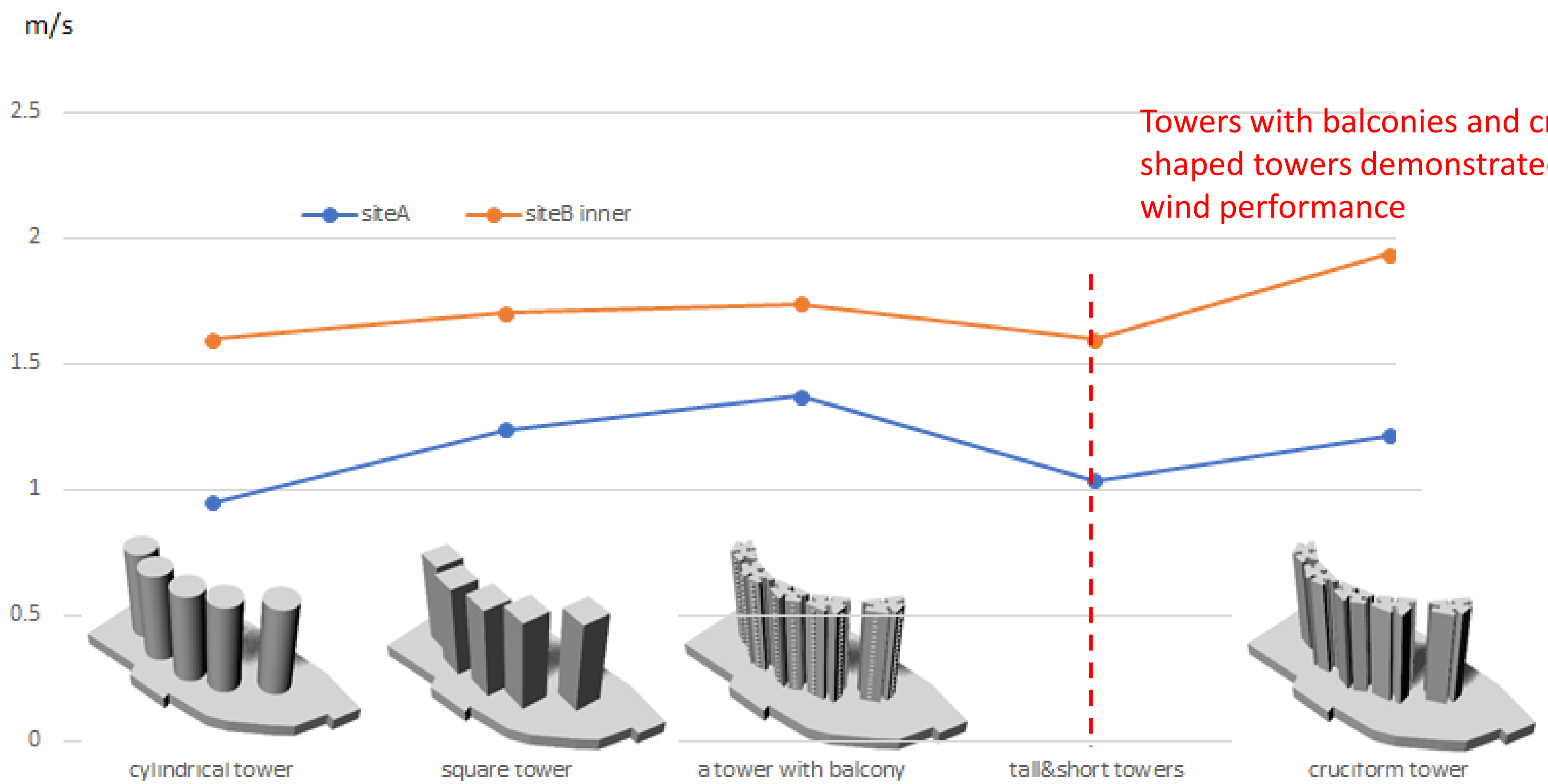
Quasi-cruciform towers with balconies

Four different building geometries tested for their impact on Urban Ventilation

Building geometry impact on wind speed at different height zones



Pedestrian wind behavior around different geometries

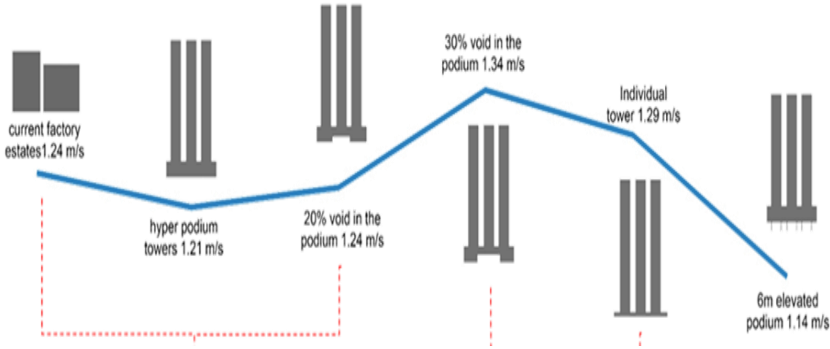


Towers with balconies and cruciform shaped towers demonstrated better wind performance

Variation in heights demonstrated the weakest performance perhaps due to the increased roughness created by changing masses

