Traffic vibration measurement in different construction phases of an acoustically high-standard building

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1. Introduction

An acoustically high-standard building was planned to be built 25 m far from the urban railway, and 200 m far from a steel railway bridge.
Before construction, we took vibration measurements in the ground, and during the construction process, on the footplate, to determine initial data necessary to set strict acoustical requirements on the building.
This presentation describes the measuring method for determining vibration load on the building, as well as the results of the measurements taken.

Vibration tests were in fact vibration speed measurements on the construction site. Vibration speed was determined with analogue integration, using signal conditioning amplifiers. Measurement results were documented as a function of vibration speed level against frequency. Sound intensity level from the structure (if the reference level of vibration speed level is V_0 = 5*10^(-8) m/s) gives direct information on the expectable sound intensity level from the building structure. On this basis, noise power from concrete slabs may be estimated.

The second series of measurements was taken on the finished footplate, which was ready to hold the superstructures and panelling.

After finishing the studied building, structural noise and vibration measurements, taken at different, more or less insulated parts of the building are shown.

2. Reason of the measurements

The new building is located in the 9^{th} district, Soroksári út, near Lágymányosi Bridge, beside the Danube and the Suburban Railway, in a – in terms of vibration – „strongly contaminated" area of Budapest. Csepel Suburban Railway is located about 25 m, while 2x3-lane Lágymányosi road and railway bridges are located approximately 200 m far from the planned building.

Among the listed environmental vibration sources, the two bridges have particular importance, since their riverside piers reach deeply into the load-bearing clay layer, and vibrations conducted by this significantly contribute to the vibration load on the planned building.

The goal of our tests was to determine initial data necessary to pre-estimate vibrations in acoustically exposed areas, and, therefore, the indoor noise.

Goal of tests performed on the footplate of the building was to determine initial data necessary to set strict acoustical requirements on the auditorium of the planned theatre, and to determine data necessary to design a suitable vibration insulation.

Structural noise caused by vibrations from the ground and conducted to the building structure forms an important part of the vibration load on the inside area of the theatre. Determination of vibrations that cause this noise is particularly important even during the groundwork, since structural noise insulation may be effective only when built during the groundwork of the building. Vibrations on concrete structure spread throughout the building in fact unhindered, without any damping, and, as a secondary air noise, are conducted to the auditorium by all edge structures, as noise sources, thus increasing the background noise.

3. Test method used

Vibration tests were in fact vibration speed measurements on the construction site. Measurement results were documented as a function of vibration speed rate against frequency.

Vibration speed level by definition is:

$$\mathbf{L_v} = 20*\log(v/ (5*E\text{-}8)) \quad [dB]$$

where - L_v – the value of vibration speed level [dB re 5*E-8 m/s]
- v – the measured vibration speed [m/s]
- V_0 = 5*E-8 [m/s] the reference speed

Numerical value of vibration speed level calculated with the above formula is – provided unit radiation degree and free-space noise radiation – equal to the sound intensity level value from the structure, therefore measurement results give direct information on the expectable sound intensity level from the building structure. Radiation degree of the planned Ferro-concrete structure may be considered as 1 or almost 1 in the acoustically important frequency range, due to the low limit frequency of the thick concrete structures. Noise power from concrete slabs can be estimated using the following formula /1/:

$$L_W = L_V + 10*\log \delta + 10*\log S + K \quad [dB]$$

where - L_W – the noise power level from the vibrating structure [dB]
- L_V – the vibration speed level on the surface [dBre5*E-8]

- δ – the radiation degree of the vibrating surface [-]
- S – the area of the vibrating surface [m^2]
- K – the local correction factor (can be determined with local measurements)

Sound pressure level in the final hall shall be determined by the set hall constant, but when calculating indoor noise, structural noise power must be considered, and, in case vibration energy is already present in the edge structure, indoor noise may be decreased by using wall and floor panelling that reduce noise radiation.

4. Test points

Measurements took place in three stages.

Stage 1: 17-18 September 2000 (during groundwork)

- ❖ On foot-piles (Piles No. 228 and 317)

Stage 2: 11 December 2000 (after finishing the footplate)

- ❖ On the raw footplate of the auditorium
- ❖ On the raw footplate of the studio stage

Stage 3: 7 April2001 (after finishing the flooring)

- ❖ On the finished footplate of the auditorium
- ❖ On the finished footplate of the studio stage

Measurements in each stage were performed along three, mutually perpendicular axes. Measurement directions were as follows:

X - axis- Horizontal, perpendicular to the track of the Suburban Railway
Y - axis - Horizontal, almost parallel with the track of the Suburban Railway
Z - axis - Vertical, perpendicular to the X- and Y-axes

Measurement axes were later renamed as a system of co-ordinates attached to the line source, since measurements taken parallel with the axis of the source had given such low values, which could be omitted. The new axes are as follows:

R – axis – Horizontal, perpendicular to the axis of the source (i.e. the railway track and the track of the Suburban Railway)
Z – axis - Vertical, perpendicular to the axis of the source (i.e. the railway track and the track of the Suburban Railway).

5. Test Results

5.1. Measurements on the foot-piles

Final results from test data results are illustrated numerically in Table R1, and graphically in Figures R1-R4. In the figures, the frequency function of long-term effective values of basic vibrations is also indicated.

5.2. Measurements on the raw footplates

Measurements on the raw footplates – since these were intermediate tests – are illustrated graphically, in Figures R5-R9.

In Figures R7-R8, measurements on the foot-piles are also indicated to show the dynamic effect of the plate on the pile.

To prove that horizontal vibration is significantly lower than Z-axis vibration, we also indicated the vibration speed level – frequency function of the R (Y) vibration in Figure R9.

5.3. Measurements on footplate with “finished” walls attached

The third series of measurements was performed on the footplate ready to hold superstructures and panelling.
Third-band measurements were illustrated both numerically (Table R3) and graphically (Figures R10 and R12), since numeric values are necessary to set the indoor acoustical design.

6. Summary

By associating train-passing and spectra, it could be unambiguously shown that peaks are a consequence of passing trains (and, less importantly, Suburban Railway trains), and “basic vibration” is caused by road traffic on Lágymányosi Bridge.

Based on the above, it is clear that acoustically exposed areas must be fitted with a suitable vibration insulation to minimise any vibrations here. These areas, as individual dilatational units, must be completely separated from the other parts of the building, and their points of support must be fitted with a suitable vibration insulation.

On both sides of dilatational gaps, between two-layer sidewalls between protected and non-protected areas, a layer of fibreglass is required.

Using the above method, acoustically exposed areas may be protected not only against vibrations from the outdoor environment, but the vibration insulation provides efficient protection against any indoor noises from out of the protected area, which are caused by the normal operation of the building (e.g. engineering, etc.) as well.

6. Improvement of the method

Improving the developed method, using boundary-element and finite-element programs, we built up a momentum model of a hospital building – that was still in designing phase -, where the expectable vibration load on the floorings of theatres in different floors had to be estimated. Then we measured real vibrations on the real building structure. The vibration sources were the road traffic and tramways. Comparison of the calculated and measured results is illustrated in Figure x.

List of references:

/1/ Cremer - Heckl: Körperschall. Springer-Verlag 1967

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