TTI Upgrades Railroad Track to facilitate introduction of high speed rail service in America

by Ken Laine, Program Manager, Government & High Speed Rail, Transportation Technology Centre Inc. (TTCI), Pueblo, Colorado.

High Speed Rail is coming to America and it will make its first debut in the Northeast Corridor. The Transportation Technology Centre Inc. (TTCI) in Pueblo, Colorado is ready to help make it happen.

As part of the Federal Railroad Administration's (FRA) Next Generation High Speed Rail Program, TCCI has been commissioned to upgrade the center's Railroad Test Track (RTT). The revamped track has the capability of testing at sustained speeds of up to 150mph (240 km/hr) in the qualification testing of AMTRAK's North East Corridor trains, scheduled to be in operation in 1999.

The FRA's RTT track upgrade is seen as a critical component in the implementation of high speed rail service. Development and testing of high speed equipment, prior to introduction in revenue service, will help ensure the safety and success of the service once offered to the public sector.

**Upgrade accomplishments include:**

- Conversion of pointed rail to continuously welded rail
- Replacement of the majority of the existing softwood ties with concrete ties and the latest elastic fasteners - the PANDROL FASTCLIP system
- Upgrading the overhead catenary system to 165mph (265 km/hr) capability
- Realignment of a reverse curve for high cant deficiency testing
- Upgrading turnout components
- Installing a broken rail and open switch point detection system
- Surface leveling and stabilization of the entire RTT

The successful completion of this track upgrade was dependent upon not only the funding of the FRA but the support of the railway supply industry as well. Congress challenged the FRA to solicit industry support for this project in order to prove that this technology is a viable transportation system option of the future.

The FRA, in turn, asked TCCI to coordinate this effort to make up the shortfall of necessary funding to complete the project. The supply industry response has been excellent, keeping the upgrade on schedule and within budget. Partnerships have been realized through donations of materials, services and expertise in excess of two million dollars.

Among the companies contributing to this effort were Pandrol USA, Fairmont Tamper, Rocla Concrete Ties Inc., and Queen City.

The PANDROL FASTCLIP system was chosen for its ease of installation and it was installed by the Fairmont Tamper 8811 track laying machine, which had been specifically designed to install this fastening system. This combination resulted in a lower cost installed tie. Rocla Concrete Ties Inc. produced the ties, and Queen City were the contractors.

Pandrol USA cooperated fully in the procurement, installation and utilization of the FASTCLIP system, which is currently installed on 11 railroads and transit in the United States.

Amtrak's North East Corridor trains will be arriving in late 1998 for a comprehensive qualification program which is scheduled to run through mid 1999. Other potential high speed customers to utilize this unique world class facility within the next few years include the Railway Technical Research Institute of Japan and the Florida Overland Express (FOD) consortium destined for service early into the 21st century.

Amtrak's North East Corridor trains, due to be tested on the new track.
The Arlandabanan Project
by Graham Davenport, Project Manager, John Mowlem Construction AB

The Arlandabanan Project is the first large infrastructure project in Sweden being co-financed by the government and private industry.

A rail link between Stockholm Central Station and Arlanda Airport to connect the main railway with air traffic has been under discussion for some time. A number of investigations and proposals for the link have been put forward over the years.

Bids were invited for the construction of Arlandabanan in 1993.

In August 1994 the contract was won by a consortium consisting of the Swedish companies NCC and Vattenfall plus the two British companies Abott and Mowlem who are responsible for all trackwork.

The consortium was contracted to build and finance the Arlandabanan and to form a company, A-Train AB, which will act as owner and will run the shuttle traffic between Stockholm Central Station and Arlanda.

Three stations have been built between Arlanda Airport, two of them will be used by Arlanda Express and a third is intended for SJ trains and other regional trains which may run to Arlanda in the future.

At Stockholm Central Station, a station is being specially built for Arlanda Express at platform 1.

The length of the new trackwork which is being installed is 20 route km consisting of approximately 40 km of track together with 29 turnouts. Work on trackwork installation, which is the responsibility of Mowlem, started in September 1997 and by the end of the year 14 km of track had been completed on the Southern open section in preparation for work starting in the tunnel section under the airport.

The 29 turnouts, and crossovers mainly 1:18.5 and 1:19.5 have been manufactured by Cogifer Nordic, and are pre-assembled in three parts complete with beacon 160 km away from the site. Each part weighs 20 tonnes, and is transported by rail on special hydraulically controlled platform wagons, and finally off loaded by the D.E.S.C. tracklaying machine. Tracklaying has continued with a winter break through January, February and March and by the end of June 20 km of track was laid, finishing all the Airport shuttle tracks leaving only the Northern Bend to complete by Christmas 1998.

Economical and low maintenance components have been selected throughout, and PANDROL FASTCLIP FC 1501 was chosen as the preferred choice for the elastic fastening. The PANDROL FASTCLIP has been used with the pre-stressed concrete sleeper supplied by Stranghorm AB Sweden; the pre-assembly of the FASTCLIP components on the sleeper being seen as a great saving of manpower on site, and saving a back bending operation.

The trial running starts during 1998 and the link is expected to be open for commercial traffic in the third quarter of 1999. By this time trains will be running at 20km/hr to the centre of Stockholm in 20 minutes.

The Arlandabanan railway, Estonia
by Kaido Simmernann, Director of Infrastructure, Estonian Railways (EVR).

The first railway in Estonia was opened in 1870 between Paldiski - Tallinn - Narna - Gatchina. In the same year, a connection was made with the St Petersburg - Vaasa railway.

Of Estonia approved the Eesti Raudtee Development Plan 1996-2000 which prescribes cost cutting, company restructuring and an investment of 4.5 billion kronos (US$380-350 million) in the railway over the next ten years.

Development Plan
In March 1996, the Government of the Republic of Estonia approved the Eesti Raudtee Development Plan 1996-2000 which prescribes cost cutting, company restructuring and an investment of 4.5 billion kronos (US$380-350 million) in the railway over the next ten years.

