DAMTEC® KRAIBURG USM – Sub Ballast Mat

Optimisation of Zillertal Railway permanent way with regard to vibrations and secondary noise

Subject to technical changes – February 2008

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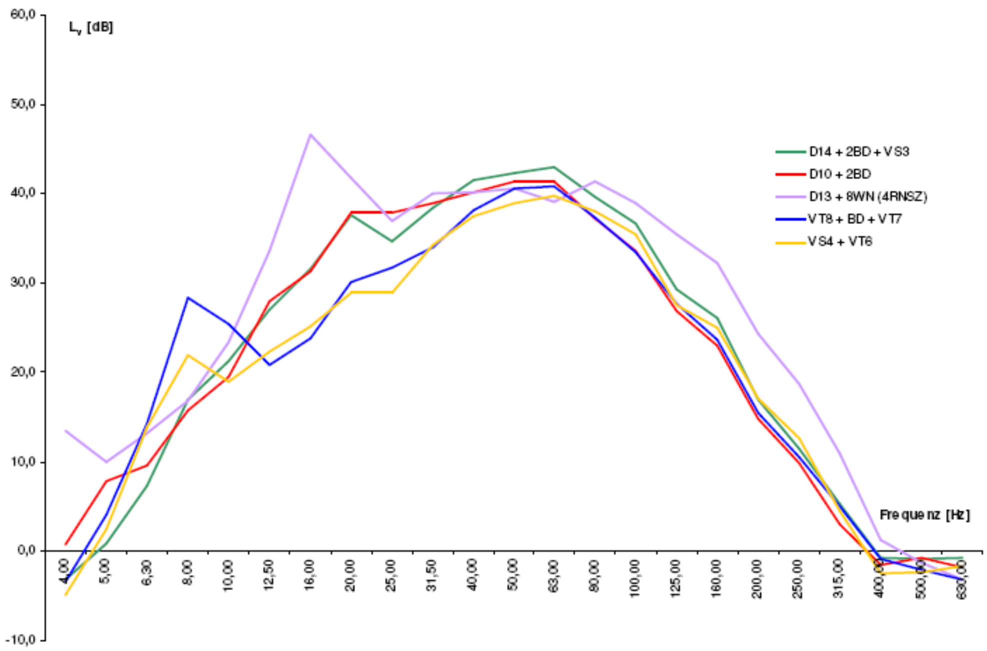
In general

In the course of the renewal of the permanent way of the Zillertal Railway, optimisation was to be sought with regard to sound and vibration emissions. The objective was a reduction of the vibration and secondary sound emissions for neighbouring residents, while at the same time there was not to be any worsening of the direct airborne noise situation.
Based upon the results of an initial measurement series (basis measurements – “Actual Situation”), it was possible to modify the standard permanent way with regard to vibration and secondary sound reduction.
Recommendations regarding the structural design of the permanent way, economic optimisation and standard cross-sections were to be drawn up as a result of the analyses. Under certain conditions, additional transitional layers were necessary between the vibration and secondary sound-reducing layer and the standard permanent way.

The results of the first measurement series served as a basis for the choice of an effective permanent way to reduce sound and vibrations. As the insulating properties of individual materials are frequency-related, it was necessary to analyse the occurring emissions with regard to frequency content.

The results of the first measurement series showed that the spread of the frequency spectrum is very varied in the case of the vehicle types being used. The following graph illustrates the influence of the various types of vehicle.



(Frequenz = Frequency)

Fig. 1: Influence of the train type on the spectral distribution of the vibration frequency level

