

Jettisoning ballast en route to the next millennium

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Railway engineering has been a traditional discipline for over hundred years. Most developments were based upon experience and progressed thus very slowly. Recent proposed new railway structures and new applications make the traditional empirical approach ineffective. To support the new developments much more research, both experimental and numerical, is required. This paper gives an overview of the role of TU Delft in the projects that were carried out in this field.

Key words: railway research, HSL, slab track, DYNATRACK, noise reduction.

1 A brief history

For more than a century and a half, ballasted track has remained the standard. The only changes have been improved rail steel quality, elastic fastenings and concrete sleepers. Continuous welded rail has been introduced, and maintenance/replacement procedures largely mechanised.

Recent decades have seen the development of high speed lines for up to 300 km/h, together with a world record of 515 km/h. Axle loads have also risen over the years, albeit primarily in “heavy haul” freight operations outside Europe; heavy haul systems use axle loads of up to 350 kN, as against the 225 kN common in Europe.

The absence of competition, together with the closed structure of the traditional railway companies, has for many years kept the scientific level of railway research relatively low. Developments were largely empirical, frequently resulting from a “trial and error” approach. Much was measured, little was modelled.

2 Recent developments

This empirical approach – which often demanded years of field trials – is no longer suitable. If rapid results are to be obtained, a much more detailed understanding is needed of both dynamics and material behaviour. That such an approach is indeed capable of yielding spectacular results in a short time was demonstrated by the development of a quiet track design as part of the STV project (STV = *Stiller Treinverkeer*, or “quieter railways”). Using advanced modelling and testing methods, a track design was developed in scarcely more than a year that produced 5dB less noise than tradi-

tional ballasted track[1]. The track in question consists of a concrete slab with two embedded SA42 rails. This type of block rail is approximately half as high as a traditional rail. Figure 1 shows an element model of the rail plus embedding compound.

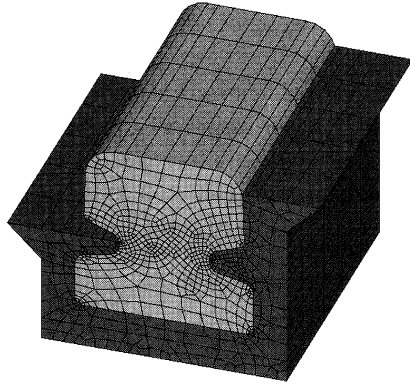


Fig. 1.



Fig. 2.

Doctoral research [2] is currently under way at the TU Delft as part of measures to develop better tools for assessing the dynamic performance of track structures. The DYNATRACK system developed in the course of this study will allow a design to be finetuned for a specific application. Over the years, little or no attention has been paid to systematic optimisation, leading to many of the structures currently in service being overdimensioned. Optimisation is currently one of the central elements in rail infrastructure research at the TU Delft [3]. Work here is addressing not only the construction aspects, but also such areas as life cycle costs, resource allocation, availability and controlling the damage caused by rail traffic.

Track maintenance specifications are meaningless unless conformity with them can be verified. This requires advanced measuring equipment. To a certain extent, such equipment is already available, but some is still under development. One example of equipment currently under development is the High Speed Deflectograph [4], a device for measuring the track modulus – the ability of the track to bear load. Figure 2 shows a test setup at the TU Delft.

3 New trends

The start of a new millennium coincides with a complete change of direction within track construction, moving from traditional ballasted track to unballasted systems. Embedded rail – originally a Dutch invention – will be one of the success stories in this field. Such designs require a high degree of compatibility between the components – rail, concrete slab or other supporting structure and subgrade. The latter may consist of earth, a slab supported on piles or a structure.

Studies carried out for the HSL-Zuid (the high speed line between Amsterdam and Antwerp) have shown that ground wave propagation issues render it impossible to simply lay a track structure on top of soft ground, such as that found in the west of the Netherlands. For the HSL-Zuid, therefore, the decision was to use a structure supported on piles.

Various life cycle studies [5,6] have shown the combination of embedded rail and a concrete slab to be at least 20% cheaper than conventional solutions. And that figure does not even take into account the savings possible due to increased availability or the reduction in bridge/tunnel costs due to the resulting decrease in weight, height and tunnel diameter. The costs linked to these parameters are generally significant when compared with the costs of the track itself.

Given the new market structure, the importance of availability is set to grow, and with it the advantages conferred by unballasted track designs. This applies not just to new track, but also to existing track, where the subgrade is generally well compacted. The stable subgrade means that differential settling is unlikely and hence that laying slab track should, in principle, be problem free. First, however, studies will have to be carried out. Priority will have to be given to main line and urban tracks, and it will be an absolute requirement that this rebuilding work take place during the track possessions available.

