

Acoustic design of reconstructed Banff Pavilion of Frank Lloyd Wright

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ABSTRACT: The late Frank Lloyd Wright designed and through an Alberta architect installed a pavilion in Banff, Alberta within the Parks Canada's land. The pavilion was built in the prairie style with a gathering space, washrooms and minimal food services. Built in 1916, it was used only in the summer. However, it was demolished in 1933 due to damage from two major floods. A group of Wright aficionados is very keen to get the pavilion rebuilt with the aim of preserving the original design. The group retained seven Ryerson University academics to study the feasibility of recreating the pavilion with the stipulation that the space can be used all through the year. One of the envisaged uses of the space is a small concert hall in the main meeting space. The original and reconstructed pavilion space uses materials such as glass, stones and concrete. The envelope materials are highly reflective. The acoustical response of the space was simulated in ODEON for different scenarios. One short jazz piece, Autumn Leaves, was used to generate wave files by conducting auralization through ODEON. Based on the responses movable acoustic panels were designed to produce acceptable concert hall from an acoustic perspective. The results of the acoustic simulations will be presented in this paper.

KEYWORDS: Wright Pavilion, Banff, Acoustic simulation, auralization, absorptive panels

INTRODUCTION

Frank Lloyd Wright, as per reliable sources, designed only two buildings in Canada. One of them, in Banff, Alberta, was built in 1916 and was used as a summer pavilion with typical Prairie design of Wright. However, after a number of floods, two major ones in 1920 and 1933, the pavilion was demolished in 1933. An archival image of the front view of the, now defunct, pavilion is shown in Figure 1 below.

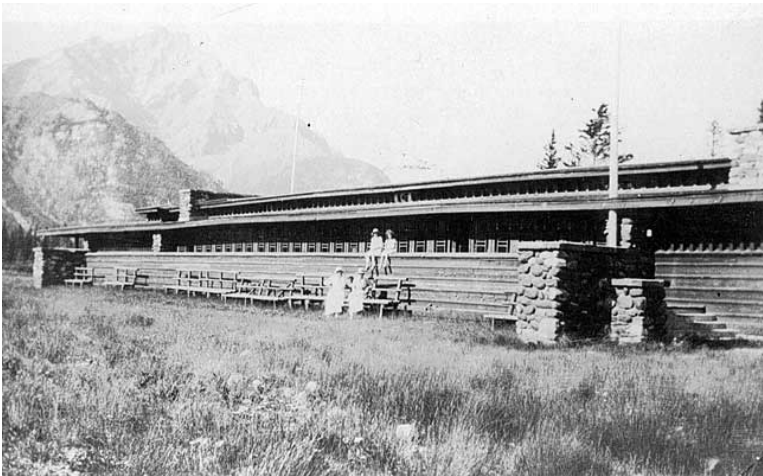


Figure 1. Front View of Banff Pavilion. Source: (www.archivesalberta.org)

Recently, there was a concerted effort to rebuild the pavilion and a group of academics from the Department of Architectural Science was tasked with the feasibility of heritage reconstruction of the pavilion. One of the main objective of the study was to investigate the

possibility of accessing the new pavilion for the entire year with various usages envisaged for the pavilion. One of the main aspect of Wright's designs is its adherence to impact of the surrounding environment and the natural forces. The proposed pavilion would investigate the possibility of having a concert hall within the central portion of the building. The proposed concert space was modelled in acoustic simulation software, ODEON, and the acoustic performance of the central hall was determined for different scenarios [ODEON]. Design details and the performance results are discussed in this paper.

1.0. BACKGROUND

An axonometric view of the pavilion reconstruction is shown in Figure 2. The foot print of the original pavilion is kept the same. However, current building code requirements of the Province of Alberta will be applied to the proposed development. Even the orientation of the pavilion will be kept identical to the original layout to take advantage of the daylighting potential. Only the location will be slightly modified to fit within the current use of the park site. Since the park will be used all through the year, heating and cooling system will be provided and insulation to reduce the heat loss will be added to the envelope of the building. All of the necessary modifications will, strictly, follow the heritage preservation regulations of the Frank Lloyd Wright designs.