Railway Reconstruction
The reconstruction of the Tallinn-Narva railway during 1997-2001 is financed by the European Investment Bank, European Bank for Reconstruction and Development, Phare, the state investment program of the Republic of Estonia and the finances of Eesti Raudtee.

The 1.3 billion kronos (US$91m) railway reconstruction, is planned to double the Tallinn - Narna line capacity opening up the line for freight and passenger traffic for the next 30 years.

In the first stage of the project (in the amount of 483 million kronos (US$34m)) 60 km of the Tallinn - Narna line will be repaired. In the next stage of the project in 1999-2001 (in the amount of 325 million kronos (US$22m)) a further 52 km of the Tallinn - Narna line will be repaired.

One objective of the reconstruction project is an improvement in capacity of the railway, and therefore 499.5 million kronos (US$35m) is earmarked for renovation of the Tapa and Narna stations and the Tallinn junction.

The continuing upgrading works comprise replacing the upper part of the formation with frost heave resistant materials, restoration of the drainage system as well as renewal of ballast, sleepers and rails.

Gibo Rail of UK was commissioned to prepare tender documents including technical specifications for the international tendering. The pre-stressed concrete sleepers are supplied by Swedtex's sleeper plant in Rakvere and the rail by Voest Alpine of Austria.

Hermann Koehne Bauunternehmung GmbH of Germany was awarded the construction contract under supervision of Gibo Rail.

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The introduction of a new rail fastening system, the PANDROL FASTCLIP, with the state of the art machinery, tools and track laying techniques was quite a challenge to us, and presented a steep learning curve.

The results were achieved without much difficulty and the new system has met all our expectations.

A 20 metre long pre-assembled panel, one of three parts each weighing 20 tonnes, being installed on a turnout.

Assembling 25 metre long panels with AWI hand propelled trolley in Tapa Depot.

PANDROL FASTCLIP
An increasing number of urban railways are adopting resiliently mounted rail supports for non-ballasted tracks, in order to reduce levels of vibration and secondary noise in homes and other buildings near to the track.

The PANDROL VIPA range of vibration isolating rail support assemblies is being established on a number of urban railway systems around the world. The system (which was described in some detail in the 1997 edition of Track Report) uses a baseplate, with two studded natural rubber pads, to prevent vibration from the rail being transmitted into the supporting structure. The system may be pre-assembled on a cast sub-plate, or concrete block, or it may be assembled in situ during track construction.

The two biggest installations of 1998 have been in Perth, Western Australia (with a sub-plate) and in Sao Paulo, Brazil (assembled in situ).

One of the major difficulties that is emerging during the introduction of systems of this kind is the problem of specifying a track design that meets the requirements of both the railway engineer (in terms of structural and geometric integrity, and low maintenance needs) and the environmental engineer (in terms of attenuation of vibration). Just to make things even more difficult, railway engineers and environmental engineers each have their own language - their own technical jargon - which makes it almost impossible to communicate with both at the same time:

To the Railway Engineer:

In order to reduce the levels of vibration in the buildings above an underground railway line, or to reduce the noise made as a train passes over a steel bridge, it is necessary to provide dynamic isolation between the rails and the structure. This solution needs to be effective in the frequency range between about 25Hz and 200Hz for many applications. Low stiffness at higher frequencies may be a disadvantage if it causes an increase in amplitude of modes which cause direct noise radiation from the rail web.

To the Environmental Engineer:

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The overall effectiveness of the system depends on the nature of the structure and the surroundings, as well as on the track support system itself. Stiffness is defined by measuring the force transmitted through the assembly with small displacement amplitudes at particular frequencies and pre-loads of interest - i.e. a dynamic tangent (transfer) stiffness.

There are two ways in which these problems can be addressed, and Pandrol is currently pursuing both - developing internationally recognised standards for testing resilient track supports, and carrying out systematic field measurements at a number of representative sites.

A draft European standard for laboratory testing of these systems is being developed (by working group CEN/TC256/WG17), based on the railway track test methods of prEN13146 and the anti-vibration mounting test methods of ISO 10846. Another similar standard is being developed to allow vibration isolation testing of resilient baseplates, ballasted and floating slab tracks, under the auspices of the German standards authority, DIN. This work is highlighting the difficulty in defining even "simple" terms like stiffness. Table 1 lists seven different values of stiffness, all determined using reasonable and acceptable methods and all determined on the very same assembly, but ranging between 17 and 100 MNm (97,000 and 570,000 lb/in). Clearly there is a need for agreement on one definition of stiffness that will be understood by everyone.

<table>
<thead>
<tr>
<th>Test Method</th>
<th>Static Stiffness</th>
<th>Dynamic Stiffness</th>
</tr>
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<tbody>
<tr>
<td>prEN13146</td>
<td>17 MNm (97,000 lb/in)</td>
<td>22 MNm (125,000 lb/in)</td>
</tr>
<tr>
<td>ISO 10846</td>
<td>25 MNm (143,000 lb/in)</td>
<td>27 MNm (154,000 lb/in)</td>
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Table 1: Stiffness of a resiliently mounted baseplate, by different test methods.
A new form of resilient rail pad has been evaluated by Pandrol for use in the PANDROL FASTCLIP rail fastening system. The pad was originally developed for use by Polish Railways (PKP), which now considers it to be its standard pad design for all applications.

The pad has two novel features - its shape, and the material from which it is made. If the pad is cut through along any line, the cross section shape is that of a sine wave. In its standard form, the top and bottom shapes match each other, but the characteristics of the pad can be modified by using "mis-matched" sine waves, or by varying the pitch of the wave across the width of the pad. In any of these forms, the pad meets the most demanding specifications for low stiffness and high impact attenuation performance.

