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Architectural Acoustics

PROFESSIONAL STUDIOS: HERE'S ANOTHER FINE MESS YOU HAVE GOT ME INTO

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Professional studios

Professional studio work is a subset of architectural acoustics that combines both art and science in the design of working rooms for music and film (video) production. These studios are not an end in themselves, nor even a place where the ultimate listener will hear music, but a step in the process of crafting an audio product. As such they may have design requirements that exceed those found in the ultimate listening environment, which may range from a living room, to a movie theater, or even to an automobile.

> *"Needless to say, the atmosphere was highly charged."*

Sound studios are generally constructed as two or more rooms: (1) a studio where the music is performed, and (2) a control room where music is recorded and processed. In addition there can be ancillary rooms for voice over, sound effects (Foley), and isolation booths for individual or small groups of instruments. Where video or film is a component there are screens that may be incorporated into a studio (for film scoring) or a control room (for dubbing or editing).

Each of these specialized rooms has specific acoustical requirements (Long, 2006). A short summary list is given below;

1. Quiet - on the order of NC 10 to 15.
2. Isolation from adjacent spaces.
3. Freedom from acoustical defects such as flutter.
4. Adequate absorption (often variable).
5. Reasonable diffusion.
6. Visual communication between the control room and the studios.
7. Control of bass reverberation and modal buildup.

There may also be specific design requirements depending on the work habits of an individual user or accommodation of technical equipment.

In this article I would like to address a portion of the first two items on the list, i.e., quiet and noise isolation from adjacent areas using three examples from real studio projects I have encountered. The most common noise problems are mechanical equipment, external factors such as transportation related sources (including footfall), and adjacency to other theaters or sensitive receivers. In all these cases the noise control begins with vibration isolation of the noise source or the receiving room itself.

Vibration isolation

Vibration isolation is a phenomenon associated with a driven spring-mass system as shown in Fig. 1. At low driving frequencies the motion of the mass exactly follows the motion of the driver. As the driving frequency increases, the mass amplitude reaches a maximum, at the spring-mass resonant frequency. As the driving frequency increases further, the mass amplitude decreases sharply until it falls below the driving amplitude at a frequency above 1.4 times the driving frequency. This is the basis for the phenomenon known as vibration isolation.

The natural or resonant frequency of a simple spring-mass system can be written in terms of the static deflection of the vibration isolator under the weight of the supported object.

$$f_n\,(\mathrm{Hz}) = \frac{3.13}{\sqrt{\delta_i}} \qquad (1)$$

where δ_i is the deflection of the isolator in inches.

As the isolator deflection increases, the natural frequency decreases, and the amount of isolation increases for a given excitation frequency. Isolator deflection can be controlled by; (1) using softer isolators (e.g. springs rather than neoprene) and (2) increasing the load on each isolator (by using a heavier mass or fewer isolators).

Figure 1 also shows the effect of damping on the amount of isolation. Damping has its greatest influence around resonance and is most useful in limiting excursion in this region. Damping actually decreases the amount if vibration isolation which can be achieved. The figure also shows two driving point locations, one directly on the supported mass and the second on the support structure. In the case of studio floors

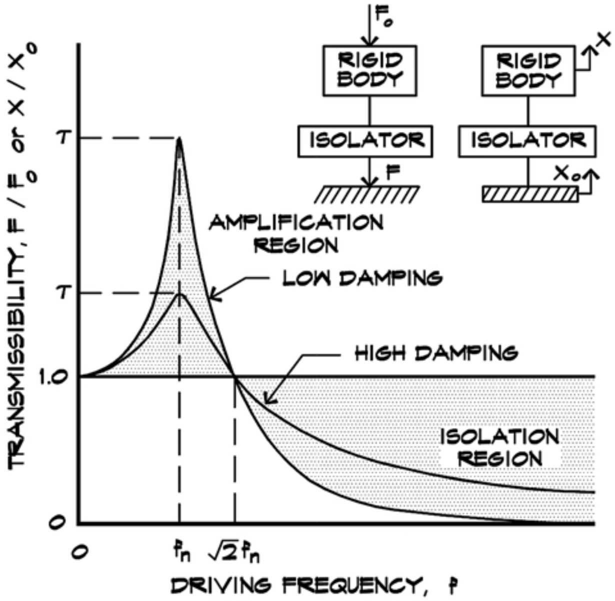

Fig. 1. Transmissibility curves for vibration isolation (Ruzicka, 1971).

the support structure is the more commonly encountered condition.