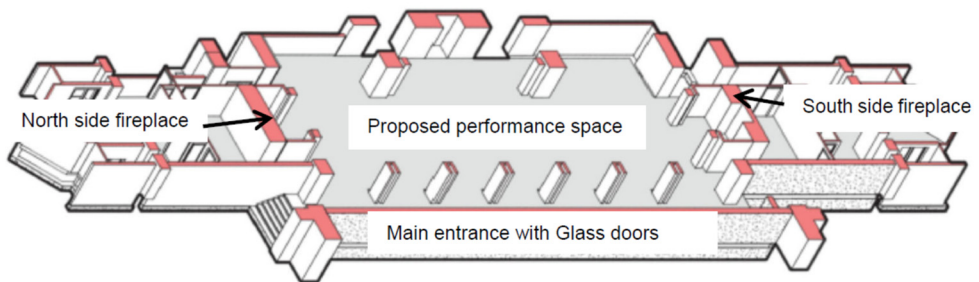


Figure 2. Axonometric View of the Proposed Banff Pavilion. Source: (Yew-Thong Leong, Ryerson University)

The main focus of the current exercise is the evaluation of the acoustic performance and acoustic design of the performance space envisaged for the central area, shown in Figure 2 above. One is immediately faced with many questions such as the impact of the performance space on the original design as well as the acoustical aspects of the performance spaces designed by Wright. It must be pointed out that Wright's performance space designs such as the multi-purpose auditorium, Grady Gammage Memorial Auditorium in Tempe, Arizona and Kalita Humphreys Theater in Dallas, Texas applied conventional acoustical techniques prevalent in the 1950s. Finally, to be financially viable, the City of Banff, Alberta would like the pavilion to be used for different purposes such as concerts and banquets etc. And hence, the current acoustical design is a part of the exercise. To alleviate any concerns that the original Wright's design may be sullied, the performance space is a temporary installation. The interior look of the pavilion will retain its original look on days without any concerts or plays. The results of the acoustic evaluation are presented in the next section.

3.0. ACOUSTICAL PERFORMANCE OF PERFORMANCE SPACE

A general layout of the performance space is shown in Figure 3. The location of the stage and audience area are also highlighted in Figure 3.

Acoustical evaluation of the performance was investigated using the acoustic simulation software, ODEON [ODEON]. Simulations included many different layouts of the performance space: a) no acoustic panels with two different seating plans; b) a single panel behind the audience seating and in front of the main glass doors; and c) three acoustic panels enclosing the performance space around the audience seating. **NOTE:** It must be pointed out that the proposed reconstruction will retain the original interior design of Wright. It will not be possible

to treat the ceiling area or the two fireplace areas with acoustical materials. The only possibilities are to add necessary amount of movable acoustical panels as shown in Figure 4.

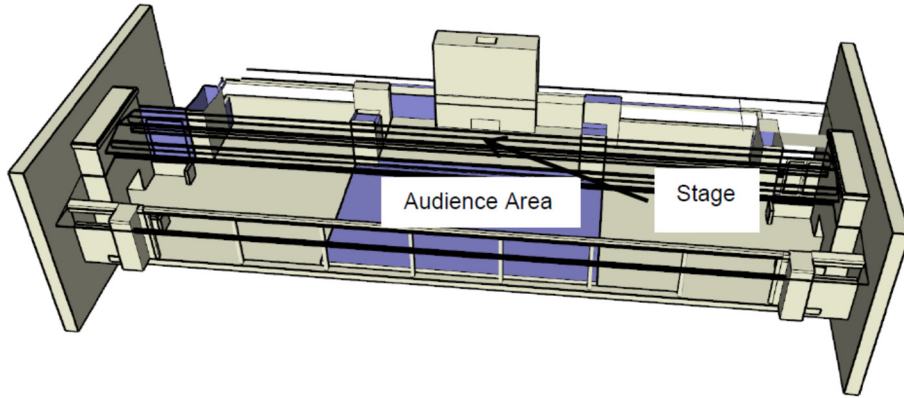


Figure 3. Schematic Details of the Performance Space
The stage is a movable platform set near the back wall of the pavilion. The audience area can be horizontal seating or ramped seating as shown in Figures 3 and 4.

