Canadian Consulting Engineering Awards 2016

Category A. Buildings

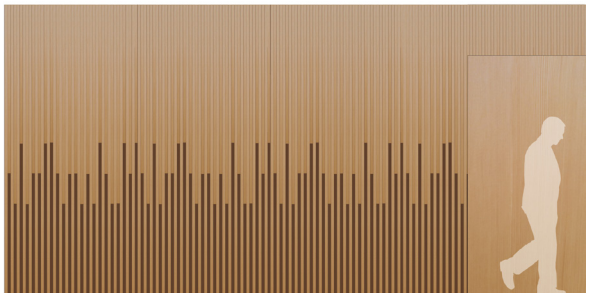
Aga Khan Museum and Ismaili Centre

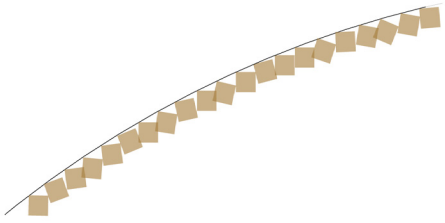
aercoustics

Aercoustics Engineering Ltd.

Acoustics, Noise, and Vibration Consultant

The Ismaili Centre does not allow for the distribution of interior photos of the Prayer Hall. In this submission, we hope to describe the unique elements of the space, made successful by acoustic design, without the support of images.





Above left: The geometric relief within the Prayer Hall was designed with Aercoustics staff to subtly redistribute energy, absorbing sound and preventing acoustic focusing, while maintaining the elegant design of the space.
Above right: The Prayer Hall relief, demonstrating the geometry required to disperse sound.

Project Summary

The Aga Khan Museum and Ismaili Centre includes a peace garden and a Recital Hall that has to serve the music of both the Occident and the Orient all located beside one of the noisiest highways in the country. To control noise, we used sophisticated 3-D environmental noise modelling calibrated to actual site measurements. We fine-tuned the room acoustics, required for the musical program, by raising the ceiling from the original plan.

Innovation

Programming at the Aga Khan Museum Auditorium showcases Sufi musical performances. The delicate instruments of Sufi tradition are designed to be enjoyed in small, intimate spaces such as the Ali Qapu palace's music room in Isfahan, Iran. However, the auditorium must also serve the purpose of a lecture theatre and double as a film screening venue. Typically, the uses of this 350-seat auditorium have acoustic requirements requiring vastly different design strategies.

To achieve ideal natural acoustics in the space with the specific type of music in mind, the volume of the space had to be significantly increased to achieve higher reverberance, and the shape of the room was designed to achieve excellent musical clarity. While extending higher than the rest of the structure, the origami dome roof was successfully made seamless with the exterior. To serve its alternate purposes, retractable acoustic curtains help provide better speech intelligibility without altering the visual aesthetic dramatically.

Originally the architect wanted to make the Auditorium symmetrical from all angles. Acoustically, that would have been problematic because it approximates a circle, and would then cause acoustic focusing. This acoustic phenomenon creates a high concentration of energy at a specific location, or acoustical 'hot-spots' in different parts of the room.

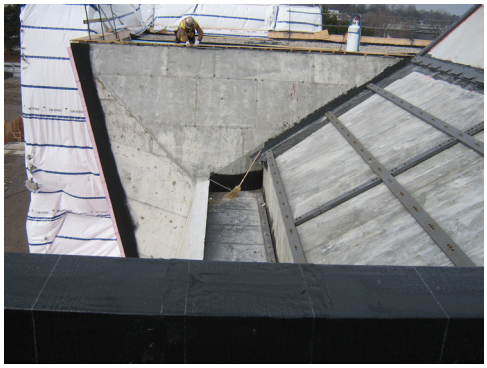
Based on our recommendation, the shape of the hall was changed slightly to be an asymmetric hexagon (in plan) for the hall but to keep the symmetrical hexagon at the ceiling level for architectural significance and acoustic function.

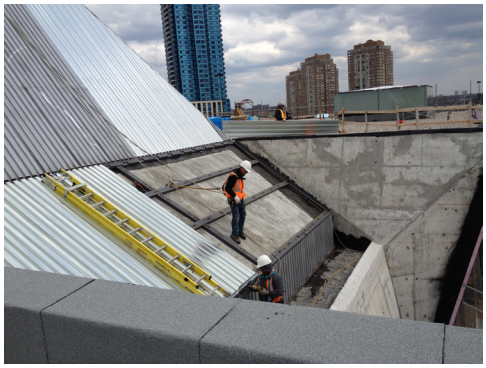
The background noise level of the space has also been designed to be Preferred Noise Criterion (PNC) 15. Noise controls included a quiet, under-floor, HVAC displacement system, discreetly controlled from grilles hidden beneath each individual seat.

