Noise and Vibration Tests for the Reconstruction of the Southern Railway Bridge in Budapest

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Summary

Hungary's busiest railway bridge is in Budapest. Currently, the construction speed of the railway bridge is 80 km / h, however, due to the state of the bridges a speed limit of 40 km / h is in force. On the planned railway bridges, this will be upgraded for passenger trains up to 100 km / h, and for freight trains up to 80 km / h.

Since the planned investment affects Budapest's buildings of especial acoustic value, we have developed a test and planning method that ensures that the current noise and vibration status of both Palace of Arts (MÜPA) and the National Theatre does not change.

We based our planning of noise and vibration protection on the concept that a similar construction as a Tisza railway bridge in Szolnok is planned to be built. At this bridge EdilonCorkelast® (Edilon ERS) continuous supported track fixation was used. Surrounding material of the rails is Edilon)(SedraCorkelast VA 60 flexible embedding compound. Trackelast 3000 flexible rail seat pad has been fitted under the rail base.

The planned bridge and the bridge in Szolnok will differ in the thickness and height of the plates. At the present railway bridge, we developed a special test method with more measurement points. So, we investigated the current noise and vibration emission, propagation conditions and imission.

We performed tests to determine radiating noise and vibration emissions for the planned bridge on the railway bridge in Szolnok as it has a similar structure to the planned one. The structural changes were taken into account during the calculations. Using the results obtained, noise maps suitable for tracking the radiation of the bridge were elaborated to determine the expected noise level and transfer functions for the expected vibration levels. Based on this, we have prepared the noise and vibration protection action plan for the bridge planning.

1. Introduction

In Budapest, a 3rd railway bridge is planned to be located between the Southern Railway Bridge and the Rákóczi Bridge. Near the bridges are the internationally famous Palace of Arts and the National Theatre. The location is shown in Figure 1.

2. Palace of Arts and the National Theatre

Since the planned investment affects Budapest's buildings of especial acoustic value, we have developed a test and planning method that ensures that the current noise and vibration status of both Palace of Arts (MÜPA) and the National Theatre does not change.

In order to achieve the above planning method, measurements were made to determine the noise and vibration emission, imission of the existing bridge. Measurements were made inside MÜPA, inside the National Theatre and at the existing Southern Railway Bridge.

3. Basic planning data

Currently, the construction speed of the Southern Railway Bridge is 80 km / h, however, due to the state of the bridge a speed limit of 40 km / h is in force. On the planned railway bridge, this will be upgraded for passenger trains up to 100 km / h, and for freight trains up to 80 km / h.