Typical values of static stiffness \( k_{\text{sat}} \) are around 50 MNm, with impact attenuation of around 50%. The Sine Pad also exhibits a highly non-linear load-deflection characteristic, similar to that of Pandrol's well established studded rubber design. Careful design of the non-linear behaviour makes it possible to obtain the best possible resilient behaviour under normal operating loads, whilst having an in-built "secondary stiffness" feature which prevents over deflection of other elements of the fastening system under severe overload conditions.

The Sine Pad is moulded from an elastomeric "alloy", which uses thermoplastic polyurethane (TPU) as a base material blended with other polymers to obtain an exceptional combination of resilience, mechanical durability and resistance to attack by moisture and chemicals. This durability was demonstrated when flat rail pads moulded from the same material were subjected to extended trials in the notoriously severe All-Russia Railway Research Institute test track at Scherbinka.

The combination of properties results in a fastening assembly which is robust and has high creep resistance, but which can be dismantled easily for maintenance work to be carried out.

A PANDROL FASTCLIP FC1501 concrete sleeper fastening was assembled with UIC60 rail and a 10mm thick Sine Pad, and subjected to the full suite of tests recommended in the draft CEN European Standards specification. The fastening system passed the tests in all respects.
Developing the new fastening system for Toronto Transit Commission

by P.J. Howse, Senior Design & Standards Engineer, Maintenance Engineering, Track & Structure Department, Toronto Transit Commission (TTC), Canada.

The Toronto Transit Commission (TTC) mass transit system is comprised of an integrated network of subway, streetcar and bus routes servicing the downtown and adjoining suburbs within the Greater Toronto Area. Over the past four decades, transit ridership has increased with City expansion and currently exceeds 300 million rides annually with more than 300 million rides attributable to subway usage.

The TTC vehicle fleet includes seven generations of subway vehicles with 36 M-series, 474 H-series and 114 T-series cars in service on the Bloor-Danforth and Yonge-University-Spadina lines. Static axle loads range from 14,200 lbs. (62.3 kN) on the 30,100 lbs. (134.0 kN) "crush load" for trains running at zone speeds up to 50 mph (80 km/h). Trains run in six-car consist servicing 60 stations from 6:00 a.m. to 2:00 a.m. with "rush hour" headways of 2.5 minutes. Revenue service typically covers more than 6.8 million train miles and exceeds 30 MGV (27.3 MT) annually.

The subway system totals 97.3 miles (156.6 km) of single direction track, including 74.4 miles (119.7 km) of mainline and 23 miles (37 km) of yard track. The mainline contains approximately 48 miles (77.2 km) of tangent track with the balance being comprised of more than 300 curves, the most severe being a 15 degree curve with 4'1" superelavation at 20mph. Curves of 2 degrees or more are guarded using horizontal restraining rail on the low rail.

The mainline is constructed from three basic track types: resilient fastener on invert; resilient fastener on concrete double-ties; and a lesser proportion of elastic dip fastener on tie and ballast. Running rail is either 100lb ARA-A with 24 in (600mm) centreline of fastener spacing or 115lb RE rail with 30 in (750mm) spacing. All 55 miles (88.5 km) of track on invert and double-tie employ some variation of the fastener depicted in Figure 1 on a means of rail fixation with the earliest assemblies dating back to the commencement of operations on Yonge Subway in 1954. These mainline fasteners are subjected to more than 2.2 million wheel passes annually to date, the oldest assemblies have accumulated in excess of 80 million load cycles. Although they have not caused sudden failures or safety concerns they do require significant maintenance.

The task of ensuring safe and reliable train operation becomes increasingly difficult as various components within the track system wear out. This reality, amidst the expectation of uninterrupted service, limited work window, and escalating material and labour costs, renders maintenance intensive track components unacceptable regardless of past performance. Cost effective track maintenance, in fact is recognized as one of the key ingredients necessary for sustaining the viability of transit operations in general. In keeping with this basic premise, TTC engineers considered the historical standard resilient fastener design unable to pass the acid test established by modern demands. To rectify this situation, a dedicated team was assembled and committed to an intense program to design, develop and eventually replace the existing invert-type and double tie-type fasteners throughout the subway network.

In 1996, the TTC requested Pandrol's assistance in developing a new Direct Fixation (DF) fastening system. From the outset, the development program was governed by two TTC directives: the first to retain favourable performance characteristics from the existing fastener and the second, to eliminate or minimize maintenance concerns inherent with the present configuration. Primarily the focus was centered around component features contributing to loss of fastener pre-load, anchor bolt fatigue, insulation failure which resulted in major electrolysis and signal fault problems; and labour intensive component replacement. Specific objectives were established and systemic and logistic restrictions identified so as to refine further the design effort. In point form, these requirements were detailed as follows:

**Design objectives:**
- Minimize change to dynamic characteristics of existing fastener
- Improve electrical isolation
- Minimize fatigue-related bolt failure
- Minimize component maintenance
- Facilitate retrofit process
- Facilitate future component replacement

**Restrictions:**
- Systematic
  - Utilize existing anchorage and fastener support systems
  - Maintain track profile
  - Use part worn restraining rail
- Logistical
  - Retrofit adjacent rails separately

Pandrol Canada Limited and Pandrol Rail Fastenings Limited working closely with staff engineers from the TTC's track and structure department proposed the general arrangement illustrated in Figure 2. This design was then thoroughly scrutinized by the TTC for conformance with established criteria. In terms of systemic restrictions, the new fastening system was configured to accommodate existing anchor bolts and grout pads while maintaining track profile, and could be used with new or part worn restraining and/or running rail. It was deemed less likely to induce bolt failure by virtue of having rigid fastener movement to the studded pad and elastic clips in the rail base area, thus allowing its cast plate to be fixed directly to invert or double-tie. The design also provided easy access for replacement of critical components such as anchor bolt insulation and Pandrol clips. It was approved in principle, pending the completion of successful performance testing.
The Mission Valley West (MWW) light rail extension in San Diego, California opened for service in November 1997. The $211-million project includes stops at two major shopping centers and Qualcomm Stadium, the 70,000-seat stadium home of the Padres and Chargers professional sports franchises. The Metropolitan Transit Development Board (MTDB) contracted with Boyle Engineering Corporation in 1992 to design the 6.1-mile extension and its three elevated and four at-grade stations.

