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Airport Railway for the MTR Corporation Hong Kong
by David Tyson, Senior Project Engineer, Balfour Beatty Rail Projects Limited

Balfour Beatty Ltd, in a joint venture agreement with Gammon Hong Kong Ltd, was awarded the contract by the MTR Corporation for the construction of the US$178 million trackwork and associated civil works for the new Airport Railway. The work includes design requirements, procurement and installation of the whole of the new system with some modification works to the existing Tsuen Wan line of the MTR Corporation.

In order to manage the contract, with its geographical and logistical problems, two construction offices were set up, one at Mei Foo in Kowloon, the other on Lantau Island at Siu Ho Wan, the location of the Airport Railway's future station and maintenance centre. Construction therefore commenced in these major site areas. As there would be no access to Lantau Island by road, all materials had to be transported by barge, a fact made somewhat easier by Hong Kong's well established water borne transportation system. A temporary depot was constructed at Mei Foo to facilitate construction of both Civil and Electrical and Mechanical Works.

THE RAILWAY CONCEPT
Existing MTR System
The existing railway carries around 2.4 million passengers during an average weekday on a railway system of just 43.2 kilometres route length. The system consists of three separate lines, the Kwun Tong Line from Yau Ma Tei to Quarry Bay consisting of fourteen stations, the Tsuen Wan Line (TWL) from Central to Tsuen Wan consisting of sixteen stations, and the Island Line from Sheung Wan to Chai Wan consisting of fourteen stations. Passengers can change to different lines via interchange platforms. Trains are operated from 06.00 to 01.00 of the following day.
The new Airport Railway currently under Construction

The new Airport Railway under construction will link Lantau, one of the territory’s islands upon which Hong Kong’s new airport is situated at Chek Lap Kok, with Central District. The 34 kilometre link will feature two services, namely a domestic mass transit service linking Central and Western Kowloon with Ting Chung on Lantau Island, called the Ting Chung Line (TCL), and a dedicated service linking Central and Western Kowloon with the new international airport at Chek Lap Kok, called the Airport Express (AEL). Train services will operate at speeds of up to 125km/h. Both services will share running tracks over most of its length.

The TCL will open with six stations namely Hong Kong, Kowloon, Olympian, Lai King, Tsing Yi and Ting Chung, with interchange facilities at Hong Kong and Lai King with the existing railway. To facilitate the horizontal passenger interchange at Lai King Station some 1.5 kilometres of the existing Up TRL will be removed and relocated in a reconstructed section at Lai King Station. Associated station reconstruction will also be undertaken.

The Airport Express features four stations, Hong Kong, Kowloon, Tsing Yi and the terminal station at the new airport at Chek Lap Kok. All of the stations with the exception of Lai King and Chek Lap Kok will be designed to allow for extensive property development to be constructed above or adjacent to the station. The AEL stations will have extensive vehicle circulation areas and therefore occupy much greater plan areas than the existing MTR stations.

The Airport Railway will run for approximately 9 kilometres in tunnel, including a new cross harbour railway tunnel, 6 kilometres on elevated structures and 16.5 kilometres at grade and 3.5 kilometres on the Lantau Link bridges. The system is designed to provide a high speed service for approximately 19 hours between 06:00 and 01:00 daily. At the commencement of revenue service the AEL will have a service interval of 8 minutes intermixed with TCL trains having a service interval of 9 minutes to Ting Chung and 4 minutes to Tsing Yi. Eventually the AEL is designed to operate on a service interval of between 2 to 4.5 minutes. Station stops will be 2 minutes for AEL trains and 30 seconds for TCL trains (except for Lai King station where TCL trains will stop for 45 seconds). In the initial years the AEL dwell will be 90 seconds until the extended overrun at Hong Kong is made available. During conditions when typhoon signal No. 8 or higher is hoisted, train services may cease on at grade and above ground.

sections of the system. However, train services will continue as required on the underground section and provision will be made to enable trains to be revisited at various locations. It will be possible to switch off traction supply on the at grade and above ground sections.

**Bridges**

One of the most dramatic features of the new Airport Railway is the Lantau Link, a combination of two bridges and a connecting viaduct which connect Lantau Island to Kowloon across the main shipping lanes at Ma Wan and Kap Shui Mun.

The Tsing Ma Bridge is a suspension bridge which carries the two tracks in an all steel ‘box’ with a 6 lane highway on the deck surface. The bridge spans a 2km gap with a clear span of 1,377 metres and a shipping navigation clearance height of 62 metres.

The second bridge is a cable stay design with concrete deck and is of smaller span proportions but with similar capacities.

**Summary of Works**

The Airport Railway consists of approximately 90 kilometres of continuously welded single track on viaduct, in tunnel and at grade with a dedicated Maintenance Depot containing 20 kilometres of single track. The quantities of mainline track and track forms are as follows:

<table>
<thead>
<tr>
<th>Ballasted at Grade (main line)</th>
<th>Non-Ballasted on Viaduct</th>
<th>Non-Ballasted in Bored Tunnel</th>
<th>Non-Ballasted in Cut and Cover Tunnel</th>
<th>Non-Ballasted at Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>(main line)</td>
<td>40km</td>
<td>17km</td>
<td>9km</td>
<td>3km</td>
</tr>
<tr>
<td>(drop in)</td>
<td>20km</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Ballasted Track**

The track on ballast utilises UC06 rail on prestressed concrete sleepers with some modifications to accept derailment containment guard rail installation (discussed later). The PANDROL ‘e’2007 clip fastening system and components including studless natural rubber rail pads are used on the sleepers. The track is basically identical to that which currently exists, albeit in smaller proportions, on the existing Mass Transit Railway.

The Depot ballasted track is constructed using BS90(N)M rail and PANDROL PR 401A clips and the rails are welded into 26 metre lengths with 4-hole flange plate connections.

**Non-ballasted Trackforms**

Various non-ballasted trackforms exist on viaducts, bored and cut and cover tunnels and certain sections at grade. All these systems use the PANDROL ‘e’2007 clip and associated components and the two main trackforms are as follows:

- **Sonnevillle LFT Block, rubber-coated, with cast-in shoulders, insulators and studless natural rail pads.**
- **Delkor Cast Basplate with adjustment and levelling shims in HDPE, the plates secured by GSB screws, plastic inserts and FEW washers etc., insulators and EVA rail pads.**

Part of the Tsuen Wan deviation track uses this system combined with BS90(N)M rails.

