

**RAILWAY ENGINEERING–2004**

# **Abstracts of the Seventh International Conference**



**“Maintenance & Renewal of  
Permanent Way;  
Power & Signalling;  
Structures & Earthworks”**

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## **Abstracts of the Seventh International Conference**

on

### **'Maintenance & Renewal of Permanent Way; Power & Signalling; Structures & Earthworks'**

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# RAILWAY ENGINEERING–2004

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# **KEYNOTE PAPERS**



## **ALIGNMENT DESIGN IN THE FEASIBILITY STUDY FOR THE CITY LINE IN STOCKHOLM**

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**Keywords:** Alignment design, design criteria, feasibility study, permissible train speeds, turnout design

The existing rail network comprises of only two tracks from Stockholm Central Station down to Stockholm South Station ('Stockholms Södra'). Some few kilometres further south, the railway system consists of six tracks. The limited number of tracks between Stockholm Central and Stockholm South constitutes a severe capacity constraint for local, regional and long-distance trains to/from Stockholm.

Therefore, Banverket (the Swedish National Rail Administration) is planning a new double track railway for commuter trains, the City Line ('Citybanan'), through central Stockholm. When the City Line is brought into traffic, the capacity will increase with 24–30 trains per hour in each direction. Even though the City Line is allocated for commuter trains, all types of trains will benefit from the increased capacity of the network.

A feasibility study for the City Line, including the extensive re-configurations of existing tracks at the both ends, was conducted during 2002–2003. Preliminary design started early 2004 and the construction work is scheduled to start 2006 and finish 2011. The City Line project interferes with several other major rail projects in Greater Stockholm, such as quadrupling of the Mälars Line, re-configuration for increased capacity in the northern end of Stockholm Central and re-configuration of Tomtebodas marshalling

yard, among others.

The tracks will be constructed with concrete sleepers or slab track, and UIC60 rails (continuously welded) with elastic rail fastenings. The new railway is expected to survive several generations of signalling systems. Hence, both in the near and far future, the alignment will constitute the binding constraint for permissible train speeds, and Banverket requires all alignment options (including all S&C work) to be already designed in detail in the feasibility study. Provisions will be made for four platform tracks at all stations.

This paper presents the Swedish track standards and the general approach in the alignment design of City Line, including criteria for locations where margins exist to the minimum requirements. A selection of detailed layouts of principal interest is shown. Certain comments on a draft CEN standard for alignment design are made. Finally, the paper discusses the importance of alignment considerations at the early planning stages of a railway project.

## **PROSPECTS FOR HIGH-SPEED RAILWAYS IN THE UK POST CTRL**

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**Keywords:** High-speed passenger railways, railway economics, railway planning, railway development, Channel Tunnel Rail Link

While the Japanese have enjoyed high-speed rail travel for 40 years and the French for over 20, the UK has been slow to appreciate the benefits that high-speed railways can bring. However, with the successful opening of the first stage of the Channel Tunnel Rail Link and the very real probability of a significant reduction in the

engineering risks associated with the second phase by March 2004 there is a need to consider the future prospects for high-speed railways in the UK.

The completion of consultancy studies for high-speed lines and proposed consultation by the Strategic Rail Authority on the high-speed line to the 'North' should have further added to the debate about the way forward for railways and how they are to be engineered and financed in the near future. Unfortunately for the UK, the problems with the existing railway and its structure are taking priority and the SRA's proposals have now been quietly dropped.

Drawing upon research and practical involvement in the planning and execution of high-speed rail projects around the world this paper sets out a systems approach to the planning of such projects and the key drivers and trade-offs for determining their costs and benefits. The paper concludes that a significant shift in UK transport policy will be required to bring about new high-speed rail lines.

## **GROUND PENETRATING RADAR FOR RAILWAY SUBSTRUCTURE CONDITION ASSESSMENT**

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**Keywords:** Track substructure, Ground Penetrating Radar, GPR, ballast, railway Investigation

Ground penetrating radar (GPR) has been employed to assess railway track substructure (ballast, subballast, and subgrade) conditions and to produce quantitative indices of substructure condition for use in track maintenance management efforts. GPR surveys have been conducted on over a combined 100 miles of track, including mainline freight and 3rd rail electrified commuter lines. Results of these surveys show the ability of GPR to distinguish between the different substructure layer conditions to determine areas of trapped water and fouled ballast.

The railway GPR equipment is mounted on a hi-rail vehicle and includes multiple sets of 1-GHz air-launched horn antennas suspended above the track that permit fast survey travel speeds and high resolution measurements to a depth of 4 to 6 ft (1 to 2m). The antenna configuration and surveying procedures are deployed to reduce the influence of ties and rail. Antennas are located at both ends of the ties as well as in the center of the track, so the variations of conditions laterally across the track are seen. The GPR system includes accurate positioning system using WAAS enabled DGPS supplemented by a vehicle distance-measuring encoder, and also includes digital video with integrated DGPS for identifying clutter/obstacles, features, and to augment accurate positioning. The GPR system has automatic calibration, processing and modeling capabilities to provide substructure condition indices for use in substructure maintenance management programs.

**BELFA-DB VEHICLE FOR TEST  
LOADING OF RAILWAY BRIDGES:  
EXPERIENCE GAINED IN  
PRACTISE**

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**Keywords:** Bridge, loading, Belfa-DB  
vehicle

During the last decade, the technology of in situ experimental safety evaluation of structures has been significantly improved and extensively tested. The research work presented here resulted in technical achievements concerning methods and equipment for loading tests. Furthermore, corresponding technical guidelines were formulated. By using state-of-the-art measuring equipment the research team could successfully evaluate the structural safety and serviceability of approximately 300 structures, among them about 30 bridges.



# **Theme 1: Railway Track**

## **Day 1:**

### **Citybanan Project, Stockholm: Planning and Design Stage**



# TRAIN TRAFFIC IN GREATER STOCKHOLM AND THE DEMAND FOR A NEW TWIN TRACK RAILWAY THROUGH STOCKHOLM

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**Keywords:** Train traffic, capacity, Stockholm

There is a great need of more railway capacity through Stockholm. Stockholm City and its suburbs grow fast. Thereby increases the demand for fast, frequent and reliable commuter traffic. New and upgraded railway lines in Mälars valley, within 100 km from Stockholm City, have opened for commuting to Stockholm from this area. This 'region enlargement' is highly dependent on fast, frequent and reliable regional traffic with comfortable trains stopping not too often.

On middle distances (50–80 km) there is a demand for fast commuter trains, running faster than commuter trains but stopping more frequent than regional trains.

In order to develop the long distance passenger traffic some high speed lines are planned between the major cities of southern Sweden. These new lines will generate more long distance traffic to and from Stockholm. Also the freight traffic will gain from these new lines in terms of released capacity on the old lines. More freight traffic through Stockholm thus is to be expected.

Today commuter trains, regional trains, long distance trains and freight trains run on the same twin track through Stockholm. The capacity constraint is severe and it is impossible to develop the traffic. For instance the lack of capacity makes it impossible to run the demanded fast commuter trains. To increase the capacity more tracks through Stockholm are needed.

Some sort of separation of traffic according to speed also has to be done on the entrance and exit lines to Stockholm.

For different reasons new tracks cannot be built alongside the old ones through the central part of Stockholm. Therefore a new line, running in a tunnel, has been studied (feasibility studies). This new line, called City Line, will get a station for passenger stop near to the existing central station and the nearby underground.

City Line is meant for commuter traffic. Regional-, long distance- and freight traffic will be able to expand on the old surface line in released capacity.

To dimension the capacity of City Line in a proper way attention has been paid to three areas:

- **Stations with regular stop** (4 stations).  
Critical questions: number of platform tracks, design of entrance and exit regions for the trains and positioning of signals.
- **Capacity of lines between stations.**  
Critical questions: signalling system and positioning of signals.
- **Connection points to existing lines** north and south of Stockholm City.  
Critical questions: planned traffic, future traffic (demand), reserve capacity, risks of building a new bottle neck

The paper will treat principles of using the new and old lines to meet future demands. Used methods to dimension the capacity of the new line will also be described.

## STATION DESIGN IN THE FINAL DESIGN STUDY FOR THE CITY LINE IN STOCKHOLM

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**Keywords:** Integrated public transport system, underground railway stations, rock tunnelling

The City Line, Stockholm planned underground commuter train system, is a 6 kilometer rock tunnel, 30–40 meters below ground, with two tracks and three stations. The City Line will connect to the existing public transport in Stockholm including an extensive metro system and inner city busses. The three stations are:

*Odenplan*, a major public transport node in the northern part of the inner city with one underground line and a great number of bus lines. This node will develop further with an additional 60,000 commuter train travellers per day.

The *City* station, strategically positioned with four entrances from different points in the core of the city. About 65% of its expected 150,000 travellers per day will benefit from convenient indoor links to all the three underground lines as well as the Stockholm central station from which only regional and long distance trains will be operating in the future.

The existing 15 year old Stockholms södra, a cut-and-cover structure which will be remodelled and upgraded in standard. This station is expected to be used by 40,000 travellers per day.

The new stations will be constructed as 22–25 meters wide and 8–10 meters high rock tunnels containing 11 or 14 meters wide and 255 meters long platforms. The *City* station will have two station tunnels and two platforms, *Odenplan* will, in the first phase, have one. Escalators, lifts and stairs will connect the platforms with mezzanines positioned above the ends and the centres of the platforms. A system of passageways and escalator shafts will link these mezzanines to connected underground stations and to tickets hall positioned at or just below street level.

The two new stations will be equipped with extensive safety arrangements. Platforms will have a smoke exhaust system. Exit routes can be screened off from all other areas.

Voids and skylights bringing daylight into underground areas will help to guide the travellers and improve their environment.

## **DETAILS ON THE ALIGNMENT DESIGN FOR CITYBANAN**

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**Keywords:** Alignment design, turnout design, alignment software, design handbook, feasibility study.

The alignment design of the City Line in Stockholm ('Citybanan'), was already at a highly developed stage for the feasibility study. For all route options, the available terrain corridor has been explicitly defined and the alignment has been optimised within each corridor.

This presentation covers certain detailed layouts along the route. It describes the constraints, the objectives, and the iterative approach to the problem using modern alignment software.

The presentation also shows the link between the input to the alignment software and the definitions of critical distances in the Swedish turnout design handbook, which has been completely revised and updated to accommodate the introduction of co-ordinate based design methods in Sweden.

# **Theme 1: Railway Track**

## **Day 1:**

### **Asset Management and Risk Assessment**



## **APPLYING CONFIGURATION MANAGEMENT PRINCIPLES ON A LARGE SCALE OPERATIONAL RAILWAY INFRASTRUCTURE**

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**Keywords:** Configuration management, asset knowledge, railway systems engineering

Running a complex, large-scale operational railway to satisfy demanding performance and safety targets requires operational and maintenance practices to be rigorous and applied in a disciplined way. When significant parts of this same operational railway infrastructure is enhanced and renewed we need to be just as rigorous and disciplined in our engineering processes to ensure performance and safety are not compromised. Configuration Management (CM) is a key part of such engineering process.

CM is a relatively well-understood discipline particularly in the manufacturing, military and aerospace industries where exacting build specifications, rigorous quality control and component traceability are critical factors. In industries where safety is a prime consideration such as the nuclear and rail sectors, CM is also a critical discipline which runs through the entire engineering lifecycle, from design to operation and maintenance and right through to decommissioning.

This paper explores the issues surrounding the application of CM on a large complex project to enhance and renew a substantial part of a major operational railway, Network Rail's West Coast Main Line, and presents a clear case for effective CM.

## **OPENTRACK – A CASE STUDY: NEWPORT, GWENT**

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**Keywords:** Capacity, simulation, maintenance productivity, possession management

Following the paper that I gave last year introducing OpenTrack as a capacity modelling tool that could aid engineers in possession planning, this is now a case study of Newport Gwent, where SMC was asked to identify 2 hour daytime slots for engineering work on a railway that Network Rail perceived to be running at 'full capacity'. In the event, we identified that 10 hour daytime blocks (i.e. through both peaks!) of pairs of adjacent lines were available with minimal service disruption.

## **A TIME OF CHANGE – THE UNIFIED RAILWAY MODEL APPROACH**

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**Keywords:** Data and Data Capture, Lifecycle Tools, Plan Design and Build, Linear Referencing, Data Centric Approach, Unified Railway Model.

Decision-makers work with information, not data. Though the information may be drawn from many sources and in many formats, the better the quality of the information, the better the decision-making that will result. To qualify as 'information', the data needs to be delivered in a format that fits the purpose of those receiving it, comprehensive, comprehensible and timely.

The industry encompasses many different disciplines; each involved in its own application areas, working with its own data and software tools. While these tools and data may be adequate for the job in hand, they may not provide the ‘information’ needed by other disciplines. The solution is a central open datahub, housing any data required across the organisation and accessible to whoever needs it.

This is central to the Bentley approach. This paper talks about the benefits of working in this way to provide:

- Support of the decision-making process
- Tailored data to decision-making requirements
- Maximises the use of expensive data
- Complements existing systems and processes.

## **GEOSPATIAL VIDEO SURVEYS IN THE FIELD OF RAIL BASED ASSET MANAGEMENT**

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**Keywords:** Geospatial, asset management, safety, efficiency, technology

The national railway infrastructure is by nature a complex and dynamic business environment, which is both regulated and highly visible within the political and public arena. Responsibility for operational and safety-related performance ultimately resides with the asset steward and, as such, must be managed to the optimum levels of efficiency whilst delivering measurable levels of performance.

Within this complex and dynamic environment, all opportunities for improvement through innovation must be

actively pursued, investigated and, where appropriate, implemented to deliver tangible benefits in the pursuit of increased levels of safety, productivity and performance.

This paper sets out to review and consider the specific innovation of inertial-based video surveys in relation to improving the visual and geospatial knowledge available to the custodians of the infrastructure, whilst maintaining their relationship with all levels of the rail transport industry.

Omnicom Engineering Limited, a York based systems engineering company, specialises in locating, maintaining and managing asset and infrastructure data within complex network environments, focusing on the transport industry.

Omnicom’s core product, OmniSurveyor3D® (OS3D), is a unique, geo-spatial digital imaging surveying system. Network Rail has been using OS3D to support the management and maintenance of their national network since February 2000.

Since the beginning of 2003 the system has been adopted as their core asset collection and design verification solution, surveying a substantial amount of the UK rail network annually. This cyclic arrangement provides Network Rail with a consistent, current and accurate visual and positional record of their transport network environment whilst significantly reducing the requirement for potentially hazardous trackside excursions.

## **AN INTEGRATED PLAN OF BALLAST TAMPING AND RENEWAL TO REDUCE WHOLE LIFE COST**

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**Keywords:** Ballast tamping, renewal, plan, whole life cost, optimization

This paper outlines the development of an analytical model aimed at achieving an optimal plan of tamping and ballast renewal from a whole life costing point of view. The geometry deterioration model employed is described by a non-linear function. The performance of track deterioration and maintenance are analyzed and modelled. Renewal cost, tamping cost and penalty cost are addressed in the analysis of ballast whole life cost. The objective of the model is to minimize maintenance cost per Million Gross Ton (MGT). Two types of problems are considered in optimizing ballast tamping and renewal, which include fixed tamping threshold and optimized tamping intervention level. Algorithms for the two cases are proposed in order to obtain the optimum integrated plan.

An example is given to show the performance of the model. The results show that much benefit could be achieved by considering ballast tamping and renewal together. The model can also be used to evaluate the cost-effectiveness of tamping at certain intervention levels.

## **RISK ASSESSMENT – TAKING A HOLISTIC VIEW, LOOKING OUTSIDE THE RAILWAY ‘BOX’**

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**Keywords:** Risk assessment, Hatfield, compliance, standards

Following the paper that I gave last year introducing OpenTrack as a capacity modelling tool that could aid engineers in possession planning, this is now a case study of Newport Gwent, where SMC was asked to identify 2 hour daytime slots for engineering work on a railway that Network Rail perceived to be running at ‘full capacity’. In the event, we identified that 10 hour daytime blocks (i.e. through both peaks!) of pairs of adjacent lines were available with minimal service disruption.

## **€COTRACK, THE RELIABLE ASSETMANAGEMENT TOOL FOR THE FUTURE: New developments up to a general maintenance management system**

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**Keywords:** Asset management, maintenance and renewal, optimisation, costs, RAMS

Several systems have been developed to help a track manager to be able to do his tasks as a professional track manager. €cotrack is one of them but is remarkable by its internationally acknowledged rule base and condition-based decisions. €cotrack as a program is now owned by the private company ARCADIS since they have taken over the program in the end of 2003

from UIC.

ARCADIS notices that the existing €cotrack has its restrictions in use. Therefore ARCADIS made a development plan to improve the existing €cotrack and to add new functionalities covering all the fields of a rail infrastructure system. Designing a new Maintenance Management System (MMS) not only based on condition indicators but also on performance indicators, does this.

In the first phase of the development the following modifications of the system are proposed:

- Interfacing with existing databases, user defined maintenance works are available.
- Inverse modelling (not only the relation from condition to costs but also from costs to condition)
- User interfaces

A new prototype of €cotrack in this MMS is under construction and the first results of it will be shown on the conference.

## **INFLUENCE OF OPERATIONAL CRITERIA ON MODERNISATION AND MAINTENANCE OF RAILWAY INFRASTRUCTURE**

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**Keywords:** Railway infrastructure, maintenance, renewals, modernisation, optimisation

In practice of infrastructure managers the demand for track maintenance and renewals usually exceeds the budget. Therefore the best possible allocation of resources can be achieved through optimisation of annual plan for track works. Two approaches are possible: (1) setting cost levels necessary for achieving desired operational standards

and (2) rationalisation of expenses according to agreed criteria. The typical criteria are optimisation of capacity, optimisation of journey time, achieving minimum value of time losses of passengers.

Analysis can be made for different levels of decision. The example of analysis is the maintenance and renewal plan for railway line of regional importance Wroclaw – Jelenia Gora forming the part of Lower Silesia regional rail development project. The condition of the infrastructure is extremely bad and journey time is about 80 minutes longer than a few years ago. It has been shown, that performing the track works on relatively short sections can lead to significant journey time reductions.

## **A VISUAL TRACK MAINTENANCE MANAGEMENT SYSTEM**

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Optram's Railway Infrastructure Management (ORIM) System is a visual information system designed for railroad infrastructure maintenance management. The system consists of visualization tools, a database, data links to connect to other systems, databases and decision support tools, analysis tools, and data import and

maintenance tools. ORIM is designed to analyze and correlate multiple and large data-sets about the rail corridor to produce a prioritized plan of maintenance and capital corridor work. The system provides the ability to display a user-defined combined view of this information for maintenance decision-making. ORIM is an enterprise-scale information system made to exchange information between frontline staff and senior management. The information is also made readily available for investigating the root-cause of track component deterioration problems. The objectives of the system are to improve maintenance efficiency, allow increased track time, provide improved reliability and increase safety, all while providing a substantial return on investment.

As an example, this paper examines how ORIM was applied on a project in Scotland. The project demonstrated that from more defined information availability it is possible to: improve understanding and gain better control of track infrastructure, plan more effective maintenance, reduce operational time delays, and use work-windows more productively. The project covered a 47 route-mile pilot project of the double-track commuter passenger line in Scotland and was later expanded to another 80 miles of track that services both intercity and freight traffic. The paper describes the project process in which the project team identified ten (10) possible areas of cost savings and then selected three of these areas to examine in detail. A cost analysis of the project area concluded that applying ORIM-based methodology for just the three cost-saving areas could result in a minimum of £21,700 per mile per year over a five year period. When the savings were scaled to the zone the per-mile savings reduced to a range of £10,300 to £4,800 per mile per year over a five year period.



