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LOW VIBRATION TRACK SYSTEM (LVT)

Vibration attenuation report

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1. General information

The modern and under different conditions well experienced slab track system Low Vibration Track (LVT) was developed in the nineties out of the twin block sleeper system for ballastless track.

Due to urban needs in concerns of effective protection of the neighbourhood to commuter lines the next step of development was made with LVT high attenuation (LVT HA), which gives very good results in vibration attenuation.

This system fills the gap between the LVT standard system and a floating slab. With the idea to reduce the costly floating slab systems to a minimum and to have a consistent track form over the entire project, the LVT HA system can to some extend substitute floating slab systems.

2. System description

The LVT HA system is an independent block system which exists out of a reinforced concrete block, a resilient block pad, a rubber boot and a rail fixation (due to customer's preference) with an elastic rail pad of about 150 kN/mm (856.5 kips/in) dynamic stiffness. The concept of two elastic levels separated by an intermediate mass effectively attenuates vibrations.

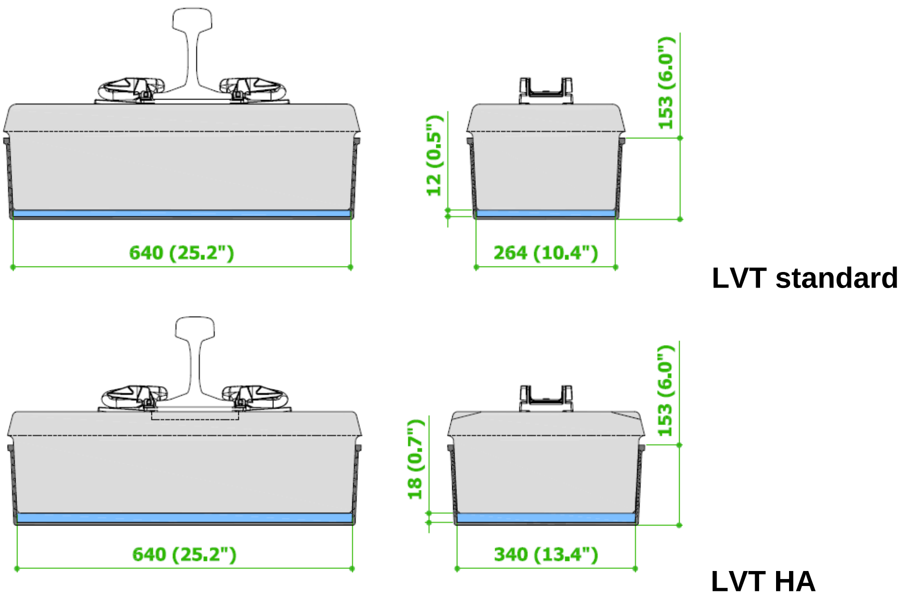

Figure 1: Typical cross sections of the LVT supports

The LVT HA support is 30 % wider than the standard support. This leads to better stability. The resilient pad is 18 mm (0.70 in) thick, what is 50 % more compared to standard LVT.

The spring rate will be designed individually for each project and depends on technical project parameters. However the vertical system deflection is limited to less than 4 mm (0.16 in). Overall this leads to a spring rate for the pad of about 10 kN/mm (57 kips/in).

The bigger mass and the higher deflection give an effective vibration attenuation improvement above 50 Hz of about 5 to 10 dB compared to ballasted track, based on report no. 10-3670 (Heitkamp Rail). The natural frequency of the system is about 30 Hz.

The prerequisite for an ideal behaviour of the LVT system is that the elastic components of the system hardly stiffen under different frequencies. The static stiffness of the material does not reflect correctly the system in service. Only the dynamic loads, implemented in the system under the rolling stock, give a realistic picture of what will happen. Therefore the dynamic stiffness, especially its comparison to the static stiffness, has to be observed. The smaller the ratio between the two (LVT: < 1.5), the more elastic the system behaves under dynamic load and consequently the system is more effective.

3. Elastic components

Sonneville AG significantly improved the vibration attenuation properties over the recent years by reducing the dynamic acoustic stiffening of the system. This involved fine-tuning of the rubber boot configuration and re-specification of the block pad material.

3.1 Rubber boot

Due to the slope of the lower block and boot walls and the surrounding concrete pressing the rubber boot to the block, the dynamic deflection of the block was limited. The reason for this limitation was the tight rubber boot / concrete block interface (wedge effect).

