Structural Design in Hong Kong: Skyscraper

Analysis and comparison of Eurocodes and Chinese codes of design

Dr Simon Wong
29 August 2018
Tall buildings in Hong Kong
Location of Hong Kong
## Hong Kong

<table>
<thead>
<tr>
<th>Category</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>7,409,000 (2017)</td>
</tr>
<tr>
<td>Area</td>
<td>1,106 km²</td>
</tr>
<tr>
<td>Land developed</td>
<td>Less than 25%</td>
</tr>
<tr>
<td>Country parts and nature reserves</td>
<td>40%</td>
</tr>
<tr>
<td>150m+ Buildings</td>
<td>317 Completed • 3 Under Construction</td>
</tr>
<tr>
<td>300m+ Buildings</td>
<td>6 Completed</td>
</tr>
<tr>
<td>Global Ranking</td>
<td>#1 in the world by no. of 150m+ completed buildings</td>
</tr>
<tr>
<td>Regional Ranking</td>
<td>#1 in Asia by no. of 150m+ completed buildings</td>
</tr>
<tr>
<td>Country Ranking</td>
<td>#1 in China by no. of 150m+ completed buildings</td>
</tr>
<tr>
<td>Average Building Age</td>
<td>17 years</td>
</tr>
</tbody>
</table>

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*a* Census and Statistics Department, The Government of the Hong Kong Special Administrative Region


*c* Council on Tall Buildings and Urban Habitat (CTBUH), http://www.ctbuh.org/
THEi Campus (TY)

THEi Campus (CW)

Source: Google Map
Hong Kong Island

Source: Google Map
Kowloon

Source: Google Map
Tall buildings in Hong Kong

- Highest rank by number of 150m+ completed buildings (April, 2018)

**Tall buildings in Hong Kong**

- 10 tallest **completed** buildings in the HK (April 2018)

<table>
<thead>
<tr>
<th>#</th>
<th>Building Name</th>
<th>City</th>
<th>Height (m)</th>
<th>Height (ft)</th>
<th>Floors</th>
<th>Completed</th>
<th>Material</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>International Commerce Centre</td>
<td>Hong Kong (CN)</td>
<td>484</td>
<td>1,588</td>
<td>108</td>
<td>2010</td>
<td>composite</td>
<td>hotel / office</td>
</tr>
<tr>
<td>2</td>
<td>Two International Finance Centre</td>
<td>Hong Kong (CN)</td>
<td>412</td>
<td>1,352</td>
<td>88</td>
<td>2003</td>
<td>composite</td>
<td>office</td>
</tr>
<tr>
<td>3</td>
<td>Central Plaza</td>
<td>Hong Kong (CN)</td>
<td>373.9</td>
<td>1,227</td>
<td>78</td>
<td>1992</td>
<td>concrete</td>
<td>office</td>
</tr>
<tr>
<td>4</td>
<td>Bank of China Tower</td>
<td>Hong Kong (CN)</td>
<td>367.4</td>
<td>1,205</td>
<td>72</td>
<td>1990</td>
<td>composite</td>
<td>office</td>
</tr>
<tr>
<td>5</td>
<td>The Center</td>
<td>Hong Kong (CN)</td>
<td>346</td>
<td>1,135</td>
<td>73</td>
<td>1998</td>
<td>steel</td>
<td>office</td>
</tr>
<tr>
<td>6</td>
<td>Nina Tower</td>
<td>Hong Kong (CN)</td>
<td>320.4</td>
<td>1,051</td>
<td>80</td>
<td>2006</td>
<td>concrete</td>
<td>hotel / office</td>
</tr>
<tr>
<td>7</td>
<td>One Island East</td>
<td>Hong Kong (CN)</td>
<td>296.1</td>
<td>973</td>
<td>68</td>
<td>2008</td>
<td>concrete</td>
<td>office</td>
</tr>
<tr>
<td>8</td>
<td>Cheung Kong Centre</td>
<td>Hong Kong (CN)</td>
<td>282.8</td>
<td>928</td>
<td>63</td>
<td>1999</td>
<td>steel</td>
<td>office</td>
</tr>
<tr>
<td>9</td>
<td>Victoria Dockside</td>
<td>Hong Kong (CN)</td>
<td>273.5</td>
<td>897</td>
<td>66</td>
<td>2017</td>
<td>concrete</td>
<td>hotel / office</td>
</tr>
<tr>
<td>10</td>
<td>The Cullinan I</td>
<td>Hong Kong (CN)</td>
<td>269.9</td>
<td>886</td>
<td>68</td>
<td>2008</td>
<td>concrete</td>
<td>residential</td>
</tr>
<tr>
<td>10</td>
<td>The Cullinan II</td>
<td>Hong Kong (CN)</td>
<td>269.9</td>
<td>886</td>
<td>68</td>
<td>2008</td>
<td>concrete</td>
<td>residential / hotel</td>
</tr>
</tbody>
</table>

