Development of a new low vibration track system for the Vienna Underground

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Introduction

In most of its tunnel lines the Vienna underground transportation company "Wiener Linien" uses a vibration and ground-borne noise attenuating ballast-less track system. This system, well known under the name "Wiener Oberbau" was developed more than 25 years ago. In addition to its low noise and low vibration features this track system has significant other advantages, such as replaceability of all components and easily cleanable drainage ditch in track axis.

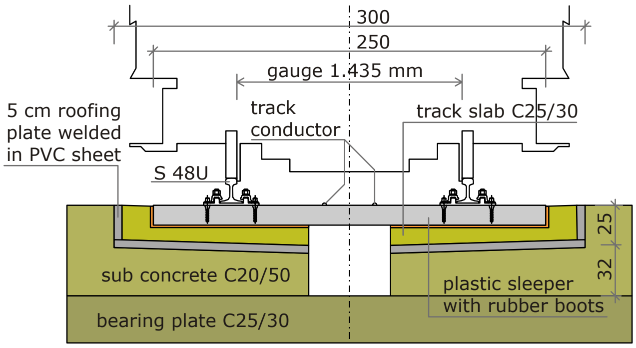

Figure 1: Cross-section "Wiener Oberbau".

Nevertheless the experience of the last 25 years has also shown some disadvantages of this system. To mention the most important ones, these are problems with the long time behaviour of the elastic layer between the track slab and the foundation leading to problems with the track stability, fatigue problems with the artificial sleepers and the hardly walkable open drainage ditch in track axis. Therefore the Wiener Linien installed a working group of experts for noise and vibrations, railway engineering and maintenance to develop a new ballast-less track system. This system shall be based on the fundamental principles of the existing "Wiener Oberbau" but shall avoid its disadvantages:

Required improvements:

- Quality of track geometry
- Long time behaviour
- Inspection (smooth closed surface)
- Maintenance and Repair
- Installation
- Economy

Retention of:

- Noise and Vibration attenuation
- Deflections and rail stresses under load
- Train control system and power supply
- Keeping spare parts

After a first study of four different ballast-less track solutions and a selection procedure in the working group, the further work focused on two remaining types – a solution with prestressed mono-block sleepers and a solution with twin-block sleepers (fig. 2) – in both cases the sleepers have an elastic coating and are embedded in a continuous floating concrete track slab. This slab is situated on an elastic layer and therefore the whole system can be called mass-spring-system. For these two types of superstructure a 300 m long test track was realised.

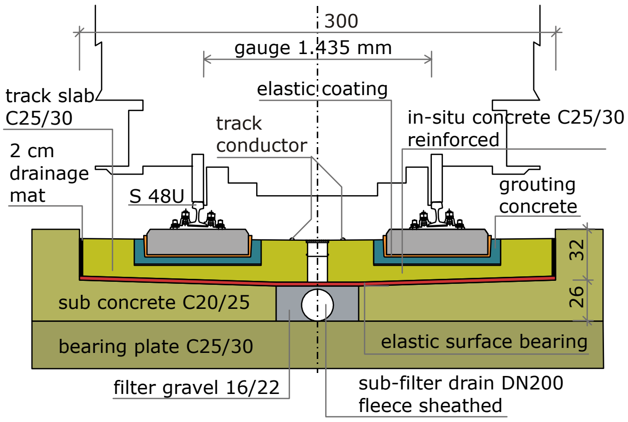

Figure 2: Cross-section twin-block system.

Test track

The theoretic studies led to the necessity of the test track to evaluate the new systems. The layout of the test track gave the possibility to run trains with constant speed of more than 70 km/h on the three types of superstructure.

Evaluation and Testing

The extensive testing and evaluation programme contents an evaluation of the construction process; tests with different speeds with unloaded and loaded vehicles with measurements of deformations, vibrations and noise and a comparison of the life-cycle costs.

Construction process and life-cycle costs

The construction process was evaluated carefully according to the following different aspects categorized into three groups: group 1 – technical assessment criteria, group 2 – economic assessment criteria and group 3 – assessment criteria with regard to maintenance.

Summarised the different construction aspects show a small advantage for the system with twin-block sleepers. The most important advantage of this system is that it led to the best geometric quality of the track (fig.3). This was one of the main targets of the project.

