DESIGN TRENDS OF TALL BUILDING IN HONG KONG

BY

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B.S.C.E., Tufts University May 2002

Submitted to the Department of Civil Engineering
in partial fulfillment of the requirements for the degree of

Master of Engineering in Civil and Environmental Engineering
Massachusetts Institute of Technology

June 2003

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Abstract

Hong Kong, located at the southern tip of China, is well known as one of the important financial capitals in Asia. As a result, high demand of space is required. With improving building technology, buildings in Hong Kong are reaching higher limits. This thesis presents an overview of design trends of tall building in Hong Kong from both architectural and structural perspectives. It also provides the design details of a few most famous and challenging structures in the past 20 years.
Acknowledgments

To My Mom and Dad:

Thank you very much for your love and support. Without you, I would never be able to become the person I am today.

I would like to thank Professor Jerome Connor for his valuable guidance and advice throughout my studies at MIT. Also, I would like to thank Arup Hong Kong for providing me with relevant information for my thesis.
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Chapter 1       Introduction

1.1   Background

Hong Kong started to develop its economic life slowly after the United Nations’ embargo on trading with China in the 1950s. Hong Kong became the link between China and other countries. Its success at being an international trade port was due to a number of factors, including cheap labour, capital input, and the government’s tax policies.
The strong capital and manpower supply from China led to the development of light manufacturing industries in 1950s and 1960s. Hong Kong’s tax policies began to attract foreigners to invest more, resulting in the rapid growth. As more people invested, more office spaces were needed in this relatively small area. After the erection of the Jadine House, the first skyscraper in Hong Kong, spaces were created by building higher office towers.
Chapter 2  Tall Buildings in Hong Kong

2.1 Overview of Tall Buildings in Hong Kong

Hong Kong, being well known as one of the important financial capitals in Asia, has a long history of building tall buildings for offices and residences. The reason would be the limitation of available space in such a dense populated city. Most of the commercial and residential buildings are, on average, more than 30 storeys high. In 1973, the first skyscraper, the Jardine House, was erected. Ever since then, the trend of building tall buildings continued and still going on today. Many well-known commercial buildings such as the Hong Kong and Shanghai Bank Headquarter, Bank of China Tower and the 72-storey Central Plaza were constructed in the 80s and 90s. Building technology has improved throughout time, allowing the building of higher skyscrapers. Some of the most famous buildings from different period are shown in table 1 below.

<table>
<thead>
<tr>
<th>Building Name</th>
<th>Year</th>
<th>Stories</th>
<th>Height (ft)</th>
<th>Main Structural Material</th>
<th>Style</th>
</tr>
</thead>
<tbody>
<tr>
<td>JARDINE HOUSE</td>
<td>1973</td>
<td>52</td>
<td>586</td>
<td>Steel</td>
<td>Modern</td>
</tr>
<tr>
<td>Hopewell Centre</td>
<td>1977-80</td>
<td>64</td>
<td>709</td>
<td>Concrete</td>
<td>Modern</td>
</tr>
<tr>
<td>Bank of China Tower</td>
<td>1982-90</td>
<td>72</td>
<td>1,205</td>
<td>Steel/concrete</td>
<td>Structural expressionism</td>
</tr>
<tr>
<td>Hong Kong &amp; Shanghai Bank</td>
<td>1983-85</td>
<td>47</td>
<td>587</td>
<td>Steel</td>
<td>Structural expressionism</td>
</tr>
<tr>
<td>Lippo Centre I</td>
<td>1986-88</td>
<td>44</td>
<td>564</td>
<td>Concrete</td>
<td>Brutalist</td>
</tr>
<tr>
<td>Central Plaza</td>
<td>1989-92</td>
<td>78</td>
<td>1,227</td>
<td>Concrete</td>
<td>Postmodern</td>
</tr>
<tr>
<td>The Centre</td>
<td>1995-98</td>
<td>79</td>
<td>1,135</td>
<td>Steel</td>
<td>Modern</td>
</tr>
<tr>
<td>Manulife Plaza</td>
<td>1996-98</td>
<td>52</td>
<td>789</td>
<td>Composite structure</td>
<td>Modern</td>
</tr>
<tr>
<td>Cosco Tower</td>
<td>1998</td>
<td>53</td>
<td>755</td>
<td>Concrete</td>
<td>Modern</td>
</tr>
<tr>
<td>Cheung Kong Center</td>
<td>1999</td>
<td>62</td>
<td>928</td>
<td>Steel</td>
<td>Modern</td>
</tr>
<tr>
<td>Two International Finance Centre</td>
<td>1999-03</td>
<td>88</td>
<td>1,352</td>
<td>Composite structure</td>
<td>Modern</td>
</tr>
</tbody>
</table>
2.1.1 Issues in tall building design and construction in Hong Kong [3]

The development of tall building construction has recently introduced a few innovations, which allow buildings to be constructed in lower cost using improved analysis technique and by using construction-led principles of design. The cost could be minimized by lowering construction time, which decrease labour time on site and prefabrication of elements off-site.