The design of floors for recording studios and critical listening rooms presents an interesting acoustical challenge, which utilizes these principles. Ultimately the goal is to obtain an environment where recording, listening, and sound mixing can take place without outside influences. Often the building sites, which are the most attractive to owners, due to price, location, or availability, are those which suffer from negative external influences of noise and vibration. This article discusses three studio projects, each of which was strongly influenced by external factors, and how technical solutions had to be developed that addressed them.

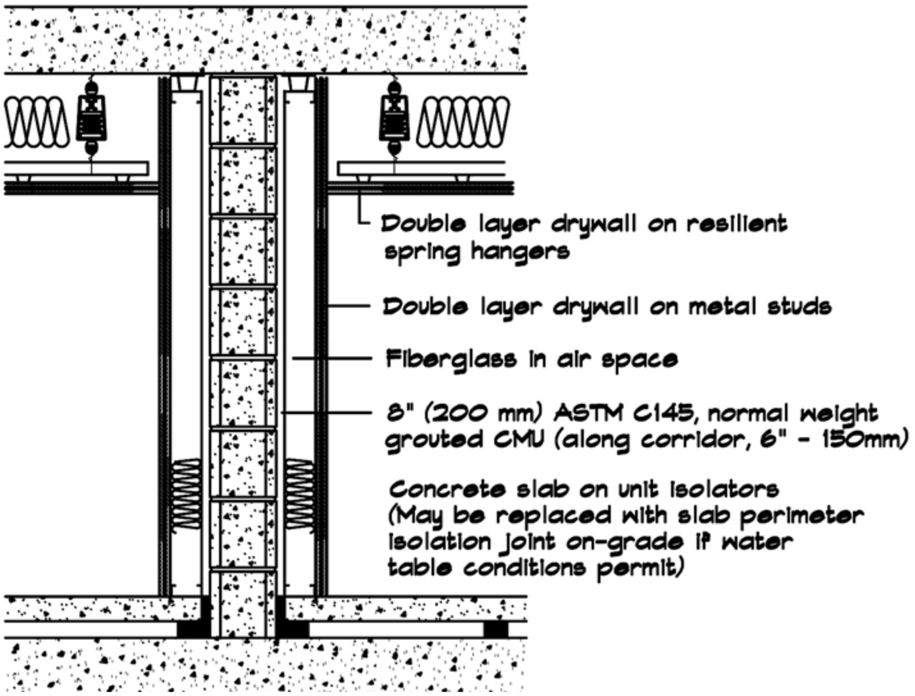

Fig. 2. Separation walls for music spaces to provide a given noise reduction between adjacent rooms (Klepper et al. 1980).

Studio 1—Railroad noise

A well known post-production company with property in Burbank, California, wanted to construct side-by-side screening rooms to be used for high end video post-production work. The rooms needed to be isolated acoustically from each other so that they could be used simultaneously, without audible sound transmission between them. Since the building was already owned by the client it was the logical location for the facility. The two major acoustical challenges were the studio adjacencies, and a main line railroad track 75 feet away, where trains passed by about once every twenty minutes. A major freeway lay on the other side of the rail line but it was at a lower elevation and the peak truck noise level was much less than that of the locomotive engines and horns.

The first step was to measure the sound and vibration of the trains. A typical engine created a maximum noise level of 87 dBA at the exterior of the building. The loudest engine octave level was 100 dB at 63 Hz. The train horns were somewhat higher overall at 95 dBA, with the highest octave band being 92 dB at 500 Hz. Surprisingly, the floor vibration in the existing slab was not noticeable inside the building.

The existing building was a concrete block (concrete masonry unit or cmu) structure with a lightweight plywood roof. The building had existing office space and was used for shipping and receiving. The shipping was important since there were lightweight rollup doors to accommodate pallet loading.

The studios were designed as a separate building within the existing space. We planned on floating floors built into a depressed slab so that handicapped access would be accommodated without ramps. The first step was to model the sound transmission between theaters. We were aiming for a Sound Transmission Class (STC) rating of about 80 with significant low frequency isolation.

The normal approach to the design of adjacent studios is to construct a separate floating floor of 4 in thick concrete slab on neoprene isolators spaced about 2 ft apart. An 8 in grouted cmu wall is built between the two floors and two separate double drywall walls are supported on the edge of the floating floor on each side. A drawing of the separation wall is shown in Fig. 2.

The neoprene isolators act as vibration isolators for the slab. One concern was that the spring mass resonance might overlap the frequency of maximum energy of the railroad. Research on railroad lines yielded a center frequency of about 30 Hz for rail engine vibration, which was well above the calculated resonant frequency of the slab/isolator system of around 7 Hz.

