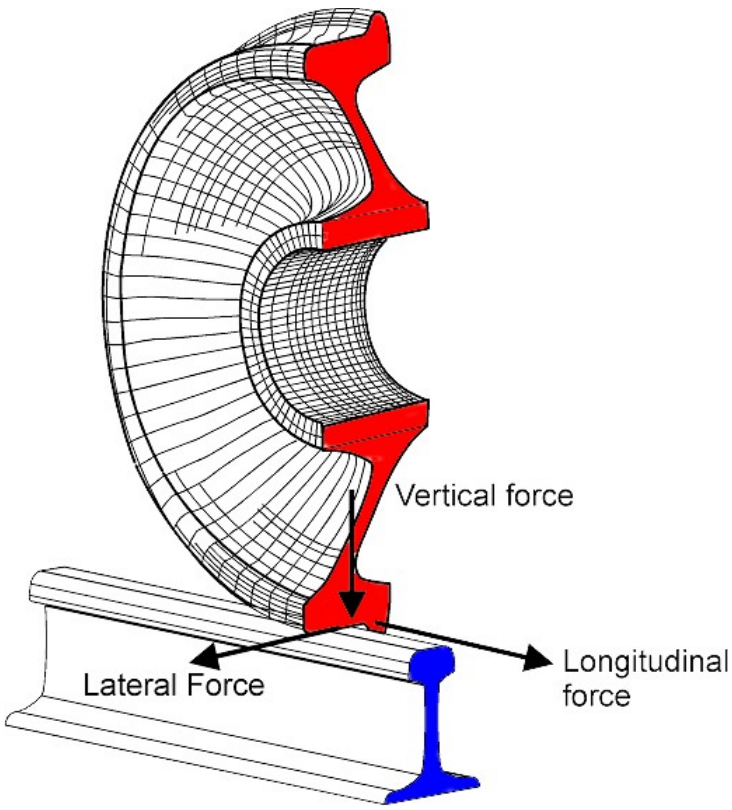
The Strength of the Track

Farewell Speech

Coenraad Esveld

Professor of Rail Engineering



12 September 2007

The Strength of the Track

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delivered on September 12, 2007

by

Prof.dr.ir. Coenraad Esveld

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Mr. Rector Magnificus, Members of the Executive Board,
Fellow professors and other members of the university community,
Family members and friends,
Highly valued listeners, Ladies and Gentlemen.

Introduction

When I took office on 1 August 1993, we were on the eve of two major railway projects: the Betuweroute and the HSL-Zuid. This certainly contributed to making rail engineering a separate chair. Before that time, this field of expertise was covered in public transport engineering group under the responsibility of Maurits van Witsen.

The rail construction sector actually has two interests in this chair:
1.Delivering civil engineers with a rail engineering background;
2.Conducting high-quality research that responds to current and structural problems.

This requires broadly trained engineers on the one hand and PhD students specialized in exact subjects on the other. This remains a kind of split within civil education. The majority of PhD students come from outside TU Delft, part of Mechanics and only a few from their own cultivation, moving on from the Masters.
In my opinion, the research is the most important aspect for the long-term viability of this chair.

Education

Rail Engineering has been struggling for years with a relatively small number of students in the Bachelors Masters programme. Incidentally, we are not the only ones within TU Delft. That is why I think that a better marketing strategy will have to be developed at TU-wide that responds to the needs of the market. Professors will not have to carry out this process themselves, but will have to support the professional marketing organization.

Within an elective, all majors must be of approximately equal weight. At the time, a very unbalanced distribution had arisen within Infrastructure. Many times more had to be performed for rail engineering than for infrastructure planning, for example. This is also evidenced by the number of graduates who were certainly a higher order in infrastructure planning.

In my opinion, it would be good if TU Delft would regularly give courses, as far as I am concerned in combination with lectures, to which the business community would also have access. Conferences with a commercial entrance fee would also be good for TU Delft and for business life. After all, high quality will have to be delivered because otherwise there will be no participants.

I have always had trouble with institutes such as Delft Top Tech and PAO. They basically let the professors and their staff do the work for a marginal fee and collect the revenues themselves.

Nowadays, a good presentation on the Internet is of vital importance and a primary marking tool. The main site of the TU looks nice but is mainly focused on finding support services. However, faculties and research groups are difficult to trace. The sites of the various research groups now form a motley collection of designs, and it would be good to introduce a professional standardization.

Research

When I took office, several spearheads for research were defined, such as:

1. High axle loads for heavy goods transport, also in the context of the studies for the Betuwe route;
2. Track dynamics and interaction with rolling stock, particularly in view of the HSL South studies;
3. Innovative track constructions such as the embedded rail;
4. Decision support systems and Life Cycle Management;
5. Track stability and longitudinal forces aimed in particular at interaction with bridges.

Ad. 1. was immediately honored with a donation from the Beek committee, whereby the influence of the then dean Johan Blaauwendraad should not be underestimated. This contribution was used to finance the HASLAST (High Axle Loads) project, which resulted in the promotion of Akke Suiker for the track section and Zili Li, under the supervision of Joost Kalker, for the wheel-rail section.

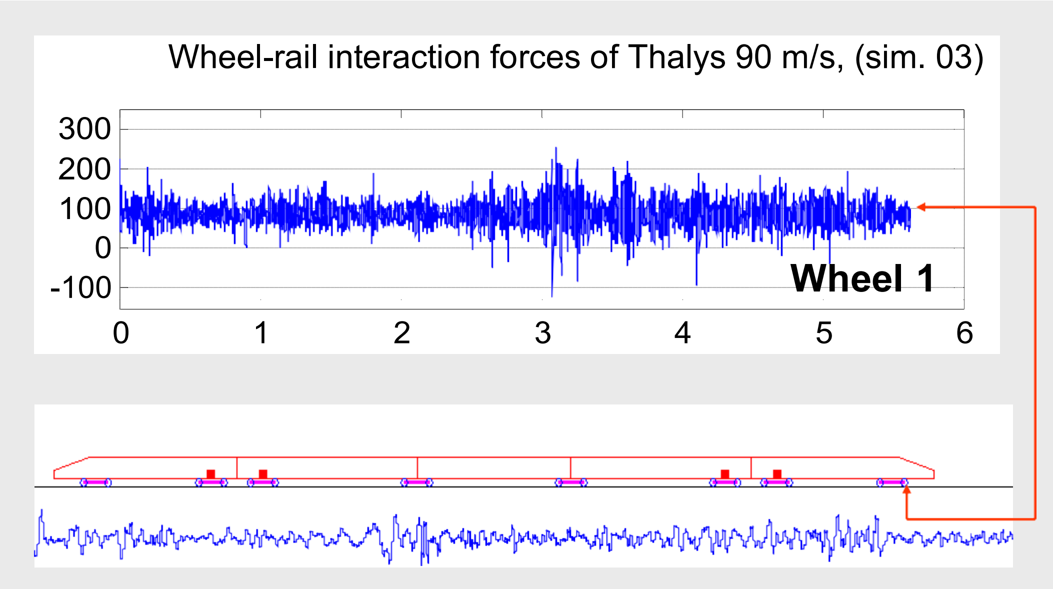
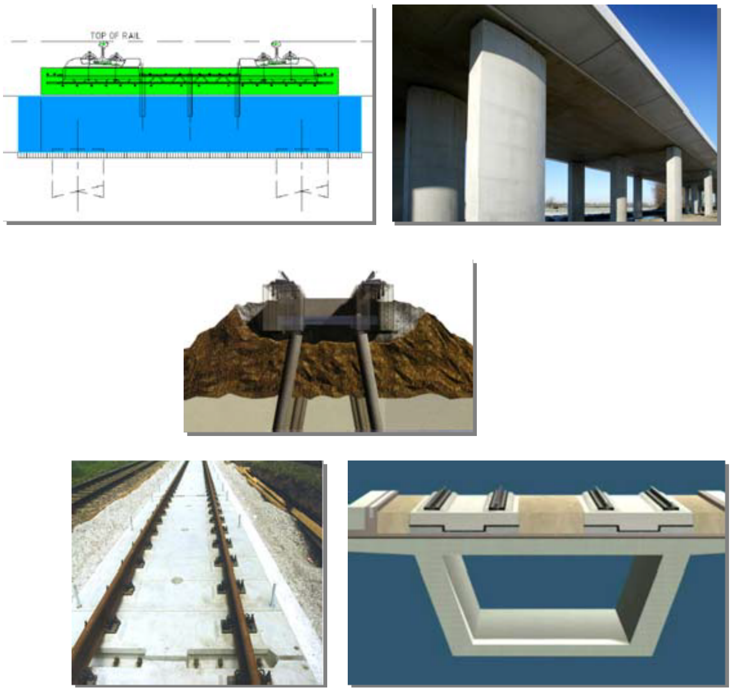