**TRACKFORM DESCRIPTION**

**General**

The trackwork embodies modern track technologies combined with a complex variety of track forms. Track formation, surrounding structures, operating parameters, proximity of residential areas and noise and vibration requirements all combine to make it necessary to establish the correct trackform design along the route of the railway.

The whole of the new railway is constructed using UC06 flat bottom rail in 900 and heat treated grades and the PANDROL ‘e’2007 clip fastening system. The modification works to the TRL are constructed using BS90(N)M rail and PANDROL PR 401 clip fastening systems to match the existing trackwork in certain sections. Similarly, the track in the Depot also uses BS11 90(A)M rail and PANDROL components. The whole railway is continuously welded using the flash butt process with aluminothermic welds for closing sections of track and in special trackwork.
Floating Slab Track

In noise and vibration sensitive areas such as at stations with integral commercial and residential developments, a system of Floating Slab Track (FST) has been installed. Special pre-cast concrete slabs, incorporating discrete intermediate upstands where appropriate, are isolated by rubber bearings on the stiff fill, the ends and between each support. The track is then installed on the slabs using the Dekker baseplate system as described above, leaving a track supported and restrained by rubber bearings. Stringent specifications and quality control was necessary in the manufacture of the bearings.

Special Trackwork - Trackform

Special trackwork has been installed on all trackforms using, wherever possible, plain line components previously described. Several particularly difficult trackforms had to be addressed in the construction.

With the floating slab trackwork, it was impossible to pre-cast the concrete support units. Therefore, a sacrificial shutter system was devised comprising galvanised and stainless steel into which the concrete is cast. The FST system, once cast, is then drilled to accept holding bolts for the baseplates that support the track. Baseplates are shimmed up using HDPE pads to obtain the correct elevation of the track.

With similar fastenings to that of the FST, non-resilient turnout track slabs were cast in situ to support the baseplates of the special trackwork. This trackform demanded a very high degree of accuracy in casting the concrete and called for specialist surface screeding equipment. Resilience is provided by 12mm thick Sybolyn polyurethane pads, which required careful design analysis to individually tailor them to suit the different baseplate footprint areas. The baseplates were fixed with M27 grade 10.9 threaded bolts.

Due to settlement predictions, the MTR Corporation required adjustment for line and level alignment on turnouts in Hong Kong Central and Kwun Tong. The baseplates had to be designed to cope with up to 20mm adjustment thus necessitating special fixing details. The isolation was derived from modifications to the baseplates fixing holes which were made elongated, provided with a suitable femur and the bolt extended in length. The increased length of bolt rotation resulted in an increase in diameter to 30mm but the end of the bolt was tapered to 27mm in order to standardise on components.

Balfour Beatty developed the design of this trackform to be capable of meeting the maintenance requirement for both horizonal and vertical adjustment under night time possession.

Turnouts on ballast are supported on spherical graphite iron baseplates on Kauri hardwood.

Several new designs of mainline turnouts were developed ranging from 1 in 7 tangential geometry with fixed weldable manganese crossings to 1 in 30/39 transverse geometry with moveable point crossings. All turnout designs have been developed with the running rails fully inclined at 1 in 20 throughout and utilise asymmetrical switch blades of 60D profile as used on the TGV system. Schwebeg inner bracket steel baseplates incorporating Hardened low friction inserts were developed to meet the varied range of switches and various trackforms.

Primarily, as noted above, the special trackwork has been developed for installation on three varying trackforms: ballasted, installation on concrete slabs and installation on floating track slabs. The latter trackform also requires both lateral and vertical adjustment of the turnouts up to a maximum of 20mm in order to accommodate any future settlement in the civil structures.

Conclusions

The Airport Railway in Hong Kong will undoubtedly set new standards in track and railway operating technology as did the first phase of Hong Kong’s Mass Transit Railway in the early 1980’s. With the new track systems installed, which bring established ideas into new applications and support structures, it is certain that other operators and constructors will be watching carefully the development and service running as once again Hong Kong takes a lead in the Mass Transit business.

In true Hong Kong style, underlined by the handover of sovereignty in 1997, extensions to the system are already being discussed and engineered.

Grateful thanks is expressed for the kind permission received from the MTR Corporation for the publication of this article.
Spanning the gap

by Johann Rieger, Project Manager, VAE Aktiengesellschaft

Austria Aktiengesellschaft, an Austrian based company, successfully competed for the Rail Movement Joints (RMJ) contract for the Lantau Link, formerly known as the Lantau fixed crossing.

The latest landmark in Hong Kong, the Lantau Link is central to the transport plan for the new Chek Lap Kok airport on north Lantau island some 32 km from central Hong Kong. The Lantau Link comprises three major structures, the Ting Ma Bridge, the Ma Wan Viaduct and the Kap Shui Mun Bridge.

In 1993 VAE Aktiengesellschaft was awarded the Rail Movement Joints contract for the Ting Ma Bridge. One year later VAE Aktiengesellschaft won the contract for the Rail Movement Joints for the Kap Shui Mun Bridge and Ma Wan Viaduct. Both contracts covered design, manufacturing, testing and installation of the track material and the related supporting structure. For both contracts VAE Aktiengesellschaft formed a consortium with Weisburger Brüder Aktiengesellschaft, a Austrian based bridge building company.

The double track Airport Railway will operate at a speed of 135 kph on a minimum headway of 2.1 minutes. The design axle load for the 8 car trains was 17 tonnes. The annual tonnage is expected to be 605000 tonnes which will operate 365 days of the year and 10 hours each day. Therefore Rail Movement Joints design is a key factor in the reliability, recovery and maintainability aspects of the railway's components forming the railway.

At five locations Rail Movement Joints were installed on the Lantau Link to allow the huge structures to move under wind, live load and temperature variations.

The deck of the Ting Ma Suspension Bridge is more mobile than that of an arch or girder bridge. The designer of the bridge decided to retain the 2.2 km continuous bridge deck at the Ma Wan abutment and to allow the full range of possible longitudinal movements at the Ting Ma Bridge. The rotational movements are relatively small due to the end spans being on separate piers. Refer to Table 1.

