The Bandra–Worli Sea Link (BWSL), officially called Rajiv Gandhi Sea Link, is a cable-stayed bridge with pre-stressed concrete-steel viaducts on either side that links Bandra in the Western Suburbs of Mumbai with Worli in
South Mumbai.[1] The bridge is a part of the proposed Western Freeway that will link the Western Suburbs to Nariman Point in Mumbai's main business district.

The ₹16 billion (US$291.2 million) bridge was commissioned by the Maharashtra State Road Development Corporation (MSRDC), and built by the Hindustan Construction Company. The first four of the eight lanes of the bridge were opened to the public on 30 June 2009.[8] All eight lanes were opened on 24 March 2010.

BWSL reduces travel time between Bandra and Worli during peak hours from 60–90 minutes to 20–30 minutes.[9] As of October 2009, BWSL had an average daily traffic of around 37,500 vehicles.[10]

**History**

Mahim Causeway was the only road connecting the western suburbs to Mumbai's central business district. This north-southwestern corridor became a bottleneck and was highly congested at peak hours. The West Island Freeway project was proposed to span the entire western coastline of Mumbai to ease congestion. BWSL, a bridge over Mahim Bay, was proposed as the first phase of this freeway system, offering an alternative route to the Mahim Causeway.

BWSL connects the intersection of the Western Express Highway and Swami Vivekanand Road (S.V. Road) in Bandra to the Khan Abdul Ghaffar Khan Road (Worli Seaface) in Worli. From Worli Seaface, it connects to Mumbai's arterial Annie Besant Road.

The project was commissioned by the Maharashtra State Road Development Corporation Limited (MSRDC). The contract for construction was awarded to the Hindustan Construction Company (HCC), with project management led by the UK offices of Dar Al-Handasah, with significant technology transfer from China.[11]

The foundation stone was laid in 1999 by Bal Thackeray. The original plan estimated the cost at ₹6.6 billion (US$120.12 million) to be completed in five years.[12] But the project was subject to numerous public interest litigations, with the 5 year delay resulting in the cost escalating to ₹16 billion (US$291.2 million),[12] with the additional interest cost alone accounting for ₹7 billion (US$127.4 million).[12]

BWSL was named in the memory of late Prime Minister Rajiv Gandhi.[1]

**Planning**

The overall project consisted of five parts, contracted separately to accelerate the overall schedule.

- **Package I**: Construction of a flyover over Love Grove junction in Worli
- **Package II**: Construction of a cloverleaf interchange at the intersection of the Western Express Highway and S.V. Road in Bandra
- **Package III**: Construction of solid approach road from the interchange to the Toll Plaza on the Bandra side along with a public promenade
- **Package IV**: Construction of the central cable-stayed spans with northern and southern viaducts from Worli to the Toll Plaza at the Bandra end
- **Package V**: Improvements to Khan Abdul Gaffar Khan Road

Package IV was the main phase, with the other packages providing supporting infrastructure.
**Geology**

Surveys of the seabed under the planned route were conducted before the bridge design commenced. The marine geology underneath the bridge consists of basalts, volcanic tuffs and breccias with some intertrappean deposits. These are overlain by completely weathered rocks and residual soil. The strength of these rocks range from extremely weak to extremely strong and their conditions range from highly weathered and fractured, to fresh, massive and intact. The weathered rock beds are further overlain by transported soil, calcareous sandstone and thin bed of coarse grained conglomerate. The top of these strata are overlain by marine soil layer up to 9m thick consisting of dark brown clay silt with some fine sand overlying weathered, dark brown basaltic boulders embedded in the silt.

**Design**

BWSL was designed as the first cable-stayed bridge to be constructed in open seas in India. Due to the underlying geology, the pylons have a complex geometry and the main span over the Bandra channel is one of the longest spans of concrete deck attempted. Balancing these engineering complexities with the aesthetics of the bridge presented significant challenges for the project.

The superstructure of the viaducts were the heaviest precast segments to be built in India. They were built using a span-by-span method using overhead gantry through a series of vertical and horizontal curves. The 20,000 tonne Bandra-end span of the bridge deck is supported by stay cables within a very close tolerance of deviations in plan and elevation.[13]

**Foundation and substructure**

The construction of the bridge's structure presented major engineering challenges. These included the highly variable geotechnical conditions due to the underlying marine geology of the seabed. At times, even for plan area of a single pile had a highly uneven foundation bed. Further complications included the presence of a variable intertidal zone, with parts of the foundation bed exposed in low tide and submerged in high tide.

The foundations for the BWSL's cable-stayed bridges consist of 120 reinforced concrete piles of 2,000 millimetres (6.6 ft) diameter. Those for the viaducts consist of 484 piles of 1,500 millimetres (4.9 ft). These 604 piles were driven between 6m and 34m into the substrate in geotechnical conditions that varied from highly weathered volcanic material to massive high strength rocks.
Pylon tower

BWSL’s largest pylon towers are 128 m (420 ft) high.