In Hong Kong, there is a trend of constructing composite structures. They are typically structures that use concrete core, steel composite floors and a steel concrete composite perimeter frame. This is a reflection of the market conditions in Hong Kong which provide a number of advantages such as the benefit on the speed for erecting floors and perimeter frames of steelwork construction, the use of mature and highly efficient climbform and jumpform construction techniques for reinforced concrete cores, the effective balance between the demand on skilled (steelwork) and less skilled (reinforced concrete) labours, offering a good balance between crane demand and the advances that have been made in concrete pumping technology and allowing the structure to benefit from the recent developments in high strength concrete.

The granites used in Hong Kong are suspected to have a limited strength potential. Therefore, Hong Kong concretes have a lower modulus of elasticity and higher shrinkage characteristics than those listed in many materials code. Commercial concrete mix design was largely based on dry-batch technology and empirical designs with little experience with low water to cement ratio and super-plasticizer designs. High strength concretes tend to have significant cracking in elevated temperatures.
2.2 The Hongkong & Shanghai Bank Headquarter

In late 1970s, Hong Kong had raised its status as an international banking and commercial centre. The Hongkong & Shanghai Bank had become known and had grown into one of the major and most important international banks in the world. Therefore, there was a need for the redevelopment of its headquarters to meet its increased spatial requirement and to become a symbol of the bank.

"The Hong Kong and Shanghai Bank by Norman Foster is probably the best known, and most widely publicized building of the decade, largely because it was claimed to have cost more money than any other building to build. Notwithstanding that kind of publicity and the building’s subsequent overshadowing by far inferior competitors, it remains a unique architectural achievement and a small wonder of the modern age."

2.2.1 Preliminary concept [7]

The Bank required the following fundamental elements.

- A basement to provide secure access to security and safe deposit vaults; loading and unloading facilities for bullion; space for normal storage and equipment of an office building; public space for exhibition and general purposes.

- A superstructure to provide a multilevel banking hall around a central atrium space; headquarters office accommodation, including the specialist departments associated with a major international bank; apartments and executive suites; recreation areas; restaurant and kitchen facilities; gardens and terraces at high level; a helipad and viewing gallery at the top of the building.

- Overall to provide maximum flexibility for changes in operational use and able to respond to the needs and demands of developing banking technology.

The structural engineering response to the preliminary architectural concepts was to create a 590 feet high tower, to create as much unobstructed floor space as possible, to prefabricate offsite because of congestion in Hong Kong’s central area, and to use the structure as the basis to give the building its distinctive architectural expression. Ground conditions in the central area of Hong Kong are not suitable for deep excavations, but the high cost of land and the planning height restrictions made multiple basements a solution.

The final design was to create a 47-storey steel framed superstructure of overall height of 656 feet standing 590 feet above ground with a four level basement. A total floor area of 1080,000 ft² is provided by the structure.
2.2.2 Superstructure [7]

The size of the superstructure is about 177 feet x 230 feet. The main vertical structure of the building is provided by two rows of four steel masts. Each mast consists of four tubular steel columns interconnection by rectangular beams haunches at storey height intervals of 12.8 feet. The column diameter remains constant on all masts within a zone but the thickness of the steel changes to suit the load requirement. The truss rectangular elements were connected with the masts by passing pins through end clevis plates into the large spherical bearings located within the thick gusset plate.
Figure 2.2.3 Suspension Truss Components
For the floor structure, it consists of a 0.33 feet thick reinforced concrete slab cast in situ on profiled metal decking. It spans 7.9 feet between secondary beams. In Hong Kong, it is not allow using the metal decking as principal slab reinforcement. Therefore, the decking was used as permanent shuttering only. The slab also acts as a horizontal diaphragm link between the masts.