Table 1: Ting Ma Bridge

<table>
<thead>
<tr>
<th>Location &amp; Movements</th>
<th>Ting Ma Bridge</th>
<th>Ma Wan Bridge</th>
<th>Kap Shui Mun Bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location (km)</td>
<td>1</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td>Longitudinal (mm)</td>
<td>0</td>
<td>2571-2951</td>
<td>2571-3071</td>
</tr>
<tr>
<td>Lateral (mm)</td>
<td>0</td>
<td>150-157</td>
<td>2571-3071</td>
</tr>
<tr>
<td>Tilt (degree)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Vertical (mm)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Horizontal (mm)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total (mm)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The supporting structure for the joints were specified to have a design life of 120 years and the joint assemblies themselves were to be designed, manufactured and installed such that excessive wear of the components due to fretting do not occur within a design life of 16 years.

From the very beginning VAE Aktiengesellschaft decided not to follow the design given in the feasibility study of the tender documents. This design was based on the RMJs installed on the Honshu-Shikoku link in Japan. As the technological leader in the production of all kind of special trackwork, VAE paid full attention to the optimisation of the running conditions, comfort and safety for train operation on this unique piece of track. Therefore VAE has chosen a top-down principle for the design of the RMJs. The supporting structure is subordinate to the requirements for a perfect track. The Rail Movement Joints of the Ting Ma Bridge will be described in more detail.

The proposal involved solving the three main problems of the rotation, lateral movement of the rails and spanning the gap at three different locations within the Ting Ma Bridge. This approach avoided the possible element instabilities and maintenance difficulties associated with a solution to all three in a single location.

Fig. 1 System of RMJ

Fig. 2 Expansion sleeve

Accommodating the longitudinal movements

VAE developed a cast tank-shaped expansion sleeve made of Austentic Manganese Steel (Hadfield steel) according to UIC 666 [1] to accommodate a UIC 60 thick-web steel rail. In principle the design follows the switch design principles for a channelled switch with straight machining for the foot of the switch rail. [2] The overrunning conditions are identical to those existing on a 300 m turnout. [3] The transition from the bolted rail to the expansion sleeve or vice versa remains constant over the whole range of movements. This RMJ design does not need a check rail because of the continuous running edge and a continuous running table, though containment is provided. The expansion sleeves are supported on a rigid steel I-section plate girder (the end girders) which in turn is supported on the abutment by a series of sliding bearings, both vertical and horizontal which allow the end girders to move freely with the bridge structure.

Fig. 3 Cross section of expansion sleeve
Test Programme for Components on the Airport Railway for Balfour Beatty Rail Projects Limited.

Pandrol Rail Fastenings Ltd. (PRL) have supplied various rail fastening components to Balfour Beatty Ltd. (BBL) for use in the Airport Railway for the MTR Corporation. Hong Kong. Pandrol Rail Fastenings Ltd. was subsequently contracted to test four rail fastening assemblies for BRL against an MTRC Specification in their Test Laboratory at Worthing.

The four assemblies included:

1. Concrete sleeper incorporating cast iron shoulders, high viscosity nylon insulators, 76mm studded rubber rail pads, and Pandrol Brand Rail Clips type ‘e’ 2007.
2. Slab track using a twin (dual) block concrete sleeper in Svelby LVT system. Each assembly incorporated cast iron shoulders, high viscosity nylon insulators, 10mm studded rubber rail pads, and Pandrol Rail Clips type ‘e’ 2007.
3. Slab track using a Dakor bonded resilient baseplate, high viscosity nylon insulators, EVA rail pad, Pandrol, Rail Clips type ‘e’ 2007, screwspikes, and HDPE levelling shims.
4. Slab track assembly using a cast iron baseplate, high viscosity nylon insulators, studded rubber rail pad, Pandrol Rail Clips type ‘e’ 2007, 12mm Sylodyn resilient baseplate pads, M27 sheredized holding down bolts.

Three tests were carried out on each assembly:

1. Electrical Isolation Resistance Test
2. Repeated Load Durability Test
3. Longitudinal Rail Resistance Test

The first test involved the complete immersion of the sleeper, or portion of slab track, in a tank of tap water for a minimum of 6 hours. On removal from the tank, the assembly was allowed to drain for 48hrs. A 10 volt AC potential was then applied to the rails, the current measured, and the resistance calculated. The minimum resistance permitted was 20KΩ and all assemblies met this criteria.

The repeated load test was carried out on two opposite rail seats simultaneously on each assembly type. For each slab track assembly, a section of the slab was precast of sufficient size to provide an adequate support for the fastener in each test. The load was applied via a spreader beam, and two pivoted struts as shown in Figure 2.

The maximum angular load applied was 67KN at 25.5° for the concrete sleeper, and 50.3KN at 26.5° for slab track assemblies, for 3 million cycles. The rail movement was monitored throughout the test. At the completion of all tests the condition of components was found to be very good and the rail movements within the permitted range.

After the repeated load testing, one rail seat assembly was subjected to a longitudinal rail creep resistance test. Again, all assemblies met the performance criteria.

Pandrol Rail Fastenings Ltd. was also contracted by GBRfpl to carry out a data collection exercise on the Tung Ma bridge on the same rail link. The objective of this exercise was to verify the design of the track components during the passage of test trains comprising of two locomotives with axle loads of 17 tonnes at speeds of 10 to 65 km/hr. The rail fastening assemblies incorporated Dakor resilient bonded baseplates (two specific thicknesses) on resilient mounted 9m long steel boarers. Sixteen analogue displacement transducers were installed over six rail seats to measure the vertical movement of the rail and boarers, see Figure 3. Eight digital transducers were also installed to measure the peak lateral movement of the rail and boarers.
The Pandrol Rail Fastening System on Italy’s High Speed Lines

by Dott. Ing Spartaco Lanni,
Solo Director of SAS Studi Ferroviani

INTRODUCTION

Before the Italian State Railways - Ferrovie dello Stato (FS) - set about building the Italian high speed system, FS ran an experimental campaign at the end of the Eighties to ascertain the reliability of the technical solutions adopted in the initial project before drafting the final version of the technical specifications.

The track selected for the trials was the last section under construction on the Rome-Florence ‘direttissima’ inter-city line between Fighine and Valdarno Nord.

