

# **DUBAI LRT VIADUCTS**

## **Precast segmented span by span erection method**

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### **Summary**

This article presents the bridge construction techniques carried out for Dubai light rail transit system red and green lines viaducts. After an overview of the whole project, more than 70 km of metro line and 43 stations, we will focus on the elevated viaduct part which represents 75% the project length, more than 52 km of viaduct.

Chosen bridge construction technique had to meet several requirements due to numerous constraints, among which speed of construction, geometry adjustability, environment disturbance. These project constraints led to use precast segmented span by span erection method. This construction method is the optimal one in terms of construction speed, quantity optimization, construction quality and risk management. On particular locations where constraints obliged to have longer span lengths, balanced cantilever erection precast segments have been used, combining the advantage of precast segment bridge (speed of construction) with balanced cantilever method advantages (longer spans).

### **Key words**

Metro rail bridge, span-by-span construction method, U shape precast segment, self-launching erection gantry, post-tensioning

### **The Project:**

Dubai Municipality identified the need for a rail system to relieve growing motor traffic and support continuing urban development based on studies that began in 1997. Systra was awarded the preliminary engineering contract, and Dubai Rail Link (DURL) Consortium, a consortium of five companies consisting of Mitsubishi Heavy Industries (MHI), Mitsubishi Corporation, Obayashi Corporation and Kajima Corporation from Japan and Yapi Merkezi from Turkey, has undertaken the first two lines of the high-tech driverless rapid transit system (Red and Green lines) on a design and build scheme in July 2005.

The metro will be fully integrated within the road network operated by the Roads & Transport Authority (RTA), a body created in late 2005. The project's ownership,

including future rail lines to be constructed, has also been transferred to RTA in November 2005. Routes will be organized around the backbone provided by the rail system.

Around 1.74 million passengers used the metro in its first month, according to the statistics released by the RTA. The average number of passengers travelling on the Red Line has recently exceeded 140,000 per day.

Red Line (52.1 km) has commenced in August 2005 and Green Line (22.6 km), which intersects the Red Line at two stations, in July 2006. Red Line has been opened into commercial operation on 09 September 2009, a famous target date (09.09.09) set at the very beginning, and Green Line will be handed over to RTA on 15 August 2011.

52.1 km (32.5 miles) long Red Line will have 29 stations, four of which will be underground. It will run from Rashidiva to Jebel Ali passing through Dubai Airport and the American University of Dubai. The whole 52.1km is expected to take 60 minutes.

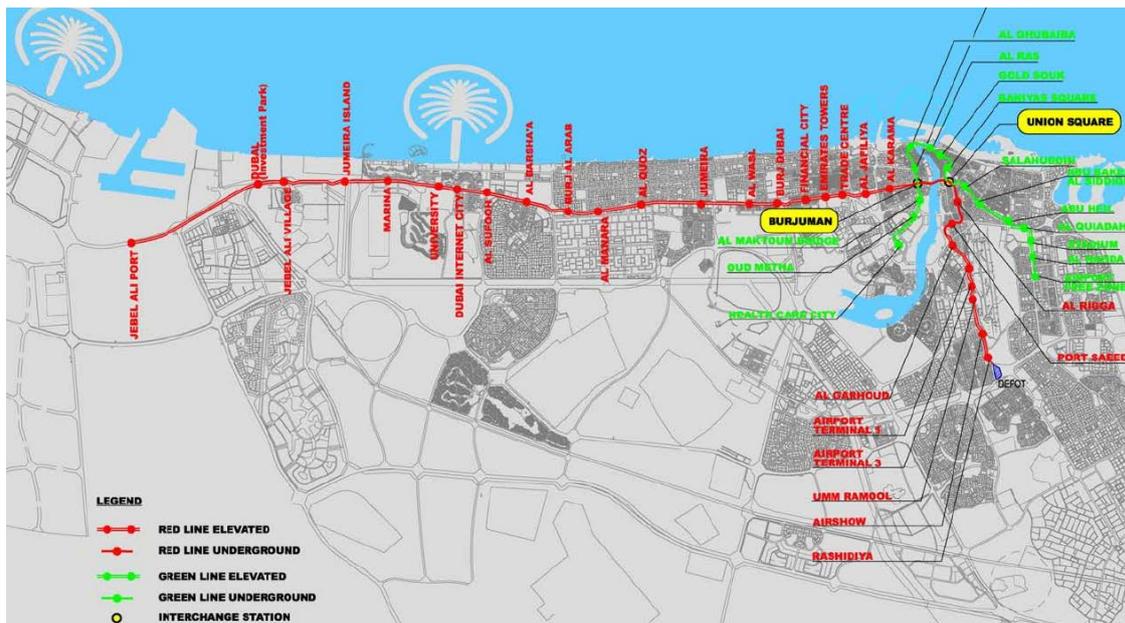
22.7 km (14.2 miles) long Green Line will have 18 stations – six underground and 12 at ground level. Interchange stations with Red Line will be built at Union Square and Burjuman with direct connections to the Red Line.

