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Installation of the first Getzner mass-spring system in Hungary – a significant reduction in noise and vibration from traffic achieved

In November 2016, the first mass-spring system in Hungary was successfully implemented on a track section of the Budapest tramway network. The adopted mass-spring system with Sylomer®, developed by Getzner Werkstoffe GmbH in collaboration with the Budapest transport company BKV Zrt. and Sika Hungária Kft., meets the requirements for modern superstructures whilst protecting residents of neighbouring buildings from tramway traffic noise and vibrations. Measurements conducted have verified the outstanding effect on vibration protection and reduction of secondary airborne noise of the implemented measure, which has also been asserted by residents of neighbouring buildings that were previously affected by vibration emissions and noise resulting from passing tramway traffic.

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The tramway of Budapest dates back to as far as 1866. When it first opened, horses were still being used to pull what was then the first modern means of transport in Budapest, satisfying the need for mass transportation. As of 1887, the first sections of line were electrified. Since then, the tramway network has been extended to a track length of 147 km. Today, the tramway, the Budapest Metro, the Budapesti Helyiérdeku Vasút suburban railway and the city's bus transport system are all operated by the Budapest transport company BKV Zrt. (BKV for short).

THE CHALLENGE OF NOISE AND VIBRATION

Today's transport operator is faced with more and more demands. In addition, an increasing number of residents that live near tramway lines tend to complain about noise and vibration from tramway traffic. This was also the case in Budapest.

To counter this negative impact from tramway traffic on the quality of life of residents of neighbouring buildings, BKV worked closely with Sika Hungária and Getzner Werkstoffe to construct a test section featuring a slab track mass-spring system. This protective measure is particularly useful when properties are located just a short distance from the centre of the track, as the cause is reduced directly at the source. Moreover, the slab track mass-spring system featuring slabs made of reinforced concrete and a full-surface bearing made of Sylomer® can also be installed quickly and accurately.

TEST SECTION IMPLEMENTATION

The approx. 96 m long test section featuring the slab track mass-spring system was installed in the existing standard superstructure in "Vörösmarty utca" street, on tramway line 52, which was originally built in 1980 and is 7 km long.

This line is operated with eight-axle type T6000 tramcars, which each have an unladen weight of 38.8 t and a passenger capacity of 176.

Installation process (see also Figs. 1-5)

The line section had to be closed off during the renewal work, which took place in the first two weeks of November 2016. The already ageing superstructure had to be exposed along the entire length of the test section.

Above the 20 cm thick sub-base, a 5 cm thick asphalt layer encloses the top of the subgrade. Full-surface 25 mm thick polyurethane mats made of Sylomer® from Getzner were installed on top of this. These take on the role of elastic bearings for the concrete slabs in relation to the substructure. A truck-mounted crane and a four-rope crane sling were used to raise the pre-fabricated concrete slabs (6 m x 2.4 m x 0.18 m) and place them onto the elastomer mats. The concrete slabs are separated by an approx. 2 cm wide gap.

Fig. 1: Initial construction phase of the test section

Fig. 4: Concrete slabs with rail channel

Fig. 2: Transition zone with Sylomer® mats

Fig. 5: Finished track

Fig. 3: Installation of the concrete slabs

Two-stage transitions to the existing standard superstructure, totalling 9 m and varying in stiffness, were installed at both the beginning and the end of the test section, in order to ensure that rail deflection is homogeneously smoothed out when a tram passes over the transition zones between the existing standard superstructure and the new mass-spring system. In this manner, an abrupt difference in bedding stiffness is avoided, thus reducing the dynamic loading of the superstructure in these zones.

Along the entire length of the test section, Sylomer® side mats with a thickness of 25 mm were installed, in order to laterally decouple the mass-spring system from the adjacent road surfacing.

Once the laying, alignment and welding work was completed, the installation work was finished off by embedding the rails in the rail channels and filling the gap between and to the side of the concrete slabs with Sika Icosit KC 340/45 PU.

MEASUREMENTS VERIFY EFFECTIVENESS OF THE INSTALLED MASS-SPRING SYSTEM

The effectiveness of the installed slab track mass-spring system as regards vibration protection and reduction of secondary airborne noise was evaluated in two stages at different times, i.e.:

- the existing condition with the standard superstructure was evaluated in October 2016; and
- measurements were conducted following the installation of the slab track mass-spring system in November 2016.

Vibration recordings were made in a residential building located directly adjacent to the test section, selected by BKV, during the passage of trams. Data was acquired from two measuring points located on the living room floor using geophones, at a very short distance – 4 m – from the centre of the track. At the same time, measuring points were also set up at three different locations on the pavement, all at a distance of approx. 3.4 m from the centre of the track and an 8 m longitudinal clearance between them.

In addition, recordings of secondary airborne noise from passing trams were made inside the residential building with the windows closed.

