MAE RESEARCH

Introduction:

As required, various concepts and design techniques from MAE coursework were applied throughout the various phases of the thesis project and were critical in ensuring that the thesis proposal and goals were addressed and completed to the fullest extent. As described in the integrated MAE coursework summary, both AE 597 computer modeling techniques and AE 542 building enclosure concepts were employed during the thesis project.

As an extension of this MAE requirement, independent research of sound isolation performance of building enclosures was conducted. Acoustic design of building envelope systems was the primary focus; however, building enclosures are culminations of multiple-disciplines and so ramifications on heat, air, and moisture control were also considered. Although not all research was directly applicable to the thesis project, all material is relevant to the field of architectural engineering and provokes a healthy contemplation of today’s building design issues.

Goal:

The primary reason for embarking on this research endeavor was to assist with my acoustic study. Through research, I was able to supplement my fundamental expertise and knowledge of AE 542 and AE 309 topics. Research regarding building envelope systems and sound isolation techniques enabled proper specification of design detail and solutions. Additionally, as a student with great interest in building enclosures, the research was conducted to promote mine and others’ awareness of how essential and important enclosure systems are in today’s building industry.

As explained in the acoustic breadth section, the goal of the acoustic study was to ensure interior residential spaces were exposed to appropriate levels of noise. As a result, design solutions were determined that addressed sound isolation from high ambient noise levels of New York City as well as sound isolation of sources in the Penthouse which included HVAC equipment, a recreation room, and laundry room equipment. A floated concrete slab, a double exterior wall, and window details were the primary focus of the acoustic study. Please see the acoustic breadth section for relevant text and figures explaining the acoustic design solution and goals.

Summary:

As for the actual research, websites, peer-edited journal articles, and textbooks were referenced to accumulate as much relevant material as possible. Various library databases were utilized including, Illiad, proquest, science direct, Compendex (Engineering Village), and the CAT. Please see the following reference section for all sources of information consulted during research. Additionally, several sources were referenced that all suggested increase in mass, (**1,9,10,15,19**)

Major Research Points:

Located in a densely populated urban setting with air and ground traffic, a subway station, nearby businesses, and pedestrians all around, a significant amount of research was done to investigate how to design exterior wall systems for sound attenuation of the ambient noise. This section summarizes the research findings; however, please see the acoustic breadth section for specific details and final design solutions.

Much of the research was done to simply gain a better understanding of the various parameters that influence the behavior and intensity of sound in urban settings. It was important to achieve a better understanding of ambient noise problems in urban settings prior to proposing any design solutions. With many surrounding buildings and two streets running parallel to the site, ambient sounds are magnified by the “street canyon” effect (**3**). Several articles were reviewed to explore how site geometry (streets and buildings), roof shape, wind turbulence, and ground properties influence ambient sound intensity in urban settings. In addition, research pertaining to ray models that apply superposition of direct and reflected sound rays was conducted. Several articles concluded in agreement that roof shape has significant impact on sound intensity by altering the distance of the propagation path along a building as well as the amount and angle of diffraction edges (**3**). After reflecting on the content of these articles, 40 Gold Street is very susceptible to high ambient noise levels due to non absorptive ground properties, wind turbulence, and street canyons on two sides of the site. All of these factors lead to multiple sound ray reflections with minimal absorption leading to increased sound levels (**3**).

For the acoustic study, another primary area of focus was sound isolation of residential spaces from an above penthouse. With large mechanical equipment, a gym, a kitchen, and laundry room, air-borne and impact sound noise is a concern. As shown in the acoustic breadth section of the report, a floated concrete slab was employed to achieve proper sound isolation. Although this type of construction was discussed briefly in AE 309, research was conducted in order to understand the basic mechanisms by which floated slabs facilitate sound transmission loss. Repeatedly, case study results have revealed the cavities and batten layers of a floor assembly are the primary sound transmission paths (**2 & 4**). In both the exterior wall and floor construction design solutions, I specified the application of resilient materials which included resilient stud attachments and thin layers of resilient materials (**2 & 4**).

