Technical Features − Sound Construction
How To Avoid Flanking Sound In Your Acoustical Design

THE PRESENCE OF FLANKING SOUND IS THE SINGLE MOST SIGNIFICANT DIFFERENCE BETWEEN LABORATORY AND FIELD PERFORMANCE

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In the evolution of building design, the architect is constantly attempting to meet the environmental needs of the apartment occupant. Thus, we have seen the progression from the wood−burning fireplace to central heating, from winter heating to year−round temperature control and from lantern candle light to 200 amp electrical service. Inter−apartment sound control for acoustical privacy has been and continues to be an ongoing design challenge for successful modern−day residential structures. In addition to the present high costs of construction and operation, today's apartment dweller demands a residence that not only meets basic needs of temperature and lighting but also one which provides maximum sound isolation from neighbors who may be living within 6−in. of his apartment.

Manufacturers have recognized this need for high performance wall, floor and ceiling systems. Using the resources of their research and development organizations, they have developed a myriad of assemblies with ratings for every conceivable set of conditions.

Developed under laboratory conditions, the test results of these assemblies have shown that the potential for high sound isolation performance is possible but not necessarily attainable.

The sound control or reduction of noise between adjacent rooms in residential and commercial units historically has been determined by considering the sound transmission characteristics of those building elements in the direct path between the source of the noise and the hearer. The commonality of the structure and its sound−transmission characteristics is generally never considered. Although the existence of transmission paths which bypass or flank the primary barriers is universally acknowledged, it is often ignored since there are not sufficient data available to determine the contribution of transmission paths to the overall objective of room−to−room noise attenuation. Generally speaking, this path of energy transmission is ignored in the United States, even though it may be a dominant source of noise to the listener. In comparison, several European countries have recognized and acknowledged the significance of this course of noise. As an example, since 1971, the United Kingdom has had requirements in their English Building Regulations, which deal with both party wall and floor transmission and flanking. The USG Corporation Acoustical Research Facility at Round Lake, Ill., was designed to study the contribution of flanking paths in common type wood, steel and concrete−frame structures and to evaluate the contribution of the structure to the overall transmission of sound.

The Study Of Flanking Sound

The uniqueness of this acoustical research facility is an important part of that research. Prior to the development of the Round Lake facility, USG Corporation had been conducting on−site field tests of partition systems in an effort to evaluate actual performance. This process was both time−consuming and subject to many interruptions — high and extraneous ambient noises, jet plane fly−over or truck pass−by, workmen, electrical disturbances, and contractor scheduling. A "field" research test facility, with a controlled acoustic environment, free of the common distractions, was warranted. The Round Lake laboratory was built in 1965 on a 40−acre rural site about 50 miles northwest of Chicago to satisfy that need.

Requirements by national and local code agencies that insist on assurance of job performance necessarily have produced "on site" acoustical testing specification for the construction industry. Until recently, sound ratings were based on values obtained by acoustical laboratories using well−established methods and procedures. But the validity of selecting a partition system on the basis of laboratory tests without regard to flanking sound has proven to be uncertain. In fact it only created a "numbers game" among manufacturers and turned into a deadly trap for the unwary. Job results often turned out to be 10 to 15 dB below laboratory findings. Since little was known about the effects of installation methods, detailing, and the contributions of the adjoining building elements, architects, engineers, builders and owners had little assurance of achieving the published laboratory sound ratings.

The USG Corporation simulated field test facility provides many answers. In the conceptual design of the Round Lake facility, four buildings were constructed to represent typical types of construction. The test buildings are each two−story structures with two rooms per floor. Two are wood−frame construction with one having modified balloon framing, with the second floor joists fastened to the exterior wall studs, supporting and tying the structure together. At the second level the joists are bearing on the center partition. The second wood−frame building is western or platform framing, where the first floor sub−flooring is put down making a platform on which the walls and partitions can be assembled in place. The joists are supported by the exterior walls and run parallel to the dividing partition. The third is of steel frame construction and the fourth, reinforced concrete. Each building was designed to permit the effect of window openings at various locations to be studied. These openings can also be enlarged to become doors along a corridor. The effects of wing walls and parapets, as well as those of attic and crawl spaces, are also evaluated.