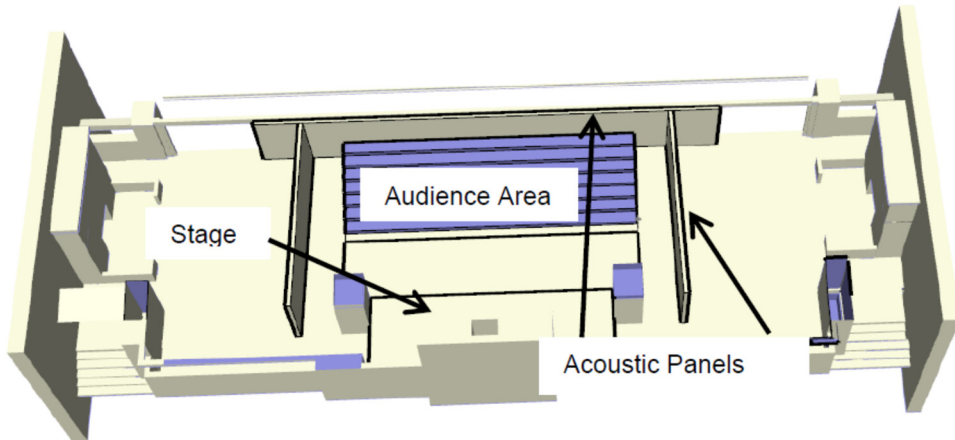


Figure 4. Acoustical Details of the Performance Space

Computer simulations to evaluate the acoustical performance in rooms have become well established practice during the design process. Four simple articles by Johnston-lafelice and Ramakrishnan, Ramakrishnan and Johnston la-Felice, Ramakrishnan and Dumoulin, and Vorlander are cited to show the successful application of computer simulations.

The simulations involved two calculation procedures. The first set evaluated different acoustic metrics at one or two locations within the audience seating with a source placed on the stage. Four of the acoustic metrics will be assessed in this paper and are described below. The acoustic results will be presented in the next section.

3.1. Acoustical metrics [Gade, Long]

3.1.1. Reverberation Time, RT_{60}

Reverberance is the best known metric of subjective room acoustic aspect. When a room creates too much reverberance, speech loses intelligibility. For music, reverberance can add an attractive fullness to the sound. The reverberation time, RT_{60} , is the traditional objective

measure of reverberance and is the time taken for the sound to decay by 60 dB after the source is turned off.

The volume of the central portion of the pavilion is around 3500 cu.m. The acceptable reverberation time for such a space is given in Table 1 below.

Table 1. Optimal Reverberation Time, sec [Source: Doelle, Mehta].

Conditions	Octave Band Centre Frequency, Hz							
	63	125	250	500	1000	2000	4000	8000
Empty Room, Floor Seating	2.3	2.15	1.7	1.50	1.50	1.50	1.40	1.35

It must be noted that the performance area seating is in the middle of the central portion and hence, the acceptable reverberation time needs to be smaller than the values given in Table 1.

3.1.2. Clarity, C_{80}

Clarity describes the degree to which every detail of the performance can be perceived as opposed to everything being blurred together by late-arriving reverberant sound components. It is evaluated by giving importance to the sound that arrives within the first 80 msec (0.080 sec). The metric is represented as dB and the usual range of acceptable C_{80} values are -5 dB to +10 dB. Positive values show a strong aspect of clarity.

3.1.3. Centre Time, T_s , msec

Center time is used to describe the balance between early and late sound and low values of T_s corresponds to a clear sound. The maximum limit of T_s is 110 msec (0.110 sec).

3.1.4. Echo Potential

One of the metrics evaluated is the echo potential between the source and the receiver. Echo values varies between 0 and 1. Any value below 0.75 is considered good and the chance of the echo at the source will be minimal.

As discussed earlier, the acoustical results for the above metrics will be presented in Section 4.

3.2 Auralization

The second simulation was performed to evaluate auralization results. Auralization is a procedure designed to model and simulate the experience of acoustic phenomena rendered as a soundfield in a virtualized space [Auralization]. This is useful in configuring the sound scape of architectural structures, concert venues, public-spaces and in making coherent sound environments within virtual immersion systems. Auralizations are experienced through systems rendering virtual acoustic models made by convolving or mixing acoustic events recorded 'dry' (or in an anechoic chamber) projected within a virtual model of an acoustic space, the characteristics of which are determined by means of sampling its impulse response (IR). Once this has been determined, the simulation of the resulting sound field in the target environment is obtained by convolution and the resulting sound is heard as it would if emitted in that acoustic space.