Before specifying any design details, research was completed to determine what properties are required for materials to perform well in sound attenuation. According to various sources, an assembly of materials that increases sound transmission and sound absorption is critical (**1**). Recommended materials included wood, fiberboard, rock wool, concrete, brick, and fiberglass (**1**). Research also revealed conclusive evidence that superior sound transmission loss in construction assemblies is achieved with high mass, reduced stiffness, and airtight materials (**1,9,10,15**).

Additional research was conducted in regards to sound isolation performance of double wall assemblies. In AE 309 and AE 542, such wall assemblies were only briefly covered. Research revealed a double wall construction with double layer of gypsum board and staggered studs generates significant sound attenuation improvements compared to a basic wall design (**5**). The final exterior wall design is shown in the acoustic breadth section, and as one can see, it is a double wall system that employs staggered studs, resilient stud attachments, and a double layer of gypsum board on the interior surface.

The third area of research concentrated on sound attenuation of glazing systems, which was also addressed in the acoustic study. Glazing systems are very complex involving many intricate components. Research was conducted to investigate how sound isolation performance is influenced by storm sash design, the thickness of the glass, the type of glass (laminated or monolithic), type of frame, the size of the window panel, the number of glazing panels (**1,2, 3**), and air cavity thickness (**6,7,10,11,13,14**).

Based on research results, it is apparent that the inclusion of multiple glazing layers improves sound attenuation. Double glaze systems have been proven to exhibit enhanced sound attenuation behavior compared to single glaze systems (**11, 14**). However, this only holds true if the double glaze system employs two layers of glass with different thicknesses. In fact, double glazed systems with identical glass panels introduce many drops in acoustic insulation for various vibration frequencies. Also, larger air cavities increase sound attenuation. Surprisingly, many case studies that were researched suggest triple glaze systems have negligible sound isolation performance benefits over double glazed assemblies (**11,14**).

Throughout the acoustic study breadth, ramifications of the exterior wall redesign on ventilation were continuously under consideration. A major part of the acoustic study involved determining the benefits and tradeoffs of specifying operable or fixed window systems. Obviously, residence of 40 Gold Street would enjoy the luxury of operable windows. Operable windows also provide a mode of natural ventilation. However, research and AE coursework both suggest operable windows perform very poorly in sound attenuation. In addition, research was done to evaluate any intermediate solutions. For instance, a special glazing construction was researched in which both high sound insulation and means of ventilation coexist (**8**). The window system referred to as a HSIVW (High Sound Insulation Ventilating Window), employs an aerator filtering system in which insulated rolling-shutter boxes are used.

The final area of focus is a very broad but important topic. Basically any performance issue of window systems not related to acoustics was analyzed. In AE 542, a great deal of coursework pertains to the performance of building enclosure systems in the control of heat, air, and moisture flow (**8,9,10,16,17,18**). The goal of this research was to ensure that any design solutions specified in the acoustic breadth study, were done with consideration for non acoustic issues such as heat, air, and moisture control. Based on the research, final exterior wall details were determined and accommodated for location of dew point relative to air and moisture barrier (condensation issues), as well as specifying proper thermal insulation layers. As mentioned in the introduction section of the thesis report, 40 gold Street has a metal clad façade. Building enclosure systems can fail in very basic ways such as sealant failures and thermal bridging, and so the first line of moisture and air defense is very important. As a result, research was done to better understand the advantages and disadvantages of the existing exterior metal trespa panel system of 40 Gold Street. Research revealed the system is susceptible to wind driven moisture penetration, rust, and thermal bridging initiated via conduction (**17**). Retrofit options were also considered and researched when considering the sound isolation and overall performance of the existing wall system (**17**).

Overall, the research was very effective in enabling proper re-design of the glazing systems, exterior wall systems, and penthouse floor construction. More importantly, a great deal of knowledge was obtained in several areas of which I am very interested, including sound isolation, ambient noises in urban areas, and building enclosure systems.