2.2.3 Superstructure Frame Analysis [7]

The design of the superstructure primary framework required extensive structural analysis. There are three main categories:

- Static analysis to demonstrate strength and to satisfy the Hong Kong Building Code requirement.
- Dynamic analysis to determine the performance of the building under wind loading
- Static analysis to determine the cumulative deflections of the framework during the construction process

Although Hong Kong is located in a low to moderate seismic region, the very high wind load cause by typhoons were the governing design case.

The detail static analysis of the framework was performed on a three-dimensional space frame skeletal finite element model. The basic model comprised elements for the masts, suspension trusses and cross bracing for one half of the structure contained over 3200 nodes and 3000 elements. All members in the eight masts were modelled as single elements with bending and shear stiffness parameters calculated in order to determine the correct sway stiffness. There are many ways for the floor to interact with the main steelwork frame. All the masts are connected together with the diaphragm action for overall movements and for torsion about the vertical axis.
In order to determine the static behaviour of the structure, the gravity load support system was divided into five zones vertically. The symmetry of structure and asymmetry of gravity loading cause the structure to deflect laterally during construction as well as coupling of translation and torsion in natural vibration modes.

The movement of the building during construction was very important for achieving an accurate final geometry of the building frame. Therefore the step-by-step construction of the building was simulated by skeletal models of the main frame at different stage of construction.

2.2.4 Wind Tunnel Testing [7]

The wind engineering study for this building is one of the most extensive studies for a building. Hong Kong is located in an area that has frequent typhoons; the wind loading was a crucial factor in the design of building frame, glazing and cladding. It is important to take account the occupant reaction to wind induced sway and wind comfort.

It is important to study the wind climate in Hong Kong in order to accurately predict the structure behaviour. There are mixed populations of winds in Hong Kong. Although typhoons are the strongest winds and always dominate the design of structures, they only occur for an average of three times per year.

Therefore, it is important to design for the non-typhoon winds, which occur for the majority of the time for the comfort aspects. It is difficult to evaluate the wind records from different areas in Hong Kong because the complex topography causes large local different in wind speeds. As a result, a large topographical wind tunnel model of the Hong Kong area was used.
2.2.5 Dynamic Analysis [7]

Dynamic analysis was needed to predict the natural period of vibration of the building. Instead of using a large skeletal finite element model, a simpler model was used. The building was divided into five zones and idealized to a five lumped mass zone with three degrees of freedom per zone.

The dynamic prediction of the building to wind was done by combining the wind tunnel force balance measurements with the predicted dynamic properties of the building. The calculations to predict the dynamic responses were based on the assumption that the mode generalized forces were proportional to the overturning moment and torque measured in the wind tunnel tests.

2.2.6 Superstructure movement analysis [7]

Because of the large floor spans and non-symmetrical load distribution, it is important to have accurate assessments of the movements of the main structural elements of the building both during construction period and during its use. The erection of the building was divided into zones. Each floors and its suspension trusses was structurally completed before handing over. The central area floor steelwork within a zone was erected closely behind the masts, instead of waiting until the suspension trusses for that zone were complete. In order to assess the movements of the lower zones during construction of the higher zone, the building sequences of the structure were broken down into 12 steps. Analytical models for representing the stage of completion of the structure at each step were made based on the main analysis model.

The total cost of this distinctive HSBC headquarter exceeded US$ 670 million. The atrium is 52 meter tall. The module design of the building consists of five steel modules prefabricated in Britain and shipped to Hong Kong. A total of 30,000 tons of steel and 4,500 tons of aluminum were used.
2.3 Central Plaza 1992

Central Plaza is a 78-storey office tower developed at the Wanchai waterfront of Hong Kong. Construction began at 1989 and finished at 1992.

2.3.1 Design [8]

Central Plaza tower contains three sections, a 100 ft high tower base forming the main entrance, a 772 ft tower body which contains 57 office floors and a 335 ft tower mast.

It is the tallest building in Hong Kong until the completion of the Two International Finance Center. It is also the World’s tallest reinforced concrete building until the completion of CITIC Plaza in Guangzhou, China.

There are 1,000 neon transformers in a total of 6,000 m on the façade of the tower. The tower shows the time by changing the colour of the 4 sets of neon tubes where each hour is represented by a different colour.
2.3.2 Design Constraints [8]

In Hong Kong, people enjoy having a harbour view. Because of this, the Central Plaza was designed to be in triangular shape where it provides 20 percent more of the office area facing the harbour than being a rectangular shaped building. Triangular shape floor plan would also provide better floor area utilization as well as an increase of overall usable floor area efficiency by 81%.