# **Theme 1: Railway Track**

## **Day 1:**

### **High Speed Railways – Issues**



## **DYNAMIC INSPECTION OF HIGH SPEED TRAIN WHEELS**

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**Keywords:** Wheels, inspection, high speed, trains

Within the operational aspects of the high speed trains (ICE) of the German Railway System (DB AG), safety has absolute priority. Besides, the high availability of the rolling stock is a prominent target for the operation of the entire railway system. For nondestructive examination in the railway business these aspects call for NDE-systems which are able to unambiguously identify and evaluate eventual defects in the most safety concerned components. This process should be performed in the minimum time feasible, in order to guarantee a commensurate cost-profit ratio through high availability.

## **EXPERIMENTAL SITE ON HIGH SPEED LINE IN NORTHERN FRANCE FOR EUROPEAN PROJECT SUPERTRACK**

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**Keywords:** Ballasted track, high speed line, experimental site, dynamic response, soil grouting

High speeds currently experienced on European high speed railway network as well as speed increases on conventional lines are responsible for a unexpected rise of railway track maintenance needs and brought railway engineers to a revision of the simple relationship between track settlement and cumulated traffic tonnage.

The link between the track long term settlement and its dynamical behaviour, even under moderate axle loads, is one of the teachings of experience and track mechanics studies of this last decade.

Track dynamical behaviour and vibrations occurring inside the ballast bed are indeed some key factors of the long term track settlement and future maintenance requirements and, among the parameters governing track dynamics, the track modulus is extensively studied and correlations between subgrade stiffness and settlement are pointed out.

The SUPERTRACK project (Sustained Performance of Railway Track), funded by the European Commission's 5th framework program aims to a better understanding and a numerical modelling of the relationship between the dynamical behaviour of the

ballasted tracks and the maintenance level they require. Moreover, the project aims to evaluate the benefits of track subgrade stiffness retrofitting actions, through the grouting of weak layers of the trackbed (Kaynia, 2003).

For this purpose, several track segments have been chosen on the French and Spanish network where to perform pre- and post-grouting dynamical measurements under running trains as well as a long term track settlement monitoring.

In this paper, the situation, the measurement device and the first measurement results on the French site of Beugnâtre are presented.

## **IMPROVED BALLASTED TRACK FOR HIGH-SPEED LINES**

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**Keywords:** Improved ballasted track, high-speed lines, vibration velocity

On the first high-speed lines of the DB-AG, which were constructed conventional with ballasted track and put into service 1991, the DB-AG noticed an increased degradation of the ballast, connected with greater maintenance expenses. Similar observations were also made on high-speed lines with ballasted track in other countries, like in Japan and France. Not only the maximum ballast pressure, which depends on the parameters of the track and the configuration of the vehicles, but additionally acting vibrations, which were transmitted to the layer of ballast, were identified to be decisive. These vibrations

are especially marked in certain ranges of frequencies.

For evaluation of the level of vibration velocities, occurring in the layer of ballast, a special measuring device has been developed using triaxial accelerometers, which were fixed within single ballast stones. These measuring devices were used in different types of track, which distinguish themselves by extremely different elastic properties and which are operated by ICE at a speed of  $V_{max} = 250$  km/h. The measurement results provide new knowledge concerning the behaviour of different track structures.

This paper reports on measurements obtained on the east-west-European main line Hannover-Berlin with an improved ballasted track for high-speed and takes comparisons with conventional ballasted track.

## **HEAD HARDENED (HSH®)-RAILS FOR HIGH SPEED TRACKS**

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**Keywords:** Rails, high-speed, hardened

With the beginning of high speed traffic the stresses in the wheel-rail interface raised significantly. Wear and especially rolling contact fatigue (RCF) defects became more prominent and very important factors of costs.

Theoretical considerations led to the assumption that head hardened rails have a better resistance against RCF-defects than

rails with as rolled hardness [1]. To investigate and verify this theoretical evaluation voestalpine Schienen GmbH and German Railway (DB AG) set a track test program to investigate and compare the damage behaviour of different rail grades in a joint project. Furthermore grinding tests were done to find an appropriate maintenance strategy for these different rail grades. The most important results of this 3-years track test will be presented in this paper.

## **DEVELOPMENT OF HIGH SPEED TURNOUTS FOR ASPHALT SLAB TRACK**

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**Keywords:** Permanent way, track engineering, slab track, turnouts, switch and crossing, concrete, asphalt, pavement engineering, high speed railways, urban rail, mixed traffic railways

Ballast-less track for high speed trains has been developed in both concrete and asphalt construction. The criteria for the successful performance of high speed turnouts are described.

Turnout systems which have been developed for the leading types of concrete and asphalt slab track and the respective construction principles are described. Installations on the DB network have delivered high quality, reliable junctions with low maintenance and excellent geometric stability.

Particular reference is made to turnouts on asphalt, and its potential advantages at

critical junctions, where possession limits would exclude normal concrete slab track construction.



# **Theme 1: Railway Track**

## **Day 1:**

### **Influence of Rolling Stock on Rail + Track**



## **NEW SUBURBAN EMU SETS IN NORWAY AND THEIR INFLUENCES DUE TO STRESSES ON THE RAILWAY NETWORK**

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**Keywords:** New EMU sets, track-fatigue measurements, rail stresses, track deterioration

Currently new suburban trains for the operating company Norwegian State Railways are being delivered. The innovative EMU Class BM72 four-unit electric train sets should replace the existing operational EMU Class BM69 three-unit electric train sets which have been in service for more than almost 40 years. Hence, a renewal of the suburban train fleet seemed to be necessary.

Due to the design, the new four-unit electric train sets have unusually high axle loads being used as suburban train for passenger traffic. As an average, the EMU Class BM72 train sets have axle loads which are approximately 22–25 per cent higher than axle loads of the existing EMU train sets of class BM69.

Hence, this paper will discuss the consequences concerning rail stresses and track deterioration tendencies with respect to a total replacement of the BM69 sets to the BM72 sets. Approved handtool calculation methods found in the literature will be applied in order to calculate the stresses. Further works completed by the ORE – committee D 161 be applied regarding considerations with respect to track damages. In this case, relative comparisons between EMU Class BM72 and EMU Class BM69 will be carried out.

## **INFLUENCE OF INTERACTION BETWEEN A LEADING AXLE AND A TRAILING AXLE ON TRACK SETTLEMENT**

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**Keywords:** Bogie, axle, track, ballast, settlement

This paper describes the influence of the distance between axles, for instance typically a distance between a leading axle and a trailing axle of a bogie, on the interaction of response such as rail seat force and sleeper displacement, with the focus placed on vehicle speed, unsprung mass, the stiffness of track structures and rail type. Also, track settlement is described from the aspect of the interaction excited by two axles.

## **LABORATORY TEST ON COMPLETE TRACK SYSTEMS: A STEP BEFORE ON LINE EXPERIENCE**

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**Keywords:** Track system, laboratory tests, dynamic simulation

Standard track systems (such as direct fastenings, ballasted track or single stage slab track) are normally put in service with the only requirements that the individual sub-components have been tested according to the relevant EN. This normally ensures the expected performance of the track system.

On the contrary, when a track system, composed of several elastic components

(such as elastic fasteners – sleeper – undersleeper mats, elastic fasteners – twin separated blocks), eventually characterised by low stiffness, is proposed for applications in some specific sites, some track operators may require a preliminary experimental assessment of the overall track performance.

Since a on-site test on a complete track system is highly money and time consuming, laboratory tests can be helpful in order to carry out the track system assessment before its service begins, allowing, in some cases, even to avoid preliminary on site tests. The connection among train-track simulation, track modelling and laboratory test, simulating curving conditions, carried out on a short section of new proposed track system are the topic of the paper, and two cases are presented.

## **NUMERICAL MODELLING OF RAILWAY VEHICLE-TRACK INTERACTION WITH INFINITE BEAM TRACK MODEL**

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**Keywords:** Infinite beam, track irregularities, contact forces, vehicle-track interaction

Recent years have seen an increase in the number of studies of railway track-vehicle interactions. This renewed interest in the subject has been due, in part at least, to the development of modern high-speed trains. This particular study forms part of an overall research project concerned with the dynamic analysis of steel railway bridges.

This component of the overall project is based upon dynamic interaction between the track and the vehicle in isolation from

the bridge system. The analysis of the overall track-vehicle system is broken down into a coupled analysis of two subsystems. The first subsystem, the vehicle, is modelled as a simplified four degree-of-freedom railway vehicle. The second subsystem is the railway track, and is modelled as an infinite beam on an elastic foundation.

The method used in this paper involves a mathematical coordinate transformation, which allows for the implementation of a quasi-infinite beam numerical formulation. However, critical to the implementation of this method is the assumption of uniformity of the track foundation stiffness. The 'sleeper effect' is not considered here.

## **NEW SENSOR FOR LATERAL AND VERTICAL WHEEL-RAIL FORCES MEASUREMENTS**

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**Keywords:** Wheel-rail interaction, contact forces, measurement, transducer

Damage accumulated in rails can lead to railway disasters. The authors propose a new sensor which is able to measure at the same time the vertical and the lateral forces applied by the wheels on the rails. The sensor is based on very well-known and absolutely reliable strain gauge techniques with simple electronics and processing procedures. The transducer is very simply mounted on the rail and any maintenance, due for example to cables torn during

unwise track tamping, is possible with simple operations and does not require specifically trained personnel.

When complemented with a system capable to detect the lateral position of the wheel tread relatively to the railhead, the use of such a sensor is absolutely necessary to develop rail life prediction models to prevent failures and to increase rail performance.

The results coming from some applications of the sensor are shown, including considerations on the applications to damage accumulation, vehicle dynamics and general condition monitoring (axle counting, speed measurement, train identification) problems. The sensor is self-checking, opening possible applications in the signalling field.

## **TEST AND STUDY ON CHINESE FREIGHT WAGON DERAILMENT ON STRAIGHT TRACK**

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**Keywords:** Derailment, freight wagon, test and study, China railway

The freight train derailment took place consecutively on China's busy main lines recent years. On the main track of Beijing-Shanghai Railway, systematic freight wagon derailment test has been conducted to find out the cause of wagon derailment taken place on straight track. 32 trains have been tested in three types of classification. During the test, derailment coefficient, rate of wheel load reduction and other dozens of parameters have been collected from wayside and on-board. Wheel/rail contact status has been recorded by photographic

method. The test shows that safety level of derailment coefficient for freight wagon on straight track can not base on the Formula Nadal only, but should take the lasting time of the maximum derailment coefficient into consideration. The test also shows that derailment is related with wheel/rail friction coefficient, technical status of wagons, loading status of wagons, position of wagons in a train, whether the train is under traction or idle operation and magnitude of braking compressive force. And curve section and elevating one side of rails of the straight track can both restrain snake movement of wagons to lower the possibility of derailment.



# **Theme 1: Railway Track**

**Day 1:**

**Rail Inspection**



**APPLICATION OF THE MAPS  
STRESS MEASUREMENT  
TECHNOLOGY IN THE RAIL  
INDUSTRY, INCLUDING A NEW  
DEVELOPMENT FOR THE NON-  
DESTRUCTIVE MEASUREMENT  
OF STRESS-FREE TEMPERATURE**

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**Keywords:** MAPS, residual Stress, rolling contact fatigue, thermally induced stress, stress-free temperature

MAPS is a non-destructive technology relying on the effect of stress on the magnetic properties of steel for the measurement of absolute biaxial stress (i.e. applied plus residual stress). MAPS has been developed recently in the rail industry to assist in the understanding and management of rolling contact fatigue in rails and wheels, and has already shown how RCF cracking can be predicted in situ. Another rail industry development is a non-intrusive measurement of thermally induced stress in rails for the management of rail buckling and breaking during extremes of environmental temperature.

**DEVELOPMENTS OF RAIL FLAW  
INSPECTION TECHNIQUES  
WITHIN THE UK RAIL INDUSTRY**

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**Keywords:** Rail, flaw inspection, NDT, combination

In 1993, the British Government introduced the Bill for the privatisation of British Rail, choosing to break up the business into a number of companies in several tiers. Railtrack became the infrastructure owner (now Network Rail), and outsourced all maintenance and renewal to a number of Contractors.

Prior to the break-up and sale of the UK rail network, it was essentially self sufficient in maintenance, plant, design, installation, testing and commissioning, this also included research and development.

Under a unified rail network, the sometimes-conflicting requirements of the train operations and infrastructure maintenance were resolved internally. The fragmentation of the industry following privatisation made this considerably more difficult, due to a number of factors including commercial constraints and business objectives.

Contractors had to balance the risk of failure against the cost of delivery in order to maximise their return under their contractual performance schemes. Although the focus was to reduce failures by using alternative techniques, Contractors were reluctant to invest large sums of money in innovation and development where there may be no performance benefits.

Development activities were also duplicated in that more than one contractor may have been developing new technologies to address the same problem.

The need to provide the passenger with a safe and reliable service has never been more prevalent and therefore the need to reduce and indeed eliminate failures has never been greater. Of all the types of failures, rail breaks not only pose the largest safety threat but also have a considerable impact on the availability of the infrastructure.

Over the last 4/5 years, the instances of rail failure have significantly reduced but the number of rail breaks and defects removed remain unacceptably high.

Although various techniques and technologies have been introduced over the years, in order to reduce rail failures, they have never been used in a complementary manner but as stand-alone techniques. This has proved to be effective in reducing the failures but has also increased the cost of inspection.

AMEC SPIE Rail (UK) and QinetiQ are working together to develop various technologies including evaluation of current NDE techniques for the detection of rail defects, against leading edge military technology.

## **NON-CONTACT ULTRASONIC TESTING OF THE RAILHEAD**

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**Keywords:** Ultrasound, EMAT, non-destructive testing, rail

Conventional ultrasonic methods of testing for defects in the railhead are limited to low speeds (about 20–30 mph), meaning regular testing of large sections of track is not

viable. Many of the serious defects that can occur in the railhead are also very hard to detect using such techniques. Non-contact ultrasonic testing removes the need for couplant between the transducer and track increasing reliability, and may be able to speed up the inspection process. Various non-contact ultrasonic techniques are being investigated by a number of international workers, for example using electro-magnetic acoustic transducers (EMATs).

We have developed a low frequency broadband Rayleigh wave EMAT system, propagating guided waves along the surface of the rail using a ‘pitch-catch’ technique. We are also investigating the potential of using laser generation coupled with EMAT detection of Rayleigh waves. By looking for enhancement of the signal from Rayleigh wave interactions or missing signals due to the presence of a crack it is possible to detect defects, including gauge corner cracking, to a depth of a few millimetres. We have also demonstrated how this approach can be used to gauge the depth of a crack type defect.

## **IMPROVING THE DETECTION OF INTERNAL RAIL CRACKS BY USING RADON TRANSFORM OF BSCAN IMAGE**

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**Keywords:** Transversal crack, ultrasonic, radon transform, BSCAN, detection, signal to noise ratio

Ultrasonic inspection systems generally use ASCAN mode to detect rail crack. A flight

time window is open where a flaw echo is validated when it occurs with a sufficient level. The maintenance operators well know the difficulties to adjust the threshold and the position of the time window : if the threshold is too high, the system misses cracks, if it is too low the system generates false alarms; if the time window is too close to the origin corresponding to the rail surface, noises disturb the detector, if it is far from the origin, the sub-surface cracks are not detected. The only solution to increase the detection robustness is to validate it only in the case of 2 or 3 successive threshold overshoots. This article introduces a new decision space that uses the Radon transform of the BSCAN image, a transform often used in straight line recognition. This approach takes benefit of the spatial coherence of the crack. The real-time implementation is possible because the computation time can be drastically reduced : only a particular angle of the Radon transform is computed, directly related to the direction of the incident ultrasonic beam. Tests on simulated and real BSCAN signatures demonstrate the good behaviour of the new detector compared to the usual one.

## **EDDY CURRENT TECHNOLOGY FOR RAILROAD INSPECTION: POTENTIAL AND IMPLEMENTATION**

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**Keywords:** Eddy current, rail, testing, safety

Railroad operators have been greatly concerned about rail safety for some time. Until now rails have only been systematically checked for defects between head and base using ultrasound but nowadays defects on the guiding surface and other areas of the head can be successfully detected and evaluated using a different method: eddy current inspection.

In recent years greater axle loads and higher speeds dramatically increased the strain on rails resulting in more defects such as headchecks along the guiding surface or squats and 'Belgrospe's' atop the rail's surface. These defects must be detected, evaluated and removed through grinding, before they can evolve into a real danger. If necessary, entire sections of rail are replaced.

BAM as part of a German consortium managed to develop probes with depth resolutions in excess of 10 mm through basic research. These probes permit an accurate analysis of the degree of damage when combined with suitable evaluation algorithms. Even at speeds of up to 100 kph each defect is accurately localized.

Handheld inspection systems, inspection trolleys, railroad vehicles, grinding and rail inspection trains are currently being equipped with this technology. Deutsche Bahn being a pilot operator approved the system. All versions are being successfully used by operators and inspection companies throughout Europe.

# **PROCESSING ALGORITHM APPLIED TO AXLE BOX ACCELERATION IN ORDER TO DETECT SHORT DEFECTS OF TRACK AND RAIL GEOMETRY IN HIGH-SPEED LINES**

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**Keywords:** high-speed lines, short defects of geometry, processing algorithm, axle box, acceleration, time-frequency analysis.

Maintenance of ballasted track geometry in high-speed lines is largely focused on correction of short defects such as:

1. ballast pitting on rail surface due to crushed ballast under wheel
2. distortion of the rail (bent rail), due to high impact forces when ballast is crushed
3. loose sleepers, due to repetitive shocks from wheels running over ballast pits or bent rails.

It is essential to detect quickly these defects, because they may increase significantly, leading to more maintenance, with the risk in the end, of compromising comfort and safety.

The paper presents a processing algorithm using the signal of axle box acceleration. This allows to detect short defects, and to evaluate the extent of their damaging effect.

The algorithm uses mainly time-frequency techniques (spectrogram or wavelet analysis), the type of defect being linked with its frequency domain. Ballast pits, for example, are mainly instanced as high frequency defects.

The assessment of robustness of the

method is also presented, this is done by repeatability tests and surveys in the field. Ultimately, this algorithm could be used for maintenance purposes since it would enable better reactivity and earlier determination of the appropriate correction method according to the type of the defect.

# **STRUCTURAL MONITORING TO AID THE SETTING AND DETERMINE FITNESS FOR SERVICE OF MECHANICAL SUPPLEMENTARY BACK DRIVES**

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**Keywords:** Mechanical supplementary drives, railway points, structural integrity monitoring, stress monitoring, stress memory technology

This paper reports the details and observations from structural measurements made on mechanical backdrives (supplementary drives) driven by conventional point machines. The drives were set up correctly and then purposefully set out of adjustment in order to study the load (and resulting stress) distribution within the drive assembly. By gaining an understanding of the relative stresses within the points system it may be possible in future to monitor these as a diagnostic tool to describe the overall fitness for service.

Strain measurements were continuously monitored during trials on different sets of

points at training schools in the UK. Results are presented for simultaneous measurements taken on connection rods and stretcher bars during point switching. The paper focuses on the most recent trial and addresses the magnitude of forces/stresses present, the repeatability of measurements, sampling frequency and whether or not these are likely to be unique to each set of points.

## **AN ANALYSIS OF INSPECTION AND FAILURE-REPORTS OF RAIL POINTS: A CASE STUDY FROM SWEDEN**

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**Keywords:** Points, turnouts, failure statistics, maintenance strategy, railways

The Swedish National Rail Administration has about 3,500 points on its main track. These points cause a significant number of traffic disturbances and disproportionately add to maintenance costs. A better understanding of the conditions of the points is needed to reduce disturbances and better manage maintenance. This study focuses on the identification of factors that explain the amount of failures and inspection remarks.

