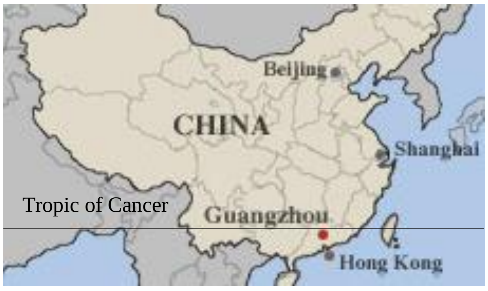
The Pearl River Tower

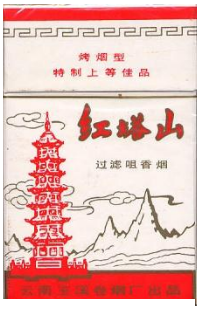
I-1 Geographical location

3 Guangzhou, (known as Canton), is the largest city of Guangdong province, located on the Pearl River, southern People’s Republic of China. The city has a population of 12.7 million. Because of the intense economic and industrial activity, they breathe one of the most polluted air on the planet.



7 Situated near the Tropic of Cancer, Guangzhou has a humid subtropical climate, with hot and wet summers and mild winters. Prevailing winds come from South-southeast.

I-2 Project owner



Hongtashan cigarettes

12 China National Tobacco Corporation, (C.N.T.C.) is the largest manufacturer of tobacco products in the world. It boasts a monopoly in the People's Republic of China, which accounts for roughly 30% of the world’s total consumption of cigarettes. C.N.T.C. produces a lot of brands of cigarettes, over 900. Among them, Hongtashan (Red Pagoda Hill) is very popular.

17 C.N.T.C. launched the project of a new headquarters building for one of its branches: Guangdong Tobacco Company, (G.T.C.) in Guangzhou. Taking into account the Chinese government’s goal of reducing carbon emission, the tobacco corporation requested a high energy efficient structure, that could produce as much energy as it consumes.

I-3 Architect company

23 Skidmore, Owings & Merrill LLP, (SOM) is a prestigious American architectural and engineering firm. Louis Skidmore and Nathaniel Owings formed it in Chicago in 1936. John O. Merrill joined them in 1939. They became leaders in skyscrapers design.

27 They have worked on several of the tallest buildings in the world, including the John Hancock Centre, in Chicago, 1969, (second tallest in the world when built), and Burj Khalifa, in Dubai, 2010, (the current world's tallest building).

31 Besides architecture and civil engineering, SOM provides services in sustainable design.

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II-1 The Net zero energy concept

SOM's engineers defined the "Net zero energy" concept as the ability of a new structure of not requiring an increase in the community's need of energy. That means that Guangzhou city should consume the same quantity of energy after the completion of the Pearl river tower, as before its construction.

The energetic and environmental specifications for the design of the building were laid out according to 4 strategies:

Reduction: The whole energy consumed by the builing has to be reduced, (high performace glazing, automated blinds, …).
This chapter won't be developped in this text.

Reclamation: The energy introduced inside the builiding has to be harvested and re-used, by means of a sophisticated air circulation inside the building. This chapter won't be developped in this text.

Production: The building is equiped with an internal micro power station, that is able to produce a "cleaner" energy more efficiently than traditionnal remote power stations, (usually fueled with coal in China).
This part won't be developped in this text.

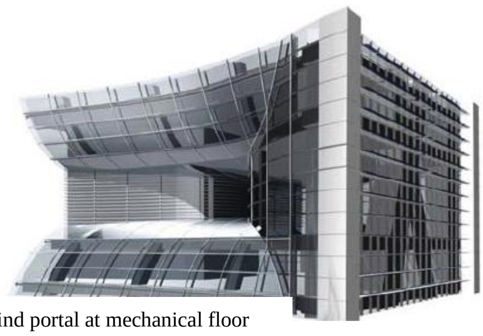
Absorbtion: The building has to take advantage of the natural and passive energy sources available in its direct environment:

* Sun ➔ Photovoltaics cells are incorporated in the building envelope, (south façade only), and on external sunshades.
* Wind ➔ Vertical axis wind turbines are located in 4 wind tunnels.