A short (51 seconds) piano piece, *Autumn Leaves*, was used for auralization. One could have used any short musical piece such as an opera aria, Moon Light sonata, solo cello piece etc. The main idea is to listen to the convolved result, assess its subjective quality and modify the acoustical requirements until the results are satisfactory. The auralization results are generated as audio files and hence will be demonstrated only during the conference presentation.

4.0. ACOUSTICAL RESULTS

The first set of simulation results were evaluated for two locations within the audience seating area. The results for a location near the stage, Location 1, are discussed in this section. The results are evaluated for five different scenarios: a) Empty room (no people) and floor seating; b) Full room (with people) and floor seating; c) Full room (with people), back acoustic panel and floor seating; d) Full room (with people), no acoustic panels and ramped seating; e) Full room (with people), back acoustic panel and ramped seating; and e) Full room (with people), three acoustic panel and ramped seating. **NOTE:** The main focus of the exercise is to create a space for natural sound from the musicians without any artificial amplification.

Reverberation Time results are presented in Figure 1 below. The main observation from the RT_{60} results are:

- a) Most of the interior surfaces of the central space of the pavilion are glass and wood, and they have more absorption in the low frequencies compared with mid-to-high frequencies. The reverberation time in the high frequency is more due to the high volume of the central area. The performance area is smaller and hence the reverberation time needs to be lower.
- b) The reverberation does reduce with the room filled with audience, but not satisfactorily.
- c) For floor seating, it can be seen that the reverberation time reduces adequately with an acoustic panel in front of the main glass doors.
- d) Similar results can be inferred for ramped seating also, except a single acoustic panel in front of the main doors had minimal impact since the ramped seating shielded the panel.
- e) The same perception can be obtained from the audio files resulting from auralization calculations.
- f) Finally, if microphone-speaker systems are required for pop music and Jazz ensembles, the reverberation time needs to be reduced substantially. Such a result can be realised (Scenario f) by adding two more acoustic panels to envelop the seating area.

The results for Clarity, Centre time and Echo Potential are listed in shown in Figures 6, 7, and 8 respectively. The clarity results clearly show that clarity, C_{80} , gets better and satisfactory as one introduces acoustic panels into the room. Centre time, T_s , is seen to be well below the acceptable range of 110 msec. The results imply that there is a good balance between the early sound and later reflections for all the six options of the performance space. The results show that echo is a major issue for the empty space without acoustics panels (Scenario a). Such a results is obvious since the large glass doors are immediately behind the seating area and all the room surfaces are highly reflective. Once the room is occupied with people the echo potential is seen to become minimal for the remaining five scenarios.

4.0. AURALIZATION RESULTS

Audio files were created for each of the six scenarios by using a short 51 second piano piece, *Autumn Leaves*, as the source on the stage. Two receiver locations, one near the stage and the other at the back of the seating area, were used to generate the audio files.

The generated results were in the form of audio wave files and hence, will be played back during the actual presentation of the paper at the conference. However, a brief subjective perception will be described for the three scenarios of floor seating.

The original recording from ODEON's database, when played back, sounded very dry without any reverberant embellishment. One of the subjective requirements for a listening space is that listener should be enveloped by the music and/or speech from multitude of reflections from all bounding surfaces within the first 80 msec. The first convolved result at location near the stage is from empty room with floor seating. The piano piece sounded very muddled due to large amount of reflections from all hard surfaces of the space such as, stone, wood and glass, with strong echoes from the main glass doors. When the room is occupied with people, the only acoustic absorption is provided by audience seating on wooden chairs. The Reverberation Time results of Table 2 showed that the absorption by audience was not sufficient and is reflected in the audio file. The auralized result sounded muddy still. Finally, when the single panel was installed in front the main doors, the result was influenced by two factors – more absorption was created in the room as well as removed the strong reflections

from the glass doors in mid-to-high frequencies. And hence, the audio file sounded to be satisfactory.

