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Please note

The old-fashioned building, in which massive walls supported massive floors, provided among its hidden virtues considerable protection against the transmission of noise. In decided contrast is the modern building, in which lightweight construction is the aim, and in which the walls, divested of their load-bearing responsibilities, have become merely curtains. The result is that in the modern building sound insulation must be dealt with explicitly, as a basic requirement.

It is proposed to discuss here the chief ways in which noise considerations affect the design of buildings, illustrating with three common structures: the apartment building, the office building, and the industrial plant. The analysis will be made as quantitative as this brief treatment will permit. A few special construction details will be discussed in the final section.

The most important point to be made is that the successful design is one in which noise is a consideration at every stage. A noisy site, for example, will strongly affect the over-all design of a building, and may necessitate costly noise control measures. Similarly within the building the spatial separation of quiet and noisy regions will simplify the problem of achieving adequate noise insulation between them. Finally, noise insulation design must be carried through to the last detail: there is no merit, for example, in specifying a good partition and then allowing it to become punctured with service outlets, or badly fitted doors.

Apartment Buildings

The problem to be considered in apartment buildings and other multiple-dwelling structures is the transmission of noise from one dwelling unit to another (on the assumption that the occupants of an individual dwelling can settle their local noise problems among themselves).

Noises produced in apartments vary with the occupants and with their activities of the moment. Similarly one's tolerance of extraneous noise varies with one's own activities; in fact if all the occupants of a building were always doing the same things at the same time there would be no noise problem. More commonly, however, one occupant will be trying to sleep while his neighbour watches a late television show; or a day worker will be living below someone who works in the evening and dines at 3 a.m. The successful building is one that can accommodate the wide variety of tenants and tenant activities amicably. A completely "soundproof" building is not practical; the modest objective in the following discussion is to satisfy perhaps 75% of apartment dwellers 90% of the time.

An apartment building can usually be laid out in plan so that the most critical rooms (bedrooms, living rooms) are protected from adjoining apartments by a buffer zone of non-critical areas such as bathrooms, kitchens, closets and hallways. For separating such noncritical areas a party wall having an average sound transmission loss of 45 decibels* is adequate. The next best arrangement is to place quiet rooms such as bedrooms on the two sides of the party wall; in this case the separation should be a 50-db wall. The worst arrangement is to place a critical region of one apartment adjacent to a noisy region (such as a bathroom or kitchen) of the adjacent unit; even a 50db wall is inadequate in this case.

Similar considerations apply to floors separating dwelling units. For separating critical areas an airborne sound transmission loss of 50-db is necessary. Since in the conventional building pattern it is not easy ta vary the floor construction from critical ta noncritical areas, it is usually the 50-db requirement that governs. An arrangement with noisy regions over critical regions should be avoided.

An additional problem of special importance in floors is impact sound (e.g. footsteps), originating as a vibration in the separating structure itself. Floors separating apartments should provide adequate insulation against impact sounds. Since a satisfactory floor design is the most costly noise control measure it is worth noting that floor transmission is the commonest and most disturbing noise problem in existing apartment buildings.

The floor problem does not arise, of course, in row dwellings. It is possible to minimize it also in apartment buildings by designing two story apartments; if they are planned so that the bedrooms of individual apartments are beneath their own living rooms the impact problem largely disappears. Airborne noise transmission is still important, but this is more readily dealt with.

Office Buildings

Noise insulation requirements for an office building are not as stringent as those for an apartment building. Offices are usually occupied for only about 8 of the 24 hours, a moderate amount of business noise is usually acceptable, and interference with sleep is rarely a concern. The main requirement for partitions between tenants in an office building is speech privacy: The speech originating in one tenancy should not be intelligible in an adjoining tenancy. An exact specification depends upon the ambient noise level in the listening "room", but generally an average transmission loss of 35 to 40 db is adequate. Office building floors usually provide adequate insulation for airborne sound, and impact noise is of minor importance except when heavy machines or other sources of vibration or impact are involved.

Unfortunately, with the current fashion in office buildings, even the modest requirement of speech privacy is not always met. Typically large floor areas are finished without partitions and subdivided to meet tenants' space requirements with prefabricated office partitions. A suspended acoustical ceiling is commonly used ta provide an unbroken surface masking miscellaneous pipes, ducts, and electrical services. However satisfying they may be visually, such partitions and suspended ceilings are frequently almost transparent acoustically.

