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Dubai metro challenge for a fast track construction

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ABSTRACT: Building a transportation infrastructure is a critical challenge for the fast growing city of Dubai. Both elevated and underground structures of the two first Metro lines of Dubai have been designed to be cost and time efficient. On the elevated section, the Railway viaduct is designed to be built extensively by precast techniques. The time efficient proven technique of precast segmental construction is implemented. The elevated station concept is in line with the standardization of the viaduct design and construction. At the end, the overall success of a speedy and timely construction depends on the quality of the planning: interface with Third Parties Projects, Utilities, resources, design freeze, quick decision process, are as usual, critical parameters.

1 INTRODUCTION

In 2003, the Road and Transport Authority of Dubai awarded a contract for the Preliminary Design of the Red Line and Green line of the Dubai Metro to SYSTRA. SYSTRA has prepared a concept for the System (Civil Works and Rail System) and then has developed a 30% Design to establish the Dubai Metro Tender documentation. Since July 2005, SYSTRA in joint venture with Parsons was awarded the Project Management and Consultancy Services, Contract that include the verification of the design, the supervision of the Civil Works construction and Rail System installation, supervision of the tests, preparation of Operation, assistance during the guarantee period.

2 DUBAI CONTEXT

The Dubai population should considerably increase over the next years. The number of residents is predicted to grow from 1.5 million who currently live in the city to more than five million by 2020. As a result, road congestion could lead to severe economic losses. The RTA announced in November 2007 that Dubai's transport infrastructure would be dramatically improved with a range of road, rail and marine projects estimated around $22 billion to be completed by 2020. The Rail Agency of the RTA has announced so far plans for four Metro lines – red, green, purple and blue.

In this context, speed of construction is a key parameter of Dubai success.

There are many aspects to the speed of construction and we can list:

Client (RTA): fast track decision process, commitment to freeze the design

Consultant (SYSTRA): consideration of construction speed criteria in the conceptual design, proposal of adequate construction methods

Contractor: resources, procurement, management of design and construction interfaces.

In this paper, we would like to review the Systra early conceptual choices for the Civil Works that were aimed at increasing the speed of construction.

3 BRIEF DESCRIPTION OF DUBAI METRO SYSTEM

The Dubai Metro will be a fully automated and driverless system. The Red and Green Line Dubai Metro lines are 75kms long of which 13km are underground and 62km are elevated.

Red Line		
Elevated	44.1 km	24 stations
Underground*	4.7 km	4 stations
At Grade	3.3 km	1 station
Total Red Line	52.1 km	29 stations

* with 2 transfer stations.

Green Line		
Elevated	14.6 km	12 stations
Underground*	7.9 km	6 stations
Total Red Line	22.5 km	18 stations

* with 2 transfer stations.

The maximal capacity of the Red Line is reached with 106 trains and a 90s headway corresponding to 25720 persons per hour and per direction (with 4 persons/m^2).

The maximal capacity of the Green Line is reached with 64 trains and a 90s headway corresponding to 25720 persons per hour and per direction (with 4 persons/m^2).

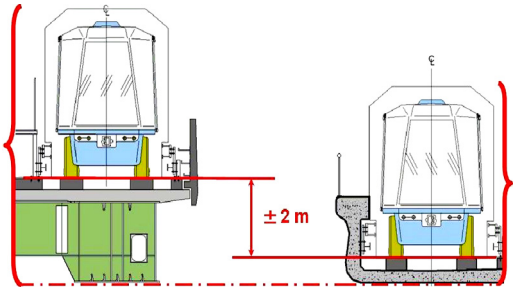
4 VIADUCT – SUPERSTRUCTURES

SYSTRA proposed an innovative design based on the U-viaduct concept.

Over the past 6 years SYSTRA fine tuned this concept in several metro projects (Delhi Line 3, Santiago Line 4 among others).

The U-viaduct offers several advantages both in terms of insertion into the city and in terms of cost.

- The rail level can be lowered due to the minimum distance between the rail and the bottom of the deck. This results in savings for the design of the foundations (lever arm of horizontal forces reduced) and of the stations.

