REVERBERATION IN GYMNASIA

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ABSTRACT

Gymnasia for public use are constructed and renovated on a regular basis, but the acoustical results are not always satisfactory or consistent. This paper examines this situation by presenting and discussing two case studies. In the first study, measurements of reverberation inside five public school gymnasia were carried out in the Mississauga area. The gymnasia were all geometrically alike, and had been constructed from typical building materials. Four of the gymnasia had been acoustically treated and were considered by the teaching staff of each to provide an adequate acoustical environment for typical activities. The remaining gymnasium was acoustically untreated, and its acoustic environment was considered by the staff to seriously impede its use. A brief literature review conducted to determine criteria specific to gymnasia revealed a notable lack of published information, both in terms of the traditional descriptor, the reverberation time (RT60), and in terms of more recently developed descriptors based on early/late arrival ratios. The measurement results and the subjective opinions expressed by each school's staff were used to determine reverberation criteria for a gymnasium, and to investigate the effectiveness of typical control measures. A second similar case study is presented. The results are discussed in terms of the relevance of various descriptors and potential building code implications.

SOMMAIRE

Des gymnases pour l'usage public sont construits et rénovés de façon régulière, mais les résultats acoustiques ne sont pas toujours satisfaisants ou conformes. Cet article examine cette situation en présentant et en discutant deux cas étudiés. Dans la première étude, des mesures de la réverbération à l'intérieur de cinq gymnases d'école publique ont été effectuées dans la région de Mississauga. Les gymnases étaient tous géométriquement semblables, et avaient été construits de matériaux de construction typiques. Quatre des gymnases avaient été acoustiquement traités et ont été considérés par le corps enseignant de chacun de ces établissements comme fournissant un environnement acoustique adéquat pour des activités typiques. Le gymnase restant n'était pas acoustiquement traité, et son environnement acoustique a été considéré par le personnel comme sérieusement empêcher son utilisation. Une brève revue de littérature conduite pour déterminer des critères spécifiques aux gymnases a indiqué un manque notable d'information publiée, en termes d'indicateurs généraux et en temps de réverbération (RT60), et en termes de d'indicateurs plus récemment développés basés sur des taux d'arrivée d'early/late. Les résultats de mesure et les avis subjectifs exprimés par le personnel de chaque école ont été employés pour déterminer des critères de réverbération pour un gymnase, et pour étudier l'efficacité des mesures de contrôle typiques. Une deuxième étude de cas semblable est présentée. Les résultats sont discutés en termes de la pertinence de divers indicateurs et l'implication potentielle du code du bâtiment.

1.0 Introduction

The reverberation time (RT60) of a room has traditionally been a key factor in quantifying its acoustic environment. Setting an objective, numeric design criteria for a room which must accommodate varied activities within a restricted budget is not straightforward. In the case of a public school gymnasium, the room must be able to house important sporting events, student assemblies, drama productions and band concerts, as well as provide the physical education instructor with a suitable environment to conduct classes.

Although it is a frequency-dependant quantity, the RT60 and other more recent acoustical descriptors are typically quoted as a function of the room volume and in terms of its mid-range (500 Hz and/or 1000 Hz) value, as this is the centre of the crucial range for speech intelligibility. Sources in the literature [1], [2] list the optimum range for the RT60 for good speech intelligibility at being around 1.5s, while the optimum range for a symphonic ensemble is anywhere from 1.6s to 2.4s. The optimum ranges for rock band concerts, drama productions, and multipurpose auditoriums lie somewhere in between.

An RT60 at the low end of the range may provide acceptable speech intelligibility for an instructor in a classroom-like setting with students at a relatively close distance, but is likely to detract from the excitement of an athletic competition or the enjoyment of a musical recital. The opposite is more common, in that unless they are specifically treated, gymnasiums typically suffer from an RT60 that is too high and consequently render the intelligibility of speech very difficult for all types of room uses and result in an overly noisy acoustic for the enjoyment of energetic events.

Varying the amount of acoustically absorbent materials in the room (particularly on the interior surfaces of the walls and ceilings) is the basic method of controlling the RT60. It is thus essential to account for the nature of the activities within the room when evaluating potential surface treatments. For example, it can be expected that all interior surfaces will be subjected to a considerable amount of physical abuse from basketballs, and volleyballs, in a gymnasium environment, and thus durability is of primary importance. Conversely, ease of cleaning and/or immunity to moisture may not be important at all.