2.3.3 Structural Constraints [8]

![Design Wind Pressure](image)

Figure 2.3-2 Design Wind Pressure

The water table of the site is about 2 meters below ground level. For a building of this height, it was designed to have a 6-storey basement. This resulted in the design of using diaphragm wall.
Because of using the diaphragm wall design, the basement was constructed by the top-down method. This allows the superstructure to be constructed at the same time as the basement, which removes the building time of the basement from the critical path.

Another structural constraint would be wind loading. Hong Kong is situated in an area with typhoons. Central Plaza was designed not only be able to resist the strong wind load, it also need to limit the acceleration on the top level in order to stay within acceptable standard of occupant comfort criteria.

2.3.4 Steel Structure Vs Reinforced Concrete [8]

The original design of the Central Plaza was to use an externally cross-braced framed tube with beams carrying metal decking with reinforced concrete slab. The core was designed to use steel for carrying vertical load only. Later, the design changed to use highstrength concrete because the developer decided to reduce the height of the superstructure by increasing the size of the floor plate. Climbing form and table form construction methods were used which reduced the construction time to meet with the construction time if building with steel. From a financial point of view, the reinforce concrete design can save HK$230 million compared to a steel design. Also, Central Plaza is now the tallest reinforce concrete building in the world.
2.4 Cheung Kong Center [4]

The completion of the 62-storey Cheung Kong Center represents a success in composite design, fast track construction and advance technology. It also represents the new design trend of using outriggers, composite slab and composite columns.

2.4.1 Design of the Office Tower [4]

The height of the tower is 928 feet and it has a 155 feet x 155 feet square floor plan. The tower is made of concrete core and composite slab. Because of having the steel beams spanned between the perimeter columns and the core, it provides a 36 to 46 feet column free space. Concrete filled tube composite columns were used for the perimeter columns.
for their simplicity, speed of erection and economy. This also minimized the steel area and to omit both formwork and fire-protection. With the steel tubes alone, it is designed to take a minimum of six floors before putting in the concrete. Three floor of C60 concrete was filled into the steel tubes each time and this did not affect the construction of the decks. The fire limit state approach was applied to the columns and slabs so that they can resist fire of 1 hour without any fire-protection. The car park is located at the basement. Therefore, it was design not to have all perimeter columns to go through the basement. As a result, all the loads from the 24 perimeter columns are transfer into 8 supercolumns using a double storey high transfer structure provided at level 2 & 4. The transfer structure is basically a group of steel box sections. The supercolumns are composite columns with cross shape steel sections filled with concrete.

At the lower zone the core of the structure is like a Roman II where it changed into a rectangular core at higher zone. The thickness of the core decrease when travel higher on the building. C60 high-strength concretes were used for the wall of the core.

2.4.2 Lateral Load Resistance [4]

As Hong Kong is located in a low to moderate seismic zone, there is not much seismic design requirement. Wind loading is the main controlling factor in the design of the main structure. In order to determine the behavior of the building under extreme wind load (it would be typhoons in Hong Kong), wind tunnel tests were done at the laboratories in Ontario, Canada. Two of the tests were done to take in account for the wind effects of adjacent buildings and possible future changes in townscape.

In order to determine the natural frequencies of the structure, a modal analysis of the tower structure was proceeded. For a structural damping ratio of 1%, the predicted fundamental natural periods of the tower is 7.6s and 5.6s for bending in weak and strong axis respectively, and 2.4s for the torsion mode.
For controlling the lateral stiffness of the tower, there are several key elements. They are the core, perimeter columns, outriggers and belt trusses. The outriggers are located at 3 levels, floor 23, 42 and 60. Other than outriggers, belt trusses are also provide at these three levels. The outriggers and the belt trusses turn the windward and leeward perimeter columns into axial tension and compression respectively under wind loading. As a result, the whole structure resists the lateral wind forces as a whole.

2.5 Two International Finance Center [5]

![Two International Finance Center](image)

Figure 2.5-1 Two International Finance Center

Two international Finance Center, also known as Hong Kong Station North East Tower, is presently under construction. It will be the tallest building in Hong Kong and the fifth tallest building in the world. The tower consists of 90-storey with a basement.
Reinforced concrete is used for the core of the structure because there would be a significant saving in cost compared to using steel or steel/composite. Instead of creating a tube in tube with a large amount of perimeter column, the perimeter structure was designed to be a minimum for two reasons, the flexibility of office layout as well as
maximizing the views. As a result, outrigger lateral stability solution with eight main megacolumns was chosen. The megacolumns are 11.5 feet x 7.6 feet at the base and significantly decrease in size when going upward.

