Vertical and horizontal insulation in a hotel complex to protect against vibrations from tram and railway tracks.

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Abstract

Adjacent to Düsseldorf main station a new hotel complex is under construction. This complex consists of three separated structures, that are connected via a collectively used underground garage. One side of the premises borders main line tracks, the side opposite is flanked by a tramway. Both railway lines cause considerable vibration emissions. In order to not disturb hotel residents in their comfort by secondary airborne noise and/or vibrations, engineering consultants imb-dynamik were commissioned with a building dynamics investigation by the project developer. The aim of this investigation was to define vibration-isolating measures, if needed. Within this analysis imb-dynamik carried out vibration measurements in the building ground. Together with the planning of the building these measurement results led to a vibration insulation concept. The predicted results showed that the whole area of the building complex had to be insulated against vibration. The same applied to wide parts of the basement walls, too.

Additonal immission measurements in the excavated construction pit carried out by imb-dynamik, then led to a more detailed design with less insulation measures required than expected after first measurements, resulting in less insulation material needed.

Below the building foundation a horizontal insulation layer was needed that is divided in two areas with different tuning frequencies (8 Hz and 11 Hz). A solid rubber product, single-layer (11 Hz) and double-layered (8Hz), has been used as horizontal bearing.

Equal to the horizontal protection measure also the insulation scheme for the basement walls had to fulfill different parameters. Areas with lower (bedding modulus <=0.04 N/mm³) and higher requirements (bedding modulus <=0.02 N/mm³) existed. Despite different loads, the whole horizontal measure could be carried out with one product only, the same applies to

almost all vertical areas, merely at some basement wall sections constructional reasons (different styles of sheeting) led to a second product type needing installed.

Apart from dimensioning the protection layer this presentation focuses on constructional details, e.g. pipe penetrations or inclined surfaces as well as on the fixation of studded „Cibatur® "mats to vertical walls. It also will be shown how sound bridges can be avoided effectively.

1. Overview

The hotel complex to be protected against immissions from tram and railway traffic consists of three buildings and lies between Harkortstrasse and Düsseldorf Main Rail Station; see shaded and numbered structures in Figure 1.