Testing of partitions and allied systems conform to present ASTM procedures as well as the existing ISO standards. The initial intent of this facility is not to develop new partition systems, but rather to evaluate systems installed in particular types of structures. The continuing objective is to assign transmissivity ratings to various building components and details. These, in turn, will be applied to establish room−to−room attenuations for a wide range of partition−structure combinations.

This article covers a series of tests determining the sound energy transmission of flanking paths in the two wood−frame buildings. In this series, partitions and floor−ceiling systems with known laboratory transmission characteristics were installed in the test structure and the combined transmissivity was measured. Differences between the total transmission of the dividing elements were ascribed to flanking.

The Modified Balloon−Style Wood−Frame Structure

This two−story, four−room building had floor joists oriented perpendicular to and bearing on the center partition, Fig. 1. The exterior wall was stucco applied to gypsum sheathing and insulated with 3−in. thick THERMAFIBER Sound Attenuation Fire Blankets (SAFB) in the walls and 6−in. thick SAFBs in the roof. The only openings were one entrance door to each room. A four−foot crawl space ran the length of the structure.

The test series was conducted by producing random broad−band pink noise by loud−speakers in one room of the building and measuring the noise transmitted to the other three rooms. The test data were analyzed in two ways, in order to take into consideration the difference between field results and laboratory testing. The first was a straight−forward analysis of the results, assuming all transmitted sound energy came through the dividing, e.g., demising wall or floor−ceiling element. The second way assumed that the energy transmitted by the dividing element (wall or ceiling) was equal to the energy transmitted, as measured in tests at Riverbank or other classical acoustical laboratories. Any excess energy transfer was ascribed to flanking. When negative differences existed, the classical values were adjusted to equal field values. Another assumption was that the flanking radiating surface area was equal to the radiating surface area of the dividing element. A final assumption was made in the determination of the common edge (diagonally separated units) acoustical path. This was necessary because acoustical laboratories are not equipped to make this measurement. It has been assumed in this article, therefore, that the transmission loss for this path is equal to the combination of the horizontal and vertical transmission loss values.

With these assumptions, the following mathematical equation was derived to determine the limiting or flanking value of the structures.

$$W_t = I S_{FP} t_{FP} + I S_{DE} t_{DE}$$

where W_t = transmitted power
I = incident sound intensity
$S_{FP} = S_{DE}$ = radiating surface area of flanking path and dividing elements, respectively
t = transmissivity

$$W_t = IS(t_{FP} + t_{DE}) \quad W_t = IS \quad TL = 10\log(W_I / W_t) = 10\log(1/t)$$

Where W_I = incident power W_t = transmitted power TL = transmission loss

$$TL = -10\log(t_{FP} + t_{DE}) \quad TL = -10\log[1/10^{TL_{FP}/10} + 1/10^{TL_{DE}/10}]$$

$$TL = 10\log[10^{(TL_{FP}/10 + TL_{DE}/10)}] - 10\log[10^{TL_{FP}/10} + 10^{TL_{DE}/10}]$$

The equipment and measuring procedures followed the prevailing American Society for Testing and Materials, ASTM Designation E336 "Standard Test Method for Measurement of Airborne Sound Insulation in Buildings." Calculations, classifications and storage of test data were accomplished by computer.

In summary, the objectives for this program were:

1. To determine the acoustical isolation of a standard wood−frame construction in order to rate its relative acoustical performance;

2. To identify areas in the building frame that were weak in acoustic isolation; and

3. To recommend what changes, if any, could be made in the building frame to improve the overall acoustical isolation of the structure.

Modified Balloon−Style Results

A. The results are presented in Table 1 on page 8. The acoustical isolation of this structure was found to be dependent on the type of element being tested, i.e., the flanking determined from the floor−ceiling tests was markedly different from that determined by wall tests. Because of this difference, the acoustical limits were calculated for three room configurations: Rooms having a) a common wall, b) a common floor/ceiling and c) a common edge (diagonal between bottom and top units offset). The average class values are shown in Table 1.

B. The edges of the floor−ceiling system constituted the only obviously acoustically weak area in this building. A crack, blocked only by the taped angle joint, at the wall−ceiling line of the first floor rooms seems to be the primary cause for the low ratings on the system. A test series has been planned to define accurately the flanking contribution of this area.

