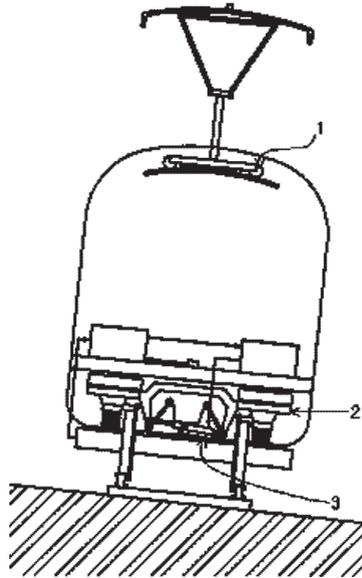


Abstracts of the Eighth International Conference



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

RAILWAY ENGINEERING–2005

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on

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Theme 1: Railway Track

Day 1:

Keynote Papers

STRUCTURAL INTEGRITY IN THE RAILWAY INDUSTRY

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Keywords: Fatigue, railways, failures, axles, wheels, rails, inspection, contact fatigue

A wide ranging overview of fatigue problems in railway applications is presented. Concentration is focussed on fatigue problems specific to the railway industry, that is, those at or adjacent to the wheel/rail interface. Some reasons why, despite its long history, fatigue is still a problem, are suggested.

XINSHISU – TILTING TRAINS ON CHINESE INFRASTRUCTURE

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Keywords: Xinshisu, X2000, tilting train, China, freight railways, alignment optimisation.

The use of tilting train technology to increase permissible speed was discussed in German literature as early as the 1930s. Countries like Japan, Italy and Sweden were the first to bring the innovation into practical application. In the Swedish case, tilting trains were first put into service on the prioritised passenger routes Stockholm – Göteborg and Stockholm – Malmö.

However, tilting trains are also required to operate on mixed traffic routes where

freight traffic is given high priority. In China, freight traffic is given very high priority as it forms an extraordinarily important part of the rail traffic. The Swedish X2000 tilting train technology has been put into service on the Hong Kong - Guangzhou route, and various feasibility studies for introduction of tilting trains on other Chinese routes have been conducted.

The present paper discusses some experiences gained from China, with a particular focus on a gradual upgrading of the infrastructure and the specific advantages of tilting trains on railways with heavy freight traffic.

Theme 1: Railway Track

Day 1:

UK West Coast Route Modernisation

THE DEVELOPMENT OF ASSET KNOWLEDGE MANAGEMENT ON THE WCRM PROGRAMME

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Keywords: Asset knowledge management, configuration management, railway systems engineering

Projects, particularly those where safety is paramount, are responsible for the delivery of a product, system or service, which is usually defined in some form of contractual agreement between clients and suppliers. These products can be physical assets, documents, records, data, processes and systems, standards, etc., a combination of them or all of them, depending on the nature of the project.

In construction and infrastructure projects, such as the West Coast Route Modernisation (WCRM) Programme (Network Rail, U.K.), the main deliverables are physical assets on the West Coast Route (London Euston to Glasgow, U.K.) and also all the necessary asset information that will facilitate the most effective and safe management of those assets.

In meeting the objectives that will enable the successful completion of the WCRM Programme, many teams and professionals take part; one of those teams is the West Coast Asset Knowledge (WCAK) team.

This paper addresses the WCRM Programme and specifically the WCAK team, its role and contributions to the success of the Programme. It highlights the processes and systems it has developed in

line with Network Rail corporate aspirations for the improvement of asset information and management to facilitate best practices in infrastructure operation and maintenance.

CREATION OF THE WEST COAST TOOLSET

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Keywords: West coast, asset store, configuration management, document management, integration

The West Coast programme of works had been on going for a number of years with no coherent approach to join up asset and document information to allow greater control of the information that it was being produced as a result of the changing infrastructure. The programme also recognised the need to introduce configuration control over this information to demonstrate correct project controls to aid the meeting of the required safety cases.

The West Coast toolset was introduced to create one virtual system, which could be made available to all West Coast staff, to hold all documents and asset data. Thus removing silos of information, which were not maintained and provide just one definitive source of information. The information stores then required CM processes and tools applied to them to give the level of data/information integrity required by the programme.

The paper shows the path that the West Coast IT team took to achieve this required level of control and the path the West Coast Toolset went through in order to produce a system that achieved this aim and aided the West Coast programme of work towards successful completion.

MOBILE COMPUTING ON THE WEST COAST PROGRAMME

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Keywords: West coast, mobile computing, technology

One of the key challenges on the West Coast Project has concerned the collection and validation of asset information. The existing practices resulted in asset data staff spending a few days per week on track and then a number of days entering the results into a computer system back in the office. These practices were vulnerable to the introduction of data quality errors and were inefficient and costly.

The Information Management (IM) and Asset Data Management (ADM) teams are part of the West Coast Asset Knowledge Management function and have worked together to develop a hand-held tool to capture more accurate asset data in a more time effective manor. The solution has been developed with the help of the Network Rail Information Management team and based on the company-wide connection backbone developed for this type of mobile technology.

The paper will follow the steps taken by the West Coast Information Technology (WCIT) team to address the difficulties associated with asset data collection through from conception and user requirements to delivering a device and the processes needed to support it. The paper will highlight the challenges faced in meeting the demanding user requirements and in selecting the right technology from the wide variety of hardware and software products that are available and will describe the solution selected.

WEST COAST ROUTE MODERNISATION IMPROVING DELIVERY OF WORK AND POSSESSIONS

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Keywords: Railway access, possession planning and delivery, train delays

The most precious resource which a railway infrastructure operator such as Network Rail has to offer is track access, and the West Coast Route Modernisation Programme (WCRM) programme has made significant progress with regard to both the planning and efficient delivery of that access. This paper summarises the situation at the beginning of the WCRM programme and then describes the managerial actions taken to address the issues and improve the efficiencies for Network Rail. A sample of the results are shown to prove the effectiveness of the actions.

INTEGRATED ACCESS PLANNING TO DELIVER THE WEST COAST ROUTE MODERNISATION

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Keywords: Access planning, integrated planning, planning timescales, possessions, worksites

The West Coast Route Modernisation programme (WCRM) is one of the largest renewal and re-engineering rail projects in

the world, delivering £7.6 billion of improvements to Europe's busiest mixed-traffic railway. Managing and co-ordinating track access to meet the requirements in a multi-contractor environment has proved a major challenge. This paper will describe the management approach to establishing an effective integrated access planning function. It will describe how this transition occurred in two phases, firstly creating a geographically grouped integrated planning function, and later evolving to a centralised planning function, co-ordinating the geographical groups.

WEST COAST ROUTE MODERNISATION (WCRM) HOT AXLE BOX DETECTORS (HABD)

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Keywords: Hot Axle Box, Infrastructure, Single & Double FUES Systems, RAD Display, Signal Boxes, Staging.

Rolling stock, which, for a variety of reasons from time to time finds that axle bearings in the wheel sets overheat. The modernisation and upgrade of the West Coast Mainline Line (WCML) with all the associated infrastructure changes presented an opportunity to renew the existing HABD's with a modern system. A strategic view was taken regarding HABD coverage taking due regards of resignalling, permanent way (Pway) realignment, line speed improvements and the requirements to provide rolling stock with diverse routing. It was concluded that supplementary coverage was required. Existing WCML HABD's are supplied in two types, Servo 7788's and 9909's. Both systems have, during the course of their lifespan, proven to be reliable and consistent in detecting rolling stock hot axle bearings but are now

deemed to be life expired. Network Rail's predecessor, Railtrack investigated the supplier base by issuing a notice in the Official Journal of the European Community (OJEC) inviting expressions of interest from potential suppliers. The GETS FUES is able to detect bearing temperatures in the target area as shown in figure 1 above and is fully compliant with the specification of the Network Rail Group Standard RGS GE/RT 8014. The on-track equipment is positioned in a steel hollow 'tenconi' sleeper bearer, which replaces an existing sleeper and is fixed to the track using fixing arrangements appropriate to the track type. System activation is made by rolling stock triggering the entry wheel sensor, the system then records the temperature of the target area (T.1). The FUES system reports data from site utilising a dedicated 2 or 4 pair communications link. The link transfers data at 33kb per second into a control reporting PC known as a RAD (remote announcement display). An activation alarm is raised at the RAD and on the signal panel should an alarm button for example exist. The alarm itself identifies the rolling stock head code, speed of train, axle number and temperature recorded. The signaller will set his signals to stop the train and initiates the agreed procedure following the activation of an HABD alarm

Theme 1: Railway Track

Day 1:

Assets + Management

LINEAR REFERENCING AND NETWORK RAIL'S CORPORATE NETWORK MODEL INITIATIVE

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Keywords: Corporate network, information

In 2004, Network Rail embarked on a programme of work to design and develop a Corporate Network Model (CNM).

As a key element of Network Rail's Information Management Strategy, CNM will eventually form much of the core of Network Rail's systems and is expected to deliver fundamental improvements to many business processes.

Two of the key objectives of CNM are to deliver:

- The definitive repository for location information of the railway.
- The definitive linear referencing system to provide a reliable, consistent method for transforming real world coordinates into Linear References and vice-versa.

The final section of this paper provides further details of some key features of CNM, and an overview of proposed applications of CNM.

This paper focuses on just *one* aspect of CNM – its ability to support a move to better methods of managing location information, while continuing to support the traditional engineering approach to locations – Linear Referencing.

BENCHMARKING OF MAINTENANCE PROCESS: TWO CASE STUDY FROM BANVERKET, SWEDEN

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Keywords: Benchmarking, maintenance performance indicators, maintenance

Maintenance is an ongoing process for any system with the purpose to maintain its given function during its lifetime. Since maintenance is an integrated part of the business process, correctly performed maintenance creates increased business values. For this, the management must strive for continuous improvement of maintenance process. One powerful tool for this purpose is benchmarking, eg comparing own performance with best in the class or other high performance organizations and learning what they do to achieve their high level of performance. To make a successful comparison, common performance indicators must be identified and used. Performance indicators can broadly be classified as lead or lag indicators, where lead indicators are performance drivers and lag indicators are outcome measures. Today, there is a lot of performance indicators in use connected to maintenance, covering for example the area of safety, asset condition and asset reliability, maintenance performance and cost control.

This paper presents two case studies, the first one deal with benchmarking the maintenance process and where as the second one compares the use of maintenance performance indicators at the Swedish National Rail Administration (Banverket). We discuss some benchmarking results indicating for example how

maintenance strategies, i.e. proactive or reactive, impact the maintenance costs and the ratio of unplanned maintenance. We also emphasize that many of the maintenance performance indicators are used by various organizations abroad and thus provide Banverket an opportunity to benchmark its operation internationally to improve its performance. One of the findings in both case studies is that there are two critical parameters that are missing from the list of indicators, namely traffic volume and infrastructure age. An attempt is also made to analyze the impact of chosen indicators, as well as suggesting future maintenance indicators for future benchmarking.

MOBILE DATA CAPTURE IN THE RAILWAY ENVIRONMENT

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Keywords: Mobile handheld technology, data capture and management, efficiencies

With the wide range of assets within the railway environment, a programme of data gathering for the analysis and management of those assets can involve the handling of a huge bank of information. Traditionally, asset information is recorded on site by manual methods then transferred to the back office for 'download', processing, compilation, reporting and archiving. This involves multiple handling of the data, is labour intensive and is inherently time and cost inefficient. First Engineering has developed customised mobile software solutions, utilising handheld technology, to drive efficiencies and cost-benefit in data acquisition and management in the railway environment.

The mobile solutions utilise handheld

PCs with software that combines customised data capture forms with GPS and GIS applications. The data that is captured is downloaded to a central database, either remotely from site using GPRS or Bluetooth technology or via docking stations from any 'dial-up' location. The asset information then becomes instantly accessible for interrogation and the automatic generation of reports. This mobile solution ensures a quality process to capture all data from site, allows the 'live' transfer of data and facilitates easy access and utilisation of the data by the end-user. To date First Engineering has developed and utilised mobile solutions for a Bridge Strike Management contract, for Track Bed Investigation works and for Facilities Maintenance management. The track bed investigation solution (Mobile Site Investigation Reporting – MSIR) was nominated as a Finalist in the Information Management 2004 Awards, with it finally receiving 'Highly Commended' status.

A FUZZY APPROACH TO RISK ASSESSMENT FOR TRACK MAINTENANCE INCORPORATED WITH AHP

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Keywords: Track maintenance, safety assessment, fuzzy logic, analytical hierarchy process (AHP)

Risk assessment provides useful decision-making support to manage risks for track maintenance. According to the new UK Railways (Safety Case) Regulations 2000 and associated guidance, railway operators

are required to provide a comprehensive safety case to reduce risks to As Low As Reasonably Practicable (ALARP). However conventional risk assessment techniques may not be appropriate to evaluate risks with their high level of uncertainty in track maintenance. Railway safety analysts need to develop and employ novel assessment approaches for their safety case preparations.

This paper presents a new methodology using fuzzy logic and Analytical Hierarchy Process (AHP) for systematic safety risk assessment. Fuzzy logic has shown its strength to conduct risk assessment in industries such as offshore and aviation. The developed safety risk model assesses the component risk level of track system by fuzzy logic based approaches. An AHP is incorporated into the model to use its advantage in determining the relative importance of the risk factors so that the assessment can be progressed from component level to system level. Expert's judgment is also involved to deal with the uncertainty in the risk assessment. An example is used to illustrate the proposed methodology for the track maintenance safety risk assessment.

IMPROVED PUNCTUALITY – A FREIGHT TRAIN STUDY

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Keywords: Punctuality, delay, data bases,
railway infrastructure, maintenance, failure,
freight train

A procedure to systematically find actions to improve punctuality concerning railway infrastructure, and giving the greatest improvement is illustrated. The transports

of a company producing steel slabs in one factory and performing rolling in another are investigated. Reliable transports between plants are crucial to market competitiveness. The transport chain of steel slabs is described and the distance by train is investigated regarding punctuality, transportation times and causes for lack of punctuality. Pros and cons of the procedure employed and ways to improve punctuality are discussed, including infrastructure maintenance.

DEVELOPMENT OF RAILWAY SAFETY AND RISK ANALYSIS SYSTEM USING FUZZY REASONING APPROACHES*

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Keywords: Railway safety risk analysis,
fuzzy reasoning approach

Railway safety is a very complicated subject determined by numerous aspects. The Quantified Risk Assessment (QRA) approaches such as Fault Tree Analysis (FTA) and Even Tree Analysis (ETA) have been used in the railway safety analysis, but often it may not be effective to deal with the uncertainty information as they rely heavily on the supporting statistical information that may not be available. A fuzzy reasoning approach may be more appropriate to analyse the risks with incomplete safety information. It can cope with imprecision, ambiguous, qualitative information as well as quantitative data in a uniform manner. The fuzzy reasoning approach permits the safety analysts to evaluate the risk level associated with the failure modes directly using linguistic terms.

This paper presents the development of railway safety risk assessment system using

fuzzy reasoning approach. The developed safety risk analysis system can process multiple risk factors, for instance, frequency of occurrence and consequence severity of a hazard event. The outcomes of risks can be represented in the terms of linguistic variables with membership function values which provide very useful safety risk information to railway designers and maintainers. The basic principles of fuzzy reasoning approaches are described in the paper. An example is given to demonstrate the application of the developed system in analysing railway safety risk.

"This work forms part of the project on 'an intelligent safety prediction system for rail design and maintenance' funded by Physical Sciences Research Council (EPSRC) under Grant No. GR/S07292

INTRODUCTION OF DISCRETE EVENT SIMULATION AND ITS APPLICATION TO RAILWAY MAINTENANCE SYSTEM

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Keywords: Discrete event simulation, maintenance, technology improvement

A lot of manufacturing knowledge and method has been applied to increase manufacturing efficiency in industry field. DES (Discrete Event Simulation) is one of solution to deal with manufacturing problems in factory.

Beginning of this research to improve railway maintenance technology, maintenance knowledge of KNR (Korea National Railroad) and its technical problems are basically investigated. KNR has been maintained railway vehicle with their own solution based on experience. But very advanced and modern railway vehicles such as KTX (Korea Train Express) and

TTX (Tilting Train Express) will be difficult to maintain with their old maintenance method.

In order to apply knowledge of DES, railway maintenance system must be systematically considered. Imaginary maintenance machine are selected to variable of DES. Maintenance capability of each machine will be evaluated base on imaginary data from imaginary machine. The machines to fix advanced train are consisted of very advanced electrical parts and very expensive to replace.

So target of research is minimization of number of machine in railway workshop. Basic knowledge of discrete event simulation is introduced. Five essential stages of discrete event simulation are provided. Each maintenance case defined as event. Each event is discrete and simulated base on different case such as one maintenance line with one machine and one maintenance line with two machines in railway workshop. Simple maintenance method, discrete event simulation, will be come out very powerful in complicate maintenance system and will be helpful to reduce maintenance cost as well as maintenance labor.

DEVELOPMENT OF A NETWORK LEVEL RAILWAY TRACK CONDITION MODEL

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Keywords: Network level, track condition, maintenance management, maintenance standards

There are a variety of decision making tools which help engineers plan timely and cost

effective maintenance. The majority of these tools address project level maintenance, such as that required for a particular section of track, where the level of benefits tends to be relatively discrete and definable. However, it is at the network level, where the benefits are less tangible, that the consideration of the benefits of investment in maintenance has an important role to play in helping frame policy. A major problem concerns how network level benefits may be presented in a simple and straightforward manner which is meaningful to politicians and senior decision makers alike. This research reported herein investigates the necessary components of a tool which may be used to achieve this.

To this end the research seeks to develop a numerical model which can describe the relationship between maintenance funding levels and subsequent track quality condition at the network level.