The new rail fastener is best measured in terms of its effectiveness in reducing rail movement. The original design employed a design that allows the rails to move laterally or "breathe" near the hinges and abutments without forcing the bridge to move with it. However, some control of the rail is required to limit the size of a gap in the event of a rail break. The resulting design uses two types of direct fastener plates (DFPs) - one that allows longitudinal movement of the rail, zero longitudinal restraint (ZLR) fasteners, and another that restrains it, standard restraint fasteners (SR). The primary difference between the two is that the ZLR direct fastener plates use a special PANDROL Clip, and a steel "toe plate" that prevent the clip from allowing the rail to shift laterally or longitudinally. Normally, BS plates are free to expand and contract at the abutments and hinges, but attaching rails directly to the bridge deck would prohibit normal movement. For this reason Boyle employed a "toe plate" that allows rail movement adequately but still provides the foundation to the bridge deck for the bridge deck to support each rail. Approximately 40% of the alignment consists of direct fixation track on aerial structures including 3,880-ft and 3,200-ft long bridges. Advantages of direct fixation track are reduced track maintenance and significantly reduced dead loads on the structure, which results from eliminating the ballast layer. Significant interactive forces between CWR and aerial structures were considered in the design of the structures and the direct fixation track.

Bridge/Rail Interaction

CWR forces are generated as thermal expansion and contraction of the rails occur. Usually, BS plates are free to expand and contract at the abutments and hinges, but attaching rails directly to the bridge deck would prohibit. Normal movement. For this reason Boyle employed a "toe plate" that allows rail movement longitudinally or "breathe" near the hinges and abutments without forcing the bridge to move with it. However, some control of the rail is required to limit the size of a gap in the event of a rail break. The resulting design uses two types of direct fastener plates (DFPs) - one that allows longitudinal movement of the rail, zero longitudinal restraint (ZLR) fasteners, and another that restrains it, standard restraint fasteners (SR). The primary difference between the two is that the ZLR direct fastener plates use a special PANDROL Clip, and a steel "toe plate" that prevent the clip from allowing the rail to shift laterally or longitudinally. Normally, BS plates are free to expand and contract at the abutments and hinges, but attaching rails directly to the bridge deck would prohibit normal movement. For this reason Boyle employed a "toe plate" that allows rail movement adequately but still provides the foundation to the bridge deck for the bridge deck to support each rail. Approximately 40% of the alignment consists of direct fixation track on aerial structures including 3,880-ft and 3,200-ft long bridges. Advantages of direct fixation track are reduced track maintenance and significantly reduced dead loads on the structure, which results from eliminating the ballast layer. Significant interactive forces between CWR and aerial structures were considered in the design of the structures and the direct fixation track.

Special Trackwork Design

Thermal CWR forces at direct fixation special trackwork raised some unusual issues for Mission Valley West designers. Because rails are discontinuous in areas such as turnouts, CWR forces must be transferred through specially designed switch, transferred around standard switches, or allowed to dissipate at expansion joints in the rails. Similar to a switch on timber ties without anchors, CWR forces left uncontrolled would push and pull switch rails out of alignment and cause creep on the rails. The use of expansion joints was ruled out because of their high initial cost and concerns about long-term maintenance. Specially designed switches were also ruled out because they are costly and spare parts are not readily available. Boyle's designers decided to anchor the rail firmly to the bridge structure at each switch, thus avoiding more costly alternatives. Fixed rail anchors were developed for this purpose. Fixed rail anchor components include standard steel shapes and high-strength steel bolts cast in the bridge deck. The fiber glass insulation used between steel components inhibits stray electrical current propagation. Each fixed rail anchor prohibits longitudinal movement, but still allows the
usual vertical movement of the rail. Anchors are positioned just ahead of the switch rails and on the diverging and through tracks beyond the frog, preventing CWR forces from entering the switch region. Locations of direct fixation crossovers and turnouts must be coordinated with bridge hinges to avoid having special trackwork over a hinge and prohibiting normal movement of the bridge.

**A Super Debut**

Direct fixation track offers many advantages when design obstacles can be overcome. Reduced structure dead loads decrease initial costs and provide a slender, more pleasant bridge section. The fixed alignment and profile reduce track maintenance and give a smooth ride. In its national debut for Super Bowl XXXII, the new extension was a huge success, with ridership reaching an all-time high of 500,000 people over the three-day weekend.

The Light Rapid Transit System 2 project for Kuala Lumpur is a 29km double track system extending from Subang Depot to downtown Kuala Lumpur and north to Terminal PUTRA 12km from the City Centre.

The LRT 2 system is primarily elevated dual guideway with 4.4km of side by side underground bored tunnels through Kuala Lumpur City Centre and 2.2km of at grade guideway through hillsides on the north end of the project.

PUTRA, the Owner and Operator of the system, has awarded a contract to the Bombardier/SNC-Lavalin Consortium as the system supplier. Trackwork installation is provided by SNC-Lavalin in association with Time-Salam (Malaysia). The track is installed with continuous welded rail on 'lord' direct fixation fasteners with Pandrol 'e' clips. The fasteners are anchored to precast panel track slabs which are secured to the concrete guideway beams that have been constructed by local civil contractors.

One advantage of the precast track slab method is the ability to pre-install the rail fasteners at the precast plant thereby eliminating the costs of distribution and handling problems as well as making rail installation with the Pandrol clips quick and easy.

While the prestressed ties with Pandrol shoulders were cast at a local Malaysian plant, Pandrol clips were provided from the manufacturing plant of PT Pandrol Indonesia.

Work on the Depot and 14 kilometres of mainline is complete and will be in public service for the Commonwealth Games to be held in September 1998.
The Heathrow Express has been designed and constructed to provide a high-speed, high-quality rail link, transporting passengers from Central London to Heathrow Airport in 15 minutes. Studies identified Paddington as the preferred terminus, utilising the existing Great Western Main Line (GWML) corridor to a point west of Hayes station. The existing Railtrack corridor required improvement and upgrading to carry the new rolling stock at short headways, but the new track required was a new branch from Hayes down into the airport. The works comprised a new high-speed junction and flyovers on the GWML, a short section of new ballasted track, and new tunnels taking the branch line beneath the M4 motorway and main runways, beneath the central terminals, and on to Terminal 4. Rolling Stock for the project was to be specified in multiple units, using 250kV overhead electrification, and this became one of the determining factors in the choice of tunnel size. Rigid track was chosen because it reduces train movement, and permits a smaller tunnel size compared to ballast track. Most of the branch line runs in 5.675m diameter tunnels, at depths of as much as 25m below ground. There are two stations, Heathrow Central, serving the main terminal area, and Terminal 4, located beneath the Piccadilly Line station of the same name. The branch is twin track from the portal, through the central station, to a crossover. There is then a single line from the crossover for 1.98km to another turnout, from which the line runs to two terminating platforms at Terminal 4. Total of the track in tunnel is 11.4 track km.

Heathrow Express provided a remarkable opportunity for Tarmac Rail Projects to compare two very different methods of forming the necessary continuous concrete slab track in tunnels. The track form selected utilised components and surface profiles compatible with Railtrack's ballasted track, built to tolerances suitable for high speed operations. Contrasting methods of 'Bottom Up' and 'Top Down' construction were used to accommodate differing logistic circumstances, and to achieve the same product. This highlighted significant differences in construction flexibility, productivity and ultimate cost. This article will describe the construction of the track on this project, and highlight the differences between the two methods.

The crossover cavern contains a double slip, with the fourth connection running into a 150m head-shunt, which provides a turn-back facility for trains running to the central station only. The head-shunt will also provide for future extension of the railway. The diameter of the tunnels, and the use of 250V overhead power supply, dictated the choice of a non-ballasted or slab-track construction. These tunnels will accommodate an initial service of 4 trains per hour between 05.00 and 24.00 hours of the year.

Heathrow Express was set up as a partnership between British Airports Authority and the British Railways Board. Railtrack managed the BRB share of the works, including the 350m infrastructure connecting the Great Western line, the traincare facility, and all works at Reddington. BAA managed works from the retained cut and tunnel portal, through to the buffers at Terminal 4, including all the tunneling, stations, and associated works. The split for the trackwork elements of each party's works was at the tunnel portal, with the transition from BRB ballasted to BAA non-ballasted track.

BAA appointed consultants Mott MacDonald for the track, who wrote the specification around the use of a paved track. BAA's ambition for the project was that it was to be a 'World Class' railway, and so, although line speeds in the tunnel would not exceed 80 mph, the specification called for tolerances capable of 1.25 mph running.

A special trackwork item was included a DV 10.75 Turnout, a DV 10.75/6.207 semi outside double slip, and a section of vertical plain line on 4 basements to permit a future turnout installation.

The HMRA required that the project should incorporate derailment containment throughout the lengths of the tunnels, to ensure that any injuries or losses caused by train derailment would be minimised. Mott MacDonald's specification covers various options for the achievement of this aim.

Tarmac Rail Projects, an operating division of Tarmac Civil Engineering, was awarded the design and construct contract by BAA in 1996. Detailed design was undertaken by Tarmac's consultants, Maunsell Parsons Brinckerhoff (MPB). Trackwork construction commenced in May 1996, and was completed within twelve months.

**Trackform**

The new track required was slab track, and new trackwork items were supplied by British Steel Track Products, in lengths of 220m UWR strings. Signalling is generally by means of pointless track circuits, except on the approaches to special track items, which results in rails over 3.5km in length, between the portal and the central station. The tunnels provide a stable temperature environment therefore the rails stressed at ambient temperature.

**Floating Slab Track**

Generally the line runs below open ground or airport terminal buildings. The only noise sensitive area is in the vicinity of the

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**Projects**

**Heathrow Central**

Construction of the northern part of the project was carried out using an adapted "bottom-up" system of cast in-situ slabs, using a specially designed shuttering system. This system had been used on a number of projects previously, and with unrestricted access from the tunnel portal, appeared to offer speedy construction with minimum set-up costs. Difficulties, however, were experienced in achieving the very tight tolerances demanded by the specification. Transporting concrete over long distances in the tunnel, the low workability permitted in the concrete, and the amount of hand-filling of the concrete required to give a true rail seat profile on heavily carded track, proved particularly challenging. The system of using one running rail as a reference in setting-out fastenings is prone to short-wavelength variations, due to the lateral flexibility of a single rail. This required heavy commitment of surveying resources in order to ensure a good quality finished alignment. The relative flexibility of the shuttering system, resulting from the inevitable compromise between rigidity and weight, meant that two poor and post-post checking also involved high surveyor input. The process was summarised as labour intensive, and highly sensitive to operator skill levels.

Concrete for the running tunnels north
was transferred either from the portal or from a shaft at portal + 2.5km, by means of rail-mounted re-mixer wagons. This system was very sensitive to the reliability of the plant, and also to minor variations in concrete workability. The rate of construction was also determined by the rate of strength gain of the concrete, as the re-mixers had to run over previously installed track.

