São Paulo Metro Adopts Advanced Technology in the Superstructures of its New Lines

by Augusto César Carreiro de Oliveira, MSc. Eng., consultant & designer of the superstructure systems of the permanent way of the Arthur Alvim - Guanazes section of São Paulo Metro.

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by Tony Smith, Project Manager - Barclay Mowlem Australia.

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Historical background
A fundamental aspect of the planning of metro lines in urban centres is controlling and preventing excessive levels of noise and vibration from the wheels of passing trains being transmitted to buildings along the tracks and to stations and causing possible damage to structures and nuisance to human beings.

Being concerned about this in the siting of its new lines, São Paulo Metro has adopted permanent way designs using superstructure systems based on the most advanced technology with regard to absorbing secondary noise and vibration within the pertinent international standards such as ISO and DIN and the requirements and guidelines of the "Environmental Impact Surveys".

In 1997 São Paulo Metro issued the public tender invitation for the preparation of the working design, supply of materials and equipment and erection of permanent way of the Arthur Alvim - Guanazes section of the eastward extension within the scope of the Eastern project with technical specifications that would only be feasible by using superstructure systems based on advanced technology.

The winning bidder, Construtora Andrade Gutierrez S/A, proposed to execute the services concerned within the most rigorous internationally established permanent way systems, products and technology with a view to providing São Paulo Metro Company with maximum guarantees of performance, safety and reliability as well as ease of maintenance for the transport system.

TRACK CHARACTERISTICS

Infrastructure
The infrastructure of the track evolved stretches from Itaquera station to Guanazes station via the Pêsoego and José Bonifácio stations, comprising 2.91km at surface level, 2.96km elevated and 1.78m of tunnel, totalling 7.6km of double track.

Permanent way
Rail: TR 57 (AREA 115)
Distance between fastenings: 650mm
Gauge: 1,600mm
Minimum radius of curvature: 300m on main track, 150m on secondary track.
Maximum super-elevation: 160m
Maximum dynamic gauge widening: 3.0mm
Track width: between 2.6 and 3.0m

Rolling stock
Load per axle: 210KN
Gross annual tonnage: 7 x 10^6 KG
Maximum speed: 97km/h
Maximum acceleration: 0.85m/s²
Emergency braking: 1.2m/s²

Design and implementation
For the preparation of the design, Construtora Andrade Gutierrez S/A not only applied its own experience and its own technical staff but also engaged specialised technical consultancy in metros and railways, searched the national and international market for the most advanced relevant systems and products and made technical visits to various suppliers in Brazil and Europe.

It also engaged the services of the Department of Railway and Systems Engineering of the Technological Centre of UNICAMP to carry out field measurements, type-approval tests and performance verification of systems and components. Surveys, analyses and tests were then carried out to determine the superstructure systems best suited to each section of the permanent way, after which, when all the systems had been designed, they successfully passed type-approval tests and performance verification in the laboratory of UNICAMP's Technology Centre.

The civil works were then completed over a period of approximately 10 months and the permanent way was completed at the end of 1999.

DEFINITION OF THE SUPERSTRUCTURE SYSTEMS BY SECTION

Surveys, analyses and tests for defining the systems
For the definition of the superstructure systems to be installed on the track, seismic tests, analyses and surveys were carried out at various points of the infrastructure (basic structure) by exciting the track with Vibrometer equipment that simulated passing trains to represent the transmissibility of vibrations at various points on and adjacent to the track.
The tests were conducted on the basis of mapping the points to be subjected to vibration measurements on the track, in buildings along it and in station technical rooms. These points were adopted as the reference basis both for defining the superstructure systems to be installed on the track and for subsequent measurement of the effects of passing trains, with the view to verifying the performance of each system adopted. Figures 1 and 2 illustrate the Vibroig tests carried out by the Department of Railway and Systems Engineering of the Technology Centre of UNICAMP.

Determining the most suitable superstructure systems for each track section, and their siting, was done by surveys and meticulous analysis of the vibration transmissibility measured in the works without superstructure, on the basis of the following parameters:

- Vibration and transmissibility on the main tracks, in buildings along the track and at stations (track, platform and technical rooms)
- Parameters of equivalent perception of vibration (EPV™)
- Maximum secondary noise and vibration acceptable for the Metro
- Expected secondary noise and vibration attenuation of each system
- Track characteristics
- Rolling stock characteristics
- Geographical conditions according to the zone of influence for the region of each structure
- Level of occupancy of the ground and leaking of the buildings along the track
- Characteristics of the buildings
- Construction methods of each type of structure (tunnels, randomness of the elevated sections and extents).

