Transportation needs are increasing very much in developing countries. Both urban and inter-cities transportation infrastructures are being developed very fast for highways and railways. Light rail transit systems are often carried by viaducts, which are more economical than tunnels.

As a consequence, the number and the length of new long bridges are increasing more than ever. In order to build these long structures in a reasonable amount of time, new construction methods have to be imagined. Many long viaduct decks are made from precast segments, 3 to 4m long, assembled using self-moving steel beam. For very long viaducts, this method requires giant precasting yards, as for Dubai metro. This construction method allows assembling a typical 30m span in 2 to 3 days. But this method, although faster than cast-in-place construction, is not sufficiently fast to build very long viaducts in a reasonable amount of time.

The logical solution is to increase the size of the segments, in order to decrease their number, and then the assembling time. We will show some examples of precast full spans, used for highway or railway long viaducts. In that case, pre-tensioning is more interesting than post-tensioning.
Introduction

Transportation needs are increasing very much in developing countries. The urban population represents now more than 50% of the world population, and is still increasing at a high rate.

So, both urban and inter-cities transportation infrastructures are developing very fast for highways and railways. Many populated areas are located near coasts. This means that many islands have to be linked to the continent, and bays or wide estuaries have to be crossed. This implies long bridges.

In towns, light rail transit systems are often carried by viaducts, which are more economical than tunnels.

As a consequence, the number and the length of new long bridges are increasing more than ever. The following table shows the characteristics of some of them.

In order to build these long viaducts in a reasonable amount of time, new construction methods have to be imagined.

Construction with Precast Segments
Many long viaduct decks are made from precast segments, 3 to 4m long, assembled span by span using self-moving steel beam for spans below 50m, or assembled by balanced cantilever for longer spans. For very long viaducts, this method requires giant precasting yards.

For the Second Expressway System in Bangkok, 47km long, the average monthly production was 630 segments. The maximum monthly production was 1013 segments. There were 50 casting cells. This was the largest casting yard in the world. Ten erection trusses were used for assembling [1].
This record was superseded for the Bang Na - Bang Pli - Bang Pakong Expressway (BBBE) in Bangkok also: 95 km long (55 km of standard viaduct and 40 km of ramps and interchange structures), with standard spans of 42 m. The project included also 36 ramps and two elevated toll plazas. The casting yard included 74 casting cells. A total of 40,000 segments were produced. The maximum monthly production reached 1800 segments. A total of 180 frame piers were made from precast segments. The 900,000 m of piles were also precast. The total volume of concrete was 180,000 m. Fourteen erection trusses were used. On this project, the mean assembling speed was 3 to 4 spans per week, with an incredible maximum rate of 1 span per day.

More recently, the Dubai metro, designed by Systra, includes 62 km of viaducts [2]. Typical spans are 32 m. A total of 16,500 segments are to be cast (75% for the Red Line and 25% for the Green line) using 66 moulds (long lines and cells). The daily production is 35 to 40 segments which require ~170 tons of reinforcement and ~800 m of concrete produced by two dedicated batching plants. Casting operations are scheduled to last 2 years.

The casting yard is served by 11 gantry cranes and 8 tower cranes.

The segment weight ranges from 49 t for the most typical to 88 t for some segments of the 3-span units. The segments are transported to site by dedicated trailers (maximum segment length is 4 m).
The spans are erected by several methods:

- span by span by overhead launching gantries (9 nos.). This method is applicable to all the spans except the 3-span units.
- span by span on ground supports (typically when overhead clearance is not available, due to existing structures or overhead power lines). This method is applicable to all the spans except the 3-span units. One span is erected in 1 week.
- balanced cantilever for the 3-span units (segments lifted by crane or lifting frames - 6 nos.). One 3-span unit is erected in approximately one month.

The choice of the overhead erection gantry meets the speed criteria: one typical 32m span is erected in less than 2 days.

In order to reduce the impact onto the traffic and to achieve a good quality, the Contractor chose to precast the pier caps (more exactly pier cap shells to minimize the cranage requirements).

After fabrication and transportation by trailer the pier cap shell is lifted on top of the pier and filled with in situ concrete. The connection to the pier is done through starter bars protruding from the pier shaft. Post-tension tendons are stressed in sequence.

For single track areas, plain pier caps are precast (with a cylindrical hole for the pier shaft starter bars).

Systra has proposed to use extensively a mono pile foundation for most of the bridges. The mono pile concept has been proposed because it increases the speed of construction in comparison with a group of piles foundation.

First, compared to a group of piles, the mono pile reduces the potential conflicts with utilities and hence reduces the re-location works and facilitates an early start of foundation works.

The construction time itself is significantly reduced, as the pile cap works are very simple (same formwork as pile, installation of reinforcement very simple) compared to rectangular piles cap.
SYSTRA designed also 6.9 km of viaduct for the Santiago metro line n°4 and 21.7 km of viaduct for the Delhi metro line n°3, using precast segments.

**Construction with precast full spans**

The construction method using precast segments, although faster than cast-in-place construction, is not sufficiently fast to build very long viaducts in a reasonable amount of time.

The logical solution is to increase the size of the segments, in order to decrease their number, and then the assembling time.

These long bridges can be divided into three categories:

- long bridges over water,
- long bridges for high speed rail,
- long bridges for light rail.

