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	DB AG	Deutsche Bahn AG	Main partner	Germany
	AEAT	AEA Technology Rail (former BR Research)	Main partner	Germany
	BANVERKET	Swedish National Rail Administration	Main partner	Sweden
	CHALMERS	Chalmers University of Technology	Main partner	Sweden
	CRONAU	Cronau GmbH	Associated partner	Germany
	TSO	Travaux du Sud-Ouest	Associated partner	France
	KASSEL	University of Kassel - Institute of Geotechnique	Main partner	Germany
	VIBRATEC		Major subcontractor	France
	IMB	Ingenieurbüro Müller-Boruttau	Major subcontractor	Germany

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1. Summary

1.1. Abstract

Granular materials such as ballast have been used for a long time to built the majority of the world's railway track. Although ballast presents specific interesting properties, degradations can be observed on ballasted tracks loaded with high speed and/or freight trains, thus leading to significant amount of maintenance or track renewal.

Understanding which parameters in the train/track interaction are responsible for this untimely degradation and being able to set criteria and limit values for these parameters are therefore necessary conditions for reducing maintenance costs and for increasing the global efficiency and the interoperability of the Trans-European railway network.

The Eurobalt II project started on September 1997 with the aim to establish an understanding of the relationships between track design parameters and long term maintenance requirements, to produce an optimised ballasted track design and to justify decisions on ballasted track versus other non-ballasted track types upon objective criteria. A partnership has been formed comprising European railway administrations, universities and railway industry participants. The project has been supported by the European Commission Brite-Euram framework.

The approach followed during the Eurobalt II project was specifically oriented towards very practical application. It relied on the hypothesis that track geometry deterioration is a direct consequence of ballast settlement and therefore a better understanding of the role of the track stiffness was clearly required.

Track assessment and monitoring requirements have been considered during the project. Banverket developed the Track Loading Vehicle into a valuable prototype assessment vehicle capable of measuring track stiffness on the move. Preliminary surveys with the new equipment have impressively confirmed the relationship between the track stiffness profile and track geometry quality.

The modelling activity has been supported by the experimental results and advanced models have been proposed to investigate a parametric study for optimising the track design and maintenance. Concluding specifications have been proposed for new construction situations but the case of most existing tracks remains open.

Thus EUROBALT has advanced the understanding of ballasted track behaviour in some potentially very productive areas. The particular objective has been achieved, in that it is now possible to relate the various vehicle and track design parameters to the long term maintenance requirements and Life Cycle Costs. Strategic decisions on the optimum solution for particular requirements, including the choice between slab track and ballasted track, can now be made based upon much more objective criteria. What is most encouraging is that large opportunities have been identified for improving the performance of many current ballasted tracks.

1.2. **Keywords**

- Ballasted track
- Track maintenance
- Train-track interactions
- Modelling
- Track stiffness

2. The Consortium

2.1. Partner organisations

The European dimension of the Eurobalt II project is represented by three different types of partners:

- Railway companies (SNCF, DB AG, Railtrack and Banverket) and a research organisation in rail technique (AEA Technology Rail)
- Companies specialised in the track construction and maintenance (T.S.O. and Cronau)
- Research centres specialised in solid mechanics and soil mechanics (Universities of Kassel and Chalmers)

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2.2. Consortium Description

2.2.1. SNCF

The Société Nationale des Chemins de Fer (SNCF) is one of the major railways companies in Europe, well-known for its high quality of services and innovative solutions in high-speed passenger transport as well as in Freight transport.

Two major departments were involved to the Eurobalt II project: the Track Department and the Research and Technology Department which is specifically in charge of the advanced studies on new transportation systems, innovative technologies and systems developments.

The role of SNCF was to coordinate the different work packages of the project, to perform well-defined track parameters measurements and to specify recommendations for the track design, the track maintenance and the values for train operations. SNCF also provided predictions obtained from models issued from the Eurobalt I project or from in-house models.

2.2.2. DB AG

DB AG is the German Railway Company which has been established after the unification and privatisation of the Deutsche Bundesbahn (DB) and the Deutsche Reichsbahn (DR).

The experience of DB AG relies on a 10000km network which is running by passenger traffic (60%) and freight traffic (40%) with a speed of 200 km/h and nearly 500km which are running with a speed of 280 km/h.