**systems adopted**

The surveys and analyses of the above parameters were used to correlate each type of section with the appropriate superstructure system determined according to the necessary degree of vibration attenuation, as follows:

- Superstructure system with concrete sleepers in ballast
- Superstructure system with concrete sleepers in ballast on resilient ballast mats
- Superstructure system with concrete sleepers in ballast on resilient antiballustratory mats
- Superstructure system with ballasting plates provided with resilient pads under the rail and the plate
- Superstructure system with CDM spring compound at discrete bearing points (DFPA)
- Superstructure system with spring compound on isolamping supports
- Superstructure system with spring compound associated with the system of bearing plates provided with resilient pads under the rail and the plate

**Systems installed**

Superstructure system with concrete sleepers in ballast

An example of the use of the superstructure system with concrete sleepers in ballast, installed on 2.7km of double track, was constructed using precast-concrete, prestressed monoblock concrete sleepers manufactured by Cavan S/A featuring a study of the Pardol Rail Fastening System. The surface sections were constructed with ballast of crushed rock and sub-ballast where the vibration transmissibility presented low values.

Superstructure system with concrete sleepers in ballast on resilient ballast mats

Track that has its ballast resting directly on a concrete slab, as in stations and on elevated sections, develops large dynamic forces at the interface between the ballast and the elevated slab, resulting in cracking of the ballast elements (crushed rock) that are in direct contact with the concrete structure. This makes fissures migrate to the upper layers, causing clogging of the ballast, increased rigidity, larger forces transmitted to the structure, track subsidence and structural noise.

For this reason, the superstructure system used on surface concrete structures and elevated sections involved concrete sleepers in ballast resting on resilient ballast mats with a view to preventing these effects and enhancing the desired vibration attenuation on 0.8km of double track.

The permanent way using this superstructure system involved pretensioned sleepers of prestressed concrete made by Cavan S/A and resilient ballast mats made of cork-based material and rubber by the Portuguese company CDM (Composite Damping Material). The Pardol system was adopted for fastening the TR5/175 rail with type "E" 2009 resilient clips.

The attenuation expected from this system is about 6DB relative to a track in conventional ballast.

Superstructure system with bearing plates provided with resilient pads under the rail and the plate

On elevated sections, at structural transitions and at the Jose Bonifacio station, the superstructure system with bearing plates provided with resilient pads under the rail and baseplate on a continuous supporting beam was adopted, resulting in two secondary noise and vibration attenuation levels.

This superstructure system involved fastening the rail to the concrete supporting beam by the Pardol VHA system on 1.5km of double track. The bearing plate of the rail fastening assembly was fastened to the supporting beam by holding-down bolts anchored in the beam and resilient rubber guide-bushes in the holes in the plates, thus enabling all the components to be removed at any time and facilitating track maintenance operations.

The attenuation expected from this system is about 15DB relative to a track system with rigid direct fastening.

Superstructure system with CDM spring compound at discrete bearing points (DFPA)

In two tunnels where the infrastructure was already complete (one of them 392m long, the other 1.140m) and a highly effective secondary noise and vibration attenuation system was needed, the superstructure system adopted
TRACK SUPPORT SYSTEMS

involved CDM spring compound with floating slab on discrete supports (DFPA) consisting of resilient rubber-based material bonded under the permanent formwork and distributed according to a pattern predetermined at design stage to make it possible to alter the rigidity of the system according to the characteristics of the track, e.g. on curves and at transitions to other systems, thus preventing elastic shocks.

Rail fastening was achieved by using the Pandrol system of bearing plates containing pads of resilient material inserted only under the rails. The plates are provided with rigid bushes with eccentric holes that make it possible to adjust them laterally, longitudinally and vertically, facilitating gauge adjustment both during track laying and during corrective operations to remedy rail wear and/or any subsidence that may occur over time.

The attenuation expected from this system is about 25dB relative to a track system with rigid direct fastening.

Superstructure system with spring compound on isolamping supports

The tunnel to the east of José Bonfácio station was provided, for 244m, with the GERB type spring compound system consisting of floating slab with coil springs immersed in a viscous medium, so-called isolampers, distributed so as to provide better damping. Vibration attenuation of the order of 22 to 26dB relative to a track system with rigid direct fastening is expected on this section.

Superstructure system with spring compound associated with the system of bearing plates provided with resilient pads under the rail and the plate

The whole elevated section where the Pibasgo station is situated, and the transitions of the two tunnels adjacent to it, comprising 1.2km of double track, needed a spring compound system associated with the system of bearing plates provided with resilient pads under the rail and baseplate, owing to the height available for laying the track and the slenderness of the elevated section.

The design of this system, owing to the resulting clear thickness for the concrete slab, involved a track system comprising the CDM spring compound system with floating slab on anti-vibratory mats (DFPA) of resilient rubber-based material and cork, combined with the Pandrol VBA system for fastening the rail to the floating slab. The result was three vibration insulation levels, the first under the rail foot, the second under the bearing plate and the third under the floating slab, forming a highly effective secondary noise and vibration attenuation system with a rather thin floating slab.