Research References:

Note: The summarized research findings on previous page are referenced to each article according to the numbers listings below.

1. Use Barriers and Enclosures to Reduce Power Plant Noise, Schiff, M.I. Power volume 123, page 103-105 (COMPENDEX)
2. Acoustical Design for the Technical Building at Skywalker Ranch: Sound Isolation and Room Acoustics, Schwin, D.R. SMPTE Journal, Volume 98, pages 100-105 (COMPENDEX / INSPEC).
3. Three-dimensional Linearised Euler Model Simulations of Sound Propogation in Idealized Urban Siuations With Wind Effects, Heimann, Dietrich, Volume 68, Issue 2, DLR Institute of Atmospheric Physics. (COMPENDEX / SCIENCE DIRECT)
4. Impact Sound Transmission Through A Floating Floor on a Concrete Slab, Stewart, Michael A., and Craik, Robert J.M., Applied Acoustics, Volume 59, Issue 4, pages 353-372. (COMPENDEX – SCIENCE DIRECT).
5. Application of the CEN Draft Building Acoustics Prediction Model to a Lightweight Double Leaf Construction, Applied Acoustics, volume 46, page 265-284. (COMPENDEX - INSPEC)
6. Window Sound Isolation Using Laminated Interior Strom Sash, Tocci, G.C., Sound and Vibration Journal, volume 24, issue 10, page 24-30. (PROQUEST)
7. Influence of the Frame on the Sound Reduction Index of a Window, Cervera,F., Building Acoustic Journal, volume 7, issue 4, pages 315-323. (COMPENDEX)
8. Acoustic Performances of High Insulation Ventilating Windows Integrated with Rolling Shutter Boxes, Asdrubali, F. Noise and Vibration Worldwide Publication, volume 38, pages 21-28, January 2007 (COMPENDEX / SCIENCE DIRECT)
9. Building Envelope Design With the Objective to Ensure Thermal, Visual, and Acoustic Comfort Conditions, Yener, Alpin Koknel, volume 39, issue 3, pages 281-287. (SCIENCE DIRECT)
10. Acoustical and Thermal Performance of Exterior Residential Walls, Doors, and Windows, Sabine, Hale J, Lacher, Myron B, Flynn, Daniel R, Quindry, Thomas L. National Bureau of Standards, Building Science Series, issue 77. (COMPENDEX)
11. Sound Transmission Through Single, Double, and Triple Glazing: Experimental Evaluation. Tadeu, Antonio J.B., Volume 62, Issue 3, pages 307-325, 2001. (COMPENDEX / INSPEC)
12. Experimental Study For Control of Sound Transmission Through Double Glazed Window Using Optimally Tuned Helmholtz Resonators. Mao, Qibo. (COMPENDEX)
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14. Sound Transmission Through Windows: Single and Double Glazing, Quirt, J.D. Volume 72, issue 3, page 834-844 (COMPENDEX)
15. New Techniques for sound isolation against external noise, Walker C., Maynard, K., Applied Acoustics, Volume 8 Issue 4, pages 257-269. (COMPENDEX – SCIENCE DIRECT).
16. Rain Control and Design Strategies, Straube, John, Burnett, Eric F.P., Journal of Thermal Envelope and Building Science, volume 23, pages 41-56, 1999. (COMPENDEX)
17. Metal Cladding Envelope Problems, Retrofit Solutions, and Quality Control Investigations, Colantonio, Antonio. International Society of Optical Engineering, volume 1682, pages 64-73, 1992 (COMPENDEX).
18. Comparison of Four Insulation Schemes for Reduction of Natural Convective Heat Transfer in Rectangular Enclosures, Sathe, S.B., Heat Fluid Flow Journal, page 389. (COMPENDEX)
19. New Results in Active and Passive Control of Sound Transmission Through Double Wall Structures, Pietrzko, Stanislaw J. Aerospace Science and Technology, volume 12, issue 1, page 42-53, 2008. (COMPENDEX).