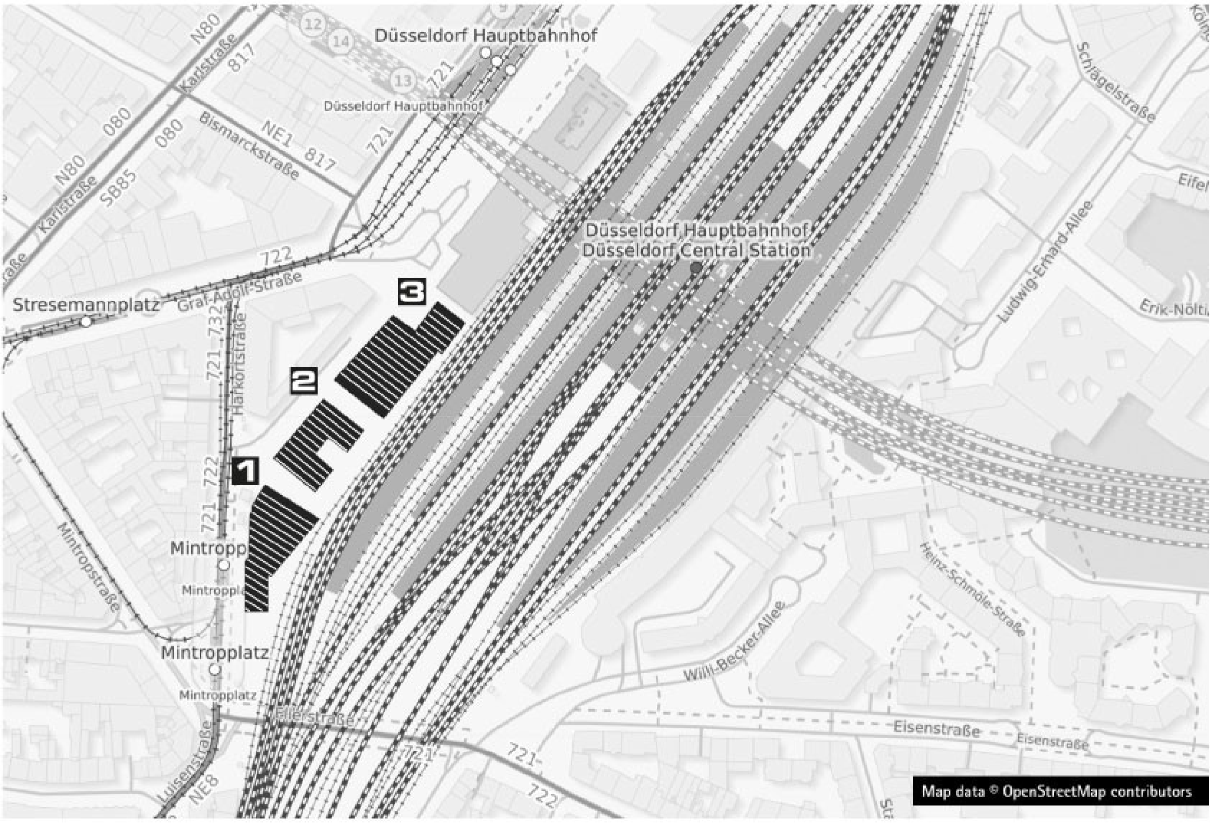


Figure 1: Building to be constructed at Düsseldorf Main Rail Station; image source: Map data©OpenStreetMap contributors

A tram line runs along Harkortstrasse on the west and north of the construction site with trams on several routes travelling in both directions. The south side of the site borders directly on the railway tracks, including the platforms, at the city's main railway station.

The engineering office imb-dynamik GmbH was commissioned to carry out work to guarantee perfect comfort in the residential sections of the three buildings. Based on specific measurements taken of vibration immissions and a preliminary support structure design, the company needed to ensure: firstly, that the secondary airborne sound and vibration immissions produced in the planned development comply with the limit values in the relevant guidelines; secondly, that the owners/users will be exposed to as few noticeable immissions as possible or even none at all after taking into account financial and structural considerations.

An adjustment to the support structure design meant that the natural frequencies in the slab were decoupled more effectively from the frequencies occurring in the immissions. The engineering consultancy thus decided that two different measures were sufficient for the horizontal vibration protection system. The vertical decoupling was also divided into two sections [1].

2. Solution for horizontal decoupling

The horizontal decoupling of all buildings could be divided into just two different requirement areas. It was determined that the natural frequency in the protective measure element in the *full requirement* area needed to have a tuning frequency of $f_{0.full}$ <= 8 Hz. The *reduced requirement* sections required $f_{0.red}$ <= 11 Hz. The protective element needed to be positioned under the floor slab.

In this case, the developer chose a profiled conical stud vibration protection mat mainly made of rubber. This solid material panelling Cibatur® was installed in a single layer in the *reduced requirement* section and in a double layer in the *full requirement* areas. The double layer version also contained a load-distributing PVC panel to meet requirements [2]. Since the vertical stress loads were similar in both sections, a transition zone was determined, the stiffness of which was between that of the one- and two-layer protective elements. The zone comprises one layer of Cibatur© and a stiffer second layer, also separated by a PVC panel. Figures 2 and 3 show the *full requirement*, *reduced requirement* and *transition* areas for the buildings referred to as 1 and 2 in Figure 1.