Progress is being made in the development of partitions, and some excellent individual panels are now available. But in typical installations they are joined together by flimsy, leaky cover plates and filler strips resulting in an assembly that has a transmission loss of less than 25 db. Frequently the partitions meet an exterior curtain wall with only a narrow window mullion on which a satisfactory joint must be attempted. Other common features of the curtain wall, such as a continuous perimeter heating strip, introduce sound channels that nullify the value of a good partition.

Finally there is the problem of noise transmission over the partition above the suspended ceiling. This may be prevented (1) by using ceiling panels backed by a heavy impervious layer that reduces sound penetration through the ceiling, or (2) by building adequate partitions in the space above the ceiling.

The whole problem might be simplified by restricting the location of major partitions to modular intervals, perhaps coinciding with the structural module. At these intervals adequate partitions could be provided above the ceiling and suitable joint details could be incorporated in the curtain wall.

Executive offices and conference rooms constitute the most critical noise control problem in office buildings. Speech privacy is usually a requirement, necessitating the same considerations as above even for walls within a tenancy. An additional concern is to provide conditions quiet enough for comfortable speech over ranges of perhaps 10 to 20 ft. Meeting the speech privacy requirements will take care of most business noises except possibly business machine noise. Commonly the remaining problem is the noise produced by mechanical equipment such as ventilators. Quiet ventilator design is primarily the responsibility of the equipment manufacturer and the heating engineer. A suitable performance specification is to require that the equipment should not raise the noise level above the appropriate Noise Criterion given below. These specify noise levels, as a function of frequency, that have been found acceptable for the applications indicated. (For further details see Reference 3)

NC-30- Executive offices, conference rooms seating 50 people.

NC-35- Small offices, semi-private offices, conference rooms seating 20 people.

NC-40- General offices, in which speech and telephone communication are important.

NC-45- Large general offices, drafting rooms. Normal communications at 3 to 6 ft.

NC-55- Business machine rooms, communication in raised voice at 3 to 6 ft.

The large general office is a compromise between sound insulation and such factors as space economy, lighting and ventilation. The main noise sources are telephone conversations, and small machines such as typewriters. A partial solution is to use sound absorbing hoods or partial partitions around the principal offenders. More mechanized equipment such as card-punching and sorting machines, and reproduction equipment should be placed in a separate room where possible. Heavy machines should be mounted on properly designed vibration-isolating bases.

Industrial Noise

The typical industrial plant comprises offices, factory areas, storage space, and other occupancies. The special noise control problem is the factory area. No general solution can be prescribed for factory noise since the intensity and character of industrial noises vary widely. Apart from airborne noise there is often a vibration problem, which can usually be solved by providing special foundations or vibration-isolating mountings. Sometimes the machine manufacturer is prepared to offer guidance; otherwise a qualified acoustical consultant should be retained. The principal considerations will nevertheless be sketched below.

The requirements are: (1) to prevent hearing impairment among machine operators, (2) to facilitate necessary speech communication among operators, and (3) to prevent the transmission of excessive noise into other parts of the building or into adjacent buildings. The building designers' share in minimizing the first two problems is to provide sound-absorbing surfaces or space absorbers within the factory space. Sound-absorbing hoods or partial enclosures around the principal noisemakers are also sometimes feasible and useful.

The third problem is dealt with as in the preceding examples, except that the frequency content of the noise should be considered in conjunction with the frequency versus transmission loss characteristics of the walls and floors used to enclose it.

Building Details

Transmission loss of walls and floors. Airborne sound transmission losses of representative walls are given in Table I. It will be noted that a high transmission loss may be achieved either with a heavy wall or with a complicated one composed of several relatively independent layers. In either case it is essential that the wall be as air-tight as possible. Cracks or holes at joints or around service outlets can spoil an otherwise excellent construction.

Table I. Airborne Sound Transmission Loss of Typical Walls

A - Transmission loss 50 db or more. (Recommended between critical areas of adjoining dwellings.)

1. Single masonry wall weighing at least 80 lb per sq ft including plaster if any.
2. Masonry cavity wall - 2 leaves of masonry spaced at least 2 in. apart, each leaf weighing at least 20 lb per sq ft. leaves tied together with butterfly ties at 2-ft^2 centres.
3. Composite wall - basic wall masonry weighing at least 22 lb per sq ft; on one side of basic wall an additional leaf consisting of M-in. gypsum lath mounted with resilient clips, %-in. sanded gypsum plaster.
4. Stud wall - 2- by 4-in. studs; on each face ½-in. gypsum lath mounted with resilient clips, ½-in. sanded gypsum plaster; paper-wrapped mineral or glass wool batts between studs.
5. Staggered stud walls - 2- by 3-in. studs at 16-in. centres on common 2- by 6-in. plate; on each face 9-in. gypsum lath, ½-in. sanded gypsum plaster; paper-wrapped mineral or glass wool batts between one set of studs.

