Fall 2014

The Movement: A Performance Venue

Matthew J. Burke

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The Movement

A Performance Venue
Master of Architecture Thesis
Rochester Institute of Technology
Golisano Institute for Sustainability
Department of Architecture
Matthew J Burke
Fall 2014
Committee Approval

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Acknowledgements

Jules Chiavaroli, Jim Yarrington, and Gabrielle Gaustad for serving on my thesis committee, providing many insights, constructive feedback, inspirations, and knowledge.

Richard Napoli, without you I would have never completed thesis (or possibly even started). Your mentorship and design knowledge are invaluable to me.

My parents, for many years of support, encouragement, wisdom, and love. You are my role models, and inspiration to always better myself.

My fellow classmates, for forging ahead in this program, despite all obstacles. This has been a long 3 and a half years, and would have felt far longer without this amazing group.

To my band, for offering me countless nights of stress relief, and comraderie.

Dorothy, for keeping me fed during the thesis process.
Preface

The following is an architectural design thesis completed in partial fulfillment of a Master of Architecture degree at the Rochester Institute of Technology. The project grew out of a passion for music, and demonstrates research on the potential for a new sustainable energy technology. It is the culmination of research on acoustics, and hydropower technology. It is also an adventure back to my hometown of Saint Albans, Vermont, and my attempts to better its built environment and community resources.
Abstract

The aim for the thesis project is to design a concert venue for the City of Saint Albans, Vermont. The venue will serve as an entertainment hotspot, an educational tool, a set of rehearsal spaces, and performance halls with recording capabilities. The goal is to create a welcoming entertainment and educational environment, open to use by all, to show that music is more than entertainment, but also a hobby, an educational medium, a skill-set, and a tool.

The driving theme behind the project is the concept of “movement.” Its first representation is in music. Sound itself is movement; it is pressure; it is the air moving around you, translated to the audible spectrum by your ears and brain. It is impossible to perform music without moving in some way. Second, water will be moving through the building (as in all buildings), but in this special case through an in-pipe micro-hydropower system. Lastly, the idea of a landmark, contemporary concert hall in Saint Albans constitutes progress and forward movement in the City’s development.
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Project Vision

This architectural thesis project is a unique amalgam of two fields of study: micro-hydropower technology, and acoustics. The acoustics component stems from my passion for music, while the micro-hydropower component comes from research conducted under an EPA funded grant.

The project is also an exploration of personal roots. The project is set in my hometown, a small city in north-western Vermont. In analyzing the city’s present building stock and business make-up, a gap was evident in what is available to the community. The project grew out of the hypothesis that Saint Albans has almost no opportunities to see live music. Furthermore, another goal for the project was to include a renewable energy component. This is done with the implementation of a micro-hydropower energy generation system.
Location

The project’s location will be 133 North Main Street, in the City of Saint Albans, Vermont. The City of Saint Albans is encompassed entirely by the Town of Saint Albans. Presently, there is a small shopping plaza with a few successful businesses, as well as the local Post Office headquarters at this site. There is also an unusually large surface parking lot for the downtown area. At the center of the lot there is a small vacant bank building. This will be demolished to make way for the proposed venue.
133 N. Main Street is within easy walking distance of prominent downtown St. Albans restaurants, bars, and the city’s 3-screen movie theatre. This focal portion of Main Street is approximately 0.4 miles in length, an easy <10-minute walk from even the furthest area restaurant. Within this walking distance is the local high school, which serves a handful of towns in Franklin County, as well as the Town Elementary School, and City Elementary School. The site is also a popular viewing site for annual parades, such as July 4th, Memorial Day, and The Maple Festival (a celebration of Maple Syrup, for which Saint Albans is famous).

The City of Saint Albans is approximately 2 square miles, encompassed by the Town of Saint Albans, which is 60.6 square miles, of which 23 square miles are water. There is not much competition for music venues in the area. The closest competitors are Higher Ground, Club Metronome, and Zen Lounge, which are 27.9 miles, 28.5 miles, and 28.6 miles away respectively in Burlington, Vermont. Saint Albans is part of the Burlington / South Burlington VT Metropolitan Statistical Area (a suburb of Burlington). Saint Albans is 15 miles from the Canadian border.
Location

Key
- Retail
- Restaurant / Bar
- Entertainment
- Non-Food Business
- Religious
- School
- Post Office
- Railroad
Climate

Saint Albans is located on Lake Champlain, and just shy of the 45-degree latitude mark (~10 miles). Snow is common from the months of November through April. Precipitation patterns are fairly consistent, ranging from 1.96” in January to 3.92” in August, with no dry months. Average snowfall is approximately 80.6” over the course of the winter months, with an average of 44 snow days\(^1\). As a result, buildings’ structures have to take 40psf snow load into consideration.

Temperatures can range from a record low of -37 °F to a record high of 99 °F, making for an average temperature of 44.1 °F\(^2\). In terms of design, the local climate is a heating load dominated area. The heating degree-days far outnumber the cooling degree-days at 7,771 to 388 respectively. In terms of solar potential, it is a relatively cloudy region, with an average of 58 clear days a year, and an average of 154 days annually with precipitation\(^3\). Nonetheless, South facing glazing is recommended in this climate\(^4\).

Wind speeds fluctuate between 8-10mph\(^5\). The majority of this wind load comes from the South, making for a great opportunity for natural cooling in the summer months. In terms of design, there are a number of possibilities to keep a building more comfortable to human occupants. Some of these options include:

- Southern glazing to maximize winter sun exposure
- Extra insulation can prove cost effective, and can help to keep indoor temperatures more uniform
- Basements must extend at least 18” below the frost line
- Vestibule entries can minimize air infiltration and eliminate drafts
Local Need

A poll was conducted to gain insights on the need for a concert venue in Saint Albans, Vermont. This was conducted with the web tool Survey Monkey, and spread through Facebook and email blasts (a full list of the questions can be seen at the end of this section). There were 89 participants, from varying backgrounds and occupations. The participants were made aware that the poll proposed questions for a hypothetical venue.

Data

Of the participants, 80.89% (72) were from Saint Albans, and it’s surrounding county, Franklin County:

Of those polled, 34.8% (31) were musicians:

Occupations of the participants varied widely, and included healthcare, retail, legal, retired individuals, and stay-at-home-moms. The breakdown is as follows:
Local Need

Of those polled, 83.14% (74) attended live musical performances:

- I attend concerts
- I do not go to concerts

Of those polled, 68.54% (61) attended a live musical performance once every 2-3 months:

- Once every 2-3 Months
- Once a month
- A couple times a month
- Every Week
- Never / This does not apply to me

Of those polled, 59.6% (53) travelled to Burlington, VT (30 miles) or farther to attend a live musical performance:

- In Town (Saint Albans)
- Close to Saint Albans (15 miles)
- Burlington, VT or farther
- This does not apply to me

Of those polled, 80.9% (72) said they would be more likely to attend a live musical performance if there was a venue in town:

- More likely to attend
- Not more likely to attend

Of the musicians polled (31), 67.7% were interested in the availability of practice space in-town:

- I’d like practice space
- I don’t need practice space
Local Need

Of those polled, 55.1% (49) believed that a music venue should have a bar. The “Depends” category gained comments such as “can be good for business,” and “some form of refreshments like coffee,” and “not necessarily, but wouldn’ t object to it.”

Finally, a summarizing comment section showed resident support for the venue. One participant said “I’ d love to see Saint Albans have a music venue,” while another said “Overdue!” while others claimed their interest in the venue depended on the genres of music brought in.

Summary

While the turnout for poll participation was not huge, the majority of participants were in favor of a new music venue for Saint Albans, Vermont. A majority occasionally attends live musical performances, but must travel far in order to do so. More importantly, an overwhelming majority would be more likely to attend musical performances if there was a dedicated venue in town. A majority of musicians polled were interested in the idea of a multipurpose music venue that included practice spaces. Many people also liked the idea of bar/concessions/refreshments availability, which suggests they don’t think Saint Albans already has adequate opportunities for “social” spaces. However, there was one comment that said a bar needed to be separated from the main music hall so that the venue can remain all ages.
Local Need

The poll was conducted through the web tool SurveyMonkey, which was posted with a link on Facebook, and spread around to as many Saint Albans community group pages as possible, as well as emailed to many people. There were 10 questions in total, and 89 participants in total.

The questions and reported answers are as follows:

Q1. What City/Town are you a resident of?
   A. Saint Albans (39); Franklin County, but not Saint Albans (33); Other (16); Skipped (1)

Q2. What is your occupation?
   A. Healthcare (13); Childcare/Education (15); Small Business Owner (2); Construction (2); Architect/Engineer/Designer (3); Government (6); Artist (1); Retail (3); Hospitality (5); IT (1); Administration (5); Banking/Financial (2); Social Services (1); Marketing/Publishing/Writing (1); Legal (1); Student (6); Other (18); Skipped (4)

Q3. Are you a musician (do you play any instruments)?
   A. Yes (31); No (56); Skipped (2)

Q4. Do you attend live musical performances?
   A. Yes (74); No (15)

Q5. If so, how often?
   A. Once every 2-3 months (61); Once a month (2); A couple times a month (6); Every week (3); Never, this does not apply to me (16); Skipped (1)

Q6. If you attend live musical performances, where do you typically go?
   A. In town [Saint Albans] (10); Close to Saint Albans [15 minutes away] (5); Burlington, VT or farther (53); This does not apply to me (14); Skipped (7)

Q7. If there was a dedicated music venue in town, would you be more likely to go see a show / see friends perform?
   A. Yes (72); No (9); Skipped (8)

Q8. If you are a musician, would you be interested in the availability of practice space?
   A. Yes (21); No (12); This does not apply to me (54); Skipped (2)

Q9. Do you believe a music venue should have a bar?
   A. Yes (49); No (27); Skipped (13)

Q10. Any other comments on this subject?
    A. (these are samples from the opinions stated by poll participants) “if the music venue featured artists and genres more like country I would be more likely to go,” and “A bar is a must. But like Higher Ground, it can be all ages with proper hand stamps and bracelets,” and “Overdue!” and “I like the idea of a multi-purpose music venue in Saint Albans.”
Demographics

The City of Saint Albans has 6,918 residents, with 31.6% of households having children. It is a youthful city, with 65.7% of the population under the age of 45. The median household income is $37.2k, while the median family income is $44.3k.

The Town of Saint Albans has 6,392 residents, with 38.2% of households having children. The town is also youthful, with 62.6% of its population under the age of 45. The median household income is $46.9k, while the median family income is $53.1k.

Saint Albans is a net import City and Town, and not a bedroom suburb. The population grows daily during business hours. During the daytime hours, the population grows 37.5%, or ~2,605 individuals (City-Data, 2014). Saint Albans sits in Franklin County, which has a total population of 47,746 people.
Character and History

The proposed project is a fairly unique building type for the City (and Town) of Saint Albans Vermont. The City has its fair share of history; it was the site of the northernmost Civil War battle, and has for more than a century and a half been a major hub for rail traffic. The existing building type of the downtown reflects this historical, industrial and transportation vernacular. Running straight through the center of the City is a primary railroad corridor, still in use today by Amtrak.

Even in the downtown core, there is a heavy use of residential-type architecture. Furthermore, more than a block of the heart of Main Street only has buildings on one side; the opposite side is a large park, making the downtown core even more unique.

Despite all of this, Saint Albans is a very progressive city. Evidence of this is littered throughout the City’s current Master Plan, with pushes for densification of the downtown core, increased development of underdeveloped parcels, walkability, avoidance of suburban-style development, and recently with the creation of a large multi-story public parking structure, the city has consolidated surface parking.

The character of the proposed venue will have to take all of this into account. It must speak the City’s historic roots, its transportation, industrial, and residential vernacular, and embrace the city’s desire to move forward and grow. The site it will sit upon could also be looked at as the gateway to the downtown, an entrance marker, and an edge condition for the downtown core. The City’s Master Plan already expresses a desire “to create an architectural presence along Main Street” on this site, which is presently the Saint Albans Shopping Center.

The site designated will also benefit from this new building. The large parking lot will have opportunity to be used during normal business hours (9-5), and gain new use in the evening and night hours, since that is when concerts tend to happen. Furthermore, any outdoor events that draw large crowds to the venue can help increase business for the existing businesses in the 1 story strip mall adjacent to the parking lot. Hopefully in the future, the surrounding lot will turn into a pedestrian friendly shopping area.

The design will thus be unique, and not conservative in aesthetics, but modern or contemporary to look to the future. The proposed building can speak to its surroundings history through its use of materials, or re-imagined historical features. It must feel new, and youthful to attract its intended users. It must be eye catching, to give Saint Albans a landmark, and make it a destination.
Context Case Study

Saint Albans already has a rich architectural vocabulary. In order to proceed with a design for a new building, a tour of the city/town was conducted to create a collection of visuals from which to draw inspiration. Drawing inspiration from the existing building stock pays respect and homage to the surrounding community.

Much of the existing building stock was built decades, or even more than a century ago. Along the railroad corridor at the heart of the city are many industrial, and transportation oriented buildings. Along the main street is a collection of mixed use type buildings (typically commercial first story, and residential upper stories), and formerly residential buildings now converted to commercial uses.

The built environment offered inspiration in two ways. First, in architectural features and details. Second, in material choices, which show both texture and color. Examples of highlighted architectural features and details are as follows:

- Strip Windows
- Usable rooftop space
- Arched and round windows
Context Case Study

Looking deeper into these features, it is important to discuss what they are created of and how they are created. Much of the building stock is clad in brick, a durable material choice, that has stood the test of decades of harsh Vermont weather. There is a variety of color options visible in this masonry work, from a spectrum of reds, to a spectrum of grays. Some examples are as follows:
Small-scale venues are not terribly expensive to keep in operation, particularly small local ones that do not pay musicians to perform, but merely give them exposure, and live practice. A small financial case study was conducted on The California Brew Haus, a concert venue/brewpub in Rochester, New York. Some of the operating costs gained from this are as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost ($)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tech cost</td>
<td>$200/event</td>
<td>This price is high for this type of venue</td>
</tr>
<tr>
<td>Touring band cost</td>
<td>$50-$2,000</td>
<td>Speciality show. Small venues do not typically bring in paid touring musicians</td>
</tr>
<tr>
<td>Security</td>
<td>$280/event</td>
<td>3-4 guards at $10/hour for a 7 hour timeframe</td>
</tr>
</tbody>
</table>

Total Max. Cost for 1 evening of entertainment = $2,480 (highest paid musicians, 4 security)
Total Min. Cost for an evening = $410 (non paid band, reduced security)
Typical Low Nightly Income = $750 (based on 50 customers, purchasing 2 drinks each, at $5 apiece, with unpaid musicians. Also included is a $5 apiece cover charge. Paid musicians bring more customers, and thus more profit)
Profit for a slow night = $340 (typical low income - typical minimum cost)

These are simply costs and profits to provide live entertainment for 1 night, a slow night at that.

To compare this area of Rochester to the proposed site in Saint Albans Vermont for a concert venue, some demographic information is helpful.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Rochester, NY 14615</th>
<th>St. Albans, VT 05478</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>16,317</td>
<td>13,310 (city &amp; town)</td>
</tr>
<tr>
<td>Land Area</td>
<td>5.8 square miles</td>
<td>62.6 square miles</td>
</tr>
<tr>
<td>Median Household Income</td>
<td>$36,749</td>
<td>$37.2k (city) $46.9k (town)</td>
</tr>
<tr>
<td>Households with Children</td>
<td>45.5%</td>
<td>31.6% (city) 38.2% (town)</td>
</tr>
<tr>
<td>Residents below age 45</td>
<td>60%</td>
<td>65.7% (city) 62.6% (town)</td>
</tr>
<tr>
<td>Competition within &lt;10 miles</td>
<td>Dozens of dedicated venues</td>
<td>No dedicated venues</td>
</tr>
</tbody>
</table>

The size of the population in this zip code in Rochester, income levels, age of population, and total land area are easily comparable to the chosen site of Saint Albans, VT for a new music venue. Rochester even has far more competition, and yet many venues are successful. Furthermore, the relatively low price of running a local venue that less frequently brings in highly paid touring bands makes a small local music venue that much more appealing for Saint Albans, Vermont.
Feasibility Study

Other means of income for the proposed music venue in Saint Albans are the rehearsal spaces and educational spaces. These spaces can be used simultaneously with the concert hall, allowing for 2 concurring profit generators. This kind of service often acts as a stand alone business; entire warehouses are often filled with rehearsal spaces that charge hourly and monthly. Some average pricing for this income is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Charge</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rehearsal Spaces</td>
<td>Starting at $25/hour;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$200/month</td>
<td>As many as 9 operating hours per day in many cities (5pm-2am).</td>
</tr>
<tr>
<td>Education, Lessons, Workshops</td>
<td>Starting at $25/hour</td>
<td>Same time opportunity as above. Furthermore, this is a job opportunity for trained musicians</td>
</tr>
</tbody>
</table>

### Building Cost Estimate

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit Cost</th>
<th>Units Needed</th>
<th>Total Cost</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auditorium</td>
<td>$161/SF</td>
<td>18,318 SF</td>
<td>$2,949,198</td>
<td></td>
</tr>
<tr>
<td>Office</td>
<td>$135/SF</td>
<td>501 SF</td>
<td>$67,635</td>
<td>Low Rise, 1-4 stories</td>
</tr>
<tr>
<td>Rehearsal</td>
<td>$143/SF</td>
<td>1,877 SF</td>
<td>$268,411</td>
<td>Based on vocational school</td>
</tr>
<tr>
<td>Demolition of Existing Building</td>
<td>$2.42</td>
<td>800 SF</td>
<td>($1,936.00)</td>
<td>$3,200 Min. allowed cost</td>
</tr>
<tr>
<td>Excavation</td>
<td>$8.97</td>
<td>7,778 SF</td>
<td>$69,768.66</td>
<td></td>
</tr>
<tr>
<td><strong>Building Subtotal Cost</strong></td>
<td></td>
<td></td>
<td>$3,358,052</td>
<td></td>
</tr>
<tr>
<td><strong>With Architectural Fee</strong></td>
<td></td>
<td></td>
<td>$3,626,696</td>
<td></td>
</tr>
<tr>
<td><strong>With Area Factor (94.2%)</strong></td>
<td></td>
<td></td>
<td><strong>$3,416,347</strong></td>
<td></td>
</tr>
</tbody>
</table>

With an estimated price tag above $3.4M, this is a building that would likely need private funding, such as a large donation from a wealthy individual or organization. Large monetary gifts are not unheard of from companies like VT company Ben & Jerry’s, or groups like the VT based jam-band Phish.
Building Type Case Study

Introduction
Case studies were conducted on differing sizes and types of music venues in New York, and Vermont. The venues that have been examined are Twiggs, in Saint Albans Vermont; The California Brew Haus in Rochester, New York; Upstate Concert Hall in Clifton Park, New York; and The Tralf Music Hall in Buffalo, New York.

Twiggs, Saint Albans, VT
Twiggs is a restaurant in the heart of downtown Saint Albans. Recently, the owners have branched their services into offering live music, mostly at a smaller capacity like an acoustic duo playing to the dining rooms. The space has exposed brick walls, hardwood floors, and exposed suspended building systems. There are 3 stages within the restaurant. The restaurant is in a mixed-use building with storefront type windows overlooking Main Street.

<table>
<thead>
<tr>
<th>Stages</th>
<th>Window stage (front); small stage (side); main stage (back)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage Sizes</td>
<td>(front) accommodates 2-3 people; (side) accommodates 3-4 people; (back) accommodates 14 people by code</td>
</tr>
<tr>
<td>Audience Count</td>
<td>Largest space can accommodate 75 people seated at tables</td>
</tr>
<tr>
<td>Total Venue Size</td>
<td>~4,500 SF</td>
</tr>
</tbody>
</table>

The California Brew Haus, Rochester, New York
The California Brew Haus is a bar, restaurant, and concert venue situated within walking distance of the Kodak plant on West Ridge Road. The Brew Haus has been open for decades serving the Rochester community. The venue hosts anything from small local bands, to large touring bands, and community fundraisers. The space is fairly simple in design, with concrete and hardwood floors, exposed suspended building systems, and some acoustic treatments (curtains) on the walls of the main performance space.

<table>
<thead>
<tr>
<th>Stages</th>
<th>Main stage (rear of venue); window stage (front of venue)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage Sizes</td>
<td>373 SF (main); 51 SF (window stage)</td>
</tr>
<tr>
<td>Hall Sizes</td>
<td>1,600 SF (main hall); 1,000 SF (window)</td>
</tr>
<tr>
<td>Bar Sizes</td>
<td>240 SF (main); 200 SF (window)</td>
</tr>
<tr>
<td>Storage Size</td>
<td>64 SF</td>
</tr>
<tr>
<td>Total Venue Size</td>
<td>~4,000 SF</td>
</tr>
</tbody>
</table>
Building Type Case Study

**Upstate Concert Hall, Clifton Park, New York**

The Upstate Concert Hall is a concert venue and bar situated in a strip plaza in the Albany suburb of Clifton Park. The plaza is a single story building. The venue tends to gear towards larger touring acts, typically drawing 1,000+ customers to each show. The venue is fairly simple in design with concrete floors, exposed suspended building systems, and some acoustical treatments (curtains) on the walls like the previously examined spaces.

<table>
<thead>
<tr>
<th>Stages</th>
<th>Main Stage (back left corner)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage Sizes</td>
<td>704 SF</td>
</tr>
<tr>
<td>Hall Size</td>
<td>~12,000 SF</td>
</tr>
<tr>
<td>Bar Size</td>
<td>600 SF</td>
</tr>
<tr>
<td>Total Venue Size</td>
<td>14,500 SF</td>
</tr>
</tbody>
</table>

**The Tralf Music Hall, Buffalo, New York**

The Tralf Music Hall is a bar, restaurant, and performance venue that hosts live bands, as well as comedians (Jay Leno, and Jerry Seinfeld performed here in the 1980’s). The venue exists in the 2nd story of a Main Street building in downtown Buffalo, nestled in with other area entertainment venues, shopping, and office spaces. The venue is accessed either through a freight entrance on the rear side, or stair lobby from the Main Street side. Similar to other venues examined, the space contains concrete floors, black acoustic wall treatments (curtains), and exposed suspended building systems. The venue sports ~15’ ceilings, and low lighting levels for an entertainment atmosphere.

<table>
<thead>
<tr>
<th>Stages</th>
<th>Main (front left)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage Sizes</td>
<td>300 SF</td>
</tr>
<tr>
<td>Hall Size</td>
<td>3 Levels: lower level ~2.5k SF, upper level ~1k SF, mezzanine ~600 SF</td>
</tr>
<tr>
<td>Bar Size</td>
<td>250 SF</td>
</tr>
<tr>
<td>Load-in size</td>
<td>5’ hallway with an approximate 40’ total length for temporary storage, gear prep, and back of stage access</td>
</tr>
<tr>
<td>Box Office Size</td>
<td>200 SF</td>
</tr>
<tr>
<td>Total Venue Size</td>
<td>Other notable spaces include a coat room at roughly 56 SF, a kitchen ~225 SF, 2 sound booths at roughly ~64 SF apiece</td>
</tr>
</tbody>
</table>

**Summary**

Overall, the venues have many similarities in design, materials and performer type. They are built for durability, using rugged materials (brick, steel, concrete), building systems exposed (and often painted black), and acoustical treatments installed in consideration of neighbors. Aesthetics are not always a top priority, but perhaps that’s okay for spaces that are often used with low lighting, or focused lighting.
Literature Review

Acoustics

Acoustics Introduction
At this point, it is evident the building type will include spaces for live music. Therefore, some information on acoustics is helpful. The field of acoustics is a widely studied one. However, the sustainability of acoustical materials is not. Sustainability is a complex term, and is one that will be discussed in the following section. This section will discuss the ways in which sound reacts against and with chosen materials.

Sound affects the hearing population, the hard-of-hearing, and the non-hearing. Scientifically, sound is comprised of waves, created by vibrations. Therefore, sound is something that cannot only be heard, but something that can be felt. Because of this, it is important to understand how sound affects the use of a space. Different spaces have different functions, and therefore have different acoustic requirements. A concert hall for example may require sound to travel far, but an office space can be more productive with sound staying isolated.

Because of the nature of how sound behaves in the environment, it will also be important to understand the placement of materials when they behave with sound, and this will also be explored. Rooms of different shapes will behave and sound differently. Sound waves bounce off of the surfaces they come into contact with, so the exact angle of a surface affects what direction the sound waves travel after they have come into contact with the surfaces, as well as how users of a space will hear or feel the sound being generated in that space. Rounded surfaces around a user will create an entirely different “soundscape” than if that same user was in a space with four straight, flat walls and flat flooring and ceiling surfaces.

While research on material properties and spatial configurations of these materials is clearly important, it is also important to consider sustainability characteristics such as recyclability and embodied energy of these products and materials. Sustainable design practices must consider where materials come from, and how their use can make an impact. These impacts can show up at a variety of life stages of the material, whether that is in the initial extraction phase, manufacturing, use, or even the end of life in recycling or discard.

Alternative Sustainable Acoustic Materials

“A Novel Sound Absorber With Recycled Fibers Coming From End of Life Tires” The article discusses a possible solution and use for end of life tires. Around the world, there is a large quantity of waste tires, mostly due to their short lifetime. The article suggests shredding these tires to create a fibrous material, which can then be used as a sound absorbing material. This creates a use for a waste material. It has been in acoustical knowledge that “fibrous material increases sound absorption
The Movement | Matthew J Burke

coefficient$^{14}$ of a material.

The process to make this material is shredding the tires to a fluff, which creates fibers with a thickness of 20-30 nanometers. The end result is a mixture of tire ingredients, which includes both textile and metal fibers. This “fluff,” or batt-like material has an open pore structure. “When a sound wave strikes a porous sound absorber, the sound wave causes the fibers of the absorbing material to vibrate. This vibration causes tiny amounts of heat due to the friction and thus the sound absorption is accomplished by way of energy to heat conversion,”$^{14}$ Thus, this may be an important factor to consider for the thesis project. Since sound absorption can actually be an energy conversion process that generates heat, the chosen materials to work with must be able to tolerate this (minimal) influx of heat.

The results found by the article suggested a couple solutions to use the material. One method was to make a more rigid version, which coupled a resin with the shredded tires. This method however decreased sound absorption qualities of the original material. Nonetheless, a rigid version presents its own opportunities and benefits in workability. The second method layered the batts of insulation, which was successful at sound absorption of lower frequencies of 0-4000 Hz (normal hearing range is about 20-20,000 Hz)$^{14}$.

While the article suggests a sustainable solution for the end-of-life use of tires, it is clearly a solution that requires a full-scale industrial process. Such a process can be energy intensive to carry out. Regardless, it appears that a batt-like material comprised of shredded tires could be a feasible solution to produce a sound-absorbing sustainable material. It creates a use for a waste material, thereby decreasing (or replacing) a need for virgin materials.

“Sustainable Acoustic Absorbers From the Biomass”$^{15}$ The study presented was conducted in the UK. It looked at biomass materials that could be used as sound absorbers. The more prominent materials researched in the article are whole straw, and reed. They are looked at for the possibility of using them to mitigate sound levels coming from highways. In this regard, they would be used outdoors predominately.

Reed and straw are ideal for this application because they are materials that have already proven to be durable and long lasting when subjected to extreme environmental conditions. A thatched reed roof for example can have a lifespan of 40-60 years. As suggested in the previous article, porous materials are good at absorbing sound, and a straw or reed layered batt can be porous$^{15}$.

Other materials considered in the article include wool, flax, and hemp. Wool batt is already in use in acoustic applications, placed within stud walls as a sound...
The only issue is that presently wool tends to be more of a by-product of sheep that are farmed for their meat. Hemp is more commonly used in animal bedding, and thus could be a cheaper alternative material for sound absorption.

The materials discussed have a wide range of thicknesses, ranging from 13 to more than 200 nanometers. As presented in the previous article, smaller diameter fiber batt is more capable in sound absorption, especially when compacted. Therefore, some of the later suggested materials such as wool, hemp, and flax may be better suited, and are already in use in such applications. However, there is a downside to the materials examined. They can be prone to fungal attacks, and may present a fire risk, unless treated with chemicals. However, treating them with chemicals then requires special considerations when they come to the end of life.

In connection to the previous article, the materials discussed here do offer up feasible solutions as sound absorbing materials. The solutions here however don’t necessarily require large-scale industrial processes; they can be acquired from traditional farming methods. It also offers some insight in looking at old materials in a new way.

**Sustainability in the Urban Environment**

“Acoustic Sustainability in Urban Residential Areas”

The study presented in this article was conducted in the UK. Its central focus is on noise pollution in urban environments, however it takes a broader focus, looking at culture, and not necessarily a single material for acoustic sound absorbing characteristics. It does however point out that “little attention has been paid to the sustainability and environmental impacts of various acoustics-related materials and building elements,” therefore suggesting that this is a field in need of and offering great opportunities for (future) research.

In the urban environment, there is a high density of buildings. These are constructed with hard materials such as steel, stone, concrete, and brick, and stretch many stories high. “The number of stories is relevant to the urban sound environment, in terms of appropriate distance between noise sources and buildings, as well as sound propagation in street canyons,”. However, there are many urban environments across the globe. The authors point out that different cultures have different tolerances to annoyances, such as sound and noise levels.

In a portion of the article, the authors discuss sustainable energy, and how they are related to acoustics. The sustainable energy source of interest is that of wind-farms. Wind farms can produce some noise pollution, particularly in the low end of the frequency spectrum. Lower frequencies tend more to be felt than heard.
disturbing both the hearing, and non-hearing populations. As windmills increase in height from 10 to 46 meters, the noise level can increase in the range of 10-20 decibels. To put this in perspective, normal conversation at about 3 feet is in the range of 60-65 decibels, and a typical concert is 110-120 decibels.

Perhaps the most important point that can be taken from this article is that sustainability is a regional and local phenomenon. As different cultures have different tolerances to things like noise pollution, so must the solutions be as varied. The urban environment is a naturally loud one. Newer, sustainable energy sources are not without their faults. These are all things that must be taken into consideration when designing.

Acoustics Summary
The connecting thread between all the pieces examined is the need for sustainable solutions to acoustical problems. Sustainability is a difficult to define term, but is one that must be understood as we design for the future. It is a cultural, regional, and local problem, and one that must have cultural, regional, and local solutions. There is no single answer.

Looking at materials in new ways, such as end of life tires as an acoustic absorbing material, could be a more universal solution, or at least one in the developing world, where this is a vast supply of waste. Biomass solutions can also be a feasible option, at least in places where it is easy, or practical to grow and farm such choices as wool, flax, straw, reed, and animals such as sheep. Our future energy sources need to also be taken into consideration, not only for their productivity, effectiveness, and embodied energy, but also for their downfalls. This can include rare materials used in PV arrays, metals used in the magnets of wind turbines, or even the radioactive materials in nuclear power plants. These energy sources especially need to be considered in their placement and proximity to urban centers.
Hydropower Introduction

Hydropower is an energy generation method that mankind has understood for hundreds of years. Hydropower has been adapted to both large scale, and small scale uses, from the enormous Three Gorges Dam in China, to simple backyard, stream sized hydropower systems. The proposed thesis aims to implement hydropower technology within the final building design.

There are many threads to study on the feasibility of a micro hydropower system implemented in a building’s storm water drainage system. First, a building’s overall form would be important to consider. One with a smaller footprint would have a smaller roof, and vice versa. What would be the minimum collection area for rainwater needed? How large, or small would the drainage pipe need to be? How many stories, or what would the minimum height need to be to create adequate head to create enough pressure in such a system? Would more stories/height introduce opportunities for multiple instances of hydropower generators?

The use of a building would also be important to consider. Different types of buildings have different energy requirements. For example, an industrial lab building would use far more energy than a single family home. This will be important to consider. Nonetheless, moving forward in the 21st century, it is important to always search for ways to reduce energy consumption.

Weather is an incredibly variable phenomenon, and one that affects every geographic location differently. A basic understanding of the local climate will be necessary for this project. A city such as Saint Albans, Vermont sees its fair share of rain, but it certainly doesn’t rain every day of the year. With this consideration, energy storage would also likely be very important to the success of the proposed system. This may take the form of a large water cistern, a large battery bank, or even some combination of the two.

Small-Scale Hydropower

“Determining Optimum Location and Capacity for Micro Hydropower Plants in Lorestan Province in Iran”

The research was conducted on determining ideal locations for micro hydropower installations in Iran. It concentrated on a mountainous region, thereby taking advantage of natural streams, and abundant precipitation generated from colliding weather fronts. The region of Lorestan, Iran contains 3,000 possible areas for in-stream micro hydropower systems. Also, due to the mountainous region, there is significant potential for larger head heights. In the scenarios studied in this region of Iran, the micro hydropower plants would pay themselves off within a year, “provided that the power plant is operated at rated capacity around the clock”.

Furthermore, this type of turbine system has a lifetime of about 50 years, with minimal maintenance. Another important insight garnered by the research is the potential for “chained”
Power plants with micro hydropower systems.

“It may be possible to build serial power plants where the water flows from one power plant to another via canals. In this system, it is only for the first power plant that a diversionary dam is constructed. The electricity generated by all the power plants in the series can be consolidated in parallel. Therefore, such power plants reduce energy production costs and increase economic efficiency”.

Knowledge of in-stream hydropower systems is crucial for the design of in-pipe micro hydropower systems. Much can be learned from in-stream solutions. For example, greater head heights can be easily achieved in buildings as they contain more and more stories. A building that takes advantage of micro hydropower could be ideal for a mountainous region, or near one, as there is more likelihood for precipitation. Other insights include water storage before release, to control the flow of water and energy generation as needed. Last but not least, there is potential for a “chained” system, particularly in a high-rise application, when a micro hydropower system could include several turbines at different heights within a building.

“The Diversity of Hydropower Projects”

Hydropower is an energy generation method that can be easily scaled; it “is based on a simple process, taking advantage of the kinetic energy freed by falling water.” The article discusses a range of hydropower plants, from small to large systems, systems that use reservoirs, systems that provide a base or peak load, small streams to large rivers, and systems that use pumped storage. Systems that use reservoirs are capable of storing large amounts of energy, and releasing a more constant flow, however they also create the most impacts from altering stream/river flows and sizes at different points. The article suggests pumped storage is not the most ideal, as it is not efficient. Pumped storage systems only ever regain about 65-75% of the energy consumed pumping the water once it is finally released.

A couple points of interest can be gained from this article. First, a reservoir style system for in-pipe micro hydropower is almost always necessary to control the flow of water for energy generation. However, it does have structural implications on a building. Second, the article makes the point “electricity can not be stored, unlike energy sources such as wood, petrol, or gas.”. Electricity is a fleeting thing. Of course energy can be stored in batteries, but batteries are not 100% efficient. Fortunately, in an in-pipe micro hydropower system, energy would be stored in a water cistern before its release, thereby retaining 100% of its potential.

The last important piece from the article
Literature Review

Hydropower

is that pumped storage placed before the in-pipe micro hydropower turbine would not be ideal since it loses so much of the generated energy. In-pipe micro hydropower is not working with anything large like gigawatts, or terawatts, but rather on the micro scale of watts, and kilowatts. An energy loss is significant on this smaller scale. However, storage placed after the energy generating turbine for reuse of the water would be acceptable. Water in most buildings is pumped to the upper stories already anyway.

Optimal Installation of Small Hydropower Plant – A Review

This article discusses the benefits of hydropower systems on a small scale. Hydropower is one of the oldest forms of energy to mankind, and furthermore “hydropower on a small scale is one of the most effective energy technologies”\textsuperscript{20}. Energy and development are closely intertwined. In a world with so many developing countries, it is an important technology type to keep in mind. Pico hydropower schemes have been used for remote, off grid rural electrification for years. The cost is lower than fossil fuels generators, as well as wind and PV generation methods. Hydropower is highly efficient, with many 20th century plants still operating at 80-90% efficiency.

The article also suggests “dams can be used to prevent floods by creating reservoirs that should be emptied ahead of the rainy season. The level difference and water releases from the reservoir can be used to generate power”\textsuperscript{20}.

Conclusions helpful to an in-pipe micro hydropower system are that hydropower on a micro scale is highly effective, and ideal for developing regions of the planet. Systems are cheaper to install than other clean energy sources such as wind or PV, and of course better for the environment than a fossil fuel combustion energy generation system. Lastly, there are benefits to water storage within such a system. Water storage controls the release of storm water to storm water systems, allowing it to be released at non-peak times. And, it generates electricity when water is released.

Cost Analysis of Pump as Turbine for Pico Hydropower Plants – A Case Study

This article discusses benefits to small-scale hydropower systems, and downfalls to large scale. Large hydropower plants face long construction time frames, create ecological changes in their vicinity, lose energy in transmission from their remote locations to the areas where the power is actually consumed, and often submerge large tracts of land underwater where valuable forests, or underground mineral resources may exist. Micro hydropower projects however are free from all of these mentioned issues\textsuperscript{21}.

A focus of the research presented was using pumps as turbines, or essentially running a pump in reverse to create energy. Efficiency is low, at around
60%, however pumps are cheaper than conventional turbines, and may make them more cost effective for small-scale hydropower”.

Applicable points from the article that could be adapted to in-pipe micro hydropower is that there are minimal environmental impacts, and fast construction times. They can be placed where the power is consumed, and not long distances away allowing the power supply to degrade in transmission. Furthermore, a pump could be used in place of a turbine to lower costs.

**Human Behavior**


This study concentrates on bathing patterns and water consumption from bathing only. Bathing accounts for the largest consumption of water in residences. In a study performed in Australia, the average consumption of a collection of two hundred households, containing an average of 2.6 persons, over a two-week period, was 335.9L per day per household. However, there are a number of factors that can influence shower end use consumption, such as individuals’ attitudes (mentioned previously), household makeup, and socio-demographic characteristics. This study did accede that “the use of efficient showerhead fixtures can result in significant reductions in this shower end use consumption,” therefore showing evidence behind the LEED guideline. But, it may be obvious, the larger the household, the more water is consumed. And stereotypically, the more females, and the more teenagers in a household, relates to increased water use.

Furthermore, “a high proportion of shower end use consumption is hot water, any conservation of shower water, has a flow-on energy and GHG conservation benefit,”. The more shower times can be reduced, the more energy can be saved in water heating. This is perhaps the most relevant piece of information from the article. Resource consumption from showering is about more than fresh water usage; it is about energy consumption. If people can strive to consume less water in their daily routines, they are inevitably also conserving energy.

“Alarming Visual Display Monitors Affecting Shower End Use Water and Energy Conservation in Australian Residential Households”

A third study, also conducted in Australia took a different approach to attempt to lower water usage. This included the installation of water usage visual displays in 44 of 151 homes. The displays proved helpful, because the homes with the installed meters showed a 27% reduction in water usage, particularly in showering. The meters also had a 1.65-year payback for the device in the savings it allowed on water expenditure.”
Conclusions
Visual, easily understood metering in homes could be applied to water usage to encourage less consumption. But perhaps it could also be applied to energy consumption. While it’s true that buildings are already metered, they are largely just for utility companies to assess consumption and generate a bill. They are not easily understood by a layperson. This is an area building systems can be improved to encourage decreased energy and water consumption.
Form Case Study

Three case studies were conducted with a specific focus on building form. The focus for the first two examples was to find buildings that collected water with a unique roof form. The 3rd example referenced was to find buildings that utilized curvilinear forms, both in plan, and the 3rd dimension.

The Magney House

The Magney house was designed by architect Glenn Murcutt in the early 1980's. The house is located in New South Wales, along the coast line. The design was to capture Northern light, and to capture water for drinking and heating of the residence by use of a curvilinear roof form. The roof directs water to a collection channel.

Fort Belvoir Community Hospital

The Fort Belvoir Hospital is a large complex located in Fort Belvoir, Virginia. The facility is 1.3 million square feet, and has achieved LEED Gold status. The building is symmetrical in form, comprised of 2 wings creating a “V” shape. Each wing has a set of opposing curvilinear roof forms which direct rainwater into central courtyard collecting tanks. The tanks are located underground, and can hold a combined total of 160,000 gallons of water, which is reused for irrigation, and toilet flushing. The design was carried out by HDR and Dewberry Architects/Engineers.
Form Case Study

Bart Prince

Bart Prince is an American architect. His designs are unique, driven by the closely held practice principle of “form follows function.” His design provided inspiration in its distinctive form, often using strong, curvilinear shapes. This architectural case study did not have to do with water collection; it was simply an exploration of curvilinear building forms.
Design Process

To begin the discussion on the design process, a brief summary of the findings so far will be presented. Great architecture comes from the synthesis of many, many pieces of information. The information gathered so far includes:

- Information on acoustics
- Information on hydropower
- The location for the project
- The climate of the location
- The needs of the community for the proposed project
- A demographic background on the chosen community
- A history of the chosen city and town
- A Visual summary of existing building stock of the chosen city and town
- A financial feasibility study for the building type
- Building type case studies on concert venues
- Form case studies

From this gathered information, a theme can be pulled which will inspire the entire project. The thesis statement is as follows:

“To create an entertainment hotspot for downtown Saint Albans, Vermont that embodies the concept of ‘movement’ through sound, water, and urban development”

Designing a concert venue stems from my own passion for music. Music is a creative outlet, a hobby, and for some a lifeskill. My goal was to introduce a venue for my hometown as an opportunity to share my passion.

Saint Albans is a land rich area pushing for a consolidated developed footprint. The first step was to look for an appropriate site; one that would not destroy anything historical, develop an underused parcel, and have opportunity for high pedestrian traffic.

In combining the sustainable technology chosen, a larger building became more ideal for its feasibility. Furthermore, a larger building could create more opportunities for education, and business.

The goal is to create a landmark building situated at the entrance to the downtown. The reasoning is to draw more people, and business into the downtown core of Saint Albans. Presently, most people leave the community for entertainment. There needs to be a reason to keep residents in town, and to draw people from the surrounding area.
Before designing the building, it is important to consider how its site will affect its design. The site chosen is a small lot, surrounded by a much larger underutilized parking lot. The topography is a gentle slope up from Main Street, which will be designated as the “front” side. Over the width of the site, the land goes up 3 feet in elevation, making building access something to consider in design.

**Orientation**
Designating the Main Street side of the site as the front side presents some immediate issues. First, any people accessing the site by car will be forced to park in the “back” or sides. Second, the Main Street side of the building is the Western side, meaning glazing on this side could result in solar heat gain in the afternoon.

**Dual Entry**
There is existing parking at both the Northern and Southern side of the building. Entrances will be required at each of these sides. This allows the lobby and public space to have presence at both ends of the building.

**Public vs. Private**
The building type is one that has two different types of users. First, are the general public, the paying customers which support the business. Access will be needed along prominent street frontages, and multiple entrances to the performance halls, since there will be many people. Second, are the performers themselves. They require more private access for undisturbed entry and exit, and loading in of large equipment. These two types of access and building users will be split in where they enter the building on the site.

**Exterior vs. Interior**
Although Saint Albans, Vermont is a cold climate, opportunities for both indoor and outdoor activities will be good for business. Bringing people outside has potential for larger crowds, since they are not hindered by the square footage of a room. Situated along Main Street and sitting in a large parking lot, there is opportunity for street festivals. A dual purpose stage is to be added into the design: this is a stage that can be used for indoor or outdoor events. This gives new life to the underused parking lot, and makes opportunity for surrounding businesses to be more prosperous.
Site Strategy
The Design

Program

The program of the building was created from knowledge gained from the building type case studies, Time Saver Standards, and personal experience. The space needs are as follows:

Main Hall ........................................... 1,250 SF
Main Stage .......................................... 150 SF
Main Bar ............................................ 300 SF
Main Tech Booth .................................... 64 SF
Hall 2 ................................................... 750 SF
Stage 2 ............................................... 90 SF
Bar 2 .................................................... 100 SF
Tech Booth 2 ........................................ 64 SF
Hall 3 .................................................... 400 SF
Stage 3 ................................................ 75 SF
Tech Booth 3 ........................................ 64 SF
Restrooms ........................................... 237 SF (min)
Dressing Room ..................................... 400 SF (min)
Loading ............................................... 500 SF
Entry / Lobby ........................................ 750 SF
Office / Administration .......................... 400 SF (min)
Classroom / Flex .................................. 600 SF
10 Rehearsal Spaces .............................. 2,400 SF

Subtotal = 8,594 SF

+ Mechanical Factor (8%) = 9,281 SF
+ Circulation Factor (18%) = 10,952 SF

Some of these spaces can be combined while others cannot. Some sizes are generous, while others are a little small. Some can exist within others. For example, the tech booths and bars can be absorbed into the hall sizes. A single set of restrooms, while allowable by code, is not convenient to building users. Dressing rooms are a luxury, and can thus become smaller or bigger with ease and as deemed appropriate.

Design Vocabulary

A design vocabulary can serve as a sort of parti, or guiding principles when planning spaces, and designing the buildings form. The words chosen are as follows: movement, flow, energy, flexibility, repetition, and oscillation.

Movement was chosen because of the 3 focal points behind the design. Movement will be present because of the building type. Sound is movement. What we perceive as sound is the air literally pushing against us, echoing in our ears, and translated to sound by our brains. It is impossible to make sound or music without moving. The building will showcase the movement of water through itself. Water already moves through every building, but this building will showcase it, and take advantage of the energy in its movement. Lastly, redeveloping this parcel pushes forward the City’s Master Plan, and desire to move away from suburban development, creating a walkable destination, and creating a City landmark.

Flow was chosen because of the use of water within the building. It was also chosen to inspire the circulation patterns of building users.
The Design

Energy was chosen because of both the hydropower and sound in the building. The hydropower system will help to offset grid dependence in the building by generating immediately usable energy. Removing dependence from the grid offsets greenhouse gas emissions, and thus unnecessary consumption of non-renewable energy sources. Energy was also chosen to reflect the energy that’s in a musical performance. A live performance can captivate an audience, make them feel emotion, and energize them.

Flexibility is a principle that can inspire the venues business plan. A building containing many spaces which can be used for different purposes is more flexible, and thus more adaptable to customers needs.

Repetition goes hand in hand with flexibility. Having multiple versions of a single space allows for multiple users, and multiple different uses, catering to different types of user groups.

Oscillation can also be likened to flexibility and repetition. It is the nature of something changing and reverting back. It represents opposites, duality, and an ability to serve two purposes.

Orthogonal versus Curvilinear
The building presents the dichotomy between orthogonal and curvilinear. The spaces to be occupied by users are orthogonal, while the circulation to get from space to space is largely curvilinear. The reason behind this is driven by the word movement.

People
The people or building users will represent movement in plan. The users are what give the building energy and life, and their movement from space to space will make the building used. The goal is to make this evident from both the exterior and interior of the building, to people inside, and people outside at the street. This is evident in the offset, opposite oscillating balconies which run between performance halls and rehearsal studios, and which are adjacent to the buildings large curtain glass wall.

Public vs. Private
The nature of the different building users are what dictate a need of public versus private access, and usable spaces. The front (Main Street) side of the building is the public side, containing main entrances. The Northern side and rear (East) of the building house entrances for private building users (musicians and staff), segregating the two entry and exit streams. The circulation within the building reflects this. Public circulation is at the front of the building, while there is private circulation running along the rear (or Eastern) side.

Main and Secondary Halls
There is a further hierarchy in the circulation space. This is most evident at the third level of the building, the rehearsal level. There is a public
The Design

circulation balcony at the front (or Western) side of the building, which allows (secured) access to interior circulation for rehearsal and classroom spaces.

Balconies and Views
The balconies oscillate opposite each other to provide differing views of the 3 story lobby atrium. This allows building users different experiences at different points in the building. Furthermore, the differently heighted round windows allow unique views.

Shapes and Movement
The curvilinear circulation of the building is inspired by nature (let’s call it biomimicry). They are inspired by the shape of waves, which is moving water. It is to represent the flow of people moving through the building.
**Hydropower Design**

The music venue will implement a new technology: the use of an in-pipe micro-hydropower system. The system will take advantage of the water that is already moving through it in its stormwater system, but storing it and channeling it for optimum pressure. Water will be collected at the roof and stored in two 1,000 gallon storage tanks (2 smaller tanks to decrease structural demand) at the 4th story until enough volume has accumulated (>1,500 gallons), and then released through a 2" pipe down through the lobby at a rate of 26.1 GPM. After passing through the energy generating turbine, the water will then be re-stored in a basement cistern for reuse as toilet flushing. There will be water-metering and energy-metering visual displays in the lobby. Computer controls for the system would be in the 4th story storage room. Water released can also be timed with weather patterns; it can be released at non-peak (non-storm) times.

**Precedent**

Through research conducted in the 2013-2014 school year, an in-pipe micro hydropower system was found to be feasible for a large, institutional size building. A system like this is a clean energy system that can reduce dependency on fossil fuel resources.

"Microhydropower is economically beneficial because aside from short term costs, there are no fees for additional inputs to the system thereafter (when using grey water). No fuel needs to be purchased, no additional water needs to be bought, and it reduces the amount of electricity drawn from the grid. Therefore, the only additional costs will be operation, repair, and maintenance, which are a relatively small portion of overall costs, 1-6% of the total. In addition, the installation of micro-hydropower could significantly reduce electrical bills."

The research included the study and design of the implementation of a micro hydropower system in a new facility on the SUNY Binghamton campus. The systems design included the use of rainwater harvesting and collection at the roof level. Once the water was channeled through the hydropower system, it could then be reused for grey-water purposes. Calculations showed that a 10,000 SF roof that was 52' above the ground had the potential to generate ~19.6 kWh with a 75% efficient turbine under peak rain conditions. Furthermore, overall building water consumption could be reduced by as much as 80%.

**Education**

This system will serve for energy generation, water conservation, and as a water feature. It will symbolize movement, and energy, and can be an educational tool to teach about hydropower technology. The building will also take use of low flow water fixtures, and visual water metering displays in the restrooms.
Water and Hydropower

Consumption and Offset
The energy offset for the hydropower system is substantial. The assumptions made for these calculations are average rainfall of 3.14” per month throughout the year, an average number of rain events at 13 per month, and 75% turbine efficiency (many hydropower systems are at 80%+ efficient)²⁹.

Energy²⁹

\[
3.14" / 13 = 0.241538" \text{ per event}
\]

\[
0.241538" \times 10,440 \text{SF roof} = 1,566.12 \text{ gallons per event}
\]

\[
1,566.12 \text{ gallons} / 60 \text{ minutes} = 26.1 \text{ GPM}
\]

\[
26.1 \text{ GPM} \times 42' \text{ head} \times 75\% \text{ efficiency} / 3960 (\text{constant})
\]

=0.208 horsepower per minute

\[
0.208 \text{ HP} \times 746 \text{ W/HP (conversion factor)}
\]

= 155.17 watts per minute

\[
155.17 \text{ w} / 1,000 = .15517 \text{ kW per minute}
\]

\[
.15517 \text{ kw/min} \times 60 = 9.3 \text{ kW per hour when the system is run}
\]

To find out how much energy this would actually offset for this building type, data was gathered from the US EIA. For public assembly use, buildings that fall between 10,000-100,000 SF consume 11.2kWH per SF per year³⁰.

\[
11.2 \text{kWh} / 365 \text{ days} = 0.03 \text{kWh/SF/day}
\]

\[
0.03 \text{kWh/SF/day} / 24 \text{ hours}
\]

=0.0012kWh/SF/hour

\[
0.0012 \text{kWh/SF/hour} \times 20,180 \text{ SF (building total)}
\]

=25.8kWh

9.3kWh

25.8kWh

36% energy offset when system is run

Water³¹
Based on DEC water design standards, this building type consumes the following quantities of water³¹:

- Concert halls = 5 gallons/day/person
- Office = 15 gallons/day/employee
- Bar = 20 gallons/day/person

<table>
<thead>
<tr>
<th></th>
<th>Office</th>
<th>Halls</th>
<th>Bars</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>184</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>10 (security)</td>
<td>94</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>361</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

15 x 15 = 225 gal/day peak H2O
361 x 5 = 1,805 gal/day peak H2O
20 x 20 = 400 gal/day peak H2O

=2,430 gallons/day peak H2O usage
Water and Hydropower

2,430 gallons/day peak H2O usage

20,359 monthly gallon average income from rain

2,430 gpd x 30 = 72,900 peak average gallon use per month

20,359.6 gallons
72,900 gallons =27.9% water offset per month

With graywater reuse, the building can offset 27.9% of its water needs.

Above, a 3D printed turbine
Materials, Colors, and Construction

Wall Structures
The curtain walls of the building will be a double curtain wall. The purpose here is for thermal retention, as this region of the world is a heating load dominated one. A double curtain wall adds an insulating air gap in the middle, and more panes of glass with insulating gas gaps between interior space and the outdoors.

The remainder of the exterior walls will be super insulated, at 1'-6" thick. They will contain the structure (steel columns) within them. The walls will be composed of a double steel stud wall (2x6), infilled with 2 layers rigid insulation, and batt insulation between. This will serve for both thermal insulation, as well as acoustic insulation. The walls will provide an impressive R70, and be punctured by minimal fenestration. The fenestration is made up of a collection of small round windows, at a diameter of 5', and will be triple pane. This window type is accompanied by a second type; a single strip window, at 4’ in height, running along the “front,” or Western side of the building.

Acoustics
The walls between the rehearsal spaces and performance halls will serve to cut down on as much sound transmission as possible. This will be achieved through a double steel stud wall (2x4), filled with batt insulation, for it provides the most sound absorption. This method was chosen over solid mass walls because it allows for the use of sustainable (renewable) acoustic materials and can be more effective across the frequency range: “if, however, a barrier is constructed of two separate layers without rigid interconnection, its performance exceeds the calculated transmission loss based on mass alone... The net result is an improvement in performance through the frequency range”.[2] Furthermore, the unique assembly of a double stud wall infilled with insulation allows for increased effectiveness: “performance can be improved still further by filling the void with porous, sound-absorbent material”.[2]

Interior
Interior materials will be simple. Floors will be exposed concrete, for durability and ease of cleaning. The structure will be exposed steel, but protected with appropriate fire resistant sprays and dark in color. Spray resistance will be applied to the underside of decks, and beams. Columns will be wrapped in layers of Type X gypsum. Mechanical, electrical, and plumbing systems will be exposed as well, and painted dark.
Materials, Colors, and Construction

Aesthetics
The building will be clad in an aluminum panel system of size 2\’x 6\’. The aluminum panels are for aesthetics only. Their color pattern of differing tints of gray and red have been pulled from the surrounding building stock. The surrounding building stock is largely brick and masonry, made up of grays and reds. The pattern on the building is made up a repeating cluster of 6 red tints, which moves (statically) across the facade of the building. Infilled between these patches, are randomized gray shades. The red patches serve as the focal point, and are another representation of movement in the design.
This section details features and decisions made on the actual design of the building. It includes a walk through, descriptions of the facades, building form, and wall construction.

**Site Plan**
The site plan demonstrates building access at different points. At the North West and Southwest, there is public entry. The main entry at the South Western side faces the downtown area. These entries are accessible from the sidewalk that runs along Main Street which sits 3' below the building’s main floor. A ramp with a slope smaller than 1/12 connects the sidewalk to the building’s level.

A goal for the design is to promote walkability in the downtown, and therefore the Main Entry is faced towards the downtown, an easy <10 minute walk from many popular restaurants, bars, and stores in the downtown. The site also sits fairly close to the train station (<0.4 miles), so it can be accessed via public transportation.

The loading dock area is separated from the public entries, due to it’s more private nature and needs.

**First Floor Plan**
Moving inside the building, the public access and circulation at the front (Western) side of the building is evident. The lobby hallway oscillates allowing visitors different views of the building at different points, as well as different views of the hydropower feature.

The oscillating shape is inspired by a wave (water), taking inspiration from nature. In the South West corner is the turbine, along with large visual displays to educate building visitors on the technology. Running along the rear (East) side of the building is private circulation for employees and entertainers. Also at the back of the Main Hall and Main Stage is a large opening wall. This is for a dual use stage; it can be used for interior or exterior performances.

The stage in this hall (as well as Hall 2, and Hall 3 on the upper levels) sits 3'-6" above the Main Hall floor.

The Bar in the Main Hall sits 1'-0" above the Main Hall floor; this is to segregate it for ease of alcohol control. This bar is handicap accessible; a ramp leads up to it (this is not the case for the bar in Hall 2).

Also at this level, some of the acoustic treatments are visible. The walls of the Main Hall are covered in thick curtains to absorb some of the sound produced.

**Second Floor Plan**
On the second floor, there are two additional music halls of differing (and slightly smaller than the main hall) size. These are offset from the main hall. This is because it’s easier (and cheaper) to make a double wall than a double floor to acoustically separate the spaces. These halls also feature acoustic treatments, and both public and private access. A balcony at the
West side allows visitors new views of the lobby below, along with the hydropower feature in the South West corner. On this floor (and all 3 other floors) something unique is displayed in the restrooms. They contain visual metering displays so people can be conscious of how much water and energy they are using.

**Third Floor Plan**
The third floor offers a second balcony with different views of the space below. This balcony oscillates at a slightly different rate than the balcony at the second floor, an additional measure to offer different views. This is also a public circulation space, segregated from an interior circulation to the private rehearsal halls. At this level there is also movement in the orthogonal spaces. They are cantilevered, slightly offset from the floors below.

**Fourth Floor Plan**
The fourth story presents an opportunity for seasonally usable outdoor space. It is covered by the roof above, allowing for mild protection from the elements. It has been designated as a possible live-music space. Live music could be placed in the South East corner of this floor, to allow the roof above to naturally amplify the sound towards the audience, and surrounding town/city. The fourth story also houses the upper water storage tanks for the micro-hydropower system.

**Basement**
The basement contains the majority of the mechanical equipment for the building. It also contains the lower water storage tank for the micro-hydropower system.

**West Elevation**
This elevation offers a glimpse of the exterior of the building. There are large expanses of fenestration on this side of the building. This is the side that faces Main Street. This is to allow views in and out, so people can see the energy and movement of the people inside the building. While a large Western glass wall could be a concern for increasing unwanted solar heat gain, this is a building time that is primarily in use at night and therefore not affected by it.

At the third story, a strip window is used, taking a cue from the areas architecture vernacular. This facade begins to showcase a moving pattern.

**South Elevation**
The moving pattern is made up of aluminum panels, sized at 2'x6'. There is a block of 6 red tints that move across the facade. In between is a randomized collection of gray panels, to offset and help highlight the red blocks. These are colors that were pulled from the surrounding architecture. They are colors from existing masonry in the City.

**East Elevation**
This elevation displays movement in the 3rd dimension. The walls are punctuated
Design Drawings

by small round windows, each at differing heights. The round window is an architectural feature “borrowed” from the City’s existing architectural vernacular. This elevation also shows the wall that opens for the dual purpose stage inside the building.

North Elevation
At the bottom middle and left in this view are the different access points. The public access at the right is much larger, and glazed, while the private access at the bottom middle and left is much smaller in scale, and not glazed.

Roof Plan
The roof plan shows that the overall roof shape is quite simple in plan. Towards the lower right corner is the drain for rooftop storm water. The drain is connected to water storage tanks on the 4th story.

Section a-a
This view offers a glimpse of the micro-hydroelectric power system. Highlighted in red are the 4th story storage tanks, pipes down through the lobby to the turbine, and then down to the basement storage tank.

Wall Sections
Wall construction for this facility is thick. The walls encase the structural system, which is steel column and beam. The exterior walls act as super insulated walls. The wall is comprised of 2 sets of 2x6 steel studs infilled with 5" of rigid insulation each, sandwiching 3" of wool batt insulation. This assembly is sandwiched by interior and exterior sheathing, with the aluminum panel system fastened to the exterior sheathing. This wall assembly serves for both acoustic and thermal insulation, and offers an impressive R70 value.

The interior wall section shows a wall type that would be used between performance halls, or rehearsal spaces within the building envelope. This wall type is a double wall type as well. It contains two sets of 2x4 steel studs containing 4" of wool batt insulation each, and both sandwiching an additional 3" of wool batt insulation in the middle. Fibrous insulations are better for acoustic absorbance. This assembly is sandwiched between layers of gypsum sheathing.

Renderings
The renderings offer perspective views from the street, and show the full scale of the roof structure. The roof cantilevers out 10' from all sides of the building (this would require a variance). This is to increase total water collection area.
Roof Construction:
- Standing Metal Seam Roof
- Water Proof Membrane
- Steel Decking
- Structural Steel
- 12" Rigid Insulation Inset; R60
- 1" Metal Furring
- 2" Drywall Finish

- Structural Steel Purlins
- Structural Steel Beams

Aluminum Soffit

- Strainer

12" Drain

- 8" Drains

H2O Storage Tank, 1,000 Gallons Each

Roof Section

2'

4'
Exterior Wall Plan

- 2 x 5 Metal Stud @ 16” OC
- 1/2” Gypsum
- 2” Rigid Insulation
- 3” Batt Insulation
- 2x6 Metal Stud @ 16” OC
- Mastic Tape
- Exterior Sheathing
- Moisture Barrier
- 1” Air Gap
- 2” x 6” Aluminum Panel Cladding

Interior Wall Plan

- 1/2” Gypsum
- 4” Batt Insulation
- 3” Batt Insulation
- 4” Batt Insulation
- 2x4 Metal Stud @ 16” OC
- 3/8” Gypsum
- 2x4 Metal Stud @ 16” OC
## Design Development

### Zoning

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Criteria</th>
<th>Site &amp; Building Conditions</th>
<th>Code Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Business I Zoning District</strong></td>
<td>Allowed Uses: assembly, bar, education, entertainment</td>
<td>Uses: assembly, bar, education, entertainment</td>
<td>Article 3, Section 304, Permitted and Conditional Uses (table)</td>
</tr>
<tr>
<td><strong>Minimum Lot Size</strong></td>
<td>2,000 SF</td>
<td>8,000 SF</td>
<td>Article 3, Section 306, Dimensional Requirements (table)</td>
</tr>
<tr>
<td><strong>Minimum Width</strong></td>
<td>20 feet</td>
<td>Smallest = 71'</td>
<td>Article 3, Section 306, Dimensional Requirements (table)</td>
</tr>
<tr>
<td><strong>Setbacks</strong></td>
<td>0' allowed 10' max</td>
<td>8' largest</td>
<td>Article 3, Section 306, Dimensional Requirements (table)</td>
</tr>
<tr>
<td><strong>Max Building Height</strong></td>
<td>60'; 72' with special permissions</td>
<td>70' (special permissions required, but within range)</td>
<td>Article 3, Section 306, Dimensional Requirements (table)</td>
</tr>
<tr>
<td><strong>Min Building Height</strong></td>
<td>2 Stories</td>
<td>4 Stories</td>
<td>Article 5, Section 513, “Height Regulations,” A.1 &amp; D</td>
</tr>
<tr>
<td><strong>Max Lot Coverage</strong></td>
<td>100%</td>
<td>68%</td>
<td>Article 3, Section 306, Dimensional Requirements (table)</td>
</tr>
<tr>
<td><strong>Parking</strong></td>
<td>Not required on lots less than 1 acre</td>
<td>No new parking provided</td>
<td>Article 3, Section 307, “Additional Provisions,” B.2</td>
</tr>
</tbody>
</table>
## Design Development

### Codes - Use & Occupancy

<table>
<thead>
<tr>
<th>Group</th>
<th>Space / Room</th>
<th>Construction Type</th>
<th>Code Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly, A-1 (1)</td>
<td>Live Music Halls</td>
<td>Type 1B</td>
<td>(1) Chapter 3, Section 303.2 (2) Chapter 5, Section 503, Table 503</td>
</tr>
<tr>
<td>Assembly, A-3 (1)</td>
<td>Rehearsal, and classroom spaces</td>
<td>Type 1B</td>
<td>(1) Chapter 3, Section 303.2 (2) Chapter 5, Section 503, Table 503</td>
</tr>
<tr>
<td>Business, B (1)</td>
<td>Office</td>
<td>Type 1B</td>
<td>(1) Chapter 3, Section 304.1 (2) Chapter 5, Section 503, Table 503</td>
</tr>
</tbody>
</table>

### Item

<table>
<thead>
<tr>
<th>Decision</th>
<th>Code Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1B Construction</td>
<td>Chapter 5, Section 503, Table 503</td>
</tr>
<tr>
<td>The office space (group B) can be classified as an accessory occupancy because it is less than 10% of the total building area. Therefore, no separation is necessary.</td>
<td>Chapter 5, Section 508.2.1 &amp; Section 508.2.4</td>
</tr>
<tr>
<td>Automatic sprinklers are required</td>
<td>Chapter 9, Section 903.2</td>
</tr>
<tr>
<td>Firewalls allowed ratings of 0 to 3 hours depending on location and use in building.</td>
<td>Chapter 6, Section 601, Table 601 Fire Resistance Rating Requirements for Building Elements</td>
</tr>
<tr>
<td>Min. snow load design = 40psf</td>
<td>VT 2012 Fire &amp; Building Safety Code, Section 1608.2.1</td>
</tr>
</tbody>
</table>

*International Building Code 2012 Edition*
### Codes - Fire Separations

<table>
<thead>
<tr>
<th>Item</th>
<th>Decision</th>
<th>Code Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columns</td>
<td>3 hour fire rated wrap</td>
<td>Chapter 7, Section 704.2</td>
</tr>
<tr>
<td>Exterior Walls</td>
<td>0 hours</td>
<td>Chapter 6, Section 602, Table 602</td>
</tr>
<tr>
<td>Curtain Walls</td>
<td>0 hours</td>
<td>Chapter 7, Section 705.8, Table 705.8</td>
</tr>
<tr>
<td>Shaft Walls</td>
<td>2 hour fire barrier</td>
<td>Chapter 7, Section 701.1, Table 706.4</td>
</tr>
<tr>
<td>Stair Towers</td>
<td>2 hour fire barrier</td>
<td>Chapter 7, Section 707.3.1</td>
</tr>
<tr>
<td>Atriums</td>
<td>1 hour wall</td>
<td>Chapter 7, Section 707.3.6</td>
</tr>
<tr>
<td>Gypsum - 5/8”, Type X</td>
<td>3 layers = 3 hour rating</td>
<td>Chapter 7, Section 721, Table 721.1</td>
</tr>
<tr>
<td>Gypsum - 1/2”</td>
<td>4 layers = 2 hour rating</td>
<td>Chapter 7, Section 721, Table 721.1</td>
</tr>
</tbody>
</table>

*International Building Code 2012 Edition*
### Design Development

#### Egress - Egress Corridors

<table>
<thead>
<tr>
<th>Zone</th>
<th>Size SF</th>
<th>Net Ppl</th>
<th>Code Reference</th>
<th>Width Min.</th>
<th>Code Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor 4</td>
<td>3,403</td>
<td>227</td>
<td>for Assembly with Chairs &amp; Tables, the net occupancy is SF/15; see IBC Chapter 10, Table 1004.1.2</td>
<td>45.5&quot;</td>
<td>IBC Chapter 10, Section 1005.3.2, egress width per occupant factor = 0.2&quot;</td>
</tr>
<tr>
<td>Floor 3 Rehearsal Space</td>
<td>1,877</td>
<td>94</td>
<td>for Educational Classroom Space, the net occupancy is SF/20; see IBC Chapter 10, Table 1004.1.2</td>
<td>32&quot;</td>
<td>IBC Chapter 10, Section 1005.3.2, egress width per occupant factor = 0.2&quot;</td>
</tr>
<tr>
<td>Floor 3 Lounge Space</td>
<td>460</td>
<td>66</td>
<td>for Assembly with Unfixed Chairs, the net occupancy is SF/7; see IBC Chapter 10, Table 1004.1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor 2 Hall 2</td>
<td>667</td>
<td>134</td>
<td>for Assembly - Standing Room only, the net occupancy is SF/5; see IBC Chapter 10, Table 1004.1.2</td>
<td>36.4&quot;</td>
<td>IBC Chapter 10, Section 1005.3.2, egress width per occupant factor = 0.2&quot;</td>
</tr>
<tr>
<td>Floor 2 Stage 2</td>
<td>210</td>
<td>14</td>
<td>for Stages &amp; Platforms, the net occupancy is SF/15; see IBC Chapter 10, Table 1004.1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor 2 Bar 2</td>
<td>167</td>
<td>34</td>
<td>for Assembly - Standing Room only, the net occupancy is SF/5; see IBC Chapter 10, Table 1004.1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor 2 Hall 3</td>
<td>503</td>
<td>101</td>
<td>for Assembly - Standing Room only, the net occupancy is SF/5; see IBC Chapter 10, Table 1004.1.2</td>
<td>22.2&quot;</td>
<td>IBC Chapter 10, Section 1005.3.2, egress width per occupant factor = 0.2&quot;</td>
</tr>
<tr>
<td>Floor 2 Stage 3</td>
<td>144</td>
<td>10</td>
<td>for Stages &amp; Platforms, the net occupancy is SF/15; see IBC Chapter 10, Table 1004.1.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*IBC Chapter 10, Table 1018.2, minimum corridor width is 44".*
## Design Development

### Egress - Egress Corridors (cont’d)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Size SF</th>
<th>Net Ppl</th>
<th>Code Reference</th>
<th>Width Min.</th>
<th>Code Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor 1 Main Hall</td>
<td>917</td>
<td>184</td>
<td>for Assembly - Standing Room only, the net occupancy is SF/5; see IBC Chapter 10, Table 1004.1.2</td>
<td>50.2&quot;</td>
<td></td>
</tr>
<tr>
<td>Floor 1 Main Stage</td>
<td>416</td>
<td>28</td>
<td>for Stages &amp; Platforms, the net occupancy is SF/15; see IBC Chapter 10, Table 1004.1.2</td>
<td>50.2&quot;</td>
<td></td>
</tr>
<tr>
<td>Floor 1 Bar 1</td>
<td>191</td>
<td>39</td>
<td>for Assembly - Standing Room only, the net occupancy is SF/5; see IBC Chapter 10, Table 1004.1.2</td>
<td>50.2&quot;</td>
<td></td>
</tr>
</tbody>
</table>

IBC Chapter 10, Table 1018.2, minimum corridor width is 44". Smallest corridor in this zone is 60". This floor is up to code.

### Egress - Egress Distances

<table>
<thead>
<tr>
<th>Zone</th>
<th>Furthest Distance</th>
<th>Allowed Distance</th>
<th>Code Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor 4</td>
<td>70'</td>
<td>250'</td>
<td></td>
</tr>
<tr>
<td>Floor 3</td>
<td>90'</td>
<td>250'</td>
<td>IBC Table 1016.2, 34</td>
</tr>
<tr>
<td>Floor 2</td>
<td>70'</td>
<td>250'</td>
<td></td>
</tr>
<tr>
<td>Floor 1</td>
<td>60'</td>
<td>250'</td>
<td></td>
</tr>
</tbody>
</table>

Allowable egress distance for sprinklered space with use of Assembly is 250'. Furthest egress distance is 90'. The building is up to code.
## Design Development

### Egress - Stairs

<table>
<thead>
<tr>
<th>Zone</th>
<th>People</th>
<th>Width Need</th>
<th>Code Reference</th>
<th>Min. Width</th>
<th>Code Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor 4</td>
<td>227</td>
<td>68.1&quot;</td>
<td>occupancy load x means of egress capacity factor 0.3&quot; per occupant; IBC Chapter 10, Section 1005.3.1</td>
<td>44&quot;</td>
<td>IBC Chapter 10, Section 1009.4</td>
</tr>
<tr>
<td>Floor 3</td>
<td>160</td>
<td>48&quot;</td>
<td>occupancy load x means of egress capacity factor 0.3&quot; per occupant; IBC Chapter 10, Section 1005.3.1</td>
<td>44&quot;</td>
<td>IBC Chapter 10, Section 1009.4</td>
</tr>
<tr>
<td>Floor 2</td>
<td>309</td>
<td>92.7&quot;</td>
<td>occupancy load x means of egress capacity factor 0.3&quot; per occupant; IBC Chapter 10, Section 1005.3.1</td>
<td>44&quot;</td>
<td>IBC Chapter 10, Section 1009.4</td>
</tr>
</tbody>
</table>

Total stair width is 96". Stairs at this floor is up to code.
Floor 4 Egress Plan

Floor 4 Egress Zone

3403 SF

Seasonal Rooftop Restaurant & Performance Space

408 SF

Sink Water Metering

408 SF

2/8" = 1'-0"
Design Development

Accessibility
The building is designed to be ADA compliant. A list of all ADA measures present in the building is as follows:

- Doors at 3’ width
- Exterior ramps 1/12
- Interior ramp (Bar 1 only) 1/12
- Corridors at 5’ width
- ADA stall in each bathroom
- 5’ clear in all bathrooms
- Elevator available
- Area of Refuge - South stair
Design Development

**MEP**
The following pages show the Mechanical, Electrical, and Plumbing schematic drawings for the building.

The building will receive natural gas, water supply, and electric, all of which are available, city provided services at Main Street (and already delivered to the existing plaza, and bank building at 133 N. Main Street). Natural gas will be dispersed to the main HVAC system, as well as 4th story rooftop space for outdoor heating fixtures. Otherwise, heating will be forced air.

Outgoing services will be sanitary waste and storm water, both of which will exit to Main Street as well.
Floor 2 MEP Plan

- Natural Gas
- Water Supply
- Electric
- Circuit Panel
- Sanitary Waste
- Storm Water

Key:
- Circuit Panel
- Water Supply
- Electric
- Sanitary Waste
- Storm Water

Legend:
- 1/8" = 1'-0"

Floor 2 MEP Plan

- Loading Dock
- Stage 2
- Floor 2
- Bar 2
- Stage 3
- Hall 3
- Men's Restroom
- Women's Restroom
- Balcony
- Area of Refuge
- Sink Water Metering
- Storm Water
- Natural Gas
- Water Supply
- Electric

Scale: 1/8" = 1'-0"
Building MEP Section
Design Development

**Sustainability**
The design calls for a number of sustainable technology systems, and design considerations. This section will summarize them.

**Water & Energy**
Stormwater is collected at the roof, and used to generate energy in the building. This system offsets ~36% of the building’s energy demand when it is run. This happens roughly 13 times a month for 1 hour on average. Some of this water is the result of snowmelt on the roof (precipitation during the colder months). Water is collected in the basement and reused for toilet flushing within the building. This reuse offsets ~36% of the building’s total peak water demand on average. The fourth story tanks are sized to hold 33% more water than the average rain event; this is to prevent loss from overflow. The basement cistern is sized the same.

Within the bathrooms of the building are water and energy metering. This is to encourage building users to consume less water, and therefore less energy. Water can be conserved by being turned off while soap is applied, and through the use of low flow fixtures. Energy can be conserved by using cold, or even lukewarm water instead of hot water for hand cleansing.

**Acoustics**
The performance halls and the rehearsal spaces of the building utilize sustainable, renewable sound absorbing materials to control and reduce sound transmission from room to room. The insulation within interior walls is designated as wool batt insulation, a renewable material.

**Super Insulation**
A majority of the building’s exterior walls are punctured sparingly, with small fenestration. Furthermore, the exterior walls use a double wall for increased thickness and insulation opportunities to keep heat in the building, because the climate is largely a heating degree day one. The exterior walls achieve an impressive R-70. This is within super-insulated building standards for exterior walls.

The western facade contains a large amount of glazing. However, it is a double curtain wall, that is semi reflective. Double curtain walls perform better than single curtain walls, and the reflective characteristics are ideal in reflecting unwanted solar heat gain during the summer months.

The roof of the building also strives for a super-insulated quality. It contains 10” total of rigid insulation, and 4” of batt insulation, adding up to an R-72 insulation value. This is also within standards for super-insulated building roofing.
Design Development

Structures
The following pages will be composed of the structural analysis for the building.

Dead Load = 100 #/SF
Live Load = 10 #/SF
Snow Load = 40 #/SF
Design Development

**BEAM A**

\[ W = (100 + 10 + 4) \frac{1}{2} = 750 \text{ lb/ft} \]

\[ \sum F_y = 0 = -750(13.5) + R_D \]

\[ R_D = 10,125 \text{ lb} \]

\[ M_{\text{max}} = 10,125(13.5) \frac{1}{2} = 681,343.75 \text{ ft-lb} \]

\[ S = \frac{M/f}{f_0} = \frac{681,343.75}{22,000} \frac{\text{ft-lb}}{\text{in}^2} \approx 37.29 \text{ in}^3 \]

- W/B x 4'H W\&L S/office

**BEAM B**

\[ W = (100 + 10 + 4) \frac{1}{2} = 750 \text{ lb/ft} \]

\[ \sum M_{RD} = 0 = -750(27)(13.5) + 27 \times R_E \]

\[ R_E = 10,125 \text{ lb} \]

\[ \sum F_y = 0 = 10,125 - 750(27) + R_D \]

\[ R_D = 10,125 \text{ lb} \]

\[ M_{\text{max}} = 10,125(3.5) \frac{1}{2} = 681,343.75 \text{ ft-lb} \]

\[ S = \frac{M/f}{f_0} = \frac{681,343.75}{22,000} \frac{\text{ft-lb}}{\text{in}^2} \approx 37.28 \text{ in}^3 \]

- W/B x 4'H W\&L S/office
Design Development

**Beam C**

\[ W = (15\times 5) = 750 \text{ lb/ft} \]
\[ \Sigma F_y = 0 = -750 (9.5) + R_E \]
\[ R_E = 7125 \text{ lb} \]
\[ M_{\text{MAX}} = 7125 (9.5)(\frac{1}{2}) = 33,843.75 \text{ ft-lb} \]
\[ S = \frac{M_{\text{MAX}}}{21,000 \text{ psi}} = \frac{33,843.75 \text{ ft-lb}}{21,000 \text{ psi}} = 1.62 \text{ in}^3 \]
\[ \rightarrow W/8 \times 24 \text{ will suffice} \]

**Beam D**

\[ A + B \]
\[ R_{A2} \]
\[ \Sigma F_y = 0 = -10,125 - 10,125 + R_{A2} \]
\[ R_{A2} = 20,250 \text{ lb} \]
\[ M_{\text{MAX}} = 20,250 (10) = 202,500 \text{ ft-lb} \]
\[ S = \frac{M_{\text{MAX}}}{21,000 \text{ psi}} = \frac{202,500 \text{ ft-lb}}{21,000 \text{ psi}} = 9.63 \text{ in}^3 \]
\[ \rightarrow W/12 \times 87 \text{ will suffice} \]
Design Development

**BEAM E**

\[ \begin{align*}
\Sigma F_y &= 0 = -10 + 125 - 7125 + A_3 \\
A_3 &= 17,250 \text{ ft-lb}
\end{align*} \]

\[ M_{\text{MAX}} = 17,250 (10) = 172,500 \text{ ft-lb} \]

\[ S = \frac{M_{\text{MAX}}}{f} = \frac{172,500 \text{ ft-lb}}{22,000 \text{ psi}} \]

\[ = 7.911 \text{ in}^3 \rightarrow W10 \times 88 \text{ will suffice} \]

**BEAM F**

\[ \begin{align*}
W &= 15 \times (5 + 6.5) = 1725 \text{ lb/ft} \\
\Sigma F_y &= 0 = -1725 (13.5) + A_2 \\
A_2 &= 23,287.5 \text{ lb} \\
M_{\text{MAX}} &= 23,287.5 (13.5) (\frac{1}{2}) = 273,152.81 \text{ ft-lb} \\
S = \frac{M_{\text{MAX}}}{f} &= \frac{273,152.81 \text{ ft-lb}}{22,000 \text{ psi}} \\
&= 12.43 \text{ in}^3 \rightarrow \text{ W11H x 99 will suffice} \]
Design Development

**BEAM G**

\[ W = 15 \cdot (5 + 6.5) = 1725 \text{ lb/ft} \]

\[ M_{A_2} = -1725 (27) (13.5) + 27A_3 \]

\[ A_3 = 23,287.5 \text{ lb} \]

\[ \Sigma F_y = 0 = -1725(27) + 23,287.5 + A_2 \]

\[ A_2 = 23,287.5 \text{ lb} \]

\[ M_{MAX} = 23,287.5 (13.5)(3) = 157,190.6 \text{ ft-lb} \]

\[ s = \frac{M}{F} = \frac{(157,190.6 \text{ ft-lb}) (44 \text{ in/ft})}{22,000 \text{ psi}} \]

\[ = 85.74 \text{ in} \rightarrow W/12 \times 65 \text{ WILL SUFFICE} \]

**BEAM H**

\[ W = 15 \cdot (5 + 6.5) = 1725 \text{ lb/ft} \]

\[ A_3 = 16,387.5 \text{ lb} \]

\[ M_{MAX} = 16,387.5 (9.5) (1/2) = 77,840.6 \text{ ft-lb} \]

\[ s = \frac{M}{F} = \frac{(77,840.6 \text{ ft-lb}) (12 \text{ in/ft})}{22,000 \text{ psi}} \]

\[ = 42.46 \text{ in}^3 \]

\[ \rightarrow W/10 \times 45 \text{ WILL SUFFICE} \]
**Design Development**

**Beam 1**

\[ W = 150 \text{ (lbs)} = 1950 \text{ #/LF} \]

\[ \sum F_y = 0 = -1950(13.5) + R_j \]

\[ R_j = 26,325 \text{ #} \]

\[ M_{max} = 26,325(13.5)(5) = 177,693,75 \text{ FT} \# \]

\[ S = \frac{M}{I} = \frac{177,693,75 \text{ FT}\#}{(1211/\text{ft})} \]

\[ = 90,911 \text{ in}^3 \rightarrow W10 \times 88 \text{ will suffice} \]

**Beam K**

\[ W = 150 \text{ (lbs)} = 1750 \text{ #/LF} \]

\[ \sum M_{Rj} = -27(1950)(18.5) + 27R_L \]

\[ 0 = -710,775 + 27R_L \]

\[ R_L = 26,325 \text{ #} \]

\[ \sum F_y = 0 = 26,325 - 1950(27) + R_j \]

\[ R_j = 26,325 \text{ #} \]

\[ M_{max} = 26,325(13.5)(5) = 177,693,75 \text{ FT} \# \]

\[ S = \frac{M}{I} = \frac{177,693,75 \text{ FT}\#}{(1211/\text{ft})} \]

\[ = 90,911 \text{ in}^3 \rightarrow W10 \times 88 \text{ will suffice} \]
Design Development

\[ \sum M_{A_2} = 0 = -13(21325+2625)+26B_2 \]
\[ B_2 = 26,325 \# \]
\[ \sum F_y = 0 = 26,325 - (26325+2625) + A_2 \]
\[ A_2 = 26,325 \]
\[ M_{MAX} = 26325(13) = 342,225 \text{ FT} \# \]
\[ S = \frac{M_{/f}}{22,000 \text{ PSI}} = \frac{342225 \text{ FT} \#}{22,000 \text{ PSI}} = 15,961.1 \text{ in}^3 \]
\[ W11 \times 120 \text{ WILL SUFFICE} \]

\[ \sum F_y = 0 = R_L - 1950(9.5) \]
\[ R_L = 18525 \# \]
\[ M_{MAX} = 18525(9.5)(12) = 237,975 \text{ FT} \# \]
\[ S = \frac{M_{/f}}{22,000 \text{ PSI}} = \frac{237975 \text{ FT} \#}{22,000 \text{ PSI}} = 10,767.5 \text{ in}^3 \]
\[ W10 \times 45 \text{ WILL SUFFICE} \]
Design Development

\[
\Sigma M_{A3} = 13(26,325 + 18,525) + 26B_3
\]

\[
\delta = 5831,05 + 26B_3
\]

\[
B_3 = 22,425 \text{ ft}^3
\]

\[
\Sigma F_y = 6 = 26,325 - 18,525 + 22,425 + A_3
\]

\[
A_3 = 22,425 \text{ ft}^3
\]

\[
M_{MAX} = 22,425 \times 13 \div 2 \times 1,525 \text{ ft} \cdot \text{ft}^3
\]

\[
S = M/f = \frac{29,1,525 \text{ ft} \cdot \text{ft}^3}{22,000 \text{ psi}}
\]

\[
= 139.01 \text{ in}^2 \rightarrow W14 \times 109 \text{ will suffice}
\]

\[
\Sigma F_y = 0 = -192,5(13.5) + B_2
\]

\[
B_2 = 25,183.75 \text{ ft}^3
\]

\[
M_{MAX} = 258(18.75)(13.5)(12) = 174,276 \text{ ft} \cdot \text{ft}^3
\]

\[
S = M/f = \frac{174,276 \text{ ft} \cdot \text{ft}^3}{22,000 \text{ psi}}
\]

\[
= 75.06 \text{ in}^3 \rightarrow W30 \times 8 \text{ will suffice}
\]
Design Development

\[
W = 150 (6.5 + 6.25) = 1125 \text{ lb/ft}
\]

\[
\Sigma M_{B_2} = 27B_3 - 27(12.5)(13.5) = 27B_3 - 7971 \text{ in-lb}
\]

\[
B_3 = 25818.75 \text{ ft}
\]

\[
\Sigma f_y = 25818.75 - 1912.5(27) + B_2
\]

\[
B_2 = 25818.75 \text{ ft}
\]

\[
M_{max} = 25818.75 (13.5)(12) = 174276.6 \text{ ft-lb}
\]

\[
S = \frac{M}{f} = \frac{174276.6}{22000} \approx 7.9 \text{ in}^3
\]

W/10 x 38 will suffice

\[
W = 150 (6.5 + 6.25) = 1125 \text{ lb/ft}
\]

\[
\Sigma f_y = 0 = B_3 - 7.5(12.5)
\]

\[
B_3 = 18168.75 \text{ ft}
\]

\[
M_{max} = 18168.75 (9.5)(12) = 86301.6 \text{ ft-lb}
\]

\[
S = \frac{M}{f} = \frac{86301.6}{22000} \approx 3.9 \text{ in}^3
\]

W/10 x 45 will suffice
**Design Development**

\[ W = 15 \times (0.25) = 4.375 \text{ lb/ft} \]

\[ Z_{fy} = 0 = 93.75 \times 13.5 + R \]

\[ R = 12,560.25 \text{ lb} \]

\[ M_{max} = 12 \times 56.25 \times 13.5 \times 12 = 854,297.7 \text{ ft-lb} \]

\[ S = \frac{M}{f} = \frac{854,297.7 \text{ ft-lb}}{22,000 \text{ psi}} = 38,672.3 \text{ in}^3 \rightarrow W/10 \times 45 \text{ will suffice} \]

\[ W = 15 \times (0.25) = 4.375 \text{ lb/ft} \]

\[ Z_{fy} = 0 = 93.75 \times R + 27 \]

\[ 0 = 27 - 341.718 + 75 \]

\[ 7 = 12,560.25 \text{ lb} \]

\[ Z_{fy} = 0 = 12 \times 56.25 \times 937.5 + 27 \]

\[ R = 12,560.25 \text{ lb} \]

\[ M_{max} = 12 \times 56.25 \times 13.5 \times 12 = 854,297.7 \text{ ft-lb} \]

\[ S = \frac{M}{f} = \frac{854,297.7 \text{ ft-lb}}{22,000 \text{ psi}} = 38,672.3 \text{ in}^3 \rightarrow W/10 \times 45 \text{ will suffice} \]
Design Development

\[ \Sigma F_y = 0 = B_2 - (12,560,25 + 890,25) \]
\[ B_2 = 25,912.5 \, \text{ft}^2 \]
\[ M_{\text{max}} = 258,12.5 \cdot 12.5 = 3,160,464.25 \, \text{ft}^3 \]
\[ S = \frac{M_{\text{pf}}}{F} = \frac{(3,160,464.25 \, \text{ft}^3)(12 \, \text{in/ft})}{22,000 \, \text{psi}} \]
\[ = 172,613 \, \text{in}^3 \rightarrow W14 \times 12.0 \ \text{will suffice} \]

\[ W = 15 \times (6.25) = 93.75 \, \text{ft/lf} \]
\[ \Sigma F_y = 0 = -93.75(1.5) + T \]
\[ T = 2900.25 \, \text{ft} \]
\[ M_{\text{max}} = 870,625 \cdot 15 \cdot (25) = 4,230,477 \, \text{ft}^3 \]
\[ S = \frac{M_{\text{pf}}}{F} = \frac{(4,230,477 \, \text{ft}^3)(12 \, \text{in/ft})}{22,000 \, \text{psi}} \]
\[ = 23,08 \, \text{in}^3 \rightarrow W16 \times 26 \ \text{will suffice} \]

\[ \Sigma F_y = 0 = B_3 - (12,560,25 + 890,25) \]
\[ B_3 = 21,562.5 \, \text{ft}^2 \]
\[ M_{\text{max}} = 215,625 \cdot 9.5 = 2,048,937.75 \, \text{ft}^3 \]
\[ S = \frac{M_{\text{pf}}}{F} = \frac{(2,048,937.75 \, \text{ft}^3)(12 \, \text{in/ft})}{22,000 \, \text{psi}} \]
\[ = 111.73 \, \text{in}^3 \rightarrow W12 \times 8.7 \ \text{will suffice} \]
Design Development

**COLUMNs - HOLDING UP ROOT**

\[ A_2 \quad 20250 + 23287.5 + 23287.5 + 26325 = 93150 \, \# \]

\[ A_3 \quad 23287.5 + 17250 + 16387.5 + 22425 = 79350 \, \# \]

\[ B_2 \quad 25818.75 + 26325 + 25818.75 + 35025 = 103127.5 \, \# \]

\[ B_3 \quad 25818.75 + 24925 + 12687.5 + 21562.5 = 87975 \, \# \]

\[ A_2 \quad 93150 / 22000 = 4.24 \, \text{in}^2 \rightarrow W_12 \times 19 \quad (266\text{#}) \]

\[ A_3 \quad 79350 / 22000 = 3.61 \, \text{in}^2 \rightarrow W_12 \times 14 \quad (196\text{#}) \]

\[ B_2 \quad 103127.5 / 22000 = 4.69 \, \text{in}^2 \rightarrow W_12 \times 19 \quad (266\text{#}) \]

\[ B_3 \quad 87975 / 22000 = 3.99 \, \text{in}^2 \rightarrow W_12 \times 14 \quad (196\text{#}) \]

**FLOOR 4 FRAMING PLAN**

![Diagram of floor 4 framing plan with labels for columns and loads.](image)
Design Development

**Beam A**

\[ W = (100 \times 10) (2.5) = 275 \text{ lb/ft} \]

\[ \Sigma F_y = 0 = -385(13.5) + D \]

\[ D = 5197.5 \text{ lb} \]

\[ M_{\text{max}} = 5197.5 (13.5) (\frac{1}{2}) = 35083.1 \text{ ft-lb} \]

\[ S = \frac{M}{f} = \frac{35083.1 \text{ ft-lb}}{22000 \text{ psi}} = 19.1 \text{ in}^3 \rightarrow W8 \times 24 \]

**Beam B**

\[ W = (100 + 40) (2.5) = 275 \text{ lb/ft} \]

\[ \Sigma M_0 = -385(27)(13.5) = 27E \]

\[ 27E = 100332.5 \]

\[ E = 3519.75 \text{ lb} \]

\[ \Sigma F_y = 0 = 5177.5 - 385(27) + D \]

\[ D = 5197.5 \text{ lb} \]

\[ M_{\text{max}} = 5197.5 (13.5) (\frac{1}{2}) = 35083.1 \text{ ft-lb} \]

\[ S = \frac{M}{f} = \frac{35083.1 \text{ ft-lb}}{22000 \text{ psi}} = 19.1 \text{ in}^3 \rightarrow W8 \times 24 \]

**Beam C**

\[ W = (100 + 15) (2.5) = 275 \text{ lb/ft} \]

\[ \Sigma M_0 = -385(15)(13.5) = 27E \]

\[ 27E = 100332.5 \]

\[ E = 3567.5 \text{ lb} \]

\[ \Sigma F_y = 0 = -385(15) \]

\[ E = 3657.5 \text{ lb} \]

\[ M_{\text{max}} = 3657.5 (15)(\frac{1}{2}) = 17573.1 \text{ ft-lb} \]

\[ S = \frac{M}{f} = \frac{17573.1 \text{ ft-lb}}{22000 \text{ psi}} = 9.48 \text{ in}^3 \rightarrow W8 \times 15 \]
Design Development

**BEAM D**

\[
\Sigma F_y = 0 = -5197.5 - 5197.5 + A_2 \\
A_2 = 10,395 \text{ lb} \\
M_{\text{max}} = 10,395 \times 5 = 51,975 \text{ ft-lb} \\
\]

**BEAM E**

\[
\Sigma F_y = 0 = -5197.5 - 3657.5 + A_3 \\
A_3 = 8855 \text{ lb} \\
M_{\text{max}} = 8855 \times 5 = 44,275 \text{ ft-lb} \\
\]

**BEAM F**

\[
W = (10+10) (2.5 + 6.5) = 910 \text{ lb/lf} \\
\Sigma F_y = 0 = -910 (3.5) + A_2 \\
A_2 = 13,365 \text{ lb} \\
M_{\text{max}} = 13,365 \times 13.5 \times \frac{1}{2} = 90,213.75 \text{ ft-lb} \\
S = \frac{M_{\text{max}}}{F} = \frac{90,213.75 \times 121,111}{22,000} \text{ in}^3 = 49.21 \text{ in}^3 \\
\Rightarrow W10 \times 49
\]
Design Development

**BEAM C**

\[ W = (16 + 12) (2.5 + 6.5) = 990 \text{ lb/ft} \]

\[ \Sigma M_{A2} = -990 (2.5)(13.5) + 27 A3 \]

\[ 27 A3 = 3608.5 \]

\[ A3 = 131.365 \text{ in}^2 \]

\[ Z F_Y = 0 = 13365 - 990 (2.5) + A2 \]

\[ A2 = 13365 \text{ in}^2 \]

**BEAM H**

\[ W = (16) (2.5 + 6.5) = 990 \text{ lb/ft} \]

\[ Z F_Y = 0 = A3 - 990 (1.5) \]

\[ A3 = 9405 \text{ in}^2 \]

\[ M_{MAx} = 9405 (1.5) (2) = 44675.75 \text{ ft-lb} \]

\[ S = \frac{44675.75 (1000)}{22600 \text{ psi}} = 9921 \text{ in}^3 \rightarrow W10 \times 49 \]

---

**REMAINDER OF BEAMS IDENTICAL TO ROOF BEAMS**

**COLUMNS HOLDING UP FLOOR 4**

**A2**

\[ 10315 + 13365 + 23287.5 + 26325 = 73,372.5 \text{ lb} \]

\[ 73,372.5 + 93150 + 266 = 166,288.5 \text{ lb} \]

**A3**

\[ 23287.5 + 8855 + 16387.5 + 22925 = 70,955 \text{ lb} \]

\[ 70955 + 79350 + 196 = 159,501 \text{ lb} \]

**B2**

\[ 103275 + 103275 + 266 = 206,816 \text{ lb} \]

**B3**

\[ 87,975 + 87975 + 196 = 176,176 \text{ lb} \]
Floor 3 Framing Plan

Design Development

\[
A2 \quad 160,000 \text{ psi} \div 20,000 \text{ psi} = 7.5 \text{ in}^2 \rightarrow W12 \times 30 (424\#)
\]

\[
A3 \quad 150,000 \text{ psi} \div 20,000 \text{ psi} = 7.5 \text{ in}^2 \rightarrow W12 \times 26 (364\#)
\]

\[
B2 \quad 200,000 \text{ psi} \div 20,000 \text{ psi} = 9.1 \text{ in}^2 \rightarrow W12 \times 35 (490\#)
\]

\[
B3 \quad 175,000 \text{ psi} \div 20,000 \text{ psi} = 8.8 \text{ in}^2 \rightarrow W12 \times 30 (420\#)
\]

DEAD LOAD = 100 #/SF
LIVE LOAD = 100 #/SF
WALL LOAD = 440 #/LF
Design Development

\[ W = (10 + 10) \times (2.5) = 27.5 \text{ kips/LF} \]

\[ Z_{FY} = E = -715(27) = -19,505 \text{ kips-ft} \]

\[ M_{MAX} = 96,525 \times (27) = 2,513,205 \text{ kips-ft} \]

\[ s = \frac{M_{DF}}{L} = \frac{(65154 \times 24)}{12 \times 24} = 35,354 \text{ in}^3 \rightarrow W8 \times 24 \]
Design Development

BEAM D
\[ A + B \]
\[ \downarrow \]
\[ -5 - A_2 \]
\[ Z \text{F}_y = 0 - A_2 - 9652.5 - 9652.5 \]
\[ A_2 = 19305 \# \]
\[ M_{\text{Max}} = 19305(5) = 96525 \text{ft-lb} \]
\[ S = M_{\text{F}} = \frac{(96525 \text{ ft-lb})(12 \text{ in}/\text{ft})}{22000 \text{ psi}} = 5265 \text{ in}^3 \rightarrow W_{10 \times 49} \]

BEAM E
\[ -5 \rightarrow A_3 \]
\[ Z \text{F}_y = 0 = A_3 - 9652.5 - 6792.5 \]
\[ A_3 = 16445 \# \]
\[ M_{\text{Max}} = 16445(5) = 82225 \text{ ft-lb} \]
\[ S = M_{\text{F}} = \frac{(82225 \text{ ft-lb})(12 \text{ in}/\text{ft})}{22000 \text{ psi}} = 4485 \text{ in}^3 \rightarrow W_{10 \times 45} \]

*F_{G,H} IDENTICAL TO FL 4. BEAMS REMAIN IDENTICAL TO ROOF BEAMS*

COLUMNS HOOPING 4TH FLOOR 3+ABOVE
\[ A_2 \]
\[ 13365 + 19305 + 13365 + 260325 = 721360 \# \]
\[ 721360 + 166788.5 + 420 = 239568.5 \# \]

\[ A_3 \]
\[ 13365 + 16445 + 9905 + 22745 = 601650 \# \]
\[ 601650 + 152501 + 320 = 1262561 \# \]

\[ B_2 \]
\[ 103275 + 206816 + 1455 = 310521 \# \]

\[ B_3 \]
\[ 87975 + 17646 + 420 = 264541 \# \]

\[ A_2 \]
\[ 239568.5 \# /2200 \text{ psi} = 10.87 \text{ in}^2 \rightarrow W_{12 \times 40} (560 \#) \]

\[ A_3 \]
\[ 212505 \# /2200 \text{ psi} = 9.66 \text{ in}^2 \rightarrow W_{12 \times 40} (560 \#) \]

\[ B_2 \]
\[ 310521 \# /2200 \text{ psi} = 14.12 \text{ in}^2 \rightarrow W_{12 \times 50} (700 \#) \]

\[ B_3 \]
\[ 264541 \# /2200 \text{ psi} = 12.02 \text{ in}^2 \rightarrow W_{12 \times 45} (630 \#) \]
Design Development

DEAD LOAD = 100 # / SF
LIVE LOAD = 10 # / SF
WALL LOAD = 440 # / LF
**Design Development**

**Beam F**

\[ W = 110 \left(5\right) = 715 \text{#} / \text{LF} \]

\[ \rightarrow 715 + 440 \text{# (WALL)} = 1155 \text{#} / \text{LF} \]

\[ \Sigma F_y = 0 = A_2 - 13.5 \left(1155\right) \]

\[ A_2 = 15.39 \text{#} \]

\[ M_{MAX} = 15592.5 \left(15.5\right) \left(5\right) = 137,504 \text{#} \cdot \text{FT} \]

**Beam G**

\[ W = 110 \left(4\right) = 440 \text{#} / \text{LF} \]

\[ \rightarrow 440 + 440 \text{# (WALL)} = 880 \text{#} / \text{LF} \]

\[ \Sigma M_{A_2} = 0 = 27 \left(880\right) + A_3 \left(27\right) \]

\[ A_3 = 11,880 \text{#} \]

\[ \Sigma F_y = 0 = 11,880 - 27\left(880\right) + A_2 \]

\[ A_2 = 11,880 \text{#} \]

\[ M_{MAX} = 11,880 \left(8.5\right) \left(2\right) = 201,900 \text{#} \cdot \text{FT} \]

**Beam H**

\[ W = 110 \left(6.5\right) = 715 \text{#} / \text{LF} \]

\[ \rightarrow 715 + 440 \text{# (WALL)} = 1155 \text{#} / \text{LF} \]

\[ \Sigma F_y = 0 = A_3 - 9.5 \left(155\right) \]

\[ A_3 = 10,972.5 \text{#} \]

\[ M_{MAX} = 18,972.5 \left(9.5\right) \left(\frac{1}{2}\right) = 521,194 \text{#} \cdot \text{FT} \]
Design Development

\[
\begin{align*}
\text{BEAM R} & : \\
& \quad \downarrow \\
& \quad \leftarrow 12.5 - \\
& S_fy = 0 = 82 - 1265.625 \times 4 \\
& B_2 = 1265.625 \times 4 \\
& M_{\text{max}} = 1265.625 \times 4 \times (12.5) = 15 \times 12 \times 3.1 \text{ ft}^2 \frac{\text{lbf}}{} \\
& S = \frac{M_{\text{max}}}{f_y} = \frac{(15 \times 12 \times 3.1 \text{ ft}^2 \frac{\text{lbf}}{})}{22 \text{ kips}} = 86.3 \text{ in}^3 \rightarrow W14 \times 61 \\
\text{BEAM T} & : \\
& \quad \downarrow \\
& \quad \leftarrow 12.5 - \\
& B_3 = 890 \times 6.25 \times 4 \\
& M_{\text{max}} = 890 \times 6.25 \times 4 \times (12.5) = 11 \times 32.1 \text{ ft}^2 \frac{\text{lbf}}{} \\
& S = \frac{M_{\text{max}}}{f_y} = \frac{(11 \times 32.1 \text{ ft}^2 \frac{\text{lbf}}{})}{22 \text{ kips}} = 60.72 \text{ in}^3 \rightarrow W14 \times 43 \\
* \text{BEAMS T, N, M, P} \text{ IS IDENTICAL TO BEAMS AT A+1 LEVEL} * \\
\text{COLUMNS HOLDING UP R, 1, & 2 + ABOVE} \\
A_2: 15592.5 + 11880 + 17274.8 + 2395.8 + 560 = 289, 875.84 \\
A_2: 1284875.8 \div 2000 = 12.95 \text{ in}^2 \rightarrow W12 \times 45 \text{ (4.3 ft)} \\
A_3: 11880 + 1972.5 + 1371.8 + 2125.05 + 560 = 249, 292.3 \\
A_3: 249, 292.3 \div 2200 = 11.33 \text{ in}^2 \rightarrow W12 \times 45 \text{ (4.30 ft)} \\
B_2: 25918.75 + 14990.2 + 1265.25 + 3105.81 + 706.25 + 364.746.2 \times 16.5 \text{ in}^2 \rightarrow W12 \times 58 \text{ (812 ft)} \\
B_3: 1190.2 + 8906.25 + 18168.75 + 2395.4 + 630 = 363, 336.2 \\
B_3: 363, 336.2 \div 2200 = 16.5 \text{ in}^2 \rightarrow W12 \times 50 \text{ (700 ft)}
\end{align*}
\]
Design Development

**FLOOR 1 FRAMING PLAN**

**Design Details:**
- **Dead Load:** 100 #/LF
- **Live Load:** 10 #/SF
- **Wall Load:** 400 #/LF
Design Development

\[ W = 11.5 \times (6.5) = 7.15 \text{ kN/lf} \]
\[ \rightarrow 7.5 + 4.48 \text{ (wall)} = 11.55 \text{ kN/lf} \]
\[ \Sigma M_{A2} = 0 = -1555(2\theta)(3.3) + 27A3 \]
\[ 27A3 = 420,997.5 \]
\[ A3 = 15,592.5 \text{ lb} \]
\[ \Sigma F_y = 15,592.5 - 1155(2\theta) + A2 \]
\[ A2 = 15,592.5 \text{ lb} \]

*BEAMS F. H. SAME AS BEAMS AT FL 2; REMAINDER SAME AS BEAMS AT ROOF LEVEL*

**COLUMNS HOLDING UP FLOOR 1 ABOVE**

- **A2**: 15,592.5 + 15,592.5 + 26325 + 281487.5 - 63 = 23,780.54 lb
  \[ A2 = 343 \times 15.8 / 22,000 = 15.57 \text{ in}^2 \rightarrow W12 \times 5.5 \]

- **A3**: 15,592.5 + 10972.5 + 22425 + 247292.3 + 63 = 298,912.3 lb
  \[ A3 = 298,912.3 / 22,000 = 13.59 \text{ in}^2 \rightarrow W12 \times 5.0 \]

- **B2**: 105275 + 364746.2 + B12 = 468,833.2 lb
  \[ B2 = 468,833.2 / 22,000 = 21.31 \text{ in}^2 \rightarrow W12 \times 7.9 \]

- **B3**: 87975 + 303336.2 + 760 = 392,011.2 lb
  \[ B3 = 392,011.2 / 22,560 = 17.82 \text{ in}^2 \rightarrow W12 \times 5.5 \]
Design Development

Energy Compliance
The building’s envelope meets energy code compliance for the State of Vermont.

COMcheck Software Version 3.9.2
Envelope Compliance Certificate

2011 Vermont Commercial Building Energy Standards

Section 1: Project Information
Project Type: New Construction
Project Title: Report date: 11/13/14
Construction Site: Owner/Agent: Designer/Contractor:

Section 2: General Information
Building Location (for weather data): Saint Albans, Vermont
Climate Zone: 6a
Building Type for Envelope Requirements: Nonresidential
Vertical Glazing / Wall Area Pct.: 20%
Building Type
Floor Area
Performing arts theater 20695

Section 3: Requirements Checklist
Envelope PASSES: Design 13% better than code.
Climate-Specific Requirements:

<table>
<thead>
<tr>
<th>Component Name/Description</th>
<th>Gross Area or Perimeter</th>
<th>Cavity R-Value</th>
<th>Cont. R-Value</th>
<th>Proposed U-Factor</th>
<th>Budget U-Factor(a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof 1: Metal Building, Standing Seam, Double Insulation Layer with Thermal Blocks</td>
<td>10340</td>
<td>30.0</td>
<td>25.0</td>
<td>0.026</td>
<td>0.049</td>
</tr>
<tr>
<td>Exterior Wall 1: Steel-Framed, 16&quot; o.c.</td>
<td>16392</td>
<td>60.0</td>
<td>9.0</td>
<td>0.031</td>
<td>0.064</td>
</tr>
<tr>
<td>Window 1: Metal Frame with Thermal Break/Triple Pane, Clear, Fixed, SHGC 0.40</td>
<td>3469</td>
<td>---</td>
<td>---</td>
<td>0.150</td>
<td>0.420</td>
</tr>
<tr>
<td>Basement Wall 1: Solid Concrete/12&quot; Thickness, Normal Density, Furring: None, Wall Ht 14.0, Depth B.G. 11.0</td>
<td>3733</td>
<td>---</td>
<td>20.0</td>
<td>0.046</td>
<td>0.085</td>
</tr>
<tr>
<td>Door 1: Upward-acting, sectional</td>
<td>208</td>
<td>---</td>
<td>---</td>
<td>0.150</td>
<td>0.100</td>
</tr>
<tr>
<td>Floor 1: Concrete Floor (over unconditioned space)</td>
<td>5000</td>
<td>---</td>
<td>10.0</td>
<td>0.076</td>
<td>0.064</td>
</tr>
</tbody>
</table>

(a) Budget U-factors are used for software baseline calculations ONLY, and are not code requirements.

Air Leakage, Component Certification, and Vapor Retarder Requirements:

1. Continuous air barrier is provided throughout the building thermal envelope.
2. Air barrier joints and seams are sealed. The joints and seals are securely installed in or on the joint for its entire length.
3. Penetrations of the air barrier and paths of air leakage are caulked, gasketed or otherwise sealed in a manner compatible with the construction materials and location. Joints and seals are sealed in the same manner or taped or covered with a moisture vapor-permeable wrapping material. The joints and seals are securely installed in or on the joint for its entire length.
4. The air barrier is continuous for all assemblies that are the thermal envelope and across the joints and assemblies.
5. Recessed lighting fixtures installed in the building envelope are Type IC rated as meeting ASTM E238, tested to <=2.0 cfm, and are sealed with gasket or caulk.
6. Assemblies of materials and components have an average air leakage <= 0.04 cfm/ft2 or are qualifying materials as per Section 502.4.1.2.2. or are concrete masonry walls coated with one application of block filler and two applications of a paint or sealer coating, or Portland cement/sand parging, stucco or plaster >=1.0 inch thickness.
7. Stairway and shaft vents are provided with Class I motorized dampers with a leakage rate <= 4 cfm/ft2. Dampers are installed with controls so that they are capable of automatically opening upon activation of any fire alarm or the interruption of power to the damper.
Conclusions

In summary, this is a project that pulls knowledge from the fields of acoustics, hydropower, and sustainability. The final design exemplifies the theme of movement through sound, water, and urban development. Its appearance is drastically different from anything in town, achieving a landmark look. It is an entertainment hotspot, providing reason to draw people into the downtown core. It relates to its surrounding context through color, and architectural vernacular. And last, it is a business and building type that the local community already wants.
Resources

Resources


Resources