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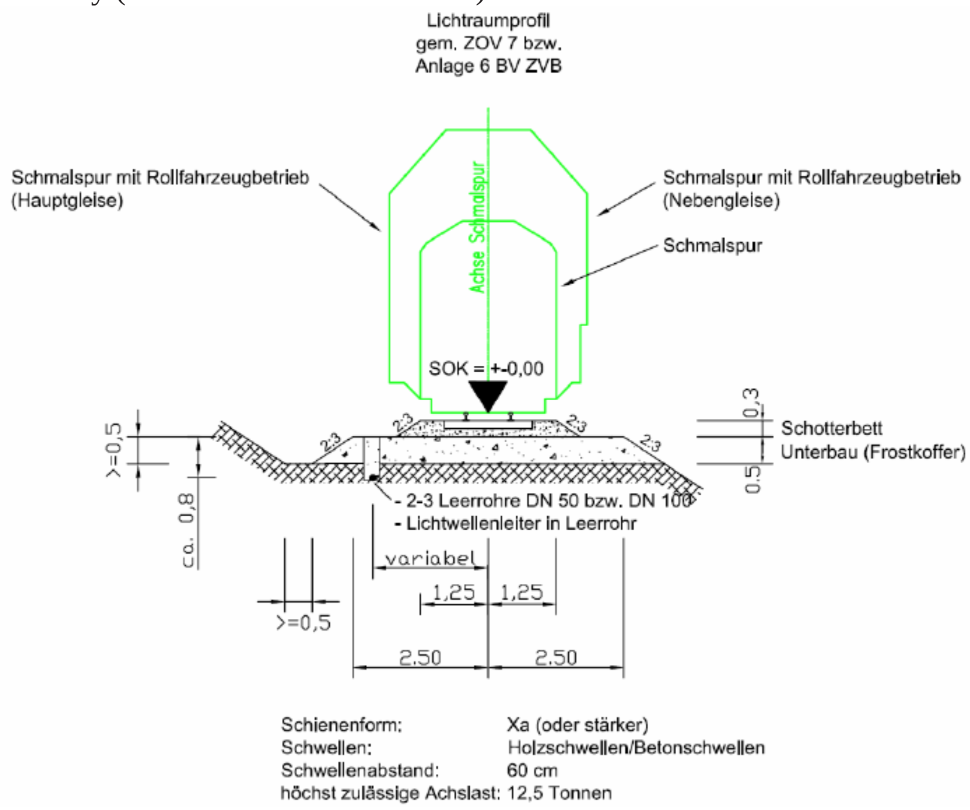
The various train types show considerable differences, particularly in the lower frequency ranges. Emissions around 16 Hz are very clearly noticeable above all in the case of goods trains.

The measurements clearly showed that the direct air-born noise emissions whilst a train was passing were within the limit values of the regulations on protection against rail emissions (*Schienenimmissionsschutzverordnung – DB-SchIV "Durchführungs-bestimmungen zur Schienenverkehrslärm-Immisionsschutzverordnung* – as amended on 01.01.2006).
According to the task definition, emissions from direct air-born noise were not to be increased in comparison with current levels as a result of the optimisation work. This aspect was taken into consideration in the choice of the suitable emission protection measures.

The following illustration shows the standard diameter for single-line track sections of the Zillertal Railway (source: Zillertalbahnen AG).



Lichtraum profil gem. ZOV 7 bzw. Anlage 6 BV ZVB = Structure gauge pursuant to ZOV 7 and/or Appendix 6 BV ZVB
Schmalspur mit Rollfahrzeugbetrieb (Hauptgleise) = Narrow gauge with rolling stock operation (main tracks)
Schmalspur mit Rollfahrzeugbetrieb (Nebengleise) = Narrow gauge with rolling stock operation (side tracks)
Schmalspur = Narrow gauge
Achse Schmalspur = Narrow gauge axis
Schotterbett = Gravel bed
Unterbau (Frostkoffer) = Foundation (frost layer)
2-3 Leerrohre DN 50 bzw. DN 100 = 2-3 empty pipes DN 50 and/or DN 100
Lichtwellenleiter in Leerrohr = Optical wave guide in empty pipe
variabel = variable
Schienenform: Xa (oder starker) = Rail type: Xa (or heavier)

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Schwellen: Holzschwellen/Betonschwellen = Sleepers: Wooden sleepers / Concrete sleepers
Schwellenabstand = Sleeper spacing
Höchst zulässige Achslast: 12,5 Tonnen = Maximum permitted axle load: 12.5 tonnes

Fig. 2: Standard permanent way - Zillertalbahn (single-line).

There was an existing wooden sleeper permanent way (rail-type Xa) at the examined location (track section Aschau – Zell am Ziller). Rails of the type 49 E1-R260 are to be installed following renewal of the permanent way.