The internal fins, which are added to the ribs of the rubber boot walls, act as spacers between the concrete block and the rubber boot during concreting of the slab. This decouples the concrete block from the rubber boot and allows the block to freely move on the block pad under dynamic loads even at higher acoustically sensitive frequencies.

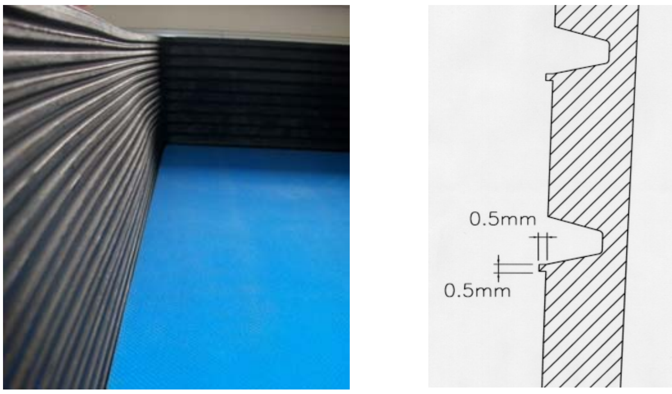

Figure 2: Interior view of the rubber boot including the fin detail

3.2 Block pad

The microcellular LVT pad, which is the main elastic component of the system, was first made of synthetic rubber. The performance of that material under dynamic loads is adverse and makes it behave stiff.

Nowadays the block pads are made out of natural rubber or engineered polyurethane. These materials allow only low dynamic stiffening, due to the much better material properties.

Determination of the dynamic stiffness of a microcellular tie pad / Müller-BBM
Report No. M 72 193/3

The object of the tests was to determine the dynamic stiffness of a microcellular block pad for the LVT system, to be able to judge the structure-borne noise insulation.

Preload in kN (kips)	Stiffness ratio dyn./stat.			
	50 Hz	100 Hz	150 Hz	Average
25 (5.6)	1.22	1.21	1.28	1.24
30 (6.7)	1.31	1.36	1.41	1.36
35 (7.8)	1.45	1.49	1.55	1.50
	Mean ratio			
25 – 35 (5.6 – 7.8)	**1.36**			

Figure 3: Stiffness ratio dynamic stiffness / static stiffness

The average ratio of the measurements (dynamic stiffness / static stiffness) is well bellow the limit of **1.5** as specified by Sonneville AG.

3.3 Result of the adjustments

With the changes in the boot and the block an acoustic dynamic to static ratio of less than 1.5 can be achieved.

That means that the performance in track (the dynamic stiffness) compared with the measured static stiffness is highly effective. The deflection under dynamic load is only 50 % less than under static load. Under dynamic loads this value guarantees good load distribution, low forces at each support and less wear of the components.

3.4 Technical specifications of Sonneville AG

The strict and comprehensive technical specifications of Sonneville AG for the rubber boots and block pads guarantee high performance. Therefore the following set values for the pad have to be achieved:

- Stiffening under dynamic load at 100 Hz of less than 50 % for the standard and the HA pad.
- No water absorption of pad (2 g [0.07 fl. oz.] for standard pad and 5 g [0.17 fl. oz.] for HA pad) allows even under wet conditions high dynamic performance.

4. Measurements with the LVT system

4.1 Measurements in Hong Kong 2002

The results of comparative measurements, performed on four adjacent track sections under identical traffic and recording conditions, demonstrate the progress made in terms of vibration attenuation.

The enclosed Figure 4 shows the insertion gains/losses measured by Wilson, Ihrig & Associates – Hong Kong, Ltd during initial tests performed in June 2002 on four adjacent LVT sections, each 48 m (157.5 ft) in length.