The attenuation expected from this system is about 24dB relative to a track system with rigid direct fastening.

Performance verification of the systems

Design development involved tests carried out in the laboratory of UNICAMP’s Technology Centre for the type-approval and secondary noise and vibration attenuation verification of the systems described above. The test results showed that all the systems produced positive results not only in dynamic and static performance and in strength of materials but also in secondary noise and vibration attenuation.

The completion of the works after installing all the signalling and electric traction systems will make it possible to carry out full-scale verification by tests covering not only vibration and noise measurement but also transmissibility between the various structures and between the ground and buildings along the line. These tests are scheduled for June 1999 and will be based on passing trains with a view to obtaining the true noise and vibration level parameters to compare with the standards specified for São Paulo’s Metro. This will make it possible to ascertain the true effectiveness of each system and monitor them with a view to verifying their behaviour and performance over time.

On completion of the tests, new material will be prepared for Track Report, using the results obtained, thereby supplementing this article.
Track Construction on the Subiaco Railway Tunnel

by Tony Smith, Project Manager - Barclay Mowlem Australia.

Subiaco is a suburb just 5km from the heart of the city of Perth, Western Australia, which is being developed as a business and leisure centre. Subiaco is an important station on the Perth to Fremantle urban railway which is a narrow gauge, dual track line with 25 KV AC overhead traction power supply. The railway provided a physical barrier to the further development of this very valuable inner city land and thus a decision was made to place the railway line and station underground. The commercial value and development of the land released by the sinking of the line and station was highly dependent on good noise and vibration attenuation within the tunnel structure.

Barclay Mowlem Construction Limited was contracted by the principal contractor, Multiplex Constructions Pty Ltd, to provide the trackwork for the Subiaco Railway Tunnel and Station project. The trackwork, which was built as a deviation on a modified alignment, included about 1,660 metres of direct fixation concrete slab track.

At contract award, the basic concept was to fix the 508mm continuously welded rail and resilient supports to a level concrete slab with holding down bolts epoxy fixed into cored holes. Rail level and superelevation were to be achieved by graded plinths at each support plate. A ‘top down’ construction method with temporary supports was envisaged.

Pandrol’s new VPA plate assembly was selected for its lower cost and its ability to meet all aspects of the tender. One of the advantages of the Pandrol VPA assembly was its ability to be easily maintained over the operating life of the line.

During the detailed design process with contributions from the client, consultants and contractors, a modified construction system evolved. This included provision of a postlift slab for superelevation as well as the adoption of Pandrol VPA supports, HDPE packers in lieu of grout and screwspikes with HDPE packers instead of holding down bolts. The length of concrete slab track increased to 2,000 metres to include approach track on the tunnel declines.

Track Design

The project included:

- Ballastless track construction for one temporary railway deviation.
- Ballasted track construction for the cut embankments connecting the new tunnel to the existing Fremantle line near Daglish and West Leederville Stations.
- Direct fixation slab track construction in the tunnel and below ground station structures.

Westrail developed a detailed specification including the following design parameters:

- **Design Speed**: 100kph (80kph minimum on temporary diversions)
- **Annual Tonnages**: 6 million gross tonne maximum
- **Axle Load**: 16 tonne maximum
- **Rail**: AU 50kgs
- **Rail Support Centres**: 710mm
- **Track Gauge**: 1567mm for tangent track
- **Track Support**: A direct fixation continuous concrete track slab provided in the tunnel and station structure.

Noise and Vibration: The realignment should be designed and constructed such that existing noise and vibration levels at properties and residences along the route should not be exceeded. The Contractor was to provide noise and vibration studies prior to and after the works to demonstrate that this had been achieved to the Superintendent’s satisfaction.

**Direct Fixation Slab Track**: The slab track should comprise (as a minimum) a reinforced concrete slab 700mm wide and 250mm thick with track fastenings of the resilient direct fixation type.

**PANDROL VPA Double Resilient Track Support System**

The slab track and rail fastenings should be designed and constructed by the Contractor to comply with the following criteria:

- **Optimise the reduction in transmission of vibration from rail to the concrete slab track consistent with the intended land uses of the proposed redevelopment above**.
- **Provide ease of inspection and replacement of the fastening components**.
- **Achieve high durability with no degradation of dynamic performance of all fastening components. The fastenings would be designed for an operational life of greater than 30 years with no requirement for periodic maintenance**.
- **Maintain long term track alignment**.
- **Provide run on slabs at each end of the tunnel to allow suitable transition between the ballasted track and slab track**.

**Testing and Commissioning**

Proof of compliance with the specified requirements for direct fixation vibration isolation system was provided by testing of completed units during the design and later during the production phase. Performance verification was provided for all components of the system, including boots, pins, clips, plates, insulators, screws, pins and inserts etc.