The remainder of the studio was isolated from the surrounding structure and the noise transmission calculations were straightforward. The existing roof supported the mechanical equipment and an additional ceiling roof was built for the interior structure. Duct silencers were located at the duct penetration of the interior shell to control both heating, ventilating and air conditioning (HVAC) and exterior break-in noise.

The studio has operated successfully since its opening. Railroad passbys are not audible. The first film edited in the studio was Avatar.

Studio 2 – Structural limitations

A studio was planned for a second floor location used by a music recording company in a building they occupied in Atlanta, Georgia. The architect, who was experienced in studio design, proposed a 4 in concrete slab on neoprene isolators on top of the existing 4 in concrete slab and a wall similar to that used above. Unfortunately the structural engineer informed him that the building slab would not support the

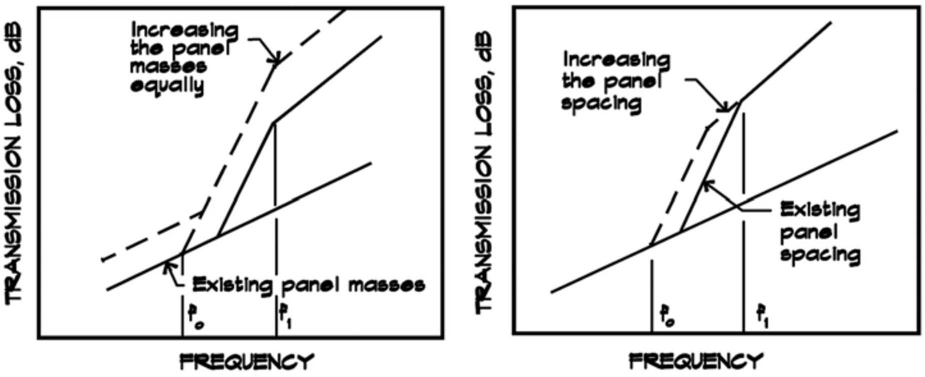

Fig. 3. Effect of mass and spacing on transmission loss; Ideal double panel construction (Sharp, 1973)

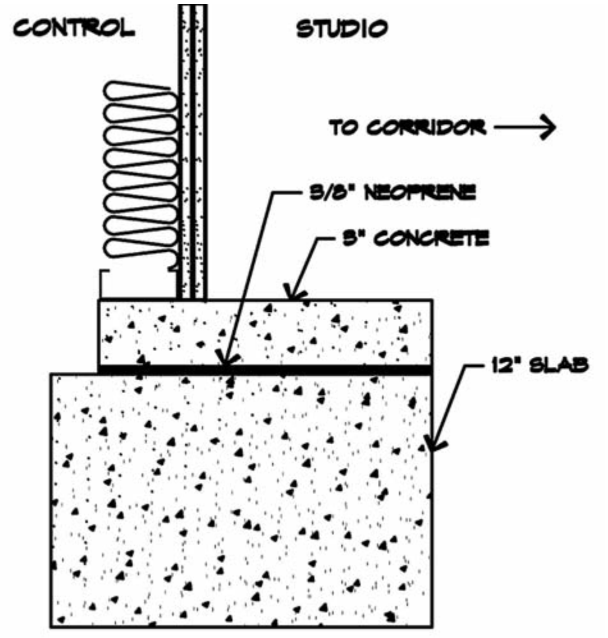

Fig. 4. Original studio floor as built.

weight of the proposed slab and walls. He limited the total static load to no more than 30 lbs/sq ft but allowed the weight within 6 in of a column or exterior bearing wall to not be counted against that limit. The studio ceiling was separately supported from the slab above on spring isolators and so it did not add to the load on the floor. The studio architect asked us to find a solution that would meet both his acoustical and structural requirements.

Most of the sound transmission problems in studios occur at the low frequencies down to around 40 Hz. Fortunately there is a tradeoff in the low frequency sound transmission of double panel systems between the panel mass and the distance between the panels. The tradeoff relationships are shown in Fig. 3.

By increasing the distance between the existing floor slab and the proposed studio slab from 2 in to 7 in we were able to lower the required studio floor mass. This allowed a design of a 1.5 in slab on 1.125 in plywood that performed as well as the original 4 in slab. The plywood was supported on 2x6 wood joists on neoprene isolators. Stepped blocking was also used to stiffen the support structure. The increased height required some additional access ramping.

