EDITORIAL

Acoustics and the Building Industry

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From the dawn of history, exploration of the relationship between sound in an enclosed space and the science of physics had been limited to ancient texts and a few early scientific observations. However, in 1898 Wallace Clement Sabine presented to the American Institute of Architects a lucid summary of what he called "architectural acoustics" that is notable in its clarity and ease of understanding. Included in Sabine's *Collected Papers on Acoustics*, 1921,[1] his seminal paper is still probably the most graphic explanation of the factors that determine reverberation. Sabine then further broadened his research so that upon his death in 1919 he bequeathed to the world a completely new science.

His discoveries inspired others to extend his research into the behavior of sound. *Acoustics of Buildings*,[2] published in 1923 by F. R. Watson, went through three editions, influencing architectural acoustics for years. Then in 1929, he and a small group of other physicists founded the Acoustical Society of America. Although their primary interest was architectural acoustics, they expressed the hope of expanding into other scientific disciplines. Now, more than 80 years later, ASA has thousands of members, encompassing 14 distinct branches of acoustics and with strong ties to societies in many other countries. But the acceptance of acoustic principles in building design has been slower to evolve.

Understanding of architectural acoustics advanced dramatically as a result of scientific work done before and during the World War II, and it gained further recognition in the tidal wave of new construction during the 1950s. In the design of spaces for music performance, former criteria of visual space and architectural expression no longer governed the design, although in many other types of building, this basic functional requirement of any occupied space has often been largely ignored. Ironically, its basic precepts are mostly commonsense and familiar to any child of five or six. For example, I don't hear mother calling me if I close the door and play the radio loud.

So why would this wealth of information and experience not be reflected in the buildings in which we live, work, play and sleep? Experience suggests that one of the reasons has been the difficulty of adapting construction methods that were dictated by other criteria to satisfy specific acoustical conditions. If these requirements were not recognized early in the design, accommodating them later could well be costly, supporting the widespread belief that "acoustics is expensive." Other possible reasons are explored from the viewpoint of one consultant after 50 years of observing the world of design and construction from the very end of the food chain.

Coming to acoustics from an architectural background, I conclude that the inability to communicate clearly between the two disciplines still remains one of the obstacles to wider acceptance of acoustic principles. Picture an architect trying to make sense of a theoretical paper on some aspect of acoustics. One can easily visualize his eyes glazing over, but the same would likely be true of a theoretical physicist trying to fathom a set of construction documents. The two disciplines use totally different languages, with physics tending to be precise and logical, while building construction is an often untidy accretion of engineering techniques and hard-earned skills, such as in masonry construction, that were better understood by unschooled medieval builders than by most modern architects and engineers. Establishing a common understanding to bridge this substantial gap is therefore essential in resolving acoustical design problems effectively.

It is also important to keep in mind that most acoustical problems can generally be predicted before the building itself exists. Over and over again, lack of careful space planning can be seen as the sole reason to require expensive acoustical revisions. With ample information readily available, it is not too difficult to define the wall, floor and ceiling construction needed for, say, an office or hospital room that overlooks a freeway, that is adjacent to a mechanical equipment room, and that is located directly beneath an exercise room. However, any designer who is even thinking about acoustics should recognize that the construction necessitated by such an arrangement could be difficult and costly, and that substantial savings could be realized by relocating such a sensitive space elsewhere in the building.

Origins of the Industry

The building industry itself depends on regionally available skills and materials, and it is constantly adapting to meet new requirements, so maintaining appropriate standards is always in a state of flux. In western Asia and Europe, over the course of centuries, safety standards were compiled for major buildings such as palaces and cathedrals, as in one example from the Code of Hammurabi:

> *"If a builder builds a house for someone, and does not construct it properly, and the house which he built falls in and kills its owner, then the builder shall be put to death."*[3]

Safety and related concerns also underlay establishing various craft disciplines, which became organized as guilds, and which, incidentally, guarded craft secrets to protect their own livelihood. By the early part of the Renaissance, some sort of procedure for control of building design and construction was fairly well in place, generally under the guidance of a master builder who was responsible for both the design and supervision of construction.