The manufacture of the rail fixation system was subject to a quality level of 2.5% (Normal Inspection Level 2 - AS1199).

The performance verification included dynamic load testing of the rail fixation system, using a system capable of three dimensional load testing.

The dynamic load testing was carried out for various loads at different frequencies. (i.e. 3, 10, 20, 30 and 40Hz)

**Track Laying**

For track construction, the concrete slab was made progressively available in the order of west tunnel, east tunnel, station area and west approach.

The first step in the track laying process was to survey, accurately, the track centre line of each rail support location which were at nominal 710mm spacings. A purpose-built core drilling rig was developed and manufactured by Barclay Mowlem. The rig enabled precise drilling of the concrete slab by setting up the platform over sequential centre line survey marks. The sixteen holes for VPA support fixings at two successive support locations were able to be drilled quickly with just one set up of the rig which comprised four drills working simultaneously. Reinforcement in the slab had been designed with splices to avoid conflict with the core drilling.

Following core drilling, which located the VPA supports, the concrete surface at each support location was ground to ensure a flat surface. A level was then taken on a template matching the complete rail assembly. From these levels the thickness of HDPE packer plates at each support was determined to achieve correct rail level and superimposition, taking into account local variations in finished concrete level.

The core holes were carefully cleaned by compressed air prior to two part epoxy fixing of HDPE screwspikes dowels. Following placement of the VPA supports with appropriate packers, the long lengths of 50kg/m rail were installed. After destressing, welding and full clamping of the rail, final adjustment of the track alignment and gauge was achieved using the slotted adjustment in the VPA plate before final tightening of the screwspikes holding the support plates down.

The trackwork was completed on time and trains have been running since early December 1998. The project is a credit to all concerned and the impressive final appearance reflects the positive contribution made by everyone involved in this project.
TFM of Mexico Upgrades Existing Tracks

Mexico’s topography has always been a challenge to railway engineers. The country’s mountainous terrain, with which railway engineers had to deal, made the planning of track location a difficult task. Consequently, in the Mexican railway system there exists a high percentage of curved tracks as well as extremely steep grades. As axle loads have been increasing over the years and operational requirements becoming more demanding with respect to speed, new options had to be evaluated in order to maintain the consistency and safety of railroad freight.

Based on the above conditions, history has shown that an unusually high percentage of derailments and accidents occur on curved track in Mexico. With this in mind, two of the new prioritized railroads decided to adopt and install new tie-fastening systems in order to reduce the number of recurring problems.

For these new installations, concrete ties were selected, considering that this was the only type of track support that could sustain the increasing lateral and vertical loads to which the tracks were subjected. Coupled with this decision was the knowledge of the excellent history of performance of concrete ties in Mexico. Following this decision, after a thorough evaluation of different fastening systems, the PANDROL FASTCLIP fastening system with gauge widening capability was selected for installation in sections of track where loading demands were high. It was concluded that the FASTCLIP fastening system provided the technical features that were necessary to meet the demanding requirements. Also the benefits of the pre-assembly capability, mechanism and low maintenance cost made FASTCLIP an attractive choice.

Specifically, FASTCLIP incorporates a high toe-load that was required in order to restrain the rail to prevent railroll and possesses the capability of assembling the track with gauge widening requirements for gauges of 1438mm, 1438mm and 1442mm with a common clip. The decision of assembling track with gauge widening flexibility was determined in each design case depending on the operational requirements of that particular section of track, with consideration being given to minimising rail wear.

In order to accommodate the FASTCLIP with concrete ties, the railroads worked jointly with the company ITSA, a concrete tie manufacturer in Mexico which has produced over 12 million concrete ties for the Mexican railway system and has developed the required tooling to incorporate the fastening system into the manufacturing process of post-tensioned concrete ties manufactured with the immediate demoulding method. The development of the FASTCLIP being incorporated into this type of tie led to extensive dynamic testing at ITSA with very good results.

With close collaboration between ITSA and railroad personnel, a schedule of events was established. The FASTCLIP was first pre-assembled in the plant according to the construction schedules and gauge widening requirements specified for each of the sections of track to be rehabilitated. The ties were then shipped to each corresponding site. A specific identification marker was stamped on the top of each tie specifying the gauge widening capability of the installed FASTCLIP.

The ties with the FASTCLIP system replaced standard pine wood ties with steel plates, spikes and anchors. Prior to installation, specialized testing in all wood tie sections of track had shown that lateral restraint was very poor. The application of FASTCLIP was an innovation for Mexico in as much as there was little knowledge by railroads and the contracting companies on how to handle and install such a new type of fastening system as FASTCLIP.

