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VIBRATION INSULATION RESEARCH RESULTS IN SWITZERLAND

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In the context of different railway infrastructure projects in Switzerland new standards for vibration mitigation measures have to be developed and introduced for various track systems, sites and conditions: tunnel and surface lines, ballasted or slab track, low and high speed, light and heavy vehicles. Earlier applications of mats under ballast showed that the ballasted track on a softer subgrade became instable. Therefore, as a first step the technical feasability of new layouts and their stability had to be tested, especially for mixed traffic of high speed and heavy trains on ballasted surface lines. Long-term behaviour and effectiveness of installed mass–spring systems in S-Bahn tunnels were reviewed and served as a basis for extrapolation for newer developments under other conditions. For technical system optimization the exact understanding of the forces and movements is important; this will be further investigated within the framework of RENVIB II on installations located and tested in Switzerland. It is important for the future of railways both to reduce the impact of the vibration and structure-borne noise of rail systems on the neighbourhood and to minimize the cost of installation and maintenance of possible insulation systems. In order to achieve this, a reasonable cost–benefit relation must be predicted.

1. GENERAL BACKGROUND

In Switzerland several new or modified railway projects are in the process of being realized. Because of the high population density the projects often are in conflict with lineside inhabitants sensitive to vibration, structure-borne and re-radiated noise. A variety of problems and difficulties have, therefore, to be considered.

1.1. PROBLEM OF ESTIMATION OR PERCEPTION

Both vibration and structure by bornenoise generated by the railway traffic are phenomena which previously unexposed persons cannot, as a rule, envisage the effect it will have on them. Therefore, they cannot judge if vibration will affect health or if it will threaten acceptable living conditions.

It is not easy for railway developers to convince people that a certain project will ensure their well being. The fact that, no agreed national limits exist for vibration or re-radiated noise does not help. Only standards with desirable impact limits (for instance DIN 4150) are available. However, these limits are so restrictive (mostly at the perception thresholds) that no existing line and virtually no new lines can meet them. Based on the Swiss experience with complaints, there people will accept much higher levels alongside a railway line. Therefore, proposals to the Swiss Ministries of traffic and environment were made some 10 years ago defining a specific scheme of limits that could be guaranteed projects (see Tables 1 and 2). Even within difficult situations in the city of Zürich no complaints have been received to date. Thus, it has been possible to convince the decision makers that reasonable levels could be defined that would not impose an unreasonable degree of noise control.

However, the discussions taking place on the revision of DIN 4150 have highlighted the continuing need to convince ministries and planners that railway vibration at much higher levels than the threshold of perception are felt to be acceptable by the population, therefore limits can be higher than the threshold of perception.

1.2. PROBLEMS OF PREDICTION

Recently, many consultants and experts with little experience have received contracts to evaluate vibration problems. In this process they often trigger problems for railway companies by overestimating the impact of new lines or ignore the technical constraints of such systems.

Decisions to install such complex technical systems, influenced by many different parameters such as traffic flow, axleload, trainspeed or geology and with tremendous cost consequences, are sometimes based on inadequate informations and lead to the demand for the highest degree of vibration reduction with little consideration of the absolute impact level.

Experts often overrate vibration impact because of unknown properties of track and traffic and unknown propagation factors through the ground and into houses. There is always a tendency to be cautious but for railway owners this may be too pessimistic and therefore too expensive.

In Switzerland there have been at least three cases in the past, in which built-in mass–spring systems have been installed in situations where afterwards the measured impact levels were below the allowed limits by more than the estimated effect of the mitigation measure. The cost-intensive insulation system was shown to be unnecessary. It is always worthwhile to confirm the plausibility and quality of any predictions by railway experts, although private consultants or industrial partners unwilling to give any guarantee for the accuracy of predicted levels or insulation values. The cost over overestimtaing the required insulation must always be carried by the railways, even in the age of privatization and uncompetitive costs of railway traffic.

