LARGE-SCALED BRIDGE PROJECTS IN RECENT HONG KONG

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1. ABSTRACT

Accompanying with the construction of the new Hong Kong International Airport at Chek Lap Kok which commenced in 1994, a series of long span and very large-sized bridges have been constructed as part of the airport or highway strategic development projects in Hong Kong.

Bridges involved in the Airport Core Projects (ACPs) comprise of 2 rough categories, one is of elevated nature with span ranging from 35m up to approximately 90m, and constructed mainly in prefabricated manner in the form of viaduct or other in-situ methods, such as those for the West Kowloon Expressway and the North Lantau Expressway. The other is of long span nature with span ranging from 430m up to 1377m in the form of cable-stayed or cable suspension bridge. Many of these bridges in the ACPs are double-decked with railway in the inner section.

Bridges constructed as part of the highway or railway strategic development projects are mainly in the form of viaduct with averaged span around 30m to 40m, such as those for the Route 3, Tsing Yi North Coastal Road and the West Rail. One most spectacular long-span highway bridge project that built in the recent years is the Ting Kau Bridge. It is a 3-span cable-stayed bridge with averaged span around 460m. It forms part of the 35km Route 3 system of Hong Kong.

This paper features the overall scope and construction process of a few of these world-renowned bridges, which include the Tsing Ma Bridge and Kap Shui Mun Bridge of the ACPs, the Ting Kau Bridge, and some representing sections of viaduct system within the overall highway and railway strategic development projects.

2. REVIEW OF THE RECENT BRIDGE CONSTRUCTION IN HONG KONG

Before the 1990's, there is practically no long-span bridge of significant being constructed in Hong Kong. As the finalization of the construction of the new international airport of Hong Kong in 1992, as well as the implementation of the Territorial Development Strategy in the late 90’s, a series of long-span bridges are come to light. This includes the well-known Tsing Ma Bridge, Kap Shui Mun Bridge and Ting Kau Bridge. Besides, there are quite a number of major bridges, not necessary very long-span in nature, being constructed as part of the airport, railway or highway development projects. This, again, includes the elevated expressway in the West Kowloon, North Lantau, Route 3, and some other new highway projects in various locations of the territory. The soon-completed West Rail projects of the Kowloon Canton Railway, also contributes to a number of such bridges in the northwestern part of the New Territory.
Though the economical climate is undergoing a downturn in Hong Kong in the recent years, the government is still committed to a few major highway projects as a continual enhancement of the long-term infrastructure development of Hong Kong. Of which the 1000m-span Stonecutters Bridge of Route 9, and the 1400m-span Tsing Lung Bridge of Route 10, has been scheduled for completion in 2007 and 2009 respectively.

3. HIGHLIGHT OF THE CONSTRUCTION OF MAJOR BRIDGES

3.1 The Lantau Fixed Crossing

The Lantau Fixed Crossing is one of the Airport Core Projects for the construction of the new international airport of Hong Kong located in Chek Lap Kok. The Lantau Fixed Crossing consists of two main bridges and an elevated expressway, which cost about US$1.4 billion, with a total length of 3.5km. The link provides a dual three-lane expressway and a dual-track for the Airport Railway that starts from the traffic interchange on the Tsing Yi Island, passing through the Tsing Ma Bridge, Ma Wan Viaduct and finally reaches Kap Shui Mun Bridge on the Lantau Island. The double deck configuration of the two bridges and the viaduct is similar, with the carriageway on the upper deck and the railway below.
3.1.1 Tsing Ma Bridge

The main span of Tsing Ma bridge is 1377m. The bridge approach on Tsing Yi is 288m long in 4 spans supported by reinforced concrete piers on the land side. The bridge approach on the island of Ma Wan is 140m long in 2 spans with a suspended side span of 355m long, making the Tsing Ma Bridge close to 2050m in length.

The main structural components of Tsing Ma Bridge compose of two bridge towers, suspension cable, bridge deck and the anchorages on two ends of the bridge. The two 206m high bridge towers are identical, both are in portal form structure. Foundation of the tower on Tsing Yi side was rested on a spread footing on rock. Ma Wan tower was founded on precast concrete caissons resting on a prepared rock seabed approximately 12m below water. Each tower consists of 2 legs, measures 6m wide and tapers from 18m to 9m on the other side. The legs were constructed in reinforced concrete using a self-lifting formwork system (slip-form). Totally 4 numbers of steel trusses were installed in between the legs afterward to improve rigidity and lateral resistance from wind loads. The trusses were later encased with concrete to form the portals. A set of cast steel saddle was placed on top of the tower over which the main suspension cable was supported.

