Acoustic Design of the Esplanade Arts and Heritage Centre

A theatre in Medicine Hat, Alberta has achieved the highest levels of sound quality thanks to sophisticated anaylis and wise judgement by Aercoustics Engineering.

The $32-million Esplanade Arts and Heritage Centre in Medicine Hat, Alberta opened in October 2005. It consists of a museum, a 150-seat studio theatre and the 700-seat main auditorium.

Aercoustics Engineering of Toronto was responsible for the acoustic design of the auditoria. They introduced two significant innovations in acoustical analysis. First, they developed signal conditioning software to analyze sound in small-scale models. Second, they developed ways to analyze noise from the auditorium's displacement ventilation system.

Analysis for a small-scale building model

The design of the Esplanade saw the first application of the Renaissance acoustic modeling software. Developed by Aercoustics over two and a half years, Renaissance is a series of signal conditioning algorithms for small scale acoustic modeling.

Small scale acoustic models – in this case 1:20 – are easier to build than the traditional 1:8 or 1:10 scale models. The acoustic analysis of small scale models, however, is fraught with difficulties. Smaller scale models, for example, require measurements at higher ultrasonic frequencies where the dissipative effects of water molecules must be compensated for.

The commercially available software that would account for small scale modeling difficulties only provided compensation in the energy domain i.e. squared sound pressure. As a consequence, the acoustic analysis was limited to the study of numbers and graphs.

Acoustical engineers also need to *hear* things. For this, a linear representation of the sound pressure is required. This means that the reactive (imaginary) component of the signal must be recovered.

While numbers and graphs can be accurately studied in a signal-to-noise ratio environment of 25 to 30 decibels, our hearing has a dynamic range of more than 90 decibels. Signal conditioning is required to artificially, yet accurately, extend the dynamic range of the sound decay.

The Renaissance package deals with all the above difficulaties. It was based on Vincent Grillon's Ph.D. thesis, "Auralisation dans les Maquettes: Traitement des Response Impulsionelle." The software now consists of a collection of 41 Matlab routines and more than 5,600 lines of computer code.

A low "acoustically transparent" ceiling

The architect desired a low, "acoustically transparent" ceiling, i.e. one that the sound could penetrate, but which presented a visual barrier so the audience could not see the catwalks and rigging. This requirement presented a challenge beyond the capabilities of modern computer modeling algorithms.

Consequently, a physical scale model using an assembly of wooden dowels as the ceiling was built and tested. The ability to "listen" to how the ceiling affected sound incident at small grazing angles proved critical in refining the architectural design.

The scale model studies also brought unexpected results. To achieve the proper reverberance – according to the computer model – the height of the building would have to be raised by 4 metres or more. But the scale model suggested otherwise, even though it wasn't fully calibrated for this type of measurement. Simple spreadsheet calucations and Aercoustics' engineering experience also disagreed with the computer model.

It was decided to leave the building height as it was. Though this was a nerve-wracking decision, when the building was commissioned and the engineers performed acoustical measurements, the results matched the scale model almost exactly.

