Making Acoustical Requirements Visible to Building Designers

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Ever since Wallace Clement Sabine's first presentation to the American Institute of Architects in 1898, a substantial gap has often existed between available information on building acoustics and its successful application to the design of buildings. Experience over at least the past 40 years suggests that one of the reasons for this has been the difficulty of adapting construction methods that were selected to meet other criteria to satisfy specific acoustical conditions. In a complex project, it is important that requirements for individual spaces be identified and resolved early in the design process so that they can be integrated successfully into the overall building design.

As standard methods of building construction are adapted to accommodate the requirements of specialized facilities and equipment, providing adequate isolation of acoustically sensitive spaces generally becomes more difficult. At the same time, pressure on architects and engineers to complete design documents imposes limits on the time that is needed for proper integration of potentially incompatible elements. Consequently, it is essential that any special acoustical requirements be identified early in the design, when plan revisions can be made simply.

The acoustical goals are: to avoid design conflicts, to control unwanted sounds, and to enhance wanted sounds, all without imposing limitations on other functions. The challenge is to compile a lot of diverse information, with noise and vibration control as the primary emphasis, in a way that can be integrated efficiently into the building design. The first priority is to identify conflicts between individual spaces and conflicts with building operating systems that could be avoided by plan revisions. Second is to establish practical sound isolation details that can be easily incorporated. Third is to record this information in a compact document that will serve as a reference for acoustics requirements throughout the project.

The study generally begins with analysis of schematic design drawings, proposed construction methods and individual occupancy requirements. To avoid difficult and expensive construction details, conflicting adjacencies – including outdoor noise sources and spaces above and below – should be resolved before the design is too advanced. A simple overlay sketch of adjacent floor levels showing where noisy spaces and those needing quiet overlap is a fast and effective way to identify severe potential conflicts between occupancies.

Criteria

All information should be tabulated on a summary sheet for ease of reference, as shown in Table 1. Acceptable background levels and expected noise levels for each space should be verified with the building owner. Maximum expected noise levels are based on what is known about the use of each space and on measured data from similar situations. Design decisions should be confirmed in writing, and background noise criteria should be included as a design requirement in the contract documents.

While background sound levels due to ventilation/air conditioning (HVAC) systems are defined by noise criteria, actual sound levels will be determined by the design and operating conditions for each system. Where variable air volume (VAV) systems are proposed, a sound-masking system may be required for predictable speech privacy. A distinction should be drawn between the gener-

Noise Criteria

Octave	63	125	250	500	1000	2000	4000
NC 15	47	36	29	22	17	14	12
NC 20	51	40	33	26	22	19	17
NC 25	54	44	37	31	27	24	22
NC 30	57	48	41	35	31	29	28
NC 35	60	52	45	40	36	34	33
NC 40	64	56	50	45	41	39	38

Maximum Anticipated Sound Levels

Octave		63	125	250	500	1000	2000	4000
I	Speech, raised voice	60	66	72	77	74	68	60
II	General activity	72	70	72	77	77	74	70
III	Lounge, recreation	70	73	75	75	74	72	68
IV	Ensemble, practice	83	87	90	90	90	87	84
V	Recital hall, choral	90	94	96	96	96	94	91
VI	Workshop, loading	85	89	91	91	92	92	90
VII	Mechanical room	92	92	90	90	88	87	85

Table 1. Summary of acoustical requirements.

				Wall Construction				Isolation from	Isolation from	Finishes			
No.	Space	NC	Max Levels	N	S	E	W	Spaces Below	Spaces Above	Ceilings	Walls	Doors	Notes
101	Lobby	40	II	EXT	C	A	EXT	NA	–	T	–	–	–
102	Green room	35	II	EXT	B	C	B	NA	SP	U	–	–	–
103	Choir studio	30	IV	SP	SP	SP	SP	NA	SP	U	*	G	4,5,9
104	Score library	35	I	EXT	B	B	C	NA	J	U	–	–	–
105	Band Studio	30	V	SP	SP	SP	SP	NA	SP	U	–	G	4,5,9
106	Corridor	40	II	–	–	–	–	NA	–	T	–	–	–
107	Women's lavatory	45	II	B	E	A	E	NA	*	–	–	–	6,9
108	Men's lavatory	45	II	E	E	A	A	NA	*	–	–	–	6,9
109	Instrument storage	30	IV	C	E	C	C	NA	SP	*	*	G	–
110	Receiving	45	VI	C	E	EXT	C	NA	SP	T	–	–	–
111	Choir rehearsal	25	V	EXT/C	EXT/C	E	EXT	NA	H	*	*	G	3,4,8,9
112	Practice	35	IV	E	C	C	E	NA	K	*	*	G	2,3,5,9
113	Mech. room	–	VII	C	C	E	C	NA	–	V	–	G	7,9
114	BOH storage	30	IV	E	B	EXT	E	NA	SP	T	–	–	8
115	Piano storage	25	II	A	B	B	E	NA	–	–	–	–	–
116	Recital hall	15	V	SP	SP	SP	SP	NA	–	*	*	G	9
117	Vestibule	30	II	C	B	B	EXT	NA	–	T	–	–	9

