A Look at Anti-vibration and Sound Isolation Structures from "the Bottom Up" – How countries without earthquake concerns build to mitigate vibration –

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Nagata Acoustics is a participant in several European concert hall projects now being constructed. In the February, 2007 issue of this newsletter, I introduced readers to our use of 1/10 scale models on two of our European projects. In this article, I will turn my focus to our strategies for ensuring "quietness" in the hall interiors of two of our European projects. Readers who are familiar with the building methods used in earthquake-prone places such as Japan will surely notice some differences between practices in earthquake-prone locations and those used on these European projects.

In this newsletter's series on sound isolation design, we previously discussed the methods we use to achieve the goal of isolating concert halls from noise and vibration generated by the environment outside concert hall buildings. Typically, we install anti-vibration materials characterized by cushiony resilience under the floors, behind the walls and above the ceilings of rooms, placing these materials in between the concert halls and their supporting anti-vibration and sound isolating structures. In major Japanese cities such as Tokyo, where trains and subways run ubiquitously in all directions and where maximum use must be made of scarce land resources, the inclusion of this kind of anti-vibration and sound isolation measure can be considered a standard part of concert hall acoustical design.

Helsinki Music Center Project

We featured the Helsinki Music Center project in the November, 2000 issue of this newsletter. This project includes a 1,650-seat concert hall that will be the home hall of both the Helsinki Philharmonic Orchestra and the Finnish Radio Symphony Orchestra (Figure 1), and a new facility to house Sibelius Academy Music University.

Figure 1: Concert Hall, Helsinki Music Center

Along the western end of the project site runs Helsinki's Mannerheim Street and a tram line. Before beginning our design work, we studied the site and determined that our design would need to include a strategy to mitigate the effects of structure-borne noise from Mannerheim Street and the tram line on the concert hall and other rooms. On the side of the building closest to Mannerheim Street, we located the orchestral, organ, chamber music and vocal rehearsal halls, as well as the "black

box" space for experimental performances, and we adopted a "box-in-box" floating structural design for each of these rooms.

The construction workflow for the box-in-box structures begins with building the floating floor of the inner box, then adding the pre-cast concrete walls, followed by spraying shotcrete on the ceilings. As I write this article, the construction work of the inner boxes for the box-in-box structures of the rehearsal halls on the west side of the building is approaching completion. In this part of the completed building, ample space can be seen below the flooring of the inner boxes and we can easily confirm the state of the resilient supports installed as an anti-vibration measure.

Figure 2: Floating floor of the concert hall, Helsinki Music Center

In Japan, the substructure below floors of box-in-box rooms typically has anti-seismic stoppers that were developed to prevent sideways movement of structures during earthquakes. Helsinki does not experience earthquakes and, therefore, anti-seismic stoppers are unnecessary there. At the Helsinki Music Center, narrow columns topped with foamed polyurethane elastomer provide the structural support for the inner boxes of the box-in-box structures. To readers who, like me, are used to seeing earthquake-resistant structures made of thick columns and beams implemented to support concrete building elements, the appearance of the Helsinki substructure may not intuitively inspire strong confidence, but this column thickness does adequately provide vertical support for the weight it bears.

Compared with the rehearsal halls, the concert hall is located at a slightly farther distance from the tram line (40 m when measured as a direct line through the building). Nevertheless, we determined the risk of the hall space being affected by structure-borne noise to still be considerably high, and we adopted a floating foundation structural design for the concert hall's main floor, including the stage (Figure 2). Because of the concert hall's vineyard configuration, the hall's floor is divided into a complex design of sections or blocks. To prevent horizontal shifting of these sections during construction, the same kind of rebar configuration that is used for seismic resistance was embedded in the structural design of this part of the project.

Elbphilharmonie Hamburg Project

We featured the Elbphilharmonie Hamburg project in the December, 2004 issue of this newsletter. This construction project includes a large hall and small hall (approx. 2,150 seats and 550 seats, respectively), condominiums and a hotel in a spectacular high-rise structure built on a site that was most recently occupied by a warehouse (Figure 3). The new structure extends into Hamburg's Elbe River harbor. To isolate the concert halls from noise sources outside the building, and to provide sound isolation both between the halls and between each of the halls and the building's condominiums and hotel, we adopted a box-in-box design strategy for this project's halls.

Partially surrounded by water, the Elbphilharmonie Hamburg building exterior environment will include large ocean freighters traveling into and out of Hamburg Port through a waterway adjacent to the south side of the building. Also, passenger ocean liners, such as Queen Mary II, are expected to tie up on the east side of the building, where passengers will disembark to spend time at the city. Ocean-going vessels blow their distinctively low-pitched horns when traveling from the port out to the ocean.

To isolate the concert halls from the low-pitched horn blasts of ocean-bound vessels, we did not use the typical cushiony anti-vibration material. Instead, we implemented building isolation springs that provide excellent and extended sound isolation performance for low frequency sound because they can be set to low natural frequencies. Specifically, this box-in-box design has an outer-box constructed using 200 mm-thick concrete inside of which is another box, also built using 200 mm-thick concrete. The springs are installed inside the outer box as the supports for the inner box. The hall's interior is built and finished inside the inner box. The natural frequency of vibration used for this design is 3.5 Hz.

Figure 3: Elbphilharmonie Hamburg

The springs used in this design can be compared to the seismic isolating mechanism used in a seismic isolation structural design. However, because seismic isolation mechanisms are designed to dampen the effects of horizontal shaking, they are comparatively stiff in the vertical direction, while the Elbphilharmonie Hamburg building's anti-vibration springs are compliant in both the horizontal and vertical directions. For this reason, the building isolation whose natural frequency of less than 5Hz has never been practiced in earthquake-prone Japan.

Figure 4: Under the inner box of Kleiner Saal, Elbphilharmonie Hamburg

Figure 5: Under the inner box of rehearsal room, Shanghai Conservatory of Music

At present, the small concert hall (the "Kleiner Saal") is the focus of construction activity at the Hamburg project. Like in Helsinki, the space beneath the inner box of the Kleiner Saal is accessible for confirmation of the design

implementation (Figure 4). Because the Kleiner Saal interior is still under construction, temporal support poles can be seen in the space below the inner box. When the hall's construction is complete, the hall will be supported entirely by the springs. An example of another example that has an entire room supported by springs can be seen in the photo of Figure 5. The use of springs in the box-in-box design of these halls effectively prevents noise and vibration in the concert hall interiors.