Figure 1: DARTS Dynamic Analysis of Railway TrackS

Ad.2. Various studies have been carried out for the HSL, ranging from wave propagation studies in the track construction and the substructure, longitudinal forces in the jointless track, to the complete dynamic analysis of the vehicle – track system. Most dyna-mica analyses were made with the DARTS (Dynamic Analysis of Railway Tracks) program developed by Anton Kok, which has since grown into an international standard.



- HSL-Zuid, Infraspeed
  - 2001 – Tender
  - 2004 – Final Design
- Neue Feste Fahrbahn
  ThyssenKrupp (2005)
- Feste Fahrbahn
  Max Bögl (2006)

Figure 2: HSL-tracks designed with DARTS

With this, many HSL constructions have been calculated, including for the HSL South, various variants of Rheda 2000, Max Bögl prefab track and new rail systems from Thyssen Krupp.

Figure 3: Hamer test on embedded rail track at Best

The dynamic behaviour of track structures has been investigated and systematised through the DYNATRACK project, on which Amy de Man obtained her PhD, here in the photo behind the lab top. In this research, both the classic constructions and the ballastless solutions were examined, with a great deal of attention also being paid to the embedded rail construction. A method has been developed to assess structures on the basis of their dynamic response, both via calculation models and experimentally with the help of an excitation hammer.

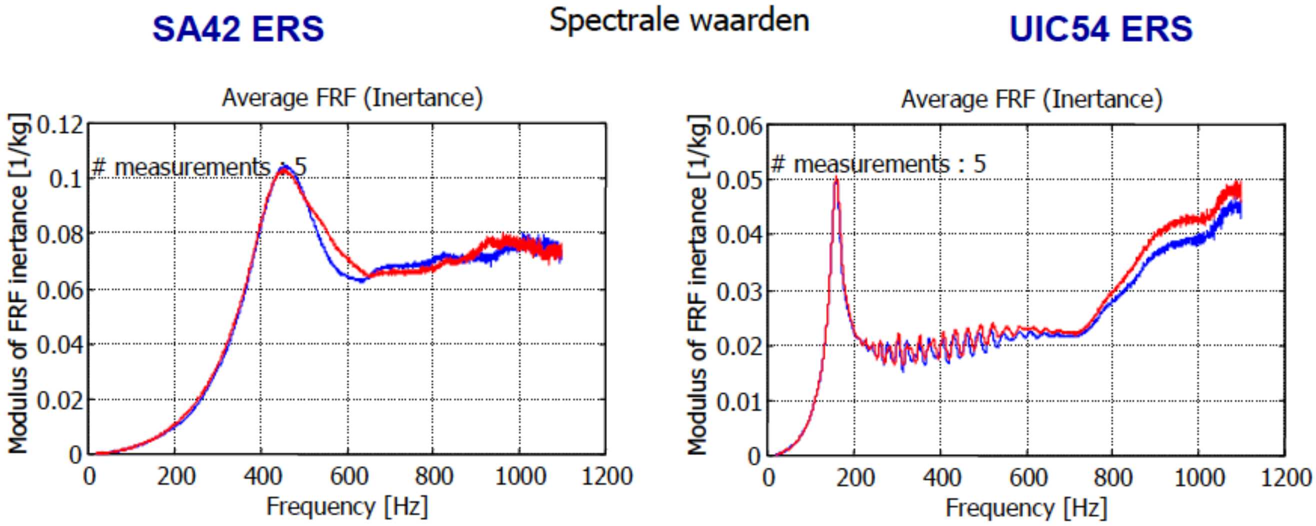


Figure 4: DYNATRACK results

Here are some characteristic graphs of the response in the frequency domain.