The role of the DB was mainly to make several measurements of different track parameters and to define recommendations for the track design, the track maintenance and the values for train operations.

2.2.3. AEA Technology Rail

AEA Technology Rail is the new name for BR Research following the privatisation of British Rail. The organisation has been responsible for railway research in Great Britain for many years. It now offers research and consultancy services on a contract basis to the newly privatised railway companies, including infrastructure owners (Railtrack), train operators, manufacturers and maintenance contractors.

AEA Technology Rail has also expertise in all railway disciplines, covering operations, signalling and software, and civil and mechanical engineering.

The role of AEA Technology Rail was to make measurements of different track parameters and to define recommendations for the track design, the track maintenance and the values for train operations. AEA Technology Rail also improved deterioration models issued from EUROBALT.

2.2.4. Banverket

Banverket (Swedish National Rail Administration), founded 1988, is responsible for planning, building and maintaining the Swedish railway infrastructure. The network has a track length of 10 197 km. The number of employees are 7800.

The role of Banverket was mainly to develop a new prototype, the so-called Track Loading Vehicle in order to continuously measure the track stiffness and to define recommendations for the track design, the track maintenance and the values for train operations.

2.2.5. TSO

Founded in 1927, Travaux du Sud-Ouest (TSO) is a French company specialised in the construction and the maintenance of railway tracks. Today, TSO is one of the first French companies in this field of activities. TSO has acquired in 60 years a large experience and an important know-how in the railway field, taking an active part in the development of modern railways.

One of the main concern of TSO has always been the technological innovation in order to combine quality and efficiency.

The role of TSO was to provide recommendations for the construction and the maintenance of tracks, and to bring its experience in the development of measurement methods.

2.2.6. Cronau

The company CRONAU GmbH is a German company established in August 1892. CRONAU employs today 260 persons and is specialised in the maintenance of railway infrastructure, and especially high speed tracks. CRONAU has developed also activities in the field of subsoil investigations and has invented solutions for improving the quality of the track, like special glue for ballast.

The role of CRONAU was to make investigation on the subsoil and provide recommendations for the construction and the maintenance of tracks.

2.2.7. University of Kassel

The Institute of Geotechnique of University of KASSEL is a teaching and researching centre for Geotechnique, especially for soil mechanics and foundation engineering. It has its own laboratory, and the behaviour of railway foundation is the main research emphasis of the Institute. A Research project regarding long-term behaviour of soft soil in substructure and subsoil, supported by the German Research Organisation, has started in April 1996.

The rôle of the University of Kassel was to rebuilt and extend some of the test devices for soils mechanical investigations so that the cyclic loading of soil and ballast could be simulated in the laboratory.

2.2.8. University of Chalmers

Chalmers University of Technology, Division of Solid Mechanics, has been selected by NUTEK (the Swedish National Board for Industrial and Technical Development) to form a Centre of Excellence in Railway Mechanics. About 35 faculty members and graduate students are involved in research activities including railway mechanics, structural dynamics, fatigue and fracture, mechanics of materials, finite element methods, and random vibrations. Railway mechanics has been a research topic during the last 15 years.

One of the main concern of Chalmers was to increase the possibilities of investigating how parameters such as speed, axle load, wheel base of a bogie, rail corrugation, pad stiffness, ballast stiffness and damping influence the stationary and transient vibrational behaviour of track and vehicle components.

The role of Chalmers University was the improvement of the train-track interaction model so that calculations of track vibrations and dynamic forces acting between wheels and rail could be performed.

2.2.9. Major subcontractors

2.2.9.1. VIBRATEC

VIBRATEC is an industrial RTD French company of 27 employees specialised in research and studies in acoustics and vibration. Main activities are the diagnosis of noise and vibration on existing equipment, and the design of low-noise solutions. At present, more than 25% of VIBRATEC's turnover is performed in the railway field. VIBRATEC co-operates with ERRI, SNCF, London Underground Ltd, RATP (Paris Underground), T.C.L. (Lyon Underground) on noise and vibration issues. Vibratec participated actively to the measurement campaign, especially on ballast settlement measurement, and proposed methods for continuous record of the track stiffness.

2.2.9.2. IMB-Dynamik

IMB is an industrial RTD German company specialised in research and studies in acoustics and vibration. Main activities are the diagnosis of noise and vibration on existing equipment, and the design of low-noise solutions. IMB was commissioned by DB AG.