This text decribes the way the Pearl river tower makes the best use of the wind for energy production.

II-2 The wind and the building

Wind has a large impact on the design of tall structures. Buildings are obstacles on its path, therefore it generates mechanical constraints on them, proportionnal to its velocity and the exposed surface area. That is the reason why rectangular based skyscrappers are usually oriented so that the narrowest façade faces the prevailing winds.



Wind portal at mechanical floor

The Pearl river tower does not respect that rule. It's a rectangular based skyscraper with an unusual curved front façade, and 4 openings, that go right through the structure, called wind tunnels. Their entrance, the wind portals, are designed with aerodynamic shapes. They are situated at two mechanical floors, approximatelly on the first and second third of the tower's high.

The Pearl River Tower

When the wind blows, the air strikes the building and flows against the façade to find its way and avoid the obstacle. The brutal stop of the runing air flow makes turbulences and creates a high pressure zone on the windward side. Then, the acceleration of the air when eventually it gets round the edge, creates a low pressure zone on the leeward side. This pressure differential generates constraints.

Figure 1: Vertical cutaway

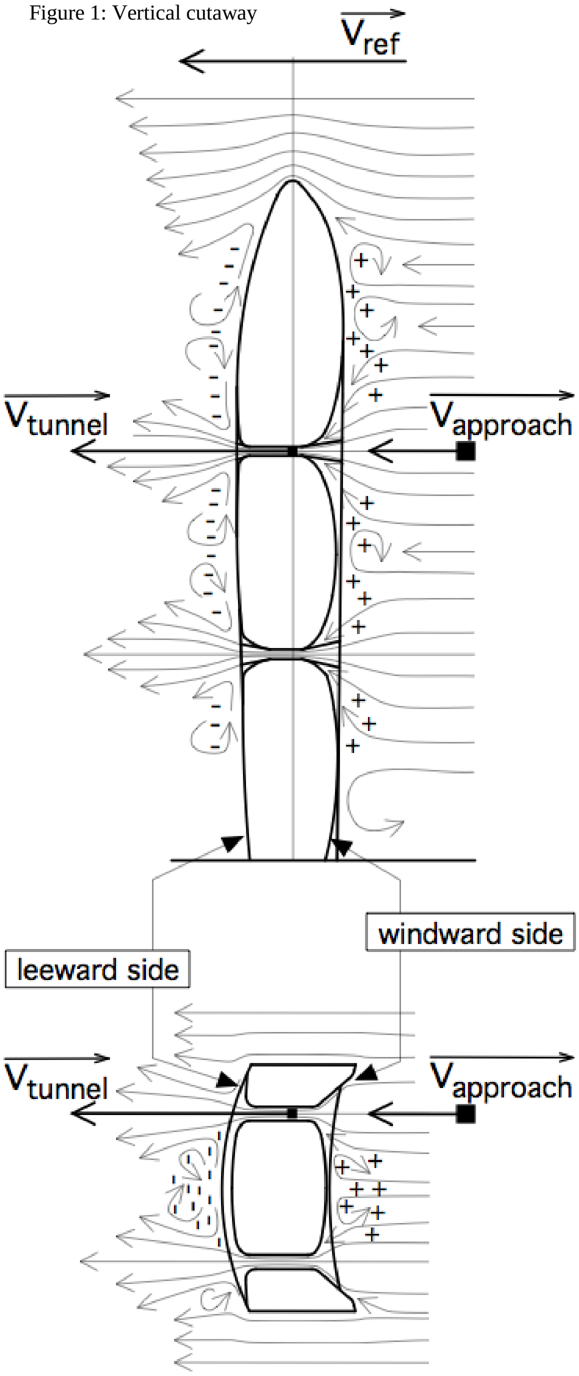


Figure 2: Horizontal cutaway

In Pearl river tower a part of the air can pass through the tunels, so the forces applied on the structure are reduced. Then, thanks to the portal's geometry, the air is led to the tunnel entrance, accelerates within it and rushes out on the other side of the tower.