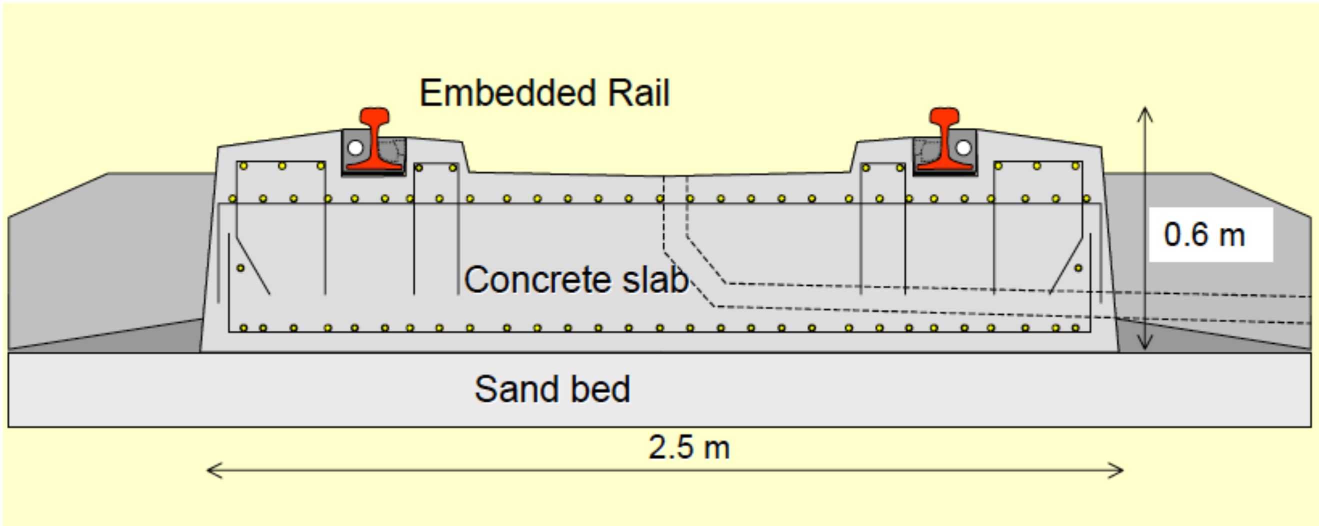


Figure 5: Embedded rail track at Best

To. 3. The embedded rail solution was initially a favourite for the HSL-Zuid, but had toin the end, they lost out because the financiers did not accept this solution. The The reason was of course simple: there was no practical experience at an operational speed. from 300 km/h. This means that the application of innovative solutions remains a difficult issue. The railway world is fairly conservative and really only wants 'proven technology'. I think that the application of advanced models and pilot trajectories improve this. could bring. However, the Dutch industry here has, in my opinion, a huge miss an opportunity. One should at least have been able to conclude the prestigious HSL-Zuid a test section of, for example, one km in embedded rail lay.

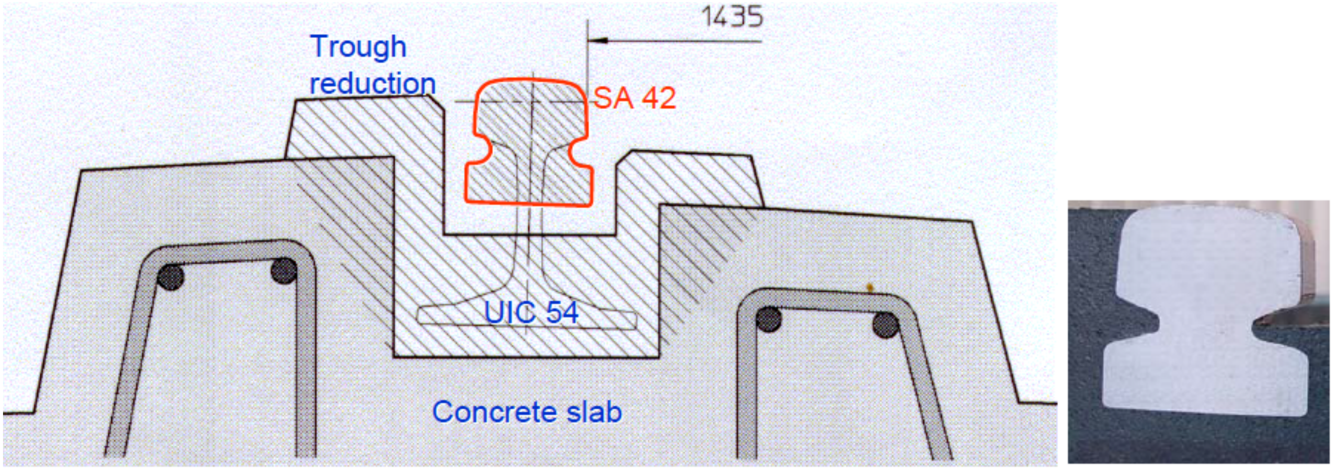


Figure 6: Low-noise SA42 rail

As part of the quieter train traffic project, which was led by ProRail, a number of knowledge institutes have developed a ballastless track structure as one of the subprojects, which produces 5 dB(A) less noise than the classic ballast construction. Led by Jelte Bos of Movares and with a large contribution from Marcel Janssens of TNO/TPD and Amy de Man of TU Delft, the ingot SA42 rail that you see pictured here came out. A beautiful innovative solution: quiet, slim, low construction height and considerably cheaper than the standard embedded rail. It is a pity that ProRail never used the construction after the Best pilot project. This is incomprehensible!

Figure 7: ERIA: Embedded Rail in Asphalt applied at HTM

The SA42 solution is of course also very suitable for light rail and metro. Of more recent date is an application of embedded rail in asphalt, or ERIA for short, at htm in The Hague. This was an SA42 rail in a steel gutter. We had insisted on the production of a variant without a steel gutter, but with polyurethane around the rail that is about ten times as strong as asphalt and much less sensitive to high temperatures. But the asphalt barons did not think that was a good idea and have cleverly managed to keep this variant out of the door.

Figure 8: Life-cycle cost: ballast or ballastless?

Ad.4. When making decisions for maintenance and renewal, it is important to have the right information and to base considerations on life cycle costs. In large new construction projects such as the HSL-Zuid, life cycle considerations were also an important factor in the choice of system components. In collaboration with Applied Public Administration, Arjen Zoeteman carried out a major study for, among other things, an HSLconsortium led by Strukton, the European Rail Research Institute (ERRI) and Pro-Rail, which ultimately resulted in a PhD.

Figure 9: LONGSTAB: Longitudinal force calculation bridges

Ad. 5. An international success is the Longstab (Longitudinal Forces and Stability) program for the analysis of stability and longitudinal forces, which was originally developed as CWERRI by Meindert Van as a PhD research for ERRI committee D202. You can see here as an example a concrete railway bridge from Korea for which the longitudinal forces could be determined with this program.

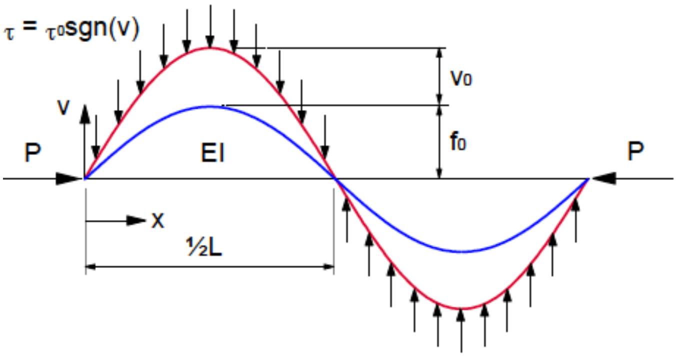


Figure 10: LONGSTAB: Stability analyses of CWR

The program has been used in ERRI research to tighten up the European regulations for joint and bound railways, in particular the risks against rail splashes. Later, this software was further developed within the rail engineering group by Valeri Markine and can now be regarded as an international standard.

