Delft University of Technology

Delft University of Technology, The Netherlands
Faculty of Civil Engineering, Section of Roads & Railways

RECENT DEVELOPMENTS IN SLAB TRACK APPLICATION

Coenraad Esveld
Professor of Railway Engineering, TU Delft

Although most of the current railway tracks are still of a traditional ballasted type, recent applications tend more and more towards non-ballasted track. The major advantages of slab track are: low maintenance, high availability, low structure height, and low weight. In addition, recent life cycle studies have shown, that from the cost point of view, slab tracks might be very competitive.

Experiences in high-speed operation have revealed that ballasted tracks are more maintenance intensive. In particular, due to churning up of ballast particles at high-speed, serious damage can occur to wheels and rails, which is of course prevented in the case of slab track.

In the paper various non-ballasted concepts are discussed and some considerations are made in relation to life cycle cost for high-speed track.

Modified: 08.02.99

1. INTRODUCTION

With the design of railway lines factors like life cycle cost, construction time, availability and durability play an increasingly important role. In this respect non-ballasted track concepts offer good opportunities. With the growth of traffic intensity it becomes more and more difficult to carry out maintenance and renewal work. On NS, night time possessions often last no longer than 5 hours, and on the future high speed link in Korea (a 435 km line from Seoul to Pusan) the maximum effective possession is estimated at no more than 1 ½ hours per night. Seen against this background, the current increase in the popularity of low-maintenance track designs is scarcely surprising.

In the past new projects were mainly assessed on the basis of investment costs, whereas today the principle of life cycle costing is strongly emerging. As a result of these new attitude ballasted track concepts will loose attractiveness in favour of slab track systems.

2. BALLASTLESS TRACK

2.1 General considerations

Presently all over the world non-ballasted track concepts are being applied, although still at a moderate volume. The great advantages of such structures can be summarized as follows:
- Reduction of structure height;
- Lower maintenance requirements and hence higher availability;
- Increased service life;
- High lateral track resistance which allows future speed increases in combination with tilting technology;
- No problems with churning of ballast particles at high-speed.

If the low-maintenance characteristics of slab track on open line are to be retained, great care must be taken to ensure that the subgrade layers are homogenous and capable of bearing the loads imposed. The slabs may be prefabricated or poured on site. The high level of investment required has prevented widespread use of slab track on open line so far. However, on the basis of life cycle costs a different picture is obtained, as will be discussed afterwards. The greatest savings will be achieved in tunnels and on bridges. The use of more efficient construction methods, of the type used in the road construction industry, could reduce construction costs still further.

The most well known slab track structures, presently in use, are:
- Rheda, Züblin and other variants (Germany);
- Stedef, Sonneville Low Vibration (France);
- Walo (Switzerland);
- Edilon block track (Netherlands);
- Shinkansen slab track (Japan, South Korea);
- IPA slab track (Italy);
- ÖBB-Porr (Austria);
- Embedded Rail Structure (Netherlands).

2.2 Non-ballasted systems in use

Ballastless track is undergoing rapid development in Germany. Since 1996, DB has been operating a test track in Karlsruhe consisting of seven new types of ballastless track. The best-known German designs are the Rheda (Figure 1) and the Züblin, named after the places where these types were first used. In both of these systems, the sleepers are cast into a concrete slab.

The French Stedef system is most often used in tunnels. Metro systems are the most

Figure 1 Rheda structure

common application, but the technique is also used on high speed networks. A rubber boot under the sleeper provides a high degree of elasticity, which ensures good noise and vibration insulation. The Sonneville Low Vibration track is closely related to the Stedef system. This is a block track design, which, like Stedef, also uses a rubber boot. Applications include the Channel Tunnel.
Another twinblock variant related to Stedef is the Swiss Walo system, mainly used in tunnels. A special slipform paver lays a concrete slab, following which the sleepers – fitted with rubber boots – are placed in position and cast into place.

Figure 2 Edilon block track

The Edilon block track system (Figure 2) falls into the same category, and is mainly used for bridges and tunnels. Under this (top-down) system, the first step is to place the rails and blocks in position. The blocks are then cast in using Corkelast, to provide the necessary elastic support. Important applications include 100 km on NS and light rail systems in the Netherlands and the Madrid metro (approximately 100 km).