2.2.9.3. ERESMAN

ERESMAN is a French company specialised in advice and assistance to industrial or research organisations in the domains of RTD Project organisation and management. ERESMAN has a dedicated experience of the management of European projects (especially in the Brite EuRam programme) in the area of Research for Ground Transportation systems, especially railways and automotive. ERESMAN contributed to the organisation and the management of the Eurobalt II project from September 1997 September 1999.

2.2.9.4. SEGIME

Filial of Altran Group, SEGIME is an engineering consulting company comprising more than 500 consultants who partners leading European companies in both the industrial sector and service industries. SEGIME is involved in EUROBALT II project since July 2000. The main contribution of SEGIME was to manage the completion of the final stage of the EUROBALT II project.

3. Technical Achievements

Granular materials such as ballast have been used for a long time to built the majority of the world's railway track. Ballast is well-known for its specific properties: limitation of sleeper movement, water drainage, load spreading, alleviating water frost problem, vegetation growth restriction, absorption of the shock due to dynamic load and capability to modify track geometry using manual or mechanised maintenance techniques. However degradations can be observed on ballasted tracks due to the static and dynamic loads applied during high speed and/or freight train passages, leading to significant amount of maintenance.

Understanding which parameters in the train/track interaction are responsible for this untimely degradation and being able to set criteria and limit values for these parameters are therefore necessary conditions for reducing maintenance costs and for increasing the global efficiency and the interoperability of the railway system.

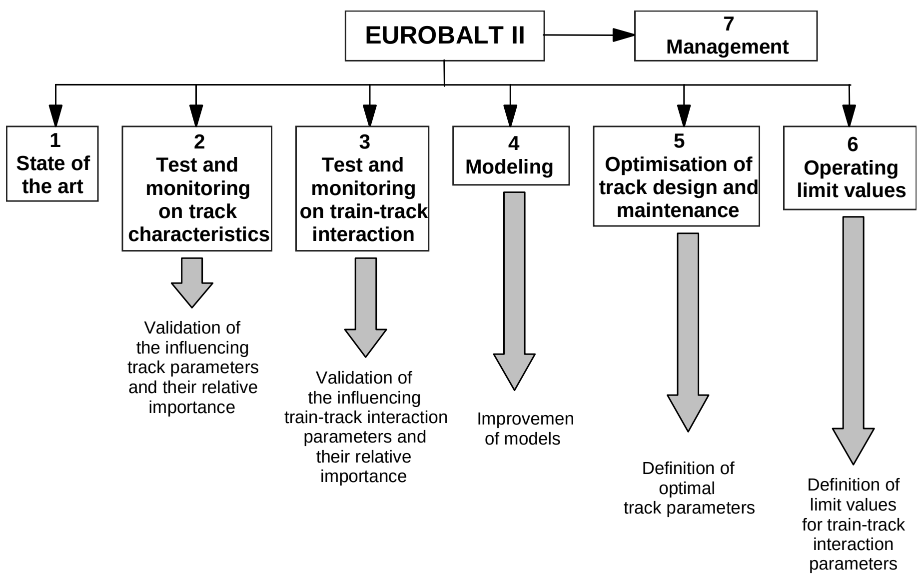
The Eurobalt II project started on September 1997 with the aim to establish an understanding of the relationships between track design parameters and long term maintenance requirements, to produce an optimised ballasted track design and to justify decisions on ballasted track versus other non-ballasted track types upon objective criteria. A partnership has been formed comprising European railway administrations, universities and railway industry participants. The project has been supported by the European Commission Brite-Euram framework.

The approach followed during the Eurobalt II project was specifically oriented towards very practical application, i.e. the only parameters which have been investigated are those that can be readily controlled in the design/construction phase or in every day monitoring conditions. It relied on the hypothesis that track geometry deterioration is a direct consequence of ballast settlement and therefore a better understanding of the role of the track stiffness was clearly required.

The purpose of the project was not just to understand the intimate behaviour of ballasted track, but:

- At first, to identify the main influencing parameters that can and must be measured by maintenance staff to detect developing flaws and acted upon to reduce track geometry damage.
- Secondly, to make modelling and monitoring tools available in practice to allow experts to control these parameters and to improve design and maintenance of the track.