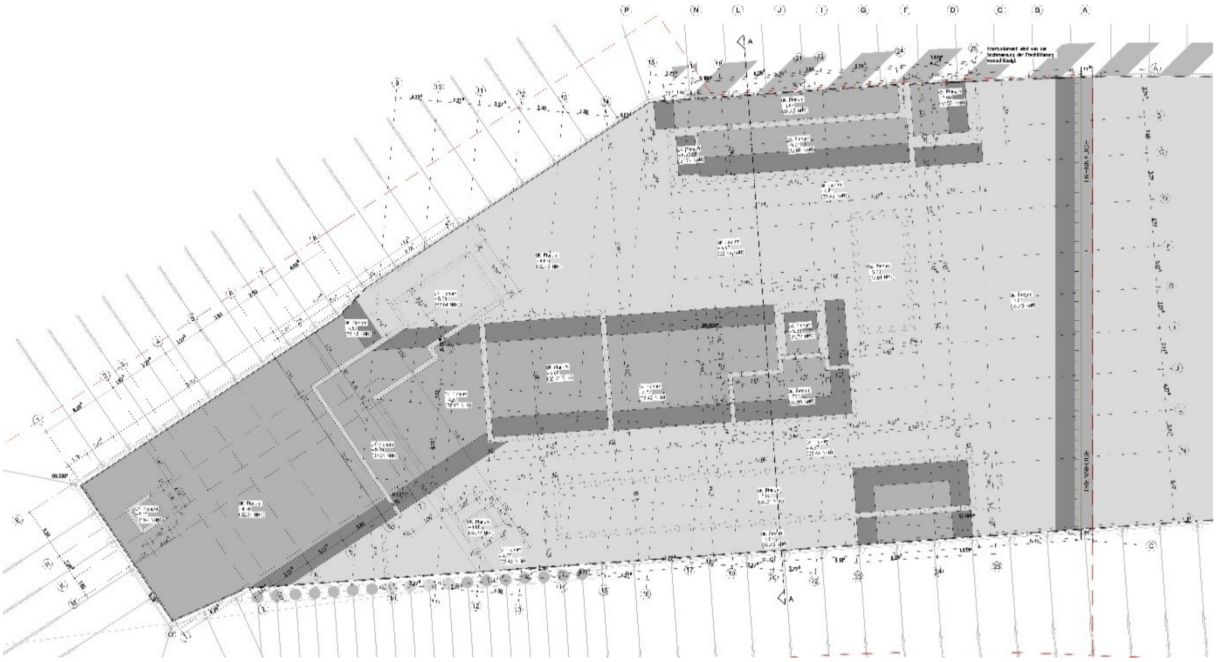


Figure 2: Single-layer horizontal decoupling (light grey), double-layer decoupling (medium grey) and transition (dark grey) in Building 1

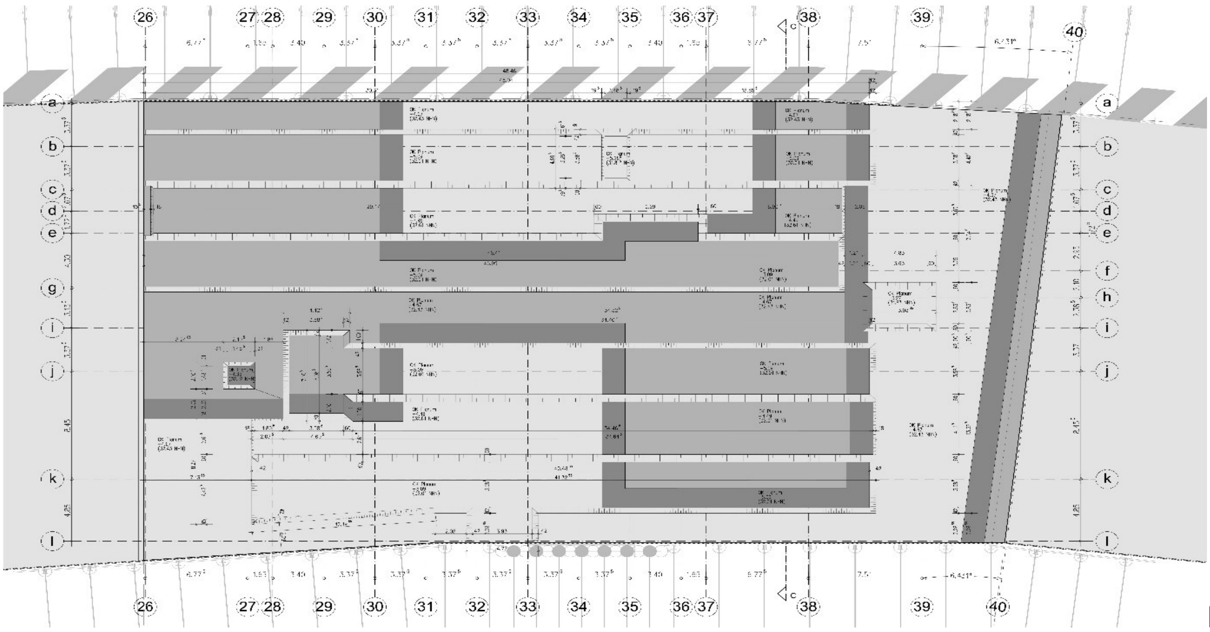


Figure 3: Single-layer horizontal decoupling (light grey), double-layer decoupling (medium grey) and transition (dark grey) in Building 2

3. Solution for vertical decoupling

The requirements for the vertical vibration protection element for the full requirement sections needed to include a bedding modulus C_{dyn} <= 0.02 N/mm³ and a shear modulus which was no more than half the value of the modulus of elasticity. The restriction with regard to the shear modulus was also critical for the reduced requirement areas. However, a bedding modulus of C_{dyn} <= 0.04 N/mm³ was sufficient in this case [1]. The thickness of the vertical protection element was adjusted, dependent on the earth pressure at rest or concreting pressure, to meet the objectives specified in paragraph 1.