**Construction - Running Tunnels South**

The second phase of the project, from November 1996 to May 1997, was the construction of the southern track, from Heathrow Central to Terminal 4. This section included all the special trackwork items, as well as 4.4km of plain line. Access into the tunnel was via a single 10.75m diameter shaft, which was 25m deep, located 1200m from the Terminal 4 buffer-stops. This was in marked contrast to the first phase, where the 3.5 km twin tunnels from the portal to Heathrow Central were serviced from the tunnel portal. This gave capacity for marshalling trains and cleaning concrete plant off-line. In contrast, the southern tunnels had no marshalling capacity, and any major breakdown or maintenance of plant would have held up the project whilst the disabled plant was returned to the shaft for removal from the tunnel.

Utilising a "Top Down" method based upon "hedgehog" sleepers enabled these logistical risks to be minimised. Instead of casting shoulders directly into a slab, pre-stressed sleepers derived from the standard 140 design were used. This provided the additional benefit of having the critical rail seat area produced under factory conditions. Protruding "hedgehog" reinforcement was cast into each sleeper, to enable it to key fully into the infill concrete, the new design being designated F40H. The "top-down" method enabled the sleepers to be spaced along the tunnels, the rails threaded and the fastening assembly clipped into position. The track was then jacked into position through holes in the sleepers, using removable jacks, and taking vertical and horizontal alignments from the rail head datum, to create a perfect alignment. Fastenings were identical with those used in running tunnels north, so the two construction methods lead to identical finished track forms.

The use of hedgehog sleepers proved more flexible than the original method, and also revealed several other advantages. Track was constructed in panels, which were jacked and braced to line and level prior to casting. These were more rigid than the single rail setting-out used in running tunnels north, and so were less prone to short wavelength irregularities, and also less prone to movement whilst in preparation. These factors considerably reduced both; the setting-out time, and the checking effort.

Other significant savings became apparent during the progress of the work, particularly because the infill concrete could be of a far greater workability than that used in running tunnels north. This was because there was no requirement to form rail seats, with all of the great accuracy that this necessitated. The workability of the concrete could be increased significantly to make it capable of being pumped, and indeed all the RTS concrete was placed by pump. Greatest single pump distance was 1360m. Use of concrete pumping eliminated all the concreting train traffic, re-mixer wagons, and reduced concrete wastage.

**Conclusions**

Track construction at Heathrow was completed on time, under difficult logistical circumstances, and gave the client the world class railway which it required. Tarmac has enjoyed the support and assistance of its suppliers, including considerable assistance from Pandrill UK, Tarmac Toppmix, Fosroc Concrete Pumps, RMC Concrete Products, and from the client, BAA's Heathrow Express Project Team. This has also been an unusual opportunity to compare directly "bottom-up" and "top-down" construction methods.

A number of direct conclusions can be drawn. The temporary works for the sleeper system need to be specially designed for the actual tunnel conditions, but the "top-down" system offers considerable savings in terms of readily available plant for sleeper handling and concrete pumping operations. The "top-down" system eliminated concrete finishing costs because hedgehog sleepers removed the requirement for very high accurate finishing at the rail seat. Tarmac's conclusion was that although the initial costs of "top-down" are higher, due to both the sleeper cost and the additional cost of pump additives in the infill concrete, the overall comparison significantly favours "top-down" construction.

The change of procedure from "bottom-up" to "top-down" construction during the contract represented a risk for Tarmac, but proved to be extremely effective, producing faster, more accurate results, and reducing the total installed cost per kilometre.
The Ferronorte Project

Project Background

How will we feed the expanding population of the world in the next century? As the population of the world continues to grow, sources of additional agricultural cultivation must be developed. Many well-developed agricultural areas, such as central North America, are near full capacity. North American cities continue to grow with suburban development consuming valuable farmland each year.

Brazil is a country moving rapidly into the world market in many areas providing the agricultural products that are, in many instances, underutilized or untapped. The central west region of Brazil in the Amazon drainage basin, south of the Amazon River and rain forest, is an agricultural region with enormous capacity. The potential of this region could rival well-developed agricultural production areas such as central North America.

Of particular importance to future Brazilian agricultural production are the states of Mato Grosso, southern Goias, and northern Mato Grosso do Sul as illustrated on the map. In this fourteen-year period from 1980 to 1994 the grain produced in these three states grew from 4.5 million metric tons to almost 13 million metric tons. These three states are a vast area of almost flat land with a humid tropical climate and exceptionally regular rainfalls from September through April. The temperature averages over 18°C even in the winter months, with sufficient sunshine, which allows for the harvesting of two crops per year. Weather history reveals no significant losses due to inclement weather conditions, a very important aspect in the farm business. Efficiently farmed, this region could produce over 100 million tons of grain per year.

So why doesn't this region contribute more to the world agricultural markets? The answer is simple - transportation now takes too long and the costs are too high. The grain production areas of the states of Mato Grosso, southern Goias, and northern Mato Grosso do Sul are not served by rail. Barges do not have an efficient route to a seaport for export. Most grain from this region is currently transported to the seaports of Santos, Paranagua, or Sao Francisco do Sul by truck. Distances from the farm to the seaport range from 1,200 to 2,000 kilometers by highway. Bulk agricultural product transportation at this extreme long distance by truck is expensive. This high transportation cost is passed along to the consumer in the price of the grain.

The Project Starts

Ferronorte was created in the late 1980’s by the Samaritani Group to provide a strong, efficient means of accessing the fertile and productive central west region of Brazil. On May 12, 1989, Ferronorte signed a concessional agreement with the Federal Government allowing for the construction of a rail line from western Sao Paulo State into the central west region. The project was divided into several phases for construction. The first phase began on the west bank of the Parana River near the town of Santa Fe do Sul, where an existing extension of Fepasa Railroad terminates. Ferronorte trains loaded with grain would have access through use of Fepasa lines to the important seaport of Santos a distance of 900 kilometers southwest of Santa Fe do Sul. From there the railroad construction was to proceed northwest 400 kilometers to the state boundary of Mato Grosso and Mato Grosso do Sul near the town of Alto Taquari.

