Tokyo Opera City Concert Hall: Takemitsu Memorial

The hall debuted on September 10, 1997, with a performance of J. S. Bach's Saint Mathew's Passion performed by the Saito Kinen Festival Orchestra under the direction of Seiji Ozawa. Acoustically, the hall is designed in the so-called shoebox style with a vaulting pyramidal with the interior completely mantled in oak. The most innovative advances of modern technology have been brought into play to create ideal acoustic conditions and the wooden interior with upper lightning furthermore stimulates a sense of tranquil composure.

The late Toru Takemitsu (1930-1996), an artistic director of the Tokyo Opera City Cultural Foundation had acted as adviser in the formulation of the basic concept of the hall and also supervised the opening series of concerts. The hall is dedicated to his memory due to his untimely death prior to its inauguration.

Acoustic of the Tokyo Opera City Concert Hall

This relatively new (1997) small concert hall in Tokyo owes a great deal of its success to Leo Branek, probably the most famous living acoustical consultant in the world. With the advantage of vast experience, computers, intelligence and boldness, Beranek designed a visually and acoustically spectacular space. We highlight it here because of the way it mimics a much larger space, without the use of artificial electronic speakers and time delays, etc. How does it work?

The secret is mainly in the ceiling and also the walls: solid oak and intricate, carefully angled grooves that diffract and reflect sound, sending it on a journey of many bounces between surfaces high above the audience (without the power loss from so many bounces being too great, since the surfaces are so hard and non-absorptive). The sound comes raining back on the audience later than one would expect from a modest hall, giving the impression of surfaces much farther away, and room size therefore much louder.

On the lower side and rear walls, much finer and irregular grooving scatters and diffuses high frequencies, reducing "acoustical glare" from smooth shiny surfaces.
Can the sense of acoustic intimacy created by a fine concert hall be measured in how many milliseconds it takes sound waves to ricochet from the walls and balconies and reach a listener in the seats? Can a hall's aural warmth be calculated from how efficiently bass notes rebound from the same surfaces? Can the prized quality called resonance be estimated from the rate at which the entire hall fades to silence after a blast of electronic sound?

More to the point, can an architect rely on studies of these quantities, using computer calculations and measurements in scale models, to ensure that a structurally innovative, visually inspiring design for a new concert hall will be an acoustical triumph rather than a disaster?

For years, the answer to all these questions seemed to be no -- the field of concert hall acoustics has had only spotty success. But now an unusually intense collaboration between architects and acousticians has put the science of acoustics to the test, with two major new successes in Tokyo.

The halls in question are the 1,632-seat concert hall of the multipurpose complex called Tokyo Opera City, and the 1,810-seat opera house of the adjacent New National Theater. Both have architecturally daring designs, yet both have been praised by musicians who have performed in them.

"This hall simply has some of the best acoustics in which I have ever had the privilege to play," the cellist Yo-Yo Ma wrote in a commentary on the concert hall that appeared recently in a technical journal. He said its visual and acoustic aspects combined in a rare synthesis -- "a miracle," he called it.
Miracle or no, this is no small feat. "Going to the Moon is much simpler as a physics problem," said William J. Cavanaugh, an acoustician at Cavanaugh Tocci Associates who consults on both the construction and restoration of concert halls. In a Moon shot, he said, "you've got one source, you've got one trajectory that will get you there, and you've got one 'listener,' or destination."

But in a concert hall, the trajectories of the sound waves begin at any number of places on the stage, bounce in complicated ways from every cornice and pillar, and reach their ultimate destinations in hundreds of occupied seats.

The research for the new halls, whose principal architect was Takahiko Yanagisawa, president of TAK Architects in Tokyo, may be the most extensive use yet of acoustical measurements and calculations in efforts to design concert halls that are not simply copies of great halls of the past. 