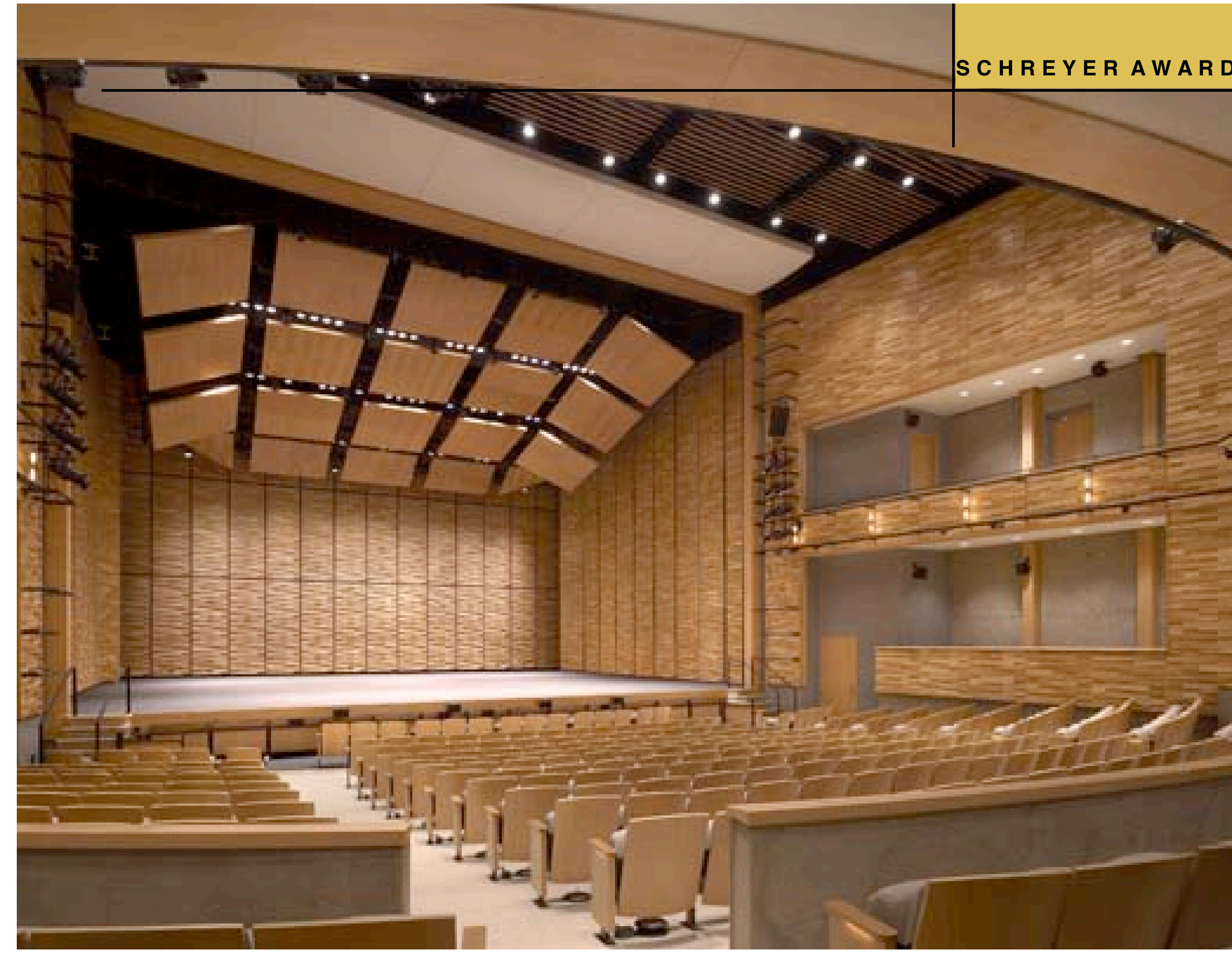
Analyzing sound from displacement ventilation

The cornerstone of good acoustics is a quiet background noise level. Musicians and actors need a quiet room in the same way that a painter needs a clean white canvas. Most of the noise generated inside this or any kind of building comes from the ventilation system.

The Esplanade, like many new performing arts centres, uses a displacement system to ventilate the room. These systems have become popular, but to date there was no recognized method of predicting or measuring their acoustical performance. Analyzing plenum noise control presents a dilemma. Line of sight is important in noise control: the more visible a source is, the louder it will be heard. But the acoustical analysis is complex: a listener in the orchestra level can see only four or five noise sources. A listener on a catwalk, however, can see several hundred noise sources. An appropriate analysis, of course, must consider both listener scenarios. But how?

The beauty of the solution is in its simplicity. The listener on the orchestra level is close to the noise sources while the listener on the catwalk is far way. Thus, the analysis can be conveniently broken down into near and far field solutions. Prediction and measurement procedures were developed accordingly. Though the procedures were used for analysis only at the Esplanade Centre, they directly influenced the noise control design for the Four Seasons Centre for Performing Arts in Toronto, designed to the threshold of hearing N1 Criterion.

As for the Esplanade Centre, it has won accolades. Carol Beatty, manager of cultural development at the centre, says: "Performers from across the country have raved about the acoustics, and in fact believe we have one of the best acoustic performance spaces in western Canada."



Above: view towards the stage with its carefully calibrated "acoustically transparent" canopy. Photo ©Tim Griffith

Name of project: *Acoustic design of the Esplanade Arts & Heritage Centre*
Award-winning firm: *Aercoustics Engineering, Toronto (John O'Keefe, P.Eng., Kiyoshi Kuroiwa)*
Role of award-winner: *acoustical engineer*
Owner: *City of Medicine Hat*
Client/architect: *Diamond Schmitt Architects Inc.*
Associate architect: *Cohos Evamy*
Other key players: *Engineering Harmonics (sound system), Fisher Dachs (theatre consultant), Crossey Engineering (mechanical & electrical), Halcrow Yolles (structural/building envelope), Ellis Don (contractor), LMDG (building code)*