RWDI
Reputation Resources Results
CONSULTING ENGINEERS
& SCIENTISTS
TECHNOTES
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ACOUSTICS - PLAN AHEAD FOR PROPER DESIGN

by Glenn Schuyler, Principal

Acoustics is the science of sound and vibration. Acoustical engineering is multi-disciplined in nature. It incorporates many elements of building design including structural and mechanical engineering; architecture; interior design; environment and urban planning; occupational health and safety; and electronics.

Indoor sound quality, communication, privacy, freedom from noise (unwanted sound), and sound isolation are concerns in the design of public buildings such as theatres, cinemas, courtrooms, arenas, hotels, and hospitals, as well as, offices, residential buildings (see Figure 1), and manufacturing facilities.

Acoustical consultants possess the knowledge and experience to ensure correct implementation of acoustical requirements, integrating the acoustical design with the architect, planner, and various engineering consultants.

Most acoustical problems have feasible, cost effective solutions provided they are addressed sufficiently early in the design process.

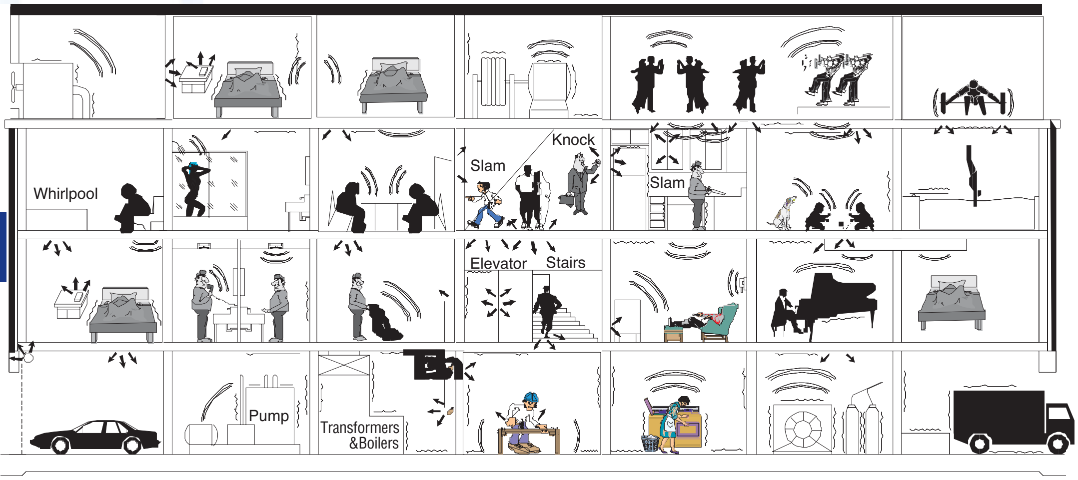


Figure 1: Noise in Multi-Family Buildings

By obtaining acoustical design services in feasibility or conceptual design stages, many situations can be analyzed and resolved to avoid future problems, major design revisions or additional costs. The result is a controlled sound environment in which people can live and work comfortably, achieved at the least cost to clients. Unfortunately, there are many examples of situations where acoustics was not considered early in the design process including the following cases.

Case 1: Penthouse Mechanical Room: A high rise residential building had a mechanical room with two hot water recirculation pumps mounted on concrete columns and neoprene waffle pads. The vibration produced structure-borne noise at sufficiently high sound levels to disturb occupants in the suite below resulting in several tenants moving out after a few months. The solution was to mount both pumps on a rigid steel framework supported on properly selected spring isolators. In this case, a practical solution was feasible, but substantial costs were incurred in terms of lost rental revenue.

Case 2: Convention Centre Storage Facility: In a major convention facility, storage areas were placed above hotel meeting and conference rooms. The floor slab consisting of 10 - 12 inch thick reinforced concrete would have been sufficiently stiff and massive to provide good airborne sound isolation for many activities. However, convention storage room activities included the use of solid rubber wheeled fork lifts and tow motors, that generated considerable moving point loads and vibration. There was no practical retrofit, so due to the noise and vibration, the meeting room spaces could only be used when the convention centre storage above them was not in use.

Both of the cases described above could have easily been avoided through proper attention to acoustics at an early design stage.