The next phase will proceed northwest another 600 kilometers to the Mato Grosso State capital of Cuiaba. Future plans call for two rail lines to be constructed from Cuiaba. The first will continue northwest for 1,500 kilometers to the city of Porto Velho in Rondonia State, which is a part on the navigation system of the Amazon River basin on the Madeira River. A second line will be built for 2,000 kilometers northward from Cuiaba to Santarem in Para State. Santarem is an important port city on the Amazon River with access to overseas ship transportation. One of the obstacles that had to be solved in order for the first phase of Ferronorte construction to commence was how to get the trains across the Parana River near Santa Fe do Sul. A project was undertaken jointly by the Brazilian Federal Government and Sao Paulo State to design and construct a river crossing for both rail and highway traffic. A massive 2.6-kilometer double-decked bridge project was started in 1991, incorporating a navigation channel with clearance for large barge traffic. At one point the piers are constructed in 60 meters of water. The top deck has a four-lane highway bridge that replaces an existing river ferryboat operation. The lower deck is a single-track open-deck railroad bridge. A new 8 kilometer highway was constructed to access the bridge along with a 16-kilometer rail line from the end of the existing Fepasa Railroad mainline at Santa Fe do Sul to the east bank of the Parana River.

by Jack E. Rahme, Director Engineering, Ferronorte S/A
Fepasa completed the mainline extension to the Panamá River bridge and track construction on the bridge on January 9, 1998. The dual railcoast-highway bridge was inaugurated officially by Brazilian President Fernando Henrique Cardoso at a special ceremony on May 29, 1998.

**Ferronorte Construction**

The construction of Phase I of the Ferronorte mainline began in August of 1992. Constrain SA, a large Brazilian company, was awarded the contract for the construction of both the infrastructure and the superstructure.

The infrastructure plan required a platform for track construction with a minimum width of 8 meters and with maximum grade of 1% in either direction. Curvature radius was not to exceed 450 meters, and design speed for the entire mainline would be 90 km/h. Earth to be moved during construction was estimated to be almost 6 million cubic meters. Most of the roadbed material is sandy clay, so it is important that the vegetation be restored promptly during construction, or erosion would be a major problem. Sub-ballast is mined locally and consists of a good inertite material that is compacted in a layer 15 cm deep. The roadbed is planned to have twenty-four 3.5-km long sidings, but at this time only eleven have been built. The remaining ten sidings will be completed to traffic density increases. A branchline with a total of 14 kilometers of rail was constructed near KM 21 to access the area where rail is welded, concrete ties are produced, and ballast is loaded.

**Laying of the Track**

A total of five prestressed ballast deck bridges will be constructed. Four traverse small rivers while the fifth is an overpass over a highway. Three railway overpasses of existing highways will also be constructed.

The major components of the infrastructure are UIC 60 continuous welded rail supported on concrete ties with elastic fasteners at 1.6 gauge. This track is laid on 15 cm of crushed basalt ballast. Turnouts into the sidings are 1 to 14 with reinforced switch points to facilitate the use of mechanical switchman stands.

The rail is imported from Poland, as there are currently no producers of rail in Brazil. It is shipped in lots of 5,000 tons each month with a total of just over 50,000 tons required to complete the first phase. The 24 meter length rails are shipped by rail to the Ferronorte branchline where the welding facility produces 11 strings of 288 meters length welded rail per day 6 days per week. They are then transferred on a rail train to the track construction sites as needed.

Concrete ties are produced by the contractor in a factory located on the branchline next to the welding plant. The ties are a concrete monoblock design with PANDROL elastic fasteners. The original tie design was to suite the TR-68 (AREA 136 RE) rail section. Later in the project it was considered economically more appropriate to use the universally available UIC 60 rail section. To accomplish this change the engineers at PANDROL proposed the inclusion of an additional gauge spacer plate located between the tie head and the rail to achieve the correct track gauge. Fastening components selected for the Ferronorte concrete ties are supplied by PANDROL Fasteners Ltda, São Paulo. The first concrete ties were produced in November 1997 and the complete fastening system was tested by installing all the components with the new UIC 60 rail. Production is currently 14,000 ties per month, which coincides with current track construction needs. The ties are shipped to the track construction sites on flat cars and distributed using gantry cranes that run on small temporary crane rails.

To enter and exit the eleven sidings trains will pass over 5 to 14 turnouts built out of TR-68 rail sections. The switches are AREA 30 foot long (9.144 meters) with adjustable braces, rods and jaws, and graduated fillets. The points are reinforced and controlled by mechanical switchman stands to allow the points to return to desired position following the passing of a train. All fasteners throughout the turnouts are PANDROL e-clips on AREA baseplates with weld-on shoulders, held down by four screws. To enter and exit the branch line and the grade point train at Inocencia Ferronorte purchased 1 to 10 turnouts also built out of TR-68 rail section with PANDROL e-clips as fasteners. These are manually controlled switches.

Initially Ferronorte trains will be controlled by a manual block communication system. Base radio will be installed along the right of way and controlled by a dispatcher based in the Control Centre. The dispatcher will have permission to occupy blocks of the mainline to trains before the movements commence. The dispatcher will have computer software programming that will protect against conflicting train or rail car movements. A point detector interlocked with approach signalling installed in advance of the turnouts will monitor the position of the moving switches. Approaching trains will get a “go” or “no go” indication over the turnout and proceed as the indication allows. This system can be integrated into a full-blown CTC system in the future when traffic increases demand better signalling to improve capacity.

Track construction schedules call for the completion of the first 110 kilometers by June 1st 1998, to coincide with the completion of the first Ferronorte mainline overpass terminal at Inocencia serving northern Mato Grosso do Sul State. This target was met by averaging 1,460 meters of track constructed per day. The first revenue producing train was loaded and dispatched on May 29. The entire mainline will be assembled to KM-Post 400 by the end of April 1999 to allow customers of Mato Grosso State and southern Goiás State the opportunity to ship the grain harvest that year for port by the new Ferronorte mainline. Track construction will have to average 1,250 meters per day in order to achieve this final Phase I goal.