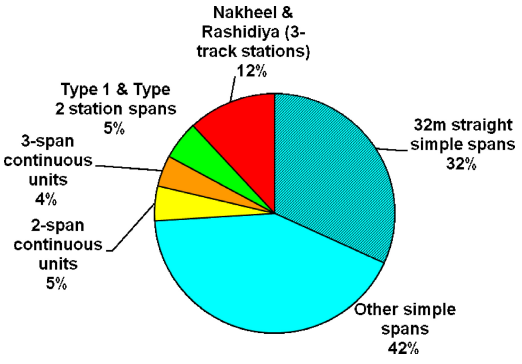


- The visual impact is reduced: no extra anti derailment barrier is required, noise barrier is integrated and the top flanges do provide emergency walkways (at coach floor level) all along the line.
- The open shape is particularly convenient for precasting (no collapsible inner form required) and for erection (workers are safely standing inside the U-girder).

5 VIADUCT – STANDARDISATION

To match the very tight time schedule (the Design and Build contract was finalized in July 2005, and revenue service is to start on 09/09/2009 for the 52 km of the Red Line and on 21/03/2010 for the 22 km of Green Line) SYSTRA proposed a limited number of versatile structures types that could accommodate all the span configurations.

5.1 *Span distribution on Red line*



- Simple spans up to 36m (typical span being 32 m);

- Twin-spans from 36 m to 44 m: these structures are erected as 2nos simple spans. Subsequently (away from the launching girders critical path) a concrete stitch is cast between the 2 spans and continuity post-tensioning is stressed;
- 3-span units up to 72 m: these long span bridges are required at most of the road interchanges crossed by the alignment. They feature a variable depth deck resulting from the combination of a U-girder and a box-girder. The depth of the deck at the end spans is identical to the depth of the adjacent spans thus providing a perfectly smooth transition. The bridge is erected by the balanced cantilever method.
- Continuous units in stations: the continuity is called by the very limited movements of the spans requested by the platform screen doors. As for the twin span units the continuity is implemented out of the launching girders critical path.
- 3-track stations (Nakheel and Rashidiya): some of the spans are cast in situ whereas the single track spans are made of precast segments.

The choice for precasting techniques meets the speed criteria: casting operations starts very early in the construction schedule and hence it reduces the overall construction duration.

The deck segments are manufactured in a 45 ha precasting yard located in Jebel Ali (5 km away from the south portion of the Red Line).

16500 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^3 of double mix concrete produced by 2 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 unit. 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) (8 nos.). 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 launching gantry meets the speed criteria: one span is erected in less than 2 days.

5.2 *Viaduct – pier head*

There are (only) 4 different pier cap shapes for the whole project. As a consequence, 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).

Erection of a simple span

3-span unit

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 eventually stressed in sequence.

For single track areas plain pier caps are precast (with a cylindrical hole for the pier shaft starter bars). The pier caps at the 3-span units central piers are cast in place.

The pier caps are manufactured in a 3.5 ha area adjacent to the deck segments yard.

1850 pier caps are to be cast (75% for the Red Line and 25% for the Green line) using 12 nos. moulds. The daily production is 4 to 5 pier caps.

The pier cap weight ranges from 44 t for the most typical to 74 t for the heaviest pier cap.

Lifting of a pier cap shell

Typical piers and pier caps

6 MONOPILE FOUNDATION SYSTEM

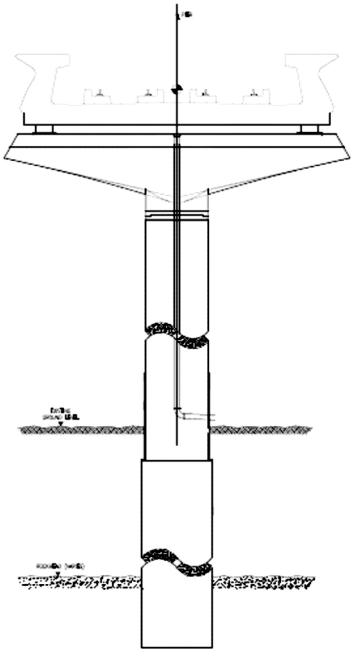
SYSTRA has proposed to use extensively a mono pile foundation for most of the bridges.