This paper describes the work effected to date in producing such a model, and outlines the key components of the model including; the way in which track condition is represented at the network level, the measure of condition and the type of treatments considered in the model, the process of treatment intervention and track degradation.

WEB-GIS INFORMATION SYSTEM FOR TRACK MAINTENANCE ON KOREAN URBAN TRANSIT

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Keywords: Web, GIS, information system, track, maintenance, urban transit, urban railway

For efficient track-maintenance of urban transit, web information system with which

workers can inquire necessary information and record maintenance data on the web is required. Also, for track information of urban transit which has geographic data, computerized system united with geographic information system (GIS) that offers visual information is required. So, web-GIS information system has been developed for past 2 years. This system consists of two big sub-system; web information system for track-maintenance and GIS system for interfacing visual information with attribute information. By web information system, maintenance process, that is, maintenance plan, data inquiry/record, data statistics/analysis, is computerized. In this paper, the web-GIS information system for track maintenance is presented. The objectives of this system are to improve maintenance efficiency and to increase safety by improving reliability through the statistics and analysis of maintenance data. This system is now being operated by SMRT (Seoul Metropolitan Rapid Transit Corporation) of Korea since June 2005. And this system is going to be applied by national standard model on the entire urban transit operating company in Korea since 2006.

PUNCTUALITY MEASUREMENTS EFFECT ON THE MAINTENANCE PROCESS –A STUDY OF TRAIN DELAY STATISTICS FOR THE SWEDISH RAILWAY

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Keywords: Maintenance, railway,
punctuality, statistics, incentive, risk, delay,
train delay

Governmental regulations state that the Swedish national railway administrator Banverket has an overall responsibility for train punctuality, independent of whether train delays are caused by Banverket or the train operating companies. Banverket is responsible for the functioning of the railway system as a whole, but can with own maintenance and reinvestment activities only affect the infrastructure. Conflicts derive from the two stakeholders' different roles and interests. In order to effectively forecast maintenance needs and costs of the infrastructure, Banverket want that the infrastructure's deterioration caused by the rolling stock should be both as small and as predictable as possible. However, the train operating companies look at the same situation from the other point of view, with a focus on their rolling stock. The interrelationship between the two stakeholder roles and their combined maintenance process is complex, since it is difficult to pinpoint the responsibility for the whole transport system and separate assets. One essential approach, in order to monitor low performance linked to responsible stakeholder roles and causes is to follow up the two measures punctuality

and train delays.

This paper explores the characteristics of existing train delay statistics and describes risks when maintenance efforts and design of incentives for improved railway operation is based on statistics that does not reflect the true root-causes of problems.

Theme 1: Railway Track

Day 1:

Rail Wear + Management

ROLLING CONTACT FATIGUE (RCF) – WHAT WE HAVE LEARNT

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Keywords: Rolling contact fatigue (RCF), gauge corner cracking (GCC), whole life rail model (WLRM), WRISA, VT-SIC

Rolling Contact Fatigue (RCF) had attracted the attention of British Rail engineers as far back as the early 1970s. At the time, the phenomenon was considered troublesome but not of great risk. However, an increase in RCF was noted during 1999 causing concern to Railtrack engineers. Research into the causes and means of control of RCF was greatly accelerated after the fall 2000 Hatfield derailment that occurred on the East Coast Main Line.

Early studies did not identify a single cause or ‘smoking gun’ that could have initiated the increase in RCF but suggested that a combination of factors was responsible. The Wheel Rail Interface Systems Authority (WRISA) embarked on further studies that were successful in identifying key factors and suggested control mechanisms. These studies were conducted in parallel with efforts managed by the Railway Safety & Standards Board (RSSB) who concentrated upon exposing underlying mechanisms and subsequent predictive tools. In 2004, WRISA was replaced by the Vehicle Track Systems Interface Committee (VT-SIC) that has continued RCF research and development.

With this knowledge Railtrack began implementing changes in practice and use of new technologies to minimize RCF and

to and reduce remediation costs. The early practice of wide spread RCF rail replacement evolved to a program of periodic ultra-sonic inspections of RCF sites with rail removal mandated only when cracks lengths become excessive or inspection results ambiguous. System-wide rail grinding was introduced to reduce the probability of RCF initiation in the first place and to reduce the growth rate of existing cracks.

As the research projects began to yield results, they were condensed into a ‘RCF Initiation Hypothesis’ that proposed a general initiation mechanism and subsequent list of key variables. The anti-RCF practice of Railtrack – by now Network Rail – and the key factors did not conflict but were shown to be complimentary. The key factors also suggested other avenues of research that included vehicle as well as shared interface attributes such as wheel/rail shape interaction and interface friction.

At present, emphasis is placed upon exploiting the knowledge gained to date in order to develop anti-RCF tools such as the Whole Life Rail Model (WLRM) and generate best practice guides for both the track and vehicle halves of the interface. Research projects are primarily focused on gaining further insight into the crack initiation process and the rate of crack growth, particularly for long cracks.

A TOOL TO PREDICT ROLLING CONTACT FATIGUE

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Keywords: Rolling contact fatigue (RCF), gauge corner cracking, crack initiation, vehicle dynamics

Over the last three years AEA Technology Rail (AEATR), with support from the Rail Safety and Standards Board (RSSB), have developed a fatigue model to predict rolling contact fatigue (RCF). Through participation in a number of industry projects it has been possible to test and validate the model against detailed observations and measurements of RCF at a number of sites.

This paper describes the underlying principles of the material fatigue model, and how vehicle dynamics simulations are used to predict the forces at the wheel/rail interface, which are used as input to the model. Results are presented to show how the model has been used to predict and understand the causes of RCF at a number of sites, together with demonstrations as to how the model can be used to assess the affects of different RCF mitigation measures. Analyses are also presented to show how the model can be applied to long sections of routes to highlight the curves which are most likely to develop RCF and identify locations where improvements to track geometry can reduce the risk of RCF.

RAIL DEFECTS MANAGEMENT IN EAST JAPAN RAILWAY COMPANY

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Keywords: Defects, management, rail

There are usually ten accidents in a year caused by broken rail in East Japan Railway Company (JR East). JR East runs very busy lines in the Tokyo Metropolitan Area, like Yamanote Line and Keihin-Touhoku Line. Thus, an accident caused by broken rail should confuse train schedule significantly. JR East has three Rail Defect Detecting vehicles (RIC-N) to prevent these critical accidents by finding rail defects in advance. According to the current rule, maintenance staffs should identify rail defects that were detected by RIC-N. However, checking rail by hand is time consuming, so JR East improves their policy about rail defects management. There are two major points in this improvement. First, we dare to stop handling small defects in order to focus on the management of larger defects that may cause broken rail sooner or later. Second, we put an emphasis on the Tokyo Metropolitan area to set the specific deadline for replacing rail without fail. These are based on the analysis of 'Prediction Model of Growth Rate of Rail Transverse Crack' and cases of broken rail accidents in the past. The number of broken rail is expected to decrease by half due to this new policy.

EMERGENCE OF GAUGE CORNER FATIGUE IN RAILS: UNDERSTANDING AND EVALUATION OF CAUSES

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Keywords: Gauge corner fatigue, rail, theory

Gauge Corner fatigue has emerged as a major area of concern in recent years.

In India at Sarai Banjara 46 passengers died and 130 were injured due to accident caused by gauge corner fatigue. But rail fractures, earlier in the fish plate joint days, used to be from the bolt hole due to stress concentration and at rail foot due to tensile stress and fretting. The weld joint later became another common area of fatigue due to hammer loading caused by impact at joint and inherently higher stresses in weld area and weakness in rail due to heat affected zone.

But the emergence of gauge corner as a fatigue point even on relatively new rails can not be explained by conventional theory. Also it is happening in several countries and can not be due to any local factor.

UNDERSTANDING TRACK DEGRADATION FOR A SUSTAINABLE INFRASTRUCTURE

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Keywords: Rolling contact fatigue, RCF, wheel-rail interaction

The fundamental cause of rail degradation is of course the passage of traffic.

Understanding and managing the wheel/rail interface is of vital importance if degradation of the rail, both wear and fatigue is to be understood and managed. This requires a holistic approach since the track is a dynamic system. Corus understands this requirement and has therefore been involved with both theoretical and practical studies of track degradation. This paper describes the strategies that Corus has adopted to move towards an understanding of how the wheel / rail interface can be managed more effectively, balancing the requirement to maintain a safe infrastructure against the costs of inspection, maintenance and renewals. The paper discusses the techniques developed by Corus to analyse wheel/rail interface conditions, predict rail defect initiation and growth, and provide guidance on methods for controlling the duty cycle to enhance infrastructure performance.

EMERGING ENGINEERING MODELS FOR WHEEL/RAIL WEAR SIMULATION

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Keywords: Wheel/rail contact, wear simulation, Archard, friction work

During recent years methods for computer aided wear simulation have improved. The evolving simulation methods seek to merge methodologies from vehicle dynamics and tribology. The aim of this contribution is to explore key properties of a few methods and compare their performance. Focus is on

possible differences between the two tribological approaches based on Archard's wear model and friction work respectively.

The vehicle model used is a commuter train from Stockholm Transport. The EMU consist is a Bo' Bo' + 2' 2' vehicle with maximum axle load 10–15 tonnes and the top speed 140 km/h. The multi-body system model is based on the trailer car and includes rigid bodies representing the car shell, bogie frames and wheel-sets.

In the first part of the paper several operating conditions are investigated. Curve radii, friction, and wheel-set guiding stiffness are varied. A few cases are selected for detailed studies. In the second part the contact and wear parameters are studied at the contact patch level. In the third part wear simulations are accounted for. The results are shown as wear depth distribution across the wheel profile.

The cases selected for detailed investigation are of moderate kind with respect to contact conditions covering sliding velocities up to 0.4 m/s and a Hertzian contact pressures below 1.5 GPa.

Similarities and differences between the compared methods are commented upon. Qualitatively better agreement between the more detailed Archard model applied locally to a discretized contact patch and the global application of the friction work model is achieved than when applying the friction based model locally as well.

The local friction model shows a principally different behaviour when following the local distribution of the friction energy throughout the contact area. The consequence seems to be a too strong dependence on the friction energy leading to underestimation of tread wear and overestimation of flange wear.

The condition of partial slip seems to be more difficult to capture in a simulation model than full slip. The agreement between

the different methods is better for the latter case. Partial slip requires assessment of the sliding zone and corresponding sliding velocities, being an advantage for the Archard based approach.

REDUCING RAIL-WHEEL WEAR BY NEW BOGIE DESIGN: THE ENERGY CHOKE APPROACH

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Keywords: bogie design, energy choke approach, rail-wheel wear

There has been considerable research done on the rail and wheel wear in the last three decades. As a result, the rail life has almost doubled and wheel life also increased. However the fact remains that most of the improvement has come through:

- i) Head hardening and pummeling of rails and perfection of track geometry.
- ii) Adoption of worn wheel profile and radial bogies with frequent turning of wheels.

But these improvements are most spectacular in countries like South Africa and Jordan where the percentage of curved track is almost one third/ or more and has many curves of 8 degree or even more.

AN INVESTIGATION TO THE COMBINATION EFFECT OF CONTACT MECHANICS AND OPERATIONAL ASPECT ON THE WHEEL WEAR RATE AND PATTERNS OF RAIL VEHICLES

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Keywords: BDR, rolling direction reversal (RDR), wheel wear rate, wheel wear pattern, failure mechanisms

Railway wheels are subject to high contact pressure and tangential stresses resulting in plastic deformation and wear. A series of activities is commonly employed by the operators to decrease the wear rate, though not addressing the hazardous failure mechanism of rolling contact fatigue (RCF). The present study has been focused on the running-in period, and on a procedure of bogie direction reversal (BDR) to show the importance of two aspects in managing a wheelset, which are contact mechanics and operational issues. The authors present wheel wear results within both the flange and tread regions obtained in experimental work, which are then analysed.

DYNAMIC ANALYSIS OF STRESSES AND EVALUATION OF SERVICE LIFE OF JOINTED RAILS

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Keywords: Jointed rail, stress, fish bolt hole, fatigue, service life

Jointed rails are replaced periodically in Japan. Their service life is governed mainly by the fracture at the joints. To evaluate the fatigue life of jointed rails, it is necessary to clarify the stress distribution around fish bolt holes and an S-N curve of jointed rails. Therefore, we carried out field tests, static loading tests in a laboratory to measure the stresses around the fish bolt holes, and further dynamic stress analysis of jointed rails and bending fatigue tests of rails used in the field.

The dynamic stress analysis model is composed of a beam model to calculate dynamic wheel/rail contact force and a solid model to calculate stress distribution from that contact force. These models were validated using field test data. Based on the study results, we established a method to evaluate the fatigue life of jointed rails. In this method, stresses are calculated for several combined conditions of jointed rail, vehicle type and vehicle speed.

The fatigue life was calculated by applying the stresses to the S-N curve. As a result, the rail replacement period have a potential to be extended except for the case of heavy wear between fishplate and rail.

STATISTICAL ANALYSIS OF RAIL BREAKAGE AND RAIL WELDING FAILURES IN IRANIAN RAILWAYS

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Keywords: Rail, breakage, welding, failures, statistical analysis

Weld and rail failure in railways happen due to some factors including, unsuitable welding, rail fatigue, heavy shocks result from wheel defects and etc. Statistical study can determine causes of arising of the defects (failure), and also ways to prevent or reduce them. It can be also used in planning for track rehabilitation and renewal tasks.

In Iranian Railways, this happens due to very old age of some track and also due to ignoring welding operation manual during welding operation. This paper deals with statistical analysis of rails and welds by considering three years data and their causes and preventive methods have been described.

RAIL VEHICLE WHEEL: PATTERN FORMATIONS GENERATED BY TANGENTIAL FORCES

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Keywords: Rail, wheel, forces, patterns

Railway wheels are subject to normal and tangential forces which are time and location dependent. These forces are functions of the vehicle weight, the suspension and braking systems, track topography and irregularities, and the wheel/rail profiles. As a result, a variety of patterns is generated in the wheel surface. The authors of this paper describe the development of longitudinal and lateral patterns in wheel surfaces and then present some measured patterns created on coach wheels under investigation.

AN EXPERIMENTAL TEST RIG FOR SHORT PITCH CORRUGATION INVESTIGATION

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Keywords: Test rig, short pitch, corrugations, numerical model

The initiation and development of the corrugation is a huge problem for Urban Transportation Authorities, especially in the case of rails in sharp radii curves. This phenomenon appears as a succession of dark and light patterns in the rolling strip on the head of the inner rail: the corrugation profile, in the vertical plane, is similar to a sine waveform with wavelengths in the field 2–20 cm.

The reasons of the beginning of such phenomenon and its relationship with the dynamic properties of the wheelset and of the track, has not yet been completely explained; on the other hand, for different track conditions (straight track and large radius curve), some researchers (Grassie et al., 1993) have found some explanations.

Many researchers were involved in the study of corrugation, both from numerical and experimental points of view. Many numerical models have been presented, in order to explain some kind of corrugation, while, from the experimental point of view, many on line tests were carried out considering different superstructure configurations (ballasted tracks, direct fastening tracks...). Nevertheless it was not possible to succeed in a complete and exhaustive explanation of the corrugation beginning and growth in order to prevent

or limit its formation. On the other side, it is possible to find only a few tests performed on test rigs: only some Japanese researchers performed tests on a test rig leading to successful results (Matsumoto et al., 2003).

The object of this work is the study of the corrugation phenomenon performed on the test rig owned by Lucchini Sidermeccanica, in Lovere, Italy. This test rig is able to perform test on a wheelset rolling on the rail rings, applying suitable dynamic vertical and lateral loads, in order to reproduce the real working condition (Bruni et al., 2003). This test rig was appropriately modified implementing suitable dynamic characteristics (stiffness and damping) of the rail in order to reproduce typical phenomena involved in corrugation.

This test rig is composed by a couple of rolling rail rings, moved by a c.c. engine; on the rail rings a complete wheelset (with disk brake) is mounted: it is possible to set up the attitude of the wheelset (yaw angle and vertical and lateral loads as dynamic variable parameters) in order to reproduce the operative condition of a wheelset negotiating a sharp radius curve.

One of the two rail rings has been suitable designed, and fastened to the rotating wheel: a discrete resilient support has been tuned up in order to reproduce the dynamic frequency response of a real track.

Tests were performed applying severe curving conditions (corresponding to curve radius 135 m and vehicle speed 50 km/h). During this test, the formation of corrugation on the rail profile was observed, with a wavelength in the field 7–8 cm.

The experimental set-up placed on the test rig (accelerometers, laser displacement sensors) allow to follow the growing of the corrugation, by means of its dynamic effects. A numerical model of the coupled system (rail ring + wheelset) has been set

up, by means of a mixed modal superposition approach: this model, which includes both the real frequency variable stiffness of the elastic fastening and the contact forces at the wheel-rail interface, allows to understand the beginning of the corrugation as a phenomenon due to the dynamic characteristics of the coupled systems (wheelset and superstructure). Thus it will give more insights on the reason for the phenomena of corrugation formation.

This work has been performed in the frame of the EU Corrugation Project.

Theme 1: Railway Track

Day 1:

Rail Inspection

ADVANCES IN RAIL INSPECTION TECHNOLOGY

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Keywords: Rail inspection, reliability, ultrasonic, magnetic flux

The rail industry, the public and regulatory authorities all seek to see improvements in the delivery of a safe, reliable rail infrastructure at affordable cost. This paper describes inspection techniques and methods for the combination of data, which have been developed by TWI for the inspection of rail. The technology used in these inspection techniques has benefited from TWI's experience developed with Tube Lines and insight gained in other industrial sectors. This paper describes progress in two inspection technologies:-

1. The application of ultrasonic phased array technology for train mounted wheel probe inspection to provide improved signal to noise and continuous compensation for the effects of rail wear on the performance of the inspection.
2. The application of magnetic flux leakage for high speed inspection of rail heads.

