Controlling Subway Noise In LG Arts Center - Sangnam Hall

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Abstract: The LG Arts Center is designed to guard against both airborne and groundborne noise. Airborne noise is controlled by enclosing the stage house and the audience chamber with two wall shells separated by a minimum of 200mm airspace. Groundborne noise is generated by subway trains in a tunnel adjacent to the site and is controlled by providing horizontal and vertical acoustical joints at the structural interface of the Arts Center facility with that of the adjacent Office Tower. Without isolation, the noise from the subway would have intrusive effects on the performance hall. The acoustical benefits of the proposed isolation bearing pads and their impact on the building design are discussed.

IMPACT OF AIRBORNE AND GROUNDBORNE NOISE ON BUILDING DESIGN

The LG building in Seoul, Korea is a multi-use facility consisting of a 40-story Office Tower, an Art Hall facility, subgrade parking, and retail space. The LG Art Center is a multi-function facility which includes a stage house that will be used for western drama and dance, chamber music, traditional Korean dance and folklore plays, oration, and digital recording. Although the 1050 seat LG Arts Center is only 14,000m², its design composition consists of a performance hall (audience chamber and stage house), and support lobbies. The audience chamber contains the main seating area, two long span seating balconies, and an acoustical canopy. The stage house includes a stage area, a fly tower, an orchestra pit with long span cantilevers, and a grid iron. The space surrounding the performance hall houses the building and theater equipment in addition to lobby spaces at all levels. The performance space is enclosed by two uninterrupted wall envelopes separated by a 200mm minimum airspace to protect this acoustically critical space from both external and internal airborne noise sources. The external airborne noise is generated by sources outside the building enclosure; however, the internal airborne noise is generated by the building mechanical and theater equipment that could be operational during a performance.

The building design composition [see FIGURE 1] is a direct expression of its internal function. The central granite finish volume encases the audience chamber, the stainless steel cladding over the stage house suggests its technical functions, and the glass curtain wall at the lobbies makes the Arts Center appear to be floating above the ground and delineates a structural separation between the Arts Center and the Office Tower subgrade structure. This separation is required to reduce the groundborne noise generated by an adjacent subway tunnel that shares the same rock stratum with the LG building foundation. This rock stratum provides a direct transmission media of the subway noise to the LG building. Proximity of the LG Arts Center to the Youksum subway station prompted an in-situ investigation of its noise impact. Preliminary measurements by Wilson Ihrig and Associates indicated that groundborne noise would be intrusive to the audience chamber and the performance space. Therefore, a complete
separation of the performance hall structure from the adjacent 40 story Office Tower and its substructure is required to achieve the stringent N-1(silence) noise criteria set by the theater and acoustical consultants, ARTEC Consultants. This separation is achieved by providing 159mm thick vertical and 127mm thick lateral laminated rubber bearing pads at the performance hall columns with each column having several vertical load bearing and lateral isolation pads. This concept simplifies the building design and detailing, and reduces the cost and the risk of isolating the building’s non-structural components. FIGURE 2 depicts the acoustical base isolation system, the subway noise level at the performance hall without building isolation, and the acoustical benefits of providing the isolation pads.

Furnishing the vertical and lateral isolation pads resulted in significant improvement of the acoustically critical space by lowering the structural borne noise level below the threshold of hearing. The laminated rubber vertical bearing pads have been designed by Wilson Ihrig and Associates for an 8Hz frequency and for a stress level averaging 5.7Mpa (820psi) to increase the rubber pad longevity to match that of the life of the building. Combining the Arts Center large column loads with the low allowable stress level results in several bearing pads at each column. The vertical bearing pad sizes are limited to 585mmx585mm to control their manufacture and behavior.

The vertical bearing pads are sandwiched within two, stiff, two-way structural grid systems consisting of a reinforced concrete substructure and a concrete encased steel superstructure. Because the clear height requirement at the bank below and the Arts Center entry elevation above, only a 100mm airspace is available between the two grids for the acoustical separation. These limitations created challenging details and very tight construction tolerances for the installation of the acoustical base isolation system [see FIGURE 2 for the vertical and lateral bearing details]. The Arts Center columns will be founded on vertical load bearing isolation pads and the pad installation will be in sequence with the building construction. However, the lateral pads will be installed after the completion of the LG Arts Center superstructure and will be prestressed to remain in compression under extreme wind and seismic events. All the lateral pads at each column will be stressed simultaneously with a single hydraulic jack. This concept allows the lateral pad to be installed and prestressed in a single cycle and insures an equal stress level and an equal load in all the pads at a particular column.

Completing the separation envelope for both airborne and groundborne noises, the performance hall is separated from the Office Tower and the LG Arts Center’s north structure which houses its air handling units, by soft joints to prevent noises from these elements being transmitted to the performance hall. A 50mm joint is adequate for the acoustical separation; however, seismic considerations require a 300mm joint. This building separation created several architectural issues to be addressed, particularly in the details of the exterior wall system. Relative silence from outside airborne and groundborne noise sources is one of the most critical design criteria of a performance hall and it cannot be fully achieved without a complete integration of the architectural, acoustical, and engineering systems.

REFERENCES