The largest pylons for the bridge consist of diamond shaped 128 metres (420 ft) high concrete tower featuring flaring lower legs, converging upper legs, a unified tower head housing the stays and a continuously varying cross section along the height of tower.

The bridge's pylon towers gradually decrease in cross-section with height. They have horizontal grooves every 3m in height, which permitted inserts. Vertical grooves in the circular sections require special form liners, as well as require attention for de-shuttering. The tower legs are inclined in two directions, which presented challenges in alignment and climbing of soldiers. Construction joints were permitted at 3m intervals only.

To build the pylons, Doka of Austria was commissioned to build a custom automatic climbing shutter formwork system, based on their SKE-100 automatic climbing shutter system. This was fabricated on site and employed to execute all tower leg lifts below deck level.

Pre-cast yard

The pre-cast yard was located on reclaimed land. The yard catered to casting, storing and handling of 2342 concrete-steel pre-cast segments for the project. The storage capacity requirement of yard was about 470 precast segments. As the area available was limited, the segments were stored in stacks of up to three layers.

Structure

BWSL consists of twin continuous concrete box girder bridge sections for traffic in each direction. Each bridge section, except at the cable-stayed portion, is supported on piers typically spaced 50 metres (160 ft) apart. Each section is designed to support four lanes of traffic with break-down lanes and concrete barriers. Sections also provide for service side-walks on one side. The bridge alignment is defined with vertical and horizontal curves.

The bridge consists of three distinct parts: the north end viaduct, the central cable-stayed spans and the south end viaduct. Both the viaducts used precast segmental construction. The cable-stayed bridge on the Bandra channel has a 50m-250m-250m-50m span arrangement and on the Worli channel it has a 50m-50m-150m-50m-50m span arrangement.
Northern & Southern viaducts

The viaducts on either side of the central cable-stayed spans are arranged in 300-metre (980 ft) units consisting of six continuous spans of 50 metres (160 ft) each. Expansion joints are provided at each end of the units. The superstructure and substructure are designed in accordance with IRC codes. Specifications conform to the IRC standard with supplementary specifications covering special items. The foundation consists of 1.5 metres (4 ft 11 in) diameter drilled piles (four for each pier) with pile caps. Bridge bearings are of disc type. The modular expansion joints for the bridge were provided by Swiss Civil Engineering firm mageba.[14]

The viaducts were built utilising pre-cast, post-tensioned, segmental concrete-steel box girder sections. An overhead gantry crane with self-launching capability was custom built on the site to lay the superstructure of the precast segments. The Pre-Cast segments are joined together using high strength epoxy glue with nominal pre-stressing initially. The end segments adjacent to the pier are short segments "cast-in-situ joints". Geometrical adjustments of the span are made before primary continuous tendons are stressed.

Segment types are further defined by the changes in the web thickness and type of diaphragms cast in cell. The segment weights vary from 110 to 140 tonnes (110 to 140 long tons; 120 to 150 short tons) per segment. The segment length varies from 3000 to 3200 mm (9.8 to 10.5 ft). Deck post tensioning is performed at the completion of the erection of each 50-metre (160 ft) bridge span.

Cable-stayed spans

The cable-stayed portion of the Bandra channel is 600 metres (2,000 ft) in length between expansion joints and consists of two 250-metre cable supported main spans flanked by 50 metres conventional approach spans. A centre tower, with an overall height of 128 metres above pile cap level, supports the superstructure by means of four planes of cable stay in a semi-harp arrangement. Cable spacing is 6.0 metres along the bridge deck.

The cable-stayed portion of the Worli channel is 350 metres (1,150 ft) in length between expansion joints and consists of one 150 metres cable supported main span flanked on each side by two 50 metres conventional approach spans. A centre tower, with an overall height of 55 metres, supports the superstructure above the pile cap level by means of four planes of cable stay in a semi-harp arrangement. Cable spacing here is also 6.0 metres along the bridge deck.

The superstructure comprises twin precast concrete box girders with a fish belly cross sectional shape, identical to the approaches. A typical Pre-Cast segment length is 3.0 metres with the heaviest superstructure segment approaching 140 tonnes. Balanced cantilever construction is used for erecting the cable supported superstructure as compared to span-by-span construction for the approaches. For every second segment, cable anchorages are provided.

A total of 264 cable stays are used at Bandra channel with cable lengths varying from approximately 85 metres to nearly 250 metres. The tower is cast in-situ reinforced concrete using the climbing form method of construction. The overall tower configuration is an inverted "Y" shape with the inclined legs oriented along the axis of the bridge. Tower cable anchorage recesses are achieved by use of formed pockets and transverse and longitudinal bar post-tensioning is provided in the tower head to resist local cable forces.

A total of 160 cable stays are used at Worli channel with cable lengths varying from approximately 30 metres minimum to nearly 80 metres maximum. Like the Bandra channel, the tower here is also cast in-situ reinforced concrete using the climbing form method of construction but the overall tower configuration is "I" shape with the inclined legs. Similarly, tower cable anchorage recesses are achieved by use of formed pockets.