This paper further discusses complementary inspection technologies and how, by careful combination of these inspection technologies, a more powerful and reliable inspection may be achieved when compared with simple analysis of the individual inspection results.

THE USE OF TAMPING MACHINE FOR DIAGNOSTIC OF CONTINUOUS WELDED RAIL TRACK

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Keywords: CWR track, longitudinal forces, lateral displacements, tamping machine, measuring apparatus

In the novel approach to the diagnostic tests of continuous welded rail (CWR) track by the use of the tamping machine, the fundamental statement related to the registration of the curvature with a definite value of the lateral displacement being subjected to verification, can provide a basis for the determination of the longitudinal axial force in the rail. An attempt has also been made to define an alternative factor which by means of the measured signals, could be used for the determination of the axial forces in the rail sections. A power engineering approach has been adopted to this concept.

The finally accepted and developed concept of the measuring apparatus was based on the determination of the distance vector between the rail head and the reference point situated on the frame of the tamping machine. For this purpose six detecting elements were designed and made. To measure the vector modulus special induction sensors sliding along the top surface of the rail head were prepared. In order to measure the angle created by the vector between the rail head and the

reference point located on the tamping machine frame, there were made induction sensors with a cam mechanism close to the axis of rotation of the instrument. Provision was also made for a central unit equipped with electronic systems for processing and filtering the signal. For the measuring data acquisition the authors have elaborated their own computer program in the Visual C++ language.

Within the framework of the experimental investigations, measurements were carried out in the track test section. The investigations were based on stretching the rail sections by stretchers and on lateral displacements of the track by the tamping machine. The operation of the measuring apparatus was also tested in the experimental railway track section while carrying out the geometrical adjustments by the tamping machine. This is of particular significance for the displacement sensors operating in an original way. They are adapted to cooperate with the tamping machine in motion. Owing to them it is possible to register also the operator's work.

In order to adopt the right method for the assessment of the curvature using experimental and numerical techniques, the rigidity of the railway track under the influence of thermal forces has also been considered.

RAIL INSPECTION USING ULTRASONIC SURFACE WAVES

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Keywords: Rail inspection, surface waves, guided waves, RCF, gauge corner defects

Surface cracks induced by rolling contact fatigue are a common problem in modern railways. In order to ensure that rail sections containing critical defects are identified and replaced in time, the rail network has to be inspected with efficient and reliable methods. Conventional ultrasonic wheel probes cannot always meet these criteria if the rail surface contains shallow damage (e.g. spalling or multiple small cracks) and therefore does not allow sufficient penetration of bulk waves into the material. In this case, the integrity of these 'shadow zones' cannot be assessed which might lead to unnecessary expensive rail replacement or critical defects remaining in the track. To overcome these problems the authors are investigating the use of short range guided waves which propagate along the rail surface and allow the inspection of problematic sections of rail from positions with good coupling at the probe/rail interface. Suitable surface wave modes in rails have been identified and their interaction with different defect geometries has been studied. The potential of this method for complementing conventional ultrasonic rail inspection is discussed.

PERFORMANCE OF A REAL TIME L/V FORCE PREDICTION MODEL

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Keywords: Performance measures, track geometry, vehicle dynamics, wheel climb, derailment risk

This paper presents the results of the latest phase of a multiyear test and analysis research program with funding contributions from Canadian Pacific Railway, Transport Canada and Canadian National Railway. An engineering-based L/V predictor model has been developed, which can be run in real time on board the geometry car to predict where the occurrences of undesirable L/V will occur. In instrumented wheel set testing, the predictor performed well in isolating track conditions that will produce high L/Vs, while the existing track standards identified very few sites. The model can predict L/V ratios in real time, for all axles, of multiple vehicles, at multiple speeds, for both directions of travel. The focus of this paper is on a case study evaluation of the model's performance in identifying geometry conditions that later contributed to wheel climb derailments.

SCREENING OF SWITCH BLADES USING GUIDED WAVES

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Keywords: Switch blades, NDT, guided waves

Switchblades are considered as a very high priority for non-destructive evaluation for several reasons. Firstly, the blade is

inherently weaker than the parent rail due to its reduced cross section, reduced mechanical support and high lateral dynamic loading. Secondly, a rail break at a switch is very likely to cause derailment of a train and thirdly, switches are very prone to rolling contact fatigue.

The inspection of switchblades is inevitably more difficult than plain rail inspection due to the continually changing profile and shape of the blade as it tapers from root to tip. Traditional ultrasonic methods such as U3 (walking stick) cannot reliably inspect the tip section where the head width tapers down from 50% to 0% (of nominal head width). Electromagnetic methods have been employed to determine the pocket length of surface emanating cracks on the running surface for the entire length of the switch. Neither method claims to detect defects which are outside the head section of the rail.

The G-Scan rail screening instrument by Guided Ultrasonics (Rail) Ltd uses guided waves which travel tens of metres down the rail and reflect from changes in cross section. Successful trials of the equipment have been carried out on Alumino-thermic welds, plain rail defects and level crossing rails. It would be attractive to employ the instrument for switchblade testing but this is potentially difficult due to the varying section along the blade. This paper describes experiments carried out on a number of switches with cracks and deliberate saw cuts at various locations. The results are very promising and indicate that defects of 5% cross sectional area and above are detectable in the base of the blade.

Theme 1: Railway Track

Day 1:

Rail Maintenance

DEVELOPMENT OF BEST PRACTICE RAIL GRINDING FOR EXTENDING SERVICE LIFE OF RAILS

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Keywords: Rail grinding, rolling contact fatigue, rail welds bending fatigue, service life of rails

Nowadays, rolling contact fatigue failure and rail welds bending fatigue failure are two main causes of rail renewal in Japan. It is well-known that rail grinding extends service life of rails. More specifically, rail grinding prevents rolling contact fatigue, by rail grinding, decreasing the amount of running surface irregularities on weld and / or weld heat-affected zone, reduce bending fatigue. However, it was un-known that the optimal grinding period, • @grinding pass, grinding angle and grinding equipment for extending service life of rails.

We investigated the depth of rolling contact fatigue from surface and the growth rate of running surface irregularities on weld and /or weld heat-affected zone at various track conditions. We also carried out tests for measuring the transformation of running surface irregularities and vertical profile by rail grinding. As a result, we developed the best practice rail grinding for extending service life of rails.

LASER PEENING – THE PROCESS FOR THE FUTURE TO SUPPRESS/ PREVENT FAILURES

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Keywords: Laser peening, fatigue, stress corrosion, crack propagation

In the past two years Metal Improvement Company (MIC) has been Laser Peening in production, components that suffered in service HCF/LCF problems. To date over 10,000 components have been processed and the technique of Laser Peening established as a reliable, production proven process. It offers quality control of the end product, a residual compressive stress, to a level unknown previously.

It is clear that this process offers the transport market, substantial benefits both technically and commercially. However, for the market to further adopt this process substantial testing needs to be conducted on specific materials under specific conditions. MIC has commenced a programme of work on four high strength materials – aluminium, titanium, carburised and through hardened steel - to investigate the influence the additional advantages of this process offers over other surface treatment techniques.

Laser Peening enables the introduction at the surface of metals, residual compressive stresses up to 6mm, with virtually no roughening and little cold work. This has in production already prevented premature failures and extended periods between repair and overhaul.

Laser Peening was invented in the 1970’s, and it uses short bursts of intense laser light to create pressure pulses on the metal surface, which generate shock waves that travel into the metal and compress it. MIC is using a Lawrence Livermore

National Laboratory developed neodymium-doped glass laser that produces one billion watts of peak power, about the output of a large commercial power plant, in 20-billionth of a second bursts. With 125 watts of average power, the laser can fire five pulses per second.

EFFECT OF RAIL GRINDING AND/OR BALLAST TAMPING ON TRACK DETERIORATION CAUSED BY RAIL CORRUGATIONS

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Keywords: Rail grinding, ballast tamping, corrugations, deterioration

Rail grinding has been currently one of most important track maintenance works. There are three categories of rail grinding: preparative, preventive, and curative (or corrective). Preparative grinding is performed to remove decarburized layer, mill scale, and any construction damage to rail materials. Preventive grinding is performed to avoid the risk of rail break through removal of potentially hazardous rail defects. Curative or corrective grinding is performed in order to improve the flatness of longitudinal rail profile or remove rail corrugations and the rail surface irregularity of rail welds to reduce dynamic interacting forces between wheel and rail. On the other hand, short pitch corrugations on low rails in sharp curves whose radius of curvature is less than 600m pose very large problems that are noise and track deterioration caused by large vibration excited with interacting forces between rail and wheel in Japanese narrow gauge tracks. The author established a track settlement prediction model which consists of a vehicle/track dynamic model and a track settlement law proposed in the

draft of ballast track design standard. The adequacy of the prediction model was roughly verified by track site measurements continued for almost six years focused on track settlement. In this study, using the prediction model of track settlement, the effect of curative rail grinding to remove rail corrugations on track deterioration has been evaluated as well as the effect of ballast tamping.

TRACK MAINTENANCE FROM A NOISE PERSPECTIVE IN THE CONTEXT OF EUROPEAN LEGISLATION, STANDARDS AND RESEARCH

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Keywords: Railway noise, environmental impact, rail roughness, corrugations, rail grinding

The interaction between wheel and rail generates the major contributor to the noise produced by a moving train. Therefore the quality of rails and track structure have a direct effect on the level of noise emitted. This noise affects drivers, passengers and people living alongside the railway. At a European level, noise legislation and standards are being introduced, including the Physical Agents Directive (Noise), the Environmental Noise Directive 2002/49/EC and the Technical Specifications for Interoperability. This paper summarises these and discusses their implications in terms of track maintenance. In particular the Environmental Noise Directive has spawned a number of research projects to examine how the required noise mapping may be achieved. A consequence of this Directive is that Action Plans must be

formulated for the control of environmental noise. One potential method of reducing noise is the control of rail head roughness and corrugations, typically through targeted rail head grinding. A number of tools available for the measurement of roughness are described.

INFRASTRUCTURE RENEWALS WITH A HEAVY LIFT RAIL CRANE

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Keywords: Track renewal, Kirow crane, structures, safety, efficiency

Since the privatisation of the National Rail Network in the UK, contractors have been tasked with developing new safer and more efficient ways of renewing the Networks ageing infrastructure. The GrantRail Group of companies have embraced this challenge and developed revised renewal techniques using heavy lift rail mounted track and bridge construction cranes. Since the introduction of the Kirow 810 UK into the UK market place track renewals and associated infrastructure projects have benefited from the advantages offered by controlled, heavy lift rail mounted cranes.

Extensively used as an S&C renewals tool the Kirow crane can be used for a variety of additional engineering activities ranging from OHLE mast installation to bridge construction and renewal. This paper will demonstrate the possible potential efficiencies and increased safety considerations available when using this extremely versatile item of plant.

TOTAL STATION MEASURING SYSTEMS FOR SWITCH AND CROSSING

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Keywords: Total station, switch & crossing measurement

In recent times, the accuracy and automatic logging of measurements on total station surveying equipment have resulted in excellent quality improvements in newly installed track. On the West Coast Main Line in the UK, it is these qualities of this new technology, developed for surveying in the construction industry that has enabled Network Rail to adopt the principle of absolute track geometry control. On plain line the adoption of the new technique has achieved impressive improvements in track geometry, which leads better durability under traffic. The ride quality for the passengers is improved and track forces are reduced as well. These are major technical benefits but with real business gains too.

Theme 1: Railway Track

Day 1:

Track Geometry + Railway Design

DEVELOPMENT AND IMPLEMENTATION OF PERFORMANCE-BASED TRACK GEOMETRY INSPECTION TECHNOLOGY

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Keywords: Track geometry, derailment, real-time inspection, and optimized track maintenance

The Transportation Technology Center, Inc. (TTCI), Pueblo, Colorado, has developed a new 'add-on' technology to conventional track geometry inspection vehicles that is referred to as the performance-based track geometry (PBTG) inspection technology. This new inspection technology relates measured track geometry and vehicle operating speed to vehicle performance on a real-time basis. This inspection technology is intended to help prioritize track geometry maintenance based on vehicle performance. The core of the PBTG technology is a group of neural networks (NNs) developed from actual vehicle track interaction test results, and the effects of other track conditions such as lubrication, rail profile, and track stiffness are indirectly considered based on their statistical distributions from test results. NNs have been trained for several freight vehicle types, including the tank car, covered hopper car, and coal gondola car, which were found to be the most sensitive to track geometry inputs on North American railroads. More NNs for other vehicle types, however, can be easily trained based on a program developed using actual vehicle performance and track geometry test results. Currently, this inspection technology is being implemented by the North American railroads.

NEW PERMANENT WAY STANDARDS FOR THE DOCKLANDS LIGHT RAILWAY

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Keywords: Permanent way, light railway, track standards, track/vehicle interaction, best practice

In 2004, Serco Docklands Ltd commissioned Halcrow to undertake the review and revision of the Docklands Light Railway's standards for Permanent Way Engineering. The revised standard is titled ES-401 Permanent Way Standards and has been approved by Docklands Light Railway (DLR).

The approach chosen by Halcrow was:

1. Review and update the relevance of the standards with respect to the state-of-the-art knowledge in the field of dynamic track/vehicle interaction.
2. Review and adopt the existing best practice, both within the UK and in Europe, which may be applicable to the DLR.
3. Prepare standards that provide Design and Build concessionaires with clear mandatory requirements where applicable as well as guidance and some degree of flexibility where necessary. This involves a close study of the language and clearly distinguishing between the mandatory requirements and recommendations.

This paper provides an overview of the most important revisions made and presents the details of certain fundamental changes in the standards.

CALCULATION OF THE GAUGE WIDENING OF A TRACK WITH THE AID OF MATHEMATICAL MODELS

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Keywords: Track alignment, gauge widening, inscription in curves

In this theoretical paper, the required gauge widening in curves of a railway track, is calculated, with the aid of mathematical models that simulate the transversal behaviour of a railway vehicle. The values of the widening are determined in relation with the alignment curve radius and for different values of the rigidity of the bogies primary suspension.

For a given alignment radius and rigidity of the springs of the primary suspension, a clearance is calculated and by extension, the gauge widening in order, during the inscription of the railway vehicle in curves:

- To avoid simultaneously the slip of the wheels (and by extension of the axles) and the wheel flange –rail contact
- If the above rolling conditions are not possible to be satisfied, and guidance forces are exerted by the wheel on the rail, to keep the forces in an acceptable level.

The whole approach:

- Refers to a track of normal gauge
- Does not take account of the track's transversal rigidity and by extension, of the sleepers type
- Considers that the track is used by vehicles equipped with conventional bogies of which the constructional characteristics are given (bogie wheelbase, wheel diameter and equivalent conicity, etc)

The results are evaluated and the

resulting gauge widening values are compared to the ones suggested by the International Union of Railways (UIC) and by different railway networks.

IDENTIFYING SAFE VELOCITY IN CURVES BY FIELD MEASUREMENTS

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Keywords: Safe, speed, velocity, curves, field measurements

In order to study the track performance, it has been surveyed when an 80 tons locomotive passed over the track in different speeds by means of proper tools. The field study has been made in a 35 meters curve, near Aprin station, and parameters such as deformity of rail profile in three various dimensions, rail displacement and sleeper displacement together with vibrations in different areas of track have been measured. The passing speed of locomotive has been increased from 30 km/h to about 75 km/h. The analysis of the registered data shows 55 km/h the best passing speed that made the lowest deformity and hence imposed the smallest forces to rail in the studied curve. Speeds lower than this may increase the imposed forces on rail, e.g. if the speed is about 40 km/h, there shall be an increased potential for derailment and abrasion of rails.

The present article offers a part of results of the research to determine the speed of trains movement in curves in Iran. Therefore it is attempted that the situation of tests and measurements be as close to Iran's situation as possible. The points to be measured have

been selected in random and within different distances in proportionate to sleepers, installation tools and different parts of curves, so that every possible situation be considered. After recording measured data, they can be analyzed from different aspects and forces, deformities, displacements and other effects can be achieved this way. In order to make these results applicable to all railway curves with any radius, it is necessary to repeat these tests on other tests with different radius in order to choose the optimum and safe speed according to present situation of curves.

OBTAINING TRACK GRADE AND CURVE INFORMATION FROM AERIAL SURVEY DATA

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Keywords: Railroad track, curve, spiral, geometry, alignment, grade, vertical curve, survey

For several years Amtrak has had excellent aerial survey based 3-dimensional data giving track centerline coordinates at approximately 5.0 meter intervals along all of its surface tracks. Software has recently been developed for relatively optimal and automated analysis of the track coordinate data to obtain vertical curves, grade lines, and horizontal curves that provide good fits to the coordinate data. This paper describes the manner in which Track Shape & Use LLC is processing track coordinate data for Amtrak, discusses some of the challenges that have been encountered, and provides examples of the results.

KINEMATICS ON VIRTUAL TRANSITIONS

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Keywords: Virtual transition, lateral jerk, rate of change of cant deficiency, kinematics

It is a good practice to arrange transition curves between track elements with constant curvature of different magnitude. The minimum length for such a transition curve is defined by a criterion for lateral jerk (or rate of change of cant deficiency which is assumed to be proportional to lateral jerk).

However, at certain locations, it may not be practical to insert transition curves. This may be the situation within or at the close proximity to turnouts. At such locations, the permissible speed must be defined by a modified criterion. Among European railways, two different approaches are used:

1. The instantaneous change of cant deficiency is compared with a limit.
2. A fictitious rate of change of cant deficiency is calculated, based on the assumptions of the principle of virtual transitions, and compared with a limit.