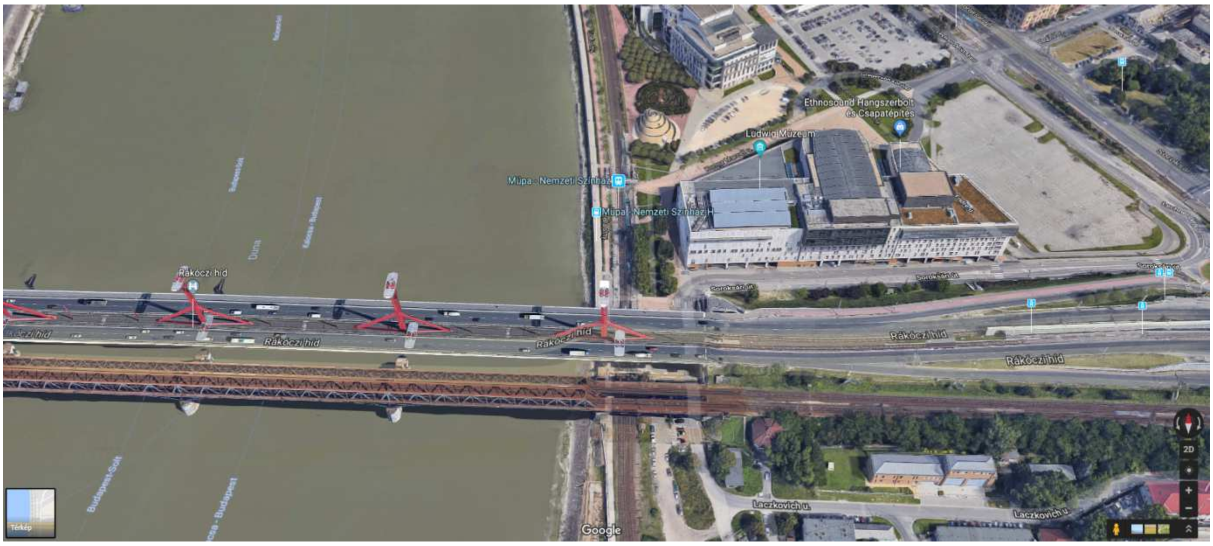

Figure 1. Site view of the development area

In order to achieve the above planning method, measurements were made to determine the noise and vibration emission, imission of the existing Southern Railway Bridge and at the Tisza Railway Bridge in Szolnok as it has a similar structure.

At the Tisza Railway Bridge in Szolnok which has a similar structure to the planned one, EdilonCorkelast® (Edilon ERS) continuous supported track fixation was used. Surrounding material of the rails is Edilon)(SedraCorkelast VA 60 flexible embedding compound – in a length of about 790 track meters. Trackelast 3000 flexible rail seat pad has been fitted under the rail base. Tile of sheet – iron were laid on the bridge.

4. Noise tests

Test method

To effectively plan the noise and vibration emission of the planned bridge, we have to know the noise and vibration component excited by each bridge structure element. Therefore, we performed two series of measurements. We have examined the maximum permissible noise and vibration transmission in the surrounding of the two bridges.

Emission noise measurements of the two bridges

Noise level was measured at noise measurement points using 4 measuring microphones located in a measurement segment over the ground perpendicular to the axis of the bridges. The points of the measuring microphones were as follows:

- measurement point (MP1): under the bridge over the dry land at the ground level along the centreline of the left track
- measurement point (MP2): in the plane of the southern handrail of the bridge over the dry land at ground level
- measurement point (MP3): at an angle of 45 degrees downwards from the edge of the pedestrian walkway of the bridge over the dry land (9,2 metres from the plane of the handrail) at the ground level
- measurement point (MP4): 19 metres from in the plane of the southern handrail of the bridge over the dry land at ground level

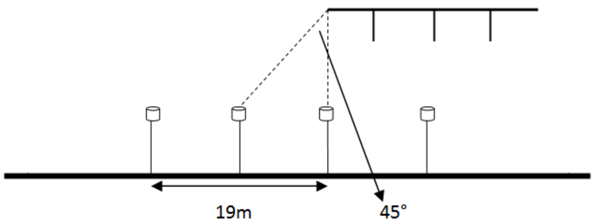

Figure 2. Microphone positions under the bridges

Noise levels from the existing railway bridge is characterized by sound exposure level values (SEL_A) and maximum passing by noise levels (SEL_{AMAX}).

Table I. Measured maximum noise levels of the two bridges.

	DÖVH	*Szolnok*	*Difference*
		$L_{Amax}(dB)$	
MP1	*103,4*	*109,7*	*6,3*
MP2	*102,0*	*107,6*	*5,6*
MP3	*97,0*	*102,6*	*5,6*
MP4	*91,6*	*99,3*	*7,7*

From the table above can be stated that the noise level value from the passage of a freight train on the railway bridge in Szolnok is 7.7 dB higher at the measurement point at 19 m than the noise level value at the existing bridge.

The different speed of the trains passing over the two bridges (DÖVH: 40 km / h, Szolnok 120/100 km / h) result a significant noise level increase: 9.5 dB for passenger trains and 8 dB for freight trains.

Noise measurements in the near-field of the railway bridge in Szolnok

Additional measurements were also performed to examine the radiation of the bridge. For this purpose, noise measurements have been carried out not only at a far – field point of the bridge, but also in the immediate vicinity of the bridge. Besides its direct evaluation, near-field noise measurements were also suitable for taking sound field simulation calculations into consideration at a perspective state.