"If you make a copy of the old, great halls, you'll have a great hall," said Dr. Leo L. Beranek, an architectural acoustician in Cambridge, Mass., who was the principal acoustical consultant for the projects in Tokyo. But the Tokyo concert halls, he said, "are different in appearance and they have the sound of great halls."

The research is described in three papers, published earlier this year in The Journal of the Acoustical Society of America, by Dr. Beranek and Dr. Takayuki Hidaka, chief researcher of the Takenaka R & D Institute, which conducted acoustical measurements and built models. The papers describe how, as the designs took shape, scientists analyzed and worked to maintain acoustical variables like reverberation time, spaciousness and intimacy, each with a precise mathematical definition and musical meaning.

Without those studies, "you're gambling" on the acoustics, Dr. Beranek said. Like intimacy and reverberation time, the additional metrics have deceptively simple names like spaciousness, bass ratio, acoustical texture and clarity. But each has a precise mathematical meaning that seeks to isolate a specific aspect of acoustical quality in a hall. In the studies leading up to the design of the new Tokyo halls, said Dr. Hidaka of the Takenaka R & D Institute, measurements of those and other metrics were made in 20 opera houses and 25 symphony halls in 14 different countries. (While New York's Carnegie Hall is considered among the world's best, it was not included in the study because there was no opportunity to make acoustic measurements there, Dr. Beranek said.)
The idea, Dr. Hidaka said, was to get a quantitative measure of what made the good halls good and the bad ones bad. For the studies, his team generally produced a burst of sound from a 12-sided speaker on the stage -- actually a dodecahedron with a small speaker on each face. Each burst and its acoustic aftermath was recorded on tiny microphones placed in the ears of dummies, and in some
cases the ears of real people, scattered around the seats.

The team worked out the value of the various metrics for each hall by analyzing detailed forms of the sound waves picked up by the microphones. Intimacy, for example, was defined as the time delay between the direct arrival of the sound from the stage and that of the very first reflections, which have presumably bounced off protruding side balconies.

Bass ratio gauges how efficiently low notes, compared with middle notes, carom from the walls and other surfaces; a high bass ratio gives a hall what musicians call warmth. Spaciousness is an estimate of what fraction of all the sound bathing a listener has been reflected laterally, from interior surfaces, as opposed to having arrived straight from the stage.

Dr. Beranek, Dr. Hidaka and their collaborators then compared those measurements with an acoustic ranking of the halls based on a survey of conductors and music critics. They found that the most beloved concert halls had reverberation times near two seconds, intimacy times of not much more than 20 milliseconds and relatively high bass ratios and spaciousness factors. Other metrics also took on fairly consistent values in the best halls.

Because of the need for greater clarity in understanding voices, the optimum reverberation times for opera houses turned out to be shorter, around 1.5 seconds.

Then the acousticians turned to large computers that had been programmed to simulate the acoustics in the basic architectural designs of Mr. Yanagisawa.

The team eventually built a 10-to-1 scale model of the proposed designs and made just the same measurements, using tiny speakers, microphones, and one-inch "heads" of dummy audience members, all scaled down in proportion to the model. Even the wavelengths of the sound in the model measurements were scaled down.
This work led to numerous adjustments in the original designs, including changes in the height of the ceiling near the stage in the concert hall, giving some of the balcony fronts a rakish, forward slant and adding a special sound-diffusing material to the pyramidal ceiling.

The reflected wave patterns in the finished Tokyo Opera City concert hall, wrote the team in one of its papers, "appear to be closest to those for Boston Symphony Hall." Dr. Hidaka said acoustic data for the opera house resembled those of the famed Vienna Staatsoper.

For all the apparent success of the Tokyo projects, Mr. Yanagisawa emphasized that acoustical studies were far from the whole story. He believes that his general immersion in the music of the great halls of the world played as large a role in his understanding of good acoustics as the results of the technical work did.

"I believe an excellent hall can only be realized by a design that assimilates nuances beyond description by scientific data," Mr. Yanagisawa said. "The final work is a world of sense created therefrom."