Legend

NC = Noise criteria
SP = Special acoustical requirements, to be defined
G = Fully gasketed door
GB = 16-mm gypsum board
2GB = Double layer
S = Sound-rated door
GF = Glass fiber batts 90-mm thick or as specified
STC = Sound transmission class
SP = Special acoustical details, to be defined
EXT = Exterior wall, to be defined
* = To be defined

Notes

1. Isolate hydraulic elevator machinery and fluid line from building structure. Provide silencer for make-up air duct to elevator room.
2. Isolate stairs from walls.
3. Floor and wall-outlet box details to be reviewed.
4. Use double-glazed hermetically sealed windows with 2- to 4-inch air space between panes.
5. Verify adequacy of mullion details to avoid cross-talk.
6. Isolate all plumbing piping with resilient sleeves at anchor points.
7. Keep all vibrating equipment and related piping and conduit free of walls.
8. No panic hardware at inner doors of rooms with vestibules.
9. No door louvers or undercuts – typical for all doors.

Sound Isolation

Walls – see details A to E

Ceilings

H – Single suspended 16-mm gypsum board with no penetrations. Calk all joints.

J – Same as Type H, except resiliently suspended via neoprene in shear isolators selected for minimum static deflection of 8 mm. Ceiling edge joint to later detail.

K – Same as Type J, except with double gypsum board and glass fiber batts in cavity above.

L – Same as Type K, except with steel spring isolators; deflection to be specified.

Interior finishes

Walls

R – Sound absorbing wall covering 50-mm thick – NRC minimum of 0.80 for Type B test mounting.

S – Same as Type R, except 25 mm thick.

Ceilings

T – Suspended acoustic ceiling – minimum noise reduction coefficient of 0.70 for E405 test mounting.

U – Acoustic tile with minimum NRC of 0.60 for Test Mounting B cemented to gypsum board.

V – Sound absorbing ceiling similar to Type R wall covering, attached to gypsum board.

ally limited number of spaces where noise criteria are mandatory and other spaces where more relaxed criteria might be tolerated. Revision of wall-ceiling types in such cases can be an effective way to reduce cost if needed to meet budget limits, but resulting noise levels should be verified by the intended users.

Sound Isolation between Spaces

For each pair of spaces, the required acoustical separation is at least the difference between the selected noise criterion and the maximum level next door. Wall types should be consistent with standard details for the project, and isolation values should be verified by reliable data sources. At least octave-band analysis is recommended; use of single-number ratings such as sound transmission class (STC) is not recommended when dealing with a wide range of noise sources and does not consider junctions between materials, wall penetrations or other site conditions.

Wall-Ceiling Construction

The required noise reduction between adjacent spaces is compared with the measured TL of the proposed wall. Suitable wall-ceiling ratings to provide speech privacy with different background noise levels can be derived from published studies such as "Speech Privacy in Buildings." Assuming metal stud and gypsum board construction, test data published in 1985 by U.S. Gypsum Company have been used here to establish wall categories. Comparison of one-third octave laboratory data with the required TL values calls attention to any deficiencies that could influence speech privacy. A 5-decibel reduction from laboratory values is generally considered acceptable for in situ measurements, provided that quality and attention to detail are controlled by inspection of the construction work.