The Eurobalt II project has been structured as follows:



A state-of-the-art review and an intensive study on main parameters that could influence the track behaviour enabled to identify the most relevant parameters that have to be monitored, viz. track stiffness, displacement of sleeper, settlement of different layers of the track structure (ballast, sub-ballast and sub-grade).

3.1. Results of the measurement Campaign

Test and monitoring of the relevant parameters have been performed during the Eurobalt II project. The most important measurements that have been performed as basis for maintenance, upgrading and traffic planning are:

- Rolling measurements of the track stiffness along the track from the Continuous Track Loading Vehicle hold by Banverket (TroLV), complementary point measurements with the Track Loading Vehicle (TLV) and the Falling Weight Deflectometer (FWD) and geotechnical investigations at specific sections.
- Track geometry quality from the Track Recording Car (TRC)
- Traffic conditions (accumulated tonnage, axle loads, speeds … etc)
- Static and dynamic loads with traffic load detectors.

Track stiffness is know to be representative of the track behaviour and is generally used to relate the track deflection to the magnitude of the loads distributed on the track. However, a better understanding of the role of this parameter is required to determine more precisely how much elasticity is desirable within the ballast and subsoil.

Track stiffness has been therefore widely investigated during the course of the Eurobalt II project and measurements were made using a large variety of techniques, namely:

- Banverket Track Loading Vehicle: a purpose built vehicle able to load the track statically and dynamically through hydraulic actuators. This device excites the track with a vertical force simulating the forces which act upon the track when a real train loads the rail and is capable of measuring track stiffness while moving (currently up to 30km/h).
- Falling weight deflectometer: an adapted road pavement testing device measuring a simulated passing wheel load response.
- Track load and deflection measurement under a train passage.

A total of nineteen test sites (each typically 200m long) were selected across the various rail administrations for monitoring (France, England, Sweden and Germany) . These sites were chosen to represent different track quality from good to poor without obvious cause for the difference stated. Some reference measurements were undertaken at the beginning of the monitoring period, including rail surface profile (from Track Recording Car) as well as track stiffness, and in most of case a geotechnical survey was carried out. Sufficient overlap of the measuring devices on the various test sites chosen meant that the results obtained from each measurement techniques could be compared.

It should be noted that some of the test sites were newly constructed. On these, settlement was evident in the formation and in the ballast whereas on the long established sites the settlement was only in the ballast, the formation having long since stabilised.

Relying on the on-site measurement results, it had become apparent that track stiffness increases when increasing track load and that this parameter could not be considered as constant along a portion of track but could vary from good to poor track geometry quality, good track having generally high and reasonably constant stiffness whereas poor track is less stiff and more variable. The reasons are complex but the biggest single cause is variation in the sub-soil properties. Moreover, in comparing the measured track stiffness, it has been established that British test sites have the lowest stiffness whereas French site Ressons has the highest stiffness. German site using soled sleepers has similar stiffness to the British and the Swedish sites.

One of the objectives of the Eurobalt II project was to investigate the effect of changing track stiffness on the track geometry degradation by means of ballast settlement rate. Track geometry quality is typically measured by using Track Recording Car. The periodic recordings of the standard deviation of vertical track geometry enable to recover the history of the track and to decide whether maintenance is required to correct track geometry. Standard deviation is obtained by means of summarising the average roughness of an individual short track segment (typically 200m in length).

In case of maintenance intervention, the resulting track can then provide a very smooth ride, thus higher ride comfort, for the passengers. Periodic measurements have shown that the track standard deviation increases with time. The deterioration is initially rapid and then stabilises to an almost constant rate as the ballast consolidates.

An important factor which is responsible to the deterioration of the track is the accumulated tonnage (traffic load) applied to the track. It was therefore interesting to estimate the influence of track stiffness and traffic load on ballast settlement rate. Measurements showed that low track stiffness as well as low traffic load give quite high settlement rates. When the traffic load gets higher the settlement rate increases. It has been possible to find a relevant relationship between track stiffness and settlement rate for high traffic load (typically over 20MGT) showing that a theoretical optimum track stiffness does exist. Unfortunately, when track is subjected to traffic load lower than 20MGT the on-site measurement results are very scattered and thus no representative relationship could be found.