This paper investigates the theoretical justification for the two approaches and briefly discusses the relevance of the criteria by means of simulations of dynamic vehicle response.

Theme 1: Railway Track

Day 1:

High Speed Railways – Issues

TARGETED RESEARCH TO REDUCE UK CONSTRAINTS TO HIGH SPEED PASSENGER AND FREIGHT TRAIN ROUTES

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Keywords: High speed, passenger, freight,
constraints

The UK rail network is a mix of passenger and freight routes, including some of Europe's most heavily trafficked, such as the West Coast Main Line. The introduction of new generation passenger trains with novel axle configurations and the aspiration for heavier freight vehicles travelling at increased speeds, places demands upon the existing infrastructure that have not previously been experienced.

Research is necessary to establish the key track, structures and earthwork factors that constrain the operation of high speed passenger and freight services and how these can be addressed in a cost effective manner that retains or enhances current levels of safety.

MOVING MODEL RIG FOR HIGH SPEED TRAIN AERODYNAMICS

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Keywords: Aerodynamics, modelling,
testing, high speed trains, pressures, air
speed, tunnels

The AEA Technology Rail Moving Model Rig is a unique facility for investigating and evaluating aerodynamic effects caused by high speed trains in the open air and in tunnels. Model trains, usually at 1/25th scale, can be fired along the 150 m long test track at full scale speeds up to 305 km/h. There are two parallel tracks which permit simultaneous firings in opposite directions and allow passing train effects to be modelled. The Rig is suited for measurements of passing pressures in the open air, pressure waves in tunnels, as well as slipstream air speeds at the trackside and on platforms.

This paper briefly describes the reasons the Rig was constructed and the technical requirements needed to ensure model scale measurements are representative of full scale; it describes how the Rig works and provides some case studies illustrating work that has been undertaken using the Rig in the past. The relevance of the Rig to new aerodynamic requirements being introduced into railway TSIs is outlined. Finally, future developments planned for the Rig, which enhance its capability in the field of high speed train aerodynamics, are described.

EVALUATION OF TILTING TRAINS RUNNING SPEED IN CONVENTIONAL CURVED TRACK CONSIDERING TRANSITION CURVE LENGTH

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Keywords: Tilting car, alignment, center of gravity, lateral displacement

The purpose of this paper is to present the alignment layout and the way of modifying transition curve for better operation of tilting trains. It is based on data from field investigation of all curves in conventional line. In general, all curves have transition parts in the beginning and end of the main curve in order to improve the passenger's comfort. The speed-up of conventional line may need an extension of transition curves. This paper checked out whether the transition curve should be modified or not and how to lengthen it. Then the maximum train speeds in curve prior to and after the modification of transition curve were evaluated.

TRACK DETERIORATION IN HIGH-SPEED RAILWAYS: INFLUENCE OF STOCHASTIC PARAMETERS

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Keywords: High-speed, track, maintenance, levelling, dynamic control

In AVE Madrid – Seville high-speed line, data of dynamic tests (one test every three weeks for the whole line) allow to study in detail the process of ballasted track deterioration and to find out the related parameters (maximum speed, axle load, traffic). The experience in operation of more than ten years throws significant results, although they are characterized by a high dispersion.

In effect, descriptive formulas of need for track maintenance are not reliable enough, because of influence of stochastic parameters, like quality of process of construction or meteorology. This circumstance affects especially infrastructure, which might have problems of high deformation in some sections.

Definition of resources for track

maintenance in high-speed lines should take into consideration not only the parameters related to traffic, but also characteristics of location, quality of construction, meteorology and efficiency of corrective tasks on track. And, even more, success of that definition will depend on the fact that railway managers counter problems of infrastructure with tamping work on the ballast layer or, contrary to this, with improved drainage, jet grouting or other adequate technical solutions in the infrastructure itself.

CHARACTERISTICS OF TRACK AND TRAIN BEHAVIORS ON BRIDGE/ EMBANKMENT TRANSITION ZONE ON HIGH-SPEED TEST SECTION

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Keywords: Transition zone, bridge, embankment, HSR

It is very important to pay careful attention to construction of bridge/embankment transition zone for high-speed railway. The transition zone of the railway is the section in which roadbed stiffness is suddenly varied. Differences in stiffness have dynamic effects and these increase the forces in the track and the extent of deformation. An abrupt change of stiffness across two adjacent track portions cause irregular settlement of roadbed, track irregularity, lack of girder bending moment and reduction of lateral resistance. Especially on high-speed railway, track irregularity at transition zone cause sincere effect to track stability and train safety. So continuous maintenance is needed. To verify this effect and to improve transition zone capacity, in situ test, track irregularity

and train acceleration test were performed on high-speed railway bridge/embankment transition zone.

HIGH SPEED FREIGHT TRAINS: ASSESSING THEIR DYNAMIC PERFORMANCE

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Keywords: TracTruc, dynamic, bimodal, ADAMS/rail, high speed freight trains

The future of freight on rail seems to be speed, both to satisfy the needs of the JIT (Just in Time) services and to reduce in differences between freight and passenger trains. This paper discusses a programme of the experiments is to understand the system's dynamic behaviour. A realistic dynamic model was created using ADAMS/Rail of the TracTruc bimodal system, and design rules developed for this type of bimodal system to control its stability and dynamic envelope. There is little evidence of other work on high-speed bimodal trains.

The paper discusses the use of simulators, such as ADAMS/Rail, VAMPIRE and SIMPACK to model and optimise dynamic performance. The purpose of the experiments is to understand how to reduce and control dynamic deflections of the suspension (secondary and primary). This will enable decisions which have to be made concerning parameters affecting the performance of suspensions and processes in the TracTruc project. A set of experiments was designed using Taguchi theory. The loss function quantifies the effects of different design factors on the performance of the system.

The paper presents a number of examples of tests on the virtual bimodal system taken from the TracTruc

development project. In particular, the implications of the very large gross/tare ratio of freight trains and of major discontinuities in track construction and geometry are discussed. This simulation was started using four bogies with three near standard fifth wheel trailers which are fixed using the fifth wheel trailer coupler system.

DYNAMIC BEHAVIOR OF KOREAN TILTING TRAIN (TTX) ON CURVED TRACK

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Keywords: Speed-up, tilting train, dynamic behavior, lateral force

Speed-up project for the conventional line is being accomplished in Korea. The tilting train is adapted to the project. Because there are a lot of curved lines in the existing lane in Korea, it is expected that the effective improvement in speed would be achieved by the tilting train. Tilting train suitable for Korean railroad is being developed by KRRI (Korea Railroad Research Institute), although several tilting systems are under the operation in other countries.

The Korean tilting train has active tilting system and self-steering wheel differently from existing trains. Especially the center of mass of the car body is moved according to curvature. These characteristics have an effect on the dynamic response of the track with the change on the speed and the load distribution of the train. As a result the maintenance regime of the track should be updated for the operation of the tilting train.

Since the Korean tilting train is being manufactured now, experimental test data cannot be captured under the real situation. Therefore the dynamic behavior of the

Korean tilting train is estimated numerically with commercial software. The main issue of this paper is to compare changes in lateral force in cases which irregularity is not exist on the track and the real irregularity is injected to the curved track.

KEY TECHNOLOGIES OF SPEED RAISING ON CHINESE EXISTING RAILWAY

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Keywords: Chinese railways, speed-raising project, technology

A series of technological results have been achieved for the speed-raising technology of the Chinese railways, thus ensuring the operation safety of speed-raising trains, accelerating the overall upgrading of railway industry and promoting the leaping development of the entire railway sector. The article elaborates the technical difficulties in speed-raising on Chinese railways, introduces the results in tackling key technical issues from 6 aspects and makes comparison of the main technical features for the domestic speed-raising equipment in China with the similar overseas technical results.

Theme 1: Railway Track

Day 1:

Signalling + ATWS

SIGNALLING SCHEME PROOF OF PERFORMANCE

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Keywords: performance proving, CBI, signalling systems, FRACAS, TRUST, FRAME

Recent years have shown that introduction of European CBIs for mainline UK use is not simple; equally, to demonstrate that an installed CBI yields an improved performance given changes in operation, maintenance methods, and fault reporting methods, has proved to be an intellectual challenge.

Siemens have relatively recently delivered a CBI into the UK on Dorset coast; the supply contract for the interlocking anticipated that performance proving would take at least a year and it was planned that this would consist of two phases, a performance improvement phase followed by a performance proving phase. Special provision was made for the monitoring of the system and for the execution of any necessary remedial activity over this period.

Siemens successfully commissioned their CBI on 15th December 2003; since that date the performance of the system has been closely monitored to determine whether it meets its predefined acceptance criteria. The new CBI introduced operational changes to the signalling area while the FRACAS set up for performance monitoring brought changes to the way in which faults were recorded and reported. The data against which the performance of the system was to be judged, out of necessity, was collated and collected years in advance of its eventual use for

performance proving.

This paper identifies the difficulties of using past information to judge the performance of future systems, considers the difficulties and pitfalls associated with this process, and, using a practical example, shows how these difficulties may be overcome.

Since the original paper abstract was written the performance of the system has been demonstrated; this occurred on the 25th January 2005, a little over a year after the original commissioning, the minimum time for demonstration of the system. Both Network Rail and Siemens are delighted with the scheme as it continues to outperform expectations.

BENEFICIAL APPLICATION OF COMPUTER BASED INTERLOCKINGS

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Keywords: Computer based interlocking, CBI, SSI, application, UK standards

In the late nineties, Railtrack, who are now Network Rail, decided to introduce interlocking technology from continental Europe, which was referred to as Computer Based Interlocking (CBI) to differentiate them from established SSI technology. One major intention when introducing CBIs was the aim to learn from their new ideas both in architecture and functionality. CBIs are different from SSI Applying them to the UK was to gain the most possible benefits from those differences, certainly without

compromising the basic UK signalling principles.

The paper outlines the main differences between SSI and a typical CBI, as recently introduced in the UK. It follows a description of the potential benefits, which a CBI can yield for a railway operator, if appropriately applied.

Examples of such appropriate application are given. Some CBIs have a reputation of being particularly suitable for large and complex schemes, thus the first example describes a CBI application to a complex terminus station. The second example looks at a less complex stretch of UK railway and shows that CBIs are a viable alternative to SSI on such schemes, too.

Most of the existing UK standards were originally based on the well known RRI and SSI technologies and therefore prescribed solutions that were optimised for these technologies. The paper gives examples on how standards have evolved or challenging the standards can enable CBI application in the most efficient manner.

TRACK WORKER SAFETY WITH MODERN TRACK WARNING SYSTEMS: AN URGENT NEED TO MAINTAIN TODAY'S RAILWAY SYSTEMS

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Keywords: Track safety, lookout operated warning systems, automatic track warning systems, signalling controlled warning systems

More than 50'000 workplaces are open along the European Railway network each year with duration of more than one week. About 52'000 employees and more than

750 Mio € are required to safeguard these workplaces. In addition to this many train free periods, night work or train speed reductions have to be given for track work, which increases the cost for construction and train operators. All this also causes a significantly high reduction of the network availability.

Experiences shows that with the consequent use of cable and radio based Track Warning Systems (TWS), the network availability increases significantly and there are almost no disruptions anymore. The warning for track workers are issued more than 1000 times safer as by human beings, the amount of work done increases significantly, train free periods are reduced and the punctuality of trains influenced by work places goes up.

Prerequisite to obtain all this advantages is a change of track work protection process from low technology and many people based methods to a few centralized professional specialists and high technology track warning systems. Top railway management is asked to change the process with the result to reduce track safety cost of about 5'000 € per kilometre railway line and year down to 2'500 € per kilometre and year, with all the other positive effects of TWS not even included!

Theme 1: Railway Track

Day 1:

Electrification + Lighting

IMPROVED DESIGN OF AN OVERHEAD RAIL CURRENT CONDUCTOR FOR APPLICATION IN UNDERGROUND LINES

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Keywords: Catenary and electrification systems, overhead conductor rail systems, optimisation, new design

Overhead rail current collector systems for railway traction offer certain features, such as low installation height and reduced maintenance, which make them predominantly suitable for use in underground train infrastructures. Due to the increased demands of modern catenary systems and higher running speeds of new vehicles, a more capable design of the conductor rail is needed.

A new overhead conductor rail has been developed and its design has been patented [13]. Modern simulation and modelling techniques were used in the development approach. The new conductor rail profile has a dynamic behaviour superior to that of the system currently in use. Its innovative design permits either an increase of catenary support spacing or a higher vehicle running speed. Both options ensure savings in installation or operating costs.

The simulation model used to optimise the existing conductor rail profile included both a finite element model of the catenary and a three-dimensional multi-body system model of the pantograph. The contact force

that appears between pantograph and catenary was obtained in simulation. A sensitivity analysis of the key parameters that influence in catenary dynamics was carried out, finally leading to the improved design.

INFLUENCE OF THE AVERAGE STRESS ON FATIGUE PROPERTIES OF CONTACT WIRE

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Keywords: Contact wire, fatigue life, average stress

The bending stress of the contact wire is caused by the pantograph upward force and the repeated occurrence of that stress will cause fatigue fracture. To evaluate the fatigue life of contact wire, railway researchers in Japan use an S-N curve that is established for the average stress of 88.2MPa. On the other hand, contact wires are gradually worn by running contact strips. This decreases their sectional area and in turn increases the average stress that largely governs the fatigue life. To evaluate the fatigue life of worn contact wires correctly, therefore, it is not appropriate to depend on the aforementioned S-N curve alone. In this study, another S-N curve has been obtained for the conditions; sectional area 95mm², tension 14.7kN and average stress 154.2MPa. Application of Smith's technique integrates these two curves into one that is applicable to the evaluation of the fatigue life of different worn contact wires.

DESIGN OF TRACTION EARTHING AND BONDING IN THE ST PANCRAS AREA

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Keywords: CTRL, traction, DC, earthing, bonding

The Channel Tunnel Rail Link is being built by Rail Link Engineering for Client Union Railways. It will be Britain's first major new railway for over a century - a high-speed line running for 109km (68 miles) between St Pancras station in London and the Channel Tunnel.

A key issue is the design of traction earthing and bonding in the St Pancras area. This paper examines the complex issues related to stray DC and touch and accessible voltages and the processes required to achieve an acceptable design solution to compliance with the relevant national, international and corporate standards.

A NEW APPROACH TO OHL

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Keywords: Electrification, over head line (OHL), traction masts, bracket arms, parafilm strops, ground anchors, railways, tramways

This paper describes the philosophy and procedures for installing a new OHL railway electrification system. This system is based on a large diameter OHL, installed without catenary from a simple bracket arm assembly. After quotations from established

OHL installers, the work, for a pioneering demonstration line at Carnforth, was undertaken by TRAM Power Ltd. The aim of this approach is to speed installations and reduce the need for track possessions, reduce first and maintenance costs, and to open up the operational flexibility that electrification offers to many secondary lines, where improved services could make the difference for long term survival. This new system also promises to reduce the cost of new tramways and light railways.

MEASUREMENT OF A DAMPING RATIO USING WAVELETS

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Keywords: Morlet, wavelets, damping, contact wire

We proposed a damping extraction method for a contact wire using a continuous wavelet transform (CWT). We used two kinds of complex Morlet wavelets as a wavelet function. In order to show that the proposed method is valid, we extracted damping ratios from the free response of the simulated system which have close natural modes in a low frequency range similar to the contact wire. According to the results, the error is less than 8% at the first natural frequency (1Hz). The errors become larger at higher natural modes. However, the estimated damping ratios at higher modes are still agreed with the true values within 20% errors. More errors at higher natural modes are mainly due to a poor

frequency resolution of the wavelet function used. For a reliable extraction of the damping ratios, we presented how to adjust a frequency resolution of the complex Morlet wavelet and how to remove noises in the free response in this paper. Because the CWT can decouple close natural modes of the contact wire, we can conclude that damping ratios can be extracted from the free response of the contact wire using the proposed method.

ANALYSIS OF FLUORESCENT LAMPS, ELECTRONIC BALLASTS AND FACTORS AFFECTING LAMP LIFE

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Keywords: Fluorescent lamps, electronic ballasts, lamp life

Fluorescent lamps are extensively used for illumination of passenger vehicle interiors. Although other light source technologies such as dichroic and LED have their applications within the vehicle interior, the fluorescent lamp remains the principle method of illumination and main provider of utility lighting.

In the vast majority of modern and refurbished rolling stock, fluorescent lamps are driven by electronic ballasts rather than traditional electromagnetic means. Indeed, the use of DC control supplies precludes the use of electromagnetic ballasts.

Electronic ballasts have many advantages over their electromagnetic predecessors such as higher efficiency, reduced operating temperatures, increased lamp life, reduced weight, improved passenger environment and the ability to employ intelligent shut down facilities for life expired lamps.

Electronic ballasts are extensively available for commercial and industrial use, however, products for use within the railway industry and compliant with the arduous railway standards are only available from a limited number of specialist suppliers. LPA-Excil Electronics Ltd is such a supplier, designing and manufacturing an extensive product range.

A key design factor with any electronic ballast is ensuring that the lamp operating parameters are precisely satisfied. Failure to satisfy the correct parameters for pre-heating, ignition and arc discharge will result in significantly reduced lamp life.

In contrast, an optimally designed product will maximise and extend lamp life often by significant factors. This is highly advantageous from a lighting system maintenance and vehicle operating cost view-point as life cycle costs and service affecting failures are significantly reduced.

This paper examines the factors affecting fluorescent lamp life and how these factors are addressed and satisfied in a modern electronic ballast design.