The technical solutions adopted for this line included the rail fastening system, mounted both on heavy 60-C type sleepers and on non-ballasted prefabricated slab track. The rail fastening used for the test was the so-called ‘Pescara’ system, comprising a steel plate attached to a pre-stressed concrete panel, with a 12mm rubber under baseplate pad, fastened by two Pandrol Rail Clips (see “Track Report” 1997).

60 UIC rail was then attached to the steel plate using two threaded fastenings, with a 5 mm rubber rail seat pad.

The main purpose of this type of rail fastening was to meet the needs of prefabricated slab track requiring double resilience in this case, because being a non-ballasted track it was essential to guarantee a level of resilience to be able to draw meaningful comparisons with traditional track.

This double clip solution was also used for the rail fastening system on the pre-stressed concrete sleepers, in order to observe the behaviour of these components in track, even though it was obvious that the financial cost of a system of this kind could only be viable if the results guaranteed substantial added value.

Trials were run between February and April 1992, and a detailed report of the results was published in Issue 6 (June 1993) of the Italian railway engineering magazine Ingegneria Ferroviaria, to which the reader can refer for more detailed information.

What is important for our purposes here is that the whole rail fastening system passed with flying colours, and what is even more interesting is that the results were hardly any different from what had been expected using a single clip. This proved that the reservations that had earlier been expressed about the higher cost of the double-clip solution adopted for the trials were unjustified.
THE DESIGN CHOSEN BY ITALFERR

On the basis of the results of these trials, Italfer (the consulting engineering company commissioned by TAV, the company responsible for the whole of the Italian High Speed Network) issued the "Technical specifications for the supply of pre-stressed reinforced concrete sleepers, including the rail fastening system, to be used as the superstructure for the high speed lines" dated 2 January 1990.

These specifications were absolutely unprecedented when compared with other specifications previously issued by the Italian State Railways and Italfer, because they grouped together in one single set of technical specifications the sleeper, the steel components and the rubber and insulating materials making up the complete rail fastening system. In other words, for the first time, the sleeper and the rail fastening system were considered to be synergistic components comprising one single mechanism able to guarantee support on ballast, to retain the rails at the correct gauge distance.

To achieve this, the document prescribed the performance features in terms of both resistance to the forces generated by the rolling stock travelling along the track, and the final values of the track geometry, as well as durability.

As for the rail fastening system in the strict sense of the term, the specifications stated that the standard solution adopted by the Italian State Railways was the PANIDROL 'o 20039 resilient rail clip, the pressed steel cast-iron shoulder, and the 10mm rubber rail pad.

THE RAIL FASTENING SYSTEM

For the practical implementation of the project to build the Italian High Speed Network to meet these stringent technical specifications, both the designers - Pandrol Rail Fastenings Ltd., who were responsible for the final choices and - Italfer, which is responsible for the overall approval of the project, devoted very careful attention to the rail pad.

Many years of experience in FS, backed up by the trials on the Rome-Florence and Rome-City Directissima line, and supported by similar conclusions reached internationally, demonstrated the very special role played by one of the superstructure components, which is only apparently of secondary importance: the rail pad.

In the functional diagrams proposed by experts on track behaviour, the rail pad is described as being like a spring, acting in series with the other resilient structural features, with a filtering function between the moving loads and forces on the one hand, and the ballast on the other. A single financial calculation of the costs and the time taken to replace the rail pad clearly shows that if it performs an effective filtering function, even if it is perhaps less durable relative to non resilient pads, it offers considerable advantages in terms of maintaining the resilient features of the ballast.

When defining the elasticity or resilience of the rail pad it must be remembered that it must not be capable of being overcompensated, or there will be excessive rail wear under moving loads. Another consideration is that the compression exerted on the rail pad generates heat, and this occurs as the hysteretic cycle widens, and this in turn is caused by excessive resilience and stiffness. The value of the elasticity expressed in terms of the secant modulus on the compression diagram measured between a load of 90 kN and the clip preload, divided by the variation in the respective compression values, has been set.

At the present time it is expected that the rail pads made of a material possessing this rheological characteristic, and with a thickness of 10 mm, should have a useful life in track of 10 years and more, which is virtually the same interval of time at which the rails are generally relaid.

As for the rail clip itself, once again the choice was made in favour of the PANIDROL Rail Clip type 'o 2039 in view of the excellent results it has achieved under normal traffic and in the High Speed trials. The adoption of the 10 mm rail pad made it necessary to redesign the shoulder to take into account the geometry of the new pad in the overall assembly.

At the same time a critical review of all the working tolerances was carried out in order to make a useful contribution to establishing the final performance features required of the sleeper/fastening system, for the purposes of gauge retention.

The construction of the Rome-Naples High Speed Line

This line is Italy’s first section of High Speed Network. The line is designed to run at 300 km/h, which is the actual operating speed. To ensure compliance with the technical specifications, the engineer of the railway works, Vittorio Indaia, working in very close cooperation with the Pandrol Rail Fastenings design engineers, compiled the following:

1. The whole system was designed in order to comply with the performance specifications, establishing a 200 kN load on the sleeper and 90 kN on the rail, respectively, as the maximum load on the rail seat and sleeper mid-point. The design also took account of the fatigue resistance specification for at least 2 million cycles under a vibrating load between 60 kN and 25 kN, because the design had been completed, the prototypes required for approval were produced. The approval tests not only included the static and dynamic tests on the concrete sleeper, but also included tests on the rail fastening components: the pull-out test (minimum 120 kN), the rail creep resistance test (minimum 12.5 kN) and the rail torsion resistance test (minimum 2.7 kN for a 1 degree twist). These tests were carried out using the procedures based on those described in the ORE 170 Report no. 3.

2. A pre-production run of 10,000 sleepers, from which samples were taken at random to carry out 200 static load tests (rail seat and sleeper mid-point), 4 fatigue tests, 2 shoulder pull out tests, and 2 assembly dynamic load tests. In this phase, the tests indicated in point 1 above were repeated on the fastening system. All of these tests have now been successfully completed, and the tests carried out at the Italian State Railways’ Experimental Institute in Rome have confirmed the positive results of the tests carried out on the pre-production works. This official certification is essential in practical terms because it authorises the sleepers and the rail fastening works to be used on the Rome-Naples High Speed line, and signifies approval for the sleeper makers to begin bulk production.