The foundations for the main tower comprise 2 metre-drilled shafts of 25 metre length each. Cofferdam and tremie seal construction have been used to construct the six metre deep foundation in the dry.
Bridge management

Toll collection

The Bandra end of the toll plaza has 16 approach lanes. The toll plaza is equipped with an electronic toll collection system.

At both ends, the toll collection options include:

- Automatic electronic payment system through On-board Units mounted on vehicles for frequent-commuters that enable vehicles to pass without stopping
- Semi-automatic cash-less electronic payment via a smart card in unattended lanes
- Manual toll collection for payment by cash, to a toll attendant

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Single Journey</th>
<th>Return Journey</th>
<th>Day Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>₹55 (US$1)</td>
<td>₹82.5 (US$1.5)</td>
<td>₹137.5 (US$2.5)</td>
</tr>
<tr>
<td>Tempo/LCV</td>
<td>₹80 (US$1.46)</td>
<td>₹120 (US$2.18)</td>
<td>₹200 (US$3.64)</td>
</tr>
<tr>
<td>Truck/Bus</td>
<td>₹110 (US$2)</td>
<td>₹165 (US$3)</td>
<td>₹275 (US$5.01)</td>
</tr>
</tbody>
</table>

Monitoring

An intelligent bridge management system (IBS) provides traffic information, surveillance, monitoring and control systems. It comprises CCTVs, automatic traffic counters and vehicle classification system, variable message signs, remote weather information system and emergency telephones. The control centre is located near the toll plaza along with the electronic tolling controls. The control system uses fibre-optic cables running the entire span of the BWSL. The toll management system and advanced traffic management system was installed by Efkon India.

For traffic enforcement, the bridge includes facilities for vehicles to pull over when stopped by enforcement officers or in the event of a breakdown.

Security

The bridge uses mobile explosive scanners for vehicles traveling on the sea link. Scans take less than 20 seconds for each vehicle with sensors above and below the vehicles. Over 180 cars can be scanned per hour by each scanner.

The pillars and the towers supporting the bridge are protected by buoys designed to withstand explosions and collisions. These inflated buoys surround each pillar of the sea link to avoid any damage.

The bridge tower and the control centers feature lightning protection, designed to protect the bridge monitoring, communication and power equipment from possible surges.
Power supply & lighting

The bridge has a reliable and redundant power supply, backed up by diesel generators and auto mains failure panels for critical loads, such as monitoring, surveillance, emergency equipment and communication services including aviation and obstruction indicators. BWSL exclusively uses energy saving illumination systems.

Criticisms

The Economic Times was critical of the Bandra–Worli Sea Link in every particular. First, the cost was not the projected 300 crore but actually cost 1,600 crore or about 430% cost overrun. Second, the project was 5 year behind schedule. Third, the supposedly reduction in commute time did not occur. Traffic bunched up at both ends of the Link causing nightmarish grid lock. The blame rest, as usual, on the notorious Indian corruption and political in-efficiencies. Compared to China, who in a span of 6 years, completed 7 sea links, under budgets and within the time schedules. [20]

References

External links

- Bandra-Worli Sealink Photo Gallery on Flickr (http://www.flickr.com/groups/bandra-worli-sealink/pool/)
- Bandra-Worli Sealink Project (http://www.msrdc.org/projects/bandra_worli.aspx)
- Bandra-Worli Sea Link Project official website (http://www.bandraworlisealink.com/index.html)
Article Sources and Contributors

Bandra–Worli Sea Link  

Image Sources, Licenses and Contributors

File:Mumbai_India_Bridge_.jpg  
License: Creative Commons Attribution-Sharealike 2.0  
Contributors: Ameya charankar

File:Indian Rupee symbol.svg  
License: Public Domain  
Contributors: Orionist

File:Bandra-Worli Sea Link Map.png  
License: Creative Commons Attribution-Sharealike 2.5  
Contributors: Mumbai_area_locator_map.png: cc-by-sa-2.5 derivative work: Abhijitsathe (talk)

File:Mumbai skyline88907.jpg  
License: Creative Commons Attribution-Sharealike 3.0  
Contributors: User:Jeet221990

File:BandraWorliSealinkInsideView.jpg  
License: Creative Commons Attribution 2.0  
Contributors: Satish Krishnamurthy

File:BWSL Cable Stay Bridge.jpg  
License: Creative Commons Attribution 2.0  
Contributors: ShashiBellamkonda

File:Worli skyline with BWSL.jpg  
License: Creative Commons Attribution 2.0  
Contributors: Woodyworldtv

File:Bandra-Worli Sea Link night.jpg  
License: Creative Commons Attribution-Sharealike 2.0  
Contributors: seanpinto

License

Creative Commons Attribution-Share Alike 3.0 Unported  
[creativecommons.org/licenses/by-sa/3.0/](http://creativecommons.org/licenses/by-sa/3.0/)