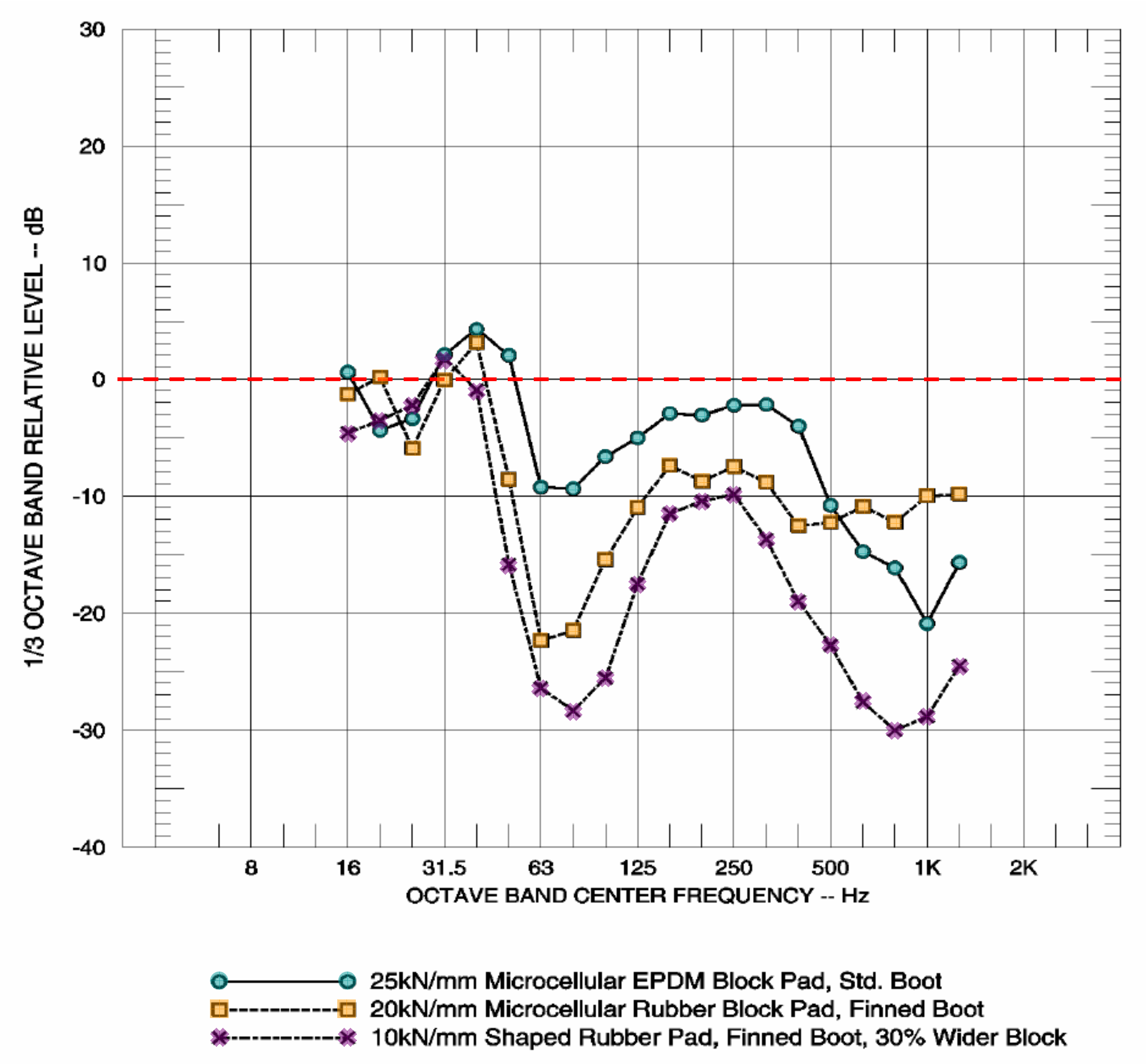

Figure 4: Insertion loss for LVT variants relative to a rigid invert

The first section taken as a “rigid” base line and represented by the zero (red) dB line consisted of the 1990’s LVT standard system with non-finned rubber boots and rigid HDPE block pads.

The second section represented by the top line consisted of the 1990’s LVT standard system with non-finned rubber boots and 30 kN/mm (171.3 kips/in) microcellular EPDM block pads (please note that the 25 kN/mm (142.7 kips/in) value indicated refers to the combined rail pad and block pad spring rate).

The third section represented by the intermediate line consisted of the current LVT standard system with finned rubber boots and 20 kN/mm (114.2 kips/in) support stiffness (microcellular natural rubber block pads).

The fourth section represented by the bottom line consisted of LVT HA with finned rubber boots and 10 kN/mm (57.1 kips/in) support stiffness.