Ankara Rapid Transit System, Ankara, Turkey

by David Tyson, Senior Project Engineer, Balfour Beatty Rail Projects Limited

Balfour Beatty’s contract with SNC-Lavalin of Montreal, Canada (through their associated company Coppee UK Ltd in London) was for the design, procurement, manufacture and supply of all track related products for the new Ankara Rapid Transit System (ARTS). Technical supervision of the installation of the track was also provided with a presence in Ankara for over two years.

The Ankara Metro Consortium constructed the works and was structured into three main groups: SNC-Lavalin handled project management; Bombardier supplied the rolling stock with special responsibilities for system integration; and Gama-Guris (a Turkish joint venture company) constructed the works. By providing assistance at a site level, Balfour Beatty’s technical supervision provided the link between the UK design and procurement activities and the project management structure, the Turkish contractor and the Polish sub-contractor track installer.

Balfour Beatty also provided training of personnel to ensure that the trackwork was installed and maintained to the required standards and provided Operation and Maintenance Manuals.

Whenever possible, as specified, standard proven products were incorporated into the track system and the PANIDROL fastening system was used throughout. However, track resistance requirements demanded by the client meant that some considerable development work on a new PANIDROL clip was necessary to ensure compatibility of the specification with the fatigue life of the components.

General Specification

The rail section for all the 14.5 route kilometres is UIC 54 and the track is constructed in a combination of track forms both on ballast at grade and on fixed (except in tunnels) at grade (7 km) and in tunnels (14 track km). Ballasted track is constructed using UIC 54 flat bottom rail section fixed to reinforced prestressed concrete sleepers (similar to the 54D as used by Railtrack) with the PANIDROL ‘o 2007 clip and pressed steel shoulder. Special trackworks, on ballast, were fabricated from the same rail section and were laid on hardwood Jarrah timbers with baseplates. Special trackwork for ballasted areas were manufactured using the same rail section (with the addition of some special sections) and laid on hardwood crossing ties with baseplates.

Cast basemat assembly on concrete slab.

Special trackwork on concrete slab.

Tracks on direct support were constructed by setting the rails on in-situ cast concrete plinths. The rails are supported on elastomeric pads and are fastened by using the specially developed PANIDROL ‘o 1889 clip system and cast iron shoulders. For plain track line, the shoulders were cast into the in-situ poured concrete plinths using a specially designed mobile shuttering system. The plinth track system is virtually identical to that which had been successfully installed on the MTRC in Hong Kong.
Crossover with central rail

However, the resilience achieved results in a safer track than that which has been previously installed. Special trackworks on direct fixation areas were installed in the same manner as for plain line track, but with the addition of baseplates through the switch area and shoulders which in this case were grouted into pre-drilled holes in the support slab.

System Layout
The system runs from Kişlalı, in the city centre, for approximately 14.5km, to Bakırkoy in the north-west of Ankara. The outbound and inbound tracks are connected by strategically placed double crossovers at Kızılay, Ulus and Bakırkoy with major junctions at Yenimahalle and Macunkoy. Kızılay station is shared with the separately constructed and independently operated Ankara LRT system and thus provides interchange facilities with the Ankara RTS.

The Operations and Maintenance Centre is positioned approximately 10km from Kızılay and is accessed by way of the junction at Macunkoy. The yard area comprises workshops, vehicle storage sidings and the main control centre.

Main Line
The track configuration is a two track system, inbound and outbound, running from Bakırkoy in the west to Kızılay in the east. The inbound track is on the south side, the direction of travel being west-east; the outbound track is on the north side with an east-west direction of travel. Double crossovers are located at Bakırkoy, Ulus and Kızılay. Access to the yard is from the east at Macunkoy with junctions either side of the Macunkoy Station. A loop facility is also available at Macunkoy. Further east, at Yenimahalle, a pocket track is installed.

Yard
The yard facility consists of a double track access to the main line in an Easterly direction. A single crossover just prior to the arrival and departure tracks provides connection between the two separate tracks. The total 10 km of track (mainly on ballast) provides a capacity consisting of eight storage sidings, eleven maintenance tracks in the OMC buildings and two engineering sidings.

Technical Requirements
The main technological demand for the project was the continuously supported rail track form. Whilst the system has been used successfully elsewhere, as mentioned earlier, the demand for a more resilient track led to the development of new components in the assembly. From the point of view of maintenance, the Pandrol Insulator was standardised throughout the track system. However, with the resilience being sought (giving the clips a mean dynamic deflection of +0.7mm), it was necessary to establish exact deflections of the rail under load and the fatigue performance of the PANOROL clip at these values.

The resultant design exercise culminated in a new 1800 series clip from Pandrol and a new formula (in terms of chemical composition and thickness) for the continuous pad from Tiflex. Balfour Beatty designed, manufactured and supplied all the special track work and associated components. Rail expansion joints, lever boxes and buffer stops (both fixed and sliding) were also manufactured and supplied by Balfour Beatty Ltd.

Component Testing
Pandrol supported all the testing aspects of the works and carried out tests as required under a brief established by Balfour Beatty and their client SNC-Lavilin. Due to the new development elements in the project, component testing to satisfy the requirements of the specification was necessary. Materials were tested in terms of assembly, performance and fatigue. The essential testing that was required was to replicate accurately the loading and deflections that would be expected on a continuously supported rail. A rigid test bed (using a surplus planting machine bed) was used. Some 10m was installed in a manner replicating the rail on the concrete plinth. Furthermore, as the Tiflex resilient pad (which was of a type and thickness not used in this situation before) has characteristics which are affected by heat, the whole assembly had to be checked and re-tested at various temperatures. Redundant switch heaters were attached to the rail for this purpose.

Double crossover on concrete slab

Conclusions
The Ankara Rapid Transit System could change significantly commuter’s travel patterns within Turkey’s capital city. The independent and smaller Ankara LRT system started operation last year and as a result these changes are already being felt. Once the ARTS is operational, the two systems will link up the Government and business centre of the city. It is not yet possible to predict the prospects for extensions to the two systems, but ideas are already being discussed.
FASTCLIP Machines

One of the great advantages of the PANDORL FASTCLIP is the fact that the pre-mounted clips, insulators and rails make it easier to mechanise the clamping up and unclamping process in track for a low cost.

In summer 1996 Rosenqvist Entreprenad AB, was contacted by Swedish Banverket Industries Division to assist in the development of a machine for the installation of PANDORL FASTCLIP at the Gardermoen air railway line in Norway.