Elastic bedding of the permanent way

Vibrations and structure-borne sound occur whilst a train passes as a result of the moving load, roughness of wheels and rails and local fluctuations in the stability of the track system.

Various measures to reduce vibrations and secondary noise can be used within the emission range depending on the type of permanent way system. The effect of the vibration-related optimised permanent way types depends mainly on the use of elastic materials in the transitional path of the oscillations. Using these materials should restrict the introduction of the vibrations into the road bed. As the spatial expansion of the measure is lowest at the point of emission because of the vibration spread, the measures are often most economical in this area.

In the case of the existing gravel permanent way, both sleeper footing and Sub Ballast Mat were examined. In view of the requirement not to worsen the air-borne sound situation, the use of wooden sleepers was recommended for track sections in the vicinity of residential housing. The tests therefore based on wooden sleepers.

The sleepers could be bedded on the gravel bed using elastic footing in order to reduce the radiation of vibrations from the track system.
In order not to increase air-borne sound emissions and to choose the most effective measure, however, elastic bedding using sleeper footing could not be recommended in the case on hand.

The elastic bedding of the gravel permanent way on Sub Ballast Mat achieves a high vibration insulating effect because of the high oscillating permanent way mass. The lower the frequencies to be insulated, the lower the dynamic bedding factor of the Sub Ballast Mat (USM) needs to be in this respect. A certain minimum rigidity of the undergravel mat (depending on axle loads and maximum speed of the rail traffic), however, must be guaranteed for dynamic travel reasons, as well as to ensure the required gravel stability. The static bedding factor is restricted per Deutsche Bahn (German Rail) regulations TB 918 071 (applicable to standard gauge rail traffic) in order to limit rail tension and subsidence.

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$\geq$ 0,02 N/mm^2 v $\leq$ 120 km/h (Radsatzlast $\leq$ 160 kN)

$\geq$ 0,03 N/mm^2 v $\leq$ 120 km/h (Radsatzlast > 160 kN)

$\geq$ 0,06 N/mm^2 120 > v > 200 km/h

$\geq$ 0,10 N/mm^2 v $\geq$ 200 km/h

Theoretically, Sub Ballast Mat achieve their greatest effect with infinitely large terminating impedance, i.e. absolutely rigid foundation. Consequently, the effectiveness of an Sub Ballast Mat can be raised by increasing the rigidity of the layer underneath it. This can be achieved by particularly high compaction of the foundation or by using rigid top layers (asphalt subbase, concrete subbase) underneath the gravel mat.

The installation of an Sub Ballast Mat was recommended as measure for vibration and secondary sound-related optimisation of the permanent way. In view of their respective characteristics, three different Sub Ballast Mat were examined more closely for suitability. A comparison of the individual products was carried out with regard to various parameters (dynamic rigidity – vibration-reducing static rigidity – rail subsidence and rain tension).

Using numerical calculations, the recommendation for the choice of Sub Ballast Mat was verified by two measurement series (before and after installation of the Sub Ballast Mat).
In doing so, the effect of the Sub Ballast Mat was determined with the help of the insertion insulation level per Wettschureck. The determining influencing variables in this respect are the unsprung axle load, the gravel rigidity and the mat rigidity.

The measured and analysed vibration emissions did not exceed the standards' limit values. The insulating effect of all examined Sub Ballast Mat was sufficient in the higher frequency range. Overall, it was therefore found that all of the examined products offer a similarly good level of insulation and were suitable for the case on hand.
In addition, calculations were made of the maximum subsidence and maximum track stress.

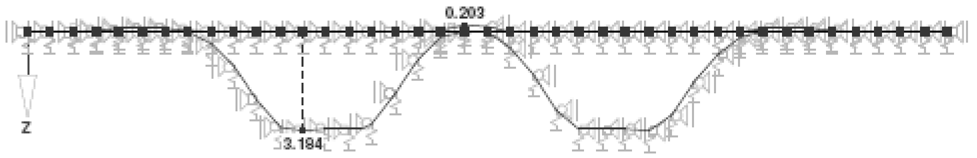

Fig. 3: Maximum subsidence under load of the DAMTEC® KRAIBURG USM Sub Ballast Mat