An EPDM-based closed cell material in different designs was used in both areas. The insulation was laid from the top edge of the terrain to the floor slab, using Civerso Type A insulation in thicknesses of 20 and 43 mm. Placed at depths of about two metres below ground level, the protective layer was installed using the same material as for the horizontal insulation – the natural rubber conical stud mat. In some sections, Civerso Type A was also used due to a few different shoring types. The outer sides of the basement walls were insulated across their entire surface. Figure 4 shows an example of a side wall with Civerso and Cibatur® as a protective element against vibrations from railway and tramway traffic.

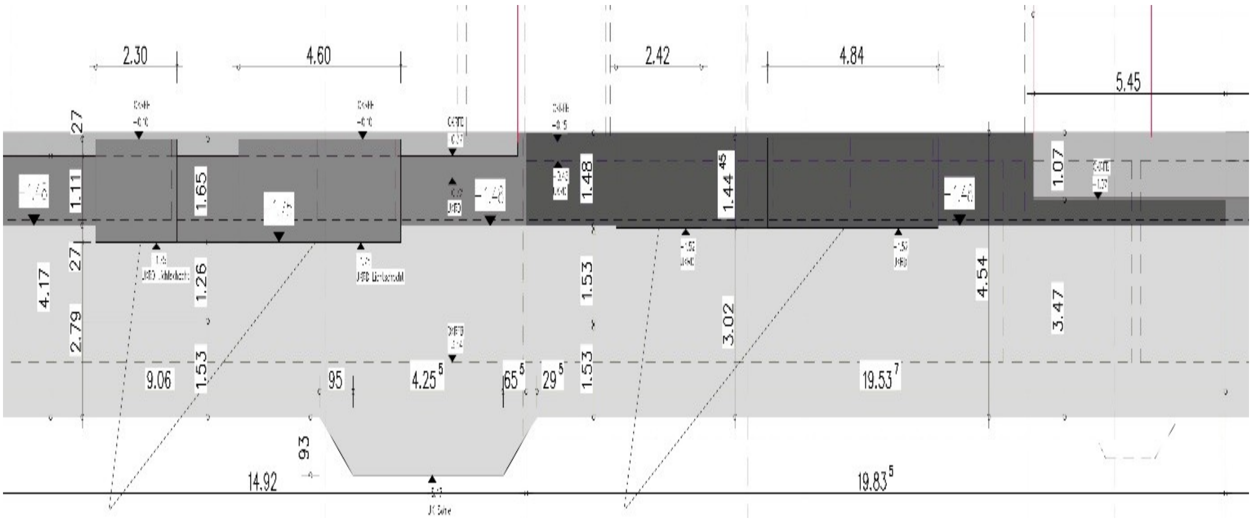


Figure 4: Single-layer vertical decoupling (medium grey), double-layer decoupling (dark grey) and Cibatur® (medium grey) due to different shoring types in Building 1

4. Layouts at detail points

Sound bridges must never be created so that effective vibration protection is provided. Even a nail struck through the insulation can mean that the calculated integrated damping values are not met. For example, insulating mandrels were used as suitable fastening materials for attaching the vertical panelling during construction – Figure 5.