New research

In recent years, the focus of the research has mainly shifted to mechanical engineering aspects. I would mention here, among other things:

- Contact mechanics;
- Optimization of the geometric interface between wheel and rail.
- Wheel-rail dynamics;

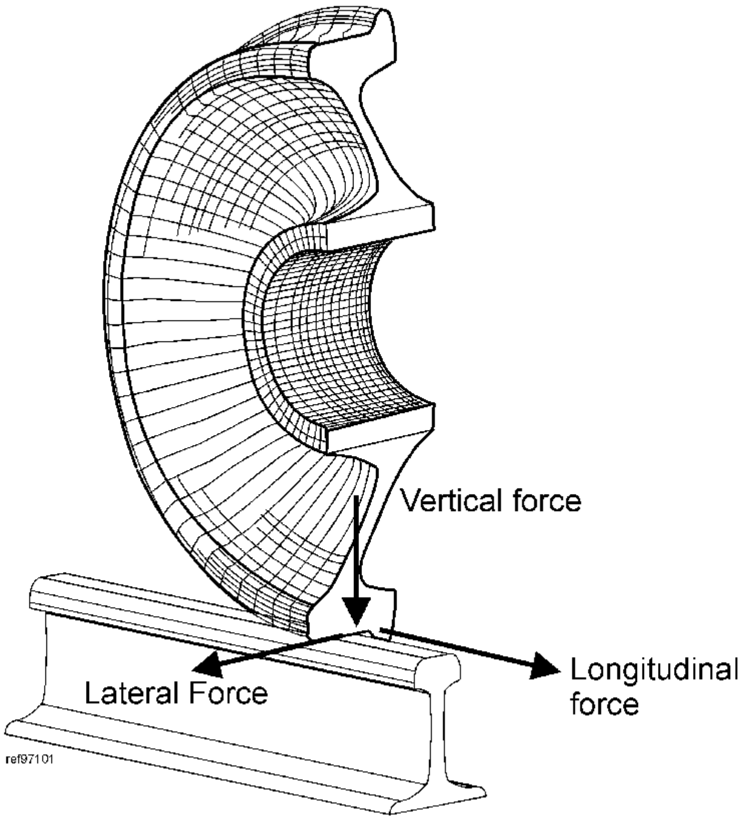


Figure 11: Wheel-rail forces

The expansion of our staff with Zili Li made it possible to respond to a large need of ProRail for more fundamental research related to the contact mechanism, say the square centimeter of the contact surface between wheel and rail.

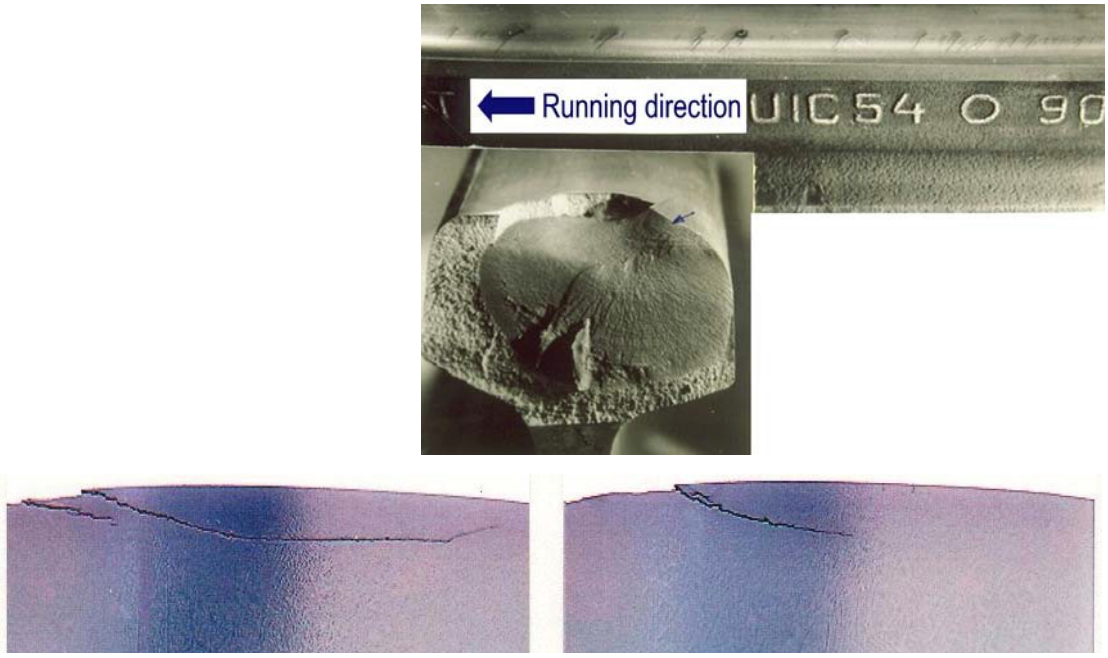


Figure 12: Headchecks

The problems initially focused mainly on headchecks, of which you can see an example here. The first major European research, led by David Canon, dates back to the beginning of the nineties. Now, many years later, it is beginning to become clear how the mechanisms for the development of RCF work. The bogies and in particular the transfer of the starting forces to the track play an important role. The con-tact geometry also has a major influence, with small changes appearing to have large effects in both positive and negative senses.

Figure 13: Grinding train on HSL-Zuid

By adjusting the rail geometry via grinding, the contact points can be shifted, reducing the problems, usually temporarily.

Figure 14: Squats

A problem already identified by Canon are the squats, as seen in this photo, which are now manifesting themselves on a large scale in the ProRail network. These are plastic deformations in the vertical direction and seem to be related to local deviations in the material properties on the one hand and overloading due to imperfections in the rail geometry on the other. The research within the rail engineering group focuses in particular on modelling the dynamic excitation and correlating axle box speeds with geometric deviations of the rail head.

Rail engineering also participates in ProRail's very ambitious ADREM project for combating slippery spores due to leaf fall. This research also includespart the universities of Wageningen and Twente.

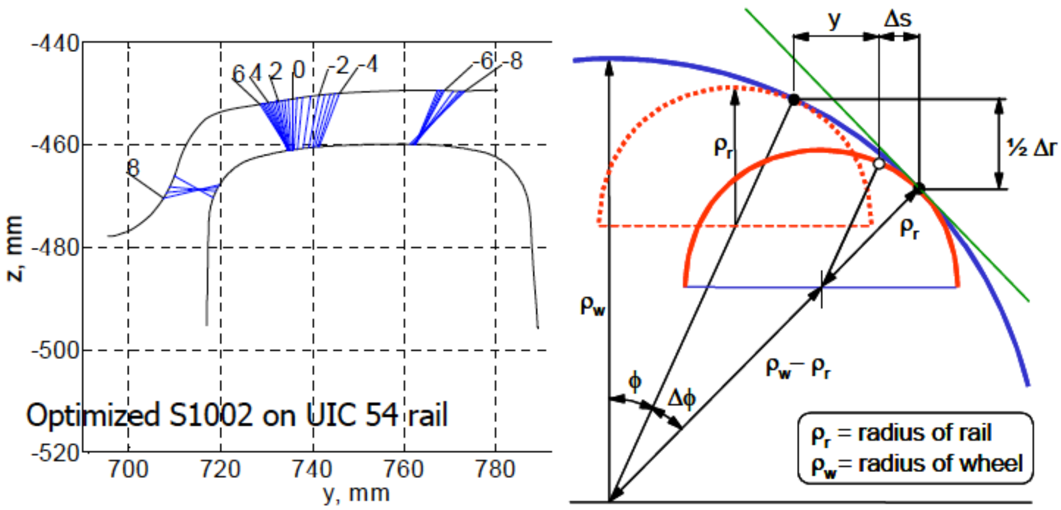


Figure 15: Optimization wheel-rail profile

For a stable running of the train and to limit the contact voltages between wheel and rail, a good conformity of wheel and rail profile is a prerequisite. However, the profiles are not stable and change over time due to wear and tear. Determining the optimal profiles is a complex matter on which Ivan Shevtsov hopes to obtain his PhD in the not too distant future. Here you can see the contact points between wheel and rail in case of lateral wheel movement. At the end of the optimization, control calculations are carried out with the vehicle dynamics package ADAMS Rail.