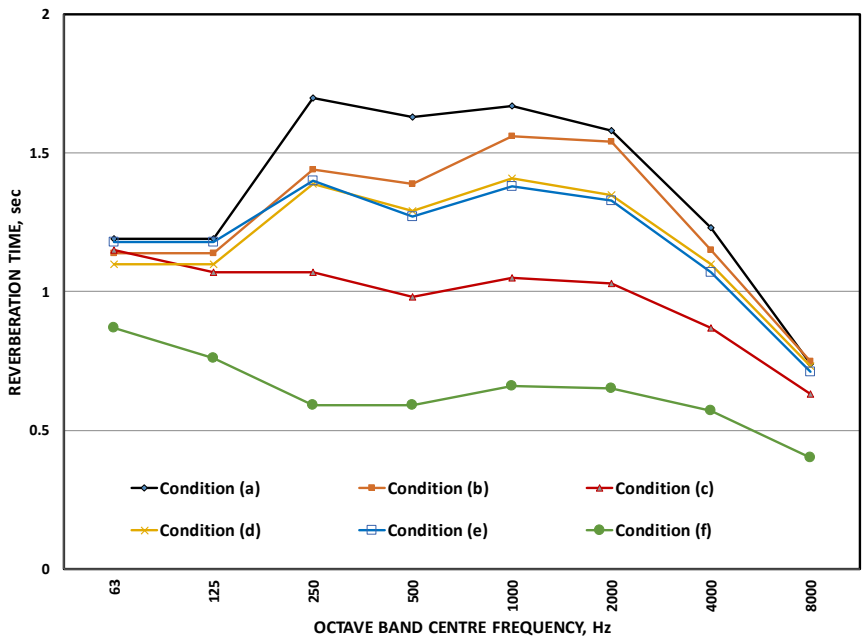


Figure 5. Reverberation Time Results for different scenarios at Location 1, sec.

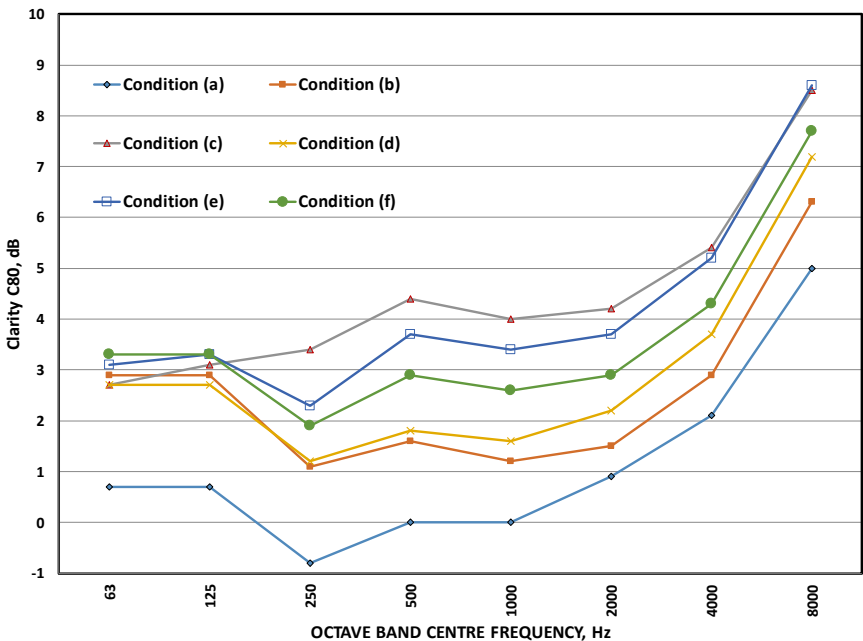


Figure 6. Clarity Results for different scenarios at Location 1, dB.