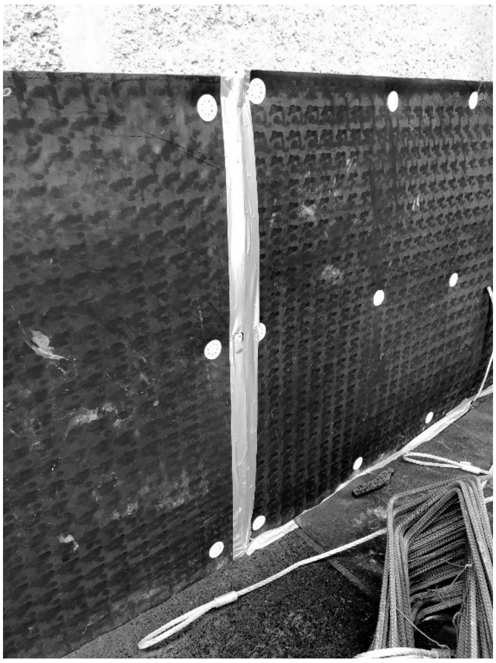
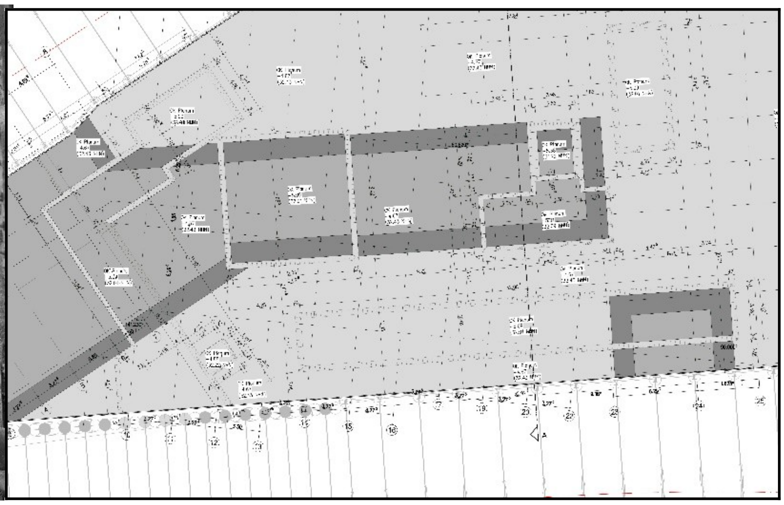


Figure 5: Sound bridges were avoided in the vertical protection layer by using suitable fastening materials (in this case: insulation mandrels)



Figures 6 and 7: Large number of tiers and haunches in and below the base slab

The base slab for the three buildings features a great number of cavities and haunched sections, as can be seen in Figures 6 and 7.

Careful planning and execution of the structure and the laying of the sound protection element is extremely important to avoid sound bridges. It must be ensured that no concrete slurry can penetrate between the conical studs, thus preventing the protective element being installed properly by stopping the elastomer mat from deflecting.

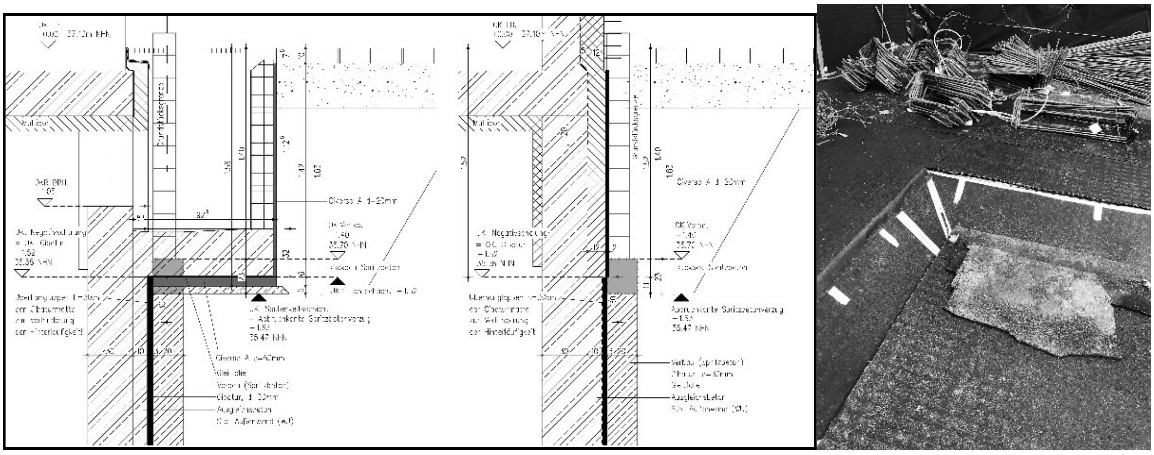


Figure 8 and 9: Careful installation in the design and in practice

A continuous elastic protective cover is essential; in the case of the horizontal insulation, this is ensured by overlapping strips, which are attached to the elastomer mat edge as standard. These strips are stapled to the adjacent web and the joints are sealed. Special care must also be taken in the transition section from horizontal to vertical areas. Sealing of all joints on elements such as shafts, pipelines or indentations require immaculate work in detailed designs and on the construction site; examples are featured in Figures 8 and 9.

[1] BV Harkortstrasse Düsseldorf, Railway Immisions, Report N3018707, imb-dynamik GmbH, Herrsching, Germany, 2018

[2] Cibatur®, technical data sheet, Calenberg Ingenieure, Salzhemmendorf, Germany, 2020