A DEVELOPMENT OF PANTOGRAPH TEST FACILITY

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Keywords: Pantograph, Test Facility

This study presents a development of pantograph test facility which is the tester to verify performance, endurance of suspension and dynamic characteristics of pantograph. The test facility consists of performance, endurance and dynamic pantograph testers. With these testers, all kinds of pantograph, such as cross arm type or single arm type, can be evaluated. Using

the performance tester, measurement of nominal static force, checking of the operating system, transverse rigidity test, air tightness test, functional check of ADD (Automatic dropping device) and etc. can be examined. With the dynamic tester, the dynamic behavior of pantograph according to the exciting frequency can be tested. Endurance behavior for pan-head spring and continuous upward and downward movements can be evaluated using the endurance tester.

FINDING THE RIGHT BALANCE BETWEEN RELIABILITY AND ECONOMICS FOR BATTERIES USED IN CRITICAL RAIL TRACKSIDE APPLICATIONS

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Keywords: Batteries, trackside, economics, reliability

In looking at a critical system it is necessary to look at the cost of failure of the system. This is likely to be far greater than the cost of the emergency back-up system and so it could be argued that the cost of the emergency back up system is not important.

However, this is very rarely the case and an analysis has to be made of the risks and the costs to choose the right system. So, the design becomes a balance between reliability and economics.

Reliable systems should be 'fault-free' systems but they may still fail because of specification or operational errors and the concept of a 'fail-safe' system assumes an important role. The costs of producing reliable systems grow exponentially as reliability requirements are increased.

The economics of the system should be calculated by life cycle costing. This is a

technique to establish a spend profile of a product over its life span. It does not calculate the cost of an unexpected failure and the consequential cost.

The basic characteristics of a battery can be split into those which are related to their reliability e.g. predictable failure mode and tolerance to overcharge and over-discharge, and those important to the economics e.g. lifetime under application conditions and installed costs.

The different battery criteria are discussed in terms of their importance to reliability and economics. These factors are then used to examine how an acceptable balance can be made to achieve an economically acceptable level of reliability in a critical system.

A STUDY ON QUALITY IMPROVEMENT OF TYPE-T RIGID CONDUCTOR LINE

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Keywords: Rigid conductor line, current collection, undulating wear

Overhead contact lines as provided for power supply through pantographs to trains are required to have a simple structure and maintenance-free characteristic where installed at limited spaces at locations such as underground or tunnels. Therefore, rigid conductor lines are often provided at such locations. In the case of type-T copper rigid conductor line of JR West Tozai Line, undulating wears with an interval of about 60 mm were found on the sliding surface of the contact wire. Such wears will be a cause to prevent speedup while increases maintenance cost for contact wires. This paper describes an investigation of the

cause, and proposes a countermeasure to improve the quality of type-T rigid conductor line.

LIFE CYCLE COSTS AND OPERATIONS MEET OVER HEAD LINE ENGINEERING

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Keywords: Life cycle cost, over head line engineering, OLE

This paper describes collaboration with Sweden's Banverket Engineering to develop and release a new application to revolutionise the design of over head line engineering projects. This new system will significantly improve the cost effectiveness of OLE design and maintenance processes through automation and incorporation of local and national standards. Design data so created will form the base for operations, management and long term maintenance of the asset.

This paper is part of an ongoing process of industry consultation and collaboration intended to ensure the application perfectly matches the global industry needs when released a little later this year.

APPLICATION OF NORMAL PANTOGRAPH TO TILTING VEHICLE WITH TECHNICAL MODIFICATION OF VEHICLE SYSTEM

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Keywords: Pantograph, tilting train, modifications

On curved rail, the speed of train must be reduced in order to keep riding comfort. So, the train has the its speed limitation in conventional railway line. But if the train has the tilting mechanism, the speed of train is increased while maintaining the riding comfort. Generally, the tilting train is faster than the non-tilting train about 30% in curve.

The tilting train technology and reduction of travel time has been carefully investigated by KRRI (Korea Railroad Research Institute). Based on the primary research result from KRRI, tilting pantograph and tilting bogie are considered its core technologies.

Due to very complicate operational mechanism and requirement of interface technology between each subsystems of tilting vehicle, tilting pantograph technology is considered most difficult technical field of tilting train development project.

In this paper, previous efforts to apply simple tilting pantograph mechanism to tilting system from foreign railway manufacture and operator are briefly introduced with tilting train technical principle. All the technologies have its technical advantage and disadvantages to practically use.

Main target of this paper is to eliminate

technical difficulties and design effort of tilting vehicle. Vehicle system and its important parts such as coupler, high voltage cable and bogie frame are technically modified to apply regular pantograph to tilting system. Maintenance solution and method of vehicle unit are explained with this system.

Theme 1: Railway Track

Day 1:

Safety

SAFETY AND WEATHER PROTECTIVE CLOTHING IN THE RAILWAY INDUSTRY

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Keywords: Safety, EN 471, high visibility, EN343, waterproofness, breathable, durability, physiological stress, safety engineer, clothing specification

The growth in the railway infrastructure activity across the EU has seen many companies offering 'orange jackets'. The change in the GATT rules will enable large numbers of garments to arrive from overseas.

Potential customers are finding it hard to distinguish good from bad and have little or no knowledge of why they should seek out performance. There have been revisions in 2003 of the two key Norms EN 471 and EN 343

The revisions in some ways add some clarity to the safety aspect of breathable clothing (including non rainwear items) but explanations covering restricted wear times of low breathability clothing are not given

The performance demands of waterproofness have been left at a low level with no demands for industrial laundry durability. Such durability is essential if garments are to be maintained as an EN 471 High Visibility garments ensuring that the wearer remains visible. The author proposes values of durability and other technical solutions which will ensure a garment that is fit for purpose.

Theme 2: Railway Structures + Earthworks

**Day 2:
Keynote Papers**

AN INTEGRATED APPROACH TO FLOOD RISK ASSESSMENT OF RAILWAY STRUCTURES

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Keywords: Flood, risk, mapping, assessment

Floods present many risks to railway infrastructure, including track inundation, scour failure, blockage of culverts and embankment failure. While there are many assessment techniques currently available, these can be self-contained and do not look at the combined risk. In particular, they do not usually consider the particular circumstances of linear assets such as railways and the practicalities of assessing large numbers of structures, often in remote locations.

This paper presents findings from two Rail Safety & Standards Board research projects, which look at integrated approaches to the assessment and mitigation of flood risk. Case studies are presented, together with comment on current and proposed flood risk assessment of railway structures in the UK. The use of remote sensing and flood risk mapping, determination of acceptable levels of risk and the key elements of effective flood risk assessment are discussed.

REPEATED GPR MEASUREMENTS FOR THE RAILWAY CORRIDOR VIENNA-WARSAW CONDUCTED ON THE TERRITORY OF THE CZECH REPUBLIC, RAILWAY TRACK SEGMENT PETROVICE – STATE BORDER, KM 291.771 – 292.602

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Keywords: Track substructure investigation, ground penetrating radar, railway, corridor line

At present, on the territory of the Czech Republic there proceed reconstructions of pan-European corridor railway lines in order to reach traffic speed of up to 160 km/h. The process of taking over single track segments after the reconstruction also includes GPR measurements. The results are stored in the GPR records database of the corridor railway lines and serve for inspection of the work handed over and for detection of changes in the layers lying below the sleepers in the next years.

Reconstruction of the VI pan-European corridor railway line (Vienna–Breclav–Ostrava–Warsaw), in the track segment between Petrovice and the state border was performed in 2001–2002. Already the primary GPR record showed detection of anomalous parts, however, the track received an acceptance certificate and was put into operation in May 2004. In the track segment between km 291.771 and km 292.602, immediately after the opening, local problems with geometric position of the track started to occur. In spite of continuous levelling of the track geometry by tamping, the problems fail to be eliminated. Repeated GPR measurements conducted in 2003 and 2004 allowed us to

locate the reason for the problems both in horizontal and vertical directions and to quantitatively assess the extent of a defect. By comparing two different geometries of measurement, stress was laid on the necessity of standardized setting-up of the GPR apparatus. Fixed geometry of the antenna systems and precise positioning of the GPR records form a prerequisite for further processing of such records. On Czech Railways, already since 1998 this problem has been addressed by a methodical regulation 'Instructions for GPR Application in the Track Recording Car'.

Theme 2: Railway Structures + Earthworks

Day 2: Masonry Bridges

MASONRY ARCH RAILWAY BRIDGES IN AUSTRIA STATISTICS, MANAGEMENT & EXAMPLES

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Keywords: Masonry arch bridges,
damages, inspection, repair, assessment

Masonry arches are among the oldest types of load-bearing structures still in service, despite of increasing axle loads, train speeds and greater volume of traffic. Since most of the railway lines in Austria date from the 19th century, the Austrian Federal Railways are constantly faced with the task of maintaining and repairing its large stock of masonry arch bridges. This paper provides general information on Railway Arches in Austria. A short overview of the bridge stock, especially masonry arches, of the Austrian Federal Railways is given. Some statistics on the masonry arch railway bridge population are shown such as span length, condition and age. Furthermore the maintenance strategies of this kind of structures, the practice of inspection, the main types of structural problems and the repair techniques are listed up. Short descriptions of the original historical design rules up to actual considerations are mentioned. At last examples of significant masonry arch bridges show the necessity to have knowledge of material properties, the change of condition and of repair and interventions carried out over the years.

IMPLICATIONS OF BA86/04 ON MASONRY BRIDGE INSPECTION

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Keywords: Bridges, masonry, arch, NDT,
advisory notes

This paper will examine the aspects of Highways Agency Advisory Note BA86/04 as they may be applied to masonry arch railway bridges.

BA86/04 was developed in order to meet the perceived specific need for a structured approach to the NDT of all types of bridges in the UK. This paper describes the background to these Advice Notes, how they were developed and trialled, what their objectives are, and how they will be extended in the future.

The contents are based on research work on various NDT techniques carried out at the University of Edinburgh. The resulting reports have been worked up by the Highways Agency's NDT Steering Committee into Advice Notes to enable these techniques to be used in practice for the investigation of Highway Structures.

The Advice Notes are formed of three tiers; the first tier consisting of General Guidance on NDT; the second tier comprising Areas of Application; and the third tier covering NDT Techniques. This

three tier format enables the Advice Notes to be readily extended in the future to cover further areas of application and other NDT techniques.

The techniques relevant to masonry arch bridges and wing walls will be reported herein.

Theme 2: Railway Structures + Earthworks

Day 2: Concrete Bridges

HEAVY HAUL TESTING OF TWO PRECAST CONCRETE RAILROAD BRIDGES

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Keywords: Railway bridge, concrete bridge, bridge testing, measurements, bridge impact loads

Two new concrete bridges were installed at the Facility for Accelerated Service Testing (FAST) at the Transportation Technology Center (TTC) in Pueblo, Colorado, USA in December 2003. A variety of tests are being conducted under 39-ton (35-tonne) axle load traffic. One bridge features three state-of-the-art (SOA) spans. The second bridge features two conventional spans. Tests underway include measurements of strain and impact in the spans and foundations, centrifugal force issues, and the effects of different tie types on both impact and track transition issues. Long-term performance evaluations include performance of the spans under heavy axle loads, field repairs to spans, and ballast puncture and abrasion resistance of waterproofing materials.

The paper describes the two FAST ballasted deck concrete bridges, the test layouts and objectives, and results to date. Comparisons to AREMA guidelines are made where appropriate. Tonnage accumulation on the bridge test sites as of March 2005 is over 150 million gross tons (MGT) (130 million gross tonnes).

IMPLICATIONS OF BA86/04 ON CONCRETE BRIDGE INSPECTION

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Keywords: Bridges, concrete, NDT, advisory notes

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BA86/04 was developed in order to meet the perceived specific need for a structured approach to the NDT of all types of bridges in the UK. This paper describes the background to these Advice Notes, how they were developed and trialled, what their objectives are, and how they will be extended in the future.

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The Advice Notes are formed of three tiers; the first tier consisting of General Guidance on NDT; the second tier comprising Areas of Application; and the third tier covering NDT Techniques. This three tier format enables the Advice Notes

to be readily extended in the future to cover further areas of application and other NDT techniques.

The techniques relevant to concrete bridges will be reported herein.

RAILWAY STRUCTURES – PECULIARITIES/DIFFERENCES IN RELATION WITH ROAD STRUCTURES

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Keywords: Railway structures, road structures, railway bridges, railway tunnels, railway overcrossings, railway noise barriers

This paper examines from a technical and functional point of view, the application of civil engineering structures in railway domain. In particular, it covers the following categories of structures: bridges, tunnels, embankments/cuts, drainage systems, overcrossings, noise barriers and fences.

On many occasions, the methods and technical specifications in the construction and maintenance of railway structures are the same that are used for road structures but many differences are also observed. This fact is the main motivating factor embarking this paper.

The research is focused on the recording and analyzing the main principles of the activities (design, construction, operation and maintenance) related with the above mentioned structures, always taking in mind the interurban railway system as the field of application. Great attention is placed on tracing the peculiarities/differences of the above activities – for each category of structures – in relation to the ones of road

structures, as well as their justification.

The paper concludes that there are indeed peculiarities/differences in the design, construction, operation and maintenance of the most of the railway structures that were examined and their equivalent ones in road. Furthermore, it shows that these peculiarities/differences are due to various causes, and in particular to the constructional and functional characteristics of the two examined means of transport. The conclusions of this paper may act as a push-factor for the writing-up of an all-inclusive regulation of the railway civil engineering structures.

STUDY OF COMPUTERIZED BRIDGE MANAGEMENT SYSTEMS (CBMS)

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Keywords: Bridge management, computer, international, systems

In this paper, definition, goals and all bases of Bridge Management System (BMS) are presented. In addition the main structure of new computerized bridge management system (CBMS) is investigated and different systems used for CBMS are compared. The Computerized Bridge Management Systems which are studied in detail are Cowi and Danbro (used in Danish roads and rail roads respectively), Brutus (used in Norway) and Bridge_A Syst (used in Australia). Through this study the advantages and disadvantages of each system is presented.

Theme 2: Railway Structures + Earthworks

Day 2: Steel Bridges

EFFICIENCY OF THE U-DECK – RECONSTRUCTION OF RAIL UNDERBRIDGE DSN1/2, NEASHAM ROAD, DARLINGTON

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Keywords: Rail bridge, U-deck, steel,
construction depth

The Government's commitment to increasing volumes of rail traffic combined with Network Rail's desire to improve punctuality of passenger services has led to a substantial investment in Britain's railways in recent years. The need to remove freight traffic from the East Coast Main Line to improve capacity for high-speed passenger trains has led to improvements on a number of secondary routes to facilitate freight traffic at increased speeds and weights. The associated improvements to load carrying capacity and line speed have resulted in a number of bridge strengthening and replacement schemes throughout the UK.

Hyder Consulting have been working with May Gurney Rail through the Network Rail Structures Partnership in the London North Eastern territory since 1998 to strengthen and replace bridges identified by Network Rail. Common features of these structures are the limitations on construction depth, the provision of collision protection beams and the need for speedy installations during limited possessions.

This paper reviews four of the bridges designed by Hyder Consulting and successfully installed by May Gurney Rail over the past 2 years. Each bridge has a significant factor that affected the choice of structural form and the method of installation. This paper reviews the general parameters which should be reviewed at the

feasibility stage, provides an overview of the options available to the bridge designer with regard to construction depths, with particular attention given to the design of the modern U-deck solution, reviews experiences of crane lifts and installation using the Heavy Duty Transporter (HDT) and finally reviews issues concerning buildability by looking at 3D modelling methods available to the designer.

STATIC AND DYNAMIC LOADING TEST ON TALE ZANG BRIDGE

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Keywords: Bridge, load test, static,
dynamic, deck

Tale Zang bridge is located at km. 587 in Lorestan railway between Dorood and Andimeshk. The bridge runs over an approximately deep valley. The concrete arched bridge is designed and constructed in 1935-1938, having a primary span of 60 m and nine other ten meters span. During the Holy Defense era, i.e. the war of Iraq and Iran, the primary span was destructed by air raid. In 1987 a new deck was designed and implemented by 6 metal beams in a length of 72m and a height of 2.5 m. But unfortunately after operation, the deck showed such deformities and vibrations that made it unsafe. Therefore in 1991, the first plan of strengthening the deck was implemented by means of pre-stressing steel beams applying 15 complete set of cables.

Although pre-stressing decreased stress and increased negative versed sine, relatively large vibrations persisted which caused problems in operation of the bridge.

At the time being, the bridge should be operated at a very trivial speed, i.e. 6 km/h, and yet its safety is under question.

In order to identify problems and find possible solutions, a full-scale test on the bridge was suggested. After primary analysis and designing the test, both dynamic and static loading tests were carried out. In the static bridge test, 3 kinds of dynamic loads were used, including a combination of locomotives and vehicles and it showed deformities at 56 points.

In dynamic test, various kinds of trainloads transversed over the bridge by different speeds and in showed acceleration at 32 points and deformities in 16 points. Studies indicated the deformities were 5 times more than the limited amount specified by UIC standards and Euro Code. Also the recorded acceleration rate was a large number amounting to about 0.5 g. The results showed insufficient stiffness in the width of the deck and supporting situation is near the roller.

By measuring structure parameters, a new point of view is provided. This article explains how to design and perform the tests. Also it gives the results and studies the bridge behavior in present situation together with solutions.

Theme 2: Railway Structures + Earthworks

Day 2: Tunnels

SIMULATION OF TRAIN MOVEMENT IN TUNNELS TO STUDY THE CLEARANCE

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Keywords: Simulation, train movements,
tunnels

The vacant area around track is not restricted to the geometrical dimensions of rolling stock, but it has different definitions depending upon various parameters; such parameters include geometrical specifications of vehicle, elastic specifications of suspension system, rolling stock velocity, curve radius, vehicle dimensions, etc.