Furthermore, while achieving the correct amount of absorption is crucial from an acoustical perspective for the reasons discussed above, budgetary factors also play an important role in the decision making process.

The challenge is to determine an RT60 that will be acceptable within a wide variety of conflicting uses, and that can be achieved with an affordable level of suitable absorptive treatment.

2.0 First Case Study

HGC Engineering was retained to provide recommendations for the treatment of the gymnasium of Valleys Senior Public School in Mississauga, Ontario. The room had been initially designed and constructed with sprayed-on absorbent material on the upper walls and on the underside of the roof deck to control the reverberation. The material had been subsequently removed by the school administration, as large quantities of the material regularly fell down during classes from numerous impacts from balls. The acoustic environment in the gym was found to be unacceptable subsequent to the removal of the absorption, and was the alleged cause of much contention and several staff resignations over the years.

3.0 Acoustical Description of Target Gymnasia

Four other gymnasia in the same school boards were identified for studying in terms of representing a target acoustical environment to use in defining appropriate reverberation criteria.

The gymnasia were all deemed to have an acceptable acoustical environment by their respective school administration and staff.

The gymnasia were all geometrically identical (90' x 70' x 24'), and had been treated with a variety of acoustically absorptive materials.

The gymnasia were all constructed with tile floors, painted concrete block walls, and exposed steel deck roofing. They were treated with various acoustically materials including sprayed-on absorbent, steel roof deck with perforated flutes and acoustical fill (acoustic roof deck), and acoustical panels comprised of a wood fibre and epoxy mixture.

The acoustically absorbent surface treatment type(s) for each are summarised in the following table along with the surface area covered by each. The gymnasia are listed in the order of the most reverberant to the least.

School	Treatment	Area (ft^2)
R.H. Lagerquist	Sprayed-on absorbent on ceiling between joists	6300
	Light curtain covering the stage opening	290
Fairwind	Acoustical panels on side & back walls	1980
	Acoustical roof deck	6300
Fletcher's Creek	Acoustical panels on side & back walls	1980
	Light curtain covering the stage opening	290
	Acoustical roof deck	6300
Sir J. A. MacDonald	Acoustical panels on side walls, above stage on front wall & between joists on ceiling	9080
	Light curtain covering the stage opening	290

Table 1 - Surface Treatment Types

4.0 Reverberation Measurements

To establish appropriate criteria, RT60 measurements were performed at the four treated gymnasia.

The measurements were performed using the impulse method at each of the gymnasium, which involved the excitation of the room by slamming a large book against the ground or bursting balloons. A microphone was positioned approximately at ear height at five locations per room, and connected to a real-time analyser to capture the time and frequency characteristics of the decaying sound field, and to determine the RT60. The individual and mean average of all four measurements are reported in Table 2.

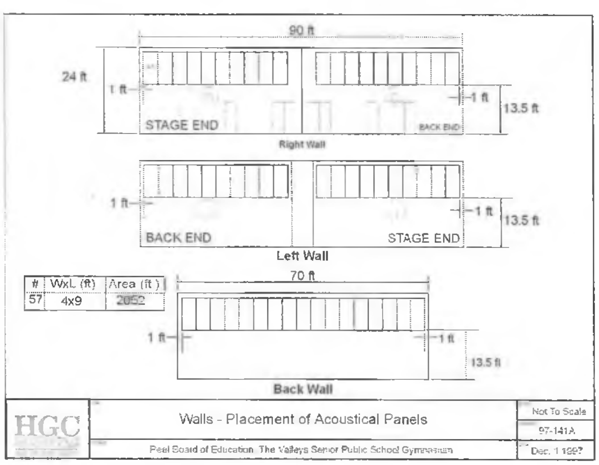
School	Octave Band Centre Frequency (Hz)					
	125	250	500	1000	2000	4000
Lagerquist	2.5	2.9	2.8	3.0	2.5	2.1
Fairwind	1.7	2.6	2.7	2.7	2.3	2.0
Fletcher	2.0	1.9	2.2	2.2	2.0	1.7
MacDonald	2.1	2.0	1.9	1.6	1.7	1.4
Mean	**2.1**	**2.4**	**2.4**	**2.4**	**2.1**	**1.8**
Untreated	3.5	3.2	4.2	4.9	4.5	3.4

Table 2: Reverberation Measurements – RT60 (s)