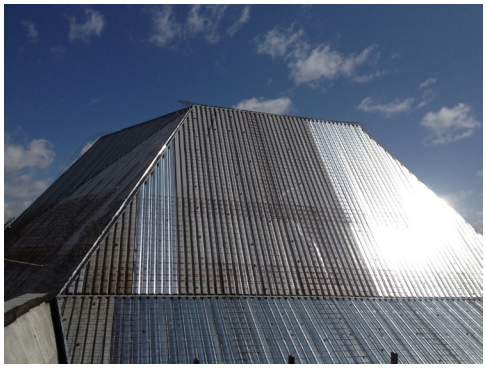
The Prayer Hall is the heart of the Ismaili Centre. Its elegant glass dome rises in the skyline, acting as a beacon when lit from within. That said, it is difficult to provide adequate acoustic absorption in a room that is mostly glass.

Diffusion/absorption panels were carefully designed to an exact geometry and size, consisting of vertical wooden slats of varying depth matching the Islamic patterns used throughout the building. These panels were optimized to break-up and absorb the sound waves to distribute the energy and prevent reflection buildup from the surfaces. The panels are lined with Canadian maple repeating the word Allah in Kufic calligraphy.

The Aga Khan and Ismaili Centre campus sits next to a six-lane highway, with average traffic volume of over 163,000 vehicles a day, making it one of the busiest highways in Canada.







Aga Khan Museum roof construction: In order to support and build the double roofs while maintaining isolation, concrete was poured in sections, with neoprene isolators set between frames and formwork.

Most of the noise generated inside this building comes from the ventilation system. The underfloor displacement tunnel below the Prayer Hall acts as the plenum. Air is inserted into the plenum where it mixes and slowly moves upward to ventilate the hall. The ventilation reaches the room through permeable carpeting.

Prior to our work on the system employed in the Auditorium and Prayer Hall, there was no recognized method of predicting or measuring the acoustical performance of a displacement system plenum. Our methods, published in the June 2006 Proceedings of the Institute of Acoustics, are the first known publication on this topic.

Complexity

The Aga Khan Museum and Ismaili Centre campus represents a significant shift for siting cultural landmarks within the Greater Toronto Area. It is located outside of the downtown core, close to one of the noisiest highways in Canada.

The cornerstone of good acoustics is a quiet background noise level. Without significant acoustic design intervention, the road traffic noise from the adjacent Don Valley Parkway would have disrupted the meditative quality of the project.

The Aga Khan Museum houses a world-class auditorium. The room had to be carefully designed to meet the background noise level goal of Preferred Noise Criterion (PNC) 15. This level produces ideal listening conditions, suitable for performance spaces. PNC-15 was confirmed during commissioning measurements conducted in October 2015. This was achieved without an acoustic joint surrounding the room.

A floating, slanted, isolated roof was employed to block out the steady hum of traffic noise. Two levels of roof were constructed, isolated from the structure and each other. This isolated design directed the construction schedule and required close coordination between the architect, contractor, and structural engineer and our acoustic engineering team.

Our noise control solution for the Prayer Hall began with the design of the intricate, glass dome. A single, outer layer of glass would not, on its own, provide adequate isolation. Traffic noise intrusion would have been in the range of PNC-35 and 10% of the time it would have been even louder. Far exceeding the PNC-25 requirement. The noise modelling conducted was calibrated to actual site measurements conducted in 2009.

Our solution: double-glazing outside and triple-glazing inside. The space between glazing acts as insulation for the hall. A combined ambient noise level of PNC-25 was achieved, including the HVAC system. This roof construction was so complex it required a full test build in Germany.

Above left: Aga Khan Museum Auditorium in construction. Above right: The Auditorium ceiling, kept as a symmetrical hexagon to serve the architectural vision and acoustic function.

Aga Khan Museum Auditorium: The HVAC displacement system, controlled from grilles hidden beneath each individual seat, is barely visible.

Social and Economic Benefits

Cultivating the space for prayer and peace in a city like Toronto is difficult. Doing this next to 6-lane highway, while housed in glass, was almost impossible. The environmental hurdles of this site were monumental. Using sophisticated 3D noise modelling and innovative isolation techniques, our team helped bend the environment to the needs of the client. The 'needs' for the Prayer Hall were informed by measurements conducted by Aercoustics at Union Hall and Vancouver Jamatkhanas (a Persian term used by some Muslims meaning 'place of gathering'). So, as cars and trucks thunder by – serenity within the museum brings calm and peace to its visitors. Calm and peace which would not have been possible without effective and innovative acoustic design.