Figure 16: Track recording cars

Measuring has always played an important role in the quality control of the track, because measuring is knowing. Already during my NS career I have been fully engaged in quality systems for processing and analyzing measurement and registration data. In order to register the track geometry nationwide, the Mauzin car of the French Railways was initially hired.

Later, with the help of the Vehicle Technology department at TU Delft, we developed a measuring vehicle ourselves: the BMS system. In the current time with the rapid technological developments, it is unthinkable to build and maintain such systems yourself.

Figure 17: Eurailscout

This market is now largely in the hands of specialized companies such as Plasser & Theurer, Eurailscout and MerMec.

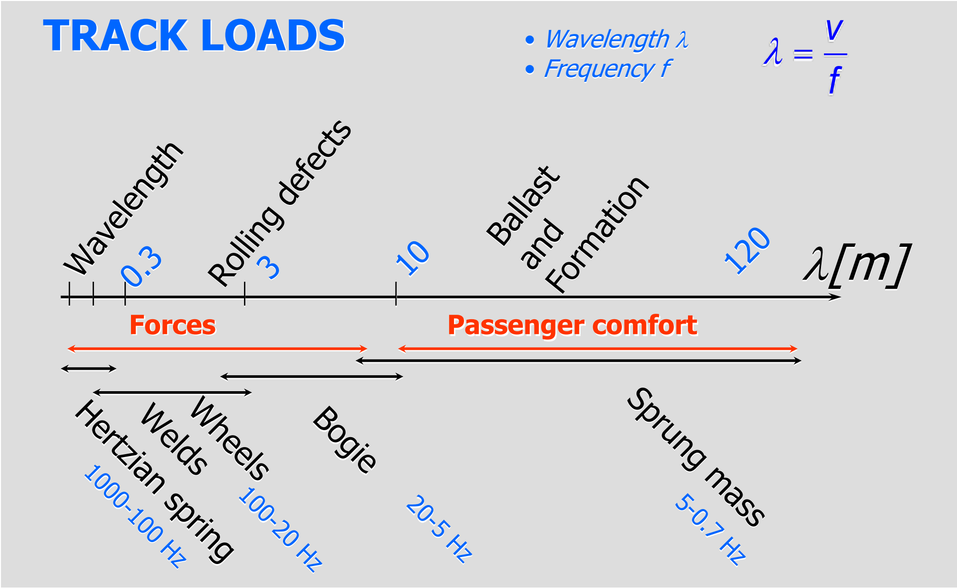


Figure 18: Track loads versus wavelength

The track recording cars initially focused on long waves in the track, order 10 – 150 m, which are responsible for the excitation of the car bodies and therefore determine the passenger comfort. An omission in these systems is that they do not take sufficient account of the short waves of roughly 10 m and shorter. These are precisely the main reasons for the dynamic track loads and therefore the strength of the track which should be mobilized and have a direct impact on issues such as sustainability and life-cycle costs.

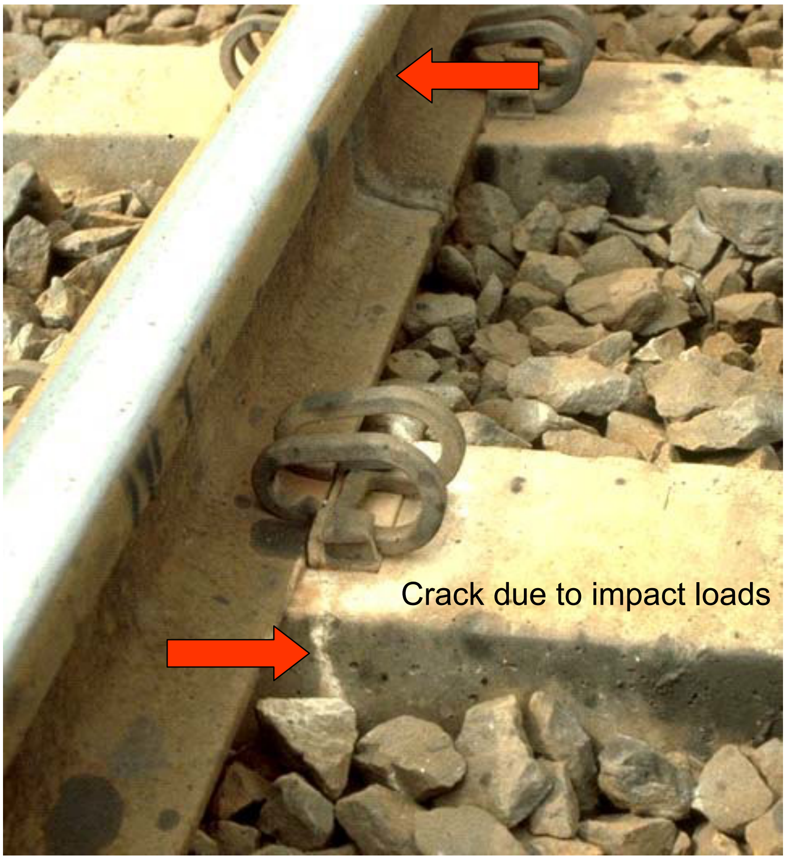


Figure 19: Poor welding geometry

The maintenance statistics show that a rapid deterioration of the track is usually caused by poor welding geometry, of which you can see an example here.
But the aforementioned RCF defects also provide an increasing share.