Equilibrium designs

Equilibrium structures have long been a feature of highway design. The principle is that the total weight of the structure may only be fractionally greater than that of the soil excavated. This limits the increase in subgrade grain stress and hence the settling. Work has been carried out at the TU Delft on application of this principle to track structures, using EPS (expanded polystyrene) [7]. The use of EPS transpired to be particularly promising for new track on soft ground, when adding additional tracks to existing lines and in the case of the transitions at bridge ends. A layer of EPS in combination with slab track proved to be the optimum solution. Furthermore, EPS can act as an antivibration layer in certain situations.

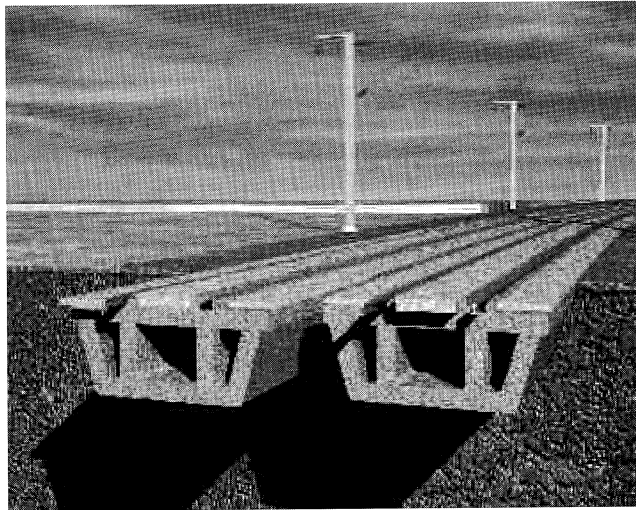


Fig. 3.

Deck Track (Figure 3, [8]) is based on the same equilibrium principle. This track structure consists of a hollow, nabra-shaped bearing member enclosing a large space. Furthermore, the stiffness of the structure is substantial, allowing unsupported spans of some 10 m to 20 m without the need for an expensive bridge.

HSL

As a result of the privatisation process, major changes are currently under way in the established relationships between the traditional railways and industry. The aim is to use competition as a means of stimulating the market to produce new concepts. One precondition to achieving this, however, is that the structures be well specified. As explained above, merely carrying out static calculations is no longer sufficient. In order to quantify all effects, it is necessary to perform a complete analysis of the dynamic interaction between vehicle, track and subgrade.

On the HSL-Zuid, for instance, there is currently no possibility of carrying out field trials at 300 km/h. Designs therefore have to be validated against models and laboratory tests. The models and test procedures used must therefore be of a high standard.

One of the options would be to select a track design with which experience has already been acquired outside the Netherlands. However, further study has revealed a need for extreme caution in this respect, as most "proven" designs still suffer from a range of problems in practice.

If an innovative design is chosen that has hitherto not been used for high speed traffic – such as embedded rail – the question arises as to the risks involved and the party that is to bear them. Those providing the finance are very much inclined to go for solutions that have been tried elsewhere, but this by no means eliminates all risk, as stated earlier. For the time being, the best route to optimum

design would appear to consist of a sound model-based approach, with a test programme designed to match, coupled with a thorough risk analysis.

One cannot expect the infrastructure authority to bear all the risks associated with a new concept of this type. The risks must be shared evenly, with the client – in this instance, the government – accepting a reasonable portion.

Design, construct and maintain

There is an increasing trend towards putting major projects out to tender in the form of “Design, construct and maintain” contracts. The HSL-Zuid is no exception, with the infrastructure provider expected to take on the design, construction and first 30 years’ maintenance [9]. Such an approach doubtless has a number of major advantages, as the design can be so optimised as to minimise the cost of maintaining agreed quality and availability levels over the period under consideration.

In such situations, it is often difficult to formulate correct (i.e. suitable) specifications – the quality requirements for the track and subgrade are affected by the quality of the rolling stock. Monitoring systems will be essential, both for wheel rail forces and for track geometry. Good cost-allocation models will also be needed, in order to charge for damage to the track resulting from use, or for the damage resulting from excessively low track quality.

If track designs are selected with which little experience has been built up, all the risks will be covered explicitly in the contract. This can quickly push up the price by 10%, 20% or more. From the client’s point of view, it would be wise to go for more of a mixed approach, under which the client bears a large percentage of the risks emanating from, in particular, the selection of innovative systems.

Speed

One of the most important reasons for choosing the train is the time saved by comparison with the car. For this to work, trains have to run at significantly higher speeds on medium and long-distance routes. Future speeds are of the order of 200 km/h to 300 km/h in the case of intercity trains, and 300 km/h to 500 km/h for high speed trains. One of the great advantages of unballasted track is that body-tilt can be used to achieve these speed increases without major changes to the infrastructure.

The low rolling resistance of a steel wheel on a steel rail forms part of the foundation on which railway systems have been developed. Contactless maglev systems come close to achieving the ideal in this sense. However, the huge investment required for the infrastructure and incompatibility with existing systems have meant magnetic levitation only being used on a very small scale so far. This mode will, however, be able to develop significantly in the coming decades.

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