ACOUSTICAL DESIGN FOR MULTI-FAMILY RESIDENTIAL DEVELOPMENTS

by Darron Chin-Quee, Acoustical Specialist/Project Manager

Noise control deficiencies often overlooked by tenants of rental apartment buildings are not acceptable to many owners and occupants of high rise residential condominiums. In many condominiums, residents have expectations of a sound environment equal to or better than the houses in which many previously lived. Unfortunately, achieving a level of acoustical privacy and freedom from noise consistent with these expectations, requires design beyond the requirements of most building codes.

Noise is defined as unwanted sound and applies to internal and external sounds. Some of the numerous sources of noise in high rise developments are illustrated in Figure 1 on the front page. Achieving desired noise control and acoustical privacy requires: proper space planning; impact noise and vibration control; and airborne noise control.

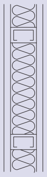
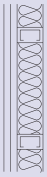
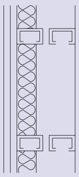
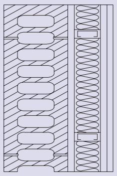
STC/ PRIVACY	TYPICAL CONSTRUCTION	TYPICAL USE
<45/Poor	 ½″ gypsum each side of 3½″ metal studs	Intra-Suite Partitions
45/Marginal	 1 layer ⅝″ gypsum each side; 3½″ metal studs; glass fiber batts in cavity	Noise Sensitive Intra-Suite Partitions (e.g., bedrooms & adjacent bathrooms
50/Good	 2 layers ⅝″ or ½″ gypsum each side; 3½″ metal studs; glass fiber batts in cavity	Marginal Inter-Suite Partition, Good Intra-Suite Partition
55/Very Good	 2 layers ½″ on 3½″ metal stud; glass fiber batts; ½″ clear; 2 layers ½″ gypsum on 3½″ metal stud	Preferred Inter-Suite Wall Marginal Mech. Rm. to Suite Partition
>60/Excellent	 8″ block (seal 1 side) ½″ space 1½″ furring glass fiber 2 x gypsum	Preferred Stairwell or Mech. Rm. to Suite Partition

Figure 2: Airborne Sound Isolation - Typical Partitions

Building Code Requirements: Design aspects, where addressed, are usually limited to sound transmission by airborne and sometimes impact noise. Code requirements should be considered the minimum for multi-family residential development. Higher ratings are recommended for condominium design. Compounding the problem are the wide variations in the requirements between codes. Those specifying requirements for field and lab test performance of airborne and impact noise isolation are best. For further information refer to BOCA Section 1214 and UBC Section 1208.

Proper Space Planning: Correct planning greatly simplifies the construction needed to achieve the desired acoustical results. Factors to consider include: stacking; noise sensitivity; capacity to generate noise; and privacy requirements of spaces. Compatible space layouts can reduce wall and floor thickness, clearances for sound control ceilings and/or floating floor requirements. Noise sensitive spaces (e.g., bedrooms) should not be placed above, below or beside noisy spaces (e.g., stairwells, party rooms, mechanical equipment rooms, or health clubs with pools, weight rooms, squash courts). If possible, similar spaces should be stacked (i.e., bedrooms with bedrooms, kitchen with kitchens).

Airborne Noise Control: Airborne (e.g., voice, television) sound isolation of space boundaries is improved with mass, thickness, and by decoupling layers within a partition (e.g., cavity wall). Airborne sound isolation performance of partitions can be specified by the Sound Transmission Class (STC) rating. The significance of STC ratings for typical interior building partitions is illustrated in Figure 2. We recommend STC 50 rated inter-suite construction as a minimum based on past practice and experience. Between suites and mechanical spaces, stairwells, garbage chutes, elevator shafts and other building service areas, minimum STC ratings of 55 should apply. Doors to corridors should be solid core wood or insulated metal having STC ratings of 35 or more.

Airborne sound isolation from the exterior depends on the proximity to significant environmental noise sources such as airports, highways, and rail and transit corridors. Windows are usually the limiting factor and in noisy areas should be minimized, double glazed (maximize airspace between lites) and made of laminated glass.

Impact Noise and Vibration Isolation: Impact noise from footfalls, chairs scraping, balls bouncing are transmitted through the building structure. To mitigate impact noise, floor systems should preferably have resilient finishes (e.g., carpet and underpad) on stiff, massive concrete floors (e.g., 6 - 8 inch thick reinforced concrete).