A model based on the factors identified (age, traffic and initial conditions) is proposed. By working with the model it is possible to identify points with abnormal failure values and/or critical inspection remarks. Examples of the observations are reviewed and discussed. Double and single track lines have large differences in how much deviating track is used. This is observed as difference in inspection remarks. Points with lighter rail-weight

needs more care than other points.

The model was tested in connection with a tryout of new tongue monitoring contacts (TMC) that was introduced during 2003. It was possible to prove the success of this project by analysing just 16 of the points during a five-month period.



# **Theme 1: Railway Track**

**Day 1:**

**Rail Maintenance**



## **TRACK MAINTENANCE AND RAIL GRINDING – AN INTEGRATED APPROACH**

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**Keywords:** Maintenance, grinding, rail, track

Rail grinding is often considered a rail maintenance activity independent of other track work. It is typically programmed when irregularities in the longitudinal plane exceed set limits, or is executed in fixed cycles determined by previous experience of the onset of rail surface fatigue problems.

With new line construction, rail grinding has become standard practise, normally as the last operation before a line opening. Logically, the routine has been adopted for rail renewal. Here too track and rail conditions can be synchronised and adapted from the beginning to specific traffic, an aspect particularly important in high-speed and heavy haul conditions.

From the common departure point the track is subjected to cyclical maintenance of its various components, notably track geometry and rail condition. But these parameters are not independent. Experience has shown that rail surface irregularities influence track quality, and conversely track quality can affect the development of rail surface fatigue. Thus the question arises whether track maintenance work should be integrated, and in particular whether track tamping and rail grinding should be linked.

The paper explains the interaction between surface irregularities and the deterioration of track quality and outlines the experience gained in linking maintenance operations. It also describes future planned activities. The overall aim is to demonstrate the technical and

economic benefits of incorporating rail grinding into an overall track maintenance strategy.

## **STUDY OF INFLUENCE ON RAIL SURFACE CHARACTERISTICS AFTER GRINDING**

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**Keywords:** Rail grinding, rolling contact fatigue, rail damage, passage tonnage

Rolling contact fatigue of rail has caused generating of rail damage. Typically rail grinding is said to be an effective means to this type of fatigue. However, there is no clear index for rail grinding. After the rail grinding examination was performed, the metal structure was investigated. It was found that the plastic flow removed through rail grinding was reproduced. Moreover, it turns out that it is required by carrying out repetition grinding to remove a fatigue layer. For the Yamanote Line, an examination of the running surface after rail grinding was performed, and the influence of the passing tonnage on some rail characteristics after grinding was investigated. Findings showed that grinding marks disappeared after about one month. In addition, it turns out that the rail surface becomes hard immediately after grinding, and the gauge corner hardens remarkably. Lastly, it was found that a metal organization is reproduced with the increase in use of the passing tonnage after grinding. As the result, damage generation of a rail can be controlled by carrying out rail grinding in a fixed cycle.

## STRUCTURAL MODEL OF RAILS' SIDE WEAR IN CURVES

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**Keywords:** Railway track, curves, rails, side wear, mathematical modelling, time series

From the measurements of the rails' side wear in curves, carried out on Rapid City Railway lines in Gdansk it follows that the measured wear indicates a considerable and violent variability along the whole length of the curve. Among others, for this reason it is difficult to identify the causes of the extensive wear and tear of the rails in curves of these lines.

For the analysis of the rails' side wear in curves use has been made of 'time series' which can be used to model phenomena of great variability. The application of the 'time series' mentioned above has enabled to distinguish, in the constructed wear-model, the following components:

- the wear trend element characterizing a certain repeatability of the wear along the length of the curve,
- the periodicity element of the wear characterizing a certain repetition of the wear magnitude along the curve length,
- the wear disturbance element including the observation error and other irregularities.

The adoption of such a model make it possible to understand better the analyzed phenomenon of the wear and to determine the causes of the extensive wear of rails in curves of the Rapid City Railway in Gdansk.

## HIGH SPEED RAIL GRINDING – THE WAY FORWARD

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**Keywords:** Rail grinding, high speed, rolling contact fatigue

Corus Rail and Stahlberg Roensch are developing an innovative approach to rail maintenance based on a high speed rail grinding. A prototype grinding unit has demonstrated excellent results during trials and a full-scale machine built for use in continental Europe is currently completing vehicle approval and validation testing.

The high-speed grinding process offers range of substantial advantages, the most attractive being the high operational speed of approximately 80–100 kph. This means that the grinder may be deployed within timetables traffic in existing mainline passenger, freight or suburban train corridors, thereby considerably improving track access and productivity by removing the reliance on possession access which is characteristic of conventional grinding operations

The system may be used as a preventive measure against rolling contact fatigue. The use of conventional grinding at regular intervals is a generally recognised strategy to counter rolling contact fatigue, but this usually involves the removal of a significant depth of rail material in each grinding pass. The high speed grinding machine removes only a very thin layer, but more frequently. Compared to conventional grinding this improves the consistency of the rail profile

and hence vehicle ride and minimizes the artificial ‘wear’ of the rail.

High speed grinding can also be used for noise control by smoothing out small surface irregularities, thereby reducing noise occurrence at source. This reduces the need for unsightly noise barriers in urban areas.

Corus Rail and Stahlberg Roensch have used a prototype of the high speed grinding unit in UK trials for addressing the issue of autumn leaf fall low rail adhesion problems. Work to date has shown the process to be an effective countermeasure; the light grinding action is suitable for the removal of organic material on the rail surface without unduly grinding away good rail material.

Corus Rail are presently developing a UK business case using information generated from the prototype trials and grinding activities undertaken by Stahlberg Roensch using the full scale operational continental gauge machine, in conjunction with the Corus in-house developed rolling contact fatigue and track degradation models, to show the benefits of using this system as part of a holistic fatigue and track management system.



# **Theme 1: Railway Track**

**Day 1:**

**Rail Design**



## **MAKING IMPROVED SPIRAL GEOMETRY PRACTICAL FOR BALLASTED TRACK**

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**Keywords:** Spiral, geometry, ballast, track

Improved spiral geometry is conceptually persuasive, offers tangible improvement in track/vehicle dynamics, and is not hard to calculate.

For tracks being constructed on fixed concrete foundations (so-called slab tracks), improved spiral geometry can be achieved using the same surveying and positioning techniques as are used when constructing slab track with traditional spiral geometry.

In contrast to slab track, ballasted track is typically aligned using a track lining machine both when initially laid and periodically thereafter. In normal North American practice, track lining machines do not move the rails to target locations that are mathematically defined. Instead they move the rails so as just to smooth out 'short wavelength' variations of curvature. It is not possible to impose mathematically defined improved spiral geometry on ballasted track using a track lining machine as such a machine is normally operated.

This paper describes a set of procedures that have been developed to allow mathematically defined improved spiral geometry to be achieved and maintained using track lining machines. One key procedure works from the measured offsets and synthesizes coordinates of points along the existing track. Another key procedure finds the improved line such that track shifts thereto from the existing line are minimized. The paper also illustrates transfer of computed track throw instructions to a track lining machine.

## **APPLYING IMPROVED SPIRAL GEOMETRY TO DESIGN OF TURNOUTS**

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**Keywords:** Spiral, geometry, turnouts

An improved method for designing transition curves for railroad track has recently become available. In this method design begins with specification of how track superelevation is to vary with distance and the chosen superelevation profile determines the horizontal geometry. In comparison to traditional spirals, spirals designed via the new method excite less fluctuation of vehicle accelerations and of lateral forces applied to the track. The present paper considers ways the improved method can be used for design of track turnouts and crossovers.

Basic shapes that emerge from the improved design method are reviewed, and ways that those shapes can be arranged to form turnouts and crossovers are presented with emphasis on accommodation of high speed passenger trains.

The paper then considers physical design of switch elements and particularly the question of how to incorporate superelevation in switch design. Significant improvement in turnout and crossover performance should be possible if inclusion of superelevation can be made practical. The paper outlines some ways of including superelevation using movable point, stub, and transfer table type switch mechanisms.

A companion paper presents calculated vehicle responses to crossovers embodying geometry with superelevation and compares those responses with calculated responses to a corresponding traditional level crossover.

## **VEHICLE RESPONSE TO TURNOUTS WITH IMPROVED SPIRAL GEOMETRY**

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**Keywords:** Vehicle response, turnouts,  
spiral

A companion paper describes and illustrates possible applications of improved transition curve geometry to the design of turnouts for tracks serving high speed passenger trains.

This paper shows how a representative passenger coach will respond to several turnout geometries as predicted by computer simulations. The paper compares vehicle responses to turnouts having superelevation upstream of the frog with responses to a turnout embodying a traditional level geometry. The comparisons provide preliminary evidence about whether incorporation of superelevation upstream of the frog could allow speeds over diverging routes to be increased. Some of the arrangements that include this superelevation appear to offer improved performance, and some others appear to have no value.

## **MODERN PERMANENT WAY DESIGN TECHNIQUES FOR TRACK RENEWALS AND MAINTENANCE**

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**Keywords:** Horizontal and vertical  
alignments, switch and crossings, computer  
aided design, 3D models

This Paper will review the modern permanent way design techniques being utilised on the current West Coast Main Line upgrade project. These techniques highlight the benefits of a 'right first time' philosophy with regard to the design and implementation of permanent way alignments from conception to completion with particular emphasis on switch and crossing installation.

Arup are currently working as Designers with both Network Rail and Carillion Rail within the Northwest and Midland Regions of Network Rail. This work is being carried out principally on two projects, which in the current year 2003/2004, has required the production of detailed topographical surveys, switch and crossing (S&C) design and setting out data for the installation of over 100 No. point ends. The experiences gained in this process will provide the basis of the Paper.

The Paper will provide an overview of how the modern permanent way design process interfaces with other related disciplines such as electrification, geotechnics, signalling and power. In addition historical, current and envisaged future techniques will be reviewed. It will be shown that the adoption of modern design techniques can provide additional benefits in improving timescales, quality,

installation and future maintenance requirements.

Design innovations will be explored such as 3D laser scanning topographical survey techniques and the production of 3D models of design alignments. It will be shown how these modern systems enable accurate installation, facilitate a reduction of the whole construction process and provide an as-built record for future maintenance requirements.

Malcolm Taylor, an Associate Director of Arup who has over 35 years experience of track renewals and maintenance in the UK, will introduce the paper. He will be supported by David Woods, who is the Arup Permanent Way Engineer responsible for producing holistic switch and crossing layout designs from specification to installation on behalf of the WCML Switch and Crossing Alliance team.

cubic parabola transition curve and has compared with the half-wave sinusoid transition curve. Also, the author has made comparison on wheel/rail dynamics simulations by using different superelevation setting methods of the Chinese Type and the Japanese Shinkansen Type. The research results show that the existing type of transition curve and Chinese type superelevation setting method are able to ensure safety and riding comfort in the high-speed test section of the Qinshen Line.

**RAIL/WHEEL DYNAMICS  
SIMULATION FOR TRANSITION  
CURVE IN THE HIGH SPEED TEST  
SECTION OF QINSHEN  
PASSENGER RAILWAY LINE**

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**Keywords:** Transition curve, super-elevation setting method, wheel/rail dynamics simulation, high-speed railway

Using the large wheel/rail dynamics simulation software package NUCARSTM developed by Association of American Railroads (AAR), the author has analyzed wheel/rail dynamics behavior when high-speed cars run in high-speed section of Qinshen (Qinhuangdao to Shenyang) Dedicated Passenger Railway Line with a



# **Theme 1: Railway Track**

**Day 1:**

**Signalling: SILS and ATC**



## **OUTLINE OF APPROVAL PROCESS FOR AUTOMATIC GUIDED TRANSPORTATION IN EUROPE**

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**Keywords:** Standards, assessment, certification, notified body, railways, safety, Automatic Train Protection (ATP), signalling system, safety architecture, life-cycle

In Europe, the Safety Assessment process of new automated public guided transportation is imposed by the Safety Authority body before issuing the Approval for Operating Revenue.

The Approval process is based upon the assessment and certification activities dedicated to the safety digital railway trains piloting, guided by the relevant European and National standards.

A significant number of railway equipment used in European network are old and need to be upgraded. Modern lines are safer than older ones, but the problems remain when they are still integrated at their (common) end points.

Furthermore, recent incidents show deficiencies at the Safety management level, staff performances, maintenance process, certification of new trains etc.

Though, the opening of the European Union market, the interoperability for high-speed train (see ERTMS system) requires from member States, to built together common safety framework legislation.

This paper deals with the railway Approval process.

We will first present a short overview of the main European Directives and Standards, related to the safety automatic

train control and secondly, a presentation of the European provisional Safety Directive will be made. Finally, conclusions will be discussed.

## **ETCS-2 COVERAGE AND CAPACITY SIMULATION EXPERIENCE IN THE UK**

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**Keywords:** ERTMS, ETCS-2, GSM-R, radio cells, path loss, capacity, message latency

ERTMS train signalling will be implemented by ETCS level 2 signalling protocols carried over a GSM-R radio bearer. The question of whether this signalling system will have sufficient capacity for expected signalling requirements, and whether it could introduce additional train running delays, has been studied by means of a computer simulation of selected geographical areas.

The principle is to use a radio traffic simulation model in conjunction with a train movement simulation model to estimate likely train signalling performance, given the known radio cell plan, current train working timetables, and other information. The study involved data preparation, simulation modelling of ETCS protocols, simulation modelling of radio transmission bit error rates, and the simulation modelling of radio connection and handover given expected train movements in the area in question.

Each simulation study takes as input a specification of the intended ERTMS

messages, the local GSM-R cell plan and frequency re-use plan, radio attenuation due to terrain, including railways cuttings, the track layout, and the pattern of train movements as predicted by a state-of-the-art train movement model. Estimates of radio bearer error rates and radio cell usage are used to compute call drop rates and ETCS message latencies. These are then used to inform the train movement model to make better estimates of potential train delays. The simulation process is iterated a number of times to ensure that representative results are obtained.

Simulations were performed for scenarios representative of railway operations in the UK, including rural mainline, urban terminus, and suburban junction operation have been selected and studied.

The main study conclusion is that GSM-R radio bearer usage does not, in general, introduce significant delays in ERTMS message transmission. Where radio cell plans are well provisioned there should be little or no impact on train running times. However, the future impact of increasing train traffic levels is an open question since cell saturation could cause radio capacity problems. The interaction of train running in otherwise separate urban terminus areas is also a potential source of concern since distant radio environments may interfere adversely with each other.

## **DEVELOPMENT OF AN EXPERIMENTAL RIG FOR HIL TESTING OF RAILWAY RADAR SPEED SENSORS**

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**Keywords:** Radar, speed sensors, test rigs

Radar speed sensors are widely diffused for railway experimental activities. Also innovative railway ECU (electronic control unit) system such as Odometry Boards, WSP, Traction Controls may use this kind of sensors to improve train speed estimation when heavy axle slips are possible (braking/traction with degraded adhesion). Developer and manufacturer of radar doppler sensor usually test their products using special test rig that are able to simulate the relative motion between carbody and the track. This experimental devices usually have limited performances (max. simulated speed of 50 km/h, bad signal to noise ratio, poor dynamical behaviour).

University of Florence and Trenitalia SPA have developed a special rig to test reliability and homologate this kind of sensor and the connected ECU boards. The new test rig is composed by an array of belts driven by motorized pulleys and idlers. Belts are covered with a special metal-organic coating that is able to reproduce

equivalent roughness and reflective properties of ballast.

Performances of the rig are higher than commercially available solutions: maximum simulated speed of 180km/h, max acceleration/deceleration of 3ms<sup>-2</sup>, good signal to noise ratio along the operating range. Also real time model of the train is implemented on the rig in order to generate virtual test runs according main features of the train such as length, weight, number of coaches, etc. In this paper HIL simulation results are shown and compared with real speed profiles recorded during experimental test runs along the AV line Firenze-Roma.

## **HIL SIMULATION OF ATP, ATC SYSTEMS FOR RESEARCH AND HOMOLOGATION PURPOSES**

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**Keywords:** HIL, simulation, test rig

HIL simulation can be a powerful tool to reduce costs and time consumption of homologation activities of new ATP/ATC equipments. Also HIL simulation may help to reproduce critical conditions (braking with degraded adhesion, system malfunctions, etc.) without safety constraints that usually make difficult and expensive experimental test runs.

Trenitalia SPA (Italian Railway Company) and University of Florence have successfully developed a test rig for HIL testing of Odometry Board, a safe relevant subsystem of ATP, ATC systems.

The rig is installed in the experimental structure of 'MI6' at Firenze Romito in Italy and it has been successfully used for the homologation of the odometry algorithm used for the new Italian ATP standard 'SCMT' ('sistema controllo marcia treno'). Authors have also developed a real time simulator of the Italian ATP system 'RS' ('ripetizione segnali').

The purpose of this research activities is to extend the capabilities of the rig to HIL simulation of ATC, ATP systems in order to compare performances of older 'fixed block systems' such as 'RS' with new standards such as 'ERTMS' (European Rail Traffic Management System).

In this paper, main features of the rig are explained, and results concerning odometry homologation and simulation of ATP systems are shown.

## **WESTLOCK – EVOLVING SSI**

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**Keywords:** Signalling, safety, interlocking

This led to the establishment of a project to develop the WESTLOCK (WESTinghouse interLOCKing) electronic interlocking system. WESTLOCK builds upon the success of SSI whilst enhancing the potential of its application through the use of high performance technology and the contribution of design, testing and maintenance tools.

## **COMPUTERIZED MAINTENANCE INFORMATION SYSTEM FOR URBAN TRANSIT INFRASTRUCTURE USING INFORMATION TECHNOLOGY**

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**Keywords:** Computerized system, urban transit, infrastructure, maintenance, GIS, PDA

For efficient maintenance of urban transit infrastructure, computerized system using wireless communication system which allows to inquire necessary information and to record maintenance data on the spot in realtime is required. Also, for efficient maintenance work on urban transit infrastructure which have geographic data, computerized system united with geographic information system that offers visual information is required. In this paper, development direction and model of computerized information system for maintenance on urban transit infrastructure are proposed. And, the present state and future plan of this system which is developing from model on SMRT(Seoul Metropolitan Rapid Transit Corporation) is presented.

## **NEW TECHNIQUES FOR WHEELSET CONDITION MONITORING AT EUROTUNNEL**

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**Keywords:** Wheels, condition, monitoring

Defective wheel-sets on trains are significant causes of delays as a result of damage to both the wheels and track if the defects are not remedied promptly. The most common defect tends to be wheel impacts caused by flat-spots but other. The cost-benefits of early detection of adverse conditions on a route such as Eurotunnel are very clear due to both limited maintenance access in the tunnel and no diversionary routes being available.

The Eurotunnel system has been installed and is operational for both Wheel Impact locations.

## **ETMS – BUT NOT TO SAVE LIVES ?**

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**Keywords:** Safety, automation, traffic, infrastructure, planning

The public debate about extra safety ignores the high level of railway safety achieved. Investing in automation not only saves lives but significantly reduces operating costs and improves service flexibility. Railways will match more closely the demands of the market. Automation would allow rail freight to compete with the service of a 12m road trailer. Automatic passenger railways should be able to compete better with car travel, provided extra revenue is greater than marginal increases in fuel consumption.