Source: [http://skyscrapercenter.com](http://skyscrapercenter.com)
73% residential
19% office

93% reinforced concrete

RESIDENTIAL BUILDINGS
Public housing

Types of building block
- Linear
- Harmony
- Cruciform
- Trident
- Concord
Standard block – New Harmony

Structural form
- Shear wall / coupled shear wall structures

Source: Housing authority
Standard block – Concord

Source: Housing authority
Construction

Housing blocks under construction with **precast concrete** components

Source: Housing authority
Pre-cast members

Bathroom module

Pre-cast facade

Semi pre-cast floor slab

Pre-cast staircase

Source: Housing authority
Private housing

Developed by various developers

Island Resort
(Sino Land)

Harbour Green
(Sun Hung Kai Properties)

Source: wikipedia
Bamboo scaffolding

By Ivan Watson, Vivian KamPamela Boykoff, CNN
Alteration & Addition (A&A) Work on Existing Building

- Practice Note for Authorized Persons and Registered Structural Engineers (PNAP) (APP-117)

- Structural requirements for alteration and addition works in existing buildings
Conversion of Industrial Building to Hotel – Wall Opening and New Staircase

Part of the existing walls to be removed to become the door opening

However, the opening will weaken the stiffness of the wall and strengthening work has to be done
Alteration & Addition (A&A) Work on Existing Building

Typical Details to strengthen lintel beam of the shear wall
Case studies

1. HSBC Main Building
2. International Commercial Centre
## HSBC Main Building

<table>
<thead>
<tr>
<th>Type</th>
<th>Commercial offices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completion</td>
<td>1985</td>
</tr>
<tr>
<td>Height</td>
<td>178.8 m</td>
</tr>
<tr>
<td>Floor</td>
<td>44</td>
</tr>
<tr>
<td>Floor area</td>
<td>99 000 m²</td>
</tr>
<tr>
<td>Material</td>
<td>Steel</td>
</tr>
<tr>
<td>Architect</td>
<td>Foster Associates</td>
</tr>
<tr>
<td>Structural engineering</td>
<td>Ove Arup &amp; Partners, Cleveland Bridge Ltd.</td>
</tr>
<tr>
<td>Main contractor</td>
<td>Wimpey International</td>
</tr>
<tr>
<td>Cost</td>
<td>HK$5.2 billion</td>
</tr>
</tbody>
</table>

Source: https://en.wikipedia.org

Source: http://skyscrapercenter.com
• **Exoskeleton steel truss system with suspended steel structure**
• Large column-free area
• Without a concrete core
• **Eight masts**, each consisting of **four columns**, supporting five discrete steel suspension structures
Provide cross-braces along the short-span direction to withstand the lateral loads.
Use extensive **prefabrications** to overcome construction difficulties due to congestion around the site, and to meet the requirements of a short timescale.

HSBC Main Building Construction

HISTORY – How Hong Kong Was Made: Iconic Buildings Under Construction, via HSBC/Foster & Partners
http://hongwrong.com/hong-kong-under-construction/
Case studies

1. HSBC Main Building
2. International Commercial Centre
# International Commerce Centre (ICC)

<table>
<thead>
<tr>
<th><strong>Completion</strong></th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of storeys</strong></td>
<td>108</td>
</tr>
<tr>
<td><strong>Height</strong></td>
<td>484 m</td>
</tr>
<tr>
<td><strong>Function</strong></td>
<td>Mixed-use</td>
</tr>
<tr>
<td><strong>Material</strong></td>
<td>Composite</td>
</tr>
<tr>
<td><strong>Architect</strong></td>
<td>Kohn Pedersen Fox Associates</td>
</tr>
<tr>
<td><strong>Structural engineer</strong></td>
<td>Ove Arup &amp; Partners</td>
</tr>
<tr>
<td><strong>Total construction cost</strong></td>
<td>USD 1.5 billion</td>
</tr>
<tr>
<td><strong>Volume of Concrete</strong></td>
<td>240,000 m³</td>
</tr>
<tr>
<td><strong>Reinforcement</strong></td>
<td>98,000 tons</td>
</tr>
</tbody>
</table>