Therefore, a good calculation program with a high degree of acuracy and a database of measured values is still one of the most important targets in research strategy. At the last Workshop in Voss Kuppelwieser pointed out the functionality of SBB's semi-empirical approach within the Windows-software package VIBRA-

TABLE 1

Standard for design of new railway lines

Target levels SBB related to	Vibration v_{rms} (mm/s) Day/night	Re-radiated noise L_{eq} dB (A) Day/night
Pure residential areas; areas for public use (schools, hospitals)	0·3/0·2	35/25
Mixed areas; urban city areas and rural village areas	0·4/0·3	40/30

TABLE 2

Standard for design of extension railway lines

Target levels SBB related to	Vibration v_{rms} (mm/s) Day/night	Re-radiated noise L_{eq} dB (A) Day/night
Pure residential areas; areas for public use (schools, hospitals)	0·4/0·3	40/30
Mixed areas; urban city areas and rural village areas	0·5/0·4	45/35

1-2-3. Since then, the software has been revised, based on new measurement data. By 2000 a new Version 2.0 will be presented to consultants and railway experts.

1.3. PROBLEMS OF TECHNICAL IMPLEMENTATION

When planning new or altered lines, it is usually not only the general planning team but also the lawyers, politicians and private landowners involved who influence the final decisions about the insulation system required. Often the result of this process may lead to a number of different system components (from tramway to high-speed train) being considered are included.

However, changes to a well-proven and well-developed track–wheel system by the addition of new elements or by allowing new constraints may adversely affect a hitherto stable system, so that it might perform in an unexpected way under new conditions.

The implementation of a project may be difficult, as solutions must be sought by the technical bodies which are compatible with the wishes of the contractors and the constraints of a modern railway. Usually, new systems must be developed in a short time and without any pretests. Technical knowledge and experience is still insufficient, especially regarding the construction of a safe and stable track system combined with effective insulation measures against vibration or re-radiated noise.

TABLE 3

Standard systems (MSS: mass–spring system/UBM: under ballast mats)

	Against vibration	Against re-radiated noise
Slab track in tunnel	Heavy MSS	Light MSS
Ballasted track in tunnel	MSS	UBM
Ballasted track surface line	(UBM)	UBM

Otherwise, the ballastbed could become instable, which could lead to a derailment of a train.

Due to such an experience in Erstfeld 1994 SBB management decided to no longer allow unproven standards to be built in, even if they had been shown to work on other railways. This moratorium gave experts more time to study technical standards until the end of 1999 when these standards must be defined.

1.4. SOLUTIONS

In practice, the principal method of reducing vibration is to install some kind of mass–spring system, although the choice of the right system is not always straight forward. As a first step, SBB still follow the principles shown in Table 3.

In the context of different railway infrastructure projects in Switzerland, these types of vibration mitigation measures have been studied in detail, in relation to the following conditions: low and high speed, light and heavy vehicles, curved and straight lines. The main results with provisional standards were presented to the management board at the end of November 1998. The preliminary points are discussed herewith.

2. VIBRATION MITIGATION MEASURES INSIDE OF TUNNELS

Mass–spring systems in tunnels are expensive but are effective mitigation measures inside a tunnel in order to prevent impact at nearby buildings. Satisfactory results for train speeds up to 80 km/h were observed for Swiss S-Bahn systems.

A UIC survey in 1995 showed that in Europe no railway company had built such a mass–spring system on a high-speed line with mixed light/heavy traffic. There are some similar S-Bahn projects in Austria, where research work is also being carried out at the same time.

The intention to study and optimize such insulation measures within the European Fourth framework programe (RENVIB) failed because of financial reasons. The RENVIB II project started by the railways themselves did not fully meet the interests of SBB within the SBB time scale. There SBB started its own research project.

Further tests at mass–spring systems (MSS) already in service on the S-Bahn in Zürich were intended to:

- provide information about the long-term behaviour of the MSS after 8 years,
- give reliable indications of insulation behaviour, for different systems,
- optimize geographical positioning of the required length of the systems,
- calibrate a static model for stress calculations,
- define the transfer of longitudinal and vertical stresses.