Figures 1 and 2 illustrate the air circulation and the pressure differential on both sides of the tower, when the wind direction is lined up with the tunels.

II-3 Wind tests

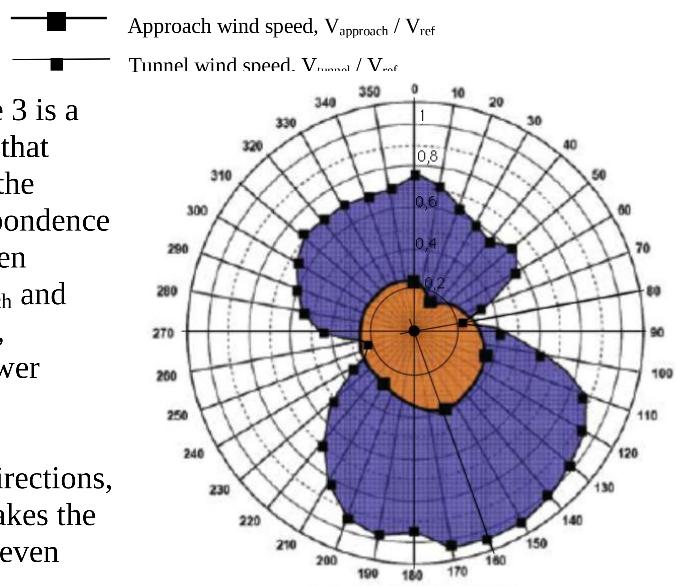
A scale model of the Pearl river tower was assembled and tested in a lab. The model's behavior was analysed under various wind conditions. The velocity of the air was measured on different points, approching the model then inside the tunnels, and compared with a wind speed reference. The model was then rotated to simulate winds coming from all possible directions. Measurements were led for upper and lower tunnels.

Curved façade of Pearl river tower

The Pearl River Tower

Wind tests

Figure 3: Wind test datas for lower tunnel



96 Figure 3 is a graph that gives the corespondence between $V_{approch}$ and V_{tunnel}, according to every wind direction, for the lower tunnel.

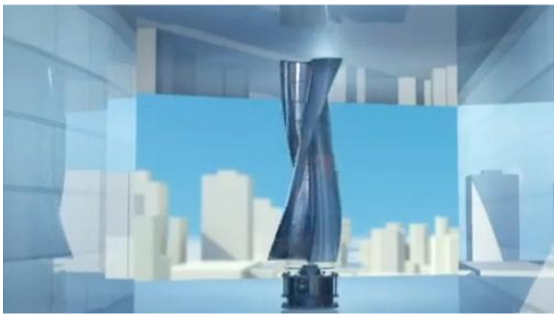
100 The graph shows that for most of the wind directions, $V_{tunnel} > V_{approach}$. This increased velocity makes the wind turbine system of the Pearl river tower even more efficient.

105 It appears as well, that for 2 wind directions, $V_{tunnel} < V_{approach}$. When the wind comes sideways, perpendicular to the tunnels, there is obviously a drop of power generation.

II-4 The vertical axis wind turbines

108 Inside each tunnel, the wind makes a vertical axis wind turbines spins, which then actuates an electrical generator. These types of wind turbines are well adapted to the turbulences of a cityscape where gusts of wind can come from all sides. They can work efficiently whatever the wind direction is.

Vertical axis wind turbine



PEARL RIVER TOWER

112 II-5 The Pearl river tower - facts and figures

Construction:	- start	2006
	- completion	2012
Height		309.6 m
Gross Floor Area, (GFA)		214,100 m^2
Number of floors:	- above ground	71
	- below ground	5
Number of elevators		29