The 52.1 km of the Red line is composed of:

- 5.5 km of tunnel ( including 4 underground stations)
- 43 km of elevated viaducts
- 3.5 km of at-grade section viaducts

The 22.7 km of the Green line is composed of:

- 7.6 km of tunnel ( including 6 underground stations)
- 15.0 km of elevated viaducts
- 0.6 km of at-grade section viaducts



Picture 1: Dubai Metro Project – Red & Green line plan view

## Project organisation:

The Owner is Roads & Transport Authority. The Engineer appointed by the Owner is Systra-Parsons JV. The Main Contractor for the Metro civil works is JAPAN-TURKEY Metro JV, a Joint Venture between Obayashi Corporation, Kajima Corporation and Yapi Merkezi. The main contractor is a part of DURL Consortium with Mitsubishi Heavy Industries and Mitsubishi Corporation.

JAPAN-TURKEY Metro JV has subcontracted elevated viaduct erection works to a joint venture, called VFR, between Freyssinet (France), VSL (Switzerland) and Rizzani De Eccher (Italy).

Elevated structure overview:

VFR has been responsible for elevated viaduct erection using segmental bridge technology, including precasting of all segments and their erection based on 3 construction methods:

- Erection by means of launching gantry
- Erection on falsework
- Cantilever erection

## Elevated viaducts deck types

Elevated viaducts deck has been design as isostatic U-shape beams. Their span length varied from 20m to 48m, with an average of 30m.

For few longer spans different design has been chosen:

- U-shape double continuous spans has been installed, with an average span length of 45m.
- Cantilever method has been used for span length up to 72m.

A total of 1.778 segmented spans have been installed. The details is presented in the herebellow table.

| Type of structure          | Unit         | RED LINE     | T1 / T3   | GREEN LINE | TOTAL        |
|----------------------------|--------------|--------------|-----------|------------|--------------|
| Iso spans double track     | span unit    | 1.012        | 24        | 325        | 1.361        |
| Iso spans single track     | span unit    | 38           | 58        | 22         | 118          |
| Twin spans                 | span unit    | 66           |           | 26         | 92           |
| Station spans double track | span unit    | 73           |           | 47         | 120          |
| Station spans single track | span unit    | 12           |           | 3          | 15           |
| Balanced cantilever spans  | span unit    | 48           |           | 24         | 72           |
| <b>Total Spans</b>         | <b>Unit</b>  | <b>1.249</b> | <b>82</b> | <b>447</b> | <b>1.778</b> |
| <b>Total Segments</b>      | segment unit | 11.730       | 576       | 4.163      | 16.469       |
| <b>Bridge Length</b>       | meter        | 45.035       | 1.926     | 9.434      | 56.395       |

Table 1: segment viaduct structure type summary

More than 90% of elevated viaducts have been installed using span by span erection method. All segments installed using this method are U-shaped.

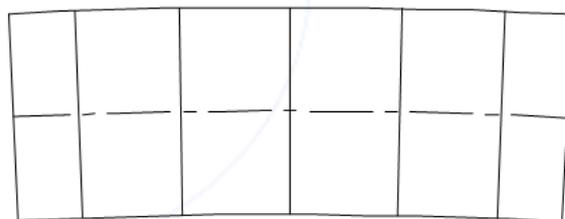
| SEGMENT TYPE | ON PIER SEGMENT   | STANDARD SEGMENT   |
|--------------|---|--|
| DOUBLE TRACK |  |  |
| SINGLE TRACK |  |  |

Table 2: Shape of segments used for span-by-span erection method

Deck classification:

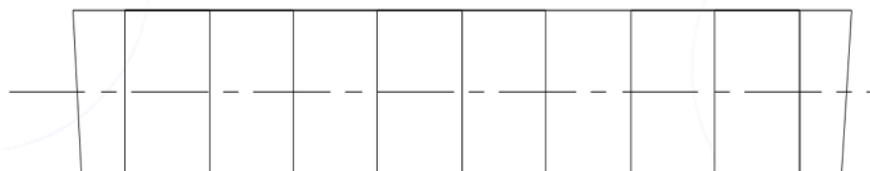
Spans erected using span-by-span method have been classified upon 3 parameters:

- Length varying from 20 to 44m
- Designation (single track or double track)
- Alignment type (straight, curve, clothoid)
- Radius in plane
  - $R < 300\text{m}$              $\Rightarrow$  none
  - $300 < R < 2000\text{m}$      $\Rightarrow$  curved alignment, all segments are curved



Picture 2: curved segments alignment

- $R > 2000\text{m}$              $\Rightarrow$  straight alignment, only on pier segments are curved



Picture 3: straight segment alignment for radius  $>2000\text{m}$

As precised in table 1 here above more than 16.400 units of segments has been precasted in less than 2 years.

For logistic purpose a dedicated precasting yard has been installed in Dubai in order to feed erection process in the requested time.

## Precasting Yard

Due to the required number of segment, a precasting yard dedicated only to this Project has been able to be installed not far from erection site, out of city down town, in Jebel Ali. The casting yard laid over a total area of 540,000m<sup>2</sup>.

This area contained:

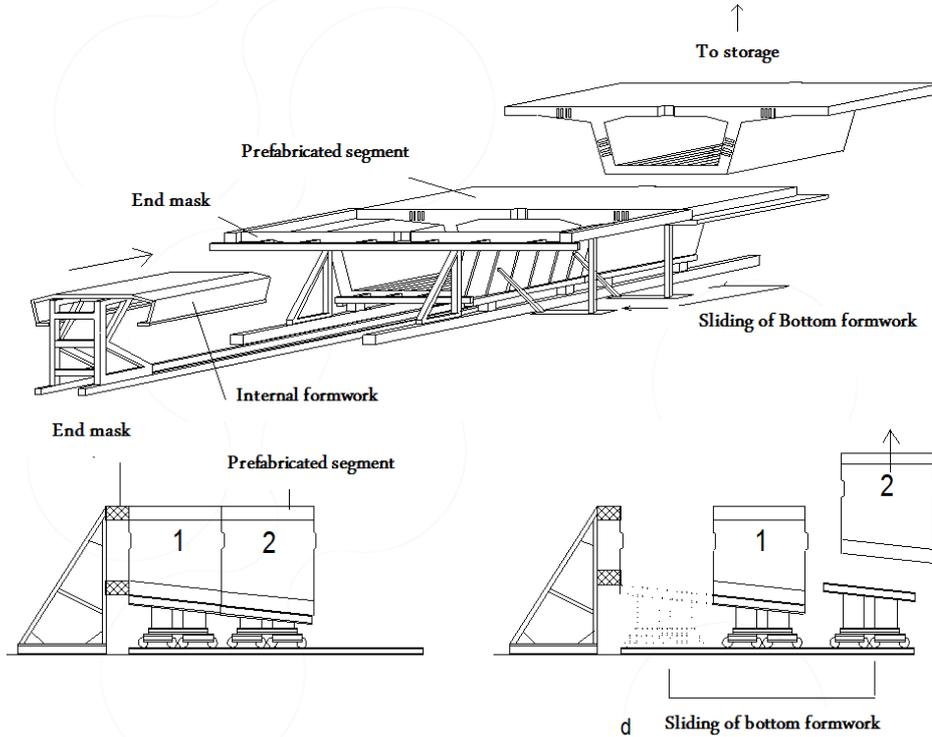
- 9 tower cranes for displacement of reinforcement cages form rebars jigs to casting moulds
- 11 gantry cranes for transport or casted segment from moulds to storage area
- 42 forms for iso segment casting
- 11 forms balanced cantilever segment casting
- 7 forms for segments T1/T3 segment casting
- 2.500 segment storage capacity
- 44 segment segment max. daily production capacity
- 985 segment segment max. monthly production capacity
- 780 employees (including 67 staff)
- Offices and personnel camp.



Picture 4: General view of segment casting yard

Match casting technique has been used on this Project to ensure a severe geometry control.

First, segment reinforcement is preassembled on rebar jig. After a first control, reinforcement cage, including post tensioning ducts, is installed in the casting form by means of tower crane. After mould closing and its geometry setting up, a second geometry control is proceeded taking into previous casted segment geometry. Prior to concreting, post-tensioning ducts are filled with a rigid pipe in order to prevent any damage during concreting. After curing, casted segment is shifted nearby the form in order match the next segment to be concreted. Here below Picture 5 presents the typical casting sequence for segment prefabrication using match casting.