# STATE-OF-THE-ART INTEGRATED CONDITION MONITORING SYSTEM FOR RAILWAY SIGNALLING SYSTEM ELEMENTS

## A Glazebrook

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**Keywords:** Railway signalling, condition monitoring

Railway signalling system installations traditionally have not included comprehensive condition monitoring as a systematically designed-in feature. Railway administrations are under increasing pressure to reduce train delay caused by infrastructure defects. Some add-on systems have been deployed with mixed results. However, the Ansaldo Signal ACC system, in current service in Italy and the UK, incorporates condition monitoring throughout, including controlled 'objects' such as signals and point machines, as an in-built feature. Maintenance diagnostics are accessed through a straightforward technician's interface and enable the continuous monitoring of critical functions and system status. Equipment element performance data is recorded such that trends can be traced and alarm levels set to predict failure, improve overall system availability and reduce train delays caused by signalling infrastructure failure. Details of these early warning alarms can be sent to pagers or cellphones (via SMS 'texts') for maintenance staff action as necessary. By these means, the eagerly sought, yet currently elusive performance improvements can be facilitated.



# **Theme 1: Railway Track**

## **Day 1:**

### **Electrification, Lighting and Power**



## **HIGH INTEGRITY LED EGRESS LIGHTING FOR RAIL CARRIAGES**

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**Keywords:** Rail carriages, internal lighting, LED

At 'Railway Engineering 2002' the author predicted the following:

"Internal lighting for trains will undoubtedly turn to the LED (light emitting diode) within the next 5 years, both for reliability, and also to save the costs of generated electrical power... other advantages ... include resistance to shock and vibration, ... and the ability to run from battery-maintained systems."

Events have overtaken these predictions, and only two years later, LED lighting specialists Marl International Limited have designed, built and commissioned two revolutionary products, which enhance passenger safety and reassurance in a serious accident.

This paper describes the design and evolution of these products, and the lengths to which designers must go to satisfy the requirements of modern train builders.

## **DEVELOPMENTS IN DC SWITCH-GEAR FOR MASS TRANSIT SYSTEMS**

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**Keywords:** DC switchgear, mass transit

In recent years major power equipment OEM's have invested considerable money and resource into new AC switchgear development. Vacuum interrupter development and modern SF6 interruption

have led to many advances at both transmission and distribution levels. As a relatively specialised product, DC switchgear development has tended to be somewhat overlooked with many manufacturers relying on refurbishing designs that go back many decades.

## **LIFE CYCLE COSTING OF BATTERIES IN RAIL TRACKSIDE APPLICATIONS**

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**Keywords:** Batteries, life-cycle cost, trackside

In order to obtain the best return on investment and to provide a very high standard of reliability of supply, it is important to match the components in the system in terms of lifetime and reliability. The return should be regarded as obtaining the best service from the components used.

The economics of the battery system comprises not only the initial cost, but also the total cost of the system during its lifetime and this needs to be established in order to have a true economic analysis.

There are a number of factors that must be taken into account when performing a life cycle costing. These are the initial investment when the battery is installed; the replacement cost which is the sum of the costs involved if a battery has to be replaced, the on-going maintenance cost and the downtime cost. The downtime cost is a cost that can arise from either planned or unexpected loss of power.

The basic purpose of the life cycle cost analysis is to produce a realistic comparison between different battery options for a particular duty. The comparison may involve different battery chemistries, such

as nickel-cadmium and valve-regulated lead-acid (VRLA) or it may involve subtler distinctions, such as comparing ‘5-year’ and ‘10-year’ design life lead-acid designs.

The paper describes the factors that have to be taken into account when carrying out life cycle costing and uses comparisons between different technologies to show how different application requirements can change the choice of battery.

## **A SIGNAL POWER MANAGEMENT SYSTEM – SIGNALSURE©**

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**Keywords:** Signal, power, traffic

The UK Rail network is a large system and faces particular challenges due to its age and complexity. It has also suffered from a lack of investment by successive governments in its British Rail guise. These factors together with the need to control multiple traffic types provide signalling engineers with a set of demanding environmental conditions. The signalling team have to control both fast intercity and high speed trains, whilst balancing these needs with local cross country and commuter traffic, and at the same time meeting the needs of large slow moving high tonnage freight trains.

This paper reports on a signal power management system.

## **ENHANCED OVERCURRENT PROTECTION IN RAILWAY APPLICATIONS**

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**Keywords:** Health and safety, circuit-breaker, hydraulic-magnetic, ambient temperature, overcurrent, protection, de-skilling

It is inarguable that health and safety plus continuity of service are prerequisite requirements for the vast majority of electricity supply applications. This is particularly true in the case of Railway applications.

For general applications, field experience covering several decades has clearly demonstrated the many advantages that can be achieved through the use of circuit breakers as opposed to fuses in overcurrent protection. This same experience has also identified the limitations of thermally sensitive circuit breakers that may be required to operate in environments that experience wide ambient temperature excursions.

In recent years, many hundreds of thousands of circuit breakers that are designed to be independent of ambient temperature have been successfully applied in Railway applications throughout the UK, Europe, and China. These circuit breakers use the extremely versatile hydraulic-magnetic principle of overcurrent sensing and detection and have been utilized in rolling stock, signaling and communications networks, power supply circuit protection as well as in trackside applications that

require close overcurrent protection characteristics.

This paper clearly demonstrates how the particular design features of these circuit breakers together with their ease of adaptability in meeting specific design requirements, including those having very low current ratings, are eminently suited to railway applications. Additional concepts and solutions for other applications are indicated through the inherent design versatility of these devices.

### **A TEST RIG FOR THE COMPARATIVE EVALUATION OF THE PERFORMANCE OF COLLECTOR STRIPS**

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**Keywords:** Contact wire, collector strip, mechanical and electrical wear, electromagnetic emission

In the operation of railway vehicle, especially at high speed, a particular care is addressed to the contact between pantograph and catenary, where thermo-electro-mechanical phenomena are present. The wear related to the collector-contact wire sliding interaction is object of research, aimed at its reduction, through the selection of suitable collector strip material or proper combination, or manufacturing of materials. Being line test very expensive, it is worth make such investigations on a test rig.

The paper describes a test rig for the experimental evaluation of the performance of collector strips for pantographs, recently developed and put in service in the

laboratories of the Department of Mechanics at Politecnico di Milano. The rig enables to measure the main variables that influence strip-wire contact and to test different strip material. The results can be used also for a prediction of the wear of the contact wire, so enabling to carry out a Life Cycle Cost (LCC) analysis of the catenary.

### **AUTOMATIC DIAGNOSIS OF TRACK CIRCUIT IN PREDICTIVE MAINTENANCE CONTEXT**

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**Keywords:** Track circuit, maintenance, diagnosis, neural network, pattern recognition

The French high speed train (TGV) are equipped with a track/vehicle transmission system that uses rails to continuously transmit modulated coded data to the train, over a carrier frequency. This system called track circuit provides to the train the maximum authorized speed on a given section with safety constraints. During maintenance tasks, different kinds of track circuit defects are identified: capacitor removal, electrical separation joint dysfunction, increasing of losses or resistance of capacitor. Until now, the diagnosis of track circuit is achieved by maintenance experts on the basis of the analysis of specific signals measured by inspection vehicles. This paper presents an

automatic diagnosis system dedicated to detect trimming capacitor defects. Its aim is to achieve both a classification task and a spatial localization of the defects. Statistical data analysis and pattern recognition approaches like neural networks are used. An incremental diagnosis is built to detect the evolution of track circuit state. This leads to improve the quality and the accuracy of the diagnosis in a context of predictive maintenance. Different results obtained on experimental data are presented to illustrate the system performances.

## **A HYBRID TERMINAL CONNECTOR FOR USE ON ALUMINIUM AND COPPER CONDUCTORS**

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**Keywords:** Electrical connectors

The form and function are given of a hybrid type connector for use with aluminium and copper conductors. The connector employs the principle of mechanical advantage gained by utilizing interacting levers to generate a pressure connection. Reference is made to existing types and methods in use and comparisons are made between them, highlighting their relative strengths and weaknesses.

The mechanisms of electrical joint interface formation are examined and factors influencing the integrity and the longevity of such interfaces are ascertained.

Compatibility between dissimilar metals is examined in terms of relative electrochemical potential as well as physical parameters such as temperature coefficients of linear expansion. The relative merits of different surface coatings of the connector are discussed together with preparation

techniques for aluminium contact surfaces.

The influence of elastic and plastic deformation of the hybrid connector type is evaluated with respect to joint interface integrity and stability, particularly in association with thermal expansion and contraction resulting from temperature changes, together with the long term effects of creep.

The factors surrounding the choice of attachment bolts are considered. The influence on axial loads generated, given a certain torque, is also examined with respect to threadform, size, lubrication and temper.

The basis and details are given of various accelerated lifetime test procedures for assessing connectors on aluminium and copper conductors. Comparisons are drawn between the tests, and those designed to produce an arduous thermal history are highlighted.

## **MAXIMISING TRACTION POWER BY INJECTION TESTING**

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**Keywords:** Power, traction, injection testing

Achievable traction power ultimately represents a railway's capability to return income from its total infrastructure investment and the core issue for electric traction is acquiring maximum safe power from the utility supply.

## MEASUREMENT METHOD OF CONTACT FORCE AND OVERHEAD CONTACT LINE DIAGNOSIS

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**Keywords:** Contact force, aerodynamic force, contact line diagnosis

In Japan, the contact loss ratio is used to estimate the contact performance between pantograph and overhead contact wire. On the other hand, it is well known that the measured contact force indicates the dynamic behavior of the contact condition including the contact loss. The contact force waveform is affected by many kinds of overhead contact line equipments. Therefore, it is expected that the contact force is applied to the diagnosis on the overhead contact line system. We have developed a method to accurately measure the contact force and studied effective means to utilize the measurement results. The new measurement method does not need to modify pantographs, and ensures higher measurement accuracy, thereby enabling effective measurement up to 100 Hz (40 to 50 Hz for low noise type pantographs).

In order to prevent the breaking of contact wire by fatigue, it is important to limit the bending strain of contact wire within an allowable range. Therefore, we have studied a method to estimate the strain based on the contact force. Running tests proves that the contact force and the strain of the contact wire approximately matches theoretical calculation and simulation results. This shows that it is possible to detect the places where large strain arises by passing pantograph. Therefore, the

contact force measurement is useful for overhead line maintenance.

## A DEVELOPMENT OF DETAIL DESIGN SOFTWARE FOR HIGH-SPEED CATENARY SYSTEM

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**Keywords:** Detail design, overhead catenary system

This study presents a development of DeCatS (Detail Design of High Speed Catenary System) which is the software to design high speed catenary system automatically. The program is developed by Korea Railroad Research Institute. A process of developing it and a comparison with LEXCAT developed in French, in order to demonstrate a preciseness of that, were performed. In the program, decision of H-beam and foundation, cantilever fitting, management of materials, automatic drawing of mounting diagram and etc. according to input conditions can be accomplished.



# **Theme 1: Railway Track**

**Day 1:**

**Safety**



## **RAILWAY SAFETY IMPLICATIONS OF CLIMATE CHANGE**

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**Keywords:** Railway safety, weather, climate change

Some hazards on the railway are weather and climate related and future climate change may increase the system's susceptibility to these hazards. Recent research, managed by the Rail Safety and Standards Board under the Railway Safety Research Programme, has evaluated the status of knowledge concerning these threats and identified areas where the industry may need to focus efforts in response to them.

Using available information concerning climate change and the susceptibility of the system to weather related hazards, a series of risk scenarios has been identified, associated with various weather factors. These scenarios have been assessed, against factors reflecting the risk likelihood (current baseline risk; system vulnerability to change; anticipated extent of climate change) and risk impact (consequence, extent of exposure, system adaptability), to identify where the primary threats to the system lie and develop a prioritised response.

Increased occurrence of extreme events appears to present the primary threat to the system. Recommendations for actions to support a response to these issues have been developed, focussing on identified priorities. New items of infrastructure will need to be planned to provide design functionality throughout their life, accommodating increased extremes. Management regimes may also need to be adapted to address the changes.

## **BRITISH RAILWAY ACCIDENTS: A SYSTEMIC ANALYSIS**

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**Keywords:** Analysis, accident, failure, railway, recursion, safety management, system, systemic.

Several railway accidents have happened in Britain before and after the privatization of the railways. Following these train accidents, there has been a large amount of public debate about safety management on the British railways. These accidents have raised issues regarding the effectiveness of the safety management of the railway system. This paper presents a summary of the results of a preliminary systemic analysis of several British rail accidents, i.e. those at Clapham Junction (1988), Edge Hill (1999), Paddington (1999), Hatfield (2000), Selby (2001) and Potters Bar (2002). It is hoped that this systemic analysis will help to identify 'learning points', which are relevant for preventing accidents in the railway industry. The model is described in the context of the British railway industry. However, the model itself is general and not specific to any particular country.

# USER SAFETY DURING RAILWAY WHEEL WEAR MEASUREMENT THROUGH A SET OF FIELD TESTS IN IRANIAN RAILWAYS: A CASE STUDY

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**Keywords:** Wear, wheel, case studies

In order to control railway wheel wear, two approaches can be adopted. The first approach to measurement of wear relies on visual tests by a member of staff followed by using a go-no go gauge. In the second approach, largely for research-oriented measurement, wear is measured by using either a miniprof or an adjustable control gauge (Asadi Lari 2004). Both of the latter methods have the potential to threaten railway system safety since they involve work near the operational railway. This paper describes the results of a case study for implementing a set of field-tests on Iranian Railways based on the second approach mentioned. The main aim of this paper is to study and visualise the user and system safety to ensure safe performance of the wheel wear measurement while the amount of such work is increasing. Fault tree diagrams have been used to provide a means for on-track hazard avoidance, and for fault identification and diagnosis of test procedures.

# RAILWAY SAFETY ASSESSMENT USING FUZZY REASONING APPROACH

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**Keywords:** Railway safety, fuzzy reasoning, risk assessment

Safety analysis is becoming increasingly important in the British railway industry. To improve railway safety, the new Railway (Safety Case) Regulation requires railway operators to prepare a comprehensive safety case and to secure its acceptance by the Health and Safety Executive (HSE). The traditional risk assessment methods, such as fault tree analysis and event tree analysis, have been used extensively in the British railway industry to find the probability of a major system failure. However, due to incomplete safety data and the high level of uncertainty in the railway industry, the traditional methods may not be the best methods for the safety and risk assessment. Fuzzy reasoning method provides a more flexible and meaningful way of assessing risk, especially concerned with uncertainty, by using linguistic variables to describe the frequency of occurrence and severity of consequences of a failure event. It has been successfully applied in offshore, nuclear and aviation industries for safety analysis and risk assessment. This paper presents a method using fuzzy reasoning to model the frequency of occurrence and severity of consequences of the hazardous event. The risk level produced by the method is used to assess the risk of railway infrastructure. An illustrated example is given to demonstrate the application of the proposed approach.

## COMFORT AND PROTECTION IN FOOTWEAR FOR THE RAILWAY INDUSTRY

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**Keywords:** Safety, boots, EN norms, waterproofness, breathable, durability, construction methods

Currently, the market offers a wide range of so called safety shoes. Customers are finding it ever harder to distinguish 'class' from 'mass', and have little or no knowledge of why they should seek out performance footwear. The EN Norms are not enough to decide.

The performance of a work boot mainly depends on good fit, a pleasant footbed, adequate shock absorption capacity and easy movement of the outer sole. The climatic comfort is determined by the temperature and moisture rates within the shoe. The wearer's feet should remain dry and comfortable in all weathers. It is common knowledge that cold (wet) feet will make the wearer susceptible to viruses (the common cold) in the short term and may even result in chronic health problems in the longer term.

The optimal foot temperature should lie between 28 and 32°C. Outwith this range, discomfort is inevitable. The foot will cool excessively, if water or snow penetrate the shoe from outside, or if perspiration moisture is trapped within the shoe. In summer, blisters may be a painful consequence of moist feet, leading to other complications.

What is necessary for footwear to function properly as PPE, is not just compliance to construction Norms but special heat and moisture regulation capacities. This can be achieved by an

adequate selection of upper and lining materials and good shoe construction.

## SAFETY MANAGEMENT IN THE UK RAILWAY NETWORK

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**Keywords:** Safety management, reorganisation, safety responsibility, risk assessment

Safety is the public's primary concern and should be the railway business core activity. Britain's railway system was restructured and privatised in the mid-1990s. The industry now consists of separate companies, including infrastructure controllers, train and freight operators, rolling stock and contractor companies, and several government bodies have regulatory roles. Most recently, the UK Network Rail has been established in order to manage safety effectively and efficiently. In order to set up the systemic safety management mechanism, this paper presents the roles and responsibilities of industry players in the railway network system. In addition, existing problems and current risk assessment methods are discussed so that more practical solutions can be developed to managing safety effectively.

## **SAFETY ON LEVEL CROSSING ACCESSES TO PLATFORMS**

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**Keywords:** Level crossings, accident risk analysis, safety measures, field test

In the wake of cost-cutting measures and the change from state-owned railways to modern privately owned railway companies, passenger safety while changing platforms has become an increasingly important problem, especially in smaller stations. On the one hand, the cost of special safety personnel must be reduced. On the other hand, at smaller stations the number of passengers per day does not generally justify the construction of a passenger bridge or tunnel. In addition, exaggerated alterations in the normal operation of trains, such as very low speeds, should be avoided.

In a recent study for the Deutsche Bahn AG the Department of Railway Systems at the University of Karlsruhe headed by Prof. Hohnecker has investigated a number of safety measures ranging from warning signs to gates. The advantages and limitations of each safety measure are discussed and their risk reduction potential under normal operation conditions is evaluated. This study provides the basis for a standardized risk analysis and makes it possible to establish appropriate guidelines on a scientific basis.

## **RESERCH OF COLLISION PREVENTION BETWEEN TRAINS AND MAINTENANCE CARS**

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**Keywords:** Collision prevention, maintenance car, shunting, signal, level crossing

In recent years, many machines have been installed for track maintenance work, and large and heavy maintenance cars were also introduced. As this result, when a maintenance car and a passenger car collide, the big damage is expected. To prevent this collision, it is necessary to assure that any trains do not enter the area where a maintenance car is operated. A train runs with track circuit shunting, and the signal turns to red automatically. However, as a maintenance car usually runs without track circuit shunting, signal does not turn to red automatically, and a train may enter the area. Therefore signaling systems cannot detect a maintenance car. The reasons why a current maintenance car runs without track circuit shunting are follows:

1. Signal facilities and level crossing equipment do not support that a maintenance car runs on track reverse course of double track. When a maintenance car runs on reverse course, level crossing equipment does not work correctly.
2. Some devices have time checking function. As a maintenance car sometimes stays for working on the same area during a long time, trouble detection of the level crossing equipment works.
3. As some maintenance cars have a light axle load, they sometimes can not shunt

track circuit certainly.

A current maintenance car runs after signal operators confirm safety by making signal to red. Here he may make mistakes, because he cannot know real position of the car and there is no mechanical backup.

To solve these problems, we focused on the difference of the frequency of track circuit. The frequency of track circuits for signaling system and that for level crossing equipment is different. We can discriminate these two frequencies by using a coil. Using this, we developed shunting device for a maintenance car which does not make level crossing equipment failure. We can detect the position of a maintenance car by shunting track circuit with the device, even if the maintenance car is on wrong position. In this paper, we explain specification of the device and result of the field test.

We tested the performance of the device by running a maintenance car with it on main track last year. As its result, when rail surface is cleaned enough, we could get enough performance we expected. We have been trying it on practice operations from February 2004 at the specified line. We are planning to use the device at some other lines after confirm that expected performance is provided.

## **SYSTEM THINKING IN PRACTICE – SAFETY MANAGEMENT ON THE COPENHAGEN METRO CIVIL WORKS**

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**Keywords:** System, civil works, safety,  
metro

This paper focuses on the IRG contribution to the safety demonstration for Phase 2B of

the Copenhagen Metro civil works – formally approved, 3 months ahead of schedule, in October 2003. The works included geotechnics, structures, track, power supply and mechanical services for a new line.