The main suspension cables were formed by the aerial spinning process. The initial strands were taken across the sea channel by barge and lifted to the tower tops. Later strands were placed by “highlining”, based on the previously installed strands. The suspension cable was divided into 97 strands each composed of 368 high tensile steel wires. Each cable was further compacted into a circular shape and bound with temporary strapping. Cast steel cable bands were then fitted, clamped into position by tightening bolts. The cable bands were placed at 18m interval, which served also as the support for the suspender cables that hanged the bridge deck underneath.

There was a gravity-type anchorage constructed at both ends of the bridge to counteract the pull from the suspension cables. The 55m deep anchorage at the Tsing Yi side contains 165000m$^3$ of concrete. The Ma Wan anchorage contains 120,000m$^3$ of concrete and is partially exposed above ground. The anchorage on Tsing Yi side serves also as a connecting structure in which the complicated traffic arrangement for the interchange both for railway and expressway takes place.
The deck units for the main span of Tsing Ma Bridge were constructed and fabricated in box-shaped modular sections. Each section measures 18m long and weighs about 490 tons. After fabrication in UK and Japan, the components were delivered to a site on the bank of Pearl River for assembly, and transported to Hong Kong by barges. The deck modules were towed and with position fine-tuned by tug-boats underneath the bridge. Strand jack gantries mounted and maneuvered using the main suspension cable, were employed for the lifting of the modules.

3.1.2 Ma Wan Viaduct

The Ma Wan Viaduct cuts the Ma Wan Island and links the Tsing Ma and Kap Shui Mun Bridges in between. It has a total length of 503m and elevated average 40m from ground level. The Viaduct consists of 6 continuous spans in a 80-87-87-87-87-75m configuration. The viaduct is a large twin-deck post-tensioned concrete structure. The construction was done in-situ by the use of traveling-type formwork, which could be easily fixed and released by hanger and moved forward to the next forming position on guide rail. The columns that support the viaduct were hollow-sectioned and constructed by self-lifting formwork system, with foundations either rest on leveled bedrock or founded on hand-dug caissons. There was also provision for the connection of a slip road to serve the traffic needs of a new residential development at Ma Wan Island.
3.1.3 Kap Shui Mun Bridge

Kap Shui Mun Bridge has a clear span of 430m and provides a navigation clearance of 47m. The bridge is of cable-stayed design and consists of 2 bridge towers with main and side span on each side of the towers. The main span is cantilevering out from the tower and balanced by stay cables that held down by anchors on the side span. The bridge towers are 150m high reinforced concrete structure, constructed using a typical self-lifting formwork system similarly to that for the Tsing Ma Bridge. Tower on Lantau side was founded on a shallow spread footing on rock and the Ma Wan tower was founded partly on 4m diameter hand-dug caissons and partly resting on rock.

The main span of Kap Shui Mun Bridge is of composite steel/concrete construction, with steel cross frames and steel plate exterior webs, and concrete top and bottom slabs forming the carriageways. The main span was divided into 8.7m long modulated units, which were fabricated in Shekou of China and assembled on a work depot adjacent the bridge on the Lantau side. The 500-ton deck unit was then floated out on a barge and lifted into position by a pair of lifting gantries that mounted on the previously secured deck. The lifting gantries would hold the unit until necessary connection had been made and stay cables installed. The bridge also consisted a section of approach span on both ends of the side span. The approach on Lantau side was constructed in reinforced concrete using incremental launching method. Each segment was 18m long and pushed forward by hydraulic jacks after casting.
3.2 Ting Kau Bridge and the approach viaduct

The Ting Kau Bridge is part of the 35km-long Route 3 expressway system, which links the northwest part of the New Territory with the city center. It is a cable-stayed bridge comprising of 3 main spans and supported by three independent towers. The bridge has two inter-connected decks located on the sides of the tower for each direction of traffic.

The Central Tower, which is the tallest one among the three towers, was founded in the middle of the Rambler Channel on a newly formed island, while the other two towers were mainly constructed on land. 2.5m bored piles were used for the foundation of the towers. The towers were constructed using slip-form with the use of 65 mpa high strength concrete. The most difficult part for the construction of the tower was the installation of two 190 tons steel tower heads for holding the stay cables. They were lifted to the top of the tower using strand jacks.

The deck of the bridge was erected using modulated steel girder segments in a balanced cantilever manner. The segments were lifted to the deck using derrick cranes which were positioned on the last segment. A composite deck was provided, comprising of precast concrete panels, in-situ joined to the main and cross girders. Each segment was further supported by a pair of stay cables.

