Canton Tower – Engineering the Elegance

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Canton Tower

The Slim Waist Lady

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Canton Tower

Site Area: 175,460 sqm
Total Gross Floor Area (GFA): 114,054 sqm
Below Plaza GFA: 69,779 sqm
Tower GFA: 44,275 sqm

The Tower is designed for:
7,000 visitors on Weekdays and
15,000 visitors on Festive Days

Construction Period: 2005 – 2010
The World’s Tallest Amusement Park
New Icon of Guangzhou

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Design Team

Architect: IBA (Information Based Architecture)

Engineer: Arup
- Structure / Geotechnical
- Wind
- Building Services
- Fire Engineering
- Special Effect Lighting

LDI: GZDI (Guangzhou Design Institute)
Form and Shape Evolution

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Form & Shape Evolution

Densification of rings

Round tower → Elliptical section
Tapering towards the top
Rotation of vertical elements to create tightening
Twisting of the top of the tower
Rotation of rings according for opening entrance
Diagonalization of nodes into a stiff structure
Materialisation of vertical elements according to moment
Materialisation of rings and diagonals according to shear

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Form & Shape Evolution

Plan at waist

Core Size
-混凝土核心筒 17mx14m
-顶部椭圆 50mx40.5m
-底部椭圆 80mx60m

Top Ellipse
Base Ellipse

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Form & Shape Evolution

Aspect Ratio @ Waist = 7.3
Aspect Ratio @ Base = 7.5

高宽比 = 7.3
高宽比 = 7.5

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Total Design Approach
Total Design

- Geometry
- Wind climate
- Wind action
- Temperature effect
- Stability
- Seismic
- Construction
- Fire engineering
- Material
- Computational fluid dynamic
- Comfortability
- Performance design approach
Structural Design Challenges

- Study and specify the performance based comfort design and lateral building deflection limit.
- Accurate assessment of wind loading.
- Structural design to achieve a perfect architectural/structural form.
- Ensure constructability of tower, cost-effective design and control the construction cost to within the project budget.
Structural System: tube in tube

Dual Defense System for Lateral Stability = 14 x 17 Core wall + Outside Tube = 24 Columns + 46 Ring Beams + Bracings

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Structural System: Antenna

- Upper Steel Structure (Closed Structure)
- Middle Steel Structure (Latticed)
- Lower Transfer Structure
Structural System: Eccentric Joint
Wind Engineering Study Flowchart

- Wind Climate study
  - Topographic study
  - Aerodynamic model study
    - Sectional Structural load test
    - Wind effect analysis
      - Wind force & Acceleration results
    - Sectional Cladding Pressure Study
      - Cladding Pressure study
    - Wind pressure Distribution
Wind Engineering

- ACCURATELY ASSESS THE WIND LOAD, TO ENSURE STRUCTURAL SAFETY
- WIND ENGINEERING STUDY INCLUDE:

(Wind Climate Study)

- APPOINTED GUANGDONG PROVINCE CLIMATE CENTRE
- COLLECT 167 NUMBER WIND DATA RECORD FROM 1949-2004 TO CARRY OUT THE MONTE-CARLO STUDY
Wind Engineering

Wind Tunnel Test

Site Topography & Physiognomy Test

Entire models to measure wind pressure

Sectional models cladding pressure test

Sectional models to measure wind forces

Full aeroelastic model to measure wind force

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Results of Tower Acceleration under Wind Load from the Aero-elastic Model

<table>
<thead>
<tr>
<th>Limiting Acceleration for the Return Period</th>
<th>Wind Tunnel Test Result</th>
<th>Limiting Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 years</td>
<td>0.255m/s²</td>
<td>0.30m/s²</td>
</tr>
<tr>
<td>5 years</td>
<td>0.155m/s²</td>
<td>0.20m/s²</td>
</tr>
<tr>
<td>1 year</td>
<td>&lt;0.1m/s²</td>
<td>0.15m/s²</td>
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</tbody>
</table>
Thermal Effect Analysis
Tower Structure and physical property

3D modeling

Build model

Calculation

Various of structure temperature

Parameter setting

Climate data
- Climate
- Sun radiation
- Wind speed

Outdoor temperature

Analysis

Maximum increase of temperature under the global warming

Global warming
**Case 1** Temperature increase/decrease on all structural elements

- Temperature decrease: -10°C
- Temperature increase: +30°C

**Case 2** Temperature increase/decrease on exposure elements

- Temperature decrease: -20°C
- Temperature increase: +20°C

**Case 3** Temperature increase/decrease on one side

- Temperature decrease: -20°C
- Temperature increase: +20°C
Other Structural Analysis
Structural Analysis - Elastic

<table>
<thead>
<tr>
<th>Period</th>
<th>Results of GSA (Including P-Δ effects)</th>
<th>Results of Sap2000 (Including P-Δ effects)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>10.23</td>
<td>10.24</td>
</tr>
<tr>
<td>T2</td>
<td>7.09</td>
<td>7.11</td>
</tr>
<tr>
<td>T3</td>
<td>2.83</td>
<td>2.84</td>
</tr>
</tbody>
</table>

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Structural Analysis – Overall Buckling

Columns

Rings

Bracings

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Non-linear Analysis under Severe Earthquake

Results of Outside Tube

Few columns will reach the plastic stage under rare earthquake load case
Non-linear Analysis under Severe Earthquake

The elasto–plastic response of Inner core

The elasto–plastic response of Antenna and Transfer Truss
Joint Design and Analysis

- Top Plate
- Ring Beam
- Circle Stiffener
- Ring Stiffener
- Stiffener
- Column
- Bracing
Damper

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Structural Health Monitor

Core wall

- Section 5: 438.4m, 12 strain gauges
- Section 4: 334.4m, 12 strain gauges
- Section 3: 272.0m, 12 strain gauges
- Section 2: 121.2m, 12 strain gauges
- Section 1: 52.8m, 12 strain gauges

Frame

- Section 5: Ring 45, 24 strain gauges, 8 temperature sensors
- Section 4: Ring 35, 24 strain gauges, 8 temperature sensors
- Section 3: Ring 28, 24 strain gauges, 8 temperature sensors
- Section 2: Ring 17, 20 strain gauges, 8 temperature sensors
- Section 1: Ring 1, 20 strain gauges, 8 temperature sensors

Anemometer

Seismograph

Accelerometer
Seismic Design – Shaking Table Test

Model Scale 1:50
Segmental Erection of Steelwork

1. Column – one section of length of 8-12 metres including the connecting joint with ring and diagonal.
2. Diagonal – 8-12 metres long.
3. Ring – 3-6 metres long

The tonnage of the segmental column is limited to 30 tones maximum for lifting weight reason.
Engineer Envisaged Construction Sequence

Estimated completion in May 2009
Construction Process – Completed on Schedule

高度Height: \( 610m - 10m = 600m \)

Due the aviation restriction, the antenna should be shortened by 10 meter.
12 November, 2010
The 16th Asian Games Opening Ceremony, Guangzhou, China
The Zhujiang New Town, Guangzhou
Thank You