The primary interface was with the Train Supply Contractor, responsible for driverless rolling-stock, operating under Automatic Train Control. This interface is discussed.

Significant hazards within the IRG scope included objects on the at-grade alignment, damage to services including gas mains, and derailment of trains on adjacent infrastructure.

Safety Cases were prepared to the EuroNorms. The paper outlines how the practicalities of system division, requirements specification, hazard budget allocation and risk minimization were achieved within this framework.

Hazard identification, quantification and control was at the core of the process. The Methods of hazard identification and comparison used to best achieve project specific hazard definition with minimum overlaps and gaps are examined in detail.

The paper considers the methods with which contract, system and physical interfaces were managed to form a coherent, robust and accurate system description.

The paper reports a practical man's experience of a complex subject, concluding with an indication of the author's views on the challenges for project risk management.



# **Theme 1: Railway Track**

**Day 1:**

**Trackbed Monitoring**



## **ELECTRONICALLY ASSISTED TRACK SURVEYING USING THE EM-SAT**

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**Keywords:** Track, ballast, maintenance, electronic surveying, EM-Sat

Today, high-capacity trains are representative of a modern, dynamic and efficient railway, demanding a high-quality track. The higher the initial quality of a high-speed track after installation, relaying or maintenance, the lower the subsequent maintenance costs will be. The initial quality of a track is greatly influenced by the accurate production of the geometrical track position. In this respect, the distortion of the track geometry is assessed and corrected not only according to its size, but also as regards its wavelength. This paper describes new developments in the technology of track surveying using EM-Sat.

## **TEKSCAN SENSORS – RAIL/SLEEPER INTERFACE PRESSURE MEASUREMENTS IN RAILWAY TRACKBEDS**

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**Keywords:** Tekscan sensor, pressure measurements, railway trackbeds, asphalt underlayments, trackbed pressure distributions.

It has been desirable for years to develop non-intrusive/non-invasive procedures to directly measure pressures and stresses at various levels and interfaces in the railway track structure in order to optimize track designs and improve subsequent track

performance. Recent research has developed satisfactory procedures for measuring pressures in the track structure at the ballast/subballast/subgrade levels using earth pressure cells. This paper documents the recent development of a technique for measuring the pressures in the track – at the rail/plate interface – using a very thin pressure sensitive Tekscan sensor. The Tekscan Measurement System uses a sensor composed of a matrix-based array of force sensitive cells, similar to mini strain gauges, to obtain accurate pressure distributions between two surfaces in the track. This paper describes 1) the optimum procedure to install the sensors into the track, 2) the recommended practices to effectively collect data with the software, and 3) the accepted techniques for analyzing the results. Both laboratory calibration and in-track testing have been conducted and the results are presented. The findings attest to the usefulness and practicality of the procedure for accurately measuring pressures in railway tracks. This procedure may also be applicable for a wide variety of specific track related measurements such as validating curve geometric design criteria, assessing crossing diamond and bridge approach impact pressures, and evaluating the advantages/disadvantages of various types of plates, fastenings, and sleeper compositions.

## **BALLAST DEGRADATION AND MEASUREMENT OF BALLAST FOULING**

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**Keywords:** railway ballast, ballast fouling index, degradation, ballast life

In service, the ballast layer is subject to both deformation and degradation due to traffic load. Therefore, in order to keep the track performance within the required standards the ballasted foundation is subjected to various maintenance cycles such as tamping, ballast cleaning or reconstruction processes. A better planning of these processes warrants the extension of ballast life and the reduction of the maintenance costs.

In practice, the extent of ballast fouling is usually based on visual inspections by track staff. Also, the current ballast fouling index does not realistically estimate the extent of ballast fouling. Therefore, ballast cleaning is not programmed as effectively as might be possible if a correct evaluation of the degree of ballast fouling would be carried out.

The proposed paper presents the degradation characteristic of ballast layer and its effect on the ballast foundation performance is discussed. The shortcomings of the currently used ballast fouling index are then identified. Based on the analysis of an extensive number of field samples, a new fouling index was proposed, which properly quantifies the extent of ballast fouling. The classification criteria and the application of proposed ballast fouling index to predict the ballast-cleaning cycles is also presented.

## **IMPROVED PRODUCTIVITY AND RELIABILITY OF BALLAST INSPECTION USING ROAD-RAIL MULTI-CHANNEL GPR**

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**Keywords:** Multi-channel GPR, rail ballast inspection

It is commonly accepted that the most efficient way to monitor track condition and other infrastructure assets is by means of track inspection vehicles, collecting multi-parameter data simultaneously at normal line speeds. However, technological limitations have meant that up until recently it has not been possible to acquire subsurface trackbed parameters such as ballast thickness and ballast quality in a similar manner.

A multi-channel ground-penetrating radar system is presented, capable of operating on a road-rail vehicle and at speeds of up to 100 mph suspended beneath a modified track inspection train. The system can collect up to 4 simultaneous channels of data across the trackbed, and provide a rapid analysis of ballast thickness and quality. This is achieved by the application of novel multivariate signal and image processing techniques to automatically detect, quantify and map variations in ballast depth and condition.

Data from between and beneath the sleepers can be separated in order to aid identification of potential problems associated with individual sleepers. Acquisition of data on a stable platform

removes the effects of operator induced noise previously observed in hand-towed slow speed systems and enables a quantifiable measure of ballast and formation condition to be achieved that can be used to QC new renewals or provide an 'inventory' of ballast condition. This sets the benchmark of current ballast condition so that deterioration can be monitored, comparisons made and renewals priorities set.

This integrated inspection system offers significant productivity and reliability improvements over conventional methods of acquiring GPR trackbed data. By combining information from track geometry surveys, GPR, video and other co-located datasets, predictability of track degradation is improved, whilst the reduction in required track possession time and the ability to interpret data on-site results in a significant reduction in site investigation costs.

## **IDENTIFICATION OF TRACK QUALITY FROM MEASURED RESPONSE DATA OF THE VEHICLE**

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**Keywords:** Railhead, irregularities, track quality, vehicle response

This paper presents a formulation to compute the root-mean-square (rms) values of the railhead irregularities. This is achieved by using the axlebox acceleration measurements as input. The model presented accounts for the interaction of the track with the subgrade. The power spectral density function of the railhead irregularities is computed and is used as a characterisation of the irregularities. The computed and

actual Fourier amplitude spectra of the railhead irregularities are compared.

## **PREDICTION OF RAILWAY TRACK DEFORMATION BASED ON GEOPHYSICAL MEASUREMENTS**

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**Keywords:** geophone, modulus of subgrade reaction, soft soil, Winkler beam

Increasing the axle loads and the velocity of freight trains strongly reduces the lifetime of a track, especially when the track has been built on soft soils like peat or clay. To gain more knowledge on the consequences of changing the operating conditions, we combine geophysical measurements along the track with the results of computed train passages based on a Winkler beam model. Geophones are installed at the foot of the ballast. Measurements during train passages, of noise (leading to H/V spectra), and impulse tests are used to determine the parameters of the Winkler beam model in a physically meaningful and convincing way.

The main frequencies induced by the train velocity, axle spacing, and wagon length cover a spectrum of up to 20 Hz. Parameter studies of train consists revealed relationships between load distribution and velocity of the train on the one hand, and

the main excitation frequencies on the other hand. The main excitation frequency must be detected by the geophone otherwise the measured track movements are underestimated. Geophones are reliable and economical but fail at frequencies below their eigenfrequency. Comparative measurements of geophones (eigenfrequency at 4.5 Hz) and accelerometers showed that the geophone response can be considerably improved by post-processing with the geophone calibration curve. Consequently, the measured geophone response is about equal in quality with the measured accelerometer response. An estimate of the geophone error is provided.

## **TRACK MEASUREMENT TECHNIQUES**

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**Keywords:** Track measurement, data capture, rail surveying system, scanning, GRP3000, GRP5000, High Definition Surveying™ (HDS™).

The gradual improvement of modern rail networks and the emergence of high-speed lines require the most accurate and efficient surveying and monitoring methods available using modern state of the art equipment. This paper covers the track measurement techniques required using such a system, the Leica GRP3000. The Leica GRP3000 is a trolley-based system for the accurate measurement of track geometry and clearances.

## **EVOLUTION OF TRACK DETERIORATION IN HIGH-SPEED RAILWAYS, DEPENDING ON THE MAIN PARAMETERS OF TRAFFIC AND CHARACTERISTICS OF INFRASTRUCTURE**

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**Keywords:** High-speed, track, maintenance, geometry inspection, dynamic inspection

The present situation of high-speed railways involves an increasing level of maintenance work and inspection. In this context, it is essential to understand in detail the process of loss of geometric quality of the ballasted track, represented by some specific parameters (gauge, alignment, levelling and cant), just in order to organize the maintenance work and establish the amount and the requirements for track machines (tamping, profiling and stabilising machines). This report describes relationship between traffic (and its characteristics) and track examination data (dynamic measurements), based on the background at the Madrid – Seville high-speed line. Results deduced from a specific analysis shows a relevant range of values according to changes in infrastructure and superstructure, which are extremely necessary to be taken into consideration in order to plan accurately maintenance. The final aim of this study consists of contributing to define criteria for the design

of new high-speed lines in order to optimize maintenance work.

## **RAILWAY TRACK AND SUB-STRUCTURE STRESS – NUMERICAL PREDICTION VERSUS IN-SITU MEASUREMENTS**

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**Keywords:** Vertical compressive stress, hot mix asphalt underlayment, railway trackbed, Kentrack, in-track measurement, Geokon earth pressure cell, Tekscan sensor

The purpose of this paper is to compare stress levels at various vertical locations in railway trackbeds. Various trackbed structural designs and axle loadings are assessed. The computer model – KENTRACK – is used as the analytical predictive procedure. In-situ pressure (vertical compressive stress) measurements were conducted on both heavy-haul CSX Transportation revenue service trackbeds and on the Association of American Railroads Transportation Technology Center test trackbed.

Pressure measurements were obtained at the rail base/sleeper plate and sleeper plate/sleeper interface using specially designed Tekscan matrix-based force sensitive sensors. Pressure measurements were obtained at the sleeper/ballast, ballast/subballast, and subballast/subgrade interface using Geokon earth pressure cells.

The predictive pressure and in-track measurements compare very favorably. These comparisons are illustrated. The findings further validate the KENTRACK procedure as a means to design and analyze railway trackbeds for a wide variety of loading configurations and trackbed designs.

## **GEOPHYSICAL EXPLORATION IN A SEGMENT OF A RAILWAY LINE BICSKE – SZÁRLIGET (HUNGARY)**

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**Keywords:** Track-substructure investigation, Ground Penetrating Radar, Refraction seismic, Microgravimetry, Railway

Geophysical exploration was performed in a segment between km 560+00 and km 570+00. Optimizing of a curve was a reason for relaying a double-track line here (transition of a railway track body from subgrade to embankment). In 2002, disturbances in stability of supporting poles of a traction system occurred, followed by occurrence of disturbances in the geometry of the left track. During autumn 2003, disturbances in the geometry of the right track appeared.

In the problematic track segment concerned, complex geophysical exploration was proposed to be performed. This exploration was intended to clarify the reasons for the deformations and to optimize subsequent geotechnical tests. Geophysical survey comprised exploration of the layers below the sleepers by the GPR method, complemented by a package of other methods (shallow refraction seismics, microgravimetry and multielectrode measurement), applied on both sides of ballast bed.

Based on the geophysical exploration, the extent and the types of anomalies were specified and the disturbances were divided into two groups. Disturbances in stability of a traction system and below the left track were connected with the anomalies in deeper subgrade. Deformations of the right track were caused by settlement of embankment due to a loss of moisture

content, probably in consequence of extremely high temperatures and only minimal rainfall in summer 2003.

## **ADVANCED ANALYSIS OF GROUND PENETRATING RADAR SIGNALS ON RAILWAY TRACKBED BALLAST**

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**Keywords:** GPR, ballast, deterioration, radar, investigation, trackbed, signal characterisation, FFT analysis

In the last five years (GPR) has become an accepted method of in-situ ballast defect monitoring. Modern GPR systems are portable and do not require a large number of operators, enabling large cost-effective surveys to be undertaken. However the technique has not been exploited to its full potential.

This paper shows that it is possible to identify the condition of railway trackbed ballast by advanced signal processing of the ground penetrating radar signals. The signal from three different antenna on two conditions of ballast was examined and the results shown. The ground penetrating radar signal was analysis using Fast Fourier Transforms. This eliminates the need to use the travel time of the radar signal to assess both the thickness and condition of the railway ballast, but use the FFT analysis to supplement the travel time so both can be

identified. The results shows there is a difference in the frequencies recorded for the ballast depending on the antenna used and the condition of the ballast.

## **GEOPHYSICAL INSPECTION OF THE TRACKBED-SUBGRADE STIFFNESS AND PERFORMANCE**

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**Keywords:** Subgrade, geophysical, stiffness, geology, geotechnical, Leominster

Trackbed stiffness is the primary control on rail performance, the subgrade providing the majority of the stiffness for ballasted-track. Most of the UK's rail track is over superficial geological deposits and weathered materials, which can lead to highly variable subgrade and problems with uneven soil compaction and bad track geometry. Geophysical data and ground models can be used to compile small strain stiffness maps and profiles along rail routes but few data are gathered beneath the working trackbed. Geophysical probes have been installed into highly variable alluvial deposits beneath a ballasted trackbed at Leominster. These measure vibrations from railway traffic on the track and within the subgrade and, subgrade resistivity and shear wave velocity. Vibration, shear wave velocity, resistivity data, and video footage

of sleeper movement above the installation are discussed. Future data gathering is planned as part of a research programme to study the effect of long-term, seasonal subgrade property changes on track performance, the development of geophysical monitoring tools for retrospective stiffening techniques of existing track, and their incorporation into telemetric monitoring systems for use in track maintenance programmes.

### **GEODETECT: THE FIRST 'INTELLIGENT' GEOSYNTHETIC FOR THE MEASUREMENTS OF STRAIN IN SOIL AND THE SURVEY OF REINFORCED EARTH CONSTRUCTION**

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**Keywords:** warning system, reinforced geosynthetic, design, optical fibre, Bragg grating.

The accurate monitoring of civil engineering works is an important ongoing industry requirement, either to evaluate their actual safety level and then to be able to optimise the design, or to survey the behaviour of a structure which may be susceptible to change during time.

For railways, such surveys have been principally required where the risk of failure due to underground cavities has been identified. Geosynthetics are commonly used to reinforce the soil and help reduce the risk of collapse of structures but this reinforcement can mask the movement of

the subsoil. Therefore monitoring is necessary to measure and promote greater understanding of the processes involved.

Until recently, the only instrumentation available was in the form of discrete monitoring points, making the survey of large areas difficult. In this context, a program was launched to develop a system which combines the reinforcement given by a geosynthetic and a monitoring system based on optical technology. This project called 'Geodetect' obtained the label Eureka (S! 2579/F958) in 2001.

The results of two years development, presented in this paper, comprises a reinforcing geosynthetic equipped with optical fibres, offering an accurate measurement system, available for very large areas and which may be adapted to the project specific requirements.

### **RAIL-TRACK INSPECTION USING TIME-OF-FLIGHT DIFFRACTION**

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**Keywords:** Track inspection, Time-of-Flight Diffraction

Recently there has been tragic loss of life in train derailment accidents worldwide. A major cause of train derailments is defects within the rail track, which may lead to breakage of the track under the stress of high-speed trains. Most of these accidents could have been prevented by better track inspection regimes. Ultrasonic Time-of-Flight Diffraction (TOFD) is a recent innovation that has proved highly effective for the inspection of steel plates and tubular pipelines and has started to take its way to replace the other ultrasonic testing techniques. TOFD technique has a lot of

advantages which make it the preferable technique in material testing. This technique gives accurate sizing, positioning and characterising of weld and other defects with a high probability of detection. Based on the experimental study, TOFD can be used for the inspection of rail-track particularly the fishplate and welds areas of the track, which are considered high failure-rate places, with satisfactory levels of accuracy and reliability. There are some restrictions on applying TOFD technique for rail-track inspection. The proposed solution for these restrictions and the procedures for applying TOFD inspection of rail-track are presented and discussed.

### **DESIGN OF A SYSTEM TO MEASURE TRACK MODULUS FROM A MOVING RAILCAR**

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Track modulus is an important parameter in track quality or performance. Modulus is defined as ratio between the rail deflection and the vertical contact pressure between the rail base and track foundation. This paper describes the design of a system for on-board, real-time, non-contact measurement of track modulus.

Measuring track modulus from a moving rail car is non-trivial because there is no stable reference for the measurements. The proposed system is based on measurements of the relative displacement between the track and the wheel/rail contact point. A laser-based vision system is used to measure this relative displacement. A

mathematical model is then used to estimate track modulus.

A mathematical analysis is presented to evaluate the design and sensitivity of the proposed system. A simulation of a moving railcar is used to show the effectiveness of the system. Finally, the results of field tests are presented for a slow (<10 mph) moving railcar over various sections of track including road crossings, rail joints, and bridges.

### **MATHEMATICAL PROGRAMMING MODEL ANALYSES FOR THE OPTIMAL RAILWAY TRACK MAINTENANCE SCHEDULING**

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**Keywords:** Railway track surface irregularity; multiple tie tamper operation; mathematical programming model

Railway track irregularities need to be kept at a satisfactory level by appropriate maintenance activities on the ballasted track. This paper aims at obtaining an optimal maintenance schedule for railway track irregularities by all-integer type linear programming model analyses.

First, we develop an all-integer type linear programming model to obtain an optimal schedule of multiple tie tamper (MTT) operation. The model takes into account both the amount of maintenance work and the level of surface irregularities that reflects riding quality and safety, then gives an optimal 10-day unit tamping schedule of MTT. The schedule indicates the divisions for which tamping must be

executed in a specified term each year. Then we apply this model to solve the optimal MTT maintenance scheduling problem for the actual railway network system in Japan. We also show that it is effective and useful.



# **Theme 1: Railway Track**

## **Day 2:**

### **Slab Track and Ballastless Track**



## **DESIGN OF A HIGH PERFORMANCE SLAB TRACK**

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**Keywords:** Slabtrack, high performance

The paper presents the results of the work carried out within the research project HIPERTRACK, funded by the European Community under the 5th Framework Program. The main objective of the project is the development and laydown of an innovative high performance ballastless track, based on a comprehensive investigation of track/vehicle dynamics, damage mechanisms of critical track components, new rail materials development as well as line techniques to assess track roughness evolution and vibro-acoustic behaviour during cycle lifetime. The main sources of innovation in the project are represented by the development of improved numerical models for train-track interaction and development of new concepts, materials and technologies for track components and their qualification. The optimised track is expected to reduce consistently vibro-acoustic emissions from

the line to train and environment, to improve the total LCC together with the quality of track geometry and to raise the utilisation rate of track infrastructure.

The design process was completed in 2003, and a demonstrator of the new track system, including the rigid foundation track and the mass spring system was manufactured and installed during March 2004 in the 'Adriatica' line near Foggia, in southern Italy. Demonstrator testing trials for performances assessment are scheduled by late May 2004.

## **DESIGN AND CONSTRUCTION OF REPAIRS TO SLAB TRACK IN THE GLASGOW TUNNELS**

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**Keywords:** Slab-track, condition, repair, tunnels

Network Rail Scotland has 73 Operational Tunnels and approximately 16 single track miles of 'concrete slab track' which is mostly in or on the approaches to tunnels and some is in platforms at terminal stations. Slab track, in its various forms, was installed mainly from 1973–1982 in the tunnels in the Glasgow Area. These include High Street, Charing Cross, Finneston, Queen Street High Level Tunnel and the Argyle Line Tunnels. Falkirk High tunnel had slab track installed in 1988 and Haymarket Tunnel in 1990. The slab track in various

terminal platforms at Glasgow Central was installed around 1984. Depots around Scotland have slab track installed for maintenance reasons.