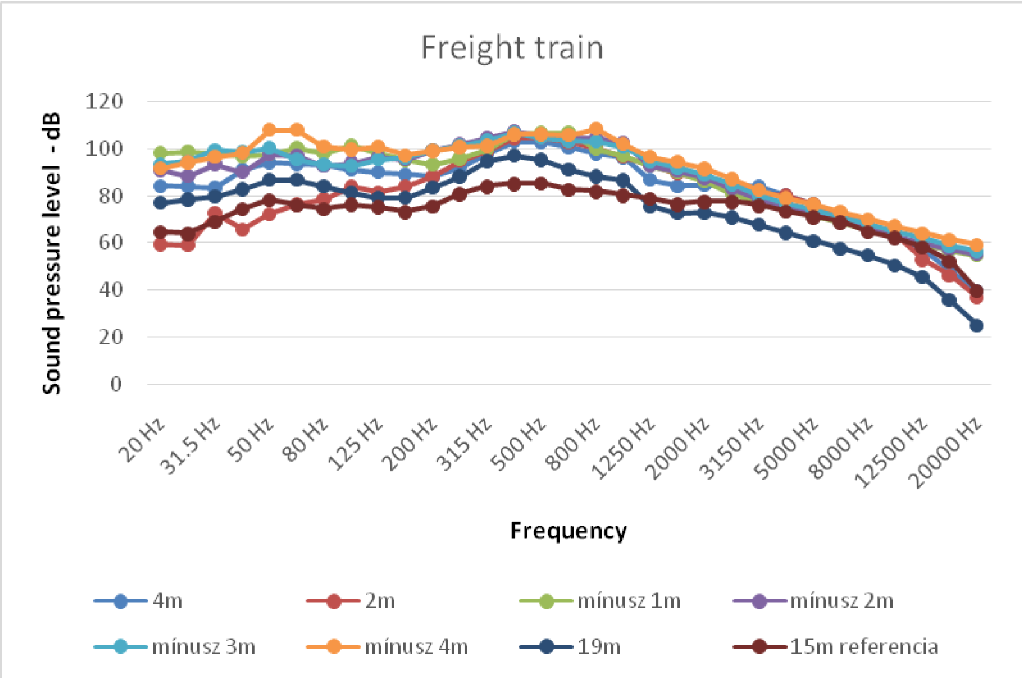

Figure 3. Near-field noise levels while passing by a freight train

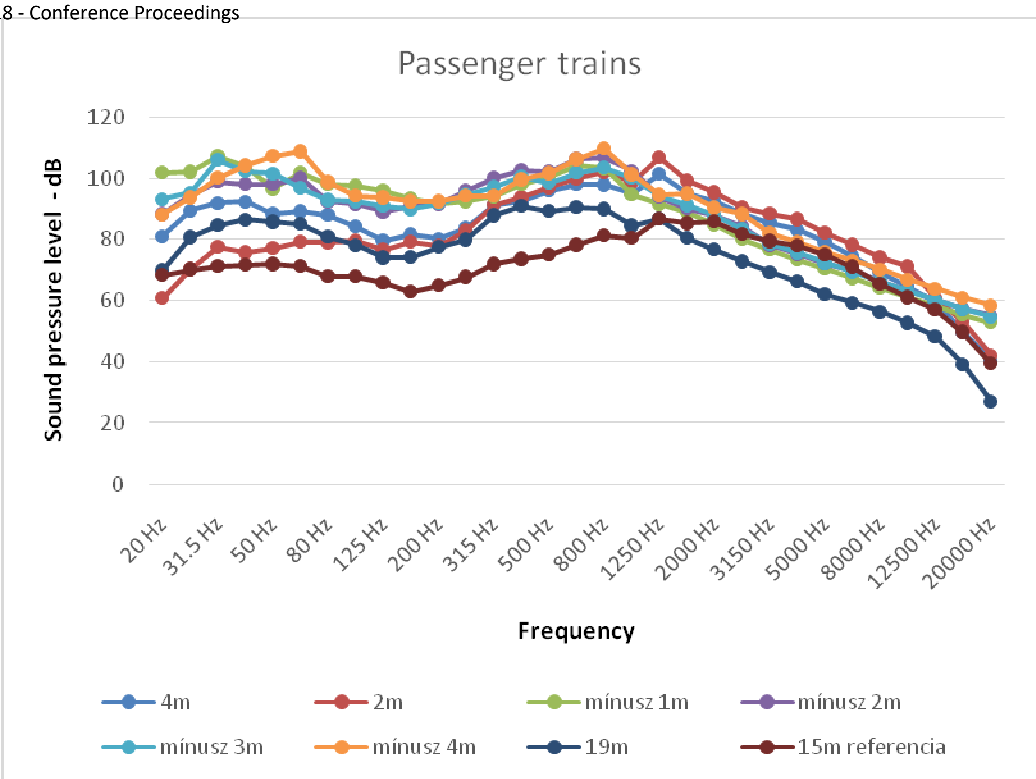

Figure 4. Near-field noise levels while passing by a passanger train

Noise Protection Proposals

Because of the above, we have planned the following noise protection measures:

In order to protect the building of MÜPA we planned noise barriers on the right side of the centre and the south bridge instead of the handrail from the beginning of the bridge located along the bridge over the dry land in length of 50 meters long 2 m over the sidewalk level and 1.5 m + 0.3 m with an incurvation angle of 90 degrees below the sidewalk level and located along the bridge over the river 1 m over the sidewalk level and 1.5 m + 0,3 m with an incurvation angle of 90 degree (below the sidewalk level). In addition, we have planned noise barriers next to the track, 2.5 m high over the rail head and 324 m long for the railway embankment in front of MÜPA.

Furthermore, we proposed to use a glass fiber reinforced polyester plate, a resin-coated lighter vibration attenuation plate on the steel bridge instead of the steel slit plate (the commonly used tile plate). Its radiation is minimum with ΔLWA= -8 dB lower than the radiation of the steel slit plate.

5. Vibration tests

We performed tests in order to determine the current vibration load, the vibration load caused by the railway. The resulting vibration load depends primarily on the dynamic properties of the track structure of the railway, the dynamics of the soil between the track and the building, and the structural properties of vibration-loaded buildings greatly determine the vibration load.

Vibration emission measurements of the two bridges

In order to determine the vibrations value of the two bridges, vibration measurements were performed at 5 measurement points located on the bridge structure and on at additional measurement points in front of the building of MÜPA at its closest point to bridge.

The measurement points are positioned perpendicular to the axis of the bridge, as follows:

- measurement point 1. (MP1): in the centre of the bridge, between the two rails, with a vibration sensor in 3 directions
- measurement point 2. (MP2): at the GEO plate of the rail fixation in vertical direction
- measurement point 3. (MP3): at the side plate of the bridge, with a vibration sensor in 3 directions
- measurement point 4. (MP4): on the beam of the bridge's supporting structure frame, horizontal, perpendicular to the longitudinal axis of the bridge
- measurement point 5. (MP5): on the bottom ridge of the bridge, bellow the rails, in the vertical direction

- measurement point 6. (MP6): in front of MÜPA with a vibration sensor in 3 directions

Vibration load of the future state with the planned bridge constructed

The following figures illustrate the pass-through spectrum of a freight train on the Southern Railway Bridge and on the railway bridge in Szolnok at different measurement points:

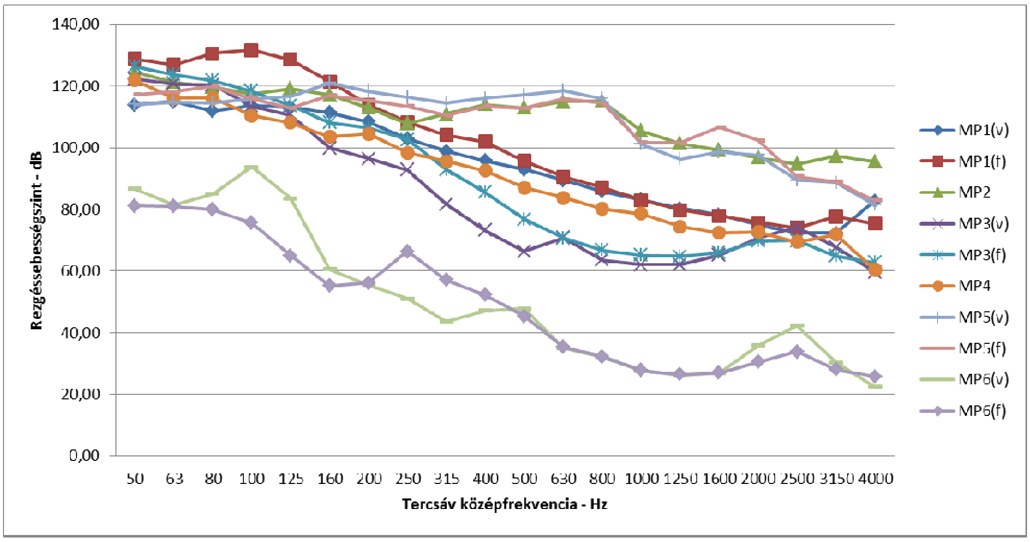

Figure 5. Vibration spectra while passing by a freight train at DÖVH

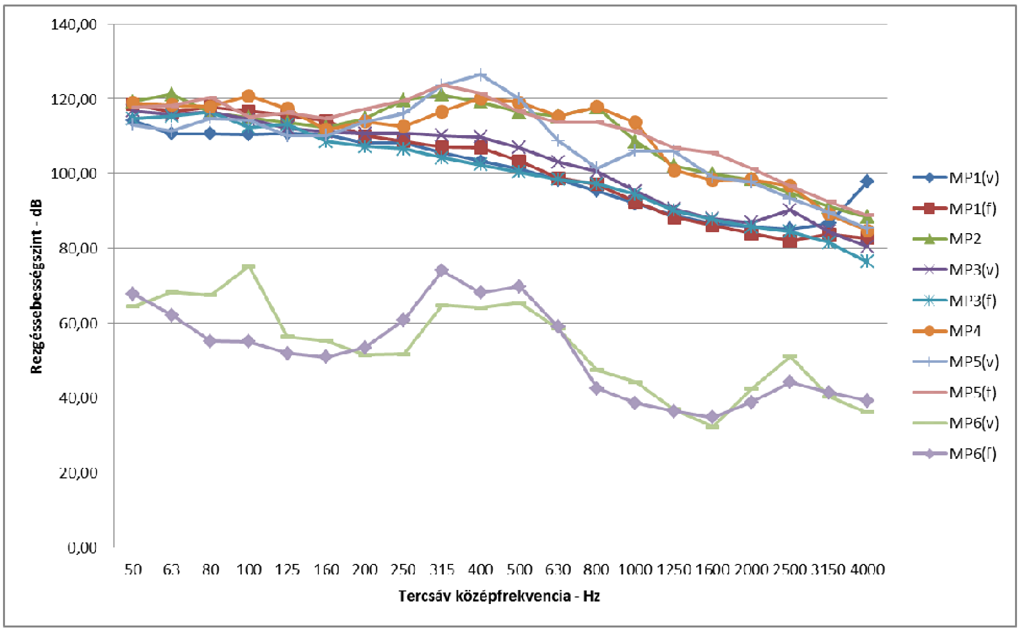

Figure 6. Vibration spectra during the passing by of a freight train at railway bridge in Szolnok

Based on the previous figures it can be stated that at the existing DÖV bridge, the vibration values in terms of frequency decrease, the summed frequency values in front of the building is 0.15 mm / s. We can count with this summed maximum during the passing of a freight train. This value can be considered as the limit value in the followings.

In order to examine the current vibration transmission in the soil of DÖVH, a transfer function has been carried out considering the passage of a freight train because the soil conditions do not change after the construction of the new bridge. The following figure shows the vibration speed at the two measurement points as a function of the frequency:

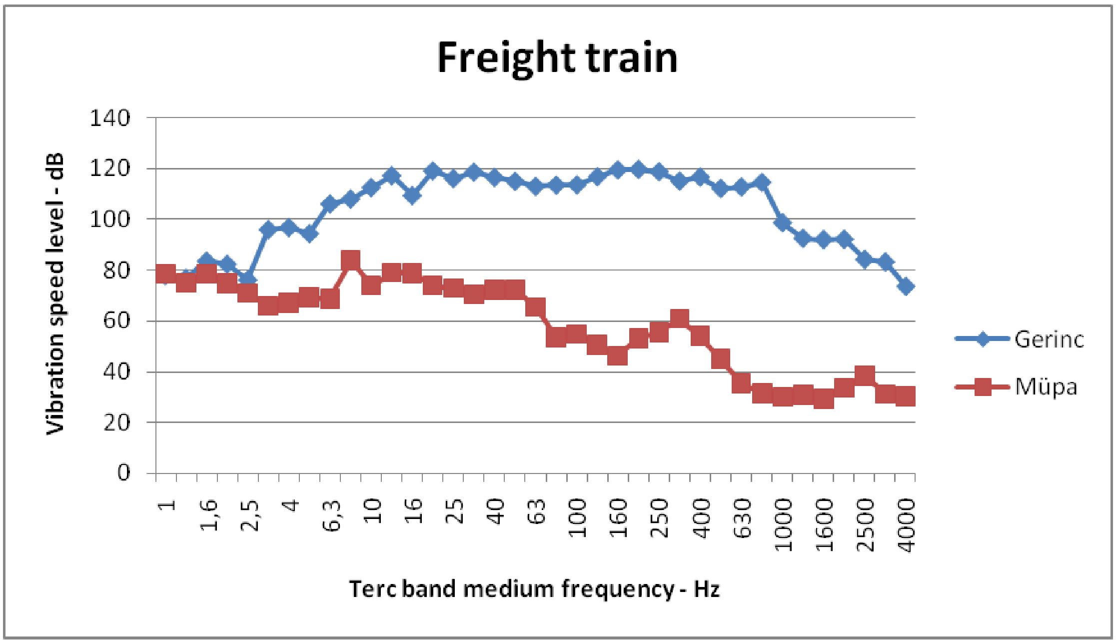

Figure 7. Vibration spectra while passing by a freight train at two measurement points at DÖVH

Between the two measurement points we get the following transfer function (vibration reduction) as a function of frequency

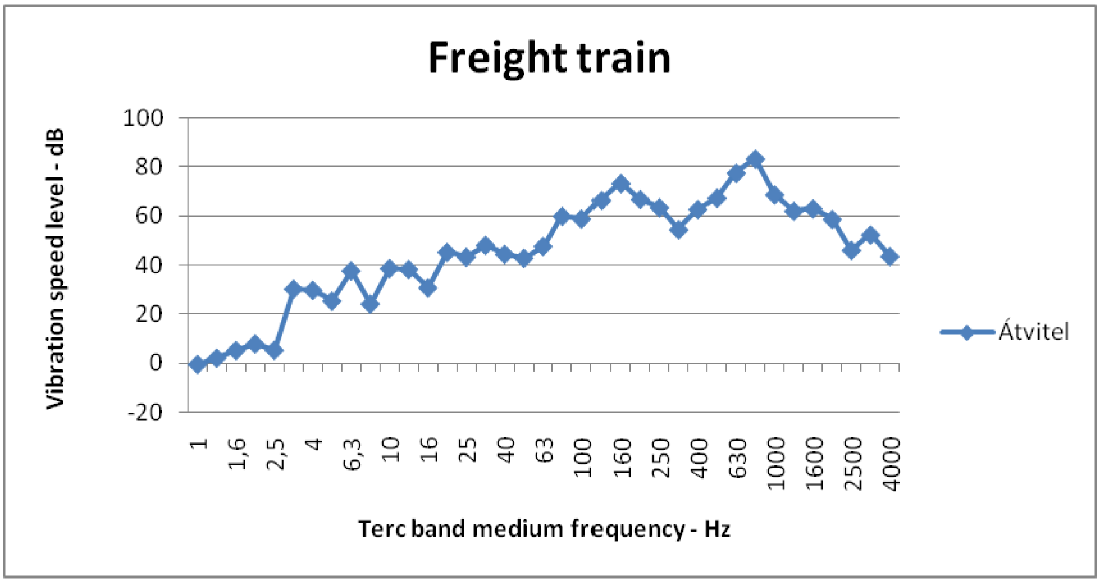

Figure 8. Vibration speed level reduction at DÖVH

The maximum value of the same vibration measurement point of the railway bridge in Szolnok and the transfer function can be used to determine the expected vibration speed value at the MÜPA building.

The calculated value is 0.08 mm / s, which is smaller than the current vibration speed from DÖVH. Therefore, no vibration reduction is required.

6. Conclusion

During the design of the new railway bridge, after the measurements and noise and vibration evaluations we concluded that further noise mitigation measures are needed to protect the Palace of Arts building because the trains speed will be higher the present. The planned vibration mitigation in the track will be appropriate to protect the building’s concert halls.