$$F_{dyn} = C * v^2 \frac{dz}{dx}$$

$$HSL: \frac{dz}{dx} \leq 1:1000$$

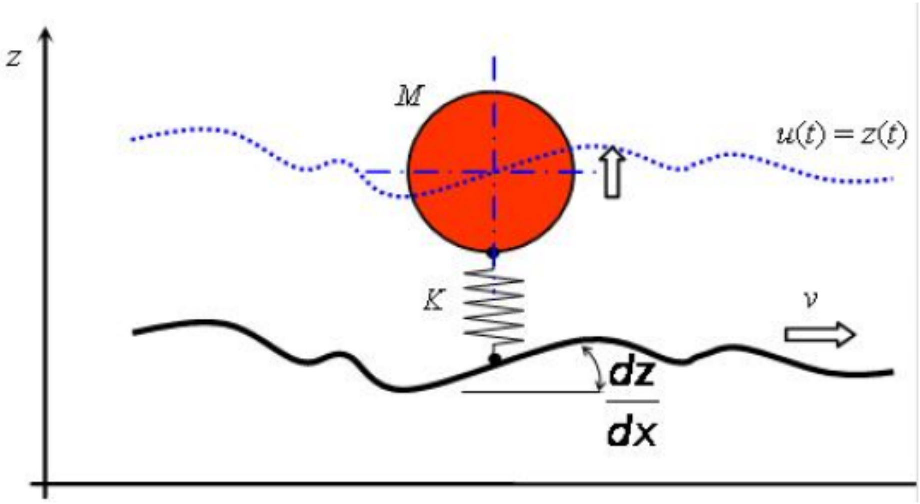


Figure 20: Dynamic contact force

In my time at NS, I started researching the influence of deviations in welding geometry on the lifespan of the track construction. The development of theory has the last years received a strong impulse thanks to the PhD research of Michaël Steenbergen. This work has also scored high marks outside our national borders and has recently been crowned with two international prizes. Within this research, TU Delft has developed new welding geometry standards for ProRail, based on limiting the dynamic force between wheel and rail. The first derivative, or slope, of the longitudinal rail geometry appears to be a normative measure for this. You should think of a slope of 1 milliradian, or 1:1000, for a weld applied in the track of the high-speed line.

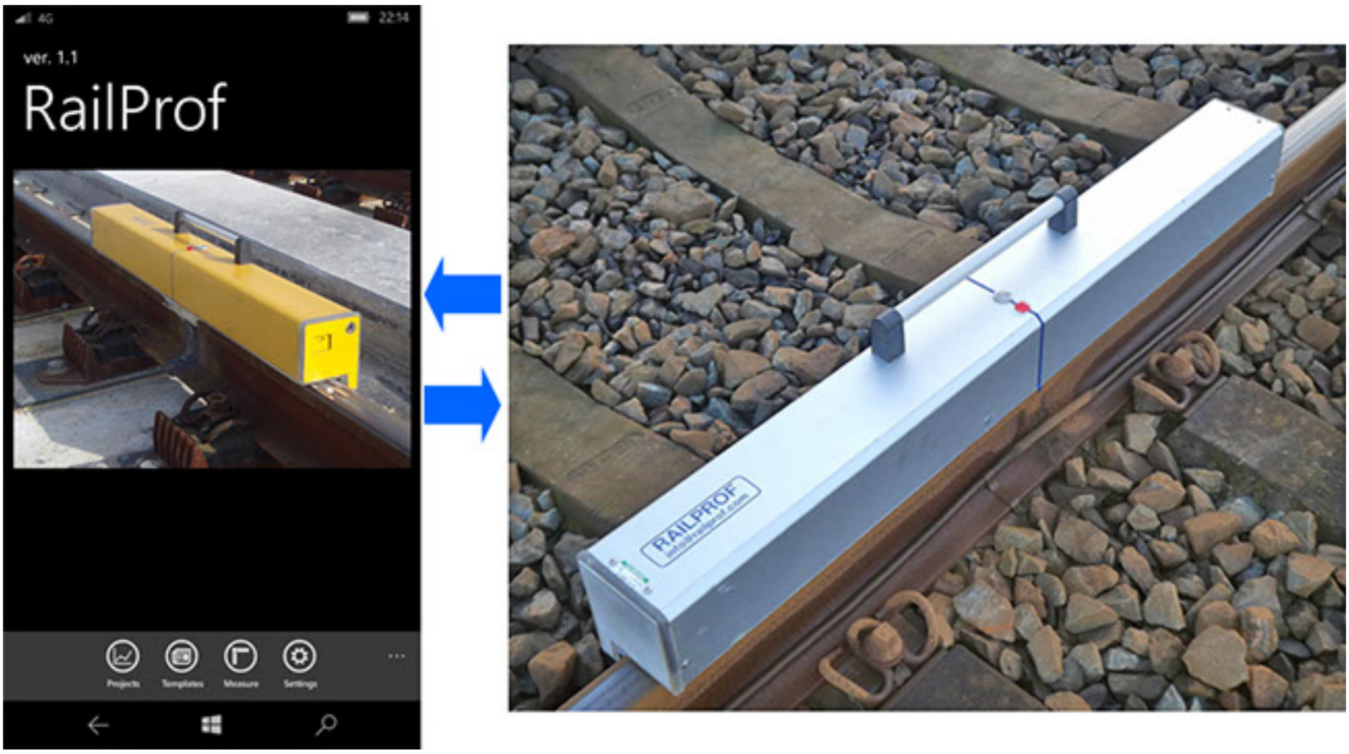


Figure 21: RAILPROF with PDA

A standard without measuring instruments for control and enforcement is, of course, a paper tiger. I realized this all too well when I was responsible for welding quality at NS at the time. During that period I came into contact with Dirk Hulshoff Pol, with whom I have worked closely in recent years in the development and realization of the RAILPROF. With this instrument, the vertical and horizontal welding geometry is measured and analyzed simultaneously. The control is done by a pocket PC in which the data are retrieved, analyzed and assessed according to the aforementioned standards on the basis of the first derivative.

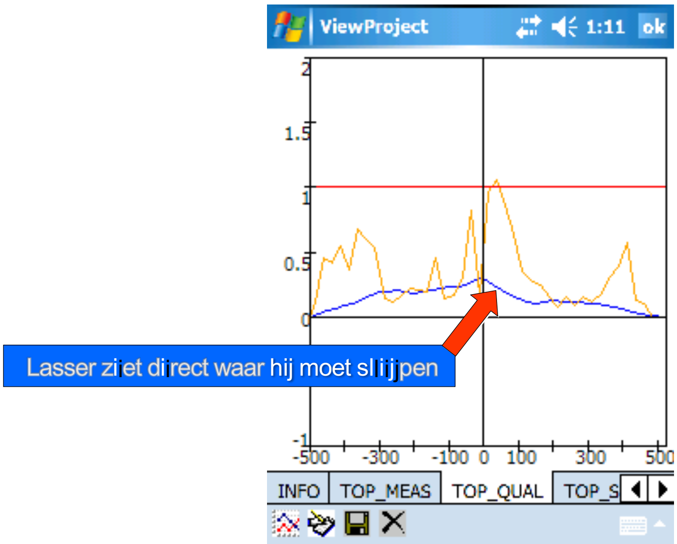


Figure 22: PDA screen

On the PDA, the welder can immediately see what is not in order and where the weld needs to be sharpened even further. You can see here that the norm is exceeded as a result of a slightly too large slope.