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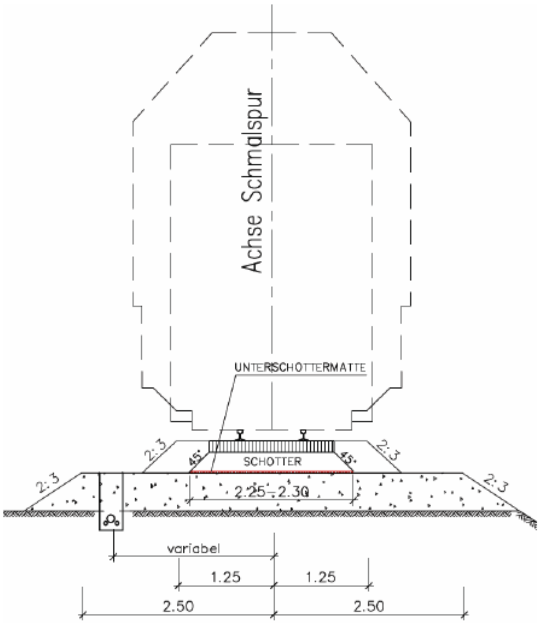
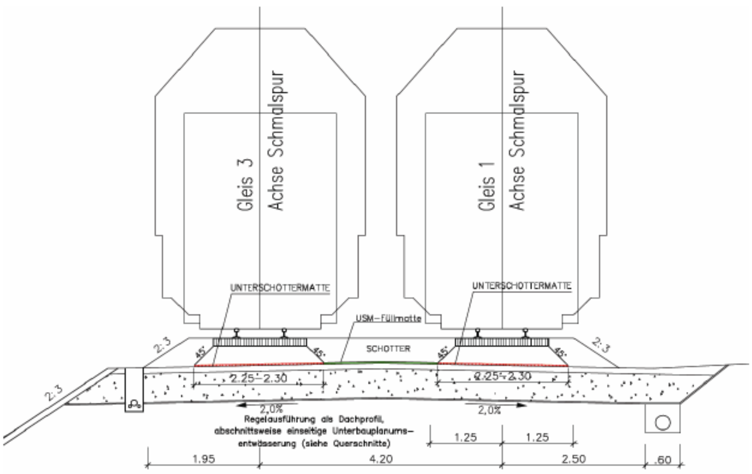
Standard cross-sections

The geometric arrangement of the mats was specified for the available standard cross-sections irrespective of the choice of the optimum type of Sub Ballast Mat. In this respect, the width of the Sub Ballast Mat mainly depends on the effective transmission area of vibrations and structure-borne noise.



Achse Schmalspur = Narrow gauge axis
Unterschottermatte = Sub Ballast Mat
Schotter = Gravel
Variabel = variable

Fig. 4: Single-track standard cross-section with Sub Ballast Mat.



Gleis = Track
Achse Schmalspur = Narrow gauge axis

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Unterschottermatte = Sub Ballast Mat
USM-Füllmatte = USM filler mat
Schotter = Gravel
Regelausführung als Dachprofil, abschnittsweise einseitige Unterbauplanumsentwässerung (siehe Querschnitte) = Standard design as upper section, discontinuous subbase drainage (see cross-sections)

Fig. 5: Two-track standard cross-section with undergravel mat underneath both tracks – upper section.

Decision

The use of DAMTEC® KRAIBURG USM single-layer Sub Ballast Mat (d = 23 mm) was recommended in view of material costs and the costs for laying, as well as the static and dynamic properties of the Sub Ballast Mat.

Fundamentally, it was pointed out that the effects of Sub Ballast Mat depend largely on the properties of the layer beneath. The analysis carried out applied for a foundation with a compression module of $E_{V,2}$ = 180 MN/m². An optimum effect was achieved through the installation of rigid covering layers (asphalt or concrete subbase). The latter possibility was not advisable in the case on hand from the overall point of view of effectiveness and economic efficiency. Nevertheless, attention was to be paid to good compaction of the upper subbase and/or frost layer.

Installation illustrations

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References

Report no. 07-1103-02 - April 2007 – Optimisation of Zillertal Railway permanent way with regard to vibrations and secondary noise – Fritsch, Chiari & Partner ZT GmbH

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