The abutment is elevated about 85m on both sides of the bridge. The arrangement on the Tsing Yi side was relatively simpler for the terraced ground could be easily formed to receive the side span of the bridge. Since the topography on the Ting Kau side was much lower, the abutment of the bridge was seated on an 80m high end pier. From the end pier there is a 510 long approach section that further provides spur arrangement to three directions of traffic. The approach was constructed in the form of viaduct using cast-in-situ method by gantry forms under balanced cantilever arrangement. The approach is sub-divided into 8 spans, with the maximum span in 110m, averaged 35m above the nearby ground level.
3.3 Elevated structures of shorter span like the West Kowloon Expressway, Route 3, Hung Hom Bypass, Tsing Yi North Coastal Road, Road T7 in Ma On Shan and the West Rail

These projects are typical recent highway or railway projects where elevated carriageways are mainly constructed in the form of segmental viaduct. The topographical conditions encountered in these projects are in general similar, with the carriageways usually constructed along sloppy ground, running on undulated or terraced surfaces, or in locations where busy traffic exists, some even with congested buried services in close proximity. Due to such physical constraints, the carriageways are often elevated, with piers positioned at desirable locations with an optimized span, usually not less than 40m, in order to gain the benefit of space and to balance other attributing factors like cost effectiveness and buildability concerns. By the use of segmental viaduct method that employs suitable type of launching machine for installing the precast beams or girder segments, is method that proved to be quite effective, in particular where the total length of the elevated structure reaches an optimistic scale.

Precast elements for these elevated structures are majority in the form of box-girder, with weight ranging from 15 tons to 160 tons each depending on the capacity and design of the carriageway. For those of smaller section like the elevated rail track of the Airport Railway or the West Rail, typical size of the girder segments are about 15 to 40 tons in weight and can be erected easily.
using methods such as ground supported falsework, balanced cantilever installation, or by the use of under-slung or overhead girder launching machines. For larger segments, like those for the Route 3, a large-sized overhead launching gantry can be used, and erection often done in balanced cantilever or simply span-by-span arrangement. The segments will be glued by epoxy-based adhesive, which serves also as a lubricant and to eliminate any minor miss-matches of the surfaces during installation. Temporary stressing will be applied after segments are mated, followed by threading and permanent post-tensioning. The spans are in general simple-supported on bearing pads on piers. The level and alignment of the spans will be fine-toned before the final positioning on piers.

Table 1 summarized the major bridges involved in the recent railway and highway development projects.

<table>
<thead>
<tr>
<th>Projects</th>
<th>Major bridges involved and the location</th>
<th>Brief description of the bridge</th>
<th>Year of completion</th>
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<tbody>
<tr>
<td>West Kowloon Expressway (WKE)</td>
<td>• 2.5km elevated structures out of the 4.5km expressway, with major elevated interchanging network at Cheung Sha Wan and Lai Chi Kok</td>
<td>• Elevated structure constructed of precast box girder in the form of segmental viaduct, with average span 40m, 15m above ground</td>
<td>1997</td>
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<tr>
<td>Route 3 – Kwai Chung Section</td>
<td>• 4.5km elevated structures out of the 6km expressway, with major elevated interchanging network at Kwai Chung and Tsing Yi</td>
<td>• Elevated structure similar to that in the WKE. Some interchange and channel crossing sections are elevated 40m, double-decked and spanned more than 90m • 1.6km section at Kwai Chung (dual 4-lane) are constructed in precast beams</td>
<td>1997</td>
</tr>
<tr>
<td>Route 3 – Country Park Section</td>
<td>• Ting Kau Bridge crossing the northern part of Rambler Channel • Approach section for Ting Kau Bridge • Interchange in Au Tau at the Yuen Long Plain</td>
<td>• 3-span cable-stayed bridge averaged 430m span • 8-span in-situ RC construction, with max. span in 110m, averaged 35m above ground • Totally 800m in length, average span about 45m and elevated 30m</td>
<td>1999</td>
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<tr>
<td>Project Name</td>
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| Airport Express Line                   | • Linking bridge crossing the Rambler Channel at Tsing Yi  
• Linking bridge between Tung Chung and Chek Lap Kok  
• A 3-span, double-decked viaduct with average span about 120m and elevated 35m  
• A 6-span bridge constructed in segmental launching method, with average span about 60m and elevated 25m above sea level | 1997 |
| North Lantau Expressway                | • 1.1km elevated linking structure at Yam O  
• Linking bridge between Tung Chung and Chek Lap Kok  
• Elevated structure of in-situ RC construction, averaged 45m span  
• A 6-span bridge constructed in segmental launching method, with average span about 60m and elevated 25m above sea level | 1997 |
| Lantau Fixed Crossing                  | • Tsing Ma Bridge linking the Island of Tsing Yi and Ma Wan, including an approach section on Tsing Yi Side  
• 650m Ma Wan Viaduct  
• Kap Shui Mun Bridge including an approach section at Lantau side  
• 1377m span suspension bridge with 288m approach section  
• 6 spanned elevated section of in-situ RC construction. Double-decked, with average span at 85m and elevated 35m from ground  
• 430m span cable-stayed bridge | 1997 |
| Hung Hom Bypass                        | • 1.3 km elevated dual carriageway located in the Kowloon downtown of Hung Hom with interchanging facilities at various locations.  
• Majority of the carriageways are constructed in segmental viaduct with average span 35m, elevated 15m. Part of the sections spanned over the rail track of the Kowloon-Canton railway and the 10-lane tolling plaza of the Cross Harbour Tunnel. | 1999 |
| Tsing Yi North Coastal Road            | • 2.2km dual 2-lane carriageway linking between Northwest Tsing Yi Interchange and Tign Kau Bridge  
• 1.4km carriageway of segmental viaduct construction, average span at 40m and elevated 30m | 2002 |
| West Rail                             | • Total 31km railway project linking the northwestern portion of the New Territory (NT) with the Kowloon downtown.  
• 13km rail-track located in the NT area are constructed in viaduct, with average span 35m and 18m elevated. Some sections at Au Tau Interchange are 90m spanned and elevated 25m | 2003 |
| Road T7 at Ma On Shan                  | • Total 3.2km carriageway as an improvement section to straighten the traffic from Ma On Shan New Town to Northeastern part of NT  
• 1.2km elevated carriageway constructed in segmental viaduct, with average span of 40m and 15m elevated | 2004 |
Fig. 23. Route 3, Country Park Section at Au Tau

