

ACOUSTIC DESIGN OF THE ESPLANADE ARTS AND HERITAGE CENTRE, MEDICINE HAT

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1. INTRODUCTION

The \$32M Esplanade Arts and Heritage Centre consists of a museum, a 150 seat studio theatre and the 700 seat main auditorium. This paper will focus on the latter. The 700 seat, single balcony theatre is located in the north-east corner of the building and is surrounded on three sides by a 50 mm acoustic joint. To simplify construction, a corridor between the north façade of the building and the audience chamber was left unisolated. Carpet on the corridor floor controls noise from footfall. The room is designed for music and theatre, both community based and professional.

2. NOISE CONTROL

The Esplanade, like many new performing arts centres, uses a displacement system to ventilate the room. The floors of the orchestra and balcony levels are perforated with a series of 150 mm diameter holes. A room below the orchestra level and the ceiling space underneath the balcony act as their respective plenum. Air is inserted into these plenum, where it mixes and slowly moves upward to ventilate the audience chamber. These systems have become quite popular of late but there is little, if any, information in the literature to guide design. Industry standard calculations such as ASHRAE¹ do have calculation procedures for plenum but not of the kind considered here. So, how does one calculate the noise attenuation of a typical displacement system plenum?

Analysis of plenum noise control presents a dilemma. Each hole in the floor is an aperture into the plenum and can thus be considered a noise source. Good sight lines, of course, make for good sound paths. With that in mind, should we concern ourselves with all these noise sources or just the few that can be "seen" by a listener sitting in his or her seat? And, if one takes this "line of sight" approach, how many noise sources are there? A listener seated in the orchestra level, for example, can see only four or five noise sources. On the other hand, in a room like the Esplanade, a listener located on the catwalk can see hundreds of noise sources. An appropriate analysis, of course, must consider both listener scenarios.

Recognising that the listener on the orchestra level is always close to the noise sources while the listener on the catwalk is always far away, a concept of Near and Reverberant Fields was developed, similar to but not quite the same as the Direct and Reverberant field solution of traditional room

acoustics theory. For the near field, the calculation model is of a partially blocked pipe. For the reverberant field the procedure is similar to a noise intrusion calculation from one room to another, where the Transmission Loss (TL) of the common partition is calculated as an area ratio combining the concrete floor and the partially blocked pipe.

Measurements have now been performed on three displacement systems: Mississauga Living Arts Centre, The Esplanade, Medicine Hat and the Four Seasons Centre for Performing Art in Toronto. The measurements to date consistently suggest the Reverberant Field is louder than the Near Field. Typical results are shown in Figure 1. At most frequencies, the Noise Reduction for the Reverberant Field is lower than the Near Field. This means that the Reverberant Field will be louder inside the auditorium. The only exceptions occur at what one might suspect to be the pipe resonance frequencies. This exception however, is limited in effect and it is a safe 1st order approximation to assume that the prediction algorithm can be limited to the Reverberant Field. This is fortunate because of the two, the Reverberant Field is easier to calculate.

Results from a recent project, the Four Seasons Centre for the Performing Arts, are shown in Figure 2. There is good agreement at most frequencies, the only exceptions being at low frequencies. It is suspected that the discrepancies may be related to pipe resonances.

3. SCALE AND COMPUTER MODELLING

Like most new auditorium designs, the original intention for The Esplanade was to predict the room's acoustical behaviour using 3-D computer models. However, the architect's desire for a low, "acoustically transparent" ceiling above the audience presented a challenge beyond the capabilities of modern computer modelling algorithms. A 1:20 scale model was built and tested. All of the 20 scale model measurements were augmented with the post-processing algorithm developed by Grillon². This routine, executed in MatLab, extends both the frequency and dynamic ranges of acquired signals. Unlike previous scale model conditioning routines³, the Grillon algorithm maintains the reactive component of the signal and, in so doing, permits auralization. The ability to "listen" to how the ceiling affected sound incident at small grazing angles proved critical.