The requirement was for:

- Application equipment mounted on a roadrail machine
- A tractor or an excavator meeting the following demands:
  - the machine should have the capability to be very flexible and to get on and off track easily
  - the roadrail machine should be used for other operations on track as well (a Multi Function Machine)
  - it should be fast and effective
  - it should be equipped to lift low sleepers

- The installation should be carried out by one operator.

The machine chosen as the carrier, the Hudig MFM roadrail tractor, was already in the product programme of Rosenqvist’s Rail Tech AB. This MFM machine has all the required power and capacity for the necessary hydraulic support and with its hydrostatic controlled hydraulic power, it is perfect for performing several functions at the same time. The machine benefits from its ability to operate in difficult terrain, on the road as well as on the track, by virtue of its four wheel drive. The machine also can support 220 volt electrical power with 3KW electric generator for hand machines or other electrical equipment.

Co-operation between Swedish AWI and Rosenqvist’s Entreprenad AB was established. AWI had in the summer 1996 made a small motor driven hand pushed trolley for installation of FASTCLIP and was contracted to the project to deliver a “beam” for the installation segment of the machine for Rosenqvist’s Entreprenad AB.

Rosenqvist’s commenced work in September 1996 on installation of FASTCLIP behind Banverket’s new high capacity tracklaying machine SVM 1000. By the end of 1996, Rosenqvist’s had installed a total of over 300,000 sleepers.

With the experience gained on the contract the Rosenqvist machine regularly achieved installation rates of up to 27 sleepers per minute.

Because of the fact that Rosenqvist’s Rail Tech AB had developed a special profile plough that was used on a machine in front of the track laying machine to prepare the ballast bed, the sleepers were laid out very accurately and the need of lifting up low sleepers was reduced significantly.

Tests and simulation on track

Towards the end of summer 1996, Rosenqvist’s Rail Tech AB had started to design and test a new application with the possibility for installation and extracting FASTCLIP with the same equipment at a panel length of FASTCLIP track outside the workshop in Hudiksvall, Sweden.

"The applications and machinery at first appear very easy to make and to operate," says Mr Erich Holmsberg Product Manager at Rosenqvist’s Rail Tech AB, "but in fact there is a number of outside problems to bear in mind which makes the issue a lot more complicated. One of the factors to consider when a high capacity is required is the increased fatigue risk. The design has to be made very strong and durable against wear. That makes the demands on the material chosen very severe and it must be tested for a long time.

Another fact is that the machine has to install and extract the FASTCLIP with the right sequence of movement, applying the forces on the FASTCLIP to change position in the correct way in order that clips and insulators are not damaged".

On the market

After tests, the machine was put into full operation by the end of the year 1996 and taken out to the rail distressing work that commenced in March 1997 at the Gardermoen. This gave the opportunity to Rosenqvist to evaluate the machine it had developed and built on track, while completing the contract which it had received.

After the evaluation and technical revisions had been carried out, the equipment was released in summer 1997.

The equipment can be attached to a tractor, excavator or other roadrail vehicle that can support the machine with hydraulic power.

Rosenqvist’s machines are now operating at Gardermoen in Norway and later this summer the machine will be used for the installation and extraction of FASTCLIP at Arlanda Banan, the Swedish airport line north of Stockholm, where Banverket will install 60,000 FASTCLIP sleepers.

Through Pandrol, Rosenqvist’s has also demonstrated the system Hudig MFM and the FASTCLIP machine in Eastern Europe and the machine is attracting interest from Pandrol’s customers worldwide.

With the Rosenqvist’s Rail Tech AB FASTCLIP machine, the capacity of installing the clips on well laid track has increased up to 40 sleepers per minute, with extracting rates up to 25 sleepers per minute.
Banverket Industridivisionen - the Airport Rail Link Builders

by Göthe Persson, Acting Managing Director, Banverket Industridivisionen

Industridivisionen "The Railway Builders" of the Swedish Rail Authority, Banverket, prides itself as the premier builder of track to the Scandinavian capitals major airports in Norway (Gardermoen near Oslo), Denmark (Kastrup in Copenhagen) and the latest in Sweden (Arlanda near Stockholm).

All the contracts have been won in competitive international tendering.

The lines mentioned above are all built with PANEROL FASTCLIP which gives the client and the contractor major benefits, meeting the technical requirements, rationalising construction, health and safety, cost savings and environmental advantages over other systems.

For track laying, the proportion of the works concerning rail fastening installation, including rail destressing, can now be performed using only 25% of the manual labour required for other fastenings. The works now mainly comprise operation of machines and supervision.

On the Gardermoen Line, a Plasser SVM 1000 track laying machine developed jointly by the Division and the supplier is employed. This machine is operated by 7 employees and lays 1,200m of track during a normal day shift. The rails are fastened to the sleeper by an automatic clipping tool attached to the track laying machine and works without the involvement of an operator.

The rail destressing is performed by a 6 man gang using light machinery for rail pulling, lifting and placing of temporary rail rollers, as well as unclipping and clipping up of FASTCLIP. The gang produces 2,200m of destressed and thermite welded track per day.

Due to the lower track laying capacities demanded in Copenhagen, the Division, together with the supplier Sjölander in Sweden, developed a low cost track laying machine which is operated by 6 people laying 650m of track per day. This machine also has an automatic FASTCLIP application unit attached to it.

It is envisaged that what is being seen today is only the beginning of a development during which new machinery with still higher capacities and less manpower requirement will emerge.

As a result of pre-assembly of the FASTCLIP components onto the sleeper, there is a tremendous environmental benefit by the removal for the need to transport the fastening separately as well as the removal of the need to dispose of the packaging.

In summary, FASTCLIP improves the rail laying ergonomics while at the same time benefiting the environment. As a result of machinery development, both by the Division and other machine builders, the manual work covering rail fastening has been greatly reduced to the extent that the only manual "back bending" operation is the placing of rail rollers to allow destressing.
Pandrol Vibration Isolation Assemblies

On non-ballasted tracks, vibration which is transmitted through the track into the supporting structure can result in low frequency secondary noise, or vibration of nearby buildings, which can represent a serious environmental problem. A wide variety of different solutions have been offered over the years, each of which claims some advantage over other available systems. Most have been developed from systems that are successful in isolating vibration in machinery or civil engineering applications. A Vibration Isolating Assembly has been developed as a practical and economical railway engineering solution to the problem.