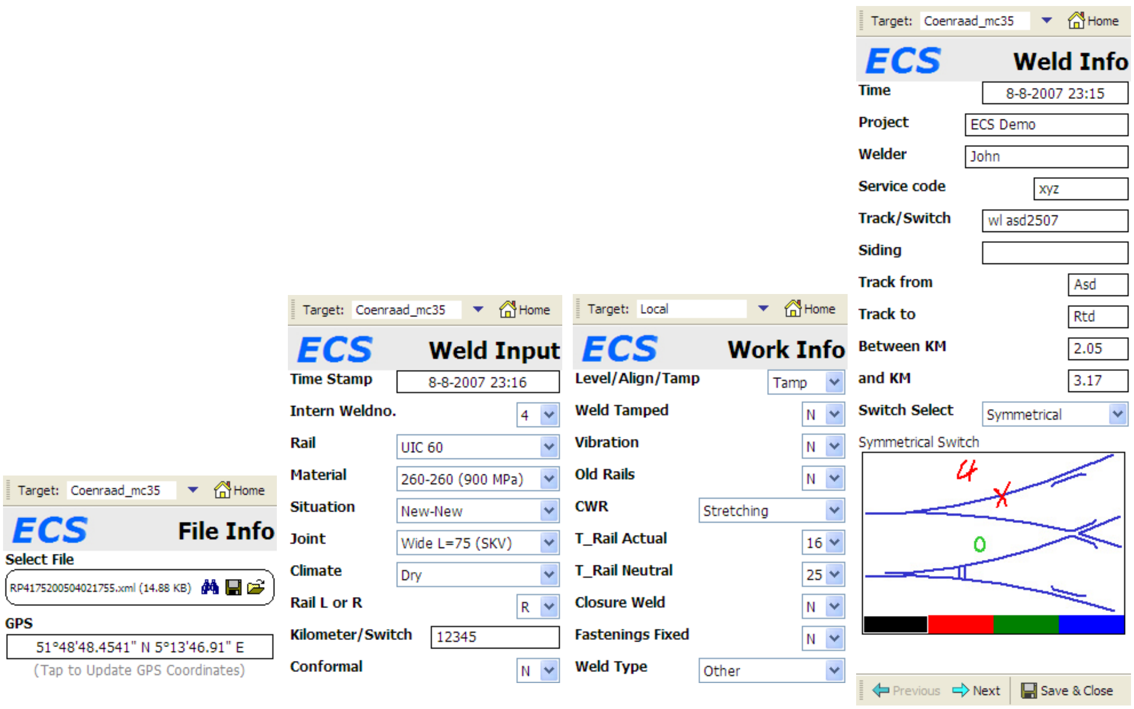


Figure 23: Welding registration via PDA

The latest development is to enter all data requested by ProRail for welding registration into the PDA. The GPS position and the measurement file of the RAILPROF are also registered. This data is then sent wirelessly to a central server via GPRS.

The problem with the measurement of welding, especially for the HSL, is of course the measurement cue which should be about 10% of the norm, i.e. 0.1 mrad. The accuracy at arrow value level is around 5 microns. This places extremely high demands on the sensors and can only be achieved via a non-contact measurement. The principle is based on eddy current, so that the measurements are virtually insensitive to rust, dirt and moisture. It has always intrigued me that in the coarse material environment of the railway such accuracy is necessary and also feasible.

Figure 24: Welding control HSL-Zuid

Infraspeed has checked all welds of the HSL-Zuid according to this standard. One of the great advantages of the new standards is that no distinction is made between positive and negative welds, while under the old guidelines negative welding is rejected. The contractors are very grateful to us for this. However, I would like to plead for ProRail to put the new welding standards on the international agenda, for example to get them included in the TSI.

General considerations

Figure 25: Construction Rheda 2000 HSL-Zuid

At the moment you see a tendency to apply more ballastless track, especially with high-speed lines. The Rheda2000 system, which has also been applied in the Netherlands, scores very well internally. Here you can see a picture of the construction of the Rheda track on the HSL-Zuid.

Figure 26: Construction Shinkansen track Taiwan

The pioneers in this field were the Japanese with their Shinkansen slab track, applied here to the HSL of Taiwan. In practice, these constructions are satisfactory, but they are far from optimal and extremely laborious when adjusting and building.

Most ballastless structures are only competitive with ball-load track at high annual tonnages. The problem is that they are actually developed according to principles from road construction, say as an element pavement without bending stiffness. When applied to an earth orbit, the full load-bearing capacity and resistance to settlement differences must be derived from the subsurface. In countries with poor soil conditions, this leads to enormous costs for soil improvement.

Figure 27: Slipform Paver

For the ballastless solutions on an earth orbit, only a continuous bending rigid plate is competitive, such as the aforementioned plate at Best, especially when using efficient construction methods with, for example, a slipform paver.

On structures, the track can be applied to the concrete deck via a direct attachment. The cost savings are then not only in a cheaper track, but also in a lower load on the artwork and a reduction in the construction height.

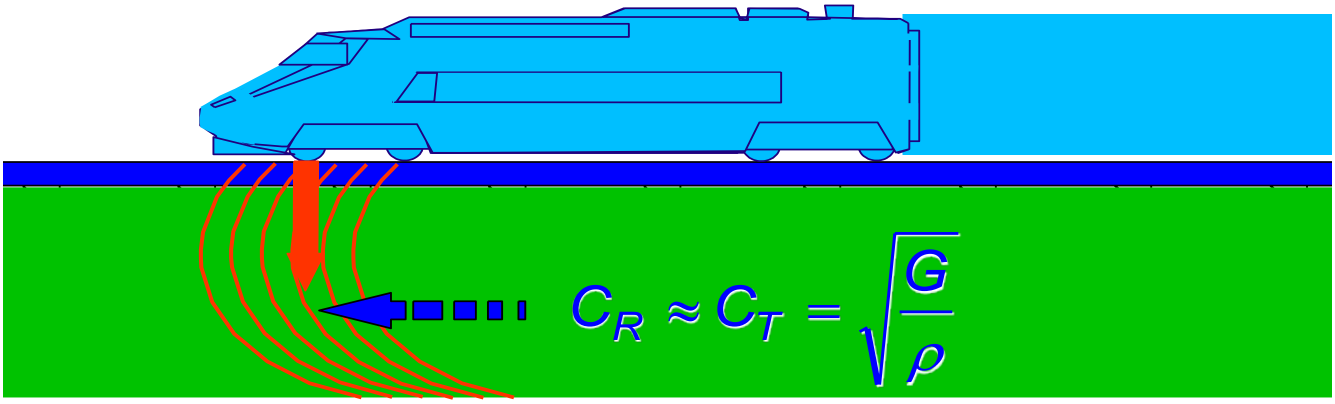


Figure 28: Rayleigh waves in soft ground

When applying to an earth orbit, it will also be necessary to look carefully at wave propagation phenomena, the so-called Rayleigh waves that have partly led to the HSL South opting for a concrete track.
There are still great opportunities for TU Delft to carry out research into the optimization of the entire railway structure, including substructure and subsoil.

Figure 29: Bridge Hollandsch Diep

We have already talked at length about high-speed lines. Despite the fact that the embedded rail construction did not go ahead, the HSL-Zuid project has led to an impressive higher speed line that we as the Netherlands can be proud of. Here you can see one of the showpieces: the bridge over the Hollandsch Diep.