Pandrol personnel were sent to the sites where required training was given to contractors and engineers responsible for the installation. Considering that these installations were limited in scope and were only going to be made in specific sections of track, the construction procedure used was semi-mechanised, such as using ordinary tie handling and track equipment. The application of FASTCLIP was made in some sections with hand tools and in others with low production mechanised application, which was the accepted requirement for the project.

All these installations were made in operating tracks, where 4 to 6 hour possession windows were available. Depending on the territory, an average of 300 metres of track was replaced each day when a 6-hour window was available. It is important to emphasise that a large number of sections of track to be rehabilitated were located in cuttings where the handling of the ties was restricted because of space limitations. This made the installation process difficult in view of the short work window. The utilisation of efficient track equipment such as the track renewal train would solve many of the problems encountered and improve the efficiency of installation.

The sections of track where these installations have been completed are in curves that range from 1 to 8, metric, and have grades from 0.5% to a maximum of 1%. Reverse curves were also part of this programme.

The final track infrastructure achieved with these installations has been extremely satisfactory compared to previous methods of installation. In the short time that the installations have been in track, it has been observed that the good track performance exhibited by the new track has resulted in a significant reduction of accidents and derailments. If the project continues to prove successful in solving the problem for which it was originally developed, the system could be adopted as a standard for these types of track in the Mexican railroads.
Turnouts on the Gardermoen Airport Rail Link

by Ulf Rohnen, Managing Director, AS Roderöden Industrier

With Cogifer selected to be the supplier to the Gardermoen Airport Rail Link, technical discussions commenced with the aim of supplying NSB Gardermoenbanen with the most modern and technically advanced turnouts in the world. NSB Gardermoenbanen selected a clotheide design for most of the turnouts (UC60 1:18.4, and UC60 1:26.1), fastened with PANDROL FASTCLIP. This decision was taken at a very late stage and Cogifer, Pandrol, Schiwaag and Strømngtønng, as the main participations suppliers for the Norwegian turnouts, had to make new designs and models in a very short period of time. From decision to delivery of the initial turnout was only an 8-9 month period.

Six months before delivery, Gardermoenbanen decided that all turnouts should be designed with lubrication free side chews due to the environmental demands, and only 2-3 months before the first turnout was to be delivered, a further decision was made regarding the incorporation of a new heating system in a special sleeper.

Because of a close cooperation between Cogifer and the other suppliers, the first turnout was delivered almost in accordance with the original time schedule.

Assembling of turnouts

The contractor for the track work was Banverket of Sweden, who were assembling turnouts with the PANDROL FASTCLIP fastening for the first time.

A pair of 1 in 16.4 concrete beam turnouts with PANDROL FASTCLIP rail fastening assembly.

Despite this, the turnouts with FASTCLIP were assembled far more quickly than Banverket had previously experienced with turnouts with other fastenings, and it emerged that Banverket estimated it probably saved approximately 50% in the time taken for assembly.

After finishing the track work, Banverket's conclusion with respect to turnouts fastened with FASTCLIP is very positive.

Customer Comments and Future

On completion of the installation of the turnouts in the Airport Link, the senior members of the Gardermoenbanen Project Team were pleasantly surprised at the outcome of the decision to put so many new designs and materials in the turnouts for Norway's most important railway project within the 1990's. Their satisfaction level is such that it is felt that this system, Cogifer and the other suppliers could be recommended to other railway companies, in respect of the way its demands on design and delivery to a very tight timetable were met.

The Norwegian railway, Jernbaneverket, is so satisfied with the turnouts with FASTCLIP that AS Roderøden Industrier, a subsidiary of Cogifer in Norway, has commenced a project together with Pandrol Rail Fastenings Ltd and Jernbaneverket to develop the full range of Norwegian turnouts for FASTCLIP, for use on both wooden and concrete bearers.

With headquarters in Atlanta, Georgia, USA, the Metropolitan Atlanta Transit Authority (MARTA) operates a comprehensive bus and rail system providing approximately 550,000 trips on an average work day.

MARTA's bus system is comprised of 157 bus routes, 1,531 route miles and nearly 31 annual million vehicle miles of service. The rail system operates over 100 miles of mainline track and services 36 rail stations. In Fiscal Year 1996, MARTA's combined bus and rail system provided over 144 million passenger trips.

Concrete Crosstie Failures

Beginning in 1991, MARTA's track inspectors began reporting isolated concrete crosstie failures. The deterioration continued and in 1995, MARTA recognised that decisive action would have to be taken to address the needs of the over 50,000 concrete crossties.

Immediately after the 1996 Olympic Games, project development began. The Engineering Team consisting of the Office of Track and Structures, Quality Assurance, Facilities Engineering, Program Management, and MARTA's General Engineering Consultant, Parsons Brinckerhoff Tudor - Turner Associates (PBTA), partnered in the Failure Analysis effort. This step began with a detailed survey of over 57,000 ties that confirmed the condition and location of deterioration. MARTA made the decision to replace approximately 52,500 concrete crossties.

