A Building Analysis of the Worcester Gospel Church

A Major Qualifying Project

Submitted to the Faculty of

Worcester Polytechnic Institute

in partial fulfillment of the requirements for the

Degree in Bachelor of Science

in

Architectural Engineering

and

Civil Engineering

Submitted by:

Cassie Graca

Aaron Kotilainen

Jason Strauss

May 6, 2020

Sponsoring Organization:

Worcester Chinese Gospel Church

Project Advisors:

Professor Steven Van Dessel

Professor Mingjiang Tao

Table of Contents

Abstract

This Major Qualifying Project performed a complete building analysis of the Christian Gospel Church located at 43 Belmont Street in Worcester, Massachusetts. This project entailed a structural, vibration, energy, and envelope analysis of the building. Through findings based on site surveys, photographs, and archive plans, and the above analyses, recommendations were compiled to determine what issues are most pressing and improvements were suggested that could be implemented to make the building more viable in the long term.

Disclaimer

The findings in this report were produced as partial fulfillment for the degree of Bachelor of Science from Worcester Polytechnic Institute. While the findings in this report were produced in good faith, this MQP group (Cassie Graca, Aaron Kotilainen, Jason Strauss) is not responsible for any issues that could arise from the implementation of any recommendations. Any implementation of recommendations suggested by this report must first be verified and approved by a Professional Engineer and installed by qualified professionals.

Capstone Statement

The Christian Gospel Church leadership approached WPI Architectural Engineering faculty with concerns in architectural and structural performance of the church due to age and neglect. The primary focus of this project was to investigate the church structurally and architecturally by means of structural, vibration, envelope, energy, and HVAC analysis. This analysis allows a better understanding of the performance of the church and can therefore determine what required fixes are necessary.

Structural analysis was performed by analyzing all members under ASCE[1], AISC[2], AWC[3], ACI[4], NCMA[5], and IBC[6] specifications for adequacy with current codes. A detailed truss, and buttress analysis was performed to look for weak points in the truss and tension in the wall that could potentially cause failure. A vibration analysis was also performed by analyzing accelerometer data in order to determine the effect of traffic-induced vibrations on the structure of the church. Architectural and envelope analysis was undertaken to determine the building construction and the insulative properties of the envelope components. This was achieved by thorough site surveys and pre-construction plan analysis. Insulative properties were determined by using ASHRAE standards based on our observations of the building construction. Part of this envelope analysis was to determine the source of water infiltration and high humidity levels experienced in the church. This was achieved by installing relative humidity sensors inside of the envelope and attempting to make poke holes in order determine sources of potential water infiltration. An energy analysis was performed by creating a model of the building in the computer

---

[1] American Society of Civil Engineers
[2] American Institute of Steel Construction
[3] American Wood Council
[4] American Concrete Institute
[5] National Concrete Masonry Association
[6] International Building Code

software, *DesignBuilder,* to determine heating and cooling loads utilizing ASHRAE baseline and weather standards. Hand calculations following ASHRAE standards were also performed to verify the results of *DesignBuilder*. This data was then used to determine heating and cooling loads and determine potential heating and cooling options that could be implemented in the church. Parametric analysis within *Designbuilder* was performed to determine the efficacy of potential insulative improvements to the building envelope could be feasibly instituted in order to reduce energy consumption and improve heat loss in the building.

Design and Professional Licensure Statement

The analysis of the Worcester Gospel Church located at 43 Belmont Street in Worcester, MA involved many aspects. Presently there are many envelope issues that the church faces. For the past 11 months, temperature and humidity monitoring has been installed to gain a better understanding of the building environment to obtain a baseline of how the building is functioning. There are gaps and issues with the envelope (roof, windows), resulting in water infiltration and high humidity levels in the church and in spaces behind walls. Finding the source of potential water infiltration and providing suggestions on remedying these issues were a main concern that we analyzed to the best of this group's abilities. The church also faces significant heating and cooling issues annually. Due to the aging 110-year-old stone construction of the church and increasing energy costs, this group aimed to provide suggestions that could be made to improve the building envelope to decrease energy usage and improve heat loss. Additionally, this group aimed to provide suggestions on proper sizing and potential options for upgrading the buildings heating and requirements if a cooling system was to be installed in the future.

A complete structural and vibration analysis of the building was also performed. Due to the age of the church, it was possible that some of the members may not comply with modern building standards. Many of the structural members were likely sized by procedural codes during the building's construction, rather than using analysis to determine the best size. Additionally, computer aided analysis can provide more depth into exactly how specific structural members behave under stress. While there still is a lot of missing information in the building plans, church representatives will have a better understanding about the structural integrity of their church. With the I-290 highway and Route 9 directly adjacent to the church, there was some concern that the traffic-induced vibrations may have been affecting the structure of the church.

Approach Taken

Envelope concerns were addressed by performing an analysis of the existing walls by making poke holes. This was done to determine the existing wall construction, analyze moisture content behind the wall and to make vent holes in the towers for the masonry walls to breathe. A humidity sensor was installed in the air gap of the right towers wall to determine the moisture content in the wall.

Based on plans and pictures, analysis of the wall and roof were undertaken in order to identify potential sources of water infiltration and suggest methods to rectify moisture transport issues. Temperature/relative humidity sensors were installed throughout the church and took readings in regular intervals over a period of 11 months in order to determine environmental issues present in the church. Accelerometers were installed in the towers in 4 axes in order to determine the extent of seismic effects on the structure. Hammerbeam truss construction was analyzed using *MATLAB* as a structural analysis program. All primary structural members in the sanctuary were analyzed for bending, shear, and deflection. The walls were also analyzed at the buttress location for any tension that could potentially cause failure under a seismic event. A vibration analysis was performed by analyzing accelerometer data in order to determine the effect of traffic-induced vibrations on the structure of the church. A complete plan set of the building was created for the building in order to obtain dimensions of the building for both structural and energy analysis. Digital models of the building were created in *DesignBuilder* to determine ASHRAE standards for the building. This was done in order to determine heating and cooling loads. Hand calculations were performed to ASHRAE standards in order to verify the findings determined by *DesignBuilder*. From this information, the church will have a much better idea of the size of the mechanical system needed that could be implemented. Parametric analysis was performed to determine potential insulative improvements to the building envelope could be feasibly instituted in order to improve energy consumption and reduce heat loss in the building.

Professional Licensure Statement

The formal process of acquiring professional engineering licensure is a critical aspect of the engineering fields. Engineers are highly respected members of the professional community and are expected to be highly competent within their fields and display inscrutable ethics. Due to the direct interaction of the public with projects that engineers may be involved with, public health and safety is of critical concern.

An engineer who achieves their PE license has worked in their field long enough to be considered an engineer who can be relied upon to make the right decisions and is held to a higher standard. The process of acquiring a PE license requires one to acquire a Bachelor of Science in an engineering field from an accredited institution. Then they must work under a Professional Engineer for 4 or 5 years depending on the field. Before the time requirement can start in the workplace one must take a “Fundamentals of Engineering” exam or the FE, which shows that the engineer has adequate skills in mathematics, physics, and other technical disciplines to start working to become a PE. After the work experience requirement has been achieved one can then take the Principles and Practice of Engineering (PE) exam which is specific to their chosen field. Once one has achieved that feat in order to maintain licensure, one must continually remain educated within their field by attending conferences.

By acquiring a PE license, it shows to the public that you are a competent and fully vetted member of the engineering field and can be trusted implicitly to make the right decisions to the client and the public at hand. It shows to the profession at hand that you have the experience and knowledge to be trusted in the field and can help lead new generations of engineers. To the individual it proves that you have the determination and willingness to achieve a difficult milestone.[7]

[7] n.d. *National Society of Professional Engineers.* Accessed January 23, 2020. https://www.nspe.org/resources/licensure/why-get-licensed.

1.0 Introduction

The project that this MQP group selected involved a thorough energy, structural, and geotechnical analysis of the Christian Gospel Church, located at 43 Belmont Street in Worcester, MA. The church was built in 1910 as the "Swedish Lutheran Gethsemane Church" and originally served Lutherans of Swedish ancestry in the Worcester area. It was purchased by the Worcester Catholic Diocese in the 1950s and renamed, "Our Lady of Fatima". The church was designed by G. Adolf Johnson, a prominent Architect in the Worcester area around the turn of 20th century who notably designed several buildings on Clark University's campus and other churches in the area.[8] The church currently serves the Chinese population of Worcester. Church leadership approached the WPI Architectural Engineering department with issues the aging building is facing. Besides heating, cooling and energy consumption issues, there are problems with water infiltration into the building envelope and the worsening of fractures in the wall plaster.

[8] "The Life of a Campus: 9 Essays on Clark Buildings Past and Present." Clark University. Accessed January 10, 2020. https://wordpress.clarku.edu/krwilson/files/2012/05/CLU_ARCH-book.pdf.