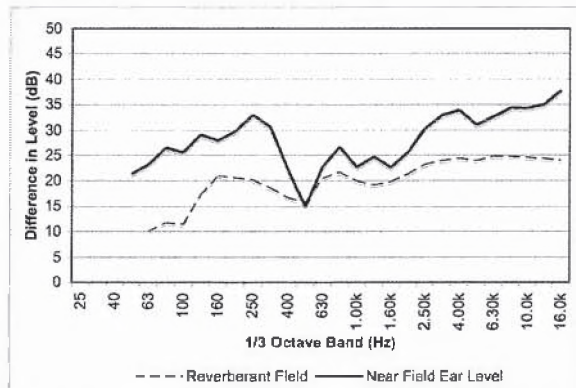


Figure 1. A comparison of Near and Reverberant Field Noise Reduction at The Esplanade.

Building and testing the scale model proved fortuitous because it turns out that the computer model had trouble dealing with the fly-tower. Through a number of trials and experiments, it consistently overestimated the effect of soft goods stored in the fly-tower above the (partially open) orchestra shell ceiling. Modern computer algorithms are known to have problems with coupled spaces like a fly-tower, an issue that was addressed by Summers et al.⁴ Even when the late energy correction developed in [4] was applied, the computer model predicted Early Decay Time (EDT) in the range of 1.5 s, far short of the goal for the symphonic programme anticipated at The Esplanade. The scale model predicted EDTs in the range of 2.2 s.

It is suspected that the problem is not with the software (an otherwise reliable commercial product) but with a fundamental anomaly in computer modelling algorithms. Computer model algorithms assume that sound behaves like light and that the path of the reflections can be quantified with rays and lines. The boundaries of the room and objects

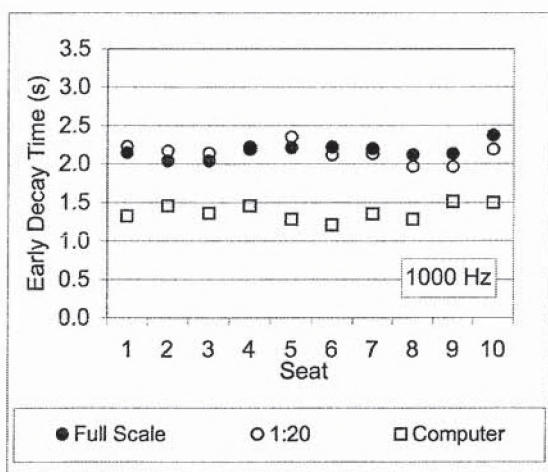


Figure 3. Predicted and measured Early Decay Times. Seats 1 to 6 are on the orchestra level, 7 to 10 in the balcony.

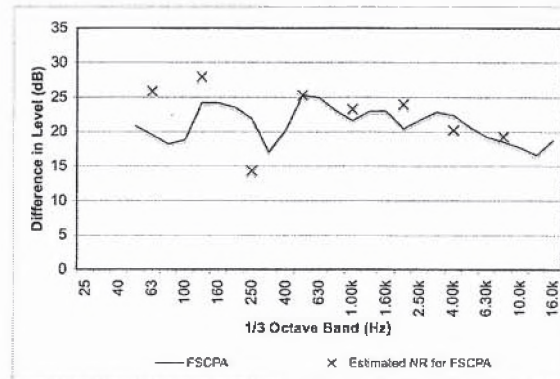


Figure 2. Calculated (X) and measured (—) Reverberant Field Noise Reduction at the Four Seasons Centre for the Performing Arts.

within the room are described mathematically as bounded (i.e. finite) planes. Thus, for a reflector, such as those making up the stage canopy at The Esplanade, the test of whether the sound goes past it or is reflected off it, is based on the intersection of a line and a plane. If the line intersects the plane within its defined boundaries the sound will reflect. If the line intersects outside the boundaries it will go past the reflector, in this case up into the acoustically absorbent flytower. The problem is that lines are infinitely thin. Acoustic waves, of course, are of finite dimension. Thus the computer model algorithm may be exaggerating the amount of sound that flows through the openings in the canopy. A comparison of the two prediction methods with the final full scale measured results is shown in Figure 3. The scale model predictions are surprisingly accurate.

The Esplanade opened in October 2005 and has quickly established a reputation as one of the best sounding rooms in Western Canada.

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