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Immediately after the 1996 Olympic Games, construction created a serious conflict with MARTA's ability to meet customer expectations. A survey was designed to validate customer expectations. Focus group sessions and an on-board survey of over 3,200 customers was conducted. Based on the findings of these activities, the engineering team modified the production schedule, confining the work to off-peak hours at night and on weekends.

PANDROL FASTCLIP Chosen

Project designers recognised that it was essential that the work be performed with as little impact on operations as possible. This theme spanned the choice of equipment, processes and material. During the design review process with the three major concrete tie manufacturers in North America, MARTA examined the use of several types of fastening systems. MARTA engineers concluded that the PANDROL FASTCLIP was the best fastening system for this application for the following reasons:

1. The cost of the PANDROL FASTCLIP was comparable with the other fastening systems.
2. The performance characteristics met or exceeded those of other fastening systems.
3. The PANDROL FASTCLIP assembly is captive to the tie. This virtually eliminates material handling and loss issues.
4. The PANDROL FASTCLIP design lends itself well to mechanized application techniques.
5. The low-profile design of the PANDROL FASTCLIP provides for more efficient ballast regulation and becoming which is important for the retention of electrical isolation properties.

The Construction Process

In July of 1998, construction began. At the end of February 1999, this $34 million project is approximately 50% complete, ahead of schedule, under budget, has a good safety record and ridership has increased 8% on the impacted rail lines. Current projections indicate that the work will be completed by the end of the 1999 calendar year.
PANDROL and JR-East: A Decade of Progress Together in Japan

by Mr Seiji Shima, Deputy Manager, Track Maintenance Dept., East Japan Railways

Japanese rail fastening has basically not changed over the years. Due to ever increasing demands for less maintenance and cost, EJR is looking for means to reduce these elements. Through years of experience with the non-threaded Pandrol rail fastening systems, EJR has seen how savings can be made by employing such systems and in order to gain the same benefits on Shinkansen lines, it was decided to use Pandrol on the Nagano Shinkansen.

The line has a design speed of 270kph and is 110 route km long, branching off from the Joetsu Shinkansen at Tatekawa. For ballasted sections, all sleepers have Pandrol 'v2009 clips and 10mm rubber pad. This track form is mainly applied on station areas and where the line goes at grade.

The slab trackform is applied on all other sections, which are in tunnels and on structures. In addition to the conventional fastening system, there are two different Pandrol track forms on the 5m slabs. In tunnels, a shoulder system is used which provides a 5mm lateral adjustment and up to 10mm of vertical adjustment, which is available for maintenance purposes. The lateral adjustment is by means of a serrated wedge shaped insulator, and vertical adjustment is by means of shims directly under the rail. Changes in clip toe load are compensated by turning an eccentric bush in the shoulder. On viaducts, there are greater possibilities of settlement, or movement as a result of minor earthquakes. Here a baseplated system is used, providing at least a 10mm of lateral adjustability. Up to 10mm of vertical adjustment can be accommodated using the eccentric bush, as with the shoulders, and even more vertical adjustment can be obtained by putting shims under the baseplate. This relatively large maintenance adjustability, which is provided in addition to the adjustment available in the slab laying at the construction phase, is necessitated by the unique experience Japanese railways have obtained from earthquake influence in high speed tracks and structures.

Both designs have been developed in close cooperation between EJR and Pandrol engineers, and subsequent laboratory tests and trials have concluded that the assemblies reached the objectives and could be approved for Shinkansen applications.

Another special feature of the non-ballasted assemblies is the requirement of a relatively low toe load of 30kN. This requirement is due to the interaction between main viaduct structures, 5m slab and track itself relative to movement caused by temperature or other environmental impacts.

Since the Nagano Shinkansen commenced operation in October 1997, the different Pandrol assemblies have performed to our full satisfaction.
Tokyo Station

Since the first Shinkansen trains started operating from Tokyo in 1964, many more Shinkansen lines have been connected to this central station. Subsequent extensions and addition of new station tracks have followed over the years.

Since the increased adoption of Pandrol fastenings over the last 10 years, more of the station tracks have adopted Pandrol. Due to special design requirements based on structural parameters and numerous related restrictions, a number of different fastening assemblies are used. These include elements like different clips, insulators and pads suited to both ballasted and non-ballasted track forms on concrete sleepers, plastic sleepers (steel bridges) and concrete slabs.

Some of these assemblies can be seen on the series of photographs which show the variety of possible designs which can be obtained with Pandrol rail fastenings. This design flexibility matched with the lesser demand for maintenance, confirms the confidence of EJR in the ability of Pandrol and its engineers to meet its requirements.

