Implementation of a PREFARAIL - COMFORT vibration isolation embedded track solution for Athens Tramway

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SUMMARY:

During the last decades of the 20th century, the increase of road traffic has caused major cities to lose attraction as living and working place. City planners have turned attention to promoting economic and clean public transport means. LRT/Tramway rail systems (LRT) on surface are an excellent cost-effective answer to fulfill these requirements. As «state-of the art» track building techniques for LRT insertion in highly populated areas were not prepared to cope with ever-growing requirements for acoustic comfort, there was need to develop cost-efficient low noise and vibration track techniques.

This article describes the implementation of simple and efficient low noise and vibration embedded track solution using fastener-less PREFARAIL ® technology for the new tramway in Athens, as part of the major infrastructure works for the Olympic Games in 2004. The concept is based on a rail completely involved in an elastic jacket with special shape and adapted stiffness characteristics; the shape is designed to ensure rail deflections of max. 2 mm. under train passage (120 kN/axle) with high lateral stability against (rail-roll in curves and seismic excitation). The insertion loss performance versus classic track is approx. 10 dBV.
1 Introduction

In 2004 the Olympics will be returning to the where it all began, Greece (Olympia). Athens, the beautiful capital of Greece, is steeped in history and legend and is the perfect place for the 2004 Olympics. However, like many major European cities, it suffers from dreadful congestion, pollution and transport problems. One of the most important improvements to the infrastructure in Athens is the new tramway system which is currently under construction.

The Athens Tramway is a 48km light rail system that dramatically improves the access from the city centre to the coastal region, to the Olympic Village and to several of the sports venues, as well as around the centre of Athens.

2 Route Map

The Greater Athens Tramway Project (GATP) consists of three new lines and a new depot:
- S1 – along the coast from north to south from Piraeus (the main port of Athens) to Farilo
- S2 – From the coast to the city centre
- S3 – along the coast going further south from Farilo to Glyfada
- The Tramway Depot - located at the site of the former Athens International Airport which connects into S3

The new tram line connects several of the Olympic sporting venues with the centre of Athens and other important centres such as the main port.

The total length of new track is 48km.

3 Time Line

The project was conceived in the year 2000 as part of the new infrastructure required for the Olympic Games in 2004.

In 2001 the permanent way owner, TRAM A.E., launched 3 major international tenders:
- the supply of the rolling stock (35 vehicles)
- the construction of the track infrastructure and related electro-mechanical works of S1, S2 and S3 + depot, including 3 years maintenance
- The project construction management
Early 2002 the rolling stock contract was awarded to the SIRIO-LRV tram from ANSALDOBREDA. The 3-bogie, 31.9m long LRV with 120 kN maximum axle load is designed to take 197 passengers at 197kph. In February 2003 the €150,000,000 track infrastructure contract was awarded to the consortium TIJV, a joint venture between Terna, one of the major construction companies in Greece, and Impreglio, a large Italian construction firm with experience in tunnelling and track work.

The successful bidder for the construction project management is a Joint Venture between APROFOS and MIVB/STIB (Brussels Public Transport Company).

The design process started immediately after the contract was awarded with construction commencing in August 2002. Completion is due by February 2004 with the system being fully operational by the Olympics in the summer of 2004.

4 Practical design issues

Several practical issues needed to be resolved for the project to be realised:

- The ‘Olympic’ time schedule is very tight requiring extremely fast methods of construction – 48 linear kilometres of single track in approximately 18 months
- The avoidance of damage to sensitive archaeological sites such as Hadrian Gate, both during construction and from vibrations caused by the running of the trains (maximum of 0.2mm/sec equivalent velocity (ppv) during tram operation) (Dr. Vogiatzis C.[1])
- The climate – the construction needed to be unaffected by the huge climate swings and weather changes in Athens
- Earthquakes – protection of the system from a region with high seismic activity (the design required protection up to a lateral acceleration of 1g) the system needed to easily accommodate level crossings and junctions

5 Technical design issues

As well as the many practical difficulties, the technical specifications for the new tram line also provided challenging problems to overcome
5.1 Vibration Specifications (ET&T Consulting Engineers Ltd, [2] & [3])

- Where the track was less than 10m (L < 10 m) from occupied buildings a vibration insertion loss (IL) of 20dBV at 63Hz was required
- When 10m < L < 15m a vibration insertion loss (IL) of 7dBV at 63Hz was required
- When L > 15m no vibration attenuation was required

5.2 Other relevant design parameters

- Maximum allowable rail deflection of 2mm during a train pass-by (120kN/axle)
- Maximum permissible noise emissions for 15 trains per hour is 67dB(A) LeqT
- Re-radiated ground borne noise levels from the tram to be restricted to 40dB(A) in dwellings and 35dB(A) in sensitive buildings such as theatres, museums, schools, concert halls etc. • To avoid stray current an electrical isolation of 250,000Wcm was specified
- Minimum flash-over voltage to be 1kV
- The track system was to have a high lateral stability to cope with rail-roll around tight curves and to protect against derailment during earthquakes

6 Solutions

The system that allowed all of the practical and technical issues to be met was based upon a LEVEL 1 (intervention between rail and rail support) low noise and vibration embedded rail solution using the fastener-less PREFARAIL® technology combined with CDM-elastomer systems. The system has already been internationally presented in various publications and conferences (Carels [4]).
The unique solution was from CYPTRAMAT, a joint venture between CDM (www.cdm.be), a Belgian company who have been designing and manufacturing noise and vibration isolation systems for over 50 years, and PREFARAIL (www.prefarail.com), a Belgian company active in the pre-fabrication of fastener-less slab-track systems. The solution consists of a rail that is completely encapsulated in an elastic jacket with a unique shape and adapted stiffness characteristics. The jackets are manufactured from resin-bonded rubber using granules that are made from 100% re-cycled tyres. The system, when installed in concrete and the road finish, provide support to all sides of the rail and allows the stringent vertical and lateral support criteria to be met.