This paper focuses on repairs to slab-track in tunnels.

## **A NEW KIND OF SLAB TRACK: STATIC AND DYNAMIC EXPERIMENTAL TEST**

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**Keywords:** Slab track, mats, flexible, full-scale experiments

In Bari (Italy) an urban-rail-project: 'Metropolitana Bari Centrale Quartiere San Paolo' is being implemented using the Margaritelli slab track system. With this system, loosely fitted pre-cast steel reinforced concrete slabs, isolated by flexible mats, are placed upon a cement-mortar-layer. In order to gain experience regarding the usability behaviour of this permanent way system, continuous threshold tests were carried out in the laboratory.

Tests are described and the results found reported. After completion of the test procedure and casual inspection of the permanent way components, no apparent damage or wear to rail fastening components was determined. The flexible mat did not show any deformation, perforation or other damage. Due to the crack creation, important information about the positioning and dimensioning of the armouring in the slab centre, as well as in the proximity of the attachments was gained.

## **DESIGN AND DEVELOPMENT OF THE BALFOUR BEATTY EMBEDDED SLAB TRACK SYSTEM**

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**Keywords:** Slabtrack, embedded, trials

This Paper describes the designs developed for construction of trial sections of the Balfour Beatty Embedded Slab Track system (BBEST) at both Medina del Campo in Spain and at Crewe in northwest England.

To start, the early development of the BBEST system is outlined and some of the key advantages it brings are described. The principles of the continuous, embedded rail support system are highlighted. The paper goes on to describe the first trial constructed in Spain and associated testing under live traffic.

The paper then describes the achievement of the first UK installation, describing processes required and giving an explanation of the structural design methodology. The paper also outlines the acceptance processes required and describes some of the supporting testing work that has been carried out as an integral part of the trial project.

The paper will conclude with a view of further developments and a summary of the performance of the BBEST system in its first year in service in the UK.

## EMBEDDED SLAB TRACK INSTALLATION IN UK USING CONCRETE SLIPFORMING METHODS

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**Keywords:** Slabtrack, embedded,  
drainage, fullscale

A section of Balfour Beatty Embedded Slab Track has been successfully installed on the Network Rail system at Crewe and has been carrying traffic since September 2003.

The system design incorporated drainage and formation requirements as well as those for a structural concrete slab and the designs satisfied the Network Rail product acceptance process.

The concrete slab slipforming technique was chosen for installation, the necessary equipment manufactured and site preparation works carried out.

Detailed interfaces with the concrete slab reinforcement and the concrete mix design were managed in order to achieve workable designs.

The execution of the paving of the base slab and the track slab were both achieved on a single shift concrete pour.

Full quality control records were compiled for the purpose of installation verification.

The embedded slab track system and the slipform method for installation have been proven as a suitable method for the renewal of mainline track on the Network Rail system.

## THE INSTALLATION OF GETRAC A-3 NON-BALLASTED TRACK IN HEILIGENBERG TUNNEL

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**Keywords:** Railway track, non-ballasted track systems, GETRACA-3 track, asphalt track systems, railway tracks in tunnels, upgrading track through tunnels on classic lines

The paper commences by briefly explaining the various types of non-ballasted track that have evolved over the past 40 years in both Europe and Japan. It then goes on to cover the basic advantages and disadvantages of non-ballasted track.

The difference between monolithic construction and direct support systems are covered, together with the advantages and disadvantages of ‘top down’ versus ‘bottom up’ forms of construction.

The fact that monolithic forms of construction (e.g. Rheda) are relatively slow to construct means that their use tends to be almost always confined to ‘New Build’ situations. The search for simpler forms, that are more suitable for use on the upgrading of classic lines where long possessions are not usually available, has led to the development of asphalt based systems – the most recent development of which is known as GETRAC A-3.

GETRAC A-3 consists of a wide pre-stressed sleeper, which is held in place by a dowel into the asphalt base.

The paper concludes with a Case Study of the installation of GETRAC A-3 in the 1350m long Heiligenberg tunnel on the line between Mannheim and Kaiserslautern. Although the fabric of this 1849 tunnel was in good condition the track quality and overhead electrification arrangement were

unsuitable for the proposed 200km/h. speeds. The works involved a track lowering of up to 185mm together with the installation of new drainage and tunnel safety installations.

German Railways (DB) chose GETRAC A-3 as the most cost effective way of obtaining the required increased clearances and the work was completed in 2002.

# **Theme 1: Railway Track**

**Day 2:**

**Ballasted Trackbed**



## **ACCELERATED TESTING OF GEOSYNTHETICS IN TRACKBED USING EUROPE'S LARGEST FULL SCALE RAIL RIG**

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**Keywords:** Geosynthetics, trackbed, fabric, testing

This paper describes the construction of a full scale trackbed load test facility which simulates the harshest conditions under which a geosynthetic layer is likely to be used. A background to the use of geosynthetics as separators between ballast and formation in the UK is given, together with a discussion of the scope for further development. The initial test schedule is described, which confirms that the loading conditions are representative of those experienced in typical main line traffic, followed by a summary of early tests on geotextiles in common use to assess their resistance to abrasion damage.

## **APPLICATION OF XiTRACK GEOCOMPOSITE TECHNOLOGY TO BLETCHLEY POINTS ON THE WEST COAST MAIN LINE**

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**Keywords:** Composites, points, Westcoast Main Line

This paper describes the successful application of the patented XiTRACK™ GeoComposite technique for the reinforcement and stabilisation of a set of points near Bletchley Station on the West Coast Main Line, UK. XiTRACK is a new design-based method to stabilise track ballast using tailored visco-elastic polymers. The properties and track distribution of these polymers are designed using advanced three-dimensional numerical programs of track behaviour. The paper discusses how the technique was applied at Bletchley points, in terms of both the mathematical modelling and the actual track treatment itself. Prior to XiTRACK treatment the points were being realigned at approximately four monthly intervals due to vertical and lateral point movement. Since treatment the points have required no maintenance after 4 years continuous use on the West Coast Main Line at full line speed and mixed traffic loading. The results of measured track behaviour, using a purpose built high-speed on-site data acquisition system and advanced computer modelling of track behaviour, are also

presented. The paper clearly demonstrates the ability of the technique to solve maintenance problems of this type on mixed high-speed lines and the computational abilities of the simulation software to analyse track behaviour.

## **TRACK DEFECTS IN DESERT AREA AND METHODS FOR DETERMINING CORRECTIVE MEASURES**

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**Keywords:** Special sleeper, track maintenance, desert, sandy lands

Existing of flowing sands and their movements during day and night was one of the main problems of dry areas; and generally residents as well as others involved, any way, in these areas suffered from this phenomenon. During a year, different executive organizations and associations bear a huge sum of expenses to cope with the problem or at least to reduce its losses, among which railway is one of them. It should be acknowledged that railway track compatibility with dry areas is very hard and imposes a dramatic sum of maintenance costs on railway organizations. For this, Railways usually try to design railway lines far from desert. However, in some countries, railway track cross through the desert and the flowing sand problem disturbs running safety of trains. In these areas, flowing sand raid on track causes to fill voids between ballast grains and, therefore, superstructure bed getting rigid. Rigidity of track superstructure cause the sleepers and other components to be damaged and broken, which, in turn, cause damage of components of rolling stocks; Passengers comfort is also disturbed. That

is why some suitable approaches should be applied to suit the track with the conditions considering the geographical and geological circumstances of the desert.

Recommended approaches and solutions including sapling planting, artificial tree planting (artificial forest), digging artificial channels vertical to the wind direction, creating physical barriers vertical to the wind direction or constructing temporary galleries, distributing oil material in a wide area to stabilize sands, designing various water ways in track infrastructure to make possible movement of flowing sands and etc. In this paper the mentioned approaches and solutions, used in different areas of railways, are described and their conclusions are presented.

## **TRACK SUB-BASE MONITORING AND PERFORMANCE**

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**Keywords:** Functional condition, structural condition, stiffness, modulus, foundation, subgrade

A research project is being undertaken under the auspices of Rail Research UK (RRUK), to investigate three important issues in railway track design and maintenance. These are: (1) the robustness of traditional track / sub-base design methods; (2) the use of whole-life costs to guide decisions; (3) the potential for

improving maintenance through an improved understanding of track/sub-base system behaviour.

This paper focuses on the first item and describes five railway track foundation design methods which are reported in the literature. These methods are those that have, or are, being used in the United States (a method proposed by Raymond (1978) and one suggested by Li and Selig (1998a and 1998b)); the United Kingdom (the former British Rail method (Heath et. al., 1972) and the current Network Rail design standard (Network Rail, 2003) and in Continental Europe (the UIC 719R Code (UIC, 1994)).

To facilitate the reader's understanding of the subject, some basic terminology is given together with a short description of the problems which may be encountered if the foundation is not designed adequately. For each method, the basis for design is described and a general discussion of the relative merits of the methodologies is given at the end of the paper.

## **PERFORMANCE EVALUATION BY FIELD MEASUREMENT FOR SPEED-UP OF CONVENTIONAL TRACK IN KOREA**

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**Keywords:** Performance, impact factor, wheel load, freight, passenger

Joong-Ang Line, which is one of the conventional lines in Korea, was constructed over half century ago. A local improvement through the repair of track and modification of alignment has been made

so far. Further, the improvement strategy for speed up needs a performance investigation of the conventional lines.

In this paper, a dynamic impact factor of the conventional track is evaluated based on the dynamic wheel load measured in the field. Total of four locations in the line are selected to measure the wheel loads of the freight and passenger trains. An approximate equation of track impact factor is derived by means of statistical analysis of measured wheel loads and compared with empirical equations from the various countries.

It is found that the proposed equation is equal to the equation of continuous welded rail track in Japan but less than the equation of AREMA. Therefore it can be concluded that the conventional track satisfies the criteria for dynamic load caused by existing trains and the moderate level of safety is secured.

## **NUMERICAL ANALYSIS OF VERTICAL STRESSES TRANSFERRED FROM THE BALLAST TO THE SUBGRADE**

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**Keywords:** Ballast, subgrade, stress, numerical modelling

Ballast and sleeper were simulated by using the discrete element method (DEM). The developed DEM algorithm can create circular elements of various radii and line elements to be changeable length. Three kinds of numerical distributions (i.e. random, normal and logarithmic normal

distributions) are realized to characterize the ballast size distributions in the algorithm. The vertical stresses transferred from the ballast to the subgrade under displacement controlled loading condition were computed for the random ballast size distribution.

## **ABRASION RESISTANT GEOTEXTILE FOR REDUCTION OF BALLAST MAINTENANCE CYCLES**

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**Keywords:** Geotextile, ballast, maintenance, reduction, abrasion

To extend the life duration of a railway in areas where the support structure is damaged or fragile, the use of a thick geotextile between the ballast and the intermediate layer was considered. The functions of this geotextile are to limit the pollution of the ballast by the fine clayey particles of soil, to allow the water flow circulation and the dissipation of the water pressure and to support the total life duration of the refurbishment cycle. Based on North American specifications for similar conditions of use, a geotextile was specially made. To verify the behaviour of this geotextile, an experiment was launched using the 'vibrogir', device simulating the solicitations of railway traffic. It shows that the geotextile keeps its characteristics of permeability, normal to or in the plane and that its duration life estimated at 25 years with the abrasion test, corresponds to the expected application.

## **THE BEHAVIOUR OF CONCRETE SLEEPERS IN BALLAST**

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**Keywords:** Railway structures, switches and crossings, concrete sleepers

The paper is focused on the behaviour of concrete sleepers in ballast. The sleeper vertical movements measurement and vibration acceleration evaluation caused by rolling stock is described in the first part. The typical behaviour of the sleeper – ballast system is demonstrated, including the typical deflection curves of the sleepers. The differences for switch concrete sleepers are presented.

The theoretical analysis of stresses in ballast under sleepers is described in the second part of the paper. The static and dynamic analyses for selected types of sleepers were done by FEM. Principal differences have been found for stress distribution in ballast for wood and concrete sleepers. That is why the behaviour of concrete sleepers in ballast is distinct from wood sleepers. The different adverse effects are observed for these material types, especially in switches.

Some defects or undesirable settlements of concrete sleepers can be explained based on the measurement and numerical solution published by authors.

## **RECENT DEVELOPEMENTS IN MAINTENANCE AND RENEWAL OF RAILWAY LINES ON SOFT SOIL: CASE HISTORY OF A FIELD EXPERIMENT**

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**Keywords:** Soil improvement, field  
experiment, dynamic measurements

During the operation of railway lines the subsoil is exposed to dynamic loading and set into damped oscillation. These traffic vibrations are associated with permanent long term deformations of the ballast and the subsoil and consequently connected with investments for maintenance and renewal of the railway line. One method to improve the dynamic ground reactions is to increase the stiffness of the ground by means of column shaped soil improvement. To get more information about the interaction between the column arrangement and the oscillation velocities in the ground field experiments are a valuable method.



# **Theme 1: Railway Track**

**Day 2:**

**Sleepers / Ties**



## **CONCRETE FRICTION SLEEPER FOR INCREASED LATERAL TRACK RESISTANCE**

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**Keywords:** Railway sleeper, track stability, lateral stability

Principally the main railway lines in Norway have CWR tracks. However, there are a lot of curves with radii less than 300 m. In these curves there are restrictions on the use of CWR, and tracks with fishplated rail joints are frequently used. These joints are expensive to maintain and have several detrimental effects. It would therefore be a great advantage if the lateral resistance of the track through these small-radius curves could be sufficiently increased to allow use of CWR. This topic was selected for a PhD thesis at NTNU (Norwegian University of Science and Technology). During the PhD research the authors invented the new Friction Sleeper to increase the lateral resistance of a ballasted railway track.

The lateral displacement resistance of a standard monobloc concrete sleeper in a ballast bed consists mainly of three components: passive pressure at the end, friction on the sides, and friction at the sleeper bottom. Under gravity load the last one is normally the largest. It consists mainly of the frictional forces of ballast stones sliding on the relative smooth concrete surface. The friction coefficient is measured to around 0.5, while the internal

friction of crushed stone ballast is in the range of 0.9–1.4.

The new concrete Friction Sleeper was designed with cross-wise ridges at the under-side to form a coarse tothing with adequate dimensions to utilise more of the high internal friction potential of the crushed stone ballast. By lateral displacement of the sleeper a more or less completely continuous layer of ballast material will be held fixed to the sleeper under-side by hooking, wedging and granular interlock. This forces the shear surface to be moved down into a deeper shear zone through the ballast material itself, utilizing its larger friction. Results from laboratory tests showed that the Friction Sleeper, in relation to standard Norwegian concrete sleepers, have a lateral resistance almost twice as large under gravity load.

Last summer a number of Friction Sleepers were installed in a curve with a radius of 250 m and commercial traffic to confirm and verify the laboratory test results.

## **APPLICATION OF HIGHER ORDER STATISTICS TO ANALYSIS OF DYNAMIC PARAMETERS OF RAIL FASTENING**

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**Keywords:** Higher Order Statistics, cumulants, bispectrum, railway superstructure

Higher Order Statistics (HOS) is extension of second-order characteristics such as the auto-correlation function and power spectrum. HOS analysis is emerging as a new powerful technique in signal analysis, offering insight into non-linear coupling

between frequencies and potential applications in many areas where traditional linear analysis provides insufficient information. This contribution describes the HOS theory and possibilities application to experimental data acquisition from measurements of rail fastening parameters.

# **Theme 1: Railway Track**

**Day 2:**

**LRT**



## OPPORTUNITIES FOR LIGHT RAIL ON HEAVY RAIL INFRASTRUCTURE

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**Keywords:** Light rail, tramtrain, conversion, accessible

Recent bids for new light rail schemes in the UK have brought their affordability into question. There are a number of reasons for the unexpected costs of these schemes but from past experience conversion of heavy rail to light rail, when appropriate, has shown potentially better value for money. It is appropriate therefore to look again at the benefits that can be realised from the use of heavy rail infrastructure for light rail operations and the technical issues involved. Four basic variations of light rail operations on heavy rail infrastructure are available, full conversion, shared operations using tramtrains, parallel operations and services beyond the conurbations. Parallel operation and services beyond the conurbation are extensions of the principles in the first two options.

The paper discusses the potential transport benefits from these options and the technical issues that need to be addressed in their implementation. The tramtrain options for shared operation are as yet the least exploited in the UK with only the Tyne and Wear Metro sharing track with Network Rail on the Sunderland extension, and this is discussed in most detail.

## VERTICAL DESIGN OF TRAMWAY ALIGNMENTS IN EXISTING STREETS

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**Keywords:** Tramway, highway, vertical design, 3-D modelling, templates

The main problem with tramway vertical design is meeting the track design requirements whilst integrating the design into an existing highway design. Track design requires/prefers long vertical straights with smooth, large radius, vertical curves connecting the straights. Whilst this design requirement is still desirable for highways, it is only applicable in areas with very little restraints to the design and for areas of high speeding traffic, motorways being a good example.

City centre highway design has been built very much to fit into the existing layout with its huge number of restraints such as doorway thresholds, building lines, walls and connecting road junctions. Road traffic is also much more flexible than the fixed line direction a tram has to run on.

Maximum and minimum gradients, horizontal curves, vertical curves and positions vary for trams and highway vehicles. For example, the maximum vertical gradient for a tram to run up or down may be very much shallower than the maximum vertical gradient a car, say, can drive on. Therefore, merging the two designs becomes a balancing act of satisfying the track design, which will drive the connecting parallel highway design, and being flexible enough with other issues, e.g. highway crossfalls, to fit the complete design into the existing layout.

Designers aim to fit the new design into the existing conditions with the limited

amount of site work required and impact on existing features and layout.

# **Theme 1: Railway Track**

## **Day 2:**

### **Vibration and Noise**



# PROGNOSIS OF TRAIN TRAFFIC INDUCED VIBRATIONS BY MEANS OF IN SITU TRAIN SIMULATION

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**Keywords:** Vibration propagation, vibration prognosis, train simulation, reaction mass exciter

Vibrations near railway lines are often a problem in urban areas. Provided that a good estimate of the vibration propagation is available, the vibration prognosis can already be considered during the construction of the track bed instead of subsequent amendments. The experimental determination of the dynamic response of buildings near future railway lines is the only way to make reliable prognoses due to the unclear propagation conditions in the surrounding soil.

In situ ‘train simulations’ can be accomplished by means of a hydraulic reaction mass exciter developed within the frame of our research activities. The passing-by of a train is simulated by an impulse series, which represents the individual axles of the train. The excitation can be arranged according to different axle set-ups of different train types and different speeds. The resulting vibrations of soil and buildings are measured and recorded.

The ratio of the applied force to the real axle load is considered in the data evaluation. Further, the decay curves of the soil vibration are determined. Thus the vibration immission is known for objects at any distance. Then the results are extrapolated from single point excitation to the real situation of a moving chain of axle loads.

Applying the immission standards a specific planning of the railway construction is possible and furthermore expensive vibration-reducing measures can be avoided afterwards.

## VIBRATION-PROOF CAPABILITY OF BALLAST MAT AND UNDER SLEEPER PAD ON THE CONCRETE BRIDGE

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**Keywords:** Ballast mat, under sleeper pad, vibration reduction, frequency band

Generally the ballast mat and the under sleeper pad are used to reduce vibration caused by operation of a train on the slab of a bridge. Effectiveness of the ballast mat and the under sleeper pad is verified by analysis of measured acceleration data for two bridges. The one is the ballast mat established bridge, and the other is the under sleeper pad established bridge. Each bridge is constructed with two sections of the established section and the unestablished section. Test data are measured on the sleeper and the slab in each section of bridges.