Yamagata Extension

In order to allow fast train service to less heavily populated areas, EJR has developed the so-called ‘Mini Shinkansen’ concept, which means converting narrow gauge lines into standard gauge in order that Shinkansen trains can operate throughout the system. The original alignment of the narrow gauge line is maintained, thus limiting the speed to typically 130km/h, although the same trains can run at up to 300km/h when they travel on the main high speed lines.

Over the last 5-10 years, two such Mini Shinkansen lines have been connected to the main Tōhoku Shinkansen north of Tokyo. These are the Akiha and Yamagata Shinkansen, both of which have ballasted track with concrete sleepers and Pandrol rail fastenings.

When it was decided to extend the Yamagata Shinkansen, EJR looked into the possibility of applying the new Pandrol fastening system: PANOROL FASTCLIP.

Gauge conversion from 1067mm to 1435mm in the main is achieved by sleeper change carried out by a track relaying machine and EJR saw the benefits of applying the most modern fastening type which can take full advantage of such mechanised track work in order to minimise manpower demand. Study tours to overseas sites where FASTCLIP was in use or under construction were undertaken and the standard Japanese laboratory tests and field trials were undertaken, followed by strict evaluation and conclusion.

All investigations led to the favourable result that FASTCLIP could be used for this project, which is now under construction. Sleeper production commenced in the first part of 1998 and track work started with semi-mechanised methods in November 1998. In April 1999, the main track work with track laying machines commenced and is expected to be completed by September/October 1999.

The new line will commence operation in December 1999.

Conclusion

Since EJR started using Pandrol some 10 years ago, experience with the system has given EJR the confidence to expand the use of Pandrol for all new concrete narrow gauge sleepers and a variety of non-ballasted applications for both conventional track and high speed Shinkansen tracks.

We expect this development to continue and expand into the future.
Track Installation on the Seoul-Pusan High Speed Rail Project

by Dr. K.D. Kang, Director, Construction Department of Korea High Speed Rail

Track installation on the 380km long Test Track for the Seoul-Pusan High Speed Rail Project commenced during February 1999 after part of track bed construction was completed.

Track installation on the Test Track is divided into two phases. The first phase is approximately 30km long and will be completed during August 1999. Catenary installation will follow and will be completed in November 1999. Testing and Commissioning of this first phase will commence during December 1999.

The following describes the organisational structure and the methodology of the track works.

TRACK INSTALLATION

Track Depot

Including 21 tracks (25,700m), two factories, one equipment maintenance workshop, site offices and storage areas for ballast, concrete sleepers, long rails and other track related materials, the 540,000m³ large Osong Track Depot is the staging area for the track construction (see Figure 1).

Rail Welding Factory

The Osong Depot comprises an approximately 300m long welding line that welds rail into 300m lengths from the 25m rails which are supplied by train from the steel mill. The rail welding factory performs 7 different processes including cleaning, straightening, welding and grinding of the rails (see Figure 2).

Installation of Temporary-Track

The temporary track is installed first to provide access for the working train, which transports and unloads the 300m long-rails necessary for the up and down tracks. The temporary track consists of 14m long panels, which are transported on 16m long wagons. An installation beam crane located at the front of the work train lifts the panels and lays them on the track bed at a rate of about 700 to 1000m a day (see Figure 3).

Transportation of 300m Long Rails

After the temporary track is installed on a sufficient length, the long-rail train transporting the 300m long rails is able to unload the rails on both tracks. The train is equipped with special rail support devices to transport up to thirty rails of 300m which are stacked in three layers on the wagons (see Figure 4). The special rail support devices which are mounted on the wagons allow the long-rail train to pass through curves with a minimum radius of 150m in the Osong depot.

Installation of PC Ties and Track Assembly

Two gantry cranes supported on the long rails are used to remove the temporary track panels and to install the concrete ties. The first gantry crane removes the 14m long temporary track panel and places them on an empty wagon for later reuse at a different location. The second gantry crane is used to lift 40 concrete ties from a wagon and place them on the track (see Figure 5). The spacing of concrete ties is 60cm and the width of each tie is 30cm.

After the concrete ties are placed the two long rails are installed with the help of a rail threader and the rails are fastened to the concrete tie with Pandrol rail clips (see Figure 6). The 300m long rail sections are then welded using a thermit welding process.
Ballasting and Tamping
The traditional operations of ballasting and tamping ensure that the track is lifted to its final level in six successive steps of a maximum of 8cm providing a minimum ballast thickness of 350mm under each sleeper. Dynamic stabilisation is carried out three times during the lifting process (see Figures 7 & 8).