C. The overall building frame is well constructed, and minor changes that could be made will not materially improve the sound transmission class of the structure. Extending the plywood subfloor under the sill plates, as done in western−style framing, is the only area where substantial improvement can be made at nominal or no cost increase.

Western−Style Results

The second building tested was the platform, western−style, wood−frame structure, Fig. 2. All other details and materials were similar to the first one described.

The results, presented in Table 2 on page 8, are substantially higher, as evidenced by the 50 STC horizontal flanking path for walls versus 39 STC in the balloon−style structure and 59 STC on the diagonal path versus 47 STC. This improvement is due primarily to the orientation of the joists and to the presence of a subfloor platform between the first and second floors. The floor flanking path yielded only 40 STC in the western−style structure, an eleven−point improvement. However, this is below the 50−54 STC requirements of most building codes and the federal guidelines.

The area needing improvement is the floor system, and it is a difficult problem. An increase in STC could be effected by isolating the facing materials on the side walls. The cost of this construction addition, however, is high and in certain installations, impractical. Instead, the basic wood structure was modified with the addition of a layer of 5/8−in. gypsum concrete, adding to mass, on the floor; SHEETROCK® RC−1 Resilient Channels, to effect decoupling, screw−attached to the wood joists in the ceiling and 3−in. THERMAFIBER SAFB insulation, to provide sound absorption, placed in between the ceiling joists. These three techniques, plus sealing gaps or openings, are the principal means to deal with most sound isolation problems. The results are tabulated in Table 3 on page 8.

Conclusions

The ability of the structure to contain the transmission of sound is the paramount feature in determining the room−to−room noise reduction. As a chain is only as strong as its weakest link, so too is a structure able to afford its occupants only the acoustic privacy of the combination of its various components. Continual care must be exercised to ensure that the design and construction of a building is consistent in that 1) the demising walls, floors and ceiling assemblies are of similar performance and 2) the interface of these elements is compatible and does not degrade their individual performance.

Thus the building acoustic system must have the following characteristics of design:

- MASS for increased inertia against excitation (building components will not transmit sound by vibrating);
- DECOUPLE to prevent the transmission sound between contiguous building elements (damp sound);
- ABSORPTION for the energy transformation (absorb sound); and
- SEALANT to prevent the passage of airborne sound (through cracks and other small openings).

Federal, state and local governing code bodies, architects, builders and developers can help the building industry recognize and work more effectively toward better sound control. One way is by recognizing that the structure and its many elements are dominant in the determination of the total acoustic isolation between living units. Specifying the acoustic isolation value of the party wall and/or floor−ceiling alone is not sufficient. Rather the overall isolation must be addressed and each element specified by its individual contribution toward this objective. Code bodies should begin a process to rewrite their performance requirements to specify overall isolation. The apartment dwellers must also strengthen their demands for acoustic performance.

To assist in the attainment of these acoustic goals, it is incumbent upon the architect/designer to utilize the services of experts. Acoustical consultants are trained in the science of building acoustics and can provide invaluable aid to establish performance objectives, recommend workable solutions and identify potential problem areas. During the construction process, the acoustical consultant can also help identify construction practices that may adversely affect acoustical performance and then instruct the contracting team on how to avoid them. The result is a consistent high quality of construction.

Another way of ensuring high acoustical performance is to make field tests a part of the architectural specifications, i.e., that field tests be performed to verify the overall level of interapartment acoustic performance. The improved−quality construction will yield an immediate pay−back to the owner/developer in both greater tenant satisfaction and lower apartment turnover. The testing procedures can also be extended to serve as a check on the quality control of the construction. A statement that "a random sample of 10% of the demising elements of the project must be field tested to verify performance" is easily incorporated within the contract documents.

U.S. Gypsum will carry on in its efforts to further define the acoustical limitations of structures and their building components. It will also continue its research and development in new and better systems to meet the growing demands for increased environmental sound control.

Two U.S. Gypsum catalogs that may provide helpful information for selecting and designing acoustically efficient walls and ceilings and minimizing sound flanking are SA−100 Construction Selectorand SA−924 Drywall/ Wood−Framed Systems. For copies of SA−100 and 924, write to Editor, Form Function, 125 S. Franklin St., Chicago, IL 60606−4678.