2 types of rail profile

- A S-49 vignola rail section for dedicated track solutions (mainly S1 and S3)
- A Ri60N grooved rail section for multimodal embedded track solutions (mainly S2) (ET&T Consulting Engineers Ltd. [2] & [3])

To meet the N&V specifications 3 types of track solutions were designed; these 3 track solutions had different track moduli (defined as 2 x the rail modulus [MN/m/Im-rail]). The following table shows an overview in function of the position of the track versus the nearest building.

<table>
<thead>
<tr>
<th>L – specs (m)</th>
<th>N&amp;V specs</th>
<th>Rail</th>
<th>Solution</th>
<th>Track modulus [MN/m/Imst]</th>
</tr>
</thead>
<tbody>
<tr>
<td>L &gt; 15</td>
<td>No isolation</td>
<td>Ri60N</td>
<td>CLASSIC</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 &lt; L &lt; 15</td>
<td>7 dBV @ 63 Hz.</td>
<td>Ri60N</td>
<td>COMFORT</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S49</td>
<td></td>
<td>Not applicable in the project</td>
</tr>
<tr>
<td>L &lt; 10</td>
<td>20 dBV @ 63 Hz.</td>
<td>Ri60N</td>
<td>COMFORT + FST (floating slabtrack type CDM-DFMA-L10)</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S49</td>
<td>Not applicable in the project</td>
<td></td>
</tr>
</tbody>
</table>
For the situation where $L > 15m$, the PREFARAIL CLASSIC system is used. This consists of the jackets without any additional vibration isolation material beneath the rail. This track solution offers resonance frequencies in the order of 60-80 Hz. and deflects under the moving trams up to approx. 0.8 mm.

Where the buildings are between 10m and 15m from the track the PREFARAIL COMFORT system is used. This consists of an adapted shape of jackets with less obstruction for vertical movement in combination with a vibration isolation strip directly beneath the rail. The rail deflects under moving tram up to approx. 1.5 mm. and shows a resonance frequency of 35-40 Hz.

Where the building is closer than 10m from the track, the PREFARAIL COMFORT system is used along with the CDM-DFMA-L10 floating slab-track; according to the relevant noise & vibration study. In this case the rail deflects 2 mm. and the track system resonates at 14 Hz.
7 Some examples of system performance

7.1 Vibration isolation performance for L < 10 m.

A noise and vibration study performed by Prof. C Vogiatzis (special consultant to TRAM SA) (TTC Traffic & Transportation Consultants Ltd [5]) suggested the implementation of a complex solution, including PREFARAIL-COMFORT-Ri60N in combination with the CDM-DFMA-L10 Floating SlabTrack. The relevant calculations on a FE model clearly show that the required insertion loss of 20dBV at 63Hz is met.

7.2 Seismic stability

The shape of the PREFARAIL jackets is specifically designed to achieve the seismic stability requirements. A FE model was prepared to study the effect of earthquake excitation on curved track (R=40 m.) loaded with a tram (ref. Vanhonacker [6]). The maximum displacement of the loaded rails during a 1g earthquake results in a maximum deflection of 2.8mm. This ensures that the trains do not derail during seismic events.

The finite element analysis shows the response of the Ri60N track in a tight curve under a 1g seismic lateral acceleration.
8 Project sequence and installation

8.1 Phase 1 – production of the jackets

The jackets in CDM-49 resin bonded rubber (RBR) are manufactured in special moulds, made to fit the desired rail shapes. The constituting elements (a) single source (post-consumer tyres) rubber granules with defined granulometry and (b) PUR-resin are submitted to a stringent QC process prior to production.

8.2 Phase 2 – quality control of the jackets

Each batch of CDM-49 RBR jackets is quality controlled to ensure that the allowable tolerances on the static and dynamic track modulus are met. The procedure developed to test the performance of the system is based upon 2 test systems:

- A test measuring static and dynamic E-modulus of the constituting elastomers (RATP [7]).
- A test procedure based upon the procedure as defined by Deman [8] is done in the CDM laboratories. This procedure allows to measure the track-modulus (static and dynamic) of the jacketed rail embedded in concrete.

8.3 Phase 3 – precoating the rail with the jackets

The 18m long rail profiles, both straight and curved, (S49 and Ri60N) are pre-coated with CDM-49 RBR jackets. This is carried out in a factory near to the old Athens International Airport.
8.4 Phase 4 – the installation on site

The track is installed using Gauge-Support-Fixation equipment (PREFARAIL-GSF). This equipment allows fast and straightforward track laying and alignment. The GSF equipment can be adapted to each type of rail profile. The rails are then welded and then treated with additional CDM-49 resin-bonded jackets.

8.5 Phase 5 – the concreting on site

After track alignment (vertical, horizontal, cant etc.) a first layer of concrete is poured to the underside of the GSF grips. The GSF are then removed.

8.6 Phase 6 – the finishing of track/road paving

The final layer of concrete or road finish can then be applied.

9 The track completed at Olympic Zeus Temple – Zappeion
10 References


[2] ET&T Consulting Engineers Ltd., “EIA Study for noise and vibration from Athen’s Tram”, October 2000