Massive floors alone, with hard surface finishes (marble, ceramic tile, hardwood) can have poor impact sound isolation, resulting in heel clicks. Lightweight floor systems with large deflections, even if finished in carpeting, will produce thumping or booming footfall sounds. Impact sound isolation is rated by the Impact Insulation Class (IIC) with ratings analogous to the STC system.

Typical construction ratings are shown in Figure 3. If hard finishes are required, resilient underlayment systems are commercially available. Most provide only minor impact noise improvement. Thin cushioned floor systems such as vinyl composite tile do not provide adequate impact isolation. Thick, resilient finishes are prerequisites for good impact isolation. Systems with adequate IIC ratings and stability to prevent cracking of grouted joints are normally an inch or more thick, and apply the hard finish to a subfloor separated from the structural floor by isolators. Due to resulting floor level discontinuities, extra height, and cost, proper impact isolation of this kind is rarely done. Rotating or reciprocating mechanical equipment should be vibration-isolated from the building structure.

Although these issues may be more important in high rise condominiums, they should be considered in rental and office buildings as well.

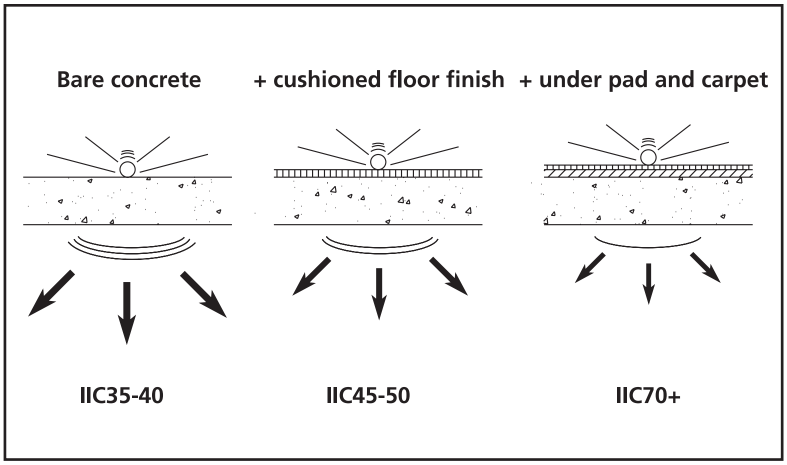


Figure 3: Impact Sound Isolation - Typical Floors

TUNED MASS DAMPERS - How They Work

The damping in a mechanical or structural system is a measure of the rate at which the energy of motion of the system is dissipated. All real systems have some damping. An example is friction in a bearing. Friction converts motion into heat, eventually bringing the system to rest if no outside forces are applied to keep the system in motion. Another example is the viscous damping created by the oil within an automotive shock absorber. The viscosity of the oil (its syrupy nature) generates heat when it is forced through a small opening in the piston of the shock absorber, thereby robbing energy from the system. In many systems, damping is an unavoidable evil to be overcome by the system input. In the case of tall buildings, however, it is beneficial, as damping reduces motion, making the building feel more stable to its occupants. Likewise, if any structural components are prone to vibration, damping is beneficial in suppressing the vibrations.

The amount of damping present in a system is commonly measured as a percent of critical damping (the level at which the system will come to rest with no oscillations). One may experience critical damping in an automobile with good shock absorbers. The car may be bounced by pushing down on the bumper, but when the pushing stops the vehicle returns to its normal position without additional bouncing.

Tall buildings typically have damping levels of one to two percent of critical (i.e., once started, oscillations will continue for many cycles). Damping can be added to a structure to increase stability by adding friction or viscous damping to the joints of the building. Since any single joint moves only slightly as a building sways, this treatment must be applied to a large number of joints within the structure. Another often more cost effective method of adding damping is to install a tuned mass damper (TMD).

A TMD consists of a mass mounted on a structure via a spring system and a viscous damper, preferably in a location where the structure's deflections are greatest. The spring and mass are "tuned" so as to have a natural frequency close to that of the primary structure. When properly tuned, the TMD mass oscillates in the opposite direction from the primary structure. The motion of the mass relative to the main structure can be very large when the system is properly tuned and this provides an opportunity to dissipate a substantial amount of energy in the damper linking the mass to the main structure. The optimum configuration of the spring system will vary depending on the application. The TMD principle also applies to individual components prone to vibration such as slender columns, truss members, and struts.