Picture 5: Segement prefabrication – casting sequence principal

After casting of the N+1 segment, N segment is transported to the storage area by means of gantry cranes, waiting for transportation the erection site dedicated trailer.

2 main types of segment has been prefabricated on the precasting yard: so called “iso segments” used for span by span erection (U-shape segments) and particular segments used for cantilever erection.



ISO segment:

|               |                   |
|---------------|-------------------|
| Reinf. weight | 3.5 mt            |
| Concr. volume | 21 m <sup>3</sup> |
| Segm. weight  | 55 mt             |

Picture 6: Typical ISO segment in storage area



Picture 7: Typical balanced cantilever at casting area

Balanced cantilever segment:

Reinf. weight 12.2 / 3.7 mt  
(max/min)

Concr. volume 36 / 18 m<sup>3</sup>  
(max/min)

Segm. weight 100 / 53 mt  
(max/min)

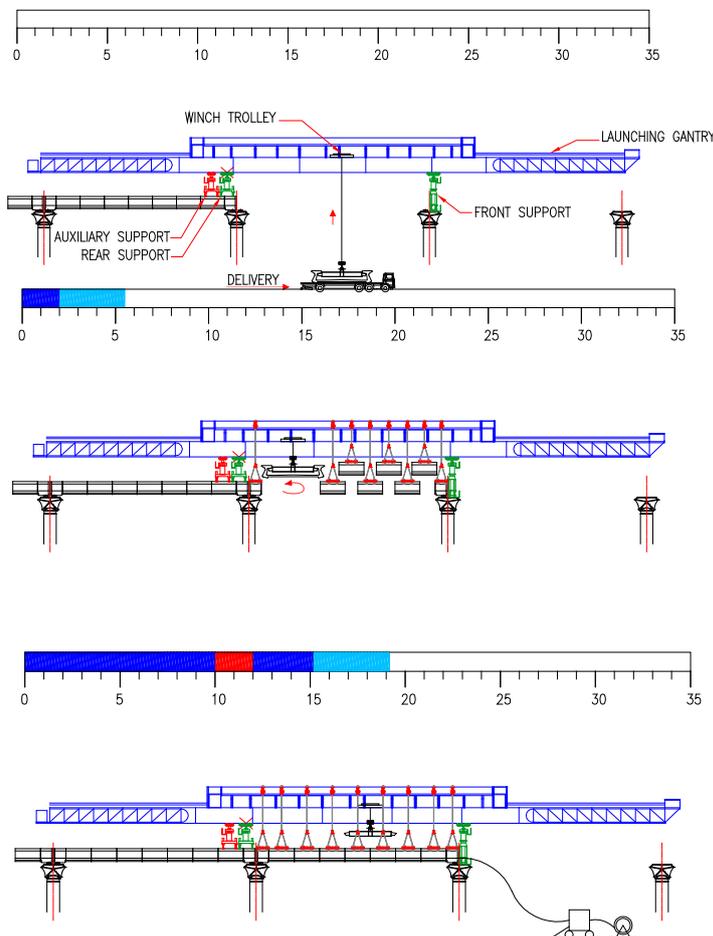
## Precast segmented span by span erection method

Span by span erection of precast segments have been proceeded using 2 technics:

- Erection using self launched girders
- Erection on falsework (to erect under obstacles as bridge or power line)

First, precast segments are delivered from precasting yard area to erection location by means of transport trailers able to bear segments weight (min. 53 mt / max. 100 mt).

Erection sequence using self launching girder is detailed here below.



Step 1:

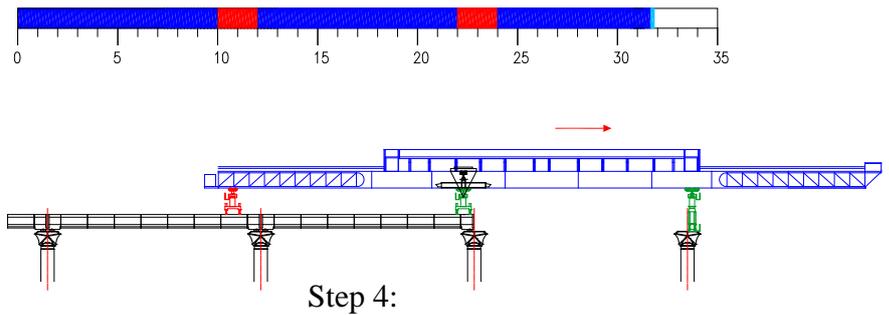
- End of gantry relocation
- Segments lifting by winch trolley