The mono pile concept has been proposed because it increases the speed of construction in comparison with a group of piles foundation:

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 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.

3-span unit central pier cap



Groups of piles are required only for the 2 spans and 3 spans bridges.

7 ELEVATED STATIONS

The station concept developed by SYSTRA has been used in several projects.

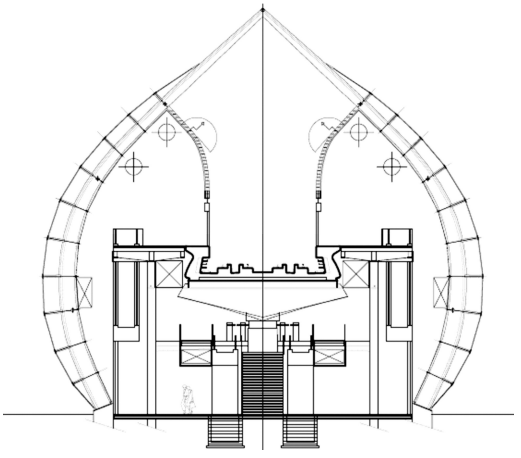
The station is build as an envelope around the viaduct.

The top flange of the U shaped viaduct forms part of the station platform.

The viaduct is built first with the same construction method as elsewhere on the Project. With this concept, there is no disruption to the viaduct construction.

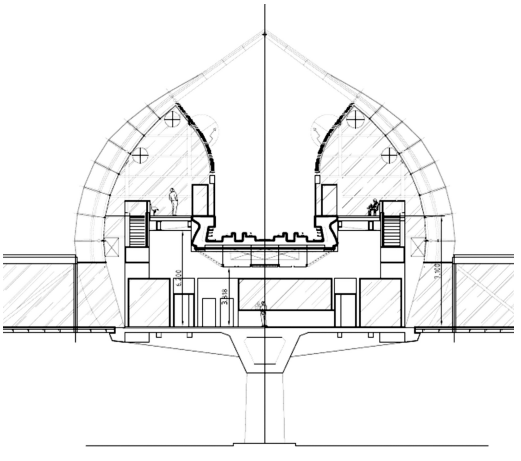
7.1 *Type 1 station concept*

Type 1 stations have a concourse at ground level underneath the viaduct.



7.2 *Type 2 station concept*

A type 2 station is typically located in the median of a road, the concourse is elevated (level 1) and the viaduct and the platforms are at level 2.



Station construction

To meet the construction schedule, 14344 tons of structural steel is to be fabricated in 12 months.

Structural steel	Type 1 station (t)
Internal structure	2885
Roof Primary Ribs	2111
Roof Secondary Members	1648
Grand Total	6544

Structural steel	Type 2 stations (t)
Internal structure	2400
Roof Primary Ribs	4385
Roof Secondary Members	1015
Grand Total	7800

Construction of the roof structure starts after viaduct completion and the completion of the internal structure works depends on the viaduct completion as well.

Managing the interface between the viaduct construction and the station construction is a key to success. Any delay to the viaduct construction will delay the station construction.

8 TUNNEL

Tunnel Boring Machines are used for the first time in Dubai to dig the 10kms long tunnels of the Red and Green lines. The TBM are Earth Pressure Balanced (EPB) with confined pressurized excavation chamber.

In order to match the construction schedule, three TBMs are used (two for the Red line and Green line with a third one only for the Green line).

tunnel lining segments are produced for the Red line and a further 33976 segments for the Green line.

As usual a key point for the overall speed of construction is the control of the timely interface between

underground stations construction and break in/out of the TBM.

9 UNDERGROUND STATIONS

For the 10 underground stations of the Red and Green line, the top down technique has been selected to minimize the disruption to roads surface traffic.

10 CONCLUSION

Red and Green line are mainly elevated. The SYSTRA concepts for the viaduct and elevated stations are cost efficient and time effective. These concepts have been validated as they have not been amended by the Contractor in the context of the tight Dubai Metro construction schedule.