The tests provide indications for extrapolation to higher speed. The most important findings are given as

- The mitigation measures installed are still successful after 8 years of service. The efficiency even increased in relation to the original acceptance measure. It still meets the requirements. The damping curve often starts below 30 Hz and increases with increasing frequency to more than 20 dB (see Figure 1, MSS and UBM in tunnels).
- The maximal vertical depressions of the systems are between 1 and 2 mm. For a punctual load the length of the trough in the track is about 30 m.
- Under strong acceleration or braking by a train on the insulation system, about 45–65% of the upward longitudinal forces in the track were overstressed above the bearings on the ground, which is more than originally estimated.
- To guarantee a damping of about 10 dB at a discrete point, it is sufficient to extend the insulation measures on both sides of the critical tunnel section by the length of about 2–3 times the shortest distance to that point.

The results of the measurement programme will give initial indications to help to define provisional requirements for main lines and high speed (up to about 220 km/h in Switzerland).

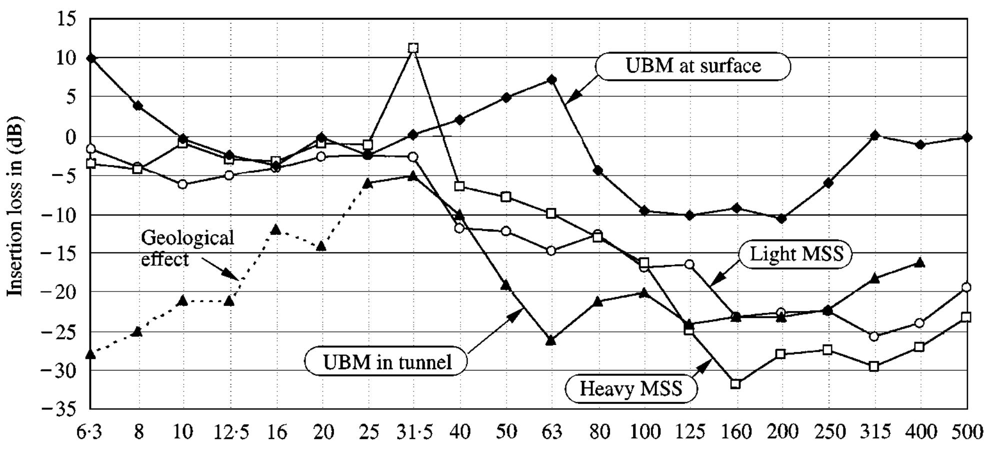

Figure 1. Insertion loss of different vibration mitigation projects in Switzerland.

3. VIBRATION MITIGATION MEASURES AT SURFACE LINES

A special test-site with four different track sections was built on an embankment beside the River Rhone:

- first section: with conventional foundation of gravel layers
- second to fourth section: with additional bitumen layers (9 cm thick) above the gravel
- third and fourth section: with two different types of under-ballast mats on the top of the bitumen layer, beneath the ballasted track.

The main issue was to study the technical feasability of under-ballast mats in a ballasted track on a normal subgrade. From the experiences in Erstfeld it was concluded, that the ballast would flow away if there was no lateral support or fixation of the ballast bed.

Therefore, two possibilities for side support were studied at the same time: a small concrete wall installed on mini piles and a clewed ballast border. Both measurements proved succesful for stabilizing the ballast bed in the long term.

Though it was not the main issue, the effectiveness of the under-ballast mats were measured. The results were rather disappointing (see Figure 1: UBM at surface line). While a damping effect only started above 60–80 Hz, the maximum value was no more than 10 dB. Below 60 Hz, there was an amplification of the signal (stronger than expected). However, a good insulation measure against re-radiated structure-borne noise should reduce, particularly, the frequences from 30 to 80 Hz. This is the frequency range where the strongest signals of the railway spectra are present.

Because the site was on the top of a raised embankment (lying on a weaker subgrade than in a tunnel), it was probably difficult to measure the real insulation effect. During September/October 1998, further measurements on a new and more reasonable site were made to obtain more reliable results.

4. CONCLUSIONS

To keep Railways alive it is important for the future of railways to reduce the vibration and structure-borne noise impact of rail systems on the neighbourhood and to minimize the cost of installation and maintenance of possible insulation systems. Thus, a reasonable cost–benefit relationship must be envisaged.

To be successful, in convincing management, RAMSES (**R**eliable, **A**vailable, **M**aintainable, **S**ecure and last but not least **E**conomic **S**ystems) must be re-discovered.