Rapid expansion of the number and type of new buildings during the Industrial Revolution led to the development of scientific techniques for structural design, first in wood and masonry and subsequently in steel and reinforced concrete. Skills residing in the guilds became the foundation for professional societies who advocated design and construction standards based initially on safety to control building methods. While the perspective of history tends to blur details and gaps in our understanding of this period, progress tended to occur unevenly, with occasional significant advances such as the development of the roof truss being followed by long periods in which methods and materials were simplified and refined.

By trial and error, many construction methods became formalized in building codes. From the start they emphasized safety in response to building disasters, and today structural integrity and fire safety still remain at the core of building regulations. As less basic needs such as ventilation and lighting became defined by experience and research, they were also incorporated into the rules that designer and builder are required by law to observe, no doubt spurred on by the growing influence of the engineering professions.

On the basis of design documents prepared by the master builder or architect, along with the estimated cost of the work, a contract was signed between owner and builder. Control of cost depended on the experience of the design team and competitive bids from several builders. Traditionally, the architect was not a party to the contract agreement but served as the owner's agent in supervising construction. This would include review of shop drawings submitted for approval of building components, such as structural steel and any mechanical systems, acceptance or rejection of product substitutions or design changes proposed by the builder and, upon completion of the work, determining whether the builder had complied with the owner's requirements as specified in the construction documents.

The success of this procedure depended on the completeness of the contract documents, the competence of the builder and sub-contractors, and on frequent and thorough site inspections. It is important to note that the owner and architect typically expected the best possible interpretation of the design, whereas the primary objective of the builder was simply to make a profit. So the details, that in many situations were crucial to the success of the building and that were often hidden from view in the completed building, had to be clearly stipulated, properly executed and verified during construction. As technical requirements became steadily more stringent (for example, in a research facility requiring close control of temperature, air quality, humidity and so forth), the ability to retain the fine details during construction could be the key to success or failure.

Building Design Protagonists

The building owner could be an individual or society, a corporation or an institution such as a university or parish, with both the need and the funds to commission the building. In most situations, the owner had to rely on a team of professionals to translate his needs into a building program, to investigate any legal requirements for the standard of construction and to define user criteria. The architect designed a facility to meet the needs of the owner and prepared drawings and supporting specifications to guide the builder.

The building design team typically comprised an architectural firm as the central agent, with the support of a variety of engineers and other professional consultants chosen for their expertise. Criticisms of the monopolistic nature of the engineering professions were generally refuted by claims of having essential knowledge coupled with self-imposed ethical standards. This remains true in principle, although individual transgressions of varying degree have led to loss of public esteem. Currently, in an era of over-supply and a buyer's market, consultants of all types are being sorely tested by pressure to subordinate their standards to the wishes of the person paying for their services.

Current Building Practices

This traditional situation flourished with only minor changes until the mid 20th century, but immediately following the war, building construction expanded and adapted to new technologies, changing all branches of the industry. Entirely new design concepts, such as open office facilities and replacement of traditional mechanical systems with complete factory-built air conditioning modules were introduced to meet new demands and reduce building costs. In turn, they brought new requirements for control of noise and reverberation.

Accordingly, special chapters on noise and vibration control were quickly added to engineering handbooks, while manufacturers established research and testing facilities to ensure that performance of their products was appropriate for these new conditions. For several years, close collaboration between engineering disciplines and innovative manufacturers led to the exchange of much product information and research, resulting in technical advances on which many of our current standards are based.

However, the initially keen architectural interest in building acoustics was short lived, being pushed aside by a succession of other design trends extending from modular schools to the current interest in energy-efficient and "green" buildings. Each new trend makes its own contribution to building design, but combining them without creating conflicts requires a common understanding of criteria and a level of integration that is seldom reached due to time constraints and imperatives of committee members with industry ties.

Other obstacles also tend to appear whenever money interests are threatened. The recent adoption of a long-overdue standard for quiet classrooms, by which it is truly possible for the teacher to be heard and understood, was strongly opposed even by some school boards and by segments of the building industry due to fears of added cost. All too often, sales talk appears to have more credibility than engineering. Meanwhile, in adapting to more general guidelines, formerly well-recognized standards of sound isolation between spaces have been arbitrarily reduced to single-number notations that are frequently misapplied. It is easy, for example, to add a note on the drawings defining STC (sound transmission class) ratings required between spaces. But this is in fact a laboratory test standard, and constructions on site could easily be 15 to 20 points below the specified value if not properly inspected during installation.