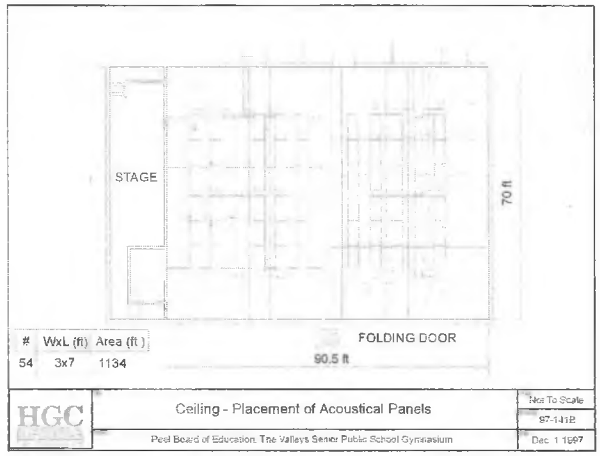
5.0 Discussion

It was evident both from the measurements and from subjective auditory evaluation that the gymnasium in question was excessively reverberant. The reverberation time in the 500 and 1000 Hz octave bands was in excess of 4s, and was a serious impediment to clear speech. The measurements of the other gymnasia further revealed that reducing the RT60 to approximately 2.4s would provide an environment that was likely to be acceptable to the staff.

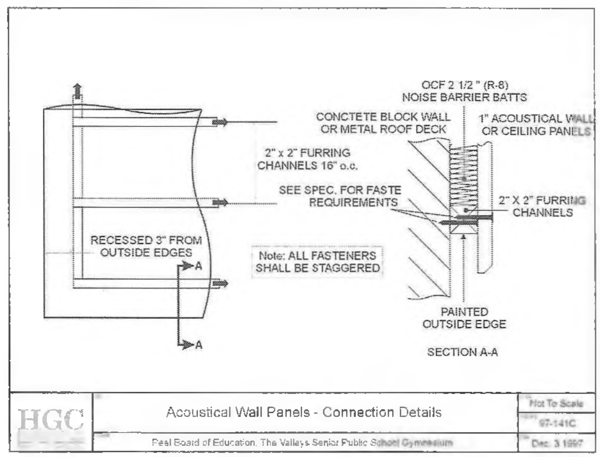
Figure 1. Acoustic Treatment of Gymnasium.



a) Wall Treatment Details



b) Ceiling Treatment Details



c) Wall Panel Details

It was decided that treating the interior surfaces of the gymnasium with absorptive materials to reduce the reverberation time was necessary. A wood fibre and resin product was chosen, primarily for its impact resistance. Calculations indicated that a 1000 Hz reverberation time of 2.4s could be achieved by the installation of 2500 sq. ft of the material. The panels were stood off from the wall on 2" x 2" wooden furring channels. Light density fibreglass insulation was

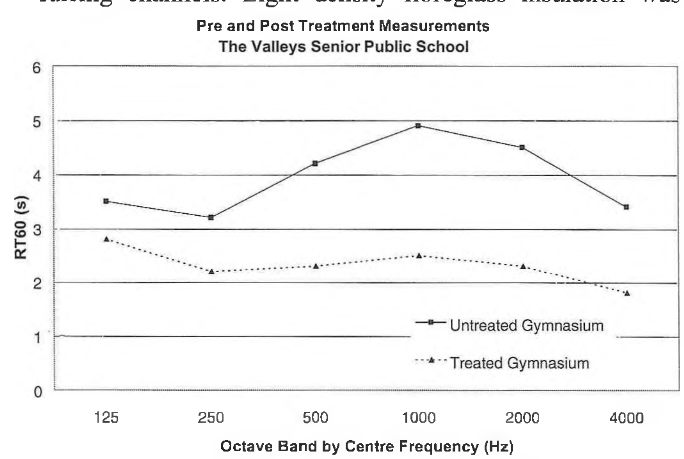


Figure 2. Results of Reverberation Time Measurements.

installed in the airspace behind the panels, to increase the low-frequency absorption as much as possible. The treatment details are shown in Figure 1.

6.0 Post-Treatment Measurements

Following the installation of the absorptive treatment, the staff noted a large improvement in the acoustic environment of the gymnasium. Speech intelligibility and overall comfort were substantially improved.

We revisited the site and conducted reverberation measurements for quality assurance purposes and to verify the calculation methods. The results are compared to the criteria in the Figure 2. The results indicate excellent correlation and verify the predictability of RT60 in this class of space.