Since the clearance (i.e. the vacant area) is divided into two parameters, goods clearance and structure clearance, every vehicle should comply with the dimensions of the clearance of the track for passing over the railway. The safety of the movement is not ensured by the compliance of the vehicle dimensions with the clearance dimensions of a track. One of the most important issues about the tunnel dimension is its circumscribing the standard clearance of the structure. In order to control and study the cross sections of tunnels in the present research, the standard clearance inside the cross sections has been drawn for every 5 meters. This is done by a TCRA1102 camera. Then by creating a 3D drawing in CAD environment as the basis, every acquired data is demonstrated in the form of points bearing CODE data, X, Y and Z. While drawing standard structure clearance, it was considered that the clearance and track axle be at the same length and also the superelevation in every section was taken into account. After it was drawn, there

seemed to be some critical sections that required more precise studies.

After increasing the width of the clearance, it was realized that in these sections, the tunnel cross-section was not circumscribed by the widened clearance. And the structure clearance was in contact with the tunnel walls. Therefore it is not possible to increase the superelevation to add up to speed, because it may increase the exceeding of structure clearance from tunnel walls and hence the possibility of vehicle collision into the tunnel walls shall be more probable.

According to above study, a lot of technical questions can be answered and also the results of this study can be used for transportation of goods outside clearance area.

Theme 2: Railway Structures + Earthworks

Day 2:

Earthworks Investigation + Management

ACCEPTABLE LEVELS OF RISK WITH PARTICULAR APPLICATION TO ROCK CUTTINGS

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Keywords: Slope stability, rock cuttings, risk, safety

Network Rail have extensive sections of the railway throughout the UK that are at risk from rockfall and slab slides within deep cuttings or escarpments above the railway. The cost of remedial work to these elements of the infrastructure is an order of magnitude greater than typical earthwork remediation measures. Therefore a risk based approach is a logical route to take if best value is to be achieved. However this approach is only helpful if this can be linked in some way to the requirements for the operation of a safe railway as perceived by the public at large. Network Rail have defined their interpretation of these perceptions in the published Safety Case and the Risk Analysis that supports it. This paper is aimed at defining and subsequently establishing quantifiable linkage between the risks set out in Network Rail's Safety Case and those apparent on site; mainly in relation to sites that have already been identified as posing a high risk to the railway and are likely to require remediation.

The main intention of this paper is to identify where improvements can be made in defining the scope of works for the remediation of steep cuttings, whilst avoiding the introduction of unacceptable risks to the railway. Whilst it is more difficult to define absolute levels of risk in geotechnical engineering the technique is very useful in making comparisons between difference remediation schemes and generating consistency throughout the

network in the level of remediation afforded to each site.

Reference will be made to a series of case studies at Winterbourne, Dawlish and Harlech where quantitative risk analyses have been carried out to define the most appropriate level of remediation to be applied to these sites. In addition, the risk reduction achieved by the introduction of monitoring systems and temporary speed restrictions, particularly in emergency situations, will be examined.

ASSET SURVEYING USING AERIAL LASER SCANNING

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Keywords: Highways, airborne laser scanning (LiDAR), topographical survey, infrastructure asset inventory, specification and procurement of remote sensing techniques, data archive

The Highways Agency (HA) is an executive agency of the Department for Transport, (DfT) and is responsible for managing the 7,088 km motorway and trunk road network in England on behalf of the Secretary of State for Transport.

DfT have set the HA the strategic target of reducing congestion on the inter-urban trunk road network significantly by 2010. To achieve this the HA is undertaking a programme of improvements to the strategic road network including enhancements to the M1, M6 and M25 motorways.

As part of the overall development of data management in the HA, Aerial Laser Scanning (LiDAR) techniques have been adopted to provide asset survey data. This data is being used for both the design of enhancements and for asset management activities.

This paper will describe the implementation of the Highways Agency National Framework to undertake LiDAR Surveys and how data from this framework is being used within the HA to improve the way in which the highways asset is managed.

In particular three topics will be described namely:

- The adoption of rapid remote sensing techniques for asset surveying;
- The development of topographic survey and mapping requirements;
- The storage, access and use of the resultant asset survey data.

The subject area addresses issues similar to those encountered by operators of other infrastructure networks such as London Underground Limited, Network Rail and the British Waterways Board, and recognises that similar techniques will have application in areas such as Flood Defences, Coastal Management, Dams etc.

MAINTENANCE LIABILITY SITES: EARTHWORKS & SUBGRADE FAILURE CASE STUDIES, NEWHAM BOG & HAYWOOD LEVEL CROSSING

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Keywords: Maintenance, earthworks, subgrade, case studies

Intrusive Trackbed Investigation Techniques are now well established in the UK, ranging from traditional methods of Trial Pitting (TP) to Automatic Ballast Sampling (ABS). These techniques allow the development of ‘intelligent’ renewal specifications including ballast replacement, ballast cleaning and choice of appropriate geotextiles or geocomposites. However, intrusive techniques, when used in isolation, do not always allow appropriate solutions to be developed for ‘problem’ sites, particularly those that are ‘maintenance liabilities’ due to inadequate transitions or varying subgrade support. This paper presents two case studies (Newham Bog and Haywood Level Crossing in the London North Eastern [LNE] Territory), where the use of the Falling Weight Deflectometer highlighted stiffness variation and critical velocity as the overriding causes of track quality deterioration. Subsequent novel renewal recommendations could then be tailored to match the specific site conditions.

QUANTITATIVE ESTIMATE OF EARTHWORK RISK

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Keywords: Risk analysis, earthworks, slope stability, uncertainty

Quantitative estimate of risk is being used successfully in a number of fields and industries and there are many examples where its application has not only highlighted critical issues but was also instrumental in saving significant amounts of financial resources. The stability of earthworks in the UK is associated with uncertainties and risks to passengers, workers, general public, tangible assets, traffic continuity, reputation and financial resources of the asset owners. A properly determined level of risk provides an effective basis for decision-making on the relative merits of various approaches to construct, upgrade and/or mitigate earthworks in light of safety and cost.

GENERIC RISK ASSESSMENT METHODOLOGY FOR OPTIMISATION OF EXAMINATION INTERVALS FOR RAILWAY STRUCTURES AND EARTHWORKS

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Keywords: Earthworks, structures, examinations, optimisation

This paper describes a project that is being undertaken to develop a procedure for establishing the optimum frequency for examinations of railway structures and earthworks based on condition and risk of failure. It is primarily focussed on underline and overline bridges, tunnels, retaining walls and earthworks. It is intended that a generic risk assessment method will be developed for generic types of structure, which will then be supplemented to take into account individual structure specific knowledge.

The currently prescribed normal periods between examinations appear to have been inherited as good practice, but without much formal justification. A risk based approach would assist engineers to justify extending the periods between detailed examinations where appropriate, and may also identify situations where more frequent examinations are warranted.

The first part of the project investigated what information and research is currently available or underway, looking at current practice and the state of the art regarding risk based determination of examination intervals, particularly for detailed examinations. This will be used to establish what gaps in knowledge exist, and what further research will be necessary to support the proposed risk based approach. The intended risk based methodology will be developed following the completion of research identified during the first phase of the work. The impact on annual visual examinations of extending the periods between detailed examinations will also be addressed.

APPLICATION OF OBSERVATIONAL METHODS IN EMBANKMENT BUILT ON SOFT GROUND TO OVERCOME LIMITATIONS OF SLOPE STABILITY ANALYSES

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Keywords: Embankment, slope stability, observational methods

Construction of embankments on soft ground requires special attention. Two major problems encountered are stability of slope and consolidation settlement. Among this two, the first one threaten the lost of infrastructure and in some cases human being life. Therefore in this paper discussion will be emphasized on the slope stability. In order to construct the embankment safely and maintain the embankment in the stable condition throughout its life, embankment was design with sufficient stability number called factor of safety (FOS). Theoretically the FOS required for stability of slope is just unity. However FOS of much greater than unity are generally adopted due to the uncertainties involved in the input parameters such as geometry of slope, soil and ground water profiles, soil parameters and theories of slope stability and the strength. Again what is the acceptable and appropriate number of FOS is uncertain and it could be varied depending upon the situation. Nevertheless several embankments have been failed due to one reason to another. Due to the fact that engineers are increasingly applying observational method to overcome these uncertainties. This paper discussed the limitations of slope stability theories, uncertainties on the soil strength and described the suitable observational

methods for construction control of embankment built on the soft ground.

SUBGRADE GEOLOGY BENEATH RAILWAYS IN MANCHESTER

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Keywords: Subgrade, geology, engineering geology, geotechnical, Manchester, 3D modelling,

It is not sufficient to identify fine-grained soils as locations for potential subgrade problems as could be done using a traditional 2D geological map. More information is required about the geological structure, lithological variability, mineralogy, moisture content and geotechnical properties of the soil, much of which can be supplied by modern 3D geospatial databases. These databases can be interrogated at key depths to show the wide variability of geological materials and conditions beneath the ground surface. Geological outcrop and thickness plus the permeability and water table level are predicted from the Manchester geospatial model based on 6500 borehole records. Geological sections along railway routes are modelled and the locations of problem soils such as alluvium, till and glaciolacustrine deposits at outcrop and shallow subcrop are identified. Spatial attribution of geotechnical data and simple methods to recast sections in engineering geological terms are demonstrated.

Theme 2: Railway Structures + Earthworks

Day 2: Slope Stabilisation

SIMULTANEOUS MULTI-SITE RAILWAY EMBANKMENT STEEP SLOPES (BATTERS) EROSION CONTROL FOR A NEW SPUR LINE

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Keywords: Embankment, steep slopes,
batters, erosion, control

The Bauhinia Regional Rail Project (BRRP) is the construction of a 110 km spur line linking the Rolleston Coal Mine to the Blackwater rail network in Central Queensland, Australia. It will generate rail traffic of 8Mt/year of coal from Rolleston mine by 2008. BRRP is currently under construction and is expected to be completed by the end of 2005. The new spur line includes several embankments that need to be protected against erosion. Erosion of unprotected railway embankments causes serious maintenance and environmental problems within the project region. Earlier research has demonstrated that revegetation of the batters minimises the erosion risks considerably. Therefore the cost-effective erosion control strategies of the ongoing HEFRAIL Research Project are integrated with the earthworks construction. In order to reduce the treatment costs, the embankment batters are categorised with different levels of treatment. The top 3 m of batters of all embankment sections exceeding 4 m in height and embankment batters on the downstream side of the two major flood plains are receiving the full HEFRAIL erosion control treatment. The

full HEFRAIL treatment involves topsoiling, grass seeding and drip irrigation system set up to aid in the grass establishment. The remaining embankment batters are receiving the full treatment except for the drip irrigation. Water from existing dams and creek water holes, from earthworks construction water tanks, and from road delivery to temporary tanks located within the rail corridor is being used to supply the irrigation water. The slow germination process and low germination rate of the preferred drought resistance buffel grass impose a serious bottleneck for the rapid grass establishment required for erosion control. Therefore an attempt has been made to increase the germination rate and accelerate the germination process by soaking seeds for 5 mins in water and pre-germinating in potting mix before spreading on the batter surface. Sulphuric acid treatment in the laboratory produced excellent results but has limitations for mass treatment, and it is being further investigated for improvement. Good emergence of buffel and Rhodes grass on the railway batters within a week of seeding with pre-germinated seeds has been observed where the irrigation water is secured. In general very good grass coverage is being achieved within 8 weeks after seeding with irrigation.

STABILISATION OF A CUTTING ON THE LONDON UNDERGROUND

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Keywords: Earthworks, stabilisation,
cutting

The earth structures design team at Metronet
Rail has been working on the design of

remedial measures for cuttings and embankments of London Underground (LU) SSL (Sub-Surface Lines, open sections) and BCV (Bakerloo, Central and Victoria Lines, deep Tube tunnels). Very tight and limited construction space, limited access, safety to the operation of railway including the passenger trains and the lineside services present the biggest challenge to the design of the improvement works. The designs need to consider in the first instance construction of the works during railway traffic hours as working during engineering hours and possession time when the trains are not running will have significant detrimental impact on the cost and programme of the projects.

An exciting and challenging project undertaken is the improvement works for a 10 m high and 500 m long cutting formed in London Clay between Chigwell and Grange Hill stations in East London. Results of slope stability analyses showed that the cutting, in many parts, has an inadequate factor of safety against deep-seated slip and need to be upgraded to meet the requirements of LUL standards.

A site-specific ground investigation comprising undisturbed sampling, effective stress triaxial testing and groundwater monitoring was undertaken to determine design parameters for the design of the remedial works.

At the feasibility and concept design stage several solutions such as re-grading, soil nailing, piling and drainage were considered for the remedial works to the earth structure. At this stage it was acknowledged that working within a high cutting above a live operational railway presents a significant risk to the safety and operation of the railway and needs to be considered very carefully. Hence, minimising risks to safety of the railway was fundamental in arriving at the preferred

solution. A spaced bored pile solution was considered as the most viable option in terms of safety to railway operation, cost, environmental issues, ease of construction and design life.

This paper presents the results of the ground investigation and the design parameters obtained for the ground condition at this site followed by a discussion on the methodology adopted for the design of the works. Details of the proposed scheme are presented including construction safety and buildability issues which imposed significant constraints on the design. Details of the instrumentation and monitoring proposed in order to monitor the performance of the structure are discussed.

Theme 2: Railway Structures + Earthworks

Day 2: Earthworks Stabilisation

UNDERSTANDING GEOTECHNICAL IMPACT OF VEGETATION ON UK'S RAILWAY EARTHWORKS

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Keywords: Geotechnics, vegetation, slope stability, pore pressures, progressive failure, strain softening, numerical analysis

The vast majority of railway embankments and cuttings in the UK are more than 100 years old. Embankments were constructed using non-engineered ("dumped") clay fill and cuttings were excavated at an angle based on previous experience of failures or simply the land take that was available.

Over time, there have been numerous recorded incidents of slope instability and it is recognised that this is an area of ongoing risk and source of disruption for the railway network. This paper discusses the effect that vegetation has on the stability of earthworks that make up the UK's transport infrastructure.

STABILISATION OF GERMAN LANE RAILWAY EMBANKMENT A COMBINED APPROACH

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Keywords: Embankment, stabilisation, piles, gabion wall

The West Coast Main Line (WCML) railway embankment at German Lane, near Euxton in Lancashire, has a long history of movement and associated track serviceability problems. Track deflection, a leaning overhead line electrification (OLE) gantry, loss of cess and over-steepened slopes were indicative of slope instability on the upside, and inclinometer data confirmed the existence of a deep-seated slip.

In 2001, Scott Wilson was commissioned by Edmund Nuttall Ltd (ENL) on behalf of Railtrack (which was bought by Network Rail in October 2002) to undertake site inspections, design and supervise a ground investigation and implement a programme of monitoring. This was followed in 2003 by analysis and outline design of a range of remedial options to improve stability of the embankment to an acceptable level. The remedial option agreed with Network Rail comprised a combination of stabilising piles, gabion walls and slope re-profiling, to address both shallow and deep-seated slope failure mechanisms. Detailed design was then undertaken by Scott Wilson with construction in the latter part of 2004 by ENL, using its subcontractors W.A.Developments (groundworks) and Skanska (piling).

This paper summarises the evaluation, design and construction processes of this £1.2 million project.

REVIEW OF RAILWAY EARTHWORKS STABILISED BY SOIL NAILING

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Keywords: Railway earthworks, soil nails, assessment, performance, detailing

Since 1997, and as part of the Extended Arm Contract (EAC) and then the Structures Framework Contract (SFC), Birse Rail and Atkins have successfully designed and implemented a number of slope stabilisation schemes using soil nails. Based on this experience and in agreement with Network Rail, we have recently undertaken a review of soil nailing practice of twenty earthworks across the former Midland Region, with the aim of learning from the schemes implemented.

This paper discusses the benefits offered from adopting soil nail remediation solutions, the performance of soil nailed railway earthworks with reference to track monitoring data, and good nailing practices that have been developed.

CASE STUDIES OF THE APPLICATION OF NUMERICAL METHODS TO THE DESIGN OF EMBANKMENT REMEDIAL SCHEMES

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Keywords: Embankments, remedial analysis, finite element

Limit equilibrium analysis has traditionally been the mainstay of slope assessment methods and continues to be the principle technique referred to in standard engineering texts. The application of powerful numerical analysis codes, such as finite element or finite difference programmes, can also enable the efficient evaluation of embankment and slope stabilisation schemes. At present the main references to numerical methods appear to be either research orientated or reserved for high profile projects, not routine design.

Numerical methods can provide the designer with considerable insight into complex soil, water and structural interactions for a broad range of physical problems. Whilst the potential benefits of advanced analysis methods are broadly recognised, the application of such methods within routine geotechnical engineering is either avoided or considered with scepticism, often based on outdated pre-conceptions.

This paper considers recent examples in the application of numerical methods to remedial scheme designs for railway embankment slopes. The examples highlight the potential benefits of numerical methods and some potential issues in respect of the calculation of global factors of safety for embankments and slopes.

The examples presented demonstrate

that the application of numerical methods can be routine, cost effective and can result in greater efficiency and confidence in the remedial design solution for embankments.

DEVELOPMENT OF RUGLEI SYSTEM TO STABILISE AND WIDEN A RAILWAY CESS

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Keywords: Railway, cess, stabilisation, widening, angular grid, pile, tie-back, Ruglei

Many of the world's railway networks established some 150 years ago have performed remarkably well but it is common to see deterioration at the crest of the embankments with fill migrating down the slope causing narrowing and instability of the cess. Support to line side services and maintenance access is endangered. Traditional methods used to remedy this situation include vertical posts driven into the embankment with horizontal lagging usually of timber sleepers or concrete planks or driven trench sheets. Whilst effective in the short term they often gradually yield, become unstable and require frequent replacement. Modern rail construction requires engineered solutions with permanence. A common solution has been to install concrete piles topped with a rectangular or L shaped reinforced concrete capping beam but this is expensive. In

Switzerland, GLEISAG, a major railway construction company and Rügger Systems, experts in geotechnical engineering, took another look at this problem and developed the Ruglei system, with encouragement from the Swiss Federal Rail Authorities. Used rail piles combined with a galvanised steel L mesh, and if necessary a soil anchor, provide an economical permanent engineered support with its advantages of widening the cess, permeability etc. Since the first structure in 1998 some 32 km of Ruglei system is in successful service and is now being introduced into France and in the United Kingdom & Ireland by Elwood International. The paper will describe the development of the system, including Swiss case histories with details of deformation monitoring and show its adaption to UK conditions.