Turnout installation
The turnouts are installed after ballasting and tamping of the fourth lifting step. The turnout is assembled and inspected at the turnout factory. The turnout is temporarily divided into 3 or 4 segments and loaded on special wagons for transport to the installation site. The turnout is pre-assembled and installed on special concrete bearers with lifting units. The turnouts are incorporated into the continuous welded rail (CWR) thus ensuring the continuity of the track.

Destressing of Long Rail
After the 360m long rails have been installed and welded, the rail fasteners are released on a 1500-1800m long section of the track. The rails are then brought artificially to the median temperature of 25°C by the means of hydraulic rail tapers before thermite welding of the cut and refastening.

Final Track Adjustment and Inspection
The final tamping of the ballast is performed with a Tamping Machine (M.T.T 09-91) that is equipped to record the geometry of the track allowing an accurate control of the track quality. Final track parameters are recorded by a track inspection car to identify any non-conformance in the track geometry relative to the tolerances for High Speed line operation.

Civil Construction
The track bed between Seoul and Pusan which includes the test track shown in figure 6 is composed of approximately 112km of bridges, 192km of tunnels and 109km of at grade sections. One of the innovations in bridge design and construction was the introduction of the Precast Span Method (PSM). Precast concrete Box Girders with a length of 25m and a width of 14m were selected for long valley viaducts to support the two mainline tracks.

The girders are precast at a temporary precast facility that is located near one end of the bridge. The precast girders which weigh about 600 tons each are transported on specially designed carriers from the precast facility over already installed concrete Box Girders to the point of installation. The concrete Box Girders are lifted from the carrier and moved along a launching beam which is supported at the front end on a completed bridge pier and on the back end on the previously installed concrete Box Girder (see Figure 9).

Composite HSR railway bridges have been selected at locations with specific site requirements such as limited clearance or construction related requirements at highway crossings.

Conclusion
The track installation on the first phase of the Test Track which is part of the permanent track of the Seoul-Pusan High Speed Rail Project is well under way and will be completed by November 1999. The transportation of the 300m long welded rails, installation of the concrete ties, ballasting, tamping and dynamic stabilisation, turnout installation, destressing of the long rails and the final adjustment and inspection of the track continues following the established track installation procedures.
VERSE®. Non-Destructive Measurement of Stress Free Temperature

from Vortok International & AEA Technology Rail

The problem of thermal expansion and contraction of rail has long been a challenge to railway civil engineers. The track engineer has a safety critical problem with this phenomenon, especially with heavy haul and medium to high speed railways. To ensure that temperature variations in continuously welded rails (CWR) do not cause track buckles in hot weather or equally dangerous rail fractures in cold weather, it is crucial that the Permanent Way engineer knows the temperature at which the rail is neither in compression nor in tension. This is known as the stress-free temperature (SFT).

Measuring the stress-free temperature has always been time consuming, difficult, destructive and labour intensive. The traditional method of cutting a perfectly good rail to determine SFT has meant re-welding the rail in two locations, an expensive and time-consuming operation that itself introduces a safety risk.

AEA Technology Rail and Vortok International have jointly developed a new technique and equipment that will significantly ease SFT assessment. VERSE® is a simple, quick and non-destructive technique requiring no cutting of the rail.

**Technique**

The SFT is determined by analysing the force and deflection during a lift of 30m of undipped rail. Factors such as the rail temperature, rail profile, sleeper type, curve radius, along with site details are entered into the computer, which then leads the operator through the measuring process. The rail is initially lifted onto 2 spacers, 20m apart so the rail is temporarily suspended. Three measuring cycles, which comprise applying a vertical force of up to 1000kgf and accurately measuring the displacement, are completed and the rail is then re-fastened. At a convenient moment, the data is transferred to a Pentium or equivalent PC to calculate the stress free temperature. The data can then be transferred to an infrastructure database to provide site history and better management of a route.

The whole process from arrival to site, assembling the equipment, un-dipping the rails, measuring both rails and leaving the site, can be as quick as an hour and usually involves only three or four men. Over 500 measurements have been taken to date and accuracies of ±0.2°C have been verified when compared to the traditional method. The technique and equipment have been approved by Railtrack in the UK after a rigorous safety case and verification programme. The technique is now in regular and growing use on plain line down to 700m radius curves, with research being done on 400m curves.

**Availability**

Vortok International is now, with AEA Technology's agreement, supplying VERSE® to the railway industry, contractors and infrastructure owners. The lifting frame and measuring equipment, special hand held PC, software and training are all part of the package on offer.
**Rapport sur les voies**

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**PANDROL**

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El metro de São Paulo adopta tecnología avanzada para la exportación de líneas de trenes

Apparición de la fusión aeronáutica de Garberden por UL Rihlon Managing Director AS Redolfi Norden

Witnchen bei der Garberden Flughafen Eröffnungsfeier

Detalhes instalados no colégio da aeroporto de Garberden

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