Where walls do not extend to the floor slab above, room-to-room attenuation through the ceiling cavity should match that of the wall, as indicated in Figure 1. The consistently unsatisfactory condition at the junction of inner wall and curtain wall mullion can be resolved by a simple and inconspicuous cover plate on each side to ensure positive sealing of sound leaks (see Figure 2). Plumbing in walls should have resilient sleeves at all contact points, but extensive piping, ductwork and wiring may dictate more elaborate details.

Floor-Ceiling Construction

Sound isolation between typical floors depends on the weight of the floor system and on whether a suspended ceiling can be used. For typical office facilities, a 2-inch-thick lightweight concrete slab on metal decking with a suspended mineral-fiber acoustic ceiling will generally provide adequate floor-to-floor sound isolation. If increased isolation is needed, a heavier floor slab and gypsum board ceiling may be adequate. Where a high order of floor-to-floor isolation is needed, the most convenient method may be a "floated" concrete floor slab on resilient isolators together with a resiliently suspended heavy dense plaster ceiling. However, such options typically entail other complications, so they should be marked for further evaluation after the initial review is completed.

Details

Doors should be acoustically matched to the wall selection and should also be located to avoid obvious privacy conflicts such as a waiting area directly outside a major conference room. Sound-rated doors should be avoided if at all possible because of their high cost, difficulty of maintaining alignment in lightweight construction, and required upkeep of edge seals. Special conditions such as sealing of joints and duct or piping penetrations should be detailed and specified, not left to the discretion of the builder. If sound masking systems are considered, they should be integrated with interior finishes with specified loudspeaker layout and system quality.

Sound-Absorbing Finish Materials

A brief reference to wall and ceiling sound-absorbing finishes is needed to alert the designer to the acoustical requirements within each space, but at this stage, it is generally enough to indicate that more precise information is to follow for each space.

Special Conditions

The final column of the tabulation is for notes that will apply to many spaces and that can be summarized efficiently. It also serves as a reminder of information to be included in drawings and specifications. Typical requirements noted here include the need for isolation from piping systems, elevator shafts and vibrating laboratory equipment, detailing of stairwells and movable walls, potential conflicts between disciplines and any construction details that should be inspected before being closed in by wall or ceiling surfaces.

Use of Summary Sheets

The preliminary summary of acoustical recommendations should be reviewed with the design team to check if anything has been omitted or if it proposes conditions that are not workable for other disciplines. It should be revised to meet any additional