INNOVATION AND RAILWAY EARTHWORKS

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Keywords: Innovation, earthworks, efficiency

This paper describes how Birse Rail has developed a number of innovative schemes to produce measurable efficiencies for earthworks renewals. Through collaboration with Network Rail LNW Territory and by working closely with their key suppliers, a number of innovative solutions have been developed to earthworks related problems that are commonly experienced and therefore

applicable across the railway network. This paper describes the specific developments and quantifies the efficiencies that have been provided or that are estimated.

Specific developments and aims of the paper:

- Cement bentonite shear trenches with combined earthworks (undertaken in Sept 03') – review of actual works designed, implemented and assessment of cost savings.
- Kingpost retaining wall – application and efficiencies by embedment in concrete filled trenches.
- Soil mixed columns to stiffen foundation (a first time for UK rail, implementation March/April 05') – embankment founded on soft alluvial soils. Review of design development with indication of estimated cost savings.

This paper also considers future areas for development and potential further cost savings.

STABILISATION OF EMBANKMENT SHOULDERS ON THE LONDON UNDERGROUND

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Keywords: Embankment, shoulders, earthworks, stabilisation

The Earth Structures design team in Metronet Rail has been working on the design of remedial measures for cuttings and embankments of London Underground SSL (Sub-Surface Lines – open sections) and BCV (Bakerloo, Central and Victoria

Lines – deep Tube). Very tight and limited construction space, limited access, safety to the operation of railway including the passenger trains and the lineside services present the biggest challenge to the design of the improvement works. The designs need to consider in the first instance construction of the works during traffic hours as working during engineering hours and possession time will have significant impact on cost and programme of the projects.

An important design undertaken is the stabilisation works for approximately 600 m of embankment between Dagenham East and Elm Park. The design is aimed at improving and widening the shoulder of the embankments as well as mitigating against deep-seated instability and minimising track differential movement. The design consists of separate sections of earthwork berm, anchored bored pile wall and a Swiss shoulder support system called “Ruglei Verge Protection System”.

The Ruglei system consists of an angular galvanised steel grid and a grid insert to contain and support the fill which can be recycled ballast or coarse granular fill. Vertical piles and in some cases inclined anchors are used to provide support to the system and to stabilise the system against rotation. Used rail sections are proposed to be used as dowels at a spacing of between 1.0 m and 2.5 m.

This system, which has been successfully used by the Swiss Federal Railway for stabilisation of shoulders of embankments, provides a very cost effective solution for embankment shoulder stabilisation. A team of engineers from the UK visited Switzerland in 2004 to inspect the system in operation and under construction. If the construction works for Dagenham project goes ahead according to the programme which is due to start in

spring 2005, this would be the first implementation of the Rugei system in the UK.

This paper presents the details of the proposed scheme, including health and safety and buildability issues, which impose significant constraints on the system. Details of the instrumentation and monitoring proposed in order to monitor the performance of the structure are discussed.

EMERGENCY RE-CONSTRUCTION OF THE CONWY VALLEY LINE EMBANKMENT

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Keywords: Railway earthworks, emergency works, flood damage, embankment remediation, climate change

Heavy rainfall in the Conwy Valley on 3rd and 4th February 2004 caused very high discharges in the River Conwy and led to overtopping and breaching of existing Environment Agency flood defence banks. Significant damage occurred to sections of the railway embankment that carries the Conwy Valley Railway Line (a bi-directional line carrying mostly passenger trains) near to the town of Llanrwst. The damage was principally concentrated in two sections of 2.5 to 3.5 m high railway embankment approximately 1350 m and 1200 m long respectively, resulting in some areas of embankment being completely washed away, leaving the track suspended in mid-air.

The repair strategy was to excavate the failed sections of earthwork and rebuild the embankment with well-graded locally sourced limestone granular fill and protect the re-built embankment with rip-rap scour

protection comprising high quality Penmaenmawr diorite. The unsuitable excavated materials arising on site were reused to provide additional flood protection. Flood relief culverts (up to 1800 mm diameter) were installed to reduce the risk of future overtopping of the embankment. Site remedial works commenced within 1 week of the floodwaters receding. Full time site supervision enabled preliminary designs to be modified, as dictated by the actual conditions encountered on site (observed method), and allowed the line to be re-opened within 3 months. This paper summarises the emergency design and construction of this £3.5M project to re-open the line.

CHALLENGING THE FACTOR OF SAFETY: THE PROBABILITY OF SLOPE FAILURE

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Keywords: Slope stability, factor of safety, probability of failure, uncertainty, earthworks

Stability of cuttings and embankments is inherently associated with uncertainty that is derived from geological anomalies, variability of material properties, scarcity of data, adopted simplifications and others. Conventional engineering practice uses a factor of safety to assess the stability of earthwork slopes, however, this practice does not explicitly address the uncertainty. Probabilistic analysis of slope stability provides a rational method how to

incorporate uncertainty into the design process and is a useful alternative/addition to the current engineering practice. The use of probabilistic analysis is beneficial to design/mitigation of railway cuttings and embankments, enhances the quality of decision-making process and allows for direct input into quantitative risk assessment. This paper critically re-examines the current practice of using factor of safety in earthworks and discusses the advantages of the probabilistic approach. The paper also presents a case study where slope design based on a target factor of safety proved expensive and a probabilistic analysis was utilized to obtain increased knowledge regarding the stability and expected performance of the slopes.

CHARACTERISTICS OF BEHAVIOR OF SOFT ROADBED THROUGH LONG-TERM INSTRUMENTATION-FIELD TEST

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Keywords: Soft roadbed, geotextiles, mud pumping, settlement, earth pressure

In this study, several types of geotextile was used on the selected track-bed. The use of geotextile prove a economical and efficient mean to prevent the problem of mud-pumping and settlement.

Field testing sections from Mock-haeng to Dong-ryang in the Jeolla lines in Korea were selected to investigate in current condition the of track and roadbed. And three places were chosen among 1,700 spots where mud-pumping was often observed and maintenance was required. At the

curved section with a radius of 500m between Mock-haeng and Dong-ryang. This testing site was divided into 5 sections. In the four sections, different types of geotextiles were installed. Fifth are remained with. Total length of the test site was 200m and individual length of each section was 40 m.

In order to understand the condition and the strength of prepared roadbed, the stiffness and physical properties of roadbed soils were evaluated and analyzed. Also, after the installation, the mud-pumping, settlement of elastic or plastic sleeper, failure of track, wheel-loads, lateral force, and earth pressures were investigated.

NUMERICAL ANALYSES ON THE EFFECTS OF MICRO PILE INSTALLATION BENEATH SLAB TRACK

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Keywords: Slab track, micro pile, settlement, bending moment, pile arrangement

The bending moment and settlement of the slab track can be reduced by the installation of a small number of micro piles beneath the track. This paper presents the effect of micro pile installation on the reduction of bending moment and settlement of slab track, estimated by a numerical method. The slab track is modeled as a plate based on the Mindlin's theory, and soil and piles are modeled as Winkler and coupled springs, respectively. The stiffness of piles is

obtained by the approximate analytical method proposed by Randolph and Wroth, and the modulus of subgrade reaction is adopted to evaluate Winkler spring constant. From the analysis results, the effect of the micro pile installation is significant to considerably reduce the settlement of slab track. However, for the proper reduction of bending moments in a slab track, the pile arrangement should be reasonably taken into account to prevent the stress concentration at the pile location.

CONSTRUCTION OF AUTOMATIC RAINFALL ALERT SYSTEM FOR RAILWAY DISASTER PREVENTION

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Keywords: Slope, failure, rainfall, monitoring, alert, automatic

Heavy rainfall has given rise to track swept away, slope failure and bridge failure and has brought on the train accidents, its service suspension and delay. To predict and prevent these disasters by heavy rainfall, it needs constructing rainfall alert system and database system with data from the proper program and devices. However, Korea National Railroad (KNR) had operated only seventy rain gauges with data measured and transmitted manually and thus, it is impossible to predict risks and hazards for lack of both real-time transferring systems and accumulated rainfall data. Even though the data from Korea Meteorological Administration have been utilized until now, it has been insufficient to prepare for disasters by every local heavy rainfall because of long distances between rainfall

gauges and railroad. This paper shows that the newly developed Automatic Rainfall Alert System indicating the local heavy rainfall and alarm threshold values for the safe train operation during the regular hours. The rainfall disaster prevention system was established on the basis of the automatic rainfall alert system.

Theme 1: Railway Track

Day 2:

Trackbed Inspection

NDT INSPECTION OF RAILWAY TRACKS EMBEDDED IN CONCRETE

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Keywords: NDT, GPR, tracks embedded in concrete

Information on the present condition of infrastructure is of particular interest within the framework of rehabilitation or in the event of damage. In order to obtain the required information an increasing number of non-destructive methods is available. Many of these methods are still in a phase of development, whereas the applicability of others has been shown for many different problems. Ground-Penetrating-Radar (GPR) has been applied successfully to a wide range of objects and applications, some of which are closely related to tracks embedded in concrete, such as the inspection of concrete bridge decks [1] or the inspection of railway ballast [2]. GPR is a method of interest because of its versatility and because of the fact that results are quasi-continuous. Moreover it has been proven to be economical for many applications.

The case-study presented here describes the application of GPR for the inspection of tracks embedded in concrete on an industrial site. The radar survey was carried out because traditional methods were unable to provide the information required for explaining causes of damage. In addition, the process of discussion between the building contractor and the client had come to a halt. In this pilot study with a very basic

set-up for data acquisition, the combination of the radar survey with a very limited number of boreholes provided all the information required for the assessment of the problems on the whole site.

FAST INSPECTION OF RAILWAY BALLAST BY MEANS OF IMPULSE GPR EQUIPPED WITH HORN ANTENNAS

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Keywords: GPR, horn antennas, ballast inspection, computer analysis

The inspection of railways ballast by use of ground penetrating radar devices has been performed for several years now. A continuous and non destructive profiling of the ballast and subsoil offers obviously significant advantages compared with the traditional way of coring and sampling. The latter method is appropriate for layered structures which can be described by statistical methods but for example local structural defects can easily be overlooked because statistical drilling patterns can not be used for addressing this kind of problem. Last but not least it is well known that the application of non destructive inspection methods like GPR is reducing the inspection costs compared with the traditional approach.

One serious handicap for the application of GPR on railways is survey speed. Exploiting the full economical potential of GPR would allow users to fit the surveys in between regular train schedules. This was not possible until newly developed

equipment became available. The risk of hitting switches or similar obstacles close to the ground was the main reason for slow data collection speed with bow-tie antennas. Bow-ties need to be operated within a quarter of a GPR-signal wavelength. Practically this forced the GPR operators to mount their antennas not higher than 10 cm above the ballast. This low height allowed a maximum data collection velocity of only 30 km/hour.

The operation of horn antennas avoids this problem because they can be mounted about half a metre above the ballast. The development of a new 400 MHz horn antenna for railways ballast and subsoil inspection was additionally triggered by the availability of new GPR control units like the GSSI SIR-20. These units allow data collection rates of several hundred scans per second with a time resolution of 5 picoseconds for 512 or 1024 samples per scan. Using the 400 MHz horns with 50 nanoseconds time range offers survey velocities of more than 100 km/hour with 20 scans per metre. This scan separation has been identified to be an important parameter for good data quality. Less scans per meter would mean less information between the sleepers.

The use of the newly developed hardware and software for collecting high speed GPR data in combination with other sensors like RTK-GPS, Doppler radar, video as well as the streamlined data processing and data interpretation routines will be presented in this paper. Examples of typical survey data and the final survey results will be shown for demonstrating the high performance of this new technology.

RAIL STRAINS, DISPLACEMENTS & GROUND VIBRATION MONITORING OF BALLASTED TRACK AT CREWE

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Keywords: Track, displacements, strains, geophones, site monitoring

As part of a Rail Research UK project investigating the behaviour of sub-ballast and formation, instrumentation is being developed by the University of Southampton and used at a variety of live railway sites to measure in-situ trackbed performance. This paper reports some initial site work carried out in conjunction with Balfour Beatty Rail at Crewe. Rail strains were measured that quantified the effect of some adjacent hanging sleepers. A remote video monitoring system for the measurement of rail displacements was tested. The system, combining a telescope and webcam, successfully measured rail displacements by monitoring a small target attached to the side of the railhead. To measure ground vibrations and dynamic displacements, geophones were placed at the ballast/subgrade interface adjacent to the track. Geophone results also showed that these seismic sensors are effective at detecting wheel-flats.

EMPLOYING HADGPS TO SURVEY TRACK AND MONITOR MOVEMENT AT CURVES

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Keywords: HADGPS RTK, track surveying, track shift, monitoring curves

Together with railway engineering expertise, high-accuracy differential global positioning system (HADGPS) real-time kinetic (RTK) technology is proving to be a promising accurate and economic tool to monitor track position, and measure track shift, to an accuracy of 2 cm. The applications discussed are the rapid surveying of a classification rail yard and measuring track shift at curves, in accordance with Federal Rail Administration (FRA) requirements. Using a hy-rail mobile platform, track can be surveyed and monitored safely, quickly, also during adverse weather conditions.

PRELIMINARY STUDIES INTO THE EFFECTS OF PRINCIPAL STRESS ROTATION ON RAILWAY SUBGRADE BEHAVIOUR

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Keywords: Railway subgrade, principal stress rotation, hollow cylinder apparatus, FLAC modelling

There are many design codes for ballasted railway track. Some codes, such as UIC 719R, have a more empirical basis whilst others, such as that of Li & Selig, are more theoretically based requiring the measurement of the engineering properties of the subgrade. However, even the more theoretical design methods were derived from cyclic laboratory testing that did not take the effects of principal stress rotation (PSR) into account.

PSR occurs in the subgrade due to the moving axle loads. Previous research has shown that, for certain types of material, PSR can have a detrimental effect on both the resilient modulus and permanent deformations.

This paper reports some initial work on PSR carried out as part of the RRUK project 'An appraisal of railway track/sub-base design using modern geotechnical principles'. A FLAC numerical model is first used to simulate the stresses in the subgrade due to a passing train. The calculated stress conditions for a soil element in the subgrade are used in Hollow Cylinder Apparatus (HCA) tests, and the results of two different stress path tests are compared.

VOID DETECTION BENEATH RAILWAY BALLAST USING GROUND PENETRATING RADAR AND RESISTIVITY

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Keywords: Voids, cavities, geophysics, ground penetrating radar, resistivity

This paper discusses the issues related to voids beneath railway track ballast. An experiment at the University of Edinburgh is described where a 40 litre plastic container is buried beneath a full scale railway track. The canister is connected with the surface by a plastic pipe which makes it possible to simulate air filled and water filled voids.

Data is presented using resistivity and ground penetrating radar methods. The results show that resistivity was reasonably effective to detect the canister, but radar was less effective to detect the presence of the plastic container. It is shown that the presence of the sleepers can seriously limit the performance of the ground penetrating radar in certain circumstances. Furthermore the canister has been inserted in high conductive material which limits the penetration depth of the radar signal. The interpretation of the results is discussed in detail.

INSTRUMENTATION TESTING AND GEOPHYSICS ON THE RICHARDS BAY COAL LINE, SOUTH AFRICA

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SPOORNET, Railway Engineering (Track Technology), Room 716,138 Eloff Street, Braamfontein 2017, South Africa

Keywords: Instrumentation, geophysics, trackbed, inspection, heavy haul

To further develop the field instrumentation work being carried out as part of the RRUK project on railway track/sub-base design, a new testing site has been established on the Richards Bay Coal Line in South Africa. The Coal Line, operated by Spoornet, is a heavy haul line with regular trains comprising 200 wagons with 26 tonne axle loads. To allow different types of instrumentation to be tested, a pit has been constructed next to the track from which horizontal boreholes, lined with flexible pipes, may be accessed. An instrumentation cage has been developed on to which a variety of instrumentation may be attached to record data in orthogonal planes. This instrumentation cage can be pushed into the boreholes facilitating measurements at different locations under the track. So far, accelerometers and two different geophone types have been tested yielding acceleration, velocity and dynamic displacement results as well as providing geophysical information about the subgrade. This instrumented site is adjacent to a section of track monitored by Spoornet. Thus, the results from the trial site have been

compared with Spornet's instrumentation, including their Multi Depth Deflectometers (chains of LVDTs).

GEOPHYSICAL MONITORING OF THE SUBGRADE WITH EXAMPLES FROM LEOMINSTER

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

Shear wave velocity, sleeper acceleration and vibration data have been gathered at a site in Leominster in response to passenger and freight traffic and other data show the site to be on poorly performing subgrade. Acceleration data indicated sleeper movements of a few millimetres. The vibration data are shown to respond to dynamic loading in key intervals of the subgrade at shallow depths. These data indicate far greater loading from freight traffic and also increased loading with depth in the subgrade at sub-10 Hz frequencies. The velocity of shear waves through the subgrade changed in response to freight traffic and also over the long term after the dry summer of 2003. The application of geophysics to the development of subgrade

models is discussed and a simple geotechnical model is presented where the ballast is of far greater stiffness than the subgrade immediately below. Finally, the potential of 3D geospatial databases in assessing the subcrop of problem soils along railway routes is discussed.