Japan was effectively the birthplace of high speed rail. Development work on the Shinkansen network started at the end of the 1950s, and the first line (between Tokyo and Osaka) opened in Autumn 1964. Five lines are currently in service and a sixth is under construction. Government plans dating back to 1970 specify a national Japanese high speed network of 3 500 km of double track. By 1993, a good 1 400 km of this had been built (double track), of which more than 1 000 km consists of ballastless double track. In Japan, ballastless track always consists of prefabricated slab track, using slabs just under 5 m long. The percentage of ballastless track varies considerably from line to line. The newer lines include a higher percentage (up to 96 %). The slab track design has remained virtually unchanged since the first sections were laid in 1972.

The Shinkansen slab track, (see example in Figure 3) consists of a sublayer stabilized using cement, cylindrical “stoppers” to prevent lateral and longitudinal movement, reinforced prestressed concrete slabs measuring 4.93 m x 2.34 m x 0.19 m (4.95 m x 2.34 m x 0.16 m in tunnels) and bituminous cement mortar injected under and between the slabs. The slabs weigh approx. 5 t.

South Korea is currently building a high speed line to link the capital, Seoul, with the port of Pusan. As in Japan, the line will include both ballasted and ballastless track. The ballastless track is based on the Japanese Shinkansen slab track.

Ballastless track has been little used in Italy. In 1992, FS had less than 100 km of ballastless track, of which 2 × 5.4 km were located on the Rome-Florence high speed line. This track, supplied by IPA, is based on the Japanese system mentioned above.

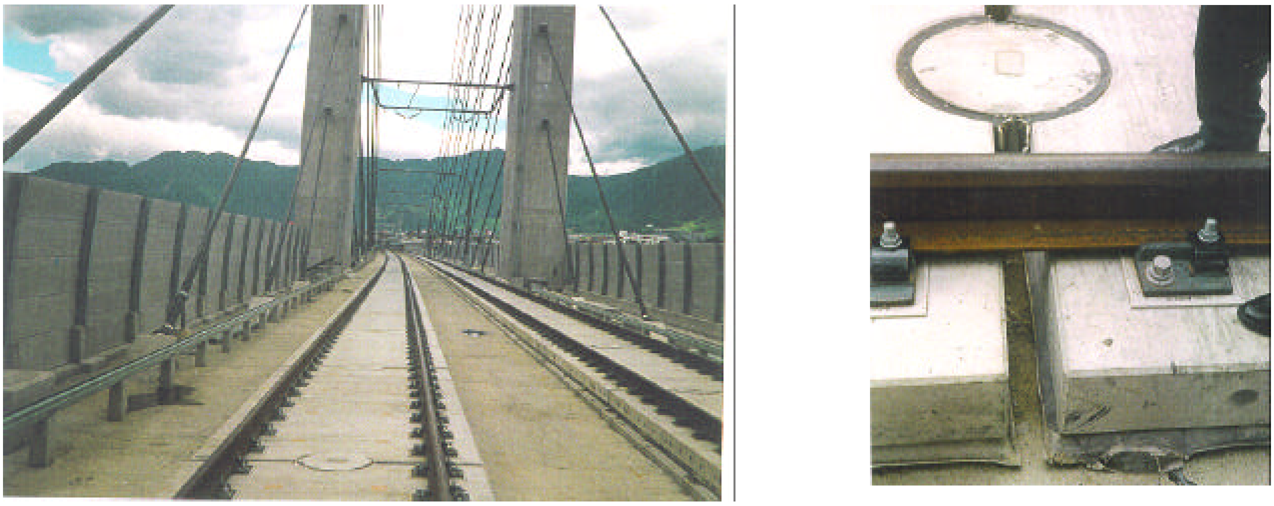

Figure 3 Japanese Shinkansen slab track

ÖBB (Austria) has 25 km of ballastless track, mainly in tunnels and on viaducts. The ÖBB-Porr system, comprising embedded monoblock sleepers enclosed in rubber, is very similar to the Züblin design mentioned above. There is also a variant using prefabricated slabs (the Porr system). A test section was set up on the Wels-Passau line in 1992 to test an ballastless track system designed for high speeds, known as Modurail. This system uses prestressed sleepers, elastically supported on a concrete slab.