Two concrete bridges are adopted to validate efficiency of vibration-proof materials. The two bridges are located on Jeolasun which is the railway lane from Seoul to Sooncheon in Korea. Because they are under service, acceleration data are measured while commercial trains are operating. Vibration reduction property is evaluated according to frequency from the measured data. It is notified that the absorbed vibration effect by the two

materials depends on frequency. The ballast mat and the under sleeper pad give a pretty big effect to reduction of vibration in the specific frequency band, but it is not true for any frequency band.

In this study, it is shown that both of them are effective for vibration reduction, particularly the ballast mat is more effective than the under sleeper pad.

## **VIBRATION REDUCTION EFFECT OF SPRING DAMPER SYSTEM IN URBAN RAILWAY STATION BUILDING**

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**Keywords:** Spring damper system, vibration reduction, urban railway station

An urban railway is one of the most important transportation system in large cities in Korea. Many stations are located within the inner city for the system and an urban railway station even can be the part of a department store or a big shopping center. The vibration of the station building by operation of urban railway can go a long way with people who use such a station building.

A vibration reduction scheme is examined to provide more comfortable serviceability for vibration of the station building by the urban train. The spring damper system is adopted as the reduction scheme for vibration. Efficiency of the damping system is analyzed with comparison of measured experimental test data. Data are measured somewhere in the two station buildings with and without spring damper system, respectively. The

former is 'Bucheon' station and the latter is 'Bupyeong' station on the first urban railway line from Seoul to Incheon in Korea. They don't have exactly same structural system but similar. Acceleration is measured on the baseplate, platform, 1st underground floor and 2nd floor. From data, we can see that vibration is increased on the sleeper but vibration is reduced on the platform.

Recently, concern about environmental pollution is increasing, but the research for reducing vibration is insufficient. In this study, it is validated that the spring damper system could be an efficient reduction scheme for vibration of the slab track in the station building.

## **DEVELOPMENT OF EMPIRICAL EQUATIONS TO ESTIMATE THE TRAIN-INDUCED GROUND VIBRATION**

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**Keywords:** Train-induced ground vibration, vibration level (dB(V)), empirical equation

Recently, the influence due to the ground vibration from the passing train has been an issue and should be considered. In this study, the train-induced ground vibration was measured at various locations in the conventional lines and the database was constructed through the measurement. The characteristics of train-induced ground vibration were categorized and the empirical equations for estimation of ground vibration were developed. The empirical equations were developed in terms of vertical vibration level (dB(V)) related to the distance from the source. The database and empirical equations can be used for the

prediction of train-induced ground vibration and countermeasures against vibration pollution in conventional lines.

## **ASSESSMENT AND REDUCTION OF TRACK RELATED ROLLING NOISE**

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**Keywords:** Railway noise, noise measurement, rail pad stiffness

Rolling noise is one of the major environmental problems of the railway system. At the moment the focus is on the rolling stock. For the first time ever, pass-by noise from interoperable high speed and conventional railway systems is limited Europe wide now by the Technical Specifications for Interoperability. However, rolling noise is not only a rolling stock related issue. Unfortunately both vehicle and track contribute to the pass-by noise and depending on the design parameter noise from vehicle or from the track can be dominant.

The European Union sponsored research project STAIRRS has developed a methodology, which is able to analytically separate track and vehicle contribution from the total pass-by noise measured. These techniques have been applied successfully in Austria to assess new track designs with regards to their noise generation. The future objective of track design is obvious: to build low noise tracks for low noise rolling stock.



# **Theme 1: Railway Track**

**Day 1:**

**Rolling Stock**



## **ROUNDED SECTION CAR-BODY (RSC) WITH ADVANCED TECHNOLOGIES**

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**Keywords:** Car-body, tilting train, rounded section

RSC(Rounded Section Car-Body) tilting train mechanism and its simple design has been introduced in railway engineering 2003 by KRRI(Korea Railroad Research Institute). Height of tilting center of RSC is quite higher than normal tilting train. Based on previous design experience, high height of tilting center of RSC has been considered its design shortcoming.

In this paper, simple tilting principle, basic operational description of RSC and conceptual design of advanced RSC are introduced. Basic design knowledge of advanced RSC system is similar to RSC. But advanced RSC system provides lower height of tilting center than RSC and normal tilting train as well as better operational reliability.

## **HOT BOX ACTUATED THERMO PNEUMATIC AIR BRAKE APPLICATION ON TRAINS (UPADHYAY SENSOR)**

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**Keywords:** Air-brake, trains

The problem of hot axle box due to bearing failure is a well-known problem in all railways. It can lead to not merely derailments but also collision on double line. In India in one such collision, many

people died when GT Express collided with a CRT wagon, which had derailed due to hot axle breakage and had infringed the opposite track in a double line section in Jhansi division. This problem was very acute when rolling stock used plain bearings, which were lubricated by cotton rolls immersed in oil. Advent of roller bearings, particularly cartridge bearings, has reduced the problem substantially.

Due to high speeds and absence of tell tale signs before catastrophic failure of roller bearings, the consequences of are much more severe now than those in plain bearing days. This was amply demonstrated in the G.T. Express derailment and collision case described above.

To prevent such accidents hot box detectors are in use in some railways. The present hot box detectors in use are track based which can not prevent such accidents as they can not stop train and may not be available at all spots where a bearing becomes hot. SKF in Europe has come out with a special bearing for this purpose. It has a sensor, which stops train through electrical/electronic signals in case of not only hot box but also derailment. Americans have developed a system where one of the of the bearing cap screw has a thermal sensor. But these systems are electrical/electronic and applicable in electrical/electronic brake systems. Most of the goods trains, world over, use only pneumatic brakes using Westing House or similar pneumatic brake system in locomotive. These trains can not use these European or American hot box detectors without extensive and costly modification in rolling stock and locomotive control circuits. Ideally a hot box detector should not require any modification in locomotive brake system and should have universal application on all types of rolling stock.

Author has developed a thermo

pneumatic hot box detector which Indian Railway has very kindly named after him (UPADHYAY SENSOR).

## **EVALUATION OF MAXIMUM ALLOWABLE SPEED OF TILTING CAR IN KOREA CONVENTIONAL RAILWAY**

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**Keywords:** Tilting car, alignment, existing track, center of gravity, lateral displacement

High speed tilting car has superior advantages to non-tilting car in curves. Quantitative analysis on such advantages is essential in reasonable estimation of the cost required to improve an alignment of existing track. In this paper, a quantitative analysis on the equivalent amounts of cant due to the introduction of high-speed tilting car are carried out, which is based on the current alignment of existing track in Joong-Ang Line. In addition, the maximum allowable speed and the amounts of speed-up in curves are also evaluated.

It is found that the tilting car gives rise to the additional amounts of cant, which corresponds to 47.5 % of the actual amounts of cant. It can be explained by the fact that the center of gravity of tilting car is 1.34m away from the rail level and is much lower than non-tilting locomotives. It also guarantees a higher level of safety against a risk of overturning in curve section.

The equivalent amount of cant due to the lateral displacement of a center of gravity followed by the tilting operation in curves is approximately 2.4 mm. It cannot be neglected and must be included in calculating a maximum speed in curve. It can be concluded that a speed-up of about

15% in curves is reasonable under the current conditions of alignment, provided that the improvement in a low level is made.

## **DEVELOPMENT OF PASSENGER SAFETY STEPPING BOARD**

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**Keywords:** Safety, passenger stepping board, curve

There are a lot of curved subway stations in Seoul metropolitan area. These must be straightly constructed as many as possible. But some of stations are roundly designed and built in order to avoid pre-existed underground obstacle such as basement of high rise building, underground gas or water pipe line and subway stations from another line.

As shown fig 1, one of the biggest problem occurring curved subway station is considered large gap between platform and vehicle when vehicle completely stop at the station.

The gap potentially is in existence to subway passenger as very dangerous factors in rush hours. If passenger accidentally drop their food or leg between this gap when they get on the train and train leaves station, the passenger will be seriously injured by vehicle.

In this paper, various design and instruments are introduced and best solution for this matter will be presented.

In order to eliminate any possibility of accident happened gap between platform and vehicle, KRRI (Korea Railroad Research Institute) have been developed new safety instrument. These technologies were applied for patent by KRRI. These mechanisms will provide confidence as well

as safety to Korean subway passenger.

## **INFLUENCE OF CREEP FORCES ON THE RATE OF WHEEL FLANGE WEAR IN IRANIAN RAILWAYS, A CASE STUDY**

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**Keywords:** Wheel tread/railhead contact, wheel flange/rail gauge contact, creepages/creep forces, wheel wear

Curving behaviour can affect significantly both wheel and rail wear. The radial forces applied to a test bogie were assessed for the Tehran-Mianeh route, which has many curves. An approximate calculation was carried out to compute the potential sliding distance by using the formula for onset of slip, as reported in a previous paper [1]. The Archard equation was then applied to quantify wheel wear due to the flange contact. However, it was identified that neither the potential sliding contact nor the Archard equation appeared adequate to predict the severe wear encountered during practical trials. The authors of this paper consider creep forces which could compensate the majority effect of the lateral forces and consequently mitigate the flange contact and the corresponding wheel wear.

## **MECHANICAL MATERIAL PROPERTIES AND FRACTURE MICRO-MECHANISM OF PEARLITIC STEEL FOR RAILWAY WHEELS OF GRADE B2N**

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**Keywords:** Wheels, fracture, properties

The B2N grade steel is the main material currently in use in Iran for railway wheels. Severe wear has been observed in the wheels made from this steel even with a service life of less than 20,000km. It is believed that the main parameters involved in the wear of the railway steel are the geometry of the wheel, its loading configuration and the mechanical characteristics of the material. The authors of this paper present recent results from an experimental study on the mechanical properties of the B2N steel and its failure micro-mechanisms. The research findings show that, while this material fulfils the specified target levels of mechanical properties, including hardness, tensile strength and impact toughness, cleavage was the dominant fracture mode in all laboratory specimens tested at low and high strain rates.



# **Theme 2: Railway Structures and Earthworks**

**Day 2:**

**Railway Bridge Investigation**

## **FIELD MEASUREMENTS OF ARCH BRIDGE DEFORMATIONS**

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**Keywords:** Arch, bridge, deformation, field

Field measurement of bridge deformation is becoming easier. Readily available electronics can handle rapid measurement. By designing simple systems for mounting gauges, it becomes possible to measure deflection patterns under live load without complex supports. The results from deflection measurements on three bridges are discussed in the context of the need for information and the value that can be extracted.

## **WAVELET ANALYSIS FOR IDENTIFICATION OF STIFFNESS DEGRADATION**

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**Keywords:** Railway bridges, damage detection, structural health monitoring, stiffness degradation, wavelet technique

A NDT approach for health monitoring (HM) of railway bridge structures and damage detection has been presented here. The proposed approach is based on wavelet analysis time-frequency technique. Frequency domain characteristics have been used earlier by engineers to detect the natural frequencies and mode shapes of vibrating bridges. However, stiffness degradation, if not significant is not shown up in the first few modes initially. Hence, it is difficult to detect the initiation of damage at an early stage and may be observed

conspicuously only later at a catastrophic stage. The time history based techniques, have also been used to qualitatively assess damages in bridges. However, inferences based on time-frequency analysis such as wavelets would provide benefits from both domains. The bridge is modelled by finite element method to study the effect on the eigenfrequencies and the mode shapes due to damage. The characteristics of the dynamic responses of bridges subjected to dynamic loading from moving trains are studied by wavelet analysis. Inferences are drawn from the wavelet coefficients obtained. Dynamic analysis of the bridges subjected to moving loads from train over irregular tracks is carried out. Numerically simulated data from this analysis is used for wavelet-based analysis. A bilinear material behaviour of the bridge with stiffness degradation is considered. Information regarding the stiffness degradation of damage is successfully obtained.

## **THE DYNAMIC RESPONSE OF BRIDGES SUBJECT TO INCREASED FREIGHT TRAIN SPEEDS**

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**Keywords:** Bridges, dynamic response, freight, trains

With the introduction of passenger trains at speeds of up to 125 mph on existing UK lines, it is likely that the speed at which freight trains operate will soon become a critical parameter.

In order to identify the main structural implications that running freight trains at increased speeds could have on the existing bridge stock, Rail Safety and Standards Board (RSSB) commissioned Mott MacDonald (MM) to undertake a generic parametric study.

The initial phase of this study was divided into two stages. For the first stage, a risk based parametric study was undertaken by analysing the overall response of a wide range of bridges under a series of freight trains at speeds over 50 mph. For the second stage, the detailed response of five bridges subjected to actual monitoring on the West Coast Main Line (WCML) was considered, to corroborate the results of the stage 1 parametric study and to extend it to consider floor, torsional, bridge skew and asymmetric loading effects.

## AE EVALUATION OF BRIDGES

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**Keywords:** Bridge, concrete, Acoustic Emission, cracks

During the last decades, the understanding and use of the Acoustic Emission (AE) technique has been developed and progressed, posing the basis for its application to real civil engineering structures. Among the latter, bridges

represent a fundamental category. Attempts to apply the AE method on bridges started in 1972, initially focusing on steel bridges. The successful results obtained on steel structures opened the way to further investigation on the feasibility of the AE technique to concrete bridges. Recently, several examples of AE study on concrete structures have been carried out, but the lack of an uniformed procedure has also been highlighted. In the light of these considerations, a draft of an experimental protocol on the use of the AE method to concrete bridges is herein proposed – each step is singularly described and discussed. The case study of the investigation of a concrete bridge in the Scottish Borders is therefore illustrated, following the suggested procedure. Conclusions are finally achieved about: the feasibility of the AE method, the proposed protocol and the particular case study structure.

## RAILWAY BRIDGE DYNAMICS

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**Keywords:** Railway, bridge dynamics, resonance, fatigue evaluation, noise, model calibration

This paper discusses the dynamic response of railway bridges subjected to vertical loading applied by moving rolling stock. The objectives for analysing the dynamic response of a railway bridge include:

- quantifying the increased peak loading
- assessing the fatigue effects due to repeated cyclic loads

- identifying potential dynamic instability and resonance effects
- analysing noise and vibration generation on the bridge.

## **SAFETY EVALUATION OF RAILWAY BRIDGES IN TURKEY**

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**Keywords:** Safety index, load-carrying capacity, rating factor, railway bridge, dynamic test

Preparing a consistent method as a practical tool for evaluation of the true safety of existing railway bridges has become a very important topic in many countries as part of the bridge management system. Such a method is especially required because bridges built in the 19th and 20th century differ from each other with regard to construction materials, erection techniques and assumptions for load-carrying mechanisms. For evaluation purposes, safety of a bridge is expressed by safety index ( $\beta$ ) and rating factor (RF). Both values should take into account the actual reduced capacity of deteriorated members and the maximum loading expressing the true composition and volume of heavy traffic that should be projected for the future.

In the view of the topics mentioned above, a series of dynamic tests, acceleration measurements, evaluation, finite element model simulations and safety index calculations were performed on selected 24 characteristic railway bridges lying on the main railway network connecting capital city Ankara through Istanbul to western border during January

and February, 2004. These bridges differ by means of construction material (steel, concrete, stone, brick, steel-concrete composite), year of construction, structural type (truss, arch, etc.) and span (from 5 up to 100 meters). Dynamic tests were performed with the help of a test train on these bridges to obtain the structural parameters and these parameters were used to refine the finite element models of the bridges. Once the models have been updated to represent the actual condition, UIC (International Union of Railways) and TCDD (Turkish State Railways Administration) train sets were loaded on the structural models and safety indices were calculated for each proposed loading condition. It is believed that this experimental programme will contribute to efforts for interoperability with the European railway network and provide a reliable background for proposed heavier axle loads resulting from new freight trains by realizing the current condition of bridge structures in Turkey. This paper aims at presenting a brief summary of the procedure followed during this programme for selected typical railway bridges.

## **COST EFFECTIVE BRIDGE-STRIKE MONITORING**

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**Keywords:** Bridges, strike, monitoring

Many rail overbridges have limited headroom for today's road vehicles. There are frequent reports in many countries describing delays to both road and rail traffic, following bridge strikes caused by overheight vehicles attempting to pass beneath low bridges.

The proposed monitoring system at the

trial site has now captured a significant number of strikes by road vehicles and recorded the impact sequence / decks affected, severity of the strikes and digitally recorded the type of vehicle involved. In many of the strikes, the CPB's have served the intended purpose in either fully eliminating or dramatically reducing the impact to the main bridge decks.



# **Theme 2: Railway Structures and Earthworks**

## **Day 2:**

### **Railway Bridge Management and Repair**



## MANAGING SCOUR AND FLOOD RISK TO RAILWAY STRUCTURES

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**Keywords:** Scour, bridges, management

Flood related failures of railway structures in the UK, while relatively few in number, remain a significant risk. While climatic change has recently raised the profile of flood risk, the past incidence of flood related failures shows that pronounced variability has always existed in the location and frequency of such incidents on the rail network.

Flood damage can take several forms, from undermining of structures to wash out or failure due to water pressure. Frequently, more than one of these mechanisms contributes to the failure of a structure. Assessment of structures for flood risk therefore requires a 'holistic' approach which considers a range of possible failure mechanisms and not just undermining from scour.

Improvements in existing management procedures are suggested including consideration of channel changes, debris loading and water pressure loading as well as scour. With these amendments, a comprehensive assessment procedure can be implemented to mitigate the risks to structures from flooding.

## TAIWAN HIGH SPEED RAIL PROJECT – VIADUCT DESIGN

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**Keywords:** High speed rail, seismic design, track-structure interaction

Taiwan High Speed Rail Project is one of the largest transport infrastructure initiatives in the world to date. The US\$16 billion scheme will enable 300,000 people a day to travel at speeds of up to 300km/h along the newly constructed 345km of high-speed line between Taipei and Kaohsiung along the island's western corridor. The major part of this route is on high level viaducts. This paper describes key aspects in the design of high level viaducts for Contract C270, one of twelve civil contracts on this project.

The Specification for the project, in line with the international high-speed rail standards, is stringent, but more onerous for seismic performance due to the frequent seismic activity in this region. The viaducts are required to satisfy three key requirements; strict ride performance under normal operating conditions; safe operation at maximum design speed during a significant seismic event; remain repairable after an extreme earthquake. The design approach adopted to achieve a compliant viaduct structure that is also economic for this fast track design and build contract is described in this paper.

## **BURNTISLAND VIADUCT STRENGTHENING OF A NINE SPAN WROUGHT IRON STRUCTURE**

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**Keywords:** Bridge strengthening, wrought iron structures, value engineering, design and implementation

This paper describes a project to strengthen an existing wrought iron structure, which is currently being implemented by Carillion Rail to a design by Corus Rail Consultancy. Both design and construction issues will be discussed.

Burntisland Viaduct was constructed in 1888 and carries the main line from Edinburgh to Dundee. It comprises nine spans of half-through construction with wrought iron lattice main girders on each elevation supporting trough decking and ballasted track. The span geometry varies throughout. Six spans are simply supported on masonry piers, but the easternmost three are continuous over intermediate cast iron columns.

The viaduct is a category C (S) listed structure and forms a significant feature within the harbour area. Three spans cross public highways and three span footpaths/pedestrian areas.

Corus Rail Consultancy were employed by Carillion Rail during 2002 to work with them to develop proposals for strengthening. Options were considered including complete reconstruction and replacement of entire girders as prefabricated elements. The chosen option

was to strengthen the girders by the addition and replacement of individual structural elements. The temporary/permanent works interface was critical and development of the design through the approval in principle and detailed design phases involved close liaison and value engineering to optimise both elements.