Theme 1: Railway Track

Day 2:

Track Maintenance

DEVELOPMENT OF LOW-MAINTENANCE TRACKS FOR EXISTING LINES

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Keywords: Low-maintenance tracks, cement filling material, dynamic loading test machine

East Japan Railway Company (JR EAST) has introduced the Technical Center (TC) type low-maintenance rail track for relatively light load rails to reduce maintenance costs since 1998. JR East has introduced this type of track to very busy lines in the Tokyo metropolitan area, such as the Yamanote Line and the Keihin-Touhoku Line. This type of track incorporates 400mm wide pre-stressed concrete (PC) sleepers, with 200mm thick ballast supporting the sleeper from underneath. The ballast includes a cement filling material.

To extend the line with low-maintenance track, JR EAST successfully completed the development of the new type of low-maintenance track, by using the full-size rail track dynamic loading test machine installed in the laboratory block of the Research and Development Center of JR East. We reinforced the cement filling material by improving the composition. The performance test results of the new type of track with the improved composition confirmed the durability of the new type of track with the dynamic loading test machine. As a result, we successfully developed the new type of low-maintenance track for various load track structures.

SUPER RESILIENT RAIL FIXATION SYSTEMS TO REDUCE SQUEAL NOISE, VIBRATION AND RAIL CORRUGATION

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Keywords: Rail, fixation, noise, vibration

Metros running in a tunnel generate vibrations that propagate, through the soil to nearby buildings, causing vibrations and/or ground borne noise inside these buildings. This is aggravated by vehicles running over corrugated rails. Tramways running in streets through tight curves generally produce wheel squeal that can reach significant noise levels in the environment. In order to find solutions at the track level to reduce these annoyances, a complete dynamic study of these phenomena was carried out under the EC research programs SQUEAL and CORRUGATION. These studies are based on site measurements and numerical simulations. This has led to the development of a resilient pre-loaded rail fixation system (APT-ST system). It significantly reduces noise and vibration at the source whilst maintaining track stability. A super resilient pre-loading process has been further developed, enabling to obtain a very low dynamic stiffness (6 kN/mm) for the complete rail fixation system (APT-BF system). Three applications of these resilient preloaded rail fixation systems are discussed: squeal noise reduction in a paved tramway track (Antwerp), superior vibration mitigation in a metro tunnel (New York) and corrugation growth reduction in a curved metro track (Milan).

PREDICTION OF BALLAST RETURN FROM HIGH OUTPUT BALLAST CLEANERS (HOBC)

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Keywords: Ballast, cleaners, high output

Network Rail has recently acquired High Output Ballast Cleaners (HOBC) to increase the effectiveness and output of track renewals in the UK. One of the most important criteria to ensure efficient programming, correct application and utilisation of the HOBC plant is to accurately predict the volume of ballast returned to track and the subsequent amount of new ballast required for the renewal. Therefore, the rate of return of ballast to the track needs to be determined accurately prior to any renewal using HOBC.

This paper presents an extensive site investigation to evaluate ballast return on a planned HOBC site. Current recommended site investigation methods to evaluate ballast return, utilising trial pitting and sub-sampling are discussed. It was considered that a more rigorous approach should be adopted to identify locations along the track that give a more representative sample for ballast return assessment. It was also noted that pitting and sub-sampling is time consuming and is subject to human error. Thus, Automatic Ballast Sampling (ABS) was conducted in addition to the more traditional methods of sample recovery in a closely monitored site investigation. The predicted ballast recovery results based on both the ABS and trial pitting are compared and discussed, and the relative merits of

both techniques identified.

THE INFLUENCE OF FINES MIGRATION ON TRACKBED PERFORMANCE: DEVELOPMENT AND PRACTICAL APPLICATIONS

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Keywords: Fines migration, pumping,
trackbed, ballast, criteria, drainage,
geotextile, geogrid, blanketing sand

The migration of fines into the ballast is one of the main causes of the deterioration of track structural performance normally associated with reduction in ride quality, limiting the speed of trains and increasing the risks of track malfunctioning such as derailment.

This paper presents the development process taking place over many years including research undertaken at the University of Birmingham into the mechanisms of pumping, development of criteria to reduce pumping through to the practical application of research findings into trackbed design.

The paper shows the different mechanisms involved in the formation of slurry with and without geotextile separators and the effects of fundamental parameters such as cyclic and mean pore water pressures and cyclic and mean deformation of subgrades. The paper also comments on the difference in performance between sand blankets and commercially available geosynthetics.

The paper provides practical examples

on fines migration and how lessons learned from recent trackbed renewals can be used to improve trackbed design and reduce the ‘whole life cost’.

VERIFICATION OF XiTRACK REINFORCEMENT OVER WEAK ALLUVIAL SOILS AT DEEP WHARF LEVEL CROSSING, PURFLEET

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Keywords: Ballast, reinforcement, level crossing, alluvial soil

In this paper the application of the XiTRACK technique to the reinforcement of the foundations at Deep Wharf Level Crossing, Purfleet is presented. The paper is particularly relevant as the level crossing forms part of the Tilbury Loop Line and Coblefret Port which are among the most important freight routes in the UK. The paper describes how both the bearing strength and settlement profile of the level crossing site was improved by deepening the granular formation depth and reinforcing the ballast using insitu polymer technology to form a flexible, but resilient, geopavement. This was considered necessary as the line is built over very soft Alluvial soils which cause significant track and road maintenance problems. The XiTRACK solution provided significant savings in both construction costs and track downtime and allowed for track transitions

to be built for gradual changes in track stiffness. These issues are then discussed and verification results are presented based on actual track measurements taken both before and after treatment using accelerometers.

TRACK DETERIORATION AND COUNTERMEASURE AFTER RUNNING 10,000-TONNE HEAVY HAUL FLEET ON DAQIN COAL LINE OF CHINA

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Keywords: Heavy haul railway, railway track structure, track maintenance

Based on the practice of Daqin line, the most typical heavy haul line in China, by observing, collecting statistics and analyzing track deterioration under the special conditions of further increasing heavier axle load, traffic and rated traction tonnage, especially after regularly running 10,000-ton heavy haul trains, the study focuses on the track deterioration patterns and mechanism under the special heavy haul performances in China through field study, theoretical and computing analysis. The paper puts forward the countermeasures to retard track deterioration and brings forward an applicable track maintenance method that is suitable to the heavy haul context in China.

MODELLING DYNAMIC BEHAVIOUR OF VERY HIGH-SPEED RAILWAYS TO EVALUATE TRACK VIBRATION AND DETERIORATION

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Keywords: track dynamics, very high speed, dynamic modelling, ballast vibrations, deterioration

The new high-speed lines actually under construction in Spain are designed to enable maximum speeds of 350 km/h on commercial operation. The consequences of travelling at such high speeds may present some concerns in terms of track geometry deterioration, and thus in track maintenance costs, due to the known increase of track vibration levels. In fact, it is known that at very high speeds, ballast vibrations, together with particles friction, leads to important settlements and, consequently, to ballast deterioration and changes in track geometry quality.

This paper focuses on this particular concern by first reviewing some considerations in how the dynamic behaviour of the track has been studied till nowadays by several authors. Multiple types of ways to model dynamical behaviour of the track and its platform are exposed. With the purpose of predicting long term and differential settlements under cyclic loads with increasing speed, a variety of existing dynamic train/track models are identified and described. Furthermore, the results obtained with these models are analysed and synthesised, in order to attain several limitations and recommendations on

nowadays state on dynamic track modelling. The main aim is to dispose of the correct (and more realistic) tools to access a first indication on how dynamic behaviour of track at speeds above 300 km/h (including ballast vibration) influences track degradation. In the presence of such a tool, it would then be possible to establish limit values for new high speed lines and measures for reducing unwanted vibrations.

ADVANCED NON-LINEAR DYNAMIC FINITE ELEMENT MODELLING OF RAILWAY TRACK BEHAVIOUR

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Keywords: Railway track, finite element, behaviour, dynamic behaviour

This paper describes the numerical modelling process used in the dynamic analysis of railway track foundations using advanced 3-dimensional finite element techniques. The developed programs are shown to reproduce the dynamic behaviour of railway track using the data from real site measurements and from an example dynamic bridge problem, in which a transition track fault is simulated. The paper describes how the computer models can be used to predict track behaviour when, for example, increases in axle weight and speed are proposed or when the XITRACK 3-dimensional ballast reinforcement technique is applied to stabilise track. The constitutive models used in the dynamic analysis vary from non-linear elastic to full

elasto-plastic in three-dimensions. In addition, the paper presents the results of finite element simulations of granular soil compaction using a multi-surface kinematic elasto-plastic constitutive soil model. This model is capable of simulating the entire track loading history and hence can be used to predict the future settlement behaviour of the track when changes in track loads or speeds are proposed. The paper describes the kinematic model and presents the results of example simulations of subballast samples under both drained and undrained cyclic loading.

RESEARCH ON RATIONAL TRACK STRUCTURE STIFFNESS AND TRACK PART STIFFNESS OF PASSENGER-DEDICATED RAILWAY LINE

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Keywords: Passenger-dedicated railway line, railway track, track stiffness, track part stiffness, allowable track displacement method, track displacement distribution method

The paper describes the development plan of China passenger-dedicated railway line in 2020. The effect of track stiffness on high speed railway train is discussed. Based on analyzing the relationship of the power dissipated by displacement of the track and the vertical dynamic stresses of the unsprung weight, and also the relationship of track maintenance and ride comfort, three methods for determining track stiffness which include allowable rail bending stress method, allowable track vertical displacement method and critical speed method are analyzed. The paper indicates

that determination of track stiffness by using allowable track vertical displacement method is suitable to high speed railway track. After determination of the track stiffness, reasonable rail fastening stiffness and ballast stiffness can be calculated through distributing their displacement for ensuring transport safety and decreasing track maintenance. Applied allowable track vertical displacement method and track displacement distribution method, the track structure stiffness and track part stiffness of passenger-dedicated railway ballasted track and ballastless track are calculated. The optimal track stiffness is given.

TRACK DETERIORATION IN HIGH-SPEED RAILWAYS: INFLUENCE OF LONGITUDINAL VARIATION OF THE VERTICAL STIFFNESS IN THE EMBANKMENT-STRUCTURE TRANSITIONS

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Keywords: High-speed, track, maintenance, stiffness, embankment-structure transition

In high-speed railway lines, designing an infrastructure with the least possible cost of conservation is an important economic objective to take into account. In all railway tracks designs there arise situations in which it is necessary to introduce a structure to the track. This circumstance is even more frequent in high-speed lines where the layout criteria are stricter than for conventional lines. The introduction of a structure gives rise to the occurrence of an abrupt change in the vertical stiffness of a transverse section of the track.

This paper explains, firstly, the bearing the longitudinal variation of vertical stiffness has on the deterioration of the track and, consequentially, to the maintenance costs. Here, the embankment-structure transitions are points that are highly susceptible to suffering a great deterioration over a long period, and therefore need frequent maintenance. Secondly, the paper analyses the results of study of the Madrid-Seville high-speed line, where there has been an appreciable increase in the deterioration of the track in areas where there exist strong changes in stiffness.

Theme 1: Railway Track

Day 2:

**Concrete Slab Track +
Bituminous Track +
Sleepers/Ties**

ACHIEVING S3 OR THE DEVELOPMENT OF A HIGHLY RESILIENT HIGH-SPEED SLAB TRACK FOR THE CHANNEL TUNNEL RAIL LINK

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Keywords: Slab track, noise and vibration mitigation, high speed, railway constraints

The Channel Tunnel Rail Link (CTRL) will provide a high speed rail link between St Pancras Station in London and the Channel Tunnel portal near Folkestone in Kent. Section 2 of the CTRL comprises the main line route connecting Section 1 at Southfleet Junction and running to St Pancras in London via open routes and bored tunnels.

For the London Tunnels 1 and 2 stretching between Dagenham and the St Pancras terminal station (see CTRL Project route on figure 1), a highly resilient concrete slab track development is necessary to meet very severe vibration mitigation requirements.

This paper describes the specific approach adopted by the Alstom Transport-Carillion Rail-TSO JV (ACT JV) and the engineering works undertaken to develop a high speed slab track system providing a high vibration mitigation.

JAPANESE EXPERIENCES IN USING AND FABRICATING SYNTHETIC SLEEPER

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Keywords: Sleeper, synthetic material, durability, bridge, turnout

To ameliorate the characteristics of wooden sleeper, especially durability, and to preserve the natural environment, the synthetic sleeper has been developed and fabricated in Japan since 1980. In these twenty five years 1.3 million of sleepers are in the track replacing the wooden sleepers in turnout and on steel bridges and working as the new part of directly fastened track. About 100 thousand synthetic sleepers are supplied per year now.

They are made of hard type foamed polyurethane and continuously long glass fiber, having much more superior characteristics than the wooden sleeper. They have been automatically fabricated in the factory. It is verified that the synthetic sleeper can maintain its physical strength for more than 500years. Actually, it has been in service for 25 years.

The specialties of them are in followings: (1) High mechanical strength; (2) High resistance to rotting depending on little water absorption; (3) Small variation in form; (4) High electrical insulation; (5)

High fastening force for dog and screw spikes; (6) High weather resistance; (7) Fabrication of large sleeper with high precision; (8) Workable as well as wood and (9) Long life.

‘OLYMPIC’ TRAM IN ATHENS 2004: EMBEDDED RAIL AND FLOATING SLABTRACK FOR FAST EXECUTION OF EARTHQUAKE RESISTANT TRACK INFRASTRUCTURE

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Keywords: Slabtrack, embedded rail, earthquake, noise, vibration

The Athens Tramway is a 48km light rail system that dramatically improves the access from the city centre to the coastal region, where many of the important ‘Athens Olympic Venues’ are situated. The design and installation of this new Tram system required extreme care with regard to noise and vibration.

A simple and efficient, low noise and vibration embedded track solution, using fastener-less PREFARAIL® technology was implemented. The concept is based on the rails being completely encapsulated in an elastic jacket with special shape and stiffness characteristics.

Three types of track solution, with different track moduli, were designed to meet the relevant noise and vibration criteria:

- For receptor distances $L > 30\text{m}$ the PREFARAIL CLASSIC® system was

implemented

- For receptor distances $10\text{m} < L < 30\text{m}$ the PREFARAIL COMFORT® system was implemented
- For receptor distances $L < 10\text{m}$ the PREFARAIL COMFORT® system was used along with the CDM-DFMA-L10® Floating slab-track

The in-situ measurements showed full compliance with the specifications.

NEW POSSIBILITIES TO REDUCE TRACK MAINTENANCE COSTS ON HIGH-SPEED LINES BY USING A BITUMINOUS SUB-BALLAST LAYER

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Keywords: High-speed, track design, vertical stiffness, sub-ballast, bituminous layer.

The establishment of very high-speeds on commercial operation will be possible in a close future thanks to the improvements made both on the vehicle and track design. Concerning the high-speed track structural design, the aim is to fulfil the highest quality standards at the lowest life cycle cost. In the case of ballasted tracks, railway research has been focusing lately on the possibilities of reducing its maintenance costs. Those track maintenance costs can be very significant at higher speeds, specially if we take into account not only the ballast tamping operations, but also the frequently required subgrade improvements and the necessary renewals of track components. From a design perspective, even if most parameters are pretty well homogenised for

conventional ballasted high-speed tracks, some previous work have shown that there is still some possible optimization related to a better understanding the influence of the track vertical stiffness parameter, and the adoption of an adequate vertical stiffness for the railpads. In another hand, one of the other possible solutions to reduce maintenance costs is to improve the substructure behaviour by using other materials rather than the traditional granular layers. Following this reasoning, this paper discusses the possible interest of using a bituminous sub-ballast layer on the new Spanish high-speed lines.

STRESS MEASUREMENT IN THE RAILWAY SUBSTRUCTURE IN THE TURNOUT

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Keywords: Stress measurement, turnout, sensors

The paper is focused on the stress measurement in the railway substructure in the turnout prototype designed for a high speed. The aim of the measurement and its evaluation was to compare the results obtained with theoretical presumptions. The methods of the measurement and its evaluation are described. The conclusions of the stress in the railway substructure included its relation with the train speed. It may also be stated that the quality elaboration of the measurement considerably contributed to modern means of the signal analysis.

DESIGN, DEVELOPMENT & IMPLEMENTATION OF A HIGH PERFORMANCE FST SYSTEM FOR DIRECT FIXATION TURNOUTS IN THE ATHENS 2004 OLYMPICS INFRASTRUCTURE EXTENSION PROGRAM OF ATHENS METRO

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Keywords: FST System, turnouts, direct fixation, metro

This paper describes the prediction methods and analysis tools used to predict re-radiated noise levels in buildings above turnouts in tunnels in the new Athens Metro. The results of the analyses were used to recommend the noise and vibration mitigation measures required to achieve an internal re-radiated noise level of less than 40dB(A).

The 4 metro extensions, located in tunnels, were divided into homogeneous sections, i.e. sections along which the tunnel, soil types, depth and distance from nearby buildings can be considered as being constant. Various analyses were then carried out focussing on the turnout region in the tunnels.

A full floating slab solution over the complete length of the turnout was predicted to achieve a re-radiated ground-borne noise level of 15-16dB(A) in buildings at the soil surface. A limited floating slab solution only at the frog area was predicted to have an

acceptable noise level with the bogie in the middle of the frog area, but a level of 49.3dB(A) was on the turnout but not on the floating slab track.

CDM-ISO-DFMA floating slab track technology was used to manufacture a bespoke system called CDM-ISO-DFSA-MA-M5, COMBISTRIP; which was specifically designed to achieve the performance requirements derived from the analyses.

In situ vibration and noise measurements are presented that verify that the installed floating slab track solutions are performing as expected, with buildings very near to the source not suffering from ground-borne noise problems.