In term of standard deviation, it can be concluded that, for a given traffic load, low value of track stiffness render quite high standard deviation and that this result is amplified with increasing the traffic load. As expected the best (viz. the lowest) standard deviation is obtained for the highest track stiffness.

Investigations on train-track interaction have also been carried out during the Eurobalt II project. Different interaction parameters such as axle load, train speed or wheel unevenness are known to be strongly responsible of the track deterioration and thus have been investigated. Altogether three different track constructions located on the German newly built high speed line Hannover-Berlin were instrumented. The measurements were obtained by monitoring the short term response of the track subjected to typical controlled conditions. It has been shown that the sleeper displacements initially decrease with rising speed. However, for typical speeds of 280km/h and higher the sleeper displacements are increasing. Referring to the damping present in the system the contrary results could be assumed, however some relevant peaks of the displacement frequency spectrum approach the wheelset superstructure resonance frequency thereby reversing the tendency.

Furthermore, experimental measurements have shown that out-of-round wheels and flat wheels cause non negligible dynamic effects on track and train vehicle. In the same way as rail irregularities, such as welds, wheel irregularities cause dynamic forces. It is worth mentioning that the sleeper forces can increase more than two times of the static value if the magnitude of the wheel defect is over the limit (viz. >0.4mm for ICE German high speed train wheel).

Further investigations have shown that contact force due to train with uneven wheels is nearly independent of resulting unbalanced mass. However, when excitation frequency of out-of-round wheel coincides with natural frequencies of train-track superstructure, critical resonance phenomena may occur additionally to the dynamic effects.

3.2. Modelling achievements

The experimental programme on ballasted track has been used to further develop models that were already available from the initial Eurobalt I project (September 1992 to August 1995), namely:

- Dynamic train-track interaction model (DIFF Chalmers model),
- Track geometry deterioration model(LONG7 AEA TR model),
- Soil/ballast behaviour model (CTRC Kassel model),

and in particular to validate these models and to quantify the parameters to be used in the models.

The modelling activity performed during the Eurobalt II project had for objectives to provide a better understanding of the experimental results obtained from the short term and long term measurements and to carry out parametric studies which allow to quantify the weight of each influencing parameters required for optimising the track maintenance.

The dynamic train-track interaction model has been further developed in order to better model the inertial effects due to ballast and sub-ground mass, and to account for track component with non linear characteristics such as, e.g., rail pad, ballast. The model relies on finite element techniques and only considers the vertical dynamics of the vehicle and of the track system. Good agreement was obtained when comparing the predicted and on-track measurement time response of a passing bogie. The parametric study performed with the linear and non linear variant of the model allowed to conclusively notice that ballast material has a damping characteristic that appears to be velocity-independent.

The track geometry deterioration model, LONG7, hold by AEA Technology has also been further developed in such way that the amount of geometry maintenance required for particular track and operating conditions could be efficiently predicted. The development relied on the quantification of the relationship between track stiffness and settlement from experimental results. The model has been successfully validated for established tracks, but not for the newly built tracks in their early life and for typical sites made of peat or soft clay, for which a more empirical approach seems to be still required. It can be used to predict accurately the long-term maintenance requirements for a track with specified parameters.

A more fundamental model of the behaviour of layered soils has also been developed to cater for the new construction situation. This particular model has so far had limited validation, but potentially offers the ability to predict soil and ballast settlement as well as to pursue the settlement relationships from a fundamental rather than an empirical “black box” approach.

Moreover, a new laboratory test device combining the resonant column test and the cyclic triaxial test (CTRC) in a single unit has been developed and can be used to investigate static, dynamic and cyclic material properties of granular materials and ballast. The results obtained from the experimental device have been confronted to those predicted from a Finite Element Model in which a quasi-static approach for granular materials and ballast under cyclic loading was implemented. Quite reasonable agreements between measured and predicted settlement have been found. The results obtained with the CTRC device looks very promising and further investigations are planed to get a better understanding of soil/ballast behaviour under train passing-like loads.

3.3. Optimisation of track design and maintenance

With the newly developed models and the range of parameters measured in the test programme, it has been possible to carry out a full parametric study covering various operating conditions from high speed passenger to medium speed passenger mixed with heavy freight. The results showed the importance of the various track parameters in determining the long-term maintenance requirement and facilitated the writing of specifications for the various values to be achieved. As well as the critical importance of the track stiffness, requirements for rail surface profile and formation and ballast level were also derived. Vehicle parameters are also relevant, of course, and criteria for vehicle parameters such as axle load, unsprung mass and suspension performance can also be considered if required.