7.0 A Second Case Study

The Central Memorial Recreation Centre in Hamilton contains an older gymnasium used for many years for community athletic events. The room was recently renovated with a hard vinyl tile floor, concrete block walls with several coats of paint and painted plaster ceiling.

These acoustically hard surfaces absorbed little sound energy. Measurements indicated that the reverberation time, after the renovation, had increased to over 8 seconds in the 1000 Hz frequency band.

The owner, in this case, decided to use acoustical panels constructed of 7.5 lb. pcf fibreglas covered with a microperforated vinyl material for durability, cleanability and light reflectance. Calculations based on the maunufacturer's published acoustical specifications indicated that a coverage area of 3500 ft. was required to reduce the reverberation time into an acceptable range.

The panels were fairly evenly distributed around the upper walls and ceiling. Post installation measurements indicated good results, again confirming the applicability and predictability of the RT60 with regard to this general class of space. The results of the measurements are presented in Figure 3.

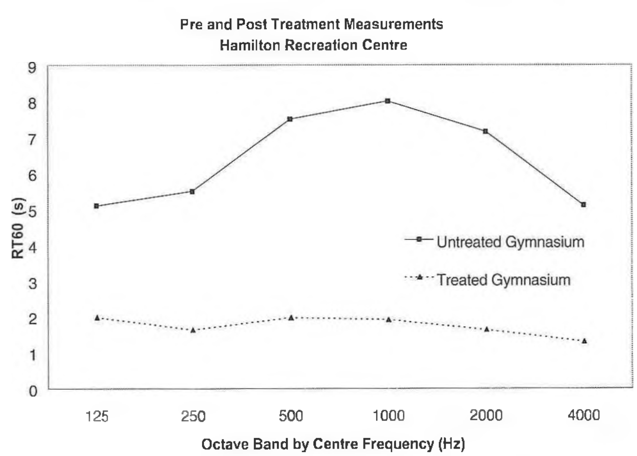


Figure 3. Results of Reverberation Time Measurements.

8.0 Alternate Acoustical Descriptors

The RT60 is a general descriptor of the acoustical conditions in a space. It describes the decay of the overall energy distribution, which is determined through integration. No consideration is given to the fine detail of the decay trace.

Any location in a gymnasium could either be a sound source or a point of reception, and gymnasia are often constructed without distinct architectural orientation. All the wall surfaces are similar and spatially homogeneous sound field with a linear time decay is often the result. A general descriptor in terms of overall energy decay (the RT60) is arguably the most appropriate.

This is not necessarily the case for spaces with a distinct physical orientation of source and receiver, such as classrooms, lecture rooms and theatres. The choice of room volume, the specific location of reflective surfaces with respect to the source and the judicious location of absorptive and diffusing elements are required to obtain the proper arrival of early and late energy. Early reflections (less than 30-50 ms) provide clarity, definition and intimacy while the later reflections can detract from intelligibility.

In these spaces more recently developed acoustical criteria such as the C50, which is based on the ratio of early to late arriving energy, find significant application and investigation. [3], [4], [5]

An investigative analysis of the C50 for the typical gymnasium space was performed using a commercially available ray-tracing software package. The results indicate negative values of C50. Less energy arrives at a typical receiver within 50 ms of the acoustical stimulus than after 50 ms. This can be understood geometrically since a surface must be located within close proximity of the source or receiver to contribute strong early reflections. At many locations in a gymnasium, the only such surface is the floor and perhaps one nearby wall, because of the large volume.

A typical decay trace from a gymnasium is shown in Figure 4. It indicates a logarithmically linear time decay with no particularly interesting detail. In this space, the 60 dB decay time calculated from early portions of the decay trace (T20, T30 and T40) are essentially equivalent and any could be used to gain the same information. In practical terms, it may be necessary to utilise the shorter time window descriptor to

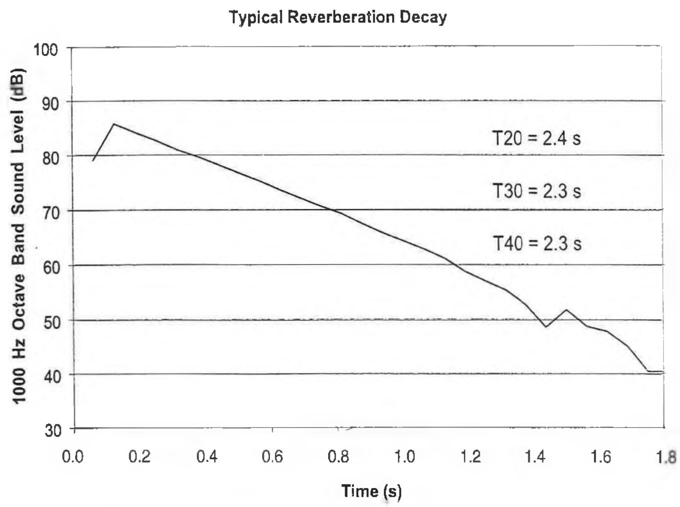


Figure 4. Decay Trace at 1000 Hz band.