**Grain Shipments**

Ferronorte trains are equipped with new aluminum grain hoppers. A total of 1,080 new hopper cars will be purchased for serving customers before the completion of the first phase. Aluminum cars were selected because their lightweight construction will allow more cargo to be shipped with the same car weight. Ferronorte plans to run heavy trains with as many as 120 cars per train. The motive power for the trains is being purchased from General Electric, a major North American locomotive manufacturer. Specifications for the first phase are for 50 modern 6-axle 4400 horsepower units.
Prior to the political upheaval in the early 1990's the railway networks of Central and Eastern Europe had been developed into major arteries for the movement of both freight and passengers. The financial situation of the operating companies deteriorated rapidly after the political changes. In the Czech Republic, for instance, 490km of track was relaid in 1990, reducing to 300km in 1991 and a total of only 300km in the period 1992-96. Much of the network has deteriorated steadily, with most relaying being restricted to the international corridors. A similar story can be told throughout the Region, encouraging railway engineers to look world wide for the latest track products and construction techniques to make the best use of their limited funds.

Virtually all Railways wished to introduce modern elastic fastenings into their track and Pandrol's engineers have worked closely with them, adapting their existing track components and relaying techniques to the use of Pandrol fastenings. Some examples are shown below.

Czech Republic
Prior to installation on Czech Railways, clips are installed on a 25 metre long PANDROL FASTCLIP concrete sleeper panel in a depot using a Pandrol Mk 4 machine. This single operator machine is capable of simultaneously driving all 4 clips on a sleeper at a rate of 18-20 sleepers per minute.

PANDROL 'K' Conversion
Much of the development of 'K' conversion took place in the Czech Republic where many of the shoulders are cast in Motor Jikov's foundry at Ceske Budvice, also home to the original Budweiser lager.

The aim was to meet a demand for a threadless elastic fastening to replace rigid screwed fastenings in 'K' baseplates. The PANDROL 'K' conversion assembly was designed as a retrofit system, to replace existing 'K' clips in track without disturbing the baseplates and to eliminate screw threads. The simplicity of the assembly has made it popular with track men and it is used in both new and old baseplates in roughly equal quantities. Versions are available for baseplates with both two and four screwspikes.

The assembly consists of a cast malleable iron adapter or shoulder, which slips vertically downwards between screwspike's heads and the rib of the baseplate, before sliding horizontally into the dovetail in the rib. The shoulder incorporates a housing and a heel seat for a specially designed conventional PANDROL 'e' clip. The toe of the clip bridges the dovetail and bears on both the railfoot and the rib of the baseplate, locking the assembly into place.

CD have installed about 50 turnouts in its Corridor No. 1 with 'K' conversion fastenings as well as about 10 kilometres of plain line. In addition to other Central and East European countries the system is now being used in Belgium and Spain.
Estonia
The Tallinn-Narva railway is being upgraded using PANDROL FASTCLIP rail fastening. (See article on page 59.)

Hungary
250 sleeper PANDROL FASTCLIP trial installation on Hungarian Railways being inspected by delegates attending a technical conference in Vep.

Lithuania
Clips are installed on 25 metre long panels with hand tools in the Lithuanian Railway's assembling yard for transportation to track on the mainline between Vilnius and Kaunas.

Poland
A new form of resilient rail pad has been evaluated by Pandrol for use in the PANDROL FASTCLIP rail fastening system. The pad was originally developed for use by Polish Railways (PKP) who now consider it to be their standard pad design for all applications. (See article on page 59.)

Romania
Pre-assembled 25 metre long PANDROL FASTCLIP concrete sleeper panels being installed into track using hand operated winches attached to a gantry system on the Romanian National Railway.

Russia
Installation of 25 metre long PANDROL FASTCLIP concrete sleeper panels being laid by crane on the October Railway 30 kilometres east of St Petersburg.

The Slovak Republic
The photograph shows the first of 7 turnouts incorporating "K" conversion supplied to ZSR by D+T at Prievidza in the Czech Republic. Main line trials of the same fastening are in track.

Slovenia - Poganek Tunnel
The two major rail routes in Slovenia meet briefly at Poganek, where they cross the river Sava on two steel truss bridges and continue through a tunnel. Slovenske Zeleznice decided to stabilise the tunnel walls which were gradually collapsing inwards, by installing a very strong reinforced concrete floor. The track was to run on this invert and there would be little room for error in alignment. Two paramount requirements for the new track fastening system were:

1. It must be as resilient as practical to absorb shock loads, which might otherwise disturb the suspect material through which the tunnel passes.
2. It must be capable of installation without the necessity for adjustment once the mass concrete had set, i.e. grinding down or building up of the concrete surface to be avoided.

It was agreed that the first requirement would be met with a cast PANDROL baseplate assembly (photograph 1) supported on the mass concrete by a very resilient 15mm pad. The pad was designed to deflect about 2mm under static 22.5 ton axle loads and about 1.5mm under trains running at maximum design speed. It will provide the optimum practical degree of shock absorption. Two stainless steel bolts locate the baseplate, which is restrained by a pair of coil springs. Double insulation is provided by nylon bushes coupled with standard Pandrol insulators. Additional pairs of unequal size insulators are provided to allow for subsequent lateral adjustment. 4.5mm EVA rail pads and PANDROL clips type "20555 complete the assembly. Similar assemblies are in service in Belgium, Singapore and Hong Kong.

The second requirement was met by employing the "top down" method of track laying. Reinforced concrete blocks (photograph 2) were manufactured by CIP Grads in Ljubljana. Pandrol exposed aggregate for optimum bonding. Reinforcement starter bars were left protruding from the sides and ends of the blocks for eventual integration with the slab reinforcement system. Once the current work in the tunnel and further work on the bridge is complete there will be four different Pandrol assemblies within a kilometre of track.