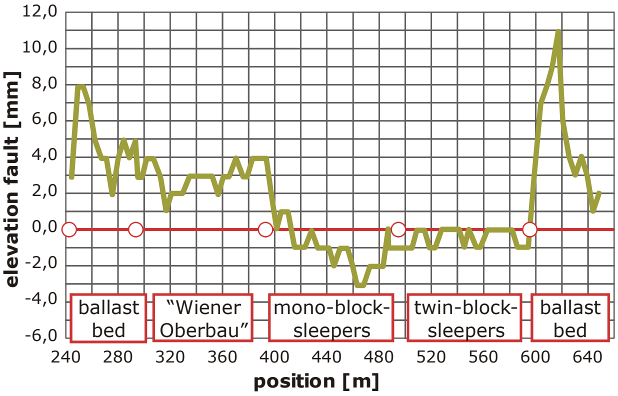

Figure 3: Example for geometric track quality

Testing

The testing programme was performed in November 2003 and consisted of a one week intensive phase. Prior to the measurements about 2000 runs with a loaded vehicle were done to achieve a realistic behaviour of the superstructures. After that the testing started. For all three types of superstructure the following tests were performed:

Run with unloaded and loaded vehicles with different speeds of 5 km/h, 20 km/h, 40 km/h, 60 km/h and maximum speed of about 70 km/h. For each speed a total of 6 runs (3 for each direction) were performed.

For all these runs the following parameters were measured:

- Deformations (deflection of rails, deflection of sleepers, deflection of floating track slab)
- Stresses (pressures in the elastic layer between floating track slab and sub-structure)
- Noise and vibration (vibrations of floating track slab, vibration of sub-structure, air-borne noise)

Deformations

The deflection-behaviour is dominated by the three elastic components of the systems: elastic rail fasteners, elastic coating / elastic boots of the sleepers, elastic layer between track slab and sub-structure. The deflections of the Wiener Oberbau are nearly independent of the speed of the running vehicles whereas the two new systems show a clear reduction of the total displacements with increasing speed. The total vertical displacements of the rails are in a range of about 2 mm up to 3.5 mm depending on the different axle loads and different speeds.

Vibrations and Noise

Vibrations were monitored in each of the sections of the test track at two monitoring sections. The sensors were placed to the side of the track directly on the concrete base slab.

The measured spectra were averaged over the various train passages and sensor locations and evaluated for all train speeds and loadings conditions. As a means of providing a good overview, a "design diagram" was developed. This design diagram contains the highest vibration level reached by each track system in each third-octave band regardless of speed and loading condition. It is therefore a synthetic summary of worst case emissions.

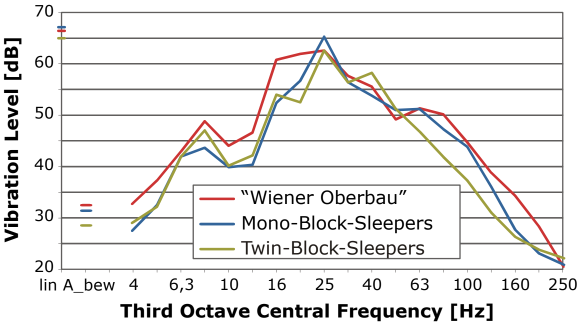

Figure 4: Design Curve.

The diagram clearly shows that the twin-block system has an advantage over both the mono-block and the "Wiener Oberbau" systems. The significant reduction in vibrations in the re-radiated noise frequency bands above 63 Hz is especially important. The slight increase at 40 and 50 Hz is regarded as a resonance produced by the sleeper padding. The mono-block system - while arguably equivalent or slightly superior to the "Wiener Oberbau" in several frequency bands – displays a clear disadvantage at 25 Hz. This is made even more clear by examining the total vibration levels (un-weighted and A-weighted), where the mono-block has a disadvantage of about 1 dB for the un-weighted case. In addition, it was observed that the increase in stiffness of the elastic layer with increasing frequency (i.e. train speed) – also noticed in the displacement measurements – leads to a continuous decrease in the vibration mitigation performance of the new system with increasing train speed. Due to the vibration behavior, the mono-block system was regarded as being insufficiently qualified for further use, although it was noted that further work might improve its response. The twin-block system was recommended for further development.

The air-borne noise level of the three systems is nearly the same – the twin-block system shows marginal advantages in comparison to the "Wiener Oberbau".

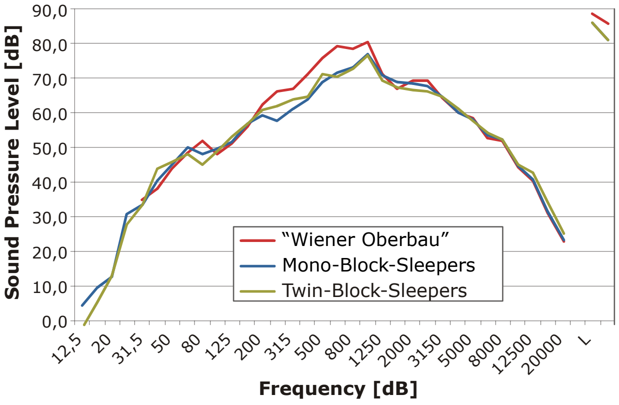

Figure 5: Air-borne noise level.

Conclusions

The targets of the working group were reached by the new twin-block system. The further work focuses on the solution of details as e.g. the fixing of the electric energy supply rail, the installation of the linear track conductor and some other special details.