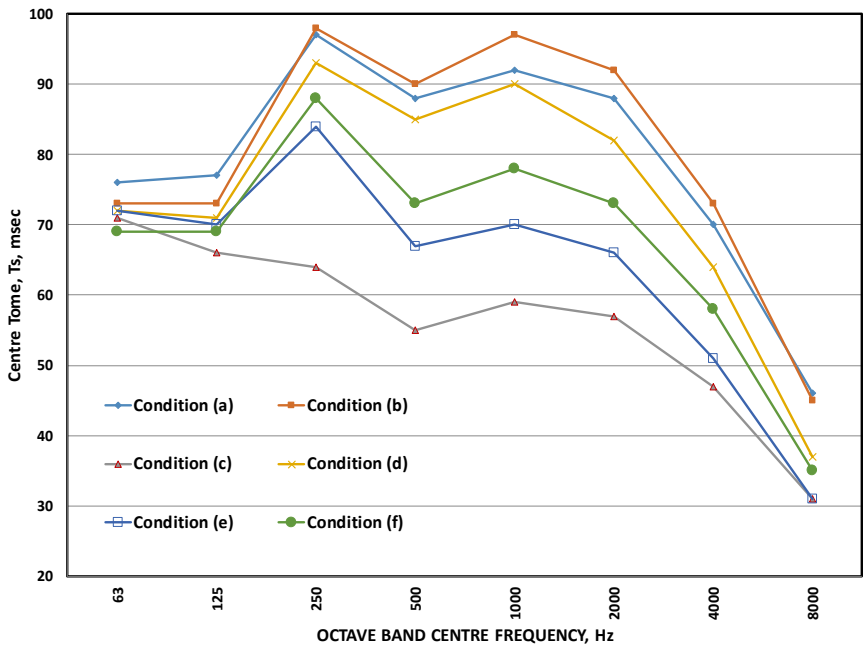


Figure 7. Centre Time Results for different scenarios at Location 1, msec.

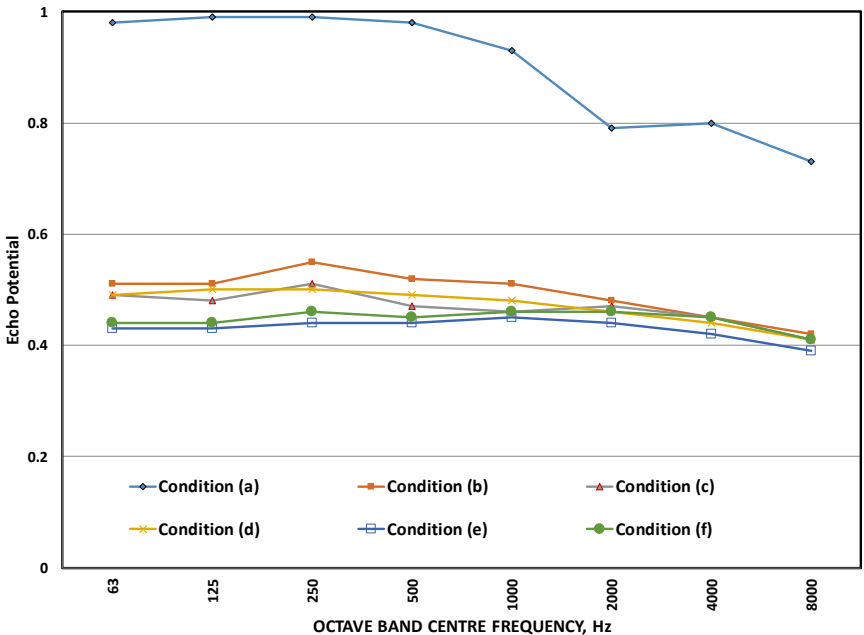


Figure 8. Echo Potential Results for different scenarios at Location 1.

CONCLUSIONS

The potential of incorporating a performance space within the central area of a reconstruction proposal of Banff Pavilion designed by Frank Lloyd Wright in 1916 was investigated in this paper. The performance area must be considered as a temporary installation with movable stage, seating area, and acoustic panels. The temporary nature of the performance space was to keep the original interior design intact on days without any performances.

Acoustic evaluations were conducted through simulation to predict values of RT_{60} , C_{80} , T_s , and Echo potential. In addition, audio files at two audience locations were generated through auralization and by using a short piano piece. The results clearly show that a performance space is possible for both mic-less concerts as well as for concerts with artificial amplification.

Finally, the current investigation shows, as well as from past acoustic design of occupied spaces for sound listening, that acoustic simulation studies must become de rigueur. Architects as front line designers of new spaces must become aware of the need for acoustical studies in any future praxis.

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