The viaduct is located within a residential area and due consideration was made throughout the design development and works planning to mitigate disruption to traffic and nuisance to neighbours, particularly noise during prolonged periods of possession working. Early consultation was made with the preferred specialist steelwork subcontractor and temporary works designer to develop the methodology to minimise nuisance. In addition the planners, highway authority and environmental health officer were consulted early to ensure the necessary statutory approvals would be obtained.

## **CHANNEL TUNNEL RAIL LINK – CONTRACT 342 INSTALLATION OF BRIDGE 3590**

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**Keywords:** Rail underbridge, bridge slide, heavy lift, Channel Tunnel Rail Link

The construction of the high speed Channel Tunnel Rail Link required the building of a number of rail and road overbridges. As these had to be built with the minimum of disruption to the rail and road users a considerable amount of engineering skill was utilised. Of particular note was the construction of Bridge 3590 in North Kent which carries the existing North Kent Line over the CTRL.

In order to minimise disruption to this busy commuter and freight line the bridge was designed to be constructed off line and then during a three day possession in May 2003 the existing line and underlying chalk were excavated; the complete bridge was lifted and moved into place; the backfill placed; and the connecting tracks laid. The lift weight of the bridge was 9200 tonnes and the length was 110 metres, making it probably the heaviest of this length ever moved.

This paper will cover the unique nature of the topography, the proximity to the live railway, the way the foundations were constructed under the live railway; the development of the tight slide tolerances needed, the controls to ensure that the tolerances were achieved, and the potential problems that had to be overcome.



# **Theme 2: Railway Structures and Earthworks**

## **Day 2:**

### **Stations and Track Furniture**



## **TRACK FURNITURE ON THE CHANNEL TUNNEL RAIL LINK**

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**Keywords:** Track furniture, structures

This paper describes the design development, construction details and site implementation of track furniture on and adjacent to a high-speed line as developed for the new Channel Tunnel Rail Link (CTRL). This includes acoustic barriers, ballast containment walls, OCS masts, under track crossings, rail safety fences, ballast retaining and ballast expansion joints, trackside vehicle restraint barriers, flood protection barriers, pedestrian handrailing, rail bridge parapets and high containment barriers.

Particular reference is made to bridge structures, the support connections required and the effect of structural gauge and clearances.

Procedures have been developed on site to ensure accurate positioning of support structures, which are constructed well in advance of placing the equipment. Significant management challenges have been overcome to resolve the interface issues between separate Civil and Railway contracts.

## **DEVELOPMENTS IN CONCRETE TROUGHING**

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**Keywords:** Concrete, troughing, developments

This paper will trace developments in concrete troughing. Today, semi-dry (as opposed to wet cast) concrete is used for pipes, manholes and troughing. Multiple moulds producing 30 or 40 units per cast and the mould is stripped every 5 minutes. These changes have become imperative for economic production and to meet demand.

## **USING LEGION PEDESTRIAN SIMULATIONS IN PLANNING A COMPLEX INTERCHANGE STATION: CASE STUDY**

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**Keywords:** Pedestrian modelling, simulation, railway station, optimisation, Legion

The use of a sophisticated pedestrian modelling system provides the designer with an invaluable tool for analysing pedestrian behaviour in railway stations, allowing more detailed analysis of potential design solutions than has been possible previously. The dynamic appraisal of the Legion model is far superior to the application of manual station sizing calculations, especially for stations exhibiting complex pedestrian movement patterns. The recent application of the Legion model for the design of a significant railway interchange in Hong Kong resulted

in an optimum design in terms of cost, functionality and safety as it allowed for a range of design schemes to be tested, and for patronage levels and operational scenarios to be varied for comparative testing.

## **OUTLINE AND FUTURE STRATEGY OF 'SUICA'**

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**Keywords:** Fare collection, automatic, Japan

Suica is our contact-less IC card's nickname: Super Urban Intelligent CARd. There are two types of IC Card: One for Suica IO•SF•Card and the other for Suica Commuter Pass, which has a function of stored fare card and commuter pass. There are 8.50million Suica holders •about 4.13million Suica Commuter Pass holders and 4.37million Suica IO Card holders•as of 18, April 2004. **Keywords**•Contact-less IC Card, Suica, Automatic Fare Collection System, Touch and Go

## **MODERNISATION OF EARL'S COURT STATION FOR THE 21ST CENTURY: THE EXAMPLE OF A MAJOR RAIL INTERCHANGE**

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**Keywords:** Station, modernisation

The Earl's Court modernisation project was served by design input from the Asset Management Group.

## **TRING STATION PLATFORM EXTENSION AND REMODELLING**

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**Keywords:** Station, platform, extension

Remodelling of the layout at Tring as part of the Watford-Bletchley Alliance programme on West Coast Main Line, together with the requirement for Silverlink served stations to be able to accommodate 12 car trains, involves extension of the five station platforms.

The platforms are being extended by Cementation Foundations Skanska using the Stepsafe Modular Station Platform System, developed by Mott MacDonald with Laing Rail, and manufactured by RMC Precast Products Ltd.

A combination of single sided and island platforms are required, with the island platforms designed to accommodate significant variations in track alignment between the tracks and to incorporate drainage and extensive services requirements. The structural layout was developed to fit into the existing and future railway infrastructure with a minimum of variation to the standard elements of the modular system.

The foundations are piled into the underlying chalk layer with installation carried out in normal working hours without the need for possessions. Installation of the platform units is being undertaken partly in possession and partly within a series of blockades between April and July 2004.

The works also include realignment and

re-covering of the existing platform edges and renewal of the surfacing together with re-lighting of the entire station, provision of ancillary power supplies, new passenger shelters and signage.



# **Theme 2: Railway Structures and Earthworks**

## **Day 2: Tunnels and Retaining Walls**



## APPLICABILITY OF GEOGRID-REINFORCED SOIL SEGMENTAL RETAINING WALL IN RAILWAY

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**Keywords:** Geogrid, reinforced soil segmental retaining wall (SRW), real scale test

Nowadays, Geosynthetics is widely used as the reinforcement materials in earth structures in order to achieve efficient land utilization as well as securing safety in railway service lines. In this study, the real scale testing with the simulated train loading including impact load was performed in order to evaluate the applicability of geogrid-reinforced soil Segmental Retaining Wall (SRW) in railway embankment. The testing was focused on the dynamic performance of geogrid-reinforced soil SRW. As a result of experiment and analysis, it was found that the effect of simulated train loading on the geogrid-reinforced soil SRW was small in terms of the vertical earth pressure within the overall backfill, the horizontal earth pressure, horizontal deformation at the wall facing and the tensile strain along the geogrid. The data gathered by various measurement devices from this real scale testing can be utilized through the further analysis for evaluation of geogrid-reinforced soil SRW and contribute in understanding the behavior of SRW.

## DEVELOPMENT OF THE TUNNEL LINING INSPECTION CAR

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**Keywords:** Tunnel inspection, a non-destructive inspection, an electromagnetic wave radar

In a measure taken against the concrete drop accident having occurred in the Shinkansen and other tunnels in 1999, visual observation at close range was carried out on a periodic basis and defects inside the lining were checked by hammering test. In this inspection, the inspector moves close to the concrete lining and hits the concrete with a hammer continuously from the side, from an upwardly inclined position or from immediately above. This requires an unnatural bodily posture, and imposes a heavy physical load on the inspector; therefore, inspection efficiency is very low. To solve the problems, we developed a system for a test to detect inside defects, to take the place of hammering test. The principle is based on the use of a multipath linear array radar in conformity to the electromagnetic wave radar technology. The frequencies used are 100 MHz to 3.5 GHz (center frequency of 1.5 GHz) in order to capture even small defects inside the concrete. The maximum inspection depth is about 400 mm, and the crack width inspection performance varies according to the depth and angle. In the less deep portion, a minimum of 1 mm or more can be detected.



# **Theme 2: Railway Structures and Earthworks**

## **Day 2: Railway Earthworks**



# A REVIEW OF DATA CAPTURE AND MANAGEMENT METHODOLOGIES FOR RAIL EARTHWORKS EXAMINATIONS

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**Keywords:** Railway earthworks, management, safety

Rail earthworks are unique in that relatively minor failures can have significant effects. Trains are heavy, cause large dynamic loads, carry many people, cannot be steered and have a long stopping distance. Trains running at speed are reliant on the rails for stability and directional control. Any deformation or removal of support may lead to a requirement for speed restrictions or line closure and will have consequences on performance. Rock falls or soil slips onto the railway have safety implications.

In recent years there has been a radical change in the approach to asset management in general and to the recognition that earthworks are an important asset. Network Rail has considered every aspect of safety on the operation of the rail network and earthworks are recognised as an important link in the chain of rail safety. Management of earthworks are no longer reactive but firmly proactive. The aim is to continuously improve safety and make efficient use of resources.

# ALFRETON RAILWAY CUTTING DERBYSHIRE

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**Keywords:** Cutting, slope, failure, stabilisation

In July 2003, Network Rail Midlands Region instructed Birse Rail through the Structures Framework Contract (SFC) to stabilise a cutting landslide on the Trent East Junction to Clay Cross railway line on the southern approach to Alfreton Tunnel. The condition of the slope was deteriorating and the safety of the railway threatened by a high rate of slope movement. The remit included site investigation (desk study and ground investigation), design and implementation.

An intensive program of slope monitoring identified a deep seated, block type failure within the cutting. The option of installing an embedded bored pile retaining wall was chosen, over other geotechnical applications, to stabilise the slope.

The railway was kept open to traffic with a precautionary Temporary Speed Restriction (TSR) whilst remedial works were carried out.

As well as reviewing the project process, this paper looks in detail at the success of monitoring to determine the extent of the problem and to assess risk. It also demonstrates the benefit of close partnering arrangements between Network Rail and Birse Rail, to achieve a rapid and cost effective solution in a potentially high risk situation.

## **AUTOMATED REMOTE SENSING TECHNIQUES FOR EARTHWORKS ASSET MANAGEMENT**

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**Keywords:** Remote sensing, highways, earthworks asset management, infrastructure earthworks, automated earthworks inventory population, airborne laser scanning (LiDAR), automated detection of earthworks geometry changes, noise assessment data

The Highways Agency (HA) in the United Kingdom is responsible for managing 9,760 km of the motorway and trunk road network in England on behalf of the Department for Transport, (DfT). As part of the development of a 'pro-active' asset management strategy to improve the safety and reliability of the roads network, the HA are developing the use of airborne remote sensing techniques to assist in prioritising their detailed ground based inspections of earthworks.

This paper will describe two particular areas of progress, namely the automated population of earthworks geometry for inventory purposes and the automated identification of 'change' in slope profile as a measure of slope condition.

Patterson (2002) has identified that approximately 50% of the cost associated with earthworks inspections is associated with obtaining the earthwork geometry. Research has identified that 'off the shelf' remote sensed digital 3-D 'terrain' data sets

are available that allow earthworks geometry (location, height and slope angle) to be determined to an adequate initial degree of accuracy in an automated manner. This potentially allows an 'initial' or 'first pass' population of earthwork geometry without ground inspection or bespoke survey. The geometry data is also likely to allow a significant improvement to noise assessment calculations.

In terms of 'change detection' helicopter and fixed wing aircraft borne laser scanning (LiDAR) offers the opportunity to rapidly obtain detailed digital ground profile data for large lengths of the highway asset. This data is sufficiently accurate to allow the digital comparison of surveys and the 'automatic' identification of areas of noteworthy earthworks deterioration. This potentially allows more focussed ground inspections, with benefits in terms of speed and the reduction in exposure of staff to the hazards of working on live highways.

Various operators of other infrastructure networks such as London Underground Limited, Network Rail Great Western Region and the British Waterways Board have been closely involved with the research, recognising that similar techniques will have application in areas such as railways, flood defences, canals, dams etc.

## **EXPANSIVE CLAYS IN TRACK SUBGRADE IN DEEP CUT (SECTION TREBOVICE – RUDOLTICE, CZECH REPUBLIC)**

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**Keywords:** Subgrade, expansive clays,  
renewal

Track section Trebovice – Rudoltice on the border between Bohemia and Moravia and European watershed is one of the most complicated sections in Czech republic. Main difficulties in that area result from expansive clays with high plasticity. Swelling of these clays caused destruction of the Trebovice tunnel built in 1842. This tunnel was restored after great difficulties in 1932.

Modernisation of railway track in that area was solved by re-alignment of existing tracks. Crossing the soils with the worst mechanical properties (highly plastic expansive clays) was designed as cut-and-cover double-track tunnel protected by diaphragm walls with invert.

Contractor that won the tender suggested solution with open cut and proclaimed significant reduction of costs. Geotechnical hazards of this alternative were discussed in paper in Railway Engineering 2003.

Expansive clays occurring at the bottom of this cut (depth of 12 m) represents the most significant geotechnical hazard. We had a short time to analyse behaviour of these expansive clays, to find out any relationships and to define and make trial tests of their treatment.

Expansive clays in that area are represented by marine Miocene highly plastic clays (CV, CE) that are stiff to firm

(unconfined shear strength is 200–300 kPa.). Linear swelling achieves values up to 25% (median is 5%); the maximal value of swelling pressure was 276 kPa (median is 111 kPa).

It is mainly organic matter dispersed within clays that causes swelling of them. The organic matter content is 4–7%, maximally 12%. Influence of mineralogical composition of clays on their swelling behaviour has not been proven.

Due to time shortage only two methods of expansive clays treatment were tested. In both cases we considered mixing of clay in situ with a binding agent and in one case we added also granular aggregates. Comparing linear swelling and swelling pressures of untreated and treated samples we obtained the best result for treatment of clay by lime (5%), cement (7%) and gravel fraction 0–4 mm (10%). In case of treatment only by lime (8%) and cement (7%), linear swelling was higher than in treatment by the first mixture.

CBR values of treated materials increased from 6–8% to 25–30%. Similarly it changed shear strength parameters (effective cohesion increased from 5 kPa to 40 kPa).

Based on our laboratory study the treatment of expansive clays on the bottom of the deep cut and in track subgrade was proposed.

## **STRUCTURAL SOLUTIONS FOR REMEDICATION OF PROBLEMATIC RAILWAY EARTHWORKS**

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**Keywords:** Railway earthworks,  
management, case studies, sheet piles,  
bored piles

For the past five years, Scott Wilson Geotechnics have been assisting Network Rail North West Region and their alliance contractor, Edmund Nuttall, in the management of earthwork assets. This work has included rapid and detailed earthwork inspection (Raybould, 2003), evaluation of earthworks through site investigation and monitoring, detailed design of remedial measures and supervision of construction works (European Foundations, 2002).

The purpose of this paper is to present four case studies of remediated earthworks from initial evaluation through to detailed design and construction supervision. Each case study, summarised below, is chosen to demonstrate a structural solutions at different locations on earthworks:

- Crewe cutting – sheet piles driven at toe of cutting and earthwork regrade.
- Bessie Gill embankment – bored piles at toe of embankment, gabion toe wall and earthwork regrade.
- Carlisle 2 embankment – bored piles at mid height of embankment and minor earthwork regrade
- Gresford embankment – bored piles at embankment shoulder

## **THE DEVELOPMENT OF RAIL-TRANSPORT OPERATION CONTROL USING THE VARIATION OF SLOPE STABILITY UNDER RAINFALL**

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**Keywords:** Rail-transport operation control, rainfall index, rainfall infiltration, stability of railway slope, train speed

Infiltration of rainfall causes railway embankment to be unstable and may result

in failure. Basic relationship between the rainfall and stability of railway embankment is defined to analyze the stability of embankment by rainfall. An experimental study for defining of infiltration rate of rainfall into slope is conducted in the lab. The results of rainfall infiltration test show that the situation of rainfall infiltration into the slope is not equal to the situation of infiltration as like reservoir because the rate of rainfall infiltration is controlled by slope angle.

Based on these results, boundary condition of rainfall is altered and various numerical analysis are performed. The variation of shear strength, the degree of saturation and pore-water pressure for railway slope during rainfall can be predicted and the safety factor of railway slope can be expressed as the function of rainfall amount, namely rainfall index. Therefore, it is judged that this rainfall index can be a good tool for the rail-transport operation control.

## **THE DEVELOPMENT OF REAL-TIME FALLING ROCKS DETECTING AND EARLY WARNING SYSTEM IN KOREA RAILWAY LINES**

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**Keywords:** Falling rocks, real-time monitoring system, early warning system

Recently, the problems with falling rocks are frequently happening in downtown and mountain area during the rainy season. The research for mitigation methods of falling

rocks is actively in progress as the scale of these problems is getting bigger. In this study, it was intended to ensure against risks of railroad facilities in falling rocks prone area, to make sure that trains can run by the early warning to disaster and the quick and accurate warning system, to choose and develop main equipments required for rehabilitation system for disasters, and to develop the hardware/software of the control program. The hardware and software of the essential elements required for the automatic warning system, that is, automatic data logger, economical and stable transmitter-receiver, the systematic construction of the database, and the early warning system was designed and applied to the field. The efficiency and the usefulness of these were evaluated, and ensuring the stability of railroad facilities was intended.

### **CHARACTERISTICS OF THE SOFT GROUND ROADBED OF RAILWAY UNDER DYNAMIC LOADING CONDITION**

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**Keywords:** Mud pumping, soft roadbed, ballast settlement, train load, model test

Ballast and roadbed are the structure damaged gradually by the repeated train loads, thus continuous maintenance work is required. Traditionally, ballast and roadbed are maintained by the empirical approaches; however, systematic researches have been carried out on the track deflection and the development of protective measures to minimize the maintenance cost. The use of roadbed for elapsed time period produces generation of fine grains from wear of

ballast, ballast settlement due to the lack of the bearing capacity of the subgrade, and subgrade softening and mud pumping caused by the thaw and freeze during winter. In this study, influence of water and loads on the softening of subgrade is investigated from model tests adopting various wheel loads and travel passing velocity conditions, and from the test results, occurrence of mud pumping under repeated loading condition, settlement of ballast into subgrade, and vertical earth pressure are examined.

### **REVIEW OF GEOPHYSICAL METHODS TO DETECT CONCEALED MINESHAFTS**

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**Keywords:** Mineshaft, geophysics, void detection, NDT

The presence of the rails and the trackbed affects the performance of standard geophysical methods to delineate abandoned mineshafts. This paper outlines the difficulties that geophysical techniques encounter when measuring at or close to the railroad track – in cutting or on embankment. All geophysical methods experience problems. Some methods are even ineffective and some methods are not able to penetrate the trackbed. Microgravity and ground penetrating radar could work under favourable circumstances. Tomography suffers little from the presence of trackbeds, but is expensive and sites are not always accessible for drilling rigs.

The feasibility of some non-standard methods is reviewed. These methods have potential. Further development and field

experiments are required to assess the full potential. In the short term, a field test will be conducted to verify some of the assumptions that have been made.

## **NUMERICAL EXPERIMENTS TO DEVELOP GUIDELINES FOR SELECTING GEOPHYSICAL METHODS FOR IDENTIFYING ABANDONED MINESHAFTS NEAR RAILWAY TRACKS**

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**Keywords:** Numerical analysis, mineshaft, geophysics, void detection

This paper contains information that can be used as guidelines for selecting a suitable geophysical method to delineate an abandoned mineshaft. The discussion regards solely the technical aspect and does not include costs, safety regulations, possession etc. The selection method is entirely based on whether the anomaly associated with the mineshaft can be detected or not. This depends on the depth, size and filling of the mineshaft. The lining of the shafts has not be taken into account, because of the wide variations in lining material and also because the lining has little influence on the methods reviewed here.

## **MINI PILING IN A RAILWAY ENVIRONMENT**

**A Mercer**

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Why use mini rigs in a railway environment? An introduction to the different types of piles and mini rigs available and their respective benefits, capabilities and limitations. Driven piles which can be installed within the tightest of confines and bored piles to rival those installed by much larger rigs. Includes references to a number of interesting case histories.