After analyzing the structure, it concluded that three outriggers levels were needed. They located at the 30th, 50th and 70th floor. Other than the eight megacolumns, there are small secondary columns in the four corners which they support gravity load only. The loads for the small columns are transferred to the megacolumns.

2.5.2 Lateral Support [5]

The same as other tall buildings in Hong Kong, the extreme wind load is often the governing factor. In order to study the response of the building due to wind loading, wind tunnel studies were performed. After performing the test, the predicted period of the building was determined to be 9.1 seconds. Lateral accelerations were also predicted for occupancy comfort. Structural dampers were built into the system for the above results.

The columns assist the core in resisting the wind induced bending moments by connecting to the core through the outriggers. The core also resists all the shear load cause by wind.
2.5.3 Megacolumns [5]

Steel elements are encased with reinforced concrete to form the composite steel/concrete megacolumns. This design was the most appropriate form in terms of cost, buildability, and the size and steel/concrete ratios were also optimize. The total weight of steel in the megacolumns is 10 psi.

2.5.4 Outriggers System [5]

Beams that connect the elevator core to the large columns at the buildings edge are outriggers. The forces of wind and earthquakes are resisted by transferring the axial load of the building to the columns. Outriggers are heavily reinforced with large rebar. The outriggers stiffness ratios for the bottom, middle and upper are 1:0.81:0.64. By making the bottom outrigger stiffer, the overall weight of steelwork decreases. A detail evaluation of the local deformations at the core wall and outrigger interface was made during the design phase.
Chapter 3 Design Trend in Architectural Style

3.1 Different Architectural Style throughout time

Although Hong Kong has only about 30 years of building skyscrapers, it is one of the cities with the most skyscrapers. Different architectural styles turn the buildings in Hong Kong into a city full of art and surprises.

3.1.1 Modernism [10]

Modernism started from about 1940 and is still the most common building style in the world. Modernist buildings have relatively simple design and do not have any applied ornament. The style is similar to the International Style but less strict in its geometry. Modern style became more flexible in shapes, which produce a variety range of designs including cylindrical buildings, sloping roofs and some other unusual shapes. Although the trend shifts toward postmodernism, which revives historical tropes, modernism is still very active of its aesthetic and economic advantages.

In Hong Kong, there is not a definite cut between different architecture periods. In 1970s the first skyscraper in Hong Kong, Jardine House, was built using modern style. The building is a 52 story cuboid with 1748 six feet diameter windows on the facade. Because of the round windows in the metal frame, it is structurally stronger than traditional rectangular windows. This allows a thinner structural frame.
In early 1980s, Hopewell Center was built and took the title of being the tallest building in Hong Kong from Jardine House. It is famous for its cylindrical appearance and its height. It has 64 stories and its diameter is 144 feet. The shape of the building increases its resistance with wind load.
The Center is another example of modern architecture with 79 stories. Other than having an interesting geometry, it has a Cozyvivid low-voltage neon system consisting of 8784 red, green and blue neon tubes. At night, the building turns into a stage of a slowly changing light show.

![The Center](image)

Figure 3.1-3 The Center

### 3.1.3 Structural Expressionism [10]

Structural Expressionism is a “high-tech” branch of modernism where buildings show their structural elements visibly both inside and outside. It is like a showcase of engineering design with detached frames, exposed trusswork and highly complex shapes which requiring unusual engineering. Two of the most famous buildings in Hong Kong in this style are the Hong Kong & Shanghai Bank and the Bank of China.
Hong Kong & Shanghai Bank has a module design consisting of five steel modules prefabricated in the United Kingdom and shipped to Hong Kong. A total amount of 30,000 ton of steel and 4,500 ton of aluminium were used. Because of the module design, the building can be separated and rebuilt at a different location.
Bank of China was designed by the famous American Chinese architect Mr. I. M. Pei. It has 70 floors and was once the tallest building in Asia until the Central Plaza was erected. The building was designed with visible triangle bracings. The façade of the building was constructed with aluminium alloy and blue glass wall.

3.1.4 Brutalism [10]

Brutalism and modernism are similar. However, Brutalist structures are heavier and more unrefined with coarsely molded surfaces, usually exposed concrete. Their designs usually show the roughness of concrete or the heavy simplicity of natural forms. The Lippo Center in Hong Kong built in 1986 is an example. Although it used glass facade, it shows a heavy block-like effect, which is similar to the strongly articulated concrete forms of early brutalism. It is also known as the “Panda” building because it looks like a few pandas climbing up a tree.