> **Matthew Hague, Azure Magazine**
> Regardless of one's faith, the dome is a stirring sight, with its glorious, uninterrupted blaze of light.
>
> The Spectacular Aga Khan Museum and Ismaili Centre, June 5, 2015,
> http://www.azuremagazine.com/article/aga-khan-museum-ismaili-centre-toronto/

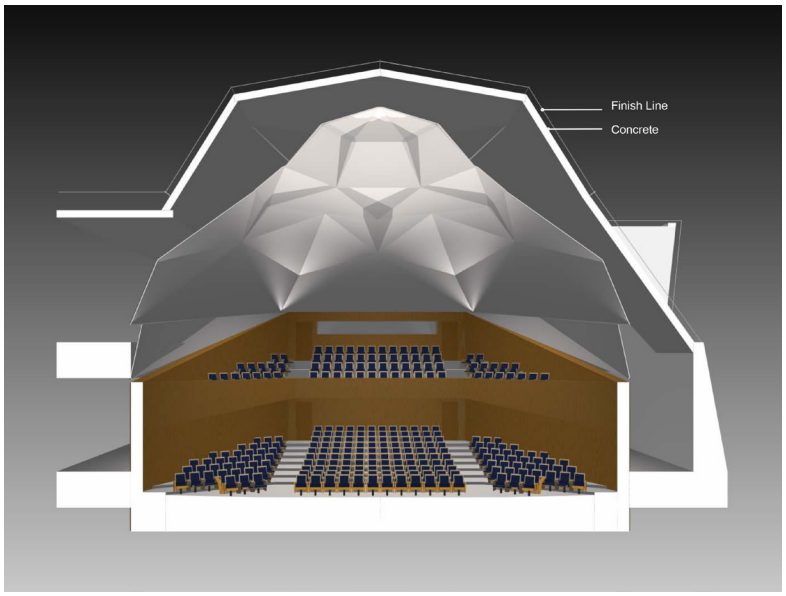
Musicians learn and perform better in a room with good acoustics. Good musician are attracted to and flourish in rooms that enhance their performance. Good musicians attract other good musicians and generate intelligent, critical audiences. Within a generation a vibrant artistic community is created. This story is repeated over and over again throughout the world. Invariably the catalyst is the building. The Aga Khan Museum Auditorium is an excellent venue for a variety of performances, and is a gem within the cultural landscape of Toronto.

Environmental Benefits

Acoustic Performance was recently added to the LEED Building Design and Construction rating system, under Indoor Environmental Quality. This acknowledges the role of acoustic in the overall comfort of a building, and wellness of its occupants.

Studies have shown that an under-floor, HVAC displacement system, used in the Prayer Hall and Auditorium, has often provided significant energy saving, when compared with mixing ventilation, and reduced life cycle costs. It is often used in the core region of a building, where no heating is needed. In addition, the sealed, double-paned, glass dome of the Prayer Hall improved thermal performance.

The Aercoustics' team considered the environmental noise impact of the site on the surrounding area in our initial assessment of the site. It was determined that the Aga Khan Museum and Ismaili Centre would have no noise impact on the surrounding community.



Computer model of the Aga Khan Museum Auditorium, demonstrating the volume of the space.

Aercoustics staff on site at the Auditorium conducting WinMLS measurements. The single omnidirectional dodecahedron (12 sided) loudspeaker is visible on stage.

Meeting Client's Needs

The auditorium's primary purpose is to showcase traditional Sufi art and musical instruments. Sufi instruments are very delicate and traditionally performed in small, intimate spaces. In contemporary performance spaces Sufi instruments are typically amplified, making for a very different and arguably less authentic experience. In order for the unamplified instruments to succeed in an auditorium, a large vertical volume was needed. This volume would allow the sound to blossom and flourish in the open space. Because of our design recommendations, the auditorium was heightened to create this volume, resulting in the current 'bumped' profile of the building.

In October 2015, we performed room acoustic measurements at the Aga Khan Museum Auditorium, using a Maximum Length Sequence analysis computer program, WinMLS. A single omnidirectional dodecahedron (12 sided) loudspeaker was used as the source, located on the stage. Receiver locations were measured throughout the audience area.

The mid frequency averaged values are outlined in the table below.

Measured Room Acoustic Parameter	Mid-Frequency Measured Values
Early Decay Time (EDT)	1.7 sec.
Reverberation Time (RT)	1.7 sec.
Musical Clarity (C80)	0.4 dB
Distinctness (D50)	39%
Acoustic Strength (G)	6.6 dB
Lateral Fraction	34%
Ambient Noise Level	NC-15

The Early Decay Time matches the Reverberation Time, which indicates that the decay of the room is constant. The Musical Clarity indicates that the musical lines will be clear, while allowing for some blending of unamplified ensembles. The Acoustic Strength indicates that the room is loud enough to perform well for unamplified, quiet instruments. Sufficient lateral energy is heard in the audience to create an enveloping experience for the listener. The ambient noise level is low enough to allow the performers to create a performance with a large dynamic range of loudness.

The design goal of an acoustically superior venue has been achieved, for the diverse program, including quiet unamplified performances as well as amplified events.