The separation walls between the studios were changed from the original triple panel construction to a double panel wall with 3 layers of drywall on each side and an 18 in airspace in the critical areas, each supported on the separate isolated floors. This provided adequate side to side isolation with a lower weight penalty. By trading off mass for distance we were able to meet the 30 lb/sq ft limit and achieve a comparable acoustical performance.

Studio 3 – Existing conditions

A recording studio was designed and built on the first floor of a multi-story building in Burbank, CA. It consisted of a studio approximately 25 ft x 20 ft x 10 ft high and an adjacent control room on a 12 in thick concrete slab above an underground garage. The studio was constructed on a 3 in concrete floating floor poured on 3/8 in neoprene sheets. The walls were 2 x 5/8 in drywall on metal studs supported on the poured floor. The ceiling was 2 x 5/8 in drywall independently supported from spring hangers with an acoustical tile ceiling below it. A drawing of the "as built" floor construction is shown in Fig. 4.

In the as built condition a number of exterior noise sources were audible. Both footfall and carts being pushed along a corridor approximately 15 ft away and separated from the studio by a stairway were clearly audible inside the studio. Footfall on the exterior parking lot and sidewalk was also audible. Flow noise from cold water supply pipes servicing the building could also be heard.

At this stage we were engaged to review the situation and make recommendations. Needless to say the atmosphere was highly charged. The owner had just completed an expensive renovation of the studio and was expecting to use it. There was not only the sunk cost but also the time and expense of the repair plus the possibility that the new construction would not cure the problem.

The configuration was technically complex. The intruding sources were complicated and the transmission paths were difficult. For example the water pipes were suspended from the slab in the garage beneath the studio. It was likely that there was also a pipe riser in one of the studio walls. To try to isolate the water pipe noise we independently suspended the piping beneath the slab on temporary wood supports. This reduced the pipe noise somewhat, at least enough that it was felt that the level was low enough for recording. Thus this part of the problem could be treated with hanger isolators for the piping.

The footfall noise was tested using a tapping machine in the corridor. The results are shown in Fig. 5. We did a number of other tests using different surfaces in the corridor. Due to the large number of origination points it was not practical to treat all the walking surfaces, some of which were outdoors. It seemed best to address the studio floor since it was likely that the floor was inadequately isolated, due to too small a static deflection in the continuous neoprene mat. Figure 6 shows a figure from Beranek and Ver (1992) which

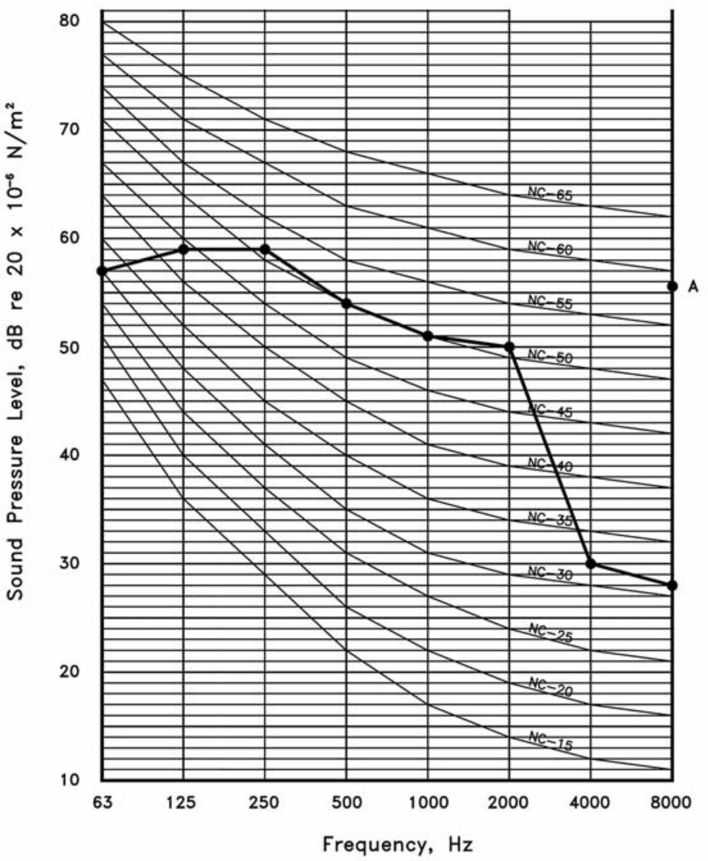

Fig. 5. Studio noise from hallway tapping machine.

gives a negative attenuation for footfall noise at low frequencies resulting from a continuous underlayerment.