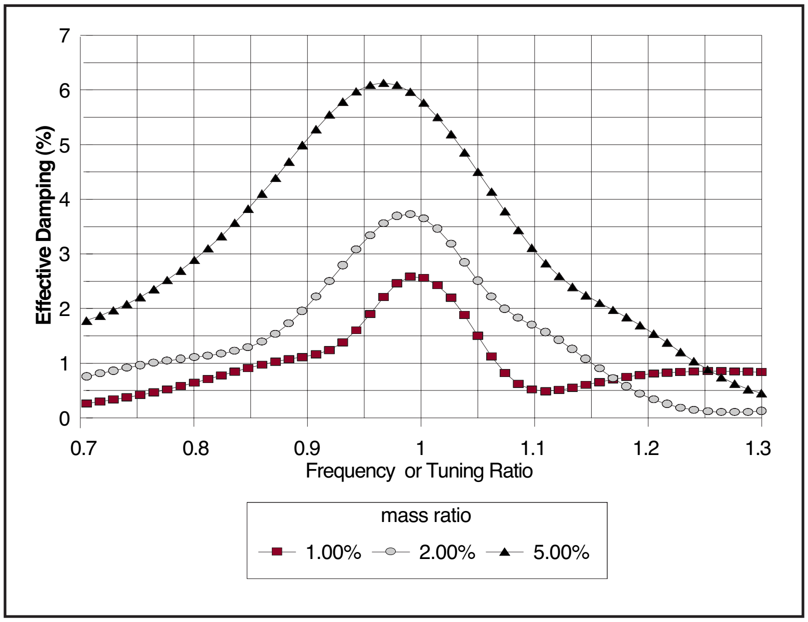
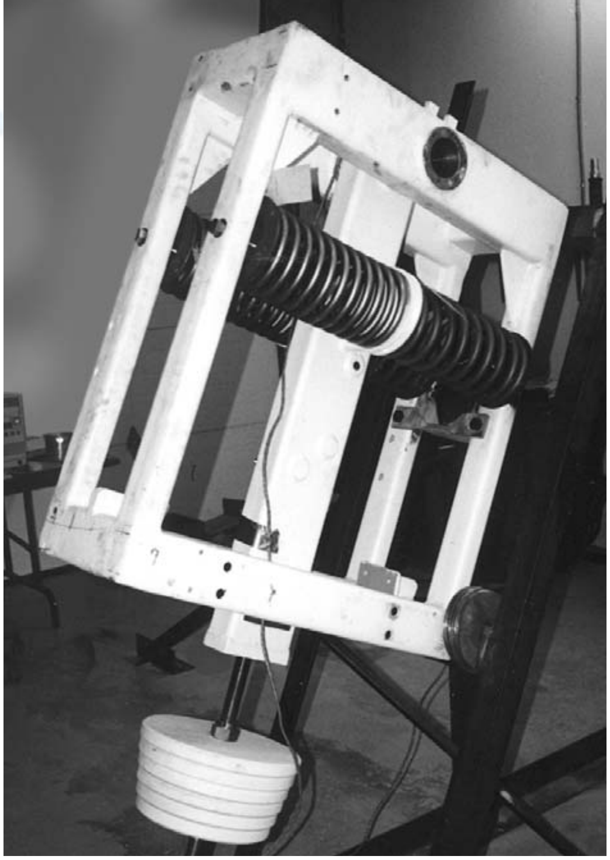


Figure 4 Effectiveness of a TMD

The effectiveness of a TMD depends on three variables: the mass ratio (i.e., ratio of TMD mass to modal mass of the structure); the damping ratio of the TMD itself; and the frequency or tuning ratio. The amount of damping added can be expressed as an effective increase in viscous damping of the main structure. Figure 4 shows the increase in effective damping of the main structure achieved for mass ratios of 1%, 2%, and 5% for various tuning ratios and optimized TMD damping. It can be seen that with a 2% mass ratio, an effective viscous damping of over 3.5% can be added. This is enough to significantly reduce building motion.

The TMD, shown in the photograph, was designed by RWDI for the skybridge legs of the Petronas Towers (currently the world's tallest building) in the Kuala Lumpur City Center, Malaysia. It is shown being tested in RWDI's laboratory prior to installation. Twelve TMD's were designed and installed (three in each of the four legs) to suppress vortex shedding vibrations of the legs in strong winds.



One of the TMDs designed for the Petronas Towers

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