Findings & conclusions

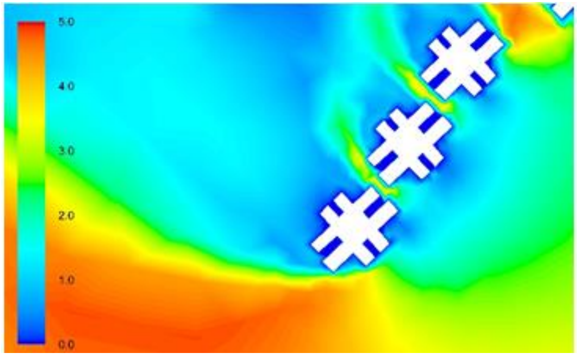
- Wind performance in the two experimental sites reports microclimatic effects influence on urban ventilation levels
- Small block sizes in the factory sites facilitate better wind performance compared with the hypothetical podium design tested
- Although marginal 30% void in the podiums & individual towers indicate improvements in the pedestrian wind levels compared to other options
- Findings from this study call for review of residential development trends and particular attention to CDA policy

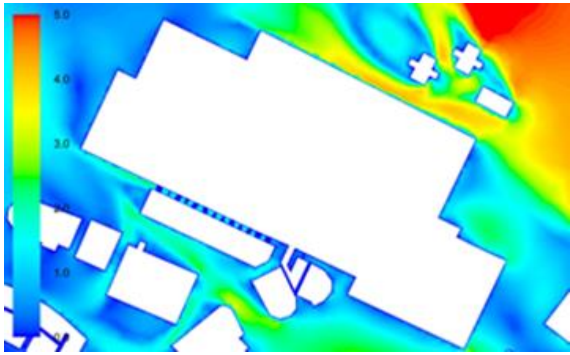


Findings & conclusions

- Individual tower developments although is more desirable than podium developments, they require adequate spacing among towers

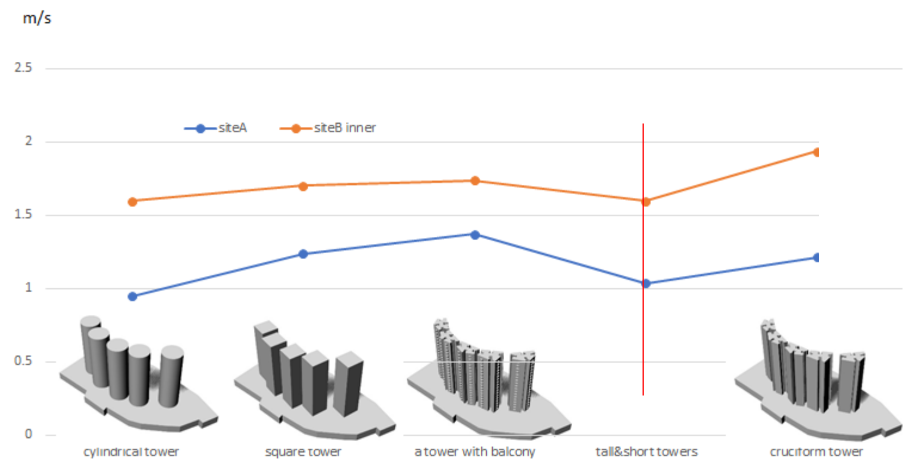
- Wind amplification could be observed around the windward side of hyper podium developments





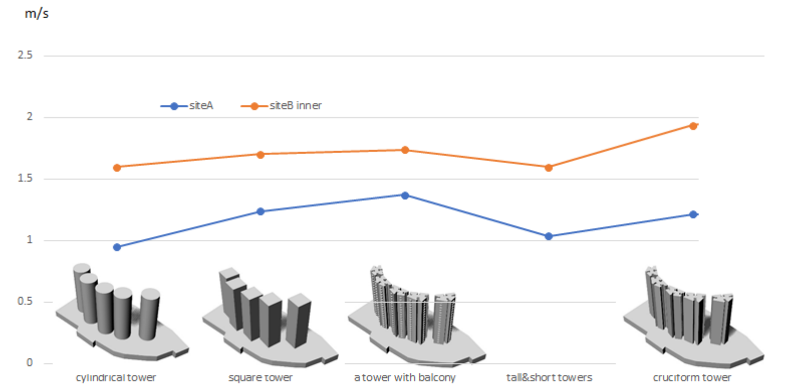
Findings & conclusions

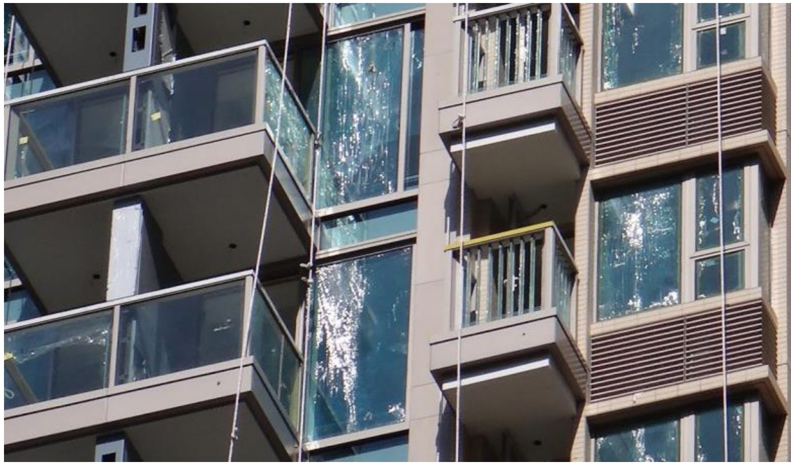
- Varying height of towers do not represent any significant impact on the wind environment
- Wind behavior around different geometries demonstrated similar trends even at varying heights



Findings & conclusions

- Cruciform towers and cruciform towers with balconies outperformed wind speed around square and cylindrical towers
- compliments the role of balconies as a green feature in improving urban ventilation
- Cylindrical towers indicate the lowest wind performance due to the laminar wind flow facilitated by the smooth building envelope.
- Initial studies indicate gap between towers influence ventilation levels
- Findings from this study provides references for designing sustainable and liveable neighborhoods.





Thank you

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