Design Features

Even in locations that are sensitive in terms of noise and vibration, the first consideration of the railway engineer must be to install a track form that is safe, durable and capable of being maintained. Considerations of maintenance of track geometry, containment of rail breaks and delaminations, and insulation of signalling and traction return currents are no less important where vibration isolating systems are required. The philosophy behind this track support system is to incorporate elastomeric elements, based on proven rail pad design experience, into standard rail fastening systems, in order to increase the overall track resilience without making sacrifices in other areas.

PANDRIL’s studbed rubber rail pads provide a combination of low stiffness, and high resilience to rail roll, by virtue of their highly non-linear characteristics. Under normal operating loads the pads have very low stiffness, but under overload conditions they become much stiffer. If a severe lateral load is applied, this behaviour reduces the degree of dynamic gauge widening for a given working pad stiffness. In the PANDRIL Vibration Isolating Assembly, two such non-linear pads are used, one between the rail foot and the baseplate, and one between the baseplate and the structure. The rail pad is designed to have low stiffness on straight track or large radius curves, but to resist rail roll in sharp curves. The lower baseplate pad operates in its high resistance range in all normal operations, but contributes to the roll resistance in cases of severe lateral overload.

The system is pre-assembled into a unit before the track is laid. This is achieved either by incorporating a bottom cast iron plate, or by assembling on a concrete block or sleeper which will later be cast into a track slab. The choice depends on the overall track construction method, and has no effect on the final performance of the system. In either case, the design of the attachment between the bottom plate or block, and the top plate with its rail fastening assembly, is a key to the performance and durability of the system. Where a cast bottom plate is used, upstands or "pillows" on that plate engage into holes in the top plate, but is isolated from it by elastomeric bushes. If the system is assembled on a concrete block or sleeper, a steel sleeve is cast or glued into the concrete to serve the same purpose, and a similar elastomeric bush fitted.

Although the assembly is delivered to site as a unit, if necessary it can be dismantled and re-assembled for maintenance without the need for special tools or adhesives.

The material used for the bush may be selected according to the track requirements—tangent track and large radius curves, natural rubber is preferred, but for sharper curves thermostet urethane elastomers give superior performance.

The rail fastening components are selected to give the maximum number of common components compared with the plain track on the approaches to the vibration sensitive area. The same clips, and insulators can be used, whether they are PANDRIL "e" clips or PANDRIL FASTCLIP components. When FASTCLIP is used, all of the parts can be pre-assembled on the unit before it is delivered to site. This "mix and match" approach to component selection makes it possible to reduce the number of special parts, with their associated costs in small batch production, and at the same time increase the flexibility of the design.

History

The first PANDRIL Vibration Isolating Assemblies were installed in track in the late 1980s.

Following the opening of the Docklands Light Railway in London in 1987, measures had to be taken to reduce the noise levels close to lightweight steel-concrete composite viaducts. PANDRIL Vibration Isolation Assemblies were installed on the track in sensitive areas, to reduce low frequency noise (around 60Hz) emitted from the viaduct structure, and acoustic barriers were erected to reduce higher frequency noise emitted from the rail and wheels.

The low frequency noise was reduced by about 8dB, and the overall noise level by several dB. An identical track support design, with BS 83A rail and PANDRIL Brand type "e"/830 clips was also used on the Manchester Metrolink light rail system.

A modification of this assembly, incorporating a cast bottom plate, was installed on timber bridge beams by the State Rail Authority of New South Wales, near Sydney in 1990. The bridge timbers were connected to deep steel I-beams to form a short bridge on a 1200 metre radius curve at Brand Street, Artarmon. Once again reduction of low frequency vibration was most significant measured between 3 and 7dB.

After about five years in service, some of the PANDRIL Vibration Isolating Assemblies on this bridge were dismantled for inspection, and found to be in excellent condition. However, some design modifications were incorporated to make it possible to use the same baseplate design in much sharper curves. The latest design has been tested successfully to draft European standards which simulate a 15 tonne axle load and 50 metre radius curve.
Products

New Developments in Resilient Rail Pads

For many years Pandrol has been in the forefront of the development of highly resilient rail pads for use on concrete sleepers. In order to make pads resilient, durable and affordable natural rubber compounds have been used. Careful design of the surface shaping makes it possible to achieve the required dynamic characteristics, but in order to make the pads strong enough, they are usually made about 10mm thick. As a result, many of the sleepers put into track over the last ten years or so have been designed to accept pads of this thickness, but there has always been a demand for thinner, resilient pads for retro-fitting onto older sleepers. The usual approach to this has been to use materials such as polyurethane, or to put textile reinforcing into the pad. Both approaches make the pad more expensive, and less resilient than its thicker counterpart.

About ten years ago, Pandrol and DuPont Engineering Polymers developed a quite different approach to pad design. By using a relatively hard thermoplastic elastomer with a novel geometry, it was possible to make a pad resilient by bending of the material, and not by compression, as shown in diagram 1. With this approach, it was possible to make a pad with similar resilience and durability to the 10mm studded rubber pad, and at a similar cost, but at half the thickness. The disadvantage of this pad design lay in the small contact area between the pad and the concrete – consequently it could only be recommended for use on baseplates or when placed on a hard slab in the rail seat. Despite these limitations almost one million pads have been installed in track.

A new version of this pad is now being tested. In order to achieve the required bending behaviour, and at the same time maintain a low contact stress on the concrete, a shape has been designed which forms an integral feature in a hollow, extruded pad. The material used - a grade of DuPont’s “Hytrek” TPE - has similar hardness to non-resilient HPDE rail pads and has flat surfaces in contact with the rail and concrete, and is thus expected to be very durable. However, the vertical stiffness of a 6mm thick pad is less than 100 MN/m.

Track trials of this new pad - nicknamed the “inside-out pad” by the design team - are now in progress.

Diagram 1

Pandrol ‘Caneclip’ on trial in Australia

In May and June 1997, two trials of a new ‘CANECLIP’ fastening were installed in the sugar cane railways in Queensland, Australia. The sugar industry operates along the coastal plains of Queensland, housing much of the harvested cane along “2 lost” gauge railways. Concrete sleepers have been progressively installed since 1970 using elastic spikes driven into square holes in the sleepers.