**Long bridges over water**

<table>
<thead>
<tr>
<th>Country</th>
<th>Name</th>
<th>Length (m)</th>
<th>Span (m)</th>
<th>Elements weight (t)</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bahrain</td>
<td>Causeway</td>
<td>12.5</td>
<td>50</td>
<td>1350</td>
<td>1986</td>
</tr>
<tr>
<td>Denmark</td>
<td>Stentoft - Waal (highway + railway)</td>
<td>4.64</td>
<td>110.4</td>
<td>7000</td>
<td>1994</td>
</tr>
<tr>
<td>Canada</td>
<td>Confederation</td>
<td>12.9</td>
<td>250</td>
<td>7000</td>
<td>1997</td>
</tr>
<tr>
<td>Portugal</td>
<td>Lisboa - Vaco da Cama</td>
<td>6.31</td>
<td>78.9</td>
<td>2200</td>
<td>1999</td>
</tr>
<tr>
<td>Denmark</td>
<td>Stensbæk - Reel</td>
<td>6.79</td>
<td>103</td>
<td>3500</td>
<td>1999</td>
</tr>
<tr>
<td>Denmark</td>
<td>Copenhagen</td>
<td>7.85</td>
<td>140</td>
<td>6650</td>
<td>2003</td>
</tr>
<tr>
<td>China</td>
<td>Donghai</td>
<td>31</td>
<td>70</td>
<td>2200</td>
<td>2005</td>
</tr>
<tr>
<td>Korea</td>
<td>Inchon</td>
<td>12</td>
<td>50</td>
<td>1400</td>
<td>2009</td>
</tr>
<tr>
<td>Qatar - Bahrain</td>
<td>Causeway</td>
<td>22</td>
<td>80</td>
<td>2000</td>
<td>2013</td>
</tr>
</tbody>
</table>
These bridges carry highway, and sometimes also railway.

Full precast spans were already used for the Bahrein Causeway built in 1986, with heaviest
deck elements weighing 1350t. Piers were also precast (maximum weight 350t). The
construction speed was 200 m per week.

Since then, this system has been used for many very long bridges located over water,
because it is easy to carry very heavy loads on water.

For very heavy loads, a giant nautical crane, called Svanen due to its swan shape, was built
for the Storebaelt project. Its maximum lifting capacity was 7123t. Its has been reused for
the Confederation bridge and for the Oresund bridge.

For the West Storebaelt (Denmark), precast concrete spans were 110.4m long. They were
"cantilever elements" comprising two half spans on both sides of the pier. Piers were also
precast.

![Storebaelt West bridge](ph: A. Aldag - structurae.de)

For the Confederation bridge (Canada), the piers were precast in two pieces. They included
a special device for ice breaking, since the bridge is located in an area where the sea can
froze.

The weight of the elements was:

- main cantilever element: 7500t
- drop-in span: 1200t
- pier base: 5000t
- pier shaft: 4000t
- For the Oresund, Svanen was used to place:
  - precast piers with caisson foundation, weight up to 4700t,
  - precast composite steel-concrete truss spans 140m long, weight 6000t.

A special lifting tool was fabricated, weighing itself 1800t, in order to place the spans with
Svanen, whose lifting capacity had been increased to 8700t.
For the cable-stayed bridge pylons foundations, foundation caissons 37m x 35m, 20m high, weighing 20,000 t, were precast and towed to the site, using the same techniques as for off-shore petroleum platforms. GPS positioning allowed tolerance of 75 mm.

For the central viaduct of Vasco da Gamma bridge in Lisbon (Portugal), 78.6m long prestressed concrete spans were placed using nautical cranes Rambiz. One preset span was prefabricated every 2 days. Spans were then made continuous with longitudinal prestressing.

Precast elements were used also for the pile caps.

Where the sea depth is not sufficient for nautical cranes, then it is necessary to transport the precast spans on the already built viaduct, and to use a special launching girder to place the precast spans. This construction method was used to place the 50m precast spans on access viaducts of Incheon bridge (South-Korea).

**Long Bridges for High Speed Rail**
In order to decrease as much as possible the land occupied by high speed line railway projects, and to avoid interference with existing infrastructures, some owners have chosen to put long portions of the line on viaducts.

This is the case for Korea and Taiwan high speed lines.

For the Seoul – Pusan high speed line in Korea, SYSTRA designed precast full spans. Typical spans were 25m long and weighted 600t. They used a combination of pre-tension and post-tension. Pre-tension is more economical than post-tension, since there is no sheath and to grouting.

The viaducts were built by Hyundai, Daewoo and Dongbu. The precast spans were brought with a trailer on the previously built spans and then launched to create the next spans. The spans were then made continuous in 2x25m or 3x25m, so as to reduce the quantities involved, reduce the number of structural expansion joints under the ballast, and improve the dynamic behavior. The construction speed was 1 span per day.

For the Taipei – Kaohsiung high speed line in Taiwan, the construction speed was 1.1 km per month. Each 30m span was prefabricated in 2 days (peak cycle), and the total production was 13 spans per week.

SYSTRA supervised the design and the construction of the high speed line between Beijing and Tianjin (China). This included 87 km made from precast spans.

**Long Bridges for Light Rail**

In order to speed up the construction of long light rail viaducts, it is interesting to use precast full spans. This has been used for Mexico line B with box-girder section. SYSTRA designed precast full spans for Taipei metro Neihu line, for Shanghai metro line 8, and for Mumbai metro [3].
Conclusion

In order to build longer and longer bridges, new construction techniques, using precast full spans, have been developed. It is now possible to build 50m of viaduct per day, which is equivalent to 1 km per month, either on land or on sea, for highway or for railway.

References

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Source: