Sound Created Form: Exploring The Influence Of Sound On Architectural Form

Ben Gaum[1,2] and Ramani Ramakrishnan[1]
1 - Department of Architectural Science, Ryerson University, Toronto, Ontario
2- Kirkor Architects, Toronto, Ontario

ABSTRACT

The Montreal Jazz Festival is one of the largest and the most important jazz festivals in the world. The festival lacks a proper central location for operations. The current project has explored the influence of sound on architectural form and the aural quality of spaces it can create, by designing a new "Maison du Festival." The original schematic design of the building called for two "amphitheatred" sections of the plan allowing for performances on the two main stages to be projected onto the building itself, essentially acting in the same way as the back of a traditional amphitheatre. The overall form of the building was mainly derived from taking various wav file recordings of the streets surrounding the proposed site and then converting those files into a three dimensional representation. This was achieved by using a software called soundplot 1.0 ™ to capture the wav files that were then generated into 3D form in Rhino. Several recordings of each street were taken at various times of the day both during and after the festival to obtain a visual representation of the types of sounds that were directly affecting the proposed site. Three dimensional 'strips' were then selected from the hundreds of forms generated that would most accurately match the proposed schematic formal design and provide the "amphitheatred" sections required. A uniform building envelope was created from the wav file strips. This building envelope was then analyzed using CATT Acoustics to test the acoustic properties of the buildings form. The results of CATT Acoustics as well as the information gathered from previous studies of outdoor performance spaces were used to alter that the form of the original building in order to satisfy desired acoustical parameters that were required for the musical performances. The CATT Acoustics software proved instrumental in providing the acoustical analysis information that would help accurately transform the buildings form to properly satisfy the acoustical requirements of the festival organizers.

RÉSUMÉ

Le festival de jazz de Montréal est l'un des plus grands et importants festivals de jazz dans le monde. Le festival n'a pas d'emplacement central approprié pour ses activités. Avec la conception d'une nouvelle « Maison du Festival », le projet actuel a exploré l'influence du sonore sur la forme architecturale et la qualité sonore des espaces qu'il peut créer. La conception préliminaire originale du bâtiment exigeait deux sections du plan en forme d'amphithéâtre permettant aux spectacles sur les deux scènes principales d'être projetés sur le bâtiment lui-même, agissant essentiellement de la même manière que l'arrière d'un amphithéâtre traditionnel. La forme globale du bâtiment provient principalement de divers enregistrements en fichier wav pris dans des rues entourant le site proposé et convertis en une représentation en trois dimensions. Ceci a été réalisé en utilisant un logiciel appelé Soundplot 1,0 ™ afin de capter les fichiers wav, qui ont été ensuite générés sous forme 3D dans Rhino. Plusieurs enregistrements pour chaque rue ont été pris à différents moments de la journée à la fois pendant et après le festival afin d'obtenir une représentation visuelle des types de sons qui affectaient directement le site proposé. Des «bandes» en 3 dimensions ont ensuite été sélectionnées parmi les centaines de formes générées qui correspondaient le mieux aux formes de la conception préliminaire proposée et qui fournissaient les sections en forme d'amphithéâtre requises. Une enveloppe du bâtiment uniforme a été créée à partir des « bandes » de fichier wav. Cette enveloppe du bâtiment a ensuite été analysée à l'aide de CATT Acoustics, pour tester les propriétés acoustiques de la forme du bâtiment. Les résultats de CATT Acoustics, ainsi que les informations recueillies des études antérieures sur les espaces dédiés aux spectacles en plein air ont été utilisés pour modifier la forme du bâtiment original afin de satisfaire aux paramètres acoustiques désirés qui étaient requis pour les concerts. Le logiciel CATT Acoustics s'est avéré utile en fournissant les informations de l'analyse acoustique qui permettront de transformer avec précision la forme des bâtiments pour répondre correctement aux exigences acoustiques des organisateurs du festival.

1. INTRODUCTION

The relationship between music or sound and architecture dates back as far as Vitruvius, and possibly further. In his book The Ten Books of Architecture, Vitruvius devotes as much text to "sound, music and acoustics as he did to site design, materials and color; a level of attention unheard of in current architectural writing [1]. Although they have always displayed strikingly similar attributes in terms of balance, structure and emotional interpretations, architecture and music have come so close, but have never fully been able to bridge the gap that lay between them. It was always a question of sensory differences that found it impossible for architecture to be "heard" and for music to be "drawn" [2]. Sound offers a rich medium for exploration: it is an essential element of how we understand and relate to space, and its properties and behavior are intimately linked to the physical experience of an environment [3]. In more recent years it has been the trend in movements such as Acoustic Ecology and Soundscape Study to try and understand the effects of sound and music in our built environment. Based on more subjective qualities, these areas of study have proved to be more interpretational or conceptual ways of thinking of sound to shape the experience of space rather than results based in a more scientific, engineering reality that could actually be proven or shown in a physical architectural model.

This paper has focused on scientific and engineering practices and has applied quantitative and numeric data to the analysis of both architectural form and the interpretations of the people who use them in the hope of finding a connection between the two and address the main problem statement of the research by asking how sound affects form. The Montreal Jazz Festival's main venue was used in this study to understand the relationship between sound, music and architecture.

The Montreal Jazz Festival is currently the largest and arguably one of the most important jazz festivals in the world. For 30 years this festival has been drawing massive crowds and continuously attracting the biggest names in the music world despite never really having a proper central location for operations. The current research project explored the influence of sound on architectural form and the aural quality of spaces it can create and was part of a Masters of Architecture thesis [4]. The main focus of the research was the design of a new "Maison du Festival" that will act as the main welcome center, archive/museum and operations center for the Montreal Jazz Festival of the future.

The growth of the festival over the last five or so years, according to the director of the festival, has been seen as a true double edged sword. Although the increase in festival goers and popularity has been great for the festival in general, it has also caused them many technical problems with regards to proper outdoor venue locations and sizes as well as surrounding acoustic conditions.

The approach to the design element was to see how sound influences architecture in three basic conditions: environmental acoustic design, formal exploration and program-experiential considerations.

The environmental acoustic design looked at the design of the building on a large urban scale. The design focus was the integration of the building form into both the overall festival site and the city as a whole. The program for the building is based on the idea of sound vs. noise. Sound is an audible experience to be embraced and enjoyed such as music and natural sounds whereas noise can be described as unwanted or undesirable sounds such as traffic or construction. The placement of the program took into consideration the proper controlling of both sound and noise in the buildings plan as well as the buildings orientation on the site. Sound was also used in the formal exploration of the building. Various sound wave samples along the length of the surrounding streets of the proposed site were taken at various times of the day, both during and after the festival. They were then converted into a three dimensionally generated form that was then used to create the overall form of the building [5]

Acoustic simulation, using CATT Acoustics Software was also undertaken to evaluate the building form's influence on the noise as well as jazz programs' acoustic responses [6]. Preliminary results of the research were presented in a conference in Niagara-on-the-Lake in 2009 [7]. Complete details of the research are presented in this paper.

The paper is divided into the following subsections. Section 2 provides details of the background to the research. Existing environmental noise at the proposed site and its impact on the formal exploration are described in Section 3. The conceptual design of the building's form and its subsequent exploration are detailed in Sections 4 and 5. The acoustic analysis of the building form using CATT Acoustics is presented in Section 6. Section 7 describes the final details of the building such as its structure, materiality and uses.

2 BACKGROUND

The program of the design of "Maison du Festival", will be a 54000 sq. ft., 3 storeys building that will act as the main welcome center, archive/museum and operations center for the Montreal Jazz Festival of the future. It will include:

- 20000 sq. ft. of gallery space for museum and festival display;
- 3500 sq. ft. café;
- 4500 sq. ft. festival operations office space;
- 5000 sq. ft. recording studio and rehearsal space;
- 2500 sq. ft. multipurpose spaces.

The site, shown in Figure 1, is located just west of the existing festival site at Place des Arts in the central downtown core of Montreal. Currently, the site is an open park site with no existing buildings on it. Focus was on designing a building with as much green space on the site to be used throughout the year.

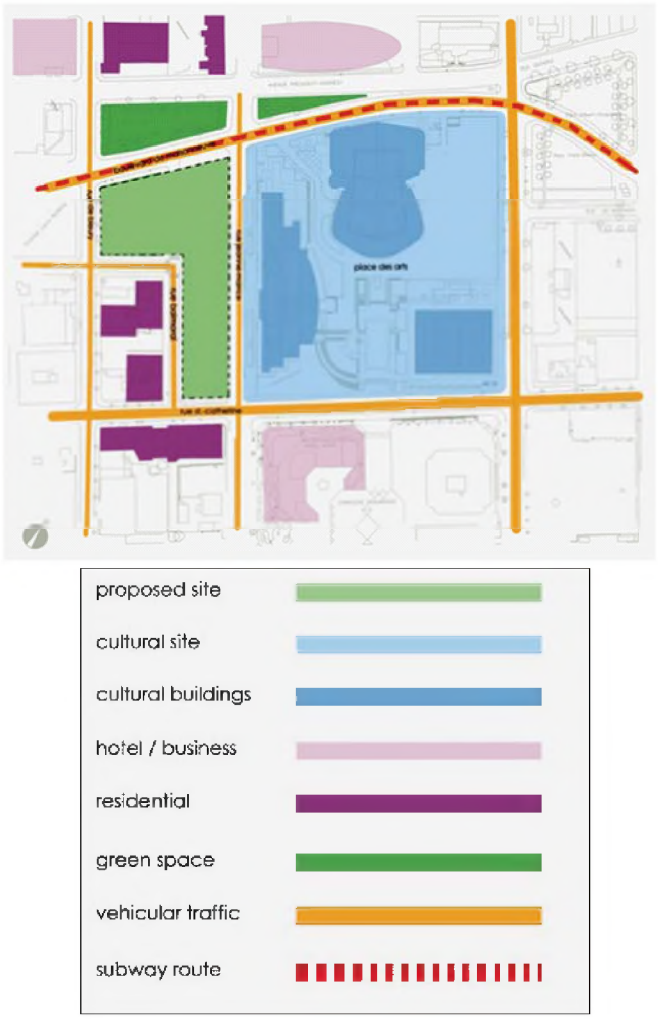

Figure 1. Site Plan of the Montreal Jazz Festival's "Maison du Festival".

3 SITE ACOUSTIC CONDITIONS

Before the design of the building itself can begin, an analysis of all the surrounding environmental acoustic and site conditions were considered. Conditions that have to be addressed include:

- Proposed site in relation to the existing site at Place des Arts;
- Building types, sizes and orientations on the Place des Arts site;
- Building types, sizes and orientations surrounding proposed site;
- Green spaces surrounding proposed site;
- Vehicular traffic surrounding proposed site;
- Existing subway conditions surrounding sit;.
- Existing and proposed festival stage locations and the size of spectators they service.

The existing Place des Arts site is a full city block that consists of two large indoor performance spaces and a large art gallery, all of which are roughly 40-50 feet in height. By having a new building on the proposed site to the west, it would solidify this entire area as a strong cultural hub of the city of Montreal as a whole. The buildings surrounding the proposed site are quite different and have to be addressed with regards to their acoustic properties. On the west side of the proposed site there are two residential brick buildings of 7 and 14 storey's high. These will have to be protected against any unwanted sounds or noise being produced during the festival. On the south side of the site, there are commercial properties that include a 20 storey hotel on the south east corner. This will also have to be considered in terms of protection of unwanted noise as well as sound reflections off the hotel back onto the outdoor performance areas. Two open green spaces with enough vegetation are to the north of the site that provide enough shielding to the residential buildings beyond them of unwanted noise from the festival. The vehicular traffic, although fairly heavy at times, both to the north (Rue de Maisoneuve) and south (Rue St. Catherine) of the site are blocked off from vehicular traffic during the festival. The subway that runs below Rue de Maisoneuve to the north shouldn't pose any serious acoustic problems as long as no part of the proposed building is placed below grade at the north end of the site.

An analysis of the current location, crowd capacity and sound projection directions of the existing outdoor venues shows that at present, an intricate choreography of different show times must be used in order for the performances to go on and not to cancel out or interfere with each other acoustically. The current venue locations in the existing festival site is shown in Figure 2. By redirecting the two large main venue positions and creating two amphitheater sections of the proposed building by projecting sound onto the new Maison du Festival, it would allow for more flexibility of the other outdoor venues around the festival site being used. The proposed modifications are highlighted in Figure 3. This design

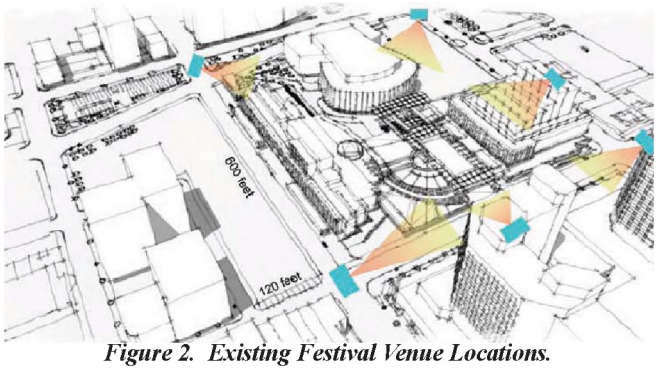

Figure 2. Existing Festival Venue Locations.

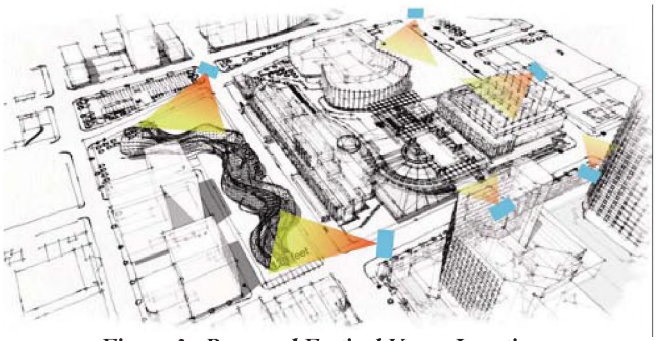

Figure 3. Proposed Festival Venue Locations.

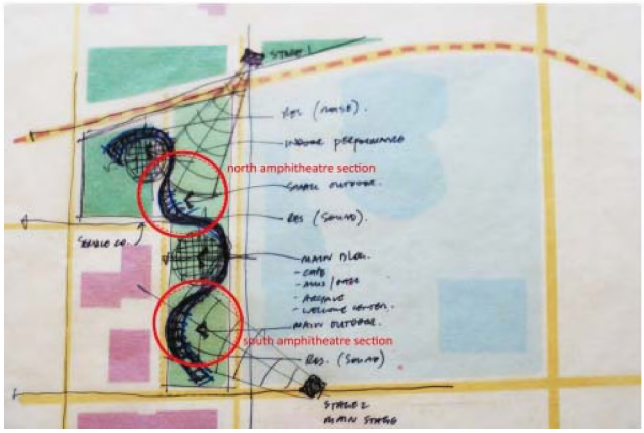

Figure 4. Conceptual sketch of the proposed building.

approach used the new building as a backdrop for the festival itself by engaging the entire festival site as well as the surrounding city. It gave organizers much more flexibility over visual considerations and circulation throughout the site as well as far more control and containment of the sound being projected from the two main event stages themselves for optimal acoustical conditions.

4 CONCEPTUAL DESIGN

The two outdoor amphitheater sections would be the strongest element in the conceptual design and will allow for performances from two outdoor stages to be projected onto the building itself. Initial sketches show how the introduction of the amphitheatre sections aim to accommodate and replace the existing performances stages being used by the festival. The conceptual sketch is shown in Figure 4. The north amphitheater section will replace the festival's largest performance area by allowing approx. 50,000 spectators and the south amphitheater will allow for performances with close to 25,000 spectators. Early diagrams of Figure 5 show the curved form of the design taking shape as theoretical sound sources from the north and south performance stages are projected onto a flat plane. Figure 5 sketches are the conceptual exploration of the form for the proposed building. Although the outdoor amphitheater sections will be mainly seasonal, the indoor program of the building will be useable all year round.

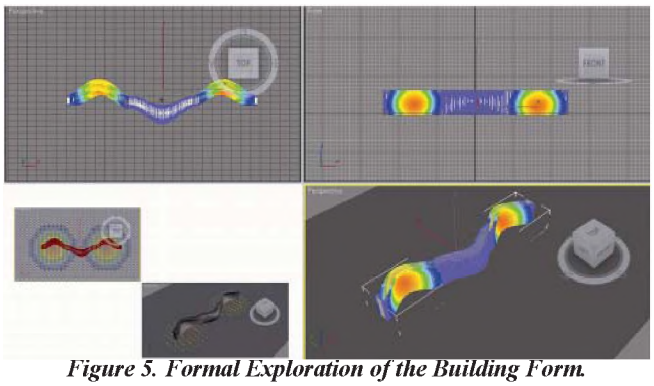

Figure 5. Formal Exploration of the Building Form.

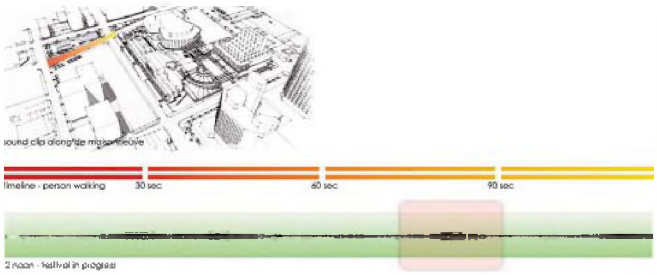

Figure 6. Recorded Sound Wav along Rue De Maisoneuve.

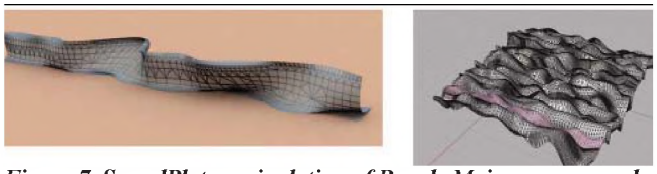

Figure 7. SoundPlot manipulation of Rue de Maisoneuve sounds.

5 FORMAL EXPLORATION

In order to explore and examine the possibilities that could inspire the formal outcome of the building, an interpretational approach to a scientifically acoustic process was taken to generate the buildings organic form. Audio recordings were taken along the length of the three streets that directly border the proposed site. Rue de Maisoneuve to the north, Rue Jeanne-Mance to the east, and Rue Balmoral to the west. The recordings were taken at three different times of day both while the festival was in full swing as well as when the festival was over. A sample recording of the Rue de Maisoneuve sound is shown in Figure 6. A multitude of interesting sounds and noises were recorded, from people walking, car traffic, truck traffic, children yelling, crowds cheering and music playing. The recordings of each street were then compiled together in bands to create an entire grouping of the possible sounds that could be heard along that street. These recordings, in wav file format, were then plugged into a 3D generation program called SoundPlot that was developed by Michael B Pliam of PliaTech Software [5]. The program served one very basic purpose. It converted sound waves into 2 and 3 dimensional surfaces which can subsequently be edited using standard engineering design tools (Soundplot). The desired sound bite is then generated and exported into a Rhino file that can be altered and manipulated to suit. One such manipulation of the Rue de Maisoneuve sounds is shown in Figure 7.

For this project, close to 200 different 3D wav file forms were generated. From this large number of series of wav files generated, a select few were chosen that would most ac-

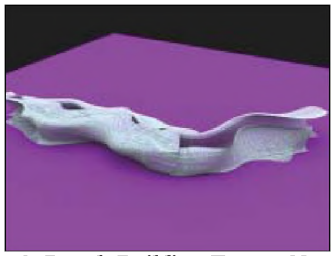

Figure 8. Rough Building Form – North East View.

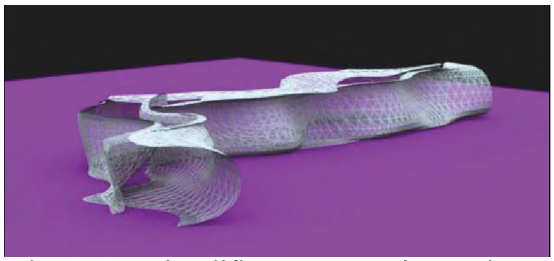

Figure 9. Rough Building Form – North West View.

curately match the desired program, form and orientation of the building required. In this case, the major forms that were trying to be matched were the amphitheater areas of both the north and south sections of the building.

The early forms of these amphitheater sections can be clearly seen in the 3D generated wav files shown in Figures 8 and 9. After selecting 'strips' that would best fit the desired form from each group, the 'strips' were put together to form a uniform building envelope. A great deal of tweaking and altering of the forms were undertaken in order to mould them into their desired shape. Over 20 different renditions were generated before the final building envelope took its final form.

6 ACOUSTICAL ANALYSIS OF BUILDING FORM

After a final general form was worked out, it had to be analyzed acoustically to determine its effectiveness on the surrounding site. Again, the two main areas that were to be analyzed were the north and south amphitheater sections. Each section was analyzed separately using CATT Acoustic. To perform the CATT Acoustics analysis, an acoustic 3D model of each section were created that included the detailed geometry file, a material's file and sound source and receiver files. The geometry file consisted of a computer generated 3D model and its general massing. The materials file identified the proper materials that were used on the final design along with its properly calculated absorption coefficients. The sound files located the source and receiver areas in relation to each amphitheatre section. By using the CATT Acoustics software as well as information gathered from previous studies of outdoor performance spaces, it was determined that the form of the original building had to be altered in order to satisfy desired acoustical parameters required for the musical performances. The results from the CATT Acoustics LEAK analysis showed that the north amphitheater section ended up being too small and was not able to contain or control enough of the projected sound to satisfy the festivals requirements. The LEAK analysis was new step undertaken in the current study and it evaluates the amount of sound that leaks out of the amphitheatre. The LEAK analysis thus calculates the amount lost to the audience space. The initial design showed that 7104 LEAKS were recorded during the analysis. The required solution consisted of: the width of the section to be enlarged drastically as well as an increase in height. The analysis of this revised version, shown in Figure 10, resulted in a drastic decrease in the number of LEAKS recorded at 1436, a much more acceptable level. The overall width of the section was increased to allow for a full 15 degrees on either side of the performances center stage. The south amphitheater section although smaller in overall size, proved to satisfy its requirements due to its slightly curved roof section that had been generated in the original 3D wav form. This slightly curved roof section essentially helped project the sound back down onto the spectators watching the performance. It was also determined that the original steel material being suggested for the outer skin layer of the building in the conceptual design proved to be too highly reflective and hence caused a large amount of unwanted reflected noise. Another solution was evaluated and is discussed in the next section. The CATT Acoustics software proved instrumental in providing the acoustical analysis information that would help accurately transform the buildings form and materiality to properly satisfy the acoustical requirements of the festival organizers. The acoustic results are evaluated in terms C-80, RT60, G and SPL distribution. The acoustic results for one frequency, at 500 Hz, are shown in Figure 11. The results for the revised design are seen to be in the acceptable range for the two open air amphitheatres. It should also be noted that the proper design of the two sections proved instrumental in providing enough environmental acoustic protection to the two residential structures to the west of the proposed building site.

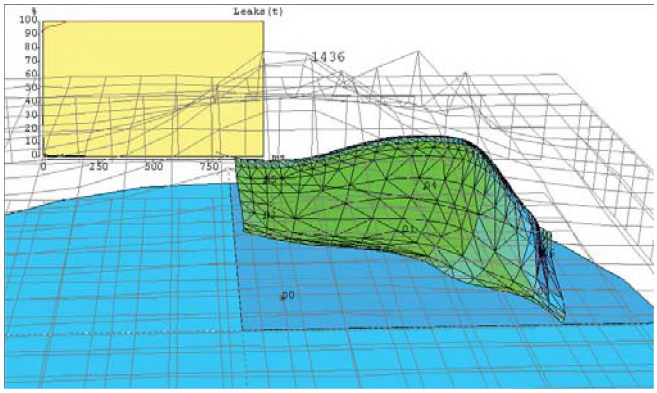

Figure 10. Revised North Amphitheatre LEAK Analysis from CATT Acoustic simulation – p0 marks the stage.

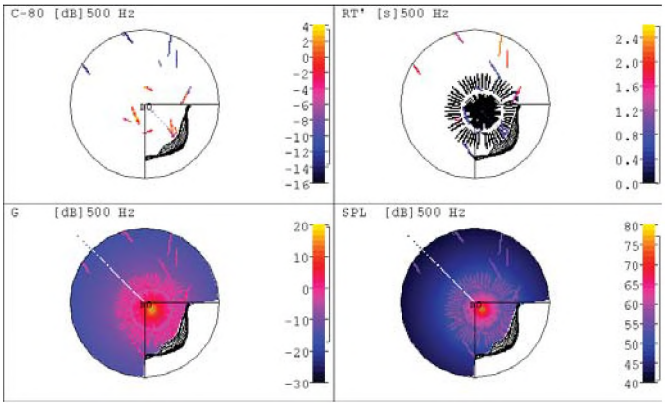

Figure 11. Revised North Amphitheatre Acoustic analysis from CATT Acoustic simulation – p0 marks the stage.

7 BUILDING DESIGN / LAYOUT

The overall layout of the building was divided into three main sections. The north section would house all of the festival offices, the central section would house the galleries and the south section would house the sound recording, rehearsal rooms and archival space. This grouping of program was done for obvious cohesive layout as well as acoustical considerations. The overall organic form of the design provided a multitude of interesting visual as well as acoustic changes throughout the building. A constant changing, opening and closing, widening and narrowing of the overall form gave a living, breathing feel to the architectural experience.

The first floor plan is shown in Figure 12. There are three entrances to the building at this level. Both the north and south ends of the building are entrances for the offices and studio spaces respectively. They are specifically acoustically separated and placed at either end of the building. During the festival these entrances would not be as directly connected to the action and large crowds entering through the eastern, main public festival entrance that is located off of Rue Jeanne Mance. This entrance is set 5 feet below grade, located at the bottom of a ramp that is gently sloped down from the street level. Acoustically, this allows visitors to gently be

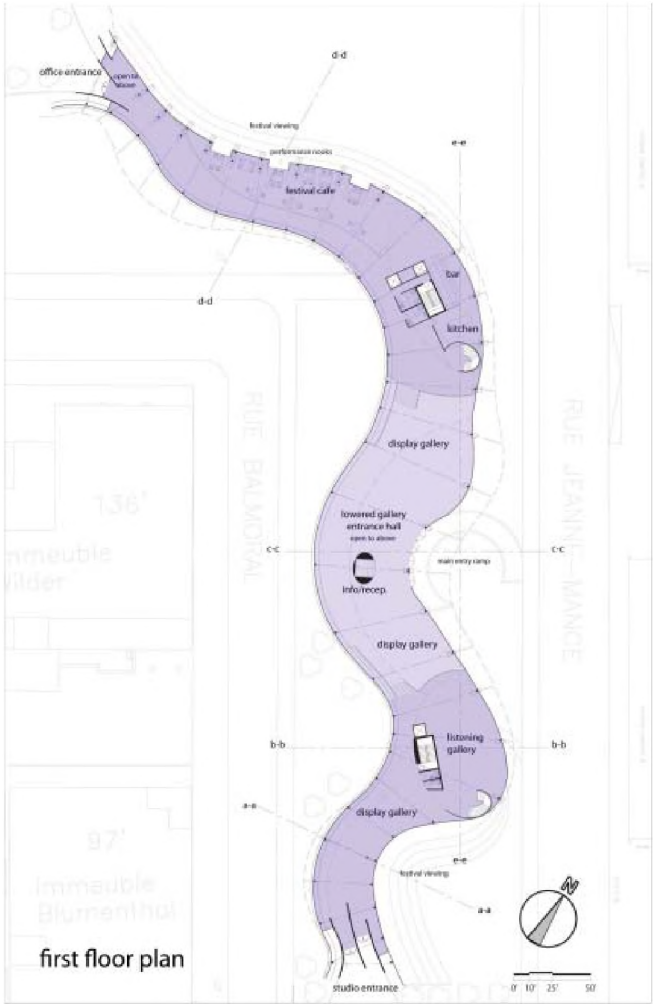

Figure 12. First Floor Plan.

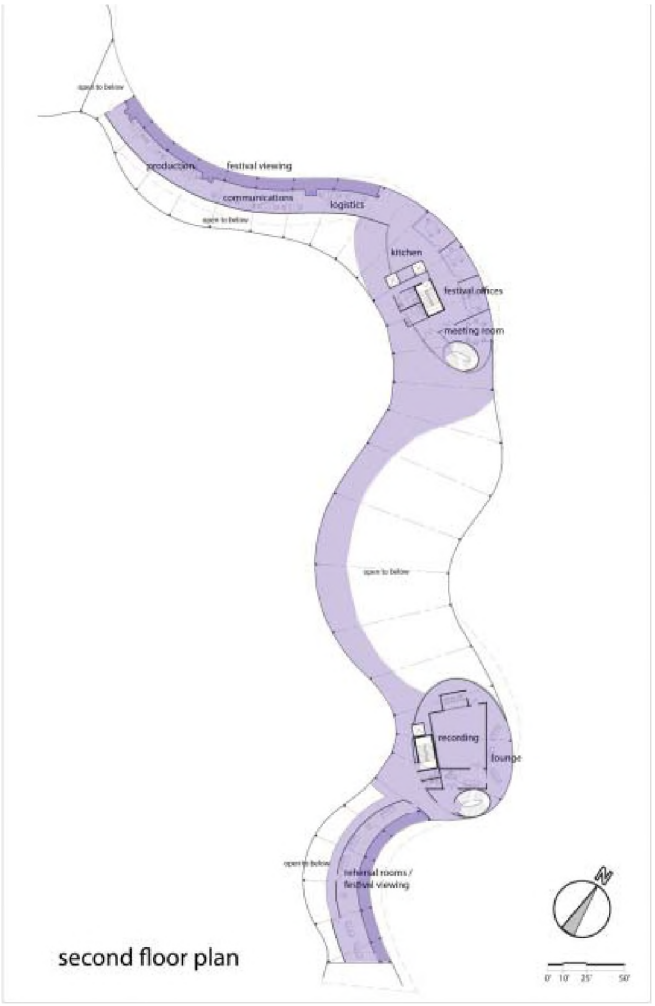

Figure 13. Second Floor Plan.

pulled out of the everyday sounds of the surrounding city and directly into the 3 storey entrance hall atrium and main display gallery spaces. These gallery spaces will house current exhibits that would highlight the current jazz festival musicians, participants and characters. The info/reception booth, an oval outer shell surrounding an inner rectilinear shape, sets a formal tone of "form within a form" that can be seen throughout the building. Primarily, this can be seen in the two large egg shaped masses that hang above the south end first floor listening gallery and north end café. These work to compliment the non linear, overall organic form of the building but were also designed specifically for acoustic purposes. In the first floor listening gallery, the resulting convex form of the ceiling helps to diffuse sounds in order to make for a more enjoyable listening experience. Individual listening pods are provided for visitors as well to help isolate and control the listening experience visitors will have in the gallery. In the north café, the convex form of the ceiling provides the same diffusion of sound for a quieter, less intrusive dining experience. Performance nooks are available for individual, random performances from musicians to come and play for patrons of the café further enhancing the musical, friendly, openly expressive nature of the jazz festival. In one nook performers might be strumming some bluegrass, while at the

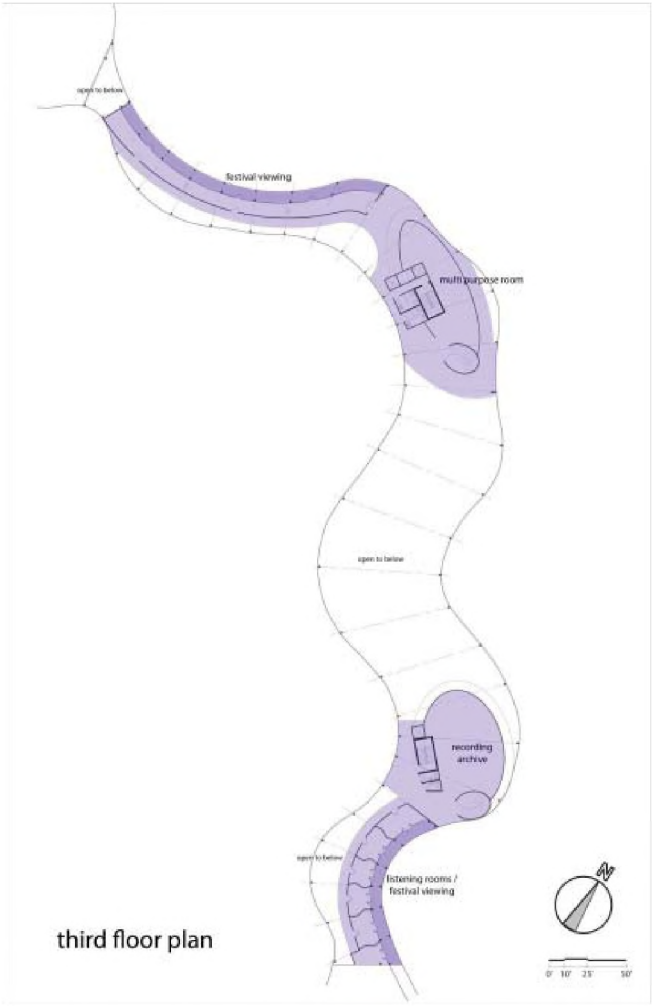

Figure 14. Third Floor Plan.

same time; in another nook separate performers might be offering acoustic blues. Exterior festival viewing or seating is also provided at both amphitheater sections. The festival viewing areas are designed in much the same way the seating was designed in traditional amphitheatres but also provide a continuity between the building form and the ground plane.

Each large egg shaped mass is offset by a central, solid rectilinear circulation core that rises up through the form and includes: elevators, emergency stairs and washrooms. As well, visitors are offered a more introspective audible ascent into the masses themselves as one leaves the openness of the first floor up into the vertical tube like effect of the circular formal staircase provided in each of the two masses.

The second floor plan is shown in Figure 13. One begins to fully experience the "form within a form" design. The south end mass houses the irregular, polygon shaped recording studio and lounge that are consistent with proper conventional, contemporary studio design. The offset or difference between the egg shape and the polygon interior produces a pochet effect that creates essentially an outer and inner shell, allowing for an inhabitable space between the two shells for acoustic separation as well as placement of services. The north end egg shaped mass houses the main festival offices that overlook the entire north side of the festival site. Both the rehearsal rooms and common festival offices double as festival viewing rooms that overlook each of the south and north amphitheatre sections respectively. Here, VIP festival onlookers can have optimal, "luxury box" like seating in which to enjoy the festival with specially designed balconies that are incorporated into the structural design of the building. This experience continues up the festival viewing areas on the third floor, shown in Figure14, as well as a recording archive room and a large multi-purpose room.

7.1 Building Details

The structural frame of the building is a triangulated steel truss system that flares out to create an inner and outer truss section at the second and third floors. This flare creates a space between the two sections of truss that can again be inhabited and is used to create the festival viewing balconies (See Figure 15). Where as in traditional design, the balconies are an added appendage that cantilever out from the main wall of the building exterior, in this design the overall flow and form of the building are never compromised or interrupted in order to accommodate the balconies. The triangulation of the truss allows for added structural strength while also allowing for maximum flexibility to achieve the desired form.

The materiality for this design was seriously considered with regards to the acoustic nature and effects the materials would have on the final design. Materials for the design had to be aesthetically pleasing as well as satisfy all required acoustic parameters. The envelope of the building is a double glazed insulated glass panel wall system. On the south/west side of the building, this double glazing allowed for the incorporation of a passive heating system that can then be distributed to the rest of the building. On the north/east side of the building, primarily on the non-amphitheatre sections of the entire façade, the outer layer of the double glazed system will be perforated with 2" diameter perforations. This will help with the absorption and diffusion of unwanted environmental noise into the cavity provided. To replace the original outer steel skin proposed in the conceptual design of the building, a green wall or living wall system will be incorporated onto the amphitheatre sections to help with the proper absorption of projected sounds from performances much the same way diffuser and absorption panels are used to line the interior walls of recording studios. The perspective view (from the south) of the final building design is shown in Figure 16.

8 CONCLUSIONS

The ever popular and successful Montreal Jazz Festival required a central operational building. The results presented in this paper resulted from a master's thesis. The building was designed so that the form conformed to the sounds that would be created at the proposed site. The form's original exploration was based on the street sounds near the jazz festival site. The street sound were manipulated into 3-D wave forms that created the building. The building's form was then simulated in an acoustic software to refine and retune. The

Figure 15. Section Showing Balcony System.

final design produced a design that satisfied both the environmental acoustical consideration as well as the required acoustics of the two amphitheatres.

ACKNOWLEDGEMENTS

We would like to acknowledge the enthusiastic support provided by Mr. Jean-Sébastien "Vince" Robillard, the Director of the Montreal Jazz Festival. The assistance of Mr. Romain Doumoulin, in translating the abstract into French is duly acknowledged.

REFERENCES

1. Sheridan, T and Van Lengen, K, "Hearing Architecture: Exploring and Designing the Aural Environment" The Journal of Architectural Education, Vol. 57 (2), pp 37-44, (2003).
2. Ripley, C, Polo, M and Wrigglesworth. Ediotrs, "In the Place of Sound: Architecture | Music | Acoustics," Cambridge Scholars Publishing, (2007).
3. Bryant, J. W. "Sound Awareness and Place: From an Aural Perspective" Faculty of Graduate Studies, University of Maryland, (2007).
4. Gaum, B., "Sound Created Form." Masters in Architecture thesis, Department of Architectural Science, Ryerson University. (2009).
5. Soundplot tm, Michael B. Pliam, Copyright PliaTech Software 2000-2008.
6. CATT Acoustics V8.0g, Copyright CATT 1988-2007.
7. Gaum. B, and Ramakrishnan. R. "Sound Created Form." Canadian Acoustics Journal, Vol. 37 (3), pp 98-99, (2009).

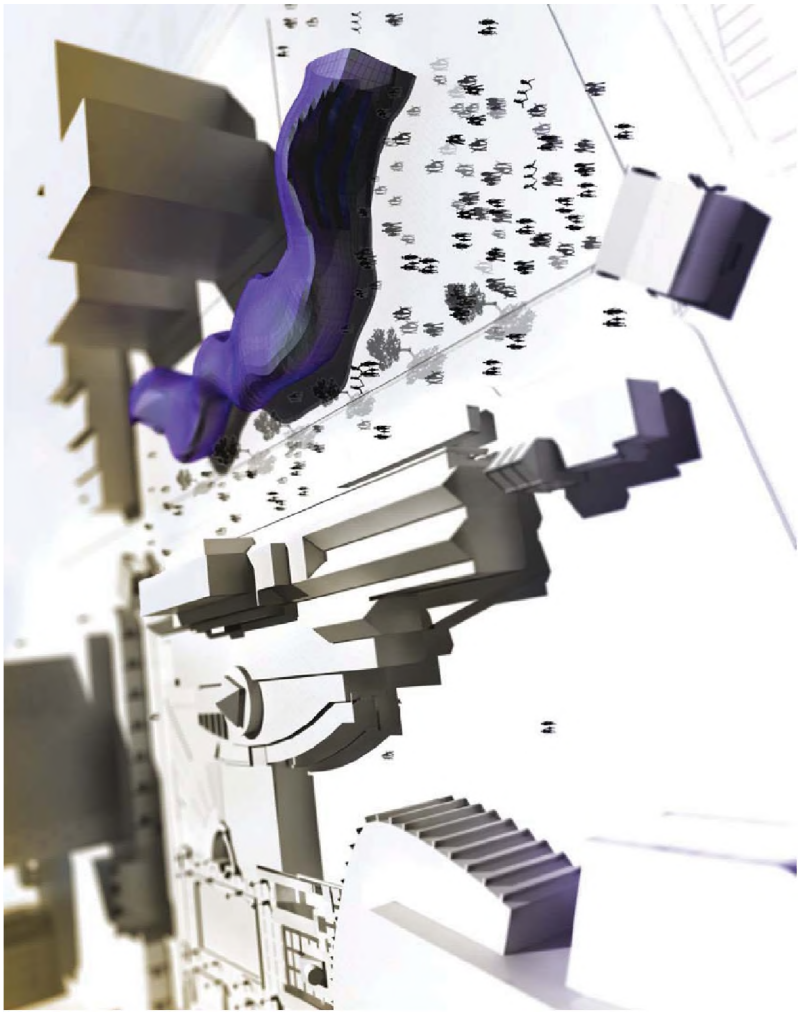

Figure 15. Perspective View looking South.