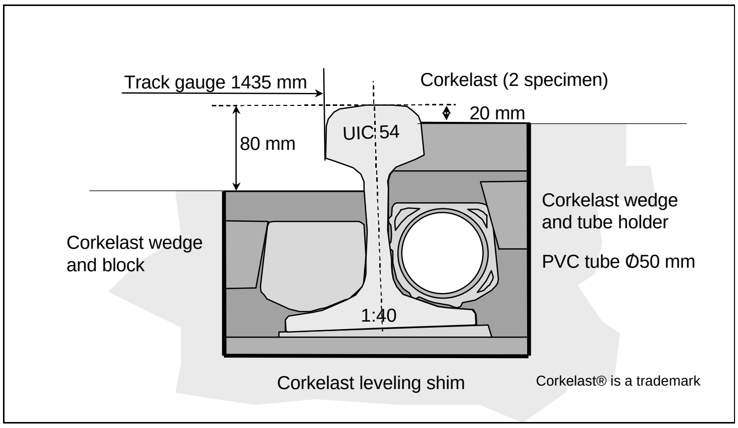

Figure 4 Embedded rail structure

All the designs mentioned so far were based on the rail being supported at discrete points – the sleeper principle. Since 1976, a continuously supported rail system has been in use in the Netherlands on a small scale. The system is known as the Embedded Rail Structure (ERS) (Figure 4), and involves providing continuous support for the rail by means of a compound consisting of Corkelast (a cork/polyurethane mixture). The great advantage of this design is that the track is built "top-down", which means that tolerances in the supporting structure have no effect on the track geometry obtained. NS now has 20 years experience with this system, and it has proved to require little maintenance.

The possibility is currently under investigation of using ERC as the standard track system for the HSL South from Amsterdam to the Belgian border. A 3 km test section was recently built in Holland as part of this study. Figure 5 illustrates the principles of this slab track system, while figure 4 shows the channel containing the embedded rail.

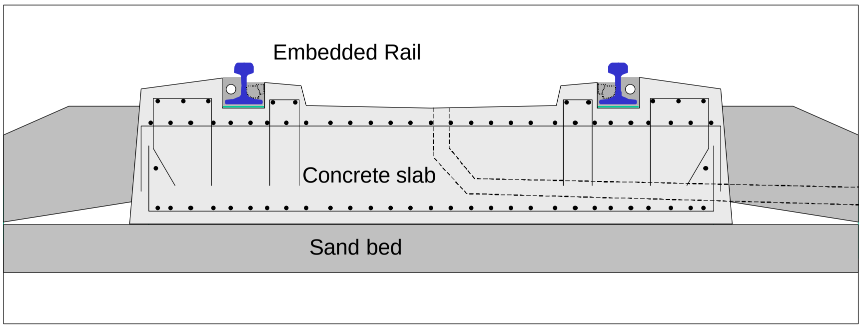

Figure 5 NS slab track near Best

2.3 Low-noise rail

In the present ERS concept still the conventional UIC 54 rail is envisaged. Recently, however, an optimized rail concept has been developed, which is depicted in figure 6. This SA42 rail is capable of carrying 225 kN axle loads and produced 5 dB(A) less noise. An additional advantage is the substantial reduction of polyurethane. This new rail concept was installed in the previously discussed test track near Best over a length of 150 m.

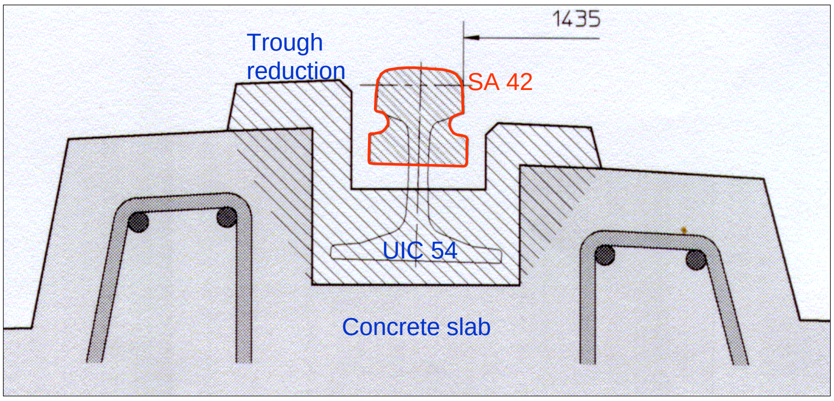

Figure 6 Low-noise track concept

3. LIFE CYCLE STUDIES

Due to the wave propagation problems in soft soils it was decided to build the sub-structure of the High Speed Line South (HSL-S) in The Netherlands as a continuous concrete slab supported by piles, a so-called low viaduct (Figure 7). For the actual track structure various concepts have been considered, which were compared, amongst others, on the basis of a Life Cycle Cost analysis. In these analyses only the costs of the superstructure on top of the concrete sub-structure, were taken into account.