obtain meaningful results with higher levels of background sound. It may not always be practical to generate a sufficiently robust sound stimulus to measure a full 60 decibels of decay.

9.0 Conclusions

These case studies illustrate that reverberation times in the general range of 2 – 2.8 seconds were judged to be acceptable by teaching and administrative staff for a broad range of activities including athletic events and student gatherings. Simple measurements and calculations of RT60 in Octave bands proved to be sufficiently accurate to specify a number of optional remedial acoustical treatments to meet this criterion. Such analysis is well within the capabilities of many architects and consultants and suitable acoustical absorption data is available from reputable suppliers.

We conclude that there is no technical reason that poorly performing spaces should be built or created through renovation. The fact that poorly performing spaces continue to be created suggests that acoustics is not given sufficient consideration in the project design criteria.

In order to obtain an acceptable acoustical space, it may be useful to include a section in the National Building Code addressing gymnasia and other similar places of public assembly. Simple reverberation time criteria should be adequate for such multifunction spaces.

10.0 References

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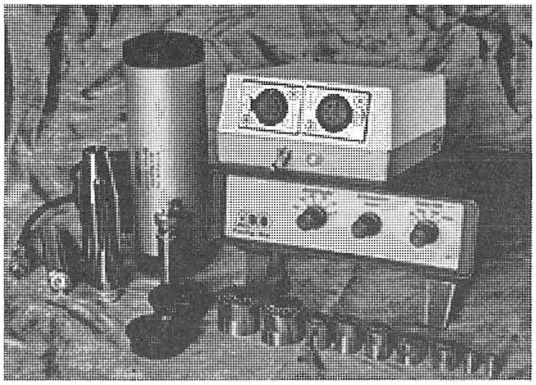

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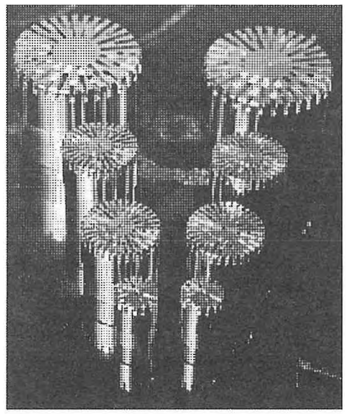

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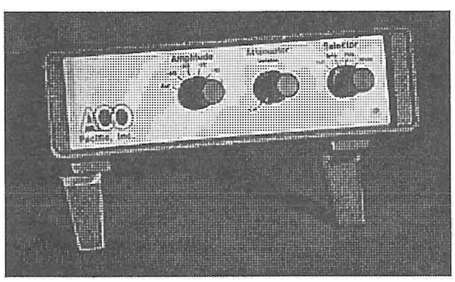

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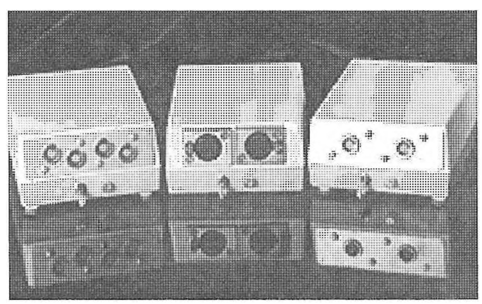

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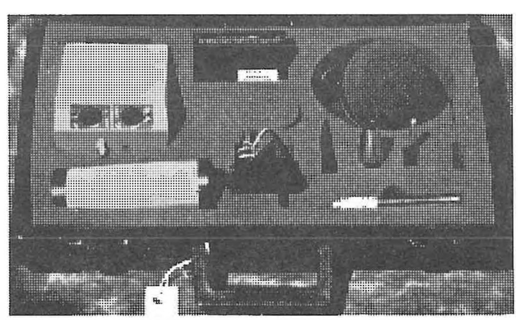

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