In 1989, PANDROL 12mm and 14mm ‘C’ clips were successfully introduced and are used extensively throughout the systems. The new, low profile ‘CANECLIP’ has been developed for this application because it is ideally suited to the small rail sections and numerous joints found on these tracks. It is used in conjunction with a flat topped pressed steel shoulder cast into the concrete sleeper.

The clip is installed along the rail and can be reversed to avoid joints, with the low profile and simple shape helping to minimise derailment damage.

The first trial installation is located close to the Invidia Sugar Mill at Giru, near Townsville. This mill first crushed sugar cane in 1873 and has recently been extensively upgraded. A section of Austrak concrete sleepers were installed on a difficult curve where the performance of the fastenings will be monitored during the ‘crush’ season during which time it is expected 3.5 MT of traffic will pass over the site.

The second trial has been installed close to Marlan Mill at Marlin, near Mackay. This mill first crushed sugar in 1894 and currently forms part of a co-operative association in the Mackay area, crushing local sugar cane.

The gauges under consideration include 914mm, 762mm, 750mm and 610mm.

The assembly will incorporate an injection moulded pad with 8mm uplift initially placed on the field side of both rail seats. This will allow up to 12mm gauge widening in two increments of 6mm in order to assist in the tight curvature common in underground trackwork.

The 14mm mini clip assembly will replace existing 16mm PANDROL ‘C’ clip fastening assemblies and the benefits of the new assembly include a lower profile, greater resistance to derailment damage, and a common assembly to suit a variety of track requirements.

Underground trials at Vital Relics Gold Mine and Impala Platinum Mine will be undertaken in the third quarter of 1997 with a view to having the sleeper assembly on trial in the mines of all the major mining houses within 6 months.

The possibility of having the sleepers delivered with fastenings attached is also under consideration.

‘Mineclip’

Pandrol South Africa, along with Grinelker Durasiol, manufacturers of Concrete sleepers, are developing a range of concrete sleepers using a fastening assembly similar in concept and components to the ‘CANECLIP’ developed in Australia. The market initially being targeted is for underground track in Gold, Platinum and Chrome mines using 30 kg/m rail with 10 tonne axle loads on the hoppers.

The two trials will enable the railway personnel to familiarise themselves with the system and allow Pandrol to evaluate fully its track performance during the cane crushing season, which runs from June to Christmas.

‘Mineclip’
The upgrading of the Buenos Aires Subway System from short jointed rails with wood sleepers and rigid fastenings to continuous welded rail on concrete bi-block sleepers with resilient fastenings is required to be carried out in five and a half hour possessions. This track renewal marks the first time a PANDROL resilient rail fastening system has been chosen to be used in conjunction with concrete sleepers in Argentina.

Metrovías S.A. is the concessionaire of the Buenos Aires Subway System in addition to the Urquiza suburban line and the Patricio trains system. During the twenty year concession period, Metrovías is responsible for both the operation of the railway services and a number of investments totalling US$435 million covering the modernisation of the entire network.

Metrovías commenced operating the system on the 1st January 1994 and has already increased the number of passengers using the trains from 192 million in 1993 to 203 million in 1996.

The B.A. Subway System is composed of five lines with a total route length of 337km with 65 stations. The Urquiza suburban line is 28km long with 23 stations and the Patricio tramway 7.4km long with 15 stations. The B.A. subway and Patricio tramway operate on a 05:00 to 22:00 hours daily basis whereas the Urquiza suburban line operates for the full twenty four hours each day.

The Proposed Investment Programme

Metrovías S.A. is currently executing the first stage of its investment programme with an investment in the region of US$220 million. The main project is the Renewal of the Track, new Signalling Systems, a new Operations Centre, Train Communications System, Mechanical Escalations, Pumping Systems, Refurbishment of Power Stations, Improvements to Passenger Transfer Centres and the acquisition of 118 new train units for the B.A. Subway Line B.

In addition to the major investment programme, Metrovías has commenced a series of investments under its own budget which includes the complete refurbishment of stations which will cost US$20 million.

Track Renewal for Line B

The renewal of the track in Line B includes the replacement of all rails, sleepers and ballast. The project is being carried out each night in a 5.5 hour possession period during which time a total of 54 metres of track is being reconstructed. The track to be replaced is prepared up to one week before the reconstruction takes place which entails:

1. Spiking the existing track into panels of 16 metres
2. Preparation of the third rail in order to remove it when replacing the track.
3. Ensure that adequate drainage and other services are of the specified level in order that the relaying work can progress smoothly.
4. At the same time the panels of new track are assembled in the depot in preparation for movement to the work site.

The track construction operation is being carried out using a special track unit that was designed to operate within the narrow clearances of the single track tunnels. The unit has to cope with the transportation of materials to the work site, the removal of the existing track and installation of the new track panels.

The work train has two principle sections:
1. A gantry unit for replacement of the track and
2. A unit for the replacement of the ballast.

The work train incorporating the wagons of new track panels, new ballast and the empty wagons for collection of the old ballast enters the tunnel first.

For the first time anywhere in Argentina it was decided to use concrete sleepers. The preference was for the use of the bi-block type manufactured with the technology from Belgium. The sleepers were manufactured by Technit, Rogge U.T.F., who was also the contractor responsible for the replacement of the track.

The principle constituent in the production of bi-block sleepers by the Belgian method is the use of dry concrete with a low water/cement ratio which produces a cylindrical strength of 450kg per square centimetre.

Some of the perceived advantages of the bi-block sleeper on which the decision was made included longer life, improved safety operation, better load distribution, better ballast adhesion and more stability which in turn permits better performance in sharp curves with an envisaged reduction in maintenance.

In support of the decision regarding the sleeper type was the need to select a rail fastening system which would provide a high level of reliability, ease of installation, would be relatively maintenance-free and feature a complete absence of threaded elements. The study concluded that the most appropriate fastening system would be the PANDROL Brand ‘e’ series clip with grooved rubber rail pads. A range of plastic insulators with varying side post thicknesses was used in order to provide lateral adjustment in the sleeper rail seats to increase the track gauge through the sharp curves.
PANDROL rail fastenings on concrete slab track on the Ankara Rapid Transit System (ARTS) installed under the technical supervision of Balfour Beatty for SNC-Lavelin Inc.