Different methodologies have been proposed for deciding track maintenance or ballast renewal operations. One way, typically used nowadays, consists in comparing the standard deviation of vertical geometrical default with international normalisation. This approach can be qualified as prospective since track quality is obtained by analysing recently monitored data and is unable to accurately predict maintenance for the long term. Furthermore, it has been shown that track maintenance “lift” could make the track less effective. Eurobalt II measurement results have shown indeed that maintenance operation drastically modify the track stiffness and thus, as relevant parameter, track stiffness should be taken into consideration for maintenance purpose.

The Eurobalt II project has allowed to propose a new making decision tool enables to avoid such a problem induced by maintenance operation. The new approach is based on taking into account both standard deviation obtained from TRC and track stiffness measured from, e.g., TLV rolling method or FWD method. A relationship between the track stiffness index obtained from the specific transfer function used for the TLV and the standard deviation measured for various test sites has been developed. The results showed that the relation is broadly parabolic thereby optimum track quality could be theoretically obtained. In practice, the results showed that for obtaining a required track quality various track stiffnesses can be proposed but a single one leads to the best track quality. It is therefore of importance to compare actual track stiffness to the optimum required one. For instance, a tamping operation loosening ballast layer is relevant if and only if the track is stiffer than the optimal track stiffness value. On the other hand, a tamping operation leading to stiffer track will be relevant if track stiffness is lower than the optimal track stiffness value otherwise worse track quality could be obtained.

3.4. Track recommendations and specifications

From the parametric study, it has been possible to propose a series of track and vehicle parameters that will give the optimum track geometry behaviour and minimise the maintenance. However, the values assigned to the parameters could also determine other track deterioration mechanisms such as rail fatigue, sleeper loading, ballast degradation. It will be therefore important to study these aspects also. It should be mentioned that other factors, e.g. noise and vibration transmission, have not been specifically considered and that the optimum for these requirements may also be different.

Furthermore, total costs have been expressed in the form of average Life Cycle Costs (LCC), i.e. the average annual maintenance cost plus the periodic renewal cost. Various categories of deterioration and associated maintenance/renewal have been considered, such as:

- Tamping for geometry maintenance
- Rail fatigue defect repair and rail renewal
- Sleeper renewal derived from structural deterioration
- Ballast degradation and renewal

The results obtained from the Eurobalt II project have demonstrated that building a track from an optimised set of parameters can result in significantly reduced life cycle costs. Current high speed lines appear to be, on average, near to the optimum design. The most cost-effective application of the Eurobalt II findings is likely to be in the area of track assessment and ballast renewal decision making.

The models developed during the Eurobalt II project also allowed to produce specifications for new construction situations that will deliver optimum solutions, but the question remains as to what to do with many existing tracks which may be shown to be sub-optimal in design. This was foreseen in the project and a range of possible formation and track structure treatments were identified as being potentially beneficial. These ranged from geogrid ballast reinforcement through increased depth of construction to soil stabilisation and piling methods. At present, these have only been assessed on a theoretical basis, but plans are already advanced to carry out trials to quantify the potential improvements and costs of work. Although long term maintenance costs will be saved, the cost of doing the work and the time taken need to be established to be certain that there is a positive Net

Present Value for doing the work. The financial criteria for carrying out such an assessment will inevitably also depend on the circumstances.

4. Exploitation plans and follow-up actions

The strategy of exploitation foreseen by Railway companies may differ on certain aspects but they all intend to make use of the results of Eurobalt II project by:

- Entering a standardisation process for the interoperability of high speed trains for passenger traffic or for the mixed traffic.
- Applying models for the optimisation of the track construction and maintenance, according to own rules and types of traffic.
- Applying technical solutions in the domains of monitoring, track design, vehicle criteria, to further optimise their own specifications, technologies and maintenance methods, in full agreement with standardisation process.
- Determining the most favourable combinations of formation, ballast, pad and rail bending stiffness, with respect to track degradation.

