Classroom Acoustics III: Acoustical Model Studies of Elementary School Classrooms

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Abstract: A 1:4 scale model of a generic classroom was constructed with a series of interchangeable wall and ceiling panels to allow a battery of acoustical tests to be conducted for a variety of classroom designs. The walls and ceiling of the room could be changed from sound absorbent to sound reflective materials quickly. Scale furniture was also constructed for the room. The walls of the model could be adjusted from approximately 7 meters to 10 meters in length and from 2.5 meters in height to 7 meters in height. Acoustical measurements of speech transmission index, reverberation time, early reverberation time, early to late energy ratios, loudness (or relative strength) and articulation index were made in a number of simulated elementary school classrooms using a TEF analyzer, a real time analyzer, and impulse spark techniques. Models of classrooms where field measurements were taken as described in Classroom Acoustics II above were modified to attempt to improve acoustical conditions in the rooms. The location and amount of absorbent material, the location and amount of sound reflective material and the room volume were the major variables considered. In general, rooms that followed good architectural acoustics design principles produced favorable acoustical measurements. The model was also used to gather sound levels at multiple locations in the room based on field data recorded at one location.

THE CLASSROOM MODEL

An acoustical model of a typical classroom was constructed at a scale of 1:4. The model was built so interchangeable wall and ceiling panels can be easily inserted within an overall frame. Absorbent and reflective panels were constructed for the walls and ceiling so the room can be built with varying amounts of absorbing materials. The ceiling height can be adjusted from 2.5 m. to 7 m. The length and width of the model can be adjusted to a maximum length of 10 m. Seats, tables, blackboards and cabinets were also constructed so they can be placed in a variety of locations in the model.

Three sets of instrumentation were used in the model studies. A TEF analyzer was used with only the data from 250 Hz to 20,000 Hz used to represent the equivalent frequencies from 63 Hz to 5000 Hz in the full size room. A Grozier Technical Systems spark was used as an impulsive source of sound. Impulse responses were filtered and recorded on a Lecroy digitizer with various acoustical measurements derived by software developed by the researchers. Steady noise was also played through a small loudspeaker. The signal was recorded with an Ivie PC-40 real time analyzer in one third octave bands to obtain relative loudness levels and to estimate Articulation Class. Larson Davis 1/4" diameter microphones and Bruel and Kjar ½" diameter microphones were used to receive the signals.

MEASURING ASPECTS OF CLASSROOM ACOUSTICS

Sound levels were recorded at various locations in actual classrooms while students and teachers were participating in normal activities using an Ivie PC-40 real time analyzer. It was very difficult to measure sound levels while the teacher was speaking at different locations and at the same time measure sound levels at or near the teacher's voice without interfering with the teaching process. The situations observed in the PAR studies described in Classroom Acoustics I above were so dynamic that standard acoustical measurement protocols seemed inadequate to assess the situations. Obtaining a signal to noise ratio was also difficult because the ambient noise in the rooms was constantly changing. Table 1 below summarizes sound levels recorded at the sides of a typical classroom while class was conducted. The scale model was used to find sound levels at other locations once these initial levels were obtained in the field. The complex geometries of most classrooms; the partial height barriers; the variable distribution of furniture; and the complex source-receiver paths made the model a very useful way to study these situations.

The sound levels measured during class visits were remarkably similar irrespective of the activity that was going on at the time. With the exception of the background noise without the air-conditioning, sound levels measured away from the general location of the person speaking were 52-62 dBA depending upon the location of the source and receiver; and the relative loudness of the speaker. The ambient noise from children talking between activities and the general classroom chatter also fell into this range.

One of the important observations of this research was that the different sounds did not occur simultaneously. The teachers did not try to talk above the talking of the children. They would use methods described in Classroom Acoustics I above to get the children quiet. The teachers could then talk without strain and be heard by the children as was evidenced from their behavior.

TABLE 1. Sound levels recorded during normal classroom activities in a typical classroom.

Activity	Sound level (dBA)	Comments
Teacher speaking, children speaking and moving about the classroom during the change of activities	68 dBA	This noise has many components including chairs moving, children talking, moving about, etc.
Teacher speaking at front of room 6.5 m. from microphone	58 dBA	In model studies levels of 64-67 dBA were measured at the locations where children were located
Teacher speaking across a table to children	66 dBA	Air-conditioning system off The greatest student to teacher distance was 4 m.
Male teacher speaking to a child at a table	65 dBA	2.7 m. from teacher to microphone The male teacher's voice was louder than the female teacher's voice and he spoke louder
Students moving between activities	60-63 dBA	General noise in room from kids
Teacher addresses class from the center of the room	62 dBA	The students are quiet and attentive while the teacher is speaking
Teacher speaking at 1.3 m.	60 dBA	
Teacher talking at front of room measured at 6.5 m. from teacher	55-56 dBA	Air-conditioning was on. This was measured at 64 dBA at the students' locations in the model tests
Long term average sound level of speech and quiet in the room	52 dBA	
Average background noise while students are writing at their desks	52 dBA	Children talking at low levels
Background noise in room with air-conditioning system off	41 dBA	This was discussed as being "quiet" by the researchers

RESULTS

There were two major results from the acoustical model studies to date. First was that communication as defined both by observation during the PAR studies and by various acoustical measurements was good in rooms that followed reasonable architectural acoustics design principles. Second, the effects of room materials and geometries for the sizes encountered in typical classrooms in Florida schools was relatively minor for the communication situations observed in the PAR studies that involved very short teacher to student distances. At the short teacher to student distances of 2 to 3 m., the communication was dominated by the direct sound and several early reflections from the ceiling and table top. The sample of rooms in this study was relatively homogeneous. It did not include any large, two story high spaces or any coupled room volumes for instance. There were two exceptions to this conclusion. The first exception was in rooms with through-the-wall air-conditioning units and other loud HVAC systems. In these cases, communication, especially in the parts of the rooms near the unit inlets and outlets were dominated by the HVAC noise. The second exception was in rooms with very high ceilings and all very hard surfaces that exhibited excessive reverberance and severe acoustical defects such as flutter echoes in several planes. The sample of actual rooms did not include any rooms with these characteristics, they were tested in model form.

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