B - Transmission loss 45 to 49 db. (Recommended between non-critical areas of adjacent dwellings.)

1. Single masonry wall weighing more than 36 lb per sq ft including plaster if any*.
2. Composite masonry - as in A-3 except gypsum lath supported on furring.
3. Staggered stud dry wall - 2 sets of 2- by 3-in. studs at 16-in. centres on common 2- by 4-in. plate; on each face 2 layers of %-in. gypsum wallboard, the first layer nailed, the second cemented; joints staggered and both sets sealed; mineral or glass wool blanket or batts in the interspace.

C - Transmission loss 40 to 44 db.

1. Single masonry wall weighing at least 22 lb per sq ft including plaster if any*.

D - Transmission loss 35 to 40 db.

1. Stud wall - 2- by 3-in. or 2- by 4-in. studs ^{3}/8-in. gypsum lath and ½-in. sanded gypsum plaster.
2. Stud wall - 2- by 3-in. or 2- by 4-in. studs, 2 layers of ^{3}/8-in. plasterboard, the first layer nailed, the other cemented, joints staggered.

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* If porous blocks are used one face of each block section must be sealed with plaster or heavy paint.

Similar considerations apply to floors, with the additional problem of impact noise. Table II lists a few typical floor constructions. The impact ratings shown are based on a nonstandard test, and are for comparison only. For separating dwelling units an impact rating of better than 20 db (in this scale) is recommended. Although a satisfactory impact rating may be obtained with a suspended ceiling arrangement (sec Table II), a floating floor is generally more successful since it prevents impact vibrations from getting into the main structure and thence into adjoining parts of the building.

Table II. Sound Transmission Loss of Typical Floors

Impact Rating (db)

A -	Airborne transmission loss 50 db or more.	
1.	4-in. solid concrete or equivalent slab weighing at least 50 lb per sq ft; ceiling side bare or plastered directly on slab; floor side wood furring, rough and finish floors.	30
2.	As in (1) except floor side 1-in. foamed plastic or paper-covered glass fibre quilt, supporting 2-in. concrete.	30
3.	As in (1) except floor side parquet or linoleum; ceiling side wood furring, ½-in. gypsum lath, ½-in. sanded gypsum. plaster.	5*
4.	As in (3) but ceiling side ½-in. gypsum lath suspended on resilient clips, ½-in. sanded gypsum plaster.	20
5.	As in (3) but ceiling mounted on separate joints supported at waIls.	25
6.	Open steel joints or similar structure; on floor side form-work, paper-covered glass fibre quilt or foamed plastic, 2-in. concrete; ceiling side ½-in. gypsum lath on resilient clips, ½-in. sanded gypsum plaster.	30
B -	Airborne transmission loss 45 - 49 db.	
1.	4-in. solid concrete or equivalent slab construction weighing 50 lb per sq ft.	2[2]
2.	As above but floor side finished in linoleum or wood parquet.	5*
3.	As in (1) but floor side finished with carpet and underlay.	10*

* Impact rating not adequate for separating dwelling units.

Doors. - Doors should be avoided in partitions for which a high sound insulation is required. Where they must be employed in such walls they should be of solid wood and should be carefully fitted to minimize cracks around them. A refrigerator-type gasket is useful around top and sides; either a sill or a special drop-strip may be used at the floor.

Plumbing fixtures. - Plumbing fixtures are troublesome noise producers, and the service pipes may provide an efficient direct path between occupancies. To minimize such problems quiet fixtures should be used; service pipes should be resiliently supported and should not be fastened to critical walls. Doors leading to public washrooms should not open directly into quiet areas and should be well fitted. Ventilating louvres, if any, should incorporate noise filters. In apartment planning it is good practice to group bathrooms and kitchens of adjacent units together, and to locate the services (with due precautions against air leaks) in the party wall. Each set then acts as a buffer against noise from the adjoining apartment.

References

1. Acoustical Designing in Architecture, by V. 0. Knudsen and C. M. Harris (John Wiley, 1951).
2. Handbook of Noise Control, edited by C. M. Harris (McGraw-Hill, 1957).
3. Revised Criteria for Noise in Buildings by Leo L. Beranek, Noise Control, Vol. 3, No. 1, p. 19-27, January 1957.

* The decibel (db) is a convenient acoustical unit used. here for specifying the transmission lose of partitions. In this article the values of airborne sound transmission loss are averages based on measurements at 9 standard test frequencies, according to ASTM Recommended Practice E90-55.