Step 2:

- Segments rotation & transfer one by one from trolley winch to hangers
- Gluing & temporary fixing of segments with post tensioning bars
- Segments geometry adjustment

Step 3:

- Post tensioning installation
- Deck load transfer from launching girder to piers



Step 4:

- Auxiliary support activation
- Rear support transfer to intermediate pier
- Front support transfer to the next pier
- Gantry self launching on rear & front supports
- Auxiliary support translation to rear support

Picture 8: Erection sequence span-by-span method using launching girder

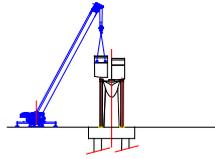
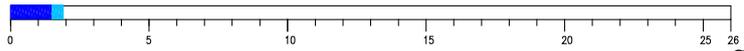
The typical cycle achieved using span-by-span erection launching gantry on Dubai red & green line metro project is on 1,75 day per span. During last month of Red line construction, 9 units of launching girders was used at the same time on site enabling a maximum speed of 150 span installed in one month in July 2008.



Picture 9: Launching gantry during segment geometry adjustment

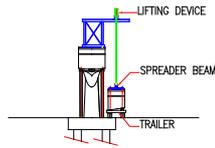
### **Precast segmented cantilever erection method**

Balanced cantilever erection of precast segments has been used where obstacle required larger span: 3 span bridges with 72 m long main span ( $44\text{m} + 72\text{m} + 44\text{m} = 160\text{m}$ ). Erection sequence is detailed here below:



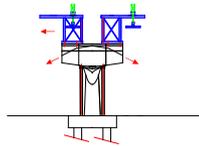
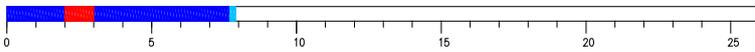
**Step 1:**

- Precast pier segment installation with lorry crane on pier & with temporary supports



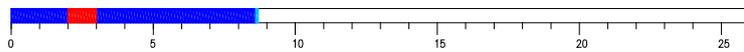
**Step 2:**

- Installation of lifting gantry on pier segment
- Lifting of 1<sup>st</sup> cantilever segments with lifting gantry



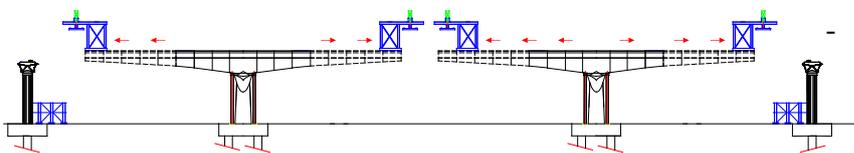
**Step 3:**

- Stressing of 1<sup>st</sup> segment cantilever tendons



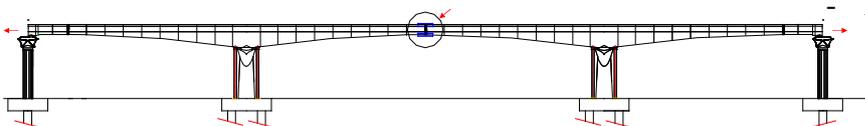
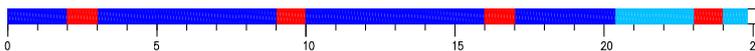
**Step 4:**

- Launching of lifting gantry on new installed segment
- Lifting of new segment pair
- Stressing of new segment installed segment cantilever tendons



**Step 5:**

- Repeat step for 3 & 4 for each new symmetrical segment
- For unbalanced back segment erection on falsework



**Step 5:**

- Cast in situ of closure segment (stitch)
- Installation continuity tendons

Picture 10: Erection sequence of precast segmented balanced cantilever bridge

The typical cycle achieved using precast segment balanced cantilever construction method on Dubai red & green line metro project is 4 weeks days for 3 continuous span deck. Use of classical cast in situ cantilever erection method would lead to 16 weeks typical cycle duration.



Picture 11: precast segment balanced cantilever erection method

## Conclusion

Post tensioned concrete precast segmented bridge technique is an advanced construction method which provides the following advantages to the project management:

- high construction quality due to quality control at precast factory
- speed of construction leading to erection 52 km of viaduct in less than 3 years
- better control of construction costs due to optimized quantities and limited equipment
- less environment disturbance due to localized working place and limited impact on the ground

All these parameters have participated to reduce the overall project risk for the contractor, designer and the owner.