Fig. 6: A T6000 tram passing over the new slab track mass-spring system

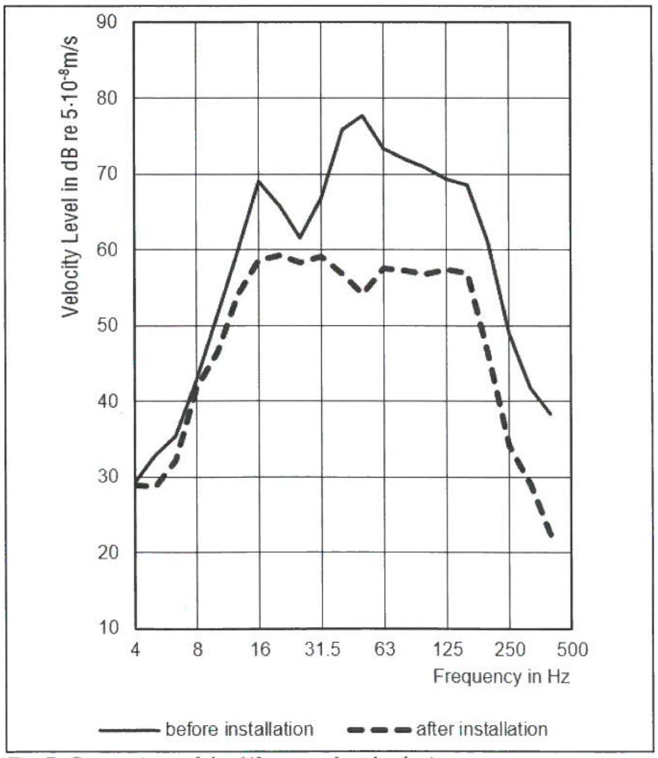

Fig. 7: Comparison of the 1/3-octave-band velocity spectra measured in the residential building, both before and after installation of the slab track mass-spring system

Analysis of vibration measurement results

In order to evaluate the effectiveness of the implemented noise and vibration mitigation measure, both before and after the installation of the slab track mass-spring system, recordings were made during the passage of 14 trams (Fig. 6).

For each individual measurement and measuring point, 1/3-octave-band velocity spectra were determined in the frequency range of 4-400 Hz using the Max Hold method ("Fast time weighting"). For each measuring point, the energetic mean value of the 1/3-octave-band velocity spectra for all 14 tram passages was calculated from the spectra of each individual passage. The arithmetic mean was calculated based on the two measuring points located in the residential building and the three measuring points located on the pavement noted earlier. These averages can be used to form a 1/3-octave-band velocity level difference for both groups of measuring points that can be presented in a graph as a function of the 1/3-octave-mid-frequency. This difference represents the vibration mitigating properties of the mass-spring system in comparison to the standard superstructure; this is referred to as the insertion loss.

In Fig. 7, an example of the 1/3-octave-band velocity spectra obtained from the measurements made in the residential building both before and after the installation of the slab track mass-spring system is shown.

As can be observed from Fig. 7, the vibration emissions within the residential building have been considerably reduced across a wide frequency range by the installation of the slab track mass-spring system.

Effect of vibrations on people

In locations where vibrations generated by traffic loading have a direct impact on residents of neighbouring buildings, the evaluation method set out in DIN 4150-2 [Ref.] is frequently applied and the maximum weighted vibration intensity KB_{Fmax} is determined. This evaluation method allows for quantification and comparison of the effect of vibrations on people. The standard also includes typical values for subjective human perception. Adhering to these values normally prevents disturbance to people in neighbouring buildings.

If the average maximum weighted vibration strength KB_{Fmax} is determined using the evaluation method of DIN 4150-2, this results in a value of 0.5 in the residential building prior to installation of the vibration mitigation measure, which can be described as "noticeable".

Following installation of the slab track mass-spring-system, the average maximum weighted vibration strength KB_{Fmax} was 0.09. This is beneath the value regarded as the "perception threshold" of $KB_{Fmax} = 0.1$, below which there is, on average, no physical perception of vibrations.

The implemented vibration mitigation measure reduced the perception of vibrations inside the residential building by approx. 80%. Comparable positive results in vibration level reduction were achieved at the measuring points on the pavement.

Analysis of airborne noise measurement results

The residential building was occupied when the airborne noise measurements were made in the living room, making the analysis of noise pollution from passing trams somewhat difficult due to people talking or dogs barking repeatedly.

However, it was possible to determine the maximum noise emission from the bogies passing by as an average A-weighted continuous sound level L_{AFeq}.

Compared to the initial value of 57.3 dB(A) measured prior to the installation of the slab track mass-spring system, the maximum level measured in the living room following installation was 48 dB(A), i.e. a reduction of 9.3 dB. This positive result was also reflected in statements made by residents of this and neighbouring buildings.

CONCLUSIONS

The first mass-spring system in Hungary was installed on a track section of the tramway network operated by the Budapest transport company BKV Zrt., aimed at minimising vibrations and secondary airborne noise from passing tramway traffic.

Measurements conducted as regards vibration and secondary airborne noise, both before and after the installation of the slab track mass-spring system, emphatically confirmed expectations. The implementation of this mitigation measure has led to a reduction in vibration level of approx. 80%, whilst the secondary airborne noise dropped by 9.3 dB.

BKV is pleased that its trams now cause significantly less vibration and noise for the residents of the buildings adjacent to the section now featuring the slab track mass-spring system. The residents in question confirmed that there is now less disturbance from passing trams – they are obviously very pleased with that result.

REFERENCE

DIN 4150-2:1999-06: 'Structural vibration - Part 2: Human exposure to vibration in buildings'.