Fig. 24. North Lantau Expressway at Yam O

Fig. 25. Hung Hom Bypass crossing the Gascoigne Road

Fig. 26. Constructing the viaduct of the Tsing Yi North Coastal Road

Fig. 27. Viaduct of West Rail crossing the Au Tau Interchange

Fig. 28. Overhead-type launching gantry for the construction of the Road T7 at Ma On Shan New Town
4. TRENDS IN THE CONSTRUCTION OF BRIDGES IN HONG KONG

Construction of large and long-span bridges is of no doubt a part of the major infrastructure development for a city, which is, again, a reflection of the economical climate and development strategy of the area. In reality, the limited land reserve in Hong Kong does imposes stringent conditions especially where the options and cost effectiveness of constructing a bridge is concerned. To cope with these considerations, a few world-class bridges over 1000m span are yet scheduled for completion in the coming decade, in view of keeping Hong Kong to be competitive in particular within the highly economic-active region in the southern part of China. The construction of these long-span bridges is, without much choice, in the form of either cable-stayed or suspension bridges. The technology and experience involved in which, fortunately due to the accumulated experience, are sufficiently mastered by local engineers.

On the other hand, the construction of other medium to short-span bridges is becoming much popular recently as part of the highway improvement strategy in Hong Kong. The shortage of space for highway improvement works, the involvement of complicated interchanging provisions, the familiarization of bridge construction techniques in catering various local constraints with acceptable cost, are factors that made bridges of this type becoming popular. However, some inherited difficulties such as the requirement of large amount of working spaces for the forming, transporting and storing of the roomy precast elements during construction; the operation of the launching works, or arrangement for traffic diversion within difficult urban environments, still makes the construction of highway bridges complicated and costly. Needless to mention working in environmental sensitive locations such as where protection to natural habitats or rural culture is required; or where waste, noise and dust problems are of ultimate concern.

The cost for constructing bridges is unavoidably high in particular working within congested and complicated urban environment like Hong Kong. As a tradition, bridges and elevated highway structures in Hong Kong are mainly constructed in concrete. As a cost saving option, steel bridges, say, in hollow section, box-girder, composite, or any other feasible design, may be alternative choices for highway bridges, like those commonly used in Mainland China and Japan. The saving in initial cost and construction time of using such alternatives may provide surplus capitals and expedite the ongoing infrastructure projects, this is essential especially in the forthcoming years when the economic situation is expected to be less favourable than before.

![Fig. 29. Complicated elevated carriageway crossing very busy servicing traffic](image)
5. CONCLUSION

It is difficult to produce a concise summary to conclude the experience and achievement of bridges construction in Hong Kong during the past years within these pages of text. This paper only aims to provide a highlight of some of these major projects. As a supplement, the author wishes to make use of some record photos, which were taken during the construction of the bridge projects, to serve as part of the illustration.

6. REFERENCE


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