All four sections were equipped with 150 kN/mm (856.5 kips/in) rail pads. Insertion gains/ losses were measured on the track concrete in the centre of each section while two identical locomotives coupled together with an average axle load of 17.5 t (19.3 US t) and an average unsprung mass of approximately 5 t (5.5 US t) per axle travelled over the track at 20 km/hour (12 mph).

The LVT system shows the following improvement in vibration attenuation at 63 Hz:
The “rigid” (red) reference line …

1. compared with the 1990’s LVT standard system = around 10 dB
2. compared with the current LVT standard system = around 20 dB
3. compared with the LVT HA system = around 30 dB

The improvement between the first and second insertion loss is around 10 dB, achieved with adding fins to the boot and changing the pad material.

The improvement between the second and third insertion loss is as well around 10 dB, achieved with using the LVT HA system instead of the LVT standard system.

4.2 Vibration investigation of LVT HA, 2008

Report No. 10-3670-B2, published by Ingenieurbüro Dr. Heiland, Bochum, 1st July 2009

Heitkamp Rail built a LVT HA system pilot track where vibration measurements were carried out in order to investigate the vibration insulation of the LVT HA system in comparison to a standard ballasted track.

For the dynamic excitation a shaker has been used which simulates vibration emissions being equivalent to vibration levels of train sets. Generally the shaker is a mechanical device which generates vibrations, in this case by four electric motors with an unbalanced mass on its driveshaft. As soon as the motors are switched on the rotating weights resonate. In contrary to trains, the shaker is frequency controlled and therefore the excitation is more reproducible and comparable.

Exemplarily a preload of 10 kN (2.24 kips) was implemented to the system during the measurement. The emission points were selected at the rail head and the measurement points were placed in 16 m (52.5 ft) distance (international standard measure distance).

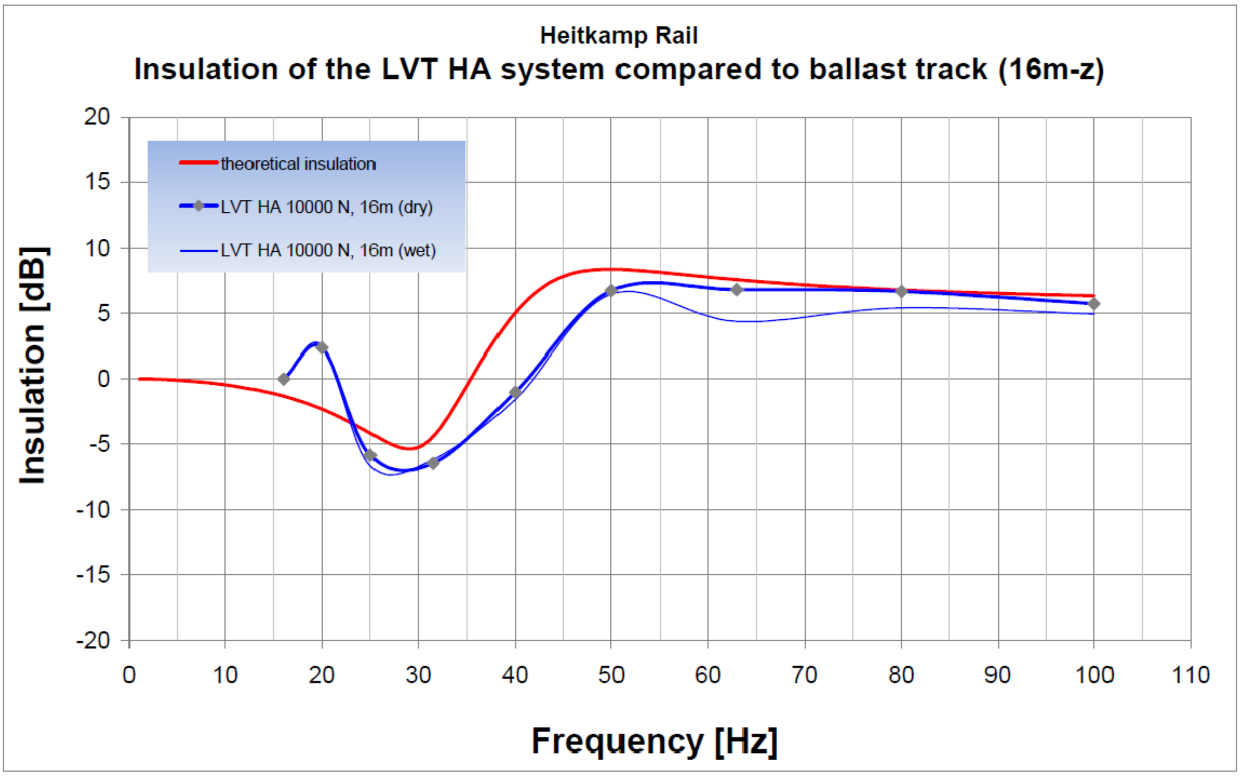

Figure 5: Vibration insulation of the LVT HA system (dry/wet) compared with 30 Hz SDOF system

The LVT HA system shows the following features:

- The vibration attenuation of the LVT HA system above 50 Hz is about 5–10 dB, depending of the 1/3 octave band.
- Under wet condition, the attenuation above 50 Hz is reduced by approx. 2–3 dB.

4.3 Summary of both measurements

It should be noted that the two measurements are not 1:1 comparable with each other. The different results regarding the vibration insulation of the LVT system have the following reasons:

1. In section 4.1, the different development stages of the LVT system are compared with each other. The insertion loss in Figure 4 shows the progress, in terms of vibration attenuation of the LVT system, which was achieved through adjustments on the elastic components and the LVT system choice.

   Furthermore, the measurements where made on a rigid subsoil (tunnel floor), and the stiff block pad has served as a reference.

2. In Section 4.2, the HA LVT system is compared with conventional concrete sleepers in ballast. The chart in Figure 5 visualizes the better insulation of LVT HA compared with the ballasted track.

   Please note that the ballasted track in general is a very soft track form and therefore the results compared to the measurements in Hong Kong are different.

4.4 Structural noise and vibration measurements of LVT HA, 2011

Study by engineering consultants “Tyréns”, measuring structural noise and vibrations from the citytunnel Malmö, Sweden

The study was undertaken during two non consecutive weeks and in four different locations above or as close as possible to the Citytunnel Malmö, measuring the structural noise and vibrations caused by passing trains.

The locations of the meters were as follows:

1. On the first floor (half story above street entrance level, basement was not suitable for measurements) of a hospital, making measurements in a patient room, in a bathroom and an air lock (UMAS Entrance, Hall 6. (see page 4 of the study)

2. In the basement of an apartment building, making two different measurements in the corridors outside of the storage rooms and one near the stairway. (Kv Guvernören 4, BRF Banéret, Banérsgatan 8 (see page 5 of the study)).
3. In the basement of an apartment building, making three different measurements outside of the corridors of the storage rooms. (Kv Munken 7, BRF Munken Munkgatan 5 (see page 6 of the study)).
4. In the basement of an apartment building, making one measure in the corridors outside of the storage rooms and two in different storage rooms. (Cronquist studenthem Sommarstadens cat 10 (see page 6 of the study)).

The maximum values required under the Swedish environmental standard applicable to this project were:

Structural Noise **L_{max} = 30 dBA**
Vibration **V_{RMS} = 0.4 mm / s**

The values obtained from measurements made were:

Location	**Struct. noise L_{max}**	**Vibration V_{RMS}**
UMAS Entrance, Hall 6	< 25 dBA	< 0.1 mm/s
Kv Guvernören 4, BRF Banéret, Banérsgatan 8	< 25 dBA	< 0.1 mm/s
Kv Munken 7, BRF Munken Munkgatan 5	< 27 dBA	< 0.1 mm/s
Cronquist studenthem Sommarstadens cat 10	28 dBA 27 dBA	< 0.1 mm/s < 0.1 mm/s

Noise level comparison: 35 dBA ≙ Whispering

5. Airborne noise attenuation

Airborne noise is generated whenever a train runs over the track (vibrations of car body, wheel and rail). Airborne noise absorption can vary depending very much on the surface structure.

A closed structure such as slab tracks has in general not the same absorption as an open structure like the ballasted track. The harsh sound of the slab track is slightly higher (about 2 dB) than the one of the noise absorbing, porous ballasted track.

This difference can be overcome by installing acoustic concrete as a finishing layer on the concrete slab. Track side noise barriers incorporated into the civil works or to attenuate the rail web, can also help reducing the noise.