Figure 3.1-6 Lippo Center
3.1.5 Postmodernism [10]

Although modernism is always very popular, there are a lot of strict rules. Postmodern architecture, started in 1970s, is a branch of modernism with more freedom in design. It reintroduces historical building elements with less detail. Common features include pyramids, obelisks, arches, columns and combinations of stone and glass on the facade. Postmodernism ranges from classical architecture imitation to playfully unusual designs. An example would be the Central Plaza in Hong Kong. It was erected in 1992 with 78 stories and it is the tallest building in Hong Kong. The pyramidal atrium at the highest floor is the world’s highest church.

Figure 3.1-7 Central Plaza
Chapter 4  Different Structural Types

Throughout time, there are many structural systems developed. It started for building the structure as a rigid frame to building as a long cantilever. Moment resistant frames can be effective options for buildings up to 20 to 30 stories; tubular frames and trusses can reach a lot higher. Other systems have characteristics taken from both.

There are many factors in determining a structural type for a building, this include the general economic considerations, soil conditions, fabrication and erection considerations, mechanical systems considerations, fire rating considerations, community factors, legal factors and availability and cost of main structural materials.

4.1 Bearing Wall Systems [9]

This is the traditional structural system in the erection of tall buildings. The vertical structural elements carry the loads directly to the foundations. The common building material would be stone, brick and reinforced concrete. The height of the structure is limited by the strength of the bearing materials. Buildings in this type are not going to be too high because of the accumulated weight of the walls plus the other dead and live loads. Too high a structure will result in wall becoming so thick that lower floors can no longer function. In Hong Kong, bearing wall systems were used for old apartment buildings, which have small spans between walls.

4.2 Bearing Walls with Core [9]

In this system, one or more cores are added to the parallel alignment of the bearing walls in order to create a lateral load resistance in a direction perpendicular to the bearing walls. The core is formed by grouping two to four bearing walls perpendicular to each other to create a closed geometry. Typical shape would be tube, round or square that is stiff and can resist torsion. The core is often placed in a central location for the convenience of
distributing building services and for an increase in structural integrity. If placing the core off center, it can create additional torsion and rotation, which might require extra resistance mechanisms. This structural system allows a greater free floor area and this is a common system in Hong Kong for building 20 to 30 storeys reinforced concrete office building.

4.3 Self Supporting Boxes [9]

In 1970s, this system was developed when the prefabrication of reinforced concrete structures was at the peak popularity. Prefabricated concrete floor are place on top of each other in a way that each later oriented perpendicular to the one directly below it. Many low cost public housings in Hong Kong use this system to lower the cost and time of construction.

4.4 Core with Cantilevers [9]

In this system, floor slabs are cantilevered out from the solid core supports in the middle. The advantage will be the absence of interior columns and freeing the facade of the structure. The disadvantage is the additional thickness needed for larger cantilever.

4.5 Rigid Frame [9]

Rigid frame system is developed by structural designers from the bearing wall system. However, it is not very efficient. Each member in the system must help in the transfer of lateral loads to the foundations through rigid connections. Buildings in this type are often very regular and not very tall. In order to reduce the lateral sway of the structure, a stiffening core would be added to the standard rigid frame.
4.6 Tube in Tube [9]

The development of this system is very important in modern skyscrapers of great height. The exterior and interior columns of the structure are placed so close together that they almost form a solid surface. The entire building acts as a huge hollow tube with a smaller tube in the middle. This resists a great amount of torsional loading and the lateral loads are supported between the inner and outer tubes. A number of tallest buildings in Hong Kong used this system.
Chapter 5 Conclusion

Hong Kong is a city full of exciting skyscrapers. A lot of tall buildings were built in the past 30 years with an interesting change in design both architecturally and structurally. In the architectural point of view, Hong Kong is a place where architects like to turn it into an architectural gallery which contains of skyscrapers in different styles. In the structural point of view, the growing in technology enables buildings to reach a higher limit.

Nowadays, building designs always use computer-modeling program, which helps the determination of the buildings behavior. The governing design factor in Hong Kong is always the wind loading cause by extreme typhoon situation. The use of wind tunnel analysis helps simulating the dynamic response of the structures. The design trends of tall building in Hong Kong are based on the increase use of computer programs, different structural systems, as well as the use of advance structural elements such as dampers and outriggers. Thus, the design of a skyscraper also depends on whether it is economical or not.
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