Figure 30: Drilling tunnel Groene Hart

I have always been very surprised about one aspect and that is the tunnel under the Green Heart. Well, a drilled tunnel in weak ground is indeed a tour de force, but to make such a mega expense for the benefit of some farmlands with some grazing cows on it, who might have found it very interesting to occasionally see an HSL flash by, is in my opinion completely out of proportion. Then I would have preferred to solve bottlenecks in our road network, for example a tunnel under Eindhoven for the A2.

The strength of the track, ladies and gentlemen, remains, in my view, unabated. Of course, it will be possible to develop and optimize the necessary technically. I am thinking of lighter rolling stock – it is curious that current passenger trains still carry more than 80 % of their own weight. But also lighter and more cost-effective rail structures, better inspection and quality control systems and further implementation of information technology, are topics that can be mentioned in this context.

Figure 31: Transrapid

I would also like to point out the application of new technologies such as the magnetic levitation train. There have been plans for years to get the Transrapid off the ground in Europe, without much success.

In my opinion, it is undoubtedly the system of the future with a number of salient advantages:

1. Operating speed 450 km/h;
2. Non-contact, so no friction, wear and high dynamic loads;
3. No vibration nuisance;
4. Low noise pollution, so hardly any costs for noise protection;
5. Rapid acceleration and braking where the energy can be returned to the system;
6. Safe, because in the same block the trains can only go one way.

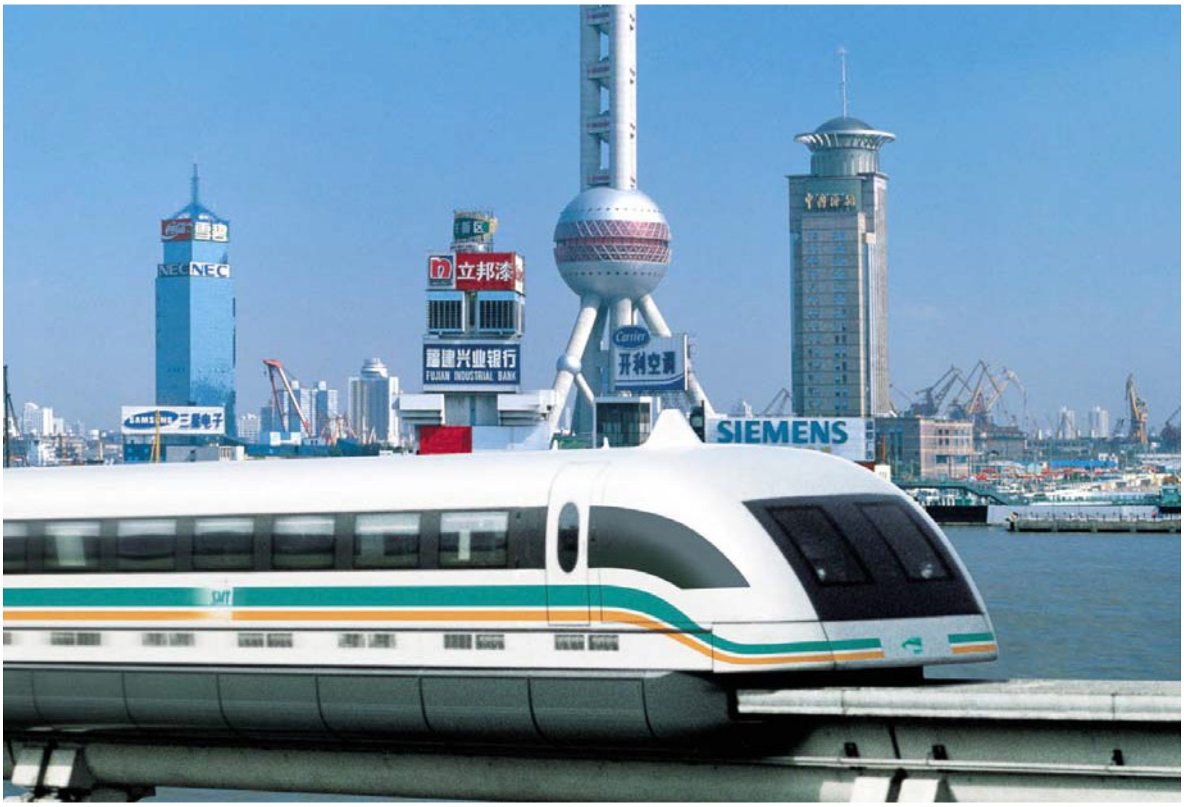


Figure 32: Shanghai project

In contrast to Europe, decision-making in China is different, and in any case much faster. A first section of about 35 km has been built there at Shanghai and there are full plans to apply this technique on a large scale.

Figure 33: Traffic jams

Finally, a few more about traffic engineering developments. The Netherlands silts up is a common complaint. The damage to the environment and the economy runs into the billions every year. But still nothing is happening, at least far too little, to be able to cope with the problems in the short term, but especially in the long term. Because more asphalt is politically sensitive, especially on the left. Member of Parliament of Zuid-Holland Ronald Waterman has calculated that with 2 extra lanes over 1,200 km, the traffic jam problem can largely be solved. You are talking about a space take of less than 0.03%. However, The Hague wants to get us on public transport at all costs, but you also prefer to go by car, don't you? At least I do, unless an attractive alternative is really offered.

Well, back to the university and the possibilities we have at TU Delft to think along and provide new concepts for solving the Dutch traffic problems. All modalities will have to be considered and looked at in full, namely: roads, railways, waterways, air transport, transport pipelines, data networks. Specifically in railway engineering, attention will have to be focused on new technologies such as magnetic levitation, new materials, as well as energy supply, telecommunications, and safety control. TU Delft has in-house expertise in all these areas, and it is therefore mainly a question of how to mobilize and manage this knowledge. Perhaps it is an idea to set up an interfaculty institute for railway engineering, with civil engineering, mechanical engineering, and electrical engineering as primary stakeholders, with which practically the entire field of railway engineering would be covered.

Finally

Ladies and gentlemen, this brings me to the end of my speech. I would like to thank all the people I have worked with in recent years. These are, of course, primarily the employees of the chair of rail engineering with whom I had direct working contacts and all other colleagues from the traffic engineering section, the colleagues within the Faculty of CISH, but of course also all external relations. I greatly appreciated the symposium, preceding this speech, and I would like to thank in particular the speakers Prof. Klaus Riessberger, Prof Manuel Melis and Ir. Peter Meijvis for the contribution they have been willing to make.

Last but not least, I would like to express my appreciation for my wife Margriet who has always been a great support to me in my work.

Although I am saying goodbye to TU Delft today, I will remain active in the railway world through my company Esveld Consulting Services. Of course, I am very curious who will be my successor and wish him or her good luck in advance. Given the wide range of subjects and the broad support from the railway industry, this promises a good future for the chair of rail engineering.

Thank you for your attention!