4.1. Banverket

Banverket, being an infrastructure owner and administrator, is continually seeking new knowledge and better methods for the development and maintenance of the track. In view of this, the rolling track stiffness measurement method and equipment will be developed in the future to make them more reliable and efficient. The technique needs to be further validated and the trolley needs further development to make measurements possible in curves, for instance.

Banverket is intending to perform more extensive measurements of track stiffness on the Swedish tracks, possibly a major part of the railway net will be surveyed in the future. The discontinuities in or sudden change of track stiffness will be measured and used to indicate problem areas along the track. The relationship between track stiffness, track quality and track maintenance will then be used to minimise the costs for track administration, maintain the correct track quality and last but not least increase safety on railway tracks.

4.2. AEA Technology Rail

Railtrack and AEA Technology Rail have some different business objectives and will exploit different aspects of the EUROBALT II findings.

For Railtrack, as an infrastructure owner, the main benefits will come from exploiting the new understanding of the relationship between track construction design parameters and long term maintenance costs. The quantified numerate relationships and models will permit the introduction of an optimum track renewal specification.

Opportunities also exist for AEA Technology Rail in its three main areas of business:

- Consultancy
- Software
- Products and Services

The LONG7 track geometry deterioration model has been validated and could now be offered for consultancy services, with a decision being made in the future on whether to carry out the further developments to sell the model directly. It is more likely that the developments made with this prototype model will be incorporated into other production software, such as the prototype Track

Usage Model being developed for Track Access Charging purposes and associated models. This model is being developed for the privatised UK railway industry, but is likely to be relevant to other railway administrations.

The WITMS (Wheel Impact Transportable Monitoring System) tested during EUROBALT II has now been successfully developed into a range of products and 14 of these systems have been sold within the UK and elsewhere in Europe. Sales opportunities therefore now exist outside Europe also.

AEA Technology Rail will be examining the economic case for developing these systems and opportunities also exist here for collaboration with other EUROBALT II partners who have already done work in track stiffness and rail surface profile measurement.

4.3. DB AG

DB AG is actually using the results from Eurobalt II and their own models for prediction of long term behaviour of ballasted track. No technical solutions/products are available so far for their exploitation.

However, further investigations for the development of useful technical solutions and statistically assessment procedures are planned. These investigations will be used to better understand the long term behaviour of track and to specify limit values for operation and new specifications for building ballasted tracks in an innovative or new way.

4.4. SNCF

SNCF is intending to perform further measurements campaign on the French north high speed line to confirm the conclusions obtained from Eurobalt II project as well as to improve track degradation laws used to link the standard deviation of vertical track default, the track stiffness and the sub-layers formation modulus. The results will be used to work out a new standardisation of the track maintenance depending not only on the track geometry evolution but also on the track stiffness. Therefore the new standard will enable either prospective or predictive maintenance operations and will allow to improve the quality of the track: more comfortable tracks for passenger and freight trains as well as better safety at higher speeds and heavier train loads. An important economical impact is expected as preventive/predictive maintenance would produce significant benefits.

SNCF Research Department will use new knowledge and practical experience gained within Eurobalt II project for the validation of advanced simulation models owned at SNCF , e.g. to further develop the Rail Ballast 3 Dimensional model (RB3D), and to include the parameters identified as the most influencing parameters include into these models.

4.5. Kassel University

The University of Kassel is intending to make use of the know-how acquired through Eurobalt II project to reinforce their capabilities of expertise in Railways-related research. This know-how could be used by Railways-related engineering consulting offices and companies inside or outside Europe.

The strategy followed by Kassel is firstly to find new partners and financial support for on-going research:

- To enhance the constitutive knowledge on granular and ballast materials
- To improve and validate the numerical model issued from Eurobalt II

- To further disseminate the scientific advances gained through this project

4.6. Chalmers University

Being an university, the main purpose of Chalmers is to produce and to spread new knowledge. The program development works performed at Chalmers University and the findings from the newly developed computer program have been presented and published in several different manners:

- Results and reports have been presented to the project partners at the Eurobalt II meetings,
- Program developments and results have been presented at international conferences,
- Papers have been written and published in international scientific journals.

The computer program developments, including verifications and simulations, will be part of the PhD thesis by Johan Oscarssson who will defend it in January 2001.

Chalmers does not intend to try selling the computer program actively, but it can be made available for anyone who requires it. For instance, the program has already been implemented at the research office of the Swedish National Rail Administration, Banverket.

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