The problem was then to try to ascertain how to build an isolated floor given the existing condition. We knew that a floating floor on proper isolators would solve the problem. The difficulty was that we did not have sufficient height and since the existing studio wall structure was supported on the floating slab, we would have to devise a way of supporting the studio while we replaced the floor. Fortunately the electrical and audio wiring came down the walls from above rather than up through the floor. If we could support the walls we could replace the floor. After much thought, I realized that the drywall would support the walls.

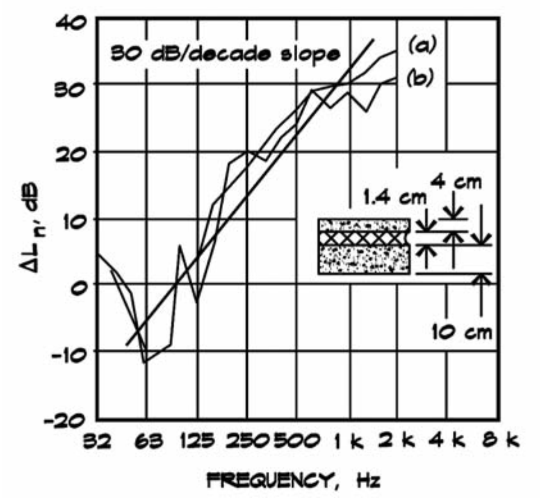

Fig. 6. Improvement in impact noise isolation, ΔL_n, for a resonantly reacting floating floor (after Beranek, 1992).

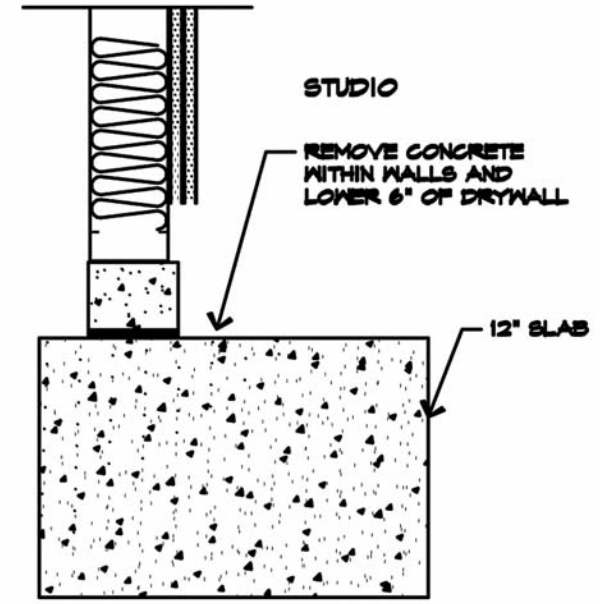

Fig. 7. First step of the repair process.

I devised a construction plan, illustrated in the following sketches. Figure 7 shows the first step, which was to remove lower six inches of drywall from the existing walls and to jack hammer out the center portion of the concrete floor down to the garage slab, leaving the outer 6 in ribbon of floor slab on the neoprene sheet to support the studio wall studs.

In the next step, shown in Fig. 8, a section of the remaining outer floor approximately 2 feet wide was chipped out from under a portion of the wall support structure. The dry-

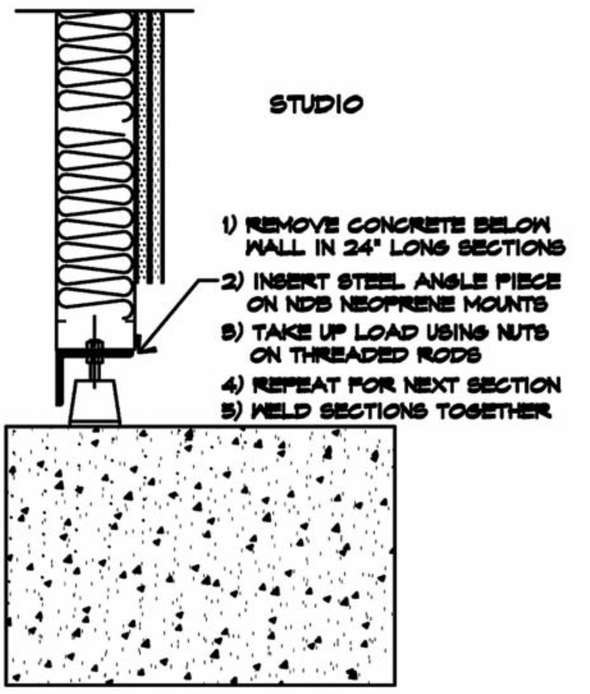

Fig. 8. Second step of the repair process.