The introduction of computer-aided design and drafting has dramatically streamlined production of design documents and created a degree of flexibility impossible with hand-drafting. However, this gain has often been at the cost of understanding how buildings are put together, as can be readily seen from comparison with architectural drawings from the mid 20th century. The older drawings typically demonstrate an understanding of materials and how they are used that is seldom found in computer-produced drawings. Details that leave a lot open to interpretation, and therefore are difficult to enforce in construction, can often mean the difference between success and failure in situations requiring noise and vibration isolation. In the same vein, design calculations and equipment selection that originate with a manufacturer may leave little room for competitive bidding.

Probably the most sweeping effect to occur over the past 50 years, however, has been a nontechnical but increasingly important change in the design-construction team itself. Two cost-saving factors are now dominant: the first is reducing total time required to create a productive building; the second is lowering of design and construction costs. Both factors were implicit in the traditional process, though at times it allowed delays and cost over-runs. But the balance changed with the introduction of a project construction manager as a representative of the owner. The construction manager took over direction of the entire design team, setting time and cost limits on design and site supervision. This began a series of procedural changes that still continues and promises to redefine the entire role of the design professions.

There is no doubt that such consolidation of work can add efficiency to a design team, but all too often the heavy hand of cost containment has been found to over-ride important design considerations. One early review process to reduce first cost, known as "value engineering," forced a hard look at each building component to determine if it were really needed. With the mere stroke of a pen, a well-meaning reviewer could make an impressive saving by deleting any specified item. Unfortunately, changes made without a full awareness of their effects often had to be corrected later. This created additional costs that in many cases could not be included as part of the initial building contract and therefore became an expensive "extra." This of course meant that the contractor could be paid first for incomplete work and then for corrections.

One example frequently subjected to criticism and sometimes discarded is the requirement for submission of shop drawings and performance data. Here, the specifications call for the fabricator of a specific item, such as an ornamental grille or a supporting bracket for a piece of machinery, to furnish drawings showing his interpretation of what was defined in the construction documents. If designer and fabricator are in agreement, a note of approval is issued. On the other hand, if the fabricator does not fully understand what is required, or proposes a better alternative, a brief exchange can usually resolve any differences and possibly result in a better final product. Similarly, a timely reminder during a site inspection of the need for attention to a given construction detail may save effort for the installer and at the same time avoid a potential problem. Probably the most commonly neglected such item is the control of flow noise in plumbing systems, which is usually easy and cheap to eliminate during construction but virtually impossible to correct after completion.

The role of the construction manager has often been absorbed by large development groups that have the resources to contract directly with an owner, replacing the traditional process entirely by a unified design and construction agreement to complete the project within a specified time for a guaranteed price. First-hand observation over at least the past 40 years indicates a consequent erosion of the authority of the design disciplines, both in production of contract documents and in supervision of construction. To many owners this may represent a big step forward suited to current financial markets, allowing them to rely on a firm initial building cost and to set other schedules, such as the lease date for a speculative building. However, if the building incorporates facilities that require careful control of environmental conditions – temperature, humidity, vibration or noise for example – what is hidden in the unsupervised construction details is of great concern to the occupants. The additional costs of lost time and correcting deficiencies could be much higher than the savings squeezed out of the original design by owner and builder.

Two current methods of reducing initial cost, as opposed to long-term cost of operation and maintenance, are known as "design-build" and "design-assist." In the former, the traditional work of the design team is truncated, and the builder becomes responsible for all details of construction. But in "design-assist," the builder attends design meetings and comments on ways to reduce cost or simplify construction methods. Such a process may well bring a note of reality to a creative design, but it also introduces divided responsibility for any decisions that may later entail "extras."

In either case, inclusion of any element of the design has to be defended against potential cost savings for its deletion, so clear and immutable design criteria on which all have agreed are essential. Past examples indicate that installation shortcuts probably cause the most serious harm for environmentally sensitive disciplines (such as noise and vibration control), because few in the building industry have a real understanding of or much interest in these requirements.