Source: [http://skyscrapercenter.com](http://skyscrapercenter.com)
Mixed-use building

Zone 5
(10 office storeys)

Zone 4
(14 office storeys)

Zone 3
(16 office storeys)

Zone 2
(14 office storeys)

Zone 1
(11 office storeys + 2 storeys trading floor)

- 6-star Hotel (Ritz Carlton)
- Mechanical Floor
- Observation Deck
- Skylobby
- Office floor
- Steelwork Outrigger
- Prestressed Outrigger
Outriggers are located at mechanical floor

Steel outrigger

Pre-stressed concrete outrigger

RC core wall

RC mega column
~2.6x2.9 m
By Angela TAM, Lofty aspirations at destination West Kowloon, HKIE

Consists of **RC core walls**, **8 RC mega columns** and **4 outriggers**

**Four** outriggers are provided at 6/F, 42/F, 78/F and 100/F
Foundation

- A 76m diameter cofferdam lined with 1.5m-thick diaphragm wall panels was formed to facilitate the construction of the 9m-deep foundation raft and core wall structure of tower using bottom up arrangement

- 241 rectangular shaft-grouted barrettes taken to an average depth of 70 m

- Each barrette is capable of supporting 40,000 kN of load

By Angela TAM, Lofty aspirations at destination West Kowloon, HKIE
Mega column and core wall

**Jump-form** were used to construct core walls. **Self-compacting concrete** was used for the core wall and mega-columns.

Source: Raymond Wong, A Construction Highlight for the International Commerce Centre at Kowloon Station
Source: Raymond Wong, A Construction Highlight for the International Commerce Centre at Kowloon Station
Grade 90 concrete up to 60/F; Grade 45 and Grade 60 for others

By Baycrest "CC-BY-SA-2.5"
https://commons.wikimedia.org/wiki/
THANK YOU
Case studies

1. HSBC Main Building
2. International Commercial Centre
3. Central Plaza
4. Bank of China Tower
Central Plaza

<table>
<thead>
<tr>
<th>Completion</th>
<th>1992</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of storeys</td>
<td>78</td>
</tr>
<tr>
<td>Height</td>
<td>373.9 m</td>
</tr>
<tr>
<td>Function</td>
<td>Office</td>
</tr>
<tr>
<td>Material</td>
<td>Concrete</td>
</tr>
<tr>
<td>Architect</td>
<td>Chun Man &amp; Associates, Architects &amp; Engineers China Ltd.</td>
</tr>
<tr>
<td>Structural Engineer</td>
<td>Ove Arup</td>
</tr>
<tr>
<td>Construction cost</td>
<td>HK$ 1,100 million</td>
</tr>
</tbody>
</table>

Source: [http://skyscrapercenter.com](http://skyscrapercenter.com)
Highest **RC building** in HK

Triangular shape has very few dead corners and offers more views from the building interiors.

Lateral system resistance is mainly provided by perimeter frame tube with core walls (**tube-in-tube**).

- Transfer beam (hxb): 5.5 x 2.8 m
- 1 m thick slab

Beam depth: 1.1 m
Slab: 160 mm
Wall: 1.3 m

1.5 wide column with spacing of 4.6 m
Entrance podium:
30.5 m high with 2 m diameter column and 8.6 m spacing
Case studies

1. HSBC Main Building
2. International Commercial Centre
3. Central Plaza
4. Bank of China Tower
# Bank of China Tower

<table>
<thead>
<tr>
<th>Completion</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of storeys</td>
<td>72</td>
</tr>
<tr>
<td>Height</td>
<td>367.4 m</td>
</tr>
<tr>
<td>Function</td>
<td>Office</td>
</tr>
<tr>
<td>Material</td>
<td>Composite</td>
</tr>
<tr>
<td>Architect</td>
<td>I.M. Pei &amp; Partners</td>
</tr>
<tr>
<td>Structural Engineer</td>
<td>Leslie E. Robertson Associates</td>
</tr>
<tr>
<td>Cost</td>
<td>$150 million</td>
</tr>
</tbody>
</table>

Source: By WiNG  
https://commons.wikimedia.org/w/index.php?curid=4252640
**Space truss structure**

**Multi-storey mega braces** are provided to transmit vertical and horizontal loads to vertical columns.

With a striking angular form, the Bank of China Tower is an iconic piece of Structural Expressionism.

The idea for the form came from bamboo, a symbol of growth and prosperity in Chinese Culture.
Construction

By ‘shuibien_chen’ on Flickr