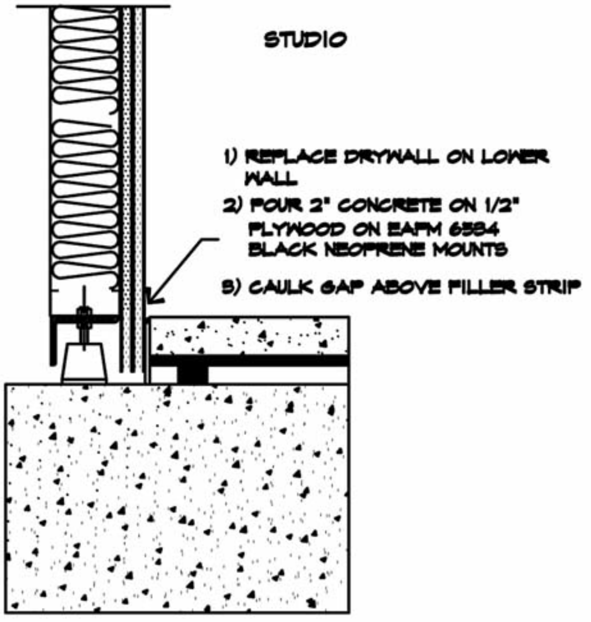

Fig. 9. Last step of the repair process.

wall spanning that area would support the wall temporarily after it was removed. A piece of angle iron on neoprene double deflection isolators could then be slid under the wall track and raised on threaded rods to support that section of the wall. The bottom track of the wall studs would then be tack welded to the angle iron. This process would be repeated around the room. After each section was installed the angle iron was welded to the adjacent section of angle iron until there was a continuous rigid steel frame around the whole room. At this point the walls would be resiliently supported, and the old floor would have been completely removed. The drywall then could be replaced and would form a pouring backstop for the new floating floor.

Figure 9 shows the last step, which was to install a floor consisting of 2 in hard rock concrete on plywood on neoprene isolators. Earthquake limit stops (not shown) were shot into the slab to restrain the motion of the new floating floor. The new structure was poured to exactly match the elevation of the previous slab. Once the wall drywall and flooring were replaced, the piping noise, footfall, and cart movement in the corridor were no longer audible in the finished studio.

Summary

Vibration isolation is a critical part of building construction particularly in studio floors. To work properly there must be adequate deflection in the support system to yield a resonant frequency well below the frequency of the intrusive noise and vibration. When there is too little deflection in the support system, poor isolation will result. Too much deflection and the system can become unstable. In wall and floor construction there is a tradeoff between the mass of the components and the spacing which can be utilized to advantage. The lesson is that although we would like to design projects in the same familiar way every time, it is not always possible to do it. Given the obstacles we encounter, we have to use the principles we learned to craft new creative solutions.**AT**

References

Klepper, David L., Cavanaugh, William J., and Marshall, L. Gerald (**1980**). “Noise control in music teaching facilities,” Noise Control Eng. J. **15**(2), Sept/Oct 1980.

Long, Marshall (**2006**). *Architectural Acoustics* (Elsevier, Oxford).

Ruzicka, Jerome E. (**1971**). “Fundamental concepts of vibration control,” Sound and Vibration magazine, July 1971.

Sharp, Ben H. (**1973**). *A Study of Techniques to Increase the Sound Insulation of Building Elements*, WR 73-5 (Wyle Laboratories, El Segundo, CA, June, 1973).

Beranek, Leo L., and Vér, István L. (**1992**). *Noise and Vibration Control Engineering Principles and Applications, Ch. 9*, “Interaction of Sound Waves with Solid Structures” (John Wiley & Sons, New York, 1992). This material is used by permission of John Wiley & Sons, Inc.

Marshall Long received a BSE degree from Princeton University in 1965, attended the University of Grenoble in France and the University of Madrid in Spain in 1966. He received M.S. and Ph.D. degrees in engineering from UCLA in 1971. While still a graduate student, he founded his own acoustical consulting firm, now in its 38th year. Marshall Long Acoustics specializes in architectural acoustics, audio visual design, noise and vibration control, and other technical areas related to acoustics. He enjoys sailing, judo, soccer, reading, and writing, and is living with his family in Sherman Oaks, California. He is a Fellow of the Acoustical Society of America.