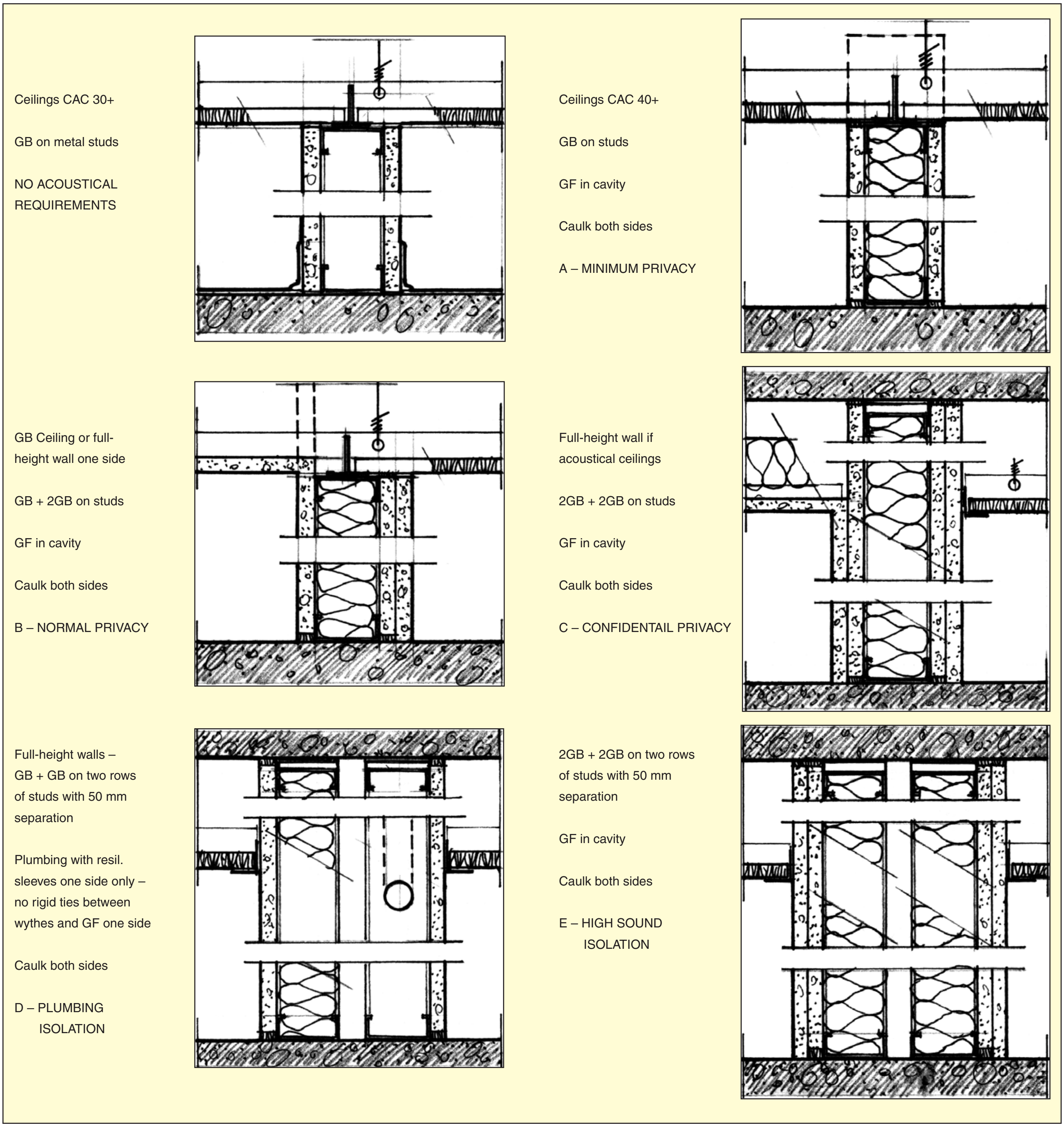

Figure 1. Typical partition-ceiling details.

needs and then accepted as a record of acoustical conditions for the duration of the project.

The design, development and construction document phases will include coordination of structure and building systems with construction details and may require further adjustments to meet special conditions. In each phase, it is important to have ready access to the summary of criteria in case of last-minute design changes. A typical example is the addition of supplemental air conditioning units to meet cooling loads of data centers, often without prior design discussion. Such units tend to be very noisy, are typically squeezed into inadequate space and are resistant to later corrective noise control work.

Limitations

The challenge of translating acoustical needs into actual construction becomes increasingly difficult as cost-reducing strategies limit architectural control of the work. For example, while value engineering can be effective in avoiding unnecessary costs, items that are essential for noise or vibration control may be deleted if their importance is not recognized by the reviewers. Similarly, decisions made during construction can be detrimental if the designer is not consulted.

The design-build process, where the building contractor is given responsibility for resolving construction details, effectively removes control from the design team. In some cases, this results in oversimplified or deleted acoustical controls that result in occupant dissatisfaction. Having a summary of acoustical goals for each space may be sufficient to guide the contractor in avoiding serious omissions, but the need for corrective work after completion is more likely. In the last analysis, control of details and site inspections to verify that the work is done as specified provide the building owner's only insurance that he is getting what he is paying for. Eliminating these final steps as a way to reduce total cost is thus always a gamble.

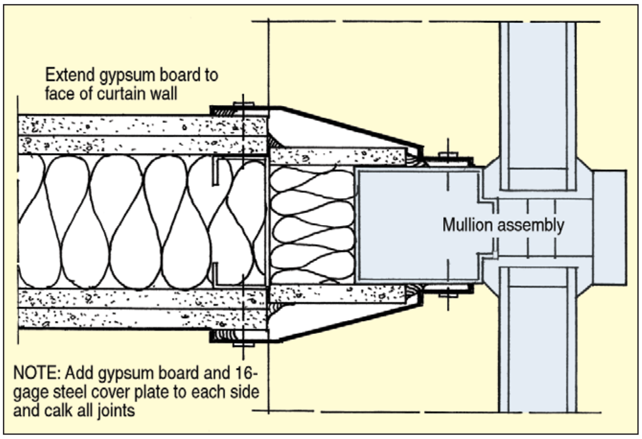

Figure 2. Example of modification of standard detail.

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