The annual costs, presented in figure 8, were determined for the following track types:

- Ballasted track with high-speed specifications;
- Rheda structure;
- Embedded Rail Structure, not integrated into the concrete substructure;
- Embedded Rail Structure, integrated into the concrete substructure;
- Conventional ballasted track, just as a reference.

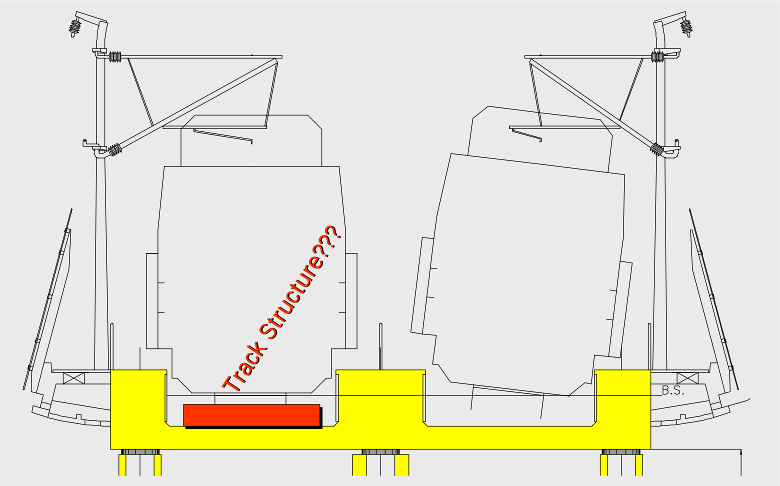

Figure 7 Sub-structure of HSL-South

The results of the Life Cycle Cost analyses for the super-structure, excluding the concrete slab, can be summarized as follows in EUR/meter (Also see figure 8):

Present cost estimate:	Construction	Annual Costs
• Slab track, ERS, NI (Not integrated)	EUR 1,200	EUR 90
• *Slab track, ERS, NI, optimized*[1]	*EUR 860*	*EUR 70*
• Slab track, ERS, INT (Integrated)	EUR 910	EUR 80
• Rheda	EUR 1,270	EUR 100
• Ballasted track	EUR 1,000	EUR 110

A salient conclusion is, that all ballastless variants are cheaper than the ballasted concept, despite the fact that in the life cycle studies the following important effects were not taken into account:

- Higher availability of the track;
- Lower dead weight on engineering structures;
- Reduced structure height;
- Savings on noise-reducing measures.

For a conventional track structure, comprised of slab/sleepers, rails and fasteners, the figures for construction and annual costs, in EUR per meter, are estimated as follows:

Present cost estimate:	Construction	Annual Costs
• Ballasted track	EUR 590	EUR 70
• ERS, optimized	EUR 800	EUR 60

On the basis of the results of such Life Cycle Cost analyses a trend break may be expected in favour of slab track.

4. CONCLUSIONS

Conventional track, using ballast, has been the norm for a long time. As concerning new main corridors for high speed and freight traffic, factors such as extended service life, low maintenance, availability and capacity for increased speeds and axle loads will gain in importance. Life cycle cost considerations discussed in this paper clearly reveal the advantages of ballastless designs.

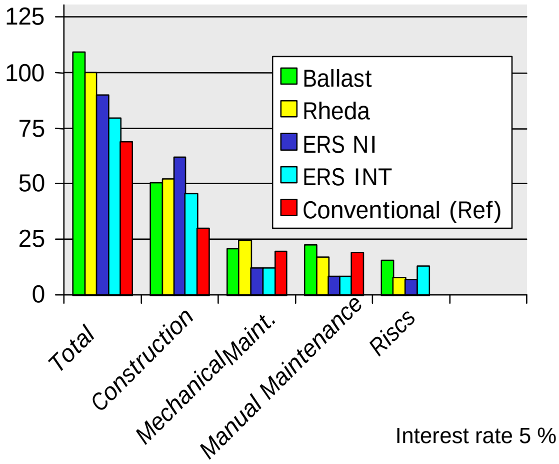

Figure 8 Annual costs in EUR/m based on NPV analysis

---

[1] With industrial construction methods and further optimization a cost reduction of 30 % for ERS may considered as feasible