" . . . our concept of progress prevents us from realizing that skills and knowledge can simply vanish from the world." [4]

The other side of the coin has been the negative effect of these sweeping changes on almost all design professions. There is no doubt that the dictates of a construction manager can be a substantial contribution to both design and budget. However, this tends to overlook the competence of most design practitioners. Replacing years of experience in dealing with difficult architectural details by an unsupervised tradesman who sees a way to simplify an installation is generally to look for trouble. The first instinct of the designer is probably to resist such loss of control and with it the related fee reduction in addition to the twin goblins of liability insurance and potential litigation. But after a few such confrontations, he or she could well give in and submit a letter disclaiming responsibility for that work.

Restrictions on both fees and control of construction quality are passed down the line to each subconsultant, usually with predictable results. In difficult economic times, some professional practices may only stay in business by accepting reduced fees, but with the uneasy knowledge that their reputations could be harmed by projects in which their recommendations had been rejected. The first casualty could be the willingness to devote more time than absolutely necessary to that project, so a design solution that might have produced savings in operating costs over the life of a building may be set aside in favor of one that requires less design effort. However, of much greater concern is the pressure for a consultant to comply rather than resist an undesirable design compromise. In too many cases, if a cost preference contradicts established criteria, the consultant may be "leaned on" to acquiesce. Such a situation leaves few viable choices and has prompted more than a few consultants to withdraw from the scene to protect their professional reputations.

Probably of more concern in the long run are the noticeable changes in attitude that can be seen in even substantial architectural and engineering offices, including the landmark building projects that are the dream of any professional, and in their way of dealing with independent consultants. One could assume this occurs because the owner has insisted on fee concessions. In turn, subconsultants are squeezed in fee negotiations, sometimes being required to sign a contract with fine print that makes a mockery of any scale of consulting fees. At each step of the way, the deciding factor becomes one of professional survival, but it may also encourage a cynical attitude toward design quality – how much extra effort and expense do I owe to a client who clearly does not respect my professional competence? Instead of taking that extra, unpaid site visit to ensure that particular details have been executed as specified, a member of the design team may be more likely to ensure that his recommendations have been carefully documented for self-protection. This may ensure that there will be no future requests for consulting work from that particular client, but in any case, client loyalty seems to have largely become a thing of the past. So in the long run, this all comes back to a building owner's view of professional services as a commodity that can be manipulated to suit market conditions.

"There is scarcely anything in the world that some man cannot make a little worse, and sell a little more cheaply. The person who buys on price alone is this man's lawful prey." [5]

What Does the Future Hold?

In his 1978 essay, *"The Professions under Siege"* [6] Jacques Barzun reflected on the declining influence of the professions and the possibility that in time they could be reduced to irrelevance and even disappear. He concluded that in some way they had to re-establish their former moral and intellectual leadership in the public eye or ". . . -without some heroic effort, we professionals shall all go down – appropriately – as nonheroes together." Certainly, we have witnessed the replacement of the old order by an industry dominated by powerful interests for whom professional design teams have become employees rather than independent agents. This, in tandem with a long-lasting and significant downturn in the economy, has dramatically revised the position of the building professions to one of dependence.

However, there is clearly no shortage of creative energy among architects, engineers and other members of the design fraternity, much of it focused on forward-thinking issues of building sustainability, reliance on natural resources and preservation of the environment that in the past have simply been laid waste with little thought of the consequences. It may still not be too late to preserve the building professions and the natural environment if the necessary steps are taken soon, but it is likely to be very difficult.

The recent death of a friend and former colleague at Bolt Beranek & Newman during the 1960s is an unwelcome reminder of the passage of time and of the profound changes we have seen in our professions. Clearly, we cannot return to the practices of earlier times, but we should be able to recapture their guiding philosophy and design appealing buildings for maximum usefulness that are appropriate for their settings.

By collaborating seriously to transcend the quick, cheap and easy, we can optimize the inherent qualities of building components to attain the most value for each of their functions for the life of the facility and for the good of all. The first step, of course, is extensive education of building owners, all of those in the design disciplines, and the people who actually build. This may be a lofty aspiration, but when one considers the alternative of a steady drift into irrelevance, it seems well worth the effort.

All that is needed is a clear sense of purpose and someone with the courage to confront the challenge; in Barzun's words: "aided of course by the many scattered men of talent and goodwill who are only waiting for a lead."

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