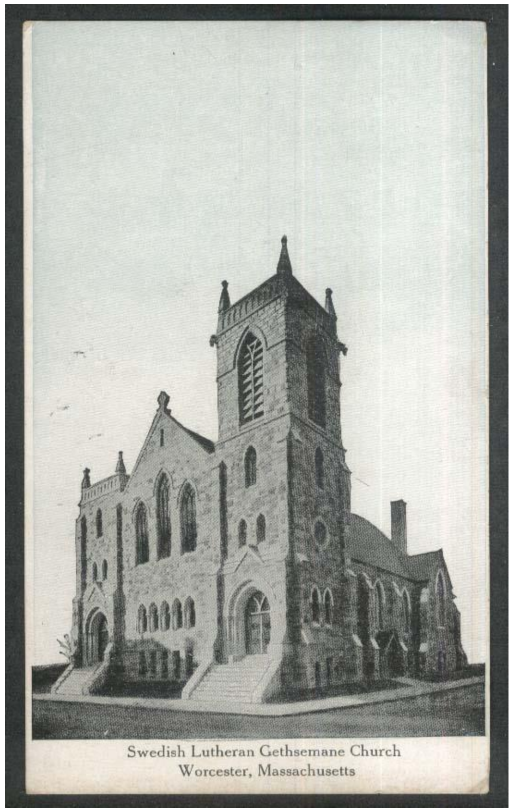


Figure 1: Postcard of the Church from circa 1920s [9]

The Church is adjacent to Route 290 in Worcester on an elevated position next to a retaining wall and adjacent to a bridge. Within the past 8 years, the highway was widened and there has been a significant increase in noticeable vibrations within the building when large vehicles drive by. The highway did not exist when the church was built. These vibrations may cause serviceability concerns. The Church is concerned that these constant vibrations are causing further damage to their structure and its envelope.

The primary concerns representatives of the church brought to this group's attention was that temperature and humidity levels were very high during the summer and low during the winter.

[9] 2020. *Swedish Lutheran Gethsemane Church.* Accessed February 5, 2020. https://www.cardcow.com/334173/swedish-lutheran-gethsemane-church-worcester-massachusetts/.

These issues raise numerous concerns with occupant comfort, energy consumption relating to the buildings insulation, heating and cooling costs, and required size of mechanical systems. Additional problems with the building envelope raise concerns regarding water infiltration and crumbling/cracking plaster. The foundation was an additional concern in which the installation of the highway's retaining wall and freezing effects in the voids of the foundation can potentially greatly expedite the failure of the foundation.

1.1 Project Timeline/Progress Report

In May 2019, our group positioned 9 temperature/humidity sensors inside the building and one outside to establish a baseline of humidity and temperature issues that were being experienced. Additionally, 4 accelerometers were installed in the two towers, all on different axes in order to quantify the vibrations that were being felt. Numerous visits were made to the church to obtain readings and check on the status of the sensors.

Over the first few weeks of A-term 2019 our group contacted several groups that may have existing documentation on the construction of the Church. We contacted the Worcester Catholic Diocese and were informed that they have no files on the church. The historical preservation group, *Preservation Worcester*, had no information but suggested that we contact the Worcester Historical Commission. We have yet to receive a response from them. We visited the Worcester Buildings Department on Thursday September 5th, 2019 and were able to find the original permitting listing and general information regarding the construction of the building in 1910. However, when the employee of the Building Department attempted to access these files, all information given on the permit was not cross referenceable. We were informed that this was most likely a clerical error that was made over 100 years ago and that any original documentation that the city may have had is now lost.

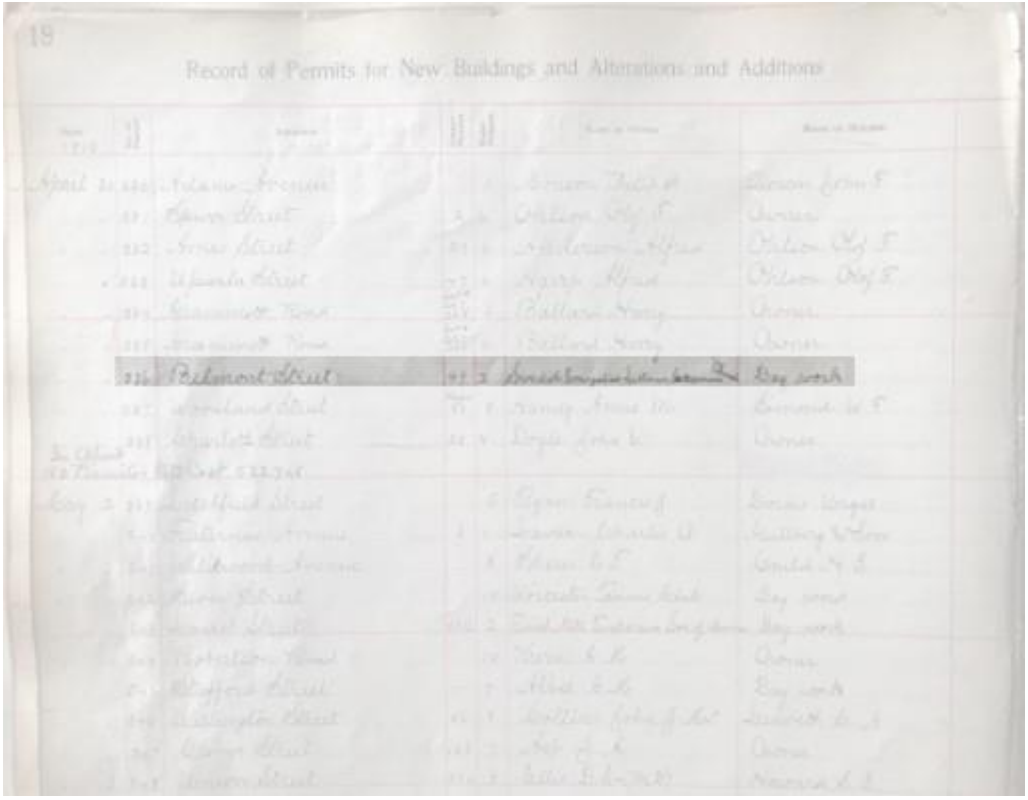


Figure 2: Original Building Permit Record from the Worcester Building Department

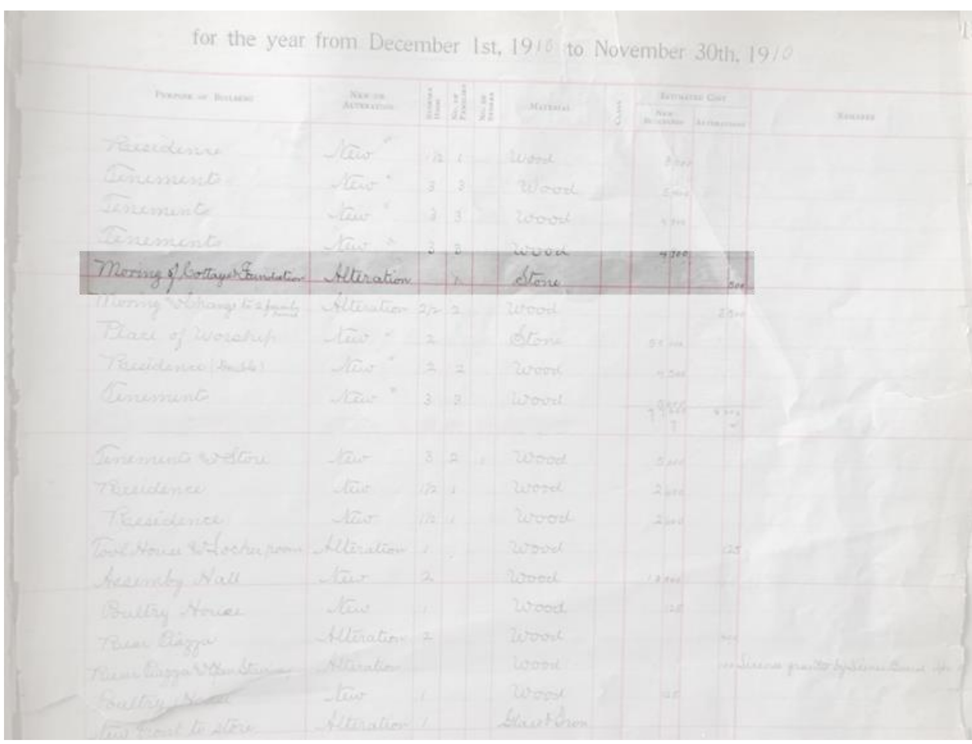


Figure 3: Original Building Permit Record from the Worcester Building Department

Throughout September and October 2019, this MQP group made several visits to the church in order to take measurements using tape measures and a theodolite in order to acquire heights that would otherwise be inaccessible. A theodolite is a precision-based surveying tool used to measure angles. By measuring the angle between the theodolite, and a point on the roof, and measuring the horizontal distance between the theodolite and the roof, the building height was calculated using trigonometry. From these calculations a massing model, using the architectural design software *Revit*, was created to better understand the geometries and construction of the church. The church also found partial floor plans that were provided by an architectural firm that remodeled the basement prior to the purchase of the church in the early 2010's. Questions about wall intersections and geometries were made more clear with the assistance of these plans and a more accurate model was able to be created.

One of the tasks in A-term was to determine a temporary heating solution that the church could be implemented over the winter for their congregants to be warm during Sunday services before a permanent heating solution could be determined. Representatives of the church presented an estimate from a local heating contracting company of what would be needed from a heating system in order to just heat the sanctuary. This estimate was roughly a 10-ton system. It was tasked to verify this estimate and determine if the numbers were accurate. To ascertain the heating loads required, rough hand calculations were created using ASHRAE heat loss methods loss based off our measurements in order gain a better understanding of the heat loss of the building. These approximate heating load calculations placed heating load estimates at just under 20 tons for the sanctuary. The discrepancy between the estimate provided by the heating contractor and hand calculations confirmed the need to create a more detailed energy analysis of the Church. With this information, church leaders have a better understanding of the size of the equipment needed to effectively condition the church.

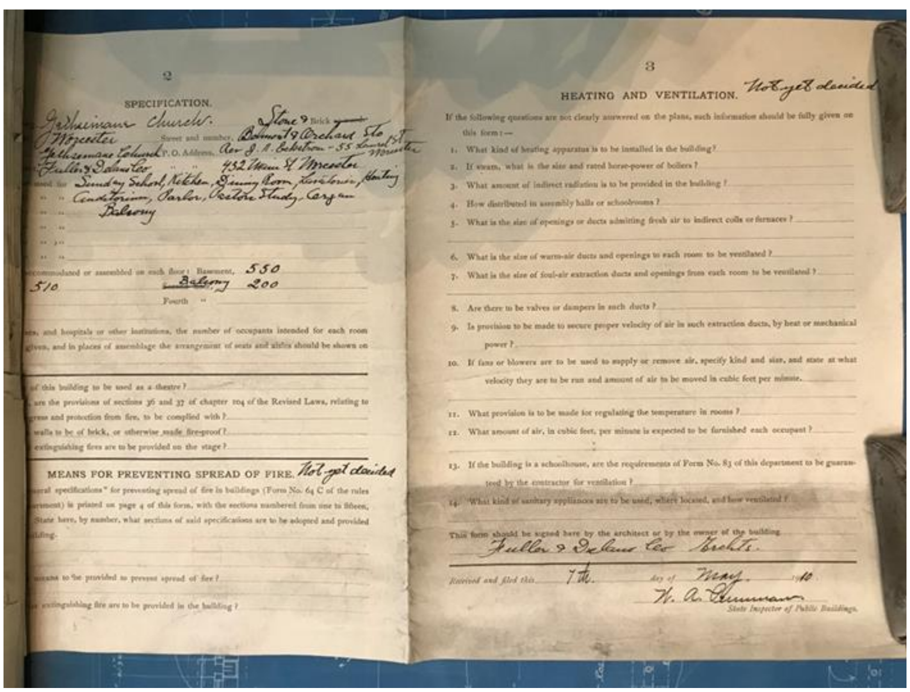
Structural analysis also began in A-term with the determination of all dead, live, snow, wind, and seismic loads acting on the church. The determination of the building geometry has allowed us to gain a better understanding of how these loads are going to act. Unfortunately, applying these loads to determine the adequacy of members was very difficult without any detailed building plans. Seismic threshold calculations were also underway by using data that was acquired by the accelerometer sensors located in the towers. From there, data could be effectively analyzed to see maximum velocity from seismic forces that could result in long-term structural damage to the church.

Professor Van Dessel visited the church to help determine the roof construction, as well as determine locations to make inspection openings and to take wall samples. It was determined that in B-term that holes would be cut (covered with a floor register) for the air gap in the tower walls to dry out due to any moisture that may be collecting in the towers and to add a humidity sensor to determine the moisture content in the walls.

At the end of A-term, a brief presentation was given to a representative of the church, Jonas Chang. This presentation went over goals for the project, what was accomplished so far, as well as action points that could be implemented immediately.

In B-Term, a full *DesignBuilder* model was created in order to calculate heating and cooling loads. This model can be extrapolated using parametric analysis to determine the total efficiency of the building and suggest improvements that could be made to the building in order to improve energy consumption in order to effectively condition the space. A site visit was made to the church where wall samples from both towers were taken for analysis as well as allowing for the tower walls to “breathe”. These holes allow extra moisture trapped behind the walls to dry out more effectively with circulating air rather than being trapped, that will eventually penetrate the internal envelope which had been noted in the original site survey. In addition, these holes allowed us to view what the wall construction of the church is like.

Professor Van Dessel contacted Rob Para, an Architect, who is a member of *Preservation Worcester*, and is aware of the church and the issues it faces. Mr. Para contacted the Massachusetts State Archives in Boston to inquire if any plans were available. Our group was informed that plans did exist and thus visited the archives on November 15th, 2020. Pre-construction drawings of building elevations, transverse sections, first and second floor plans, as well as connection details as they relate to the truss and roof were acquired from this visit. This wealth of information was incredibly helpful in order to make proper determinations for creating an accurate section drawing to see how the building components interacted with each other. The State Archives provides a scanning and documentation service of all their plans on file. It is recommended that the church takes advantage of this service and preserves the information on their church.



2

SPECIFICATION.

Gethsemane Church. Stone & ~~Brick~~

Worcester Street and number, Belmont & Orchard Sts

P. O. Address, Fuller & Delano Co 452 Main St Worcester

Sunday School, Kitchen, Dining Room, Auditorium, Parlor, Balcony

accommodated or assembled on each floor: Basement, 550

510 Balcony 200

Fourth "

... and hospitals or other institutions, the number of occupants intended for each room ... given, and in places of assemblage the arrangement of seats and aisles should be shown on ...

... of this building to be used as a theatre?

... are the provisions of sections 36 and 37 of chapter 104 of the Revised Laws, relating to ... egress and protection from fire, to be complied with?

... walls to be of brick, or otherwise made fire-proof?

... extinguishing fires are to be provided on the stage?

MEANS FOR PREVENTING SPREAD OF FIRE. Not yet decided

... general specifications" for preventing spread of fire in buildings (Form No. 64 C of the rules ... department) is printed on page 4 of this form, with the sections numbered from one to fifteen. ... State here, by number, what sections of said specifications are to be adopted and provided ... building.

... means to be provided to prevent spread of fire?

... extinguishing fire are to be provided in the building?

3

HEATING AND VENTILATION. Not yet decided

If the following questions are not clearly answered on the plans, such information should be fully given on this form: —

1. What kind of heating apparatus is to be installed in the building?
2. If steam, what is the size and rated horse-power of boilers?
3. What amount of indirect radiation is to be provided in the building?
4. How distributed in assembly halls or schoolrooms?
5. What is the size of openings or ducts admitting fresh air to indirect coils or furnaces?
6. What is the size of warm-air ducts and openings to each room to be ventilated?
7. What is the size of foul-air extraction ducts and openings from each room to be ventilated?
8. Are there to be valves or dampers in such ducts?
9. Is provision to be made to secure proper velocity of air in such extraction ducts, by heat or mechanical power?
10. If fans or blowers are to be used to supply or remove air, specify kind and size, and state at what velocity they are to be run and amount of air to be moved in cubic feet per minute.
11. What provision is to be made for regulating the temperature in rooms?
12. What amount of air, in cubic feet, per minute is expected to be furnished each occupant?
13. If the building is a schoolhouse, are the requirements of Form No. 83 of this department to be guaranteed by the contractor for ventilation?
14. What kind of sanitary appliances are to be used, where located, and how ventilated?

This form should be signed here by the architect or by the owner of the building.

Fuller & Delano Co Archts.

Received and filed this 7th day of May 1910.

W. A. [illegible]

State Inspector of Public Buildings.

Figure 4: Original Pre-Construction Drawings and Permit Listing from the Massachusetts Archive

Performing structural analysis at this point was difficult because very conservative guesses were made for the size of members that were far out of sight and reach. Many members were being analyzed as inadequate due to lack of information. Fortunately, with the building plans acquired from the Massachusetts State Archives, a full reanalysis was able to be performed with much greater confidence, and the results were much closer to what was expected. Roof members, floor members, and buttresses were analyzed by hand and with *RISA*, a structural analysis program, and a preliminary truss analysis was performed using *RISA*. One of the main complaints heard from the church elders that pertained to this project related to vibrations occurring in the building from traffic passing by. With the church's location on Route 9 and slightly raised above I-290 it was not surprising to hear this. Accelerometer sensors were placed in both towers to record data of the vibrations. There are two in the East tower and two in the West tower. All sensors were mounted on the wall of the towers. These accelerometers gathered data since May 2019 until February 2020.

The data obtained from the accelerometers is the acceleration of the vibrations being felt by the church over time. This data was imported into excel spreadsheet so that it could be converted appropriately. First, time was converted to frequency, 1/t, and acceleration to velocity through integration. This produced a velocity versus frequency graph which was used to determine the peak particle velocity (PPV).

The period over winter break was spent running multiple computer simulations utilizing parametric optimization in order to determine what practical changes could be implemented in the church to improve heat loss and energy consumption. Such improvements that were suggested were potentially adding insulation to the uninsulated roof deck, adding another layer of glass on the existing stained-glass windows in the sanctuary, and establishing appropriate heating and cooling set points and analyzing their overall effect on total annual energy consumption.

The beginning of 2020 was spent analyzing our results and compiling this report.

1.2 Background

In order to gain an understanding of the structural system of the church as well as the requirements of vibration analysis, background research was performed on these topics to become more knowledgeable on specific needs of the church.

1.2.1 Hammer Beam Truss

Figure 5: Hammer Beam Truss in the Church Sanctuary

One of the primary decorative and structural features of the church are the hammer beam Trusses that are used in the roof design of the sanctuary. This type of truss has been commonly used in open timbered roofs and are most commonly found in gothic churches and halls in Western Europe. The first recorded instance of a hammer beam truss being utilized into a building design was that in Westminster Palace (1397) and is very common in English buildings of the 15th century. These designs add ornamental qualities to the design of a building but allows for significant structural support on sloped roofs. The term "hammer beam" refers to the horizontal beams at the foot of the principle members. While most of these trusses are very similar in design, it is nearly impossible to find two designs that are identical.[10]

Seen in Figure 6, the red members are the hammer beams, the blue members are the hammer posts, and the green members are the hammer braces. The braces are primarily responsible for transmitting the load from the roof into the walls and the posts and beams work to hold the truss together. The posts, typically under compression work to transmit some of the load from the upper braces onto the lower braces. The beams, typically under tension, work to keep the braces from separating. The primary upside to using hammer beam trusses is that they require shorter member sizes and hold aesthetic value. The primary downside to hammer beam trusses is that they submit potentially great seismic loads into the walls resulting in required reinforcement or large amounts of material used in the walls/buttress to resist the horizontal component reactions. In addition, all attaching joints must be strong enough to prevent the truss from racking due to wind pressure and seismic loads.

---

[10] Kidder, F.E. 2018. *The Hammer-Beam Truss.* Accessed January 2, 2020. https://chestofbooks.com/architecture/Construction-Superintendence/21-The-Hammer-Beam-Truss.html.

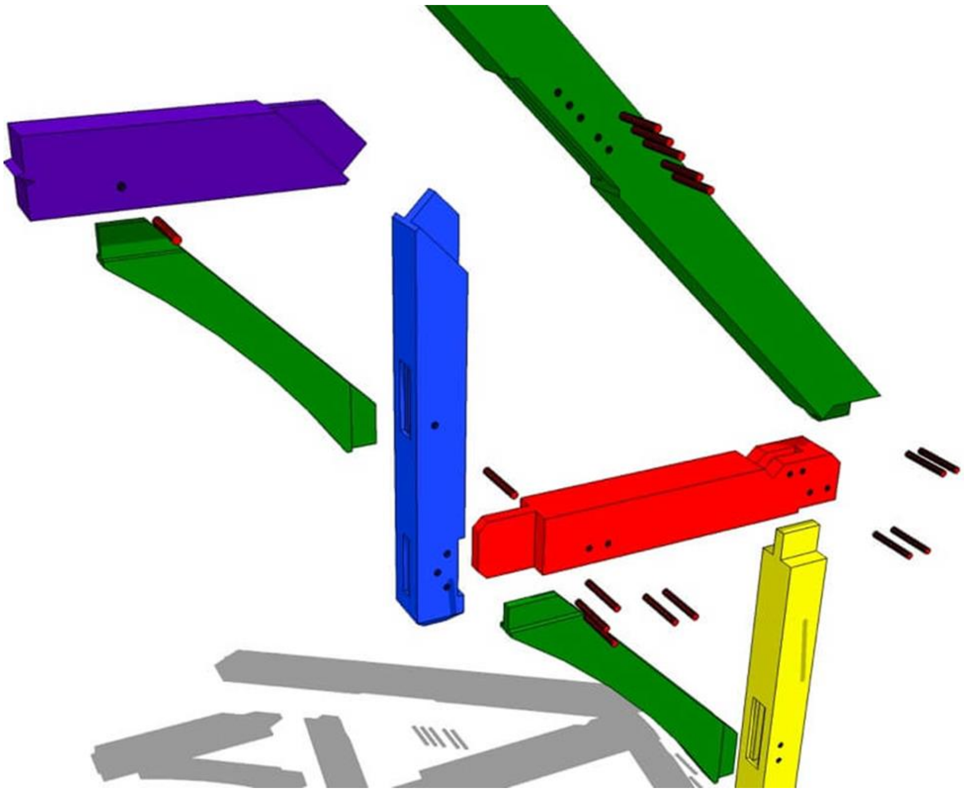


Figure 6: Hammer Beam Truss Axial Forces and Primary Members [11]

2.0 Goals and Objectives

1. Analyze the structural integrity of the church and determine if there are any critical issues regarding the structure that need to be addressed immediately. Identify the extent of seismic effects on the church and if any long-term effects are being experienced by the building.
2. Identify sources of water infiltration that is contributing to the cracking of wall plaster and high humidity levels behind the walls and in the building itself.
3. Perform an energy analysis of the building to determine heating and cooling loads.
4. Determine the required size of heating and cooling systems to properly condition the building.

[11] Cochran, Brice. 2018. *Hammer Beam Truss Details.* https://timberframehq.com/hammer-beam-truss-detail/.

5. Recommend potential improvements to the building envelope to reduce heat loss and energy consumption.

3.0 Building Status

Before the church could be analyzed, observations had to be made through a comprehensive site survey and by referencing building plans. This was done to determine building construction and design to determine elements that should be analyzed moving forward and to better understand the most pressing issues facing the church.

3.1 Plan Sets

Obtaining any prior construction or repair plans could help gain insights to the building construction and connection details, that were not able to be discerned from site surveys was an important goal. Any plans that may have been filed with the City of Worcester or the Catholic Diocese have most likely been lost. However, thanks to the assistance of Rob Para, the original proposed building plans that were submitted to the State of Massachusetts in 1910 were able to be located. These plans are housed currently at the Massachusetts State Archive, 220 Morrisey Boulevard, Boston. An appointment is required in order to view any documents at the Archive. These original drawings include floor plans, sections, and other construction and connection details that made this analysis possible. It is recommended that the church requests digital copies of these plans for their own reference as well as for future repair work that may be undertaken in the near future. Photos of these plans are attached in Appendix D. The scanning process will cost approximately $500 dollars due to the age of the plans and the need to be handled by a paper conservator. When the plans were reviewed, they were beginning to disintegrate and tear, so it is recommended that these scans occur sooner rather than later.

Plans were also obtained from the church directly that provided the renovation plans of the basement, prior to the purchase of the church in the early 2010s. These plans aided in determining building geometry, however the accuracy of these plans was questionable and should not be used as a master plan set. One of the goals of this project was to create a new master plan set for the church. These drawings are attached in Appendix. Based on this groups site analysis, these drawings are believed to be the most accurate but should still be reviewed prior to being used as the basis of any major project.

One major fact to note here and noticed in Figure 1, was the existence of a bell tower on the right tower that has since been removed. It was brought to the attention of this group that Consigli Construction Group was tasked to reinforce this tower in the late 1990s which involved the removal of the bell chamber from the right tower. Communication with employees of Consigli determined that any existing plans relating to work performed on the towers are no longer available.

3.2 Roof

Based on visual inspection of the roof from ground level, there are many sections that have gaps or broken pieces of slate. The photos that were sent by Jonas Chang were very helpful to gain an insight of the roofs condition since an in-person roof inspection was not possible. See Appendix J. There are open holes due to missing and separating pieces of slate. There is also missing slate and flashing where the roof meets one of the towers.

Figure 7: Photos of the Church's Slate Roof provided by Jonas Chang

The parapets as well as flashing and counterflashing of the towers are suspect and should be investigated for more defects. The primary concern is with the condition of these components in the valleys where the towers and roof meet. All flashing on the roof should be updated to modern standards. Water entering through the flashing and counterflashing at these locations would immediately travel downward until it reached an interior finish and would ultimately result in water damage. A thorough inspection of the roof and timely replacement of failed components is critical to ensure no further damage to the building structure and envelope. A replacement roof whether it be slate, or a more affordable alternative is the first step to improve the church. This will also dramatically improve energy consumption because the actual envelope will be able to retain heat much more effectively. These issues with the roof are most likely causing most of the water infiltration due to over 100 years of freeze-thaw cycles and precipitation resulting in thermal hysteresis of the slate and breakdown of the original waterproofing methods.

3.3 Documentation of Pre-Existing Conditions

The Massachusetts Department of Transportation produced a pre-construction survey of the church that was produced prior to the widening of the bridge on Rt. 9 over I-290 at the intersection of the church in 2014. This report is attached in Appendix H. The photos and details in the report were documented from 2012 and provide a guide as to which cracks in interior plaster walls have widened or appeared in the past 8 years. The cracking of the plaster is of concern but is mostly a cosmetic issue. These cracks are most likely related to the high moisture content in the building. One of the goals of this project was to determine whether these issues were induced by traffic vibrations or vibrations originating from adjacent bridge construction combined with a failure of the building structure or envelope.

3.4 Temperature/Humidity Issues

Beginning in late April 2019, 9 temperature and relative humidity sensors were installed throughout the building to gain an understanding of thermal comfort and hygroscopic issues (See Figure 11 and Table 1). One additional temperature sensor was placed outside at the entrance to acquire a baseline outdoor temperature. These temperature sensors are the Onset HOBO U12-012 Temperature/Relative Humidity/Light/External Data Loggers (See Figure 8). Please see attached Appendix A for the recorded temperature information for various locations around the church.

Figure 8: Onset Hobo U12-013 Temperature/Relative Humidity/Light/External Channel Data Logger [12]

A comparison between the recorded outdoor temperatures from the outdoor sensor and the given ASHRAE weather data for Worcester, MA on a given year was also performed. The humidity data from this sensor was skewed, most likely because of the sensor being directly exposed to water giving false readings of the true relative humidity levels outside. Based on the graphical comparisons between the two data sets, the differences between the outside temperature/RH collected (Figure 10) and data collected annually by ASHRAE and averaged

[12] 2020. *HOBO U12 Temperature/Relative Humidity/Light/External Data Logger.* Accessed January 28, 2020. https://www.onsetcomp.com/products/data-loggers/u12-012.

(Figure 9). It was determined that the cumulative weather data provided by ASHRAE would be a solid basis for the outdoor temperature and humidity factors to create an accurate digital model.

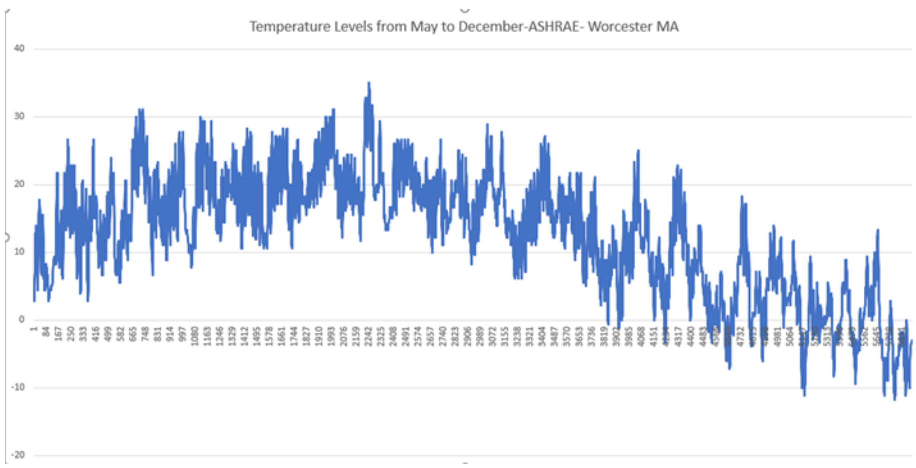


Figure 9: Annual ASHRAE Temperature Data for Worcester, Massachusetts from May to December Cumulatively

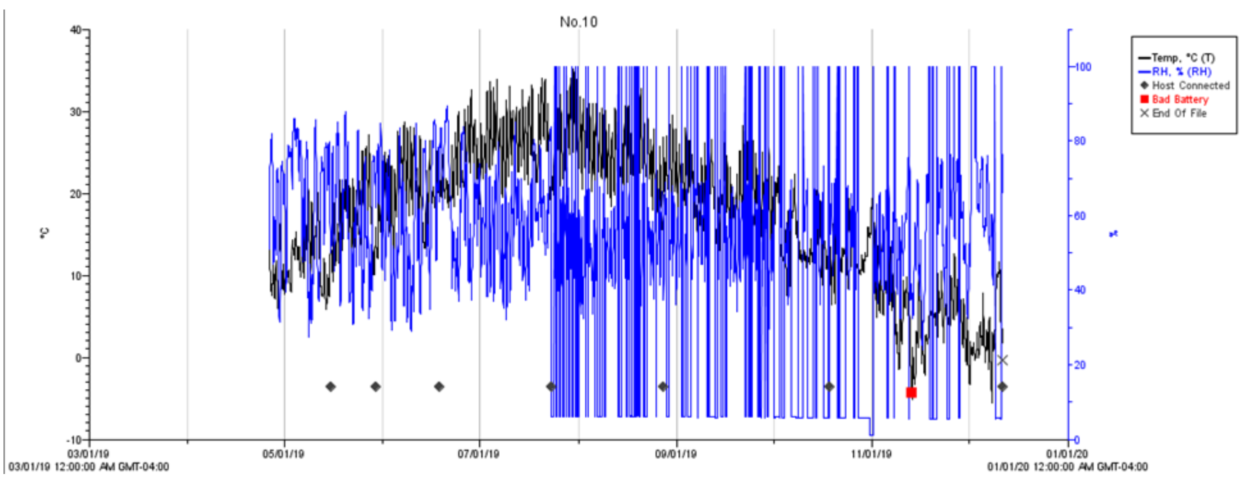


Figure 10: Recorded Temperature and Humidity Data from outside the Church from May to December 2019

ASHRAE codes state that a building should be conditioned around 40-60% RH in order to prevent mold growth. Excessive moisture levels can also lead to water being absorbed into the building envelope and can degrade internal components.

As displayed by the analysis of the Relative Humidity data (Table 2), the Sanctuary topped out at over 80% RH and the towers reached RH levels over 90%. The sanctuary experiences RH levels higher than 60%, on average 35% of the total time between May to December. This continued exposure to high humidity levels will degrade the building envelope. It is critical for the longevity of the building that issues with the building envelope be corrected and proper building conditioning through mechanical systems be instituted. This temperature/humidity data can be found in Appendix A.

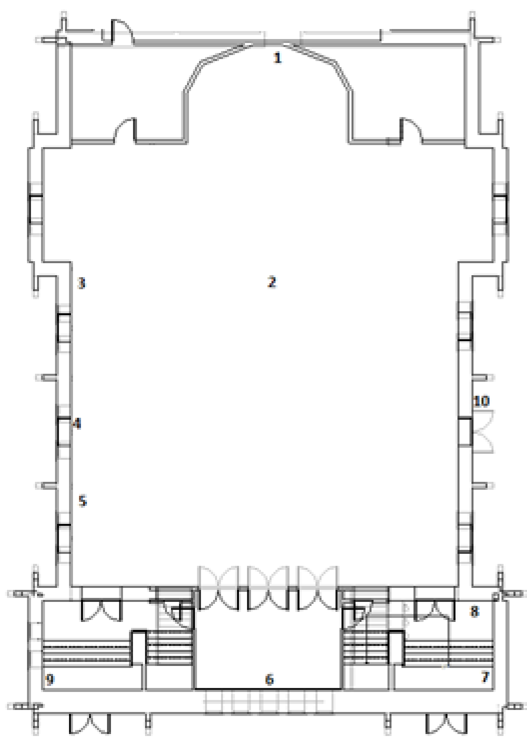


Figure 11: Location Diagram of Temperature/Relative Humidity Sensors

Table 1: Location of Data Loggers

Logger	Location
1	Back of stage in Sanctuary
2	Under 1st pew in center
3	Under pew on left side

4	On side of window
5	On Left Truss/Mezzanine Level
6	Center of Window/Mezzanine Level
7	Upstairs of Right Tower
8	Bell Tower
9	Upstairs of Left Tower
10	Outside Next to Ground Entrance

Table 2: Recorded Temperature/Humidity Data

May 1st to December 22, 2019	#1	#2	#3	#4	#5	#6	#7	#8	#9
Highest Recorded Temp. (F)	91.87	92.15	90.14	96.33	93.09	119.84	92.46	86.07	90.19
Lowest Recorded Temp. (F)	48.32	47.37	46.49	43.39	46.48	39.60	31.35	36.70	40.35
Highest Recorded %RH	77.95	81.46	78.95	80.84	82.1	85.33	91.49	87.54	82.13
Lowest Recorded %RH	29.4	38.35	28.58	26.67	31.53	10.86	58.38	63.84	48.72
% of Time Humidity Over 60%	26.96	61.82	30.38	39.71	23.89	24.14	99.89	99.95	64.22
% of Time Humidity Lower Than 40%	3.36	0.21	3.67	3.69	2.46	20.29	0.00	0.00	0.00

3.5 Windows

Figure 12: Examples of Broken Stained Glass in the Sanctuary

When initial site surveys were made to assess the condition of the church, it was observed that there was plastic wrap used on most of the stained-glass windows in the sanctuary. This is a commonly used, affordable method to control drafty windows in the winter, but is not the proper way to repair fenestration issues. On closer inspection of the stained-glass windows, there are portions of the stained-glass that are broken, missing, or have failing components (Figure 12). Due to warping of the window frames, openings in the windows no longer sit flush, allowing direct openings to the outdoors. These holes are creating significant air and water infiltration points into the church that are also affecting comfort levels in the sanctuary. Fixing these cracks, and repair or replacement of warped window frames will eliminate much of the draft that is being experienced by members of the congregation during services. An analysis of these windows was performed and potential options that could be implemented to improve heat loss but still retaining the overall aesthetic of the building were considered.

4.0 Methodology

In order to analyze the church beyond visual observation, digital models were created using the computer programs, *AutoCAD* and *Revit*. These models were then analyzed using *RISA, MATLAB, and DesignBuilder* to determine if there are any structural, geotechnical, envelope, or energy related concerns with the Church that should be addressed. This section discusses the process under which this analysis was performed.

4.1 Structural Analysis

The structural analysis for the church was performed top down and specifically focused on areas most susceptible to failure. These areas primarily consisted of sections in the church's envelope that experience the greatest loads and eccentricity under the smallest cross-section. The materials of construction that go into the church are primarily hard pine or spruce wood (roof and floors) and granite and brick masonry (walls). Allowable stress design (ASD) typically used with wood, masonry, and geotechnical applications was used throughout this analysis process rather than load resistance factor design (LRFD) typically used with steel and concrete applications. All structural analysis calculations can be seen in appendix C.

4.1.1 Determination of Loads

In order to analyze all major structural members, dead load, live load, snow load, wind load, and seismic loads were calculated according to American Society of Civil Engineering

(ASCE) standards. Dead load in roof members was estimated based on the material used in the roof construction. All members experienced dead loads of overlapping 1/8” slate as well as their own respective self-weights of eastern spruce wood. The unit weight for eastern spruce wood was estimated using American Wood Council National Design Standards (AWC NDS). The purlins experienced an additional dead load corresponding to the weight of the chandeliers estimated to be about 100 lb, and the truss experienced additional dead loads corresponding to electrical components involved with lighting as well as plaster sheathing estimated to be 5 psf and 1.6 psf respectively applied uniformly over the top chord of the truss. The roof also contained uniform and concentrated live loads estimated using ASCE 7-10 Table 4-1. A profile for the roof members can be seen in Figure 14.

Deadloads for the floor joists were calculated from the deadloads of carpeting and decking. Uniform and concentrated live loads were estimated based on ASCE 7-10 table 4-1 for fixed seated assembly rooms. Loads on the girders were based on the reaction forces from the joists. Additional self-weight and MEP loads were added to the girders. The reason MEP was not added to the joists is because it was evident from visual inspection that all basement lighting and other electrical and ceiling components were attached directly to the girders.

Snow Loads were calculated using regional constants determined from the Massachusetts State Building Code (MSBC) as well as design specifications from ASCE. According to the MSBC, Worcester has a ground snow load of 50 psf. The church is under category B for urban area and the roof is fully exposed giving the church an exposure factor of 0.9. The church is also heated so the thermal factor is 1.0. The church can be considered to be at a risk category III corresponding to a high-risk assembly building. While the church doesn’t often fill with people according to church representatives, any event in which the church was to fill up with more than

300 people would classify the church as high risk. The flat roof snow load can then be calculated using the factors above estimated at 35 psf. A slope factor based on roof insulation is then determined based on roof insulation from figure 7-2a ASCE 7-10 and is used to find the slope roof snow load of acting vertically.

Wind loads were determined using the directional procedure under ASCE specifications. This procedure is outlined in Table 3. Specific regional constants such as basic wind speeds for Worcester were determined from the MSBC. The church is assumed to be a rigid closed building and contain a gable roof of a 45° slope. In Table 3, under step 7 wind pressures were calculated using the equation

$$q_z = 0.00256 K_z K_{zt} K_d V^2 \ (psf) \qquad \text{Equation 1}$$

where q_z is the wind velocity pressure, K_z is the velocity pressure exposure coefficient, K_{zt} is the topographical factor, K_D is the wind directionality factor, and V is the basic wind speed. The wind velocity pressures were then used to determine the wind loads using the equation

$$p = qGC_p - q_t(GC_{pi}) \qquad \text{Equation 2}$$

where p is the wind load in psf acting on the surface of the church, q is the wind velocity pressure, G is the gust-effect factor, C_p is the external pressure coefficient, q_t is the wind velocity pressure at the mean roof height (for enclosed buildings), and GC_{pi} is the internal pressure coefficient. For additional details and notes on the various load parameters, see appendix C.

Table 3: Steps to Determine MWFRS Wind Loads for Enclosed, Partially Enclosed, and Open Buildings of All Heights (Taken from ASCE 7-10, Table 27.2-1)

Step 1: Determine risk category of building or other structure, see Table 1.5-1

Step 2: Determine the basic wind speed, V, for the applicable risk category, see Figure 26.5-1A, B, or C

Step 3: Determine wind load parameters:
- Wind directionality factor, K_d, see Section 26.6 and Table 26.6-1
- Exposure category, see Section 26.7
- Topographic factor, K_{zt}, see Section 26.8 and Figure 26.8-1
- Gust-effect factor, G, see Section 26.9
- Enclosure classification, see Section 26.10
- Internal pressure coefficient, (GC_{pi}), see Section 26.11 and Table 26.11-1

Step 4: Determine velocity pressure exposure coefficient, K_z or K_h, see Table 27.3-1

Step 5: Determine velocity pressure q_z or q_h, see Eq. 27.3-1

Step 6: Determine external pressure coefficient, C_p or C_N:
- Fig. 27.4-1 for walls and flat, gable, hip, monoslope, or mansard roofs
- Fig. 27.4-2 for domed roofs
- Fig. 27.4-3 for arched roofs
- Fig. 27.4-4 for monoslope roof, open building
- Fig. 27.4-5 for pitched roof, open building
- Fig. 27.4-6 for troughed roof, open building
- Fig. 27.4-7 for along-ridge/valley wind load case for monoslope, pitched or troughed roof, open building

Step 7: Calculate wind pressure, p, on each building surface:
- Eq. 27.4-1 for rigid buildings
- Eq. 27.4-2 for flexible buildings
- Eq. 27.4-3 for open buildings

The first step in seismic design was determining the risk-targeted maximum considered earthquake (MCEr) spectral response accelerations at short periods, Ss, and at 1-second period, S1. These values were determined through ASCE 7-10 figures 22-1 through 22-6. The next step was to determine if there was an exemption factor, which there was not for the location of the church. The third step is the determination of the Seismic Design Category (SDC). The SDC assigned to a structure is a classification based on the risk associated with its unacceptable performance, and the level of soil-modified seismic ground motion at its site determined based on a 1% risk of structural failure in 50 years. In order to determine the SDC, the following items needed to be determined. The first is soil classification class, which was found to be class D through a web soil survey. Soil classes are based on the soil's runoff potential. Soil class D consists of soils that are clay loam, silty clay loam, sandy clay, silty clay or clay. Another is the S_{ds} and S_{d1}. These were found through ASCE 7-10 Tables 11.4-1 and 11.4-2. The church was found to be in Risk Category III based ASCE7-10 Table 1.5-1. Next, we had to determine the fundamental period, T, and Ts. This was done through ASCE 7-10 table 12.8-1 and table 12.8-2. The response modification coefficient, R, was then determined which was 1.5, and the seismic importance factor, Ie, was 1.0. The final step was to determine the seismic base shear, V. This is found with the equation

$$V = C_s W \quad \text{Equation 3}$$

The base shear was determined over the height of the structure.

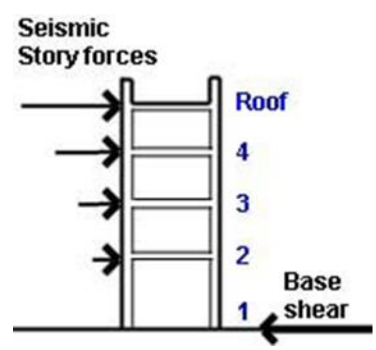


Figure 13: Location of Seismic Forces on Building Structure

The forces act differently on the separate stories of the building, as shown above in Figure 13. Once the shear was found, the seismic load effects were able to be determined, E and E_M using equation

$$E = pQ_E \pm 0.2S_{DS}D \quad \text{Equation 4}$$

4.1.2 Roof

The roof of the church consists of three primary layers which all worked to distribute the load onto larger members with greater load capacity and ultimately onto the truss. These members were determined through visual inspection and confirmed with the Massachusetts State Archive plan photos. These three layers include a 1.125 in roof deck running north-south, 2x8 rafters spaced 16 in O.C. running east-west, and 8x10 purlins spaced 9.7 ft O.C. running north-south.

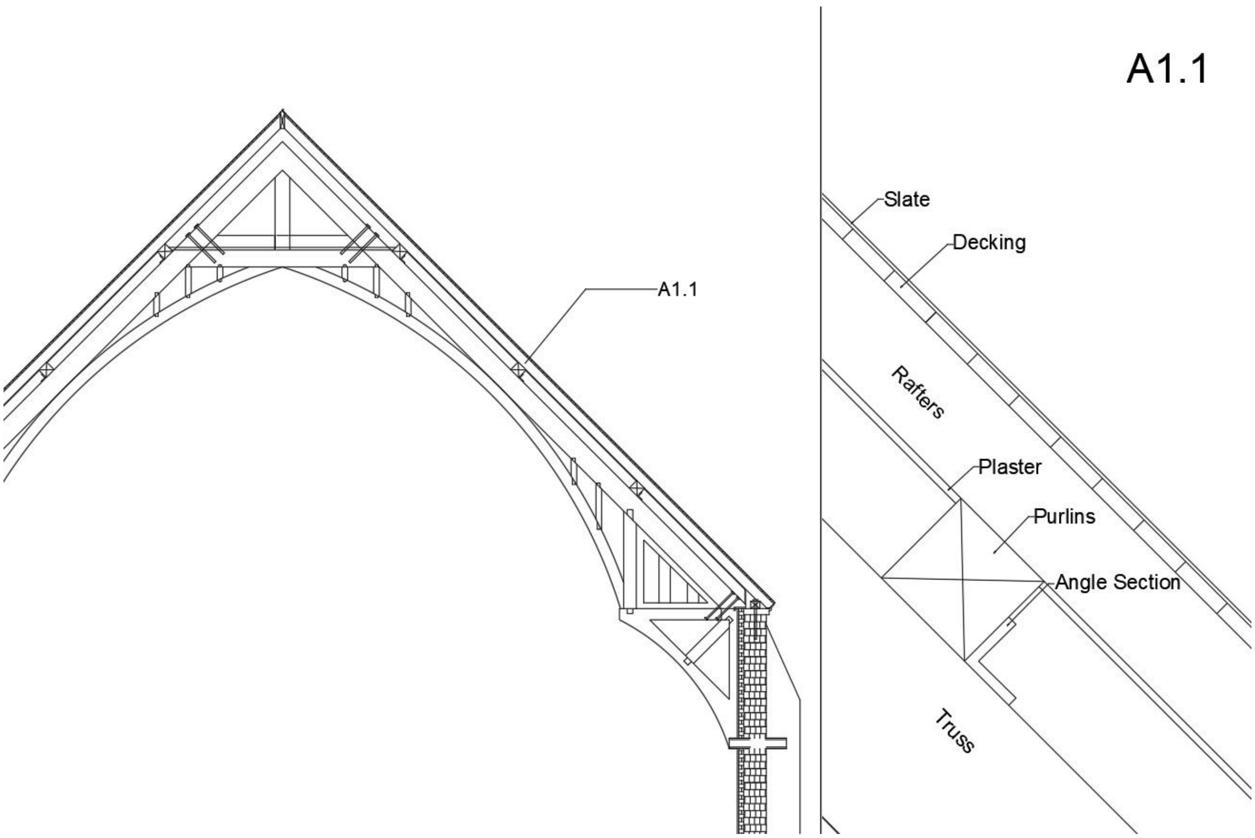


Figure 14: Roof Members

Governing load combinations were determined from ASCE section 2.4. Each load combination considered dead loads, live loads, snow loads, wind loads, and seismic loads. These load combinations were calculated on a spreadsheet, and all the combinations that yielded a possible maximum load based on uniform loads and concentrated loads were tested on *RISA 2D* analysis software to determine maximum moments, shear, and deflection. The maximum moments and shear that resulted from *RISA* could then be used for bending stress and transverse shear stress considerations.

The 2D analysis was performed along the length of the member (perpendicular to the members that ran beneath). This presented a challenge due to the roof angle causing the decking and purlins to exhibit a 3D loading scenario along its length. In order to convert the 3D loading into 2D loading, equivalent component loads acting perpendicular and parallel to the plane of the members were used. These conversions and resulting loading scenarios are shown in Figures 15-22. Only, the forces acting perpendicular to the members were used to test for flexural strength, but all forces acting on the member were used to determine reaction forces that will be passed on to the members that lie below. The rafters (and truss) were analyzed without the conversion of component forces, as the model was already in a 2D loading scenario along its length. The original plan photos show that angle section members were used in order to resist the purlins from sliding due to the component forces acting parallel to the plane of the member (see Figure 14). Details of these angle section members are unknown.

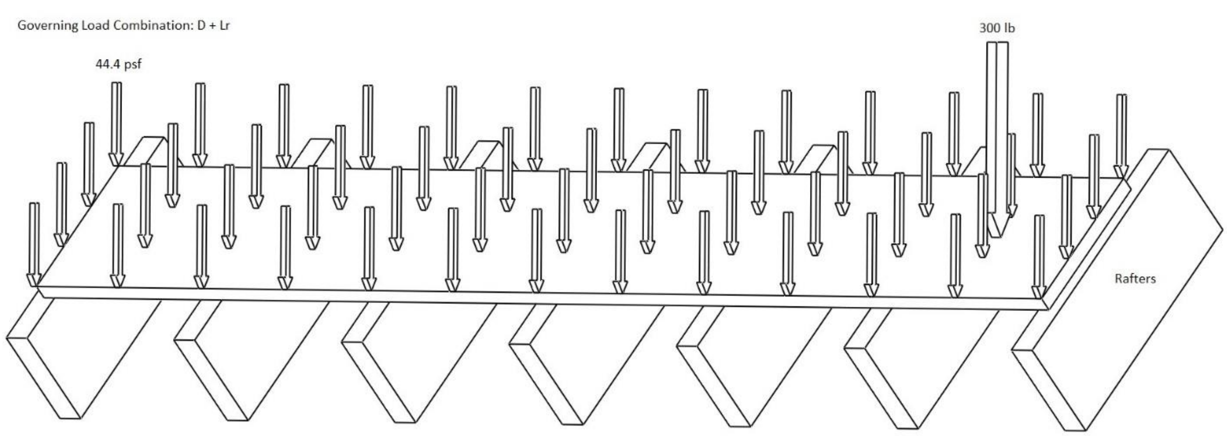


Figure 15: Original Loading Scenario on the Roof Deck

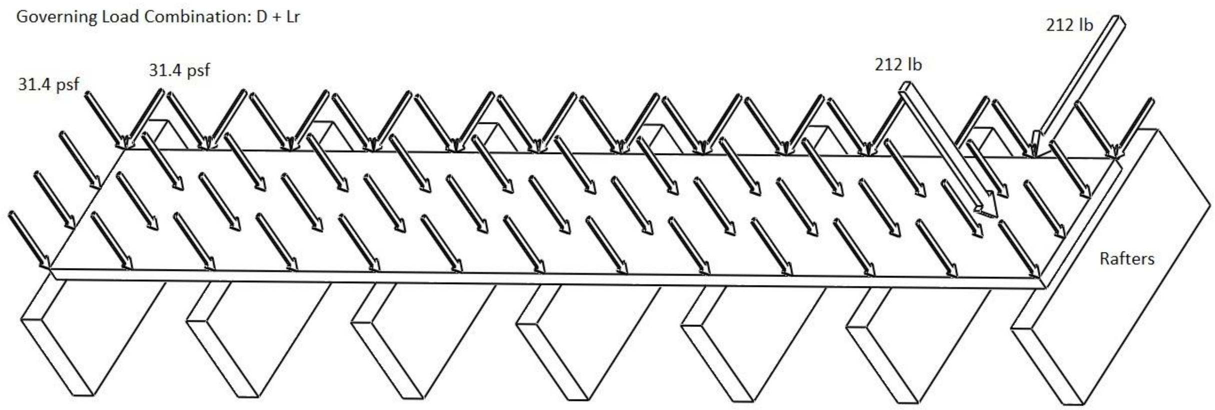


Figure 16: Adjusted Loading Scenario on the Roof Deck

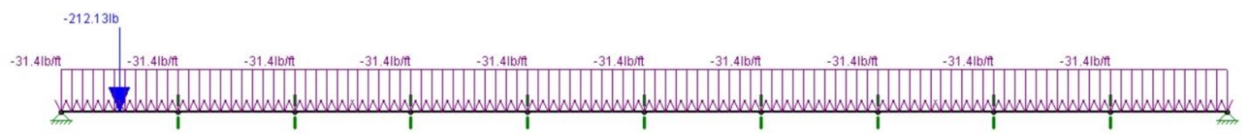


Figure 17: 2D RISA Design Loading for Roof Deck

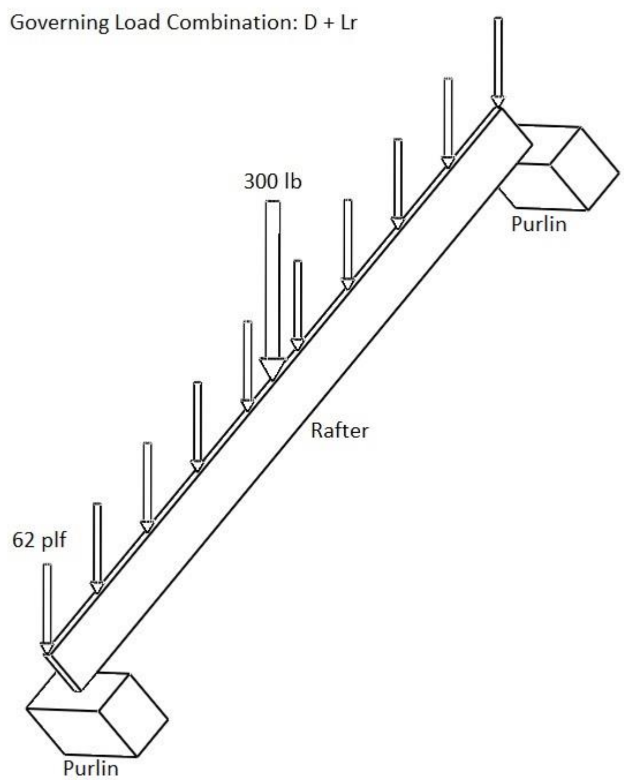


Figure 18: Rafter Loading Scenario

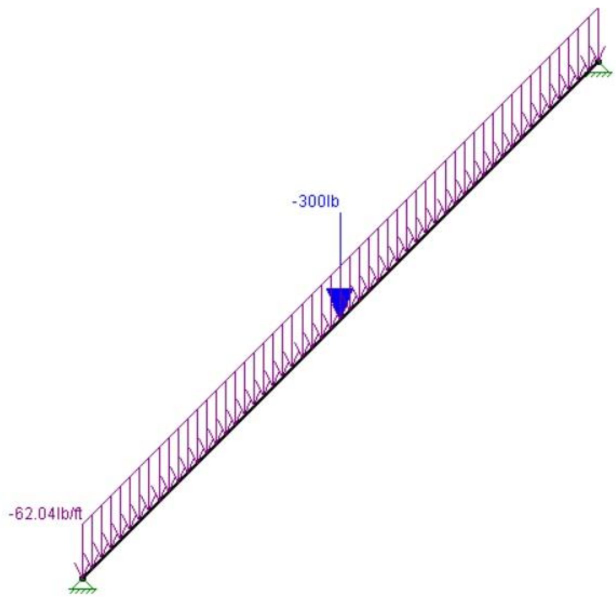


Figure 19: 2D RISA Design Loading for Rafters

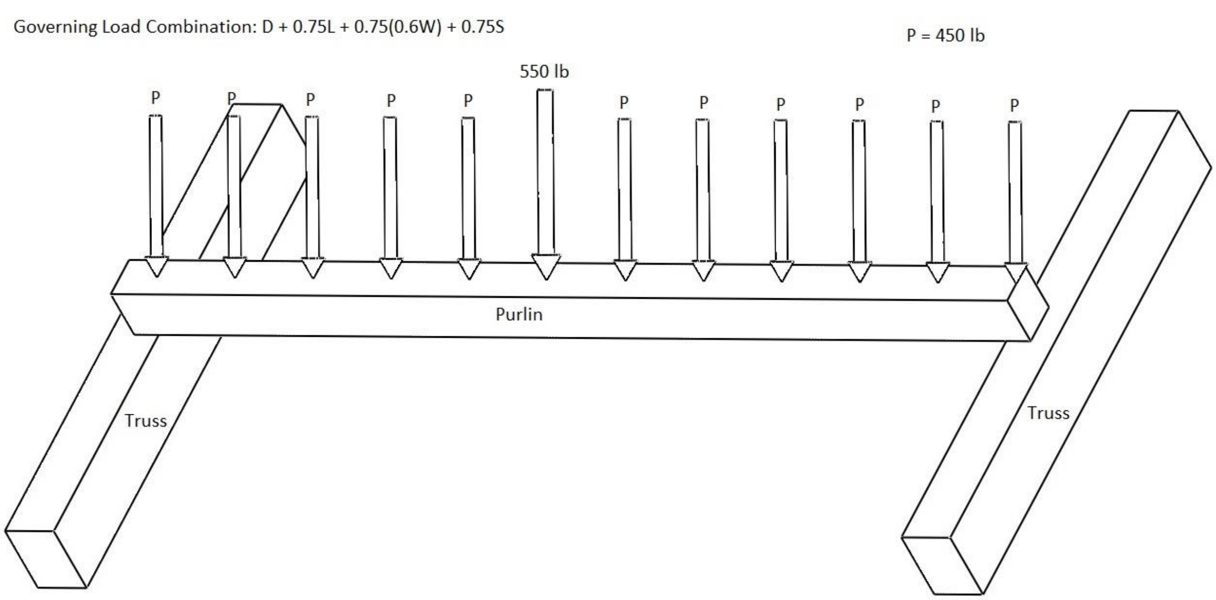


Figure 20: Original Purlin Loading Scenario

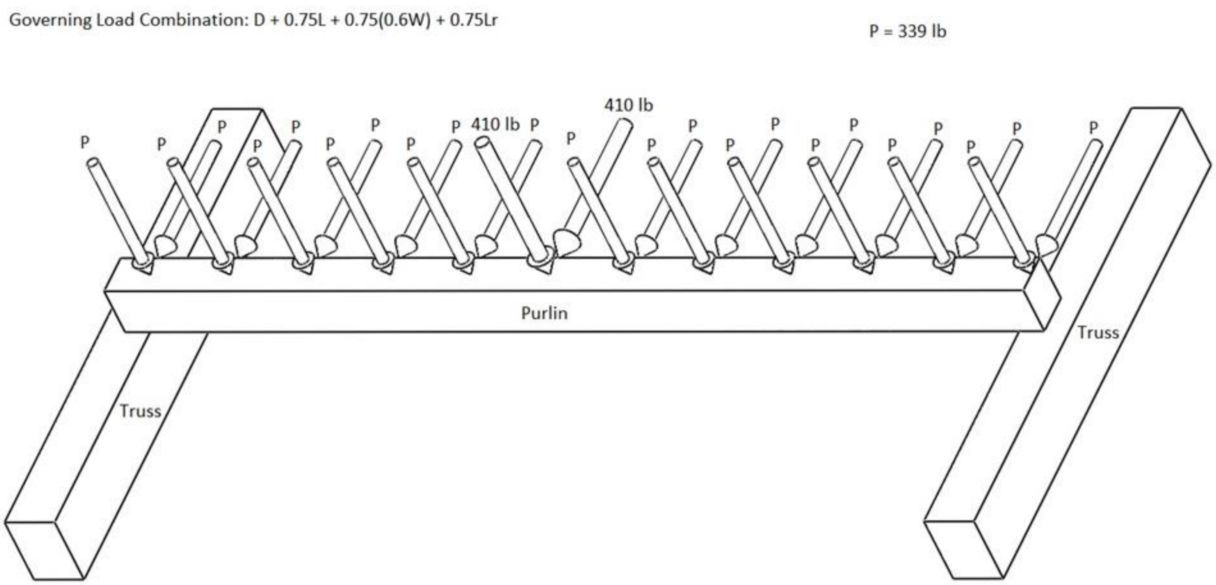


Figure 21: Adjusted Purlin Loading Scenario

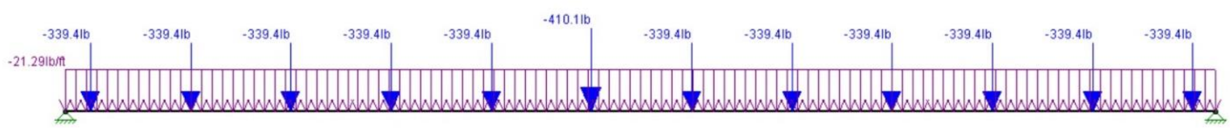


Figure 22: 2D Design Loading for Purlins

Maximum allowable bending and shear stress was determined through the AWC NDS based on various factors such as load duration, temperature conditions, moisture conditions, member dimensions, type of wood used, and what the member is used for. The maximum allowable bending and shear stress can then be compared with the ultimate bending and shear stress the member experiences to determine member adequacy.

4.1.3 Hammer Beam Trusses

The truss was analyzed separately using a *MATLAB* structural analysis program, due to limitations with *RISA 2D*. Three different cases were analyzed based on different load combinations. The first of these combinations was primarily gravity governed and can be seen in Figure 23. The loads in this case were calculated from the total reaction forces of the purlins under

D + 0.75L + 0.75(0.6W) + 0.75S loading conditions. Additional uniform deadloads from sheathing and mechanical, electrical, and plumbing (MEP) were added to the top chord of the truss. Self-weights for all truss members were also added to the model.

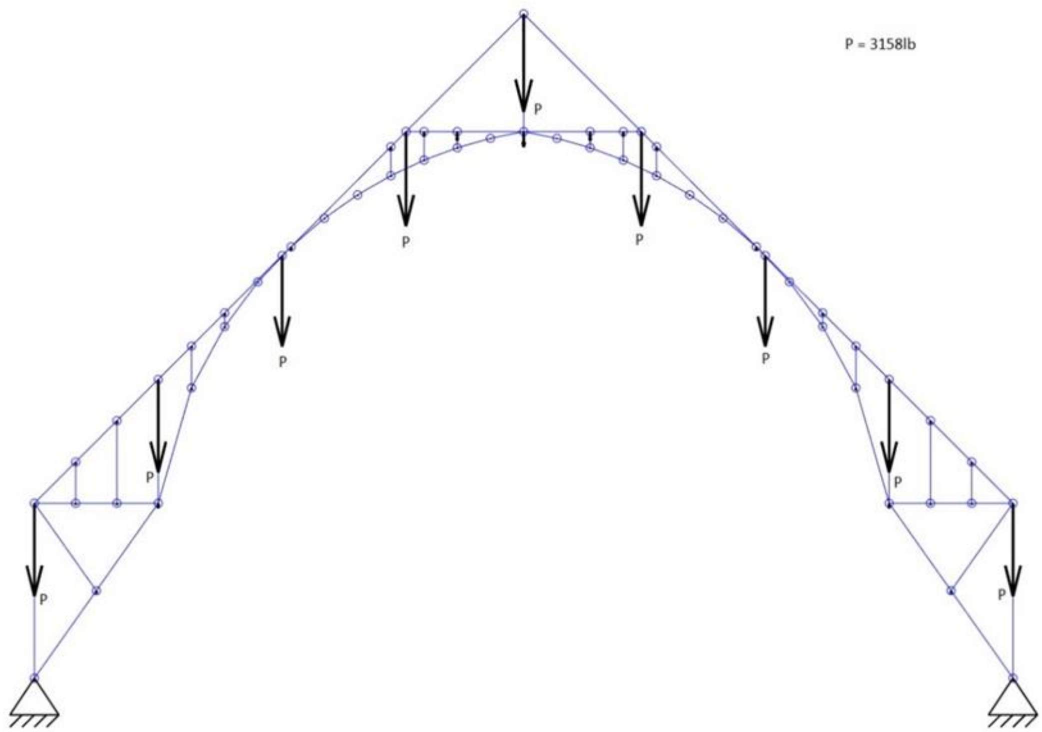


Figure 23: Truss Case 1 Loading Scenario (Primarily Gravity Governed)

The second combination tested was primarily seismic governed and can be seen in Figure 24. The loads in this case were calculated from the total reaction forces of the purlins under D + 0.7E loading conditions. The same additional deadloads were added as in case one. Seismic loads were added at two discreet locations representing horizontal chords of a frame: at the base of the roof and the apex of the roof.

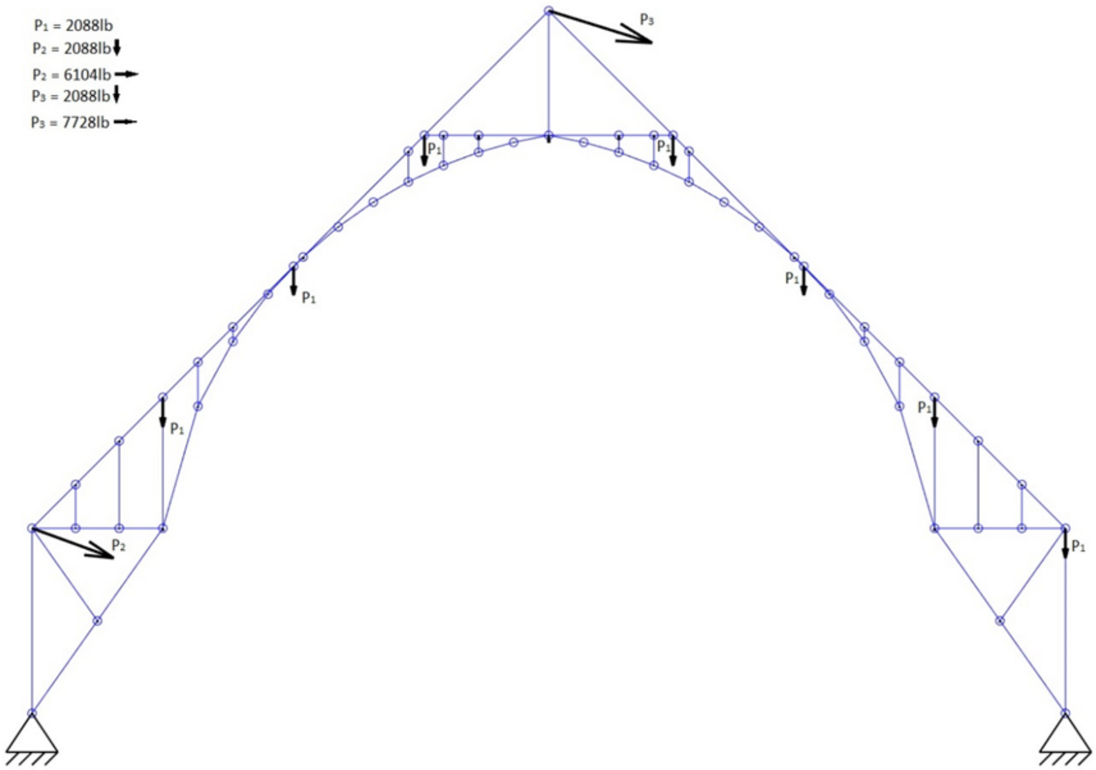


Figure 24: Truss Case 2 Loading Scenario (Primarily Laterally Governed)

The third combination tested was seismic and gravity governed and can be seen in Figure 25. The loads in this case were calculated from the total reaction forces of the purlins under D + 0.75L + 0.75(0.7E) + 0.75S loading conditions. