Visit: Central
Structure of Skyscrapers
[Teacher notes]
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Design and Applied Technology | Visit: Central - Structure of Skyscrapers
**Topic 11**  
**Visit: Central - Structure of Skyscrapers**

**Major teaching area**  
**Design and Applied Technology**  
Strand 2 Technological Principles

- Nature of Technology

**Interdisciplinary teaching areas**  
**Physics**
- Chapter VIII Energy and Use of Energy

**Liberal Studies**
- Module 2 Hong Kong Today  
- Module 6 Energy Technology and Environment

**Learning objectives**
- To experience the various form of architectural structure of different times in 1:1 scale and in the city context

**Teaching plan**

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<td>1. <strong>Old Supreme Court</strong></td>
<td>• Comparison to modern high-rise buildings</td>
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<td>• Western/ Classical style</td>
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<td>• Structure of dome and columns</td>
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<td>Council Building)</td>
<td>• Solutions in response to local climate</td>
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<td>2. <strong>HSBC Headquarters</strong></td>
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<td>• Exoskeleton steel truss and column structure</td>
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<td>• Load transfers from truss to columns and to the ground</td>
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<td>3. <strong>Cheung Kong Centre</strong></td>
<td>• Modern skyscraper</td>
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<td>• Composite structural system</td>
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<td>• Load transfer from bearing columns at the perimeter to the central core and to the ground</td>
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<td>• Curtain wall</td>
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<td>• Modern Hi-Tech style</td>
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<td>• Strength of the triangular geometry</td>
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<td>• Load transfer from the five columns and cross-bracing to the ground</td>
</tr>
<tr>
<td>5. <strong>Murray Building</strong></td>
<td>• Modernism architectural style</td>
</tr>
<tr>
<td></td>
<td>• Regular geometrical shaped</td>
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<td></td>
<td>• Composite structural system</td>
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<tr>
<td></td>
<td>• Core wall and external reinforced concrete wall</td>
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<tr>
<td></td>
<td>• Central core for vertical circulations and mechanic uses</td>
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<tr>
<td></td>
<td>• Tube-in-tube structure to resist horizontal force</td>
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<tr>
<td></td>
<td>• Vertical load transfers from load-bearing walls to the ground</td>
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<td>• Sun-shading features incorporated in the building envelope</td>
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1.1 Itinerary

Pre-Trip Introduction (20 min)
- Structural system, structural element, structural material and spatial arrangement in skyscrapers
- Objectives and on-site exercise introduction
- Planned route

Field Trip (approximately 2 hours)

1. Court of Final Appeal (Former Legislative Council)
2. HSBC Headquarter
3. Cheung Kong Centre
4. Bank of China Tower
5. Murray Building

Design and Applied Technology | Visit: Central - Structure of Skyscrapers
1.2 Introduction

Tall buildings are symbolic elements within any city, carrying significant political, social, cultural and even religious meanings. Today cities compete to produce the tallest building in the world as a way of showcasing financial and economic power. Understanding the structures of these buildings, and how they support themselves as well as the loads imposed on them by the environment, is a fascinating way to see the real-life applications of physics.

Core and Outrigger Structural System

- **Core wall**
  usually located at the centre or side of building, the reinforced concrete wall, which is the major structural load bearing element and provides rigidity to resist deflection caused by strong wind

- **Structural Steel External Frame**
  series of steel column located at the building perimeter, with steel beams connecting the steel columns to core wall

- **Outrigger**
  huge braced frame (with height equivalent to 2-3 storeys), located at each 20-30 storeys to enhance the rigidity of external frame

- **Transfer truss**
  usually adopted to provide spacious ground entrance. Building load from columns on upper floors is transferred down to fewer main columns (super / mega columns) through huge truss system (with height equivalent to 2-3 storeys), and then down to the underground foundation.

The International Finance Centre is built using a ‘Core and Outrigger’ concept. The core at the centre of the building bears most of the vertical load, while columns at the perimeter carry less weight and are thus smaller in dimension. Loads are transferred to the core through steel outriggers that balance the lateral forces on the whole building.

Steel Structural System

Steel is a common construction material for tall buildings because it has good performance in withstanding compressive and tensile forces. Steel bars can be used to reinforce concrete to add extra structural performance. However, steel is relatively weak in fire-resistance. An extra layer of fire-resisting coating is often put onto the steel surface.

Examples of Structure in skyscraper

- **Core and Outrigger system**: Cheung Kong Centre (CKC), IFC2
- **Steel Frame system**: HSBC Headquarters, Bank of China Tower

Teaching Tips

More information about Forces and Structure

Topic 01 ‘Forces in Buildings — A Historical Review’
Topic 03 ‘Model Making Workshop — Structure of Tall Buildings and Towers’.
### 1.3 Structural System Comparison of Skyscrapers

<table>
<thead>
<tr>
<th></th>
<th>HSBC Headquarters</th>
<th>Cheung Kong Centre</th>
<th>Bank of China Tower</th>
<th>Murray Building</th>
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</thead>
<tbody>
<tr>
<td>Completion</td>
<td>1986</td>
<td>1999</td>
<td>1990</td>
<td>1969</td>
</tr>
<tr>
<td>Height</td>
<td>180 m</td>
<td>283 m</td>
<td>367 m</td>
<td>89 m</td>
</tr>
<tr>
<td>Storey</td>
<td>47</td>
<td>62</td>
<td>72</td>
<td>25</td>
</tr>
<tr>
<td>Architect</td>
<td>Norman Foster</td>
<td>Cesar Pelli</td>
<td>I.M. Pei</td>
<td>Former Public Works Department</td>
</tr>
<tr>
<td>Structure</td>
<td>Exoskeleton steel Truss</td>
<td>Composite structure: Core wall and composite column external frame</td>
<td>Triangular truss in composite steel and reinforced concrete</td>
<td>Composite structure: Core wall and external reinforced concrete shear wall</td>
</tr>
</tbody>
</table>
### Court of Final Appeal 終審法院
(Former Legislative Council Building 前立法會大樓)

<table>
<thead>
<tr>
<th>Built in</th>
<th>1900-1912</th>
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<tr>
<td>Architects</td>
<td>Aston Webb and E. Ingress Bell</td>
</tr>
<tr>
<td>Structure</td>
<td>Granite column and Dome structure</td>
</tr>
</tbody>
</table>

**Use**
- **1912-1978:** Supreme Court
  During Japanese occupation in World War II (December 1941 to August 1945), the building was used as the headquarters of Hong Kong Military Police.
- **1985–2011:** Legislative Council
  Due to structural crack discovered during the construction works of the Mass Transit Railway in 1978, the building was temporarily closed for reinstatement and alteration works. It was reopened in 1985 as Legislative Council Building.

In 2012, the building was closed and planned to open as the Court of Final Appeal by 2015.

#### Various parts of a classical Greek façade, composed mainly of stylobate, colonnade, entablature and pediment. Some of these features are also used in the Neoclassical Old Supreme Court Building.

#### Structure under Western Classicism’s Influence
The three storey granite structure contains design features of Roman and Greek architecture, with Ionic style columns and dome elegantly proportioned. The wide arcade on ground floor and balcony above is designed to respond to sub-tropical climate of Hong Kong. It acts as a buffer zone to prevent direct sunlight from entering to the building.

- Pediment
- Frieze
- Architrave
- Entablature
- Columns
- Stylobate
- Ionic Column
- Dome
- Pediment
**Dome**

A dome is a hemispheric roof structure. Structurally, it can be analysed as an arch that has been rotated around a central axis. Like an arch, a dome enables large spaces without interior support. Tension rings can be used to withstand the outward pushing forces of the dome.

**Arch structure**

The dome is a form seen in many old structures, e.g. Pantheon (Italy), Taj Mahal (India).

It is a spherical surface structure having a circular plan, constructed in rigid material like granite or reinforced concrete.

**[Do you know...?]**

Under the rule of the British colonial government, the Old Supreme Court was built in a Western architectural style in the Eastern city of Hong Kong. This is Neoclassical style, with features of classical Greek and Roman architecture (850 BC-476 AD), but constructed after 18th century. However, because of climatic and geographical differences, architectural features were altered to fit local conditions. This mixed, adaptive design is what we call the Colonial Style.
### Structural Features

1. **The structure can be disassembled into kits-of-part and reassemble in another site**

2. **Column free floor area**
   The 8 steel masts carry all the structural loads and allow the creation of column-free floor area. It maximizes the flexibility to adopt to different spatial arrangement.

4. **Clear and unobstructed circulation**
   All lifts and escalators located at the side of the building.

5. **Unobstructed view within the building and towards external area.**

6. **Sustainable design**
   - 40 m high atrium with a bank of giant mirrors on its top, which reflects the sunlight from a light scoop down through the atrium to the public plaza.
   - Exterior reflector reflects natural sunlight into the atrium space
   - Building services are laid under raised floor to allow the most efficient air-conditioning control and flexible use of electrical supply

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### HSBC Headquarters

- **Built in**: 1983-1985
- **Architect**: Lord Norman Foster, Pritzker Prize-winning architect

### History of the HSBC Main Building

- **First generation**: 1865-1886
- **Second generation**: 1886-1935 (Victorian style)
- **Third generation**: 1935-1978 (mixed Art Deco and Stripped Classical Style i.e. classical elements simplified to show only structural or proportional systems)
- **Current building**: 1986 (High-tech architecture)

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**Contrasting architectural styles in Central — Old Supreme Court in Neoclassical style and the nearby HSBC Main Building in High-tech style (Source: Ian Lambot)**

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**[Do you know...]**

The HSBC Headquarters is surrounded by tall buildings and a hill at the south. In order to introduce natural light into the atrium, a solar reflector was installed to reflect sunlight from higher level into the 40 m atrium space. This approach was relatively new in the 1980s. Although people doubt the performance of this sun reflector, the goodwill behind the idea should be appreciated.

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**Phototaking Tips**

Photography is not allowed anywhere in the building except in the atrium.
How are different loads on the building transferred to the underground structure?

In the following diagram, it is given that the distance between two structural masts = d; and weight of the floor slab = W. Assume the weight of each floor is acting in the middle of the floor slab.

1. Identify how the weight of each floor transferred through the structure.
2. Can you identify the pivot points of the structure?
3. Calculate the moments of force (torque) at each pivot point of the structure.

Moment at each pivot point
= \( F \cdot d \)
= \( \frac{W}{2} \times \frac{d}{2} \)
= \( \frac{Wd}{4} \)

[Exercise]

The structural system of the HSBC Headquarters is called ‘Exoskeleton Truss Frame’. Floor slabs are suspended by pairs of trusses. The trusses are supported by the structural masts which transfer all vertical forces to the underground structure.

The structural system of the HSBC Headquarters

Simplified diagram of the structural system of the HSBC Headquarters
Cheung Kong Centre (長江集團中心)

- **Built in**: 1999
- **Structure**: Composite structure - Core wall and composite column external frame
- **Architect**: Cesar Pelli
- **Use and Facts**: The headquarters of Cheung Kong (Holdings) Limited, and is owned and managed by its associated company Hutchison Whampoa Limited, while other tenants include several multinational banking firms.

It sits on the combined sites of the former Hong Kong Hilton, which was demolished in 1995/6, and Beaconsfield House, sold by the Government in 1996.

[Exercise]

1. Transfer truss structure (see photo on right) used about ground level entrance. Suggest the function of it.

   **Suggested Answers**
   - Transfer vertical loading from perimeter column to core
   - Allow spacious open on G/F entrance
**Bank of China Tower (中國銀行)**

**Built in**: 1985-1990  
**Structure**: Triangular truss in composite steel and reinforced concrete  
**Architect**: I. M. Pei, Pritzker Prize-winning architect  
**Use**: Headquarters of Bank of China Hong Kong. Part of the storeys are leased out. The site was the former address of the Murray House, which had been dismantled in 1982 and relocated to Stanley in 2000s.

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. However, there have been comments on the ‘poor Feng Shui’ the buildings causes to the surrounding due to the triangular form and the many crosses (X) of its structural frame.

**Teaching Tips**  
When having field trips in Central, references can be made on Liberal studies 06: 'VISIT : Central - Central Business District (CBD)' and Arts 09: ‘VISIT: Central - Architectural Forms in Different Times’.

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**Exercise**

1. Draw the load path to show how the loads on the building being transferred to the earth.  

2. Why do you think the architect choose to use triangle as the composition of the structure?

**Suggested Answers**

**Structurally effective:**
- Triangular shape as most structural stable geometry  
- Pure use of cross brace and triangular framework effectively carries building load, and reduces use of steel by 30% as compared to typical column and beam system

**Structural aesthetics:**
- Concise geometry & structurally expressive  
- Given relatively small footprint, the structure adopted a square base with offset of triangular prism up along the tower (mimic of bamboo)  
- The proportion was carefully considered to provide a slender appearance  
- Distinctively different elevations on four sides.  
- The effective use of footprint free up large landscaping space on ground level beside the entrance.
Murray Building (美利大廈)

- **Built in**: 1969
- **Structure**: Composite structure - Core wall and external reinforced concrete shear wall
- **Architect**: Public Works Department of the time
- **Historical Facts**: Upon its completion, it was the tallest government building at that time.

  The site was the former address of the Murray House, which had been dismantled in 1982 and relocated to Stanley in 2000s.

  Murray Building became vacant upon relocation of its current offices to the new Central Government Complex at Tamar by end-2011.

**Teaching Tips**

More information about sustainability in Architecture


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**Exercise**

1. Identify the direction where solar glare comes from during morning and late afternoon.

   - **Suggested Answers**
     - Morning - SE
     - Sunset - SW

2. Suggest the advantages of the design of perimeter shear wall and angular oriented windows.

   - **Suggested Answers**
     - It is a sun-shading device that lowers the air-conditioning loading of the building.
     - It also avoids discomfort due to solar glare during morning and late afternoon.
Summary

The field trip introduces typical structural systems used in skyscrapers in Hong Kong, and explains how they support themselves as well as the loads imposed on them by the environment. They are the real-life applications of physics. Skyscrapers in Central are not only aesthetically pleasing, but also showcase innovations in building materials and technology and influence the identity of the city. Some even show environmental concerns that have been a hot global issue in recent years.

Key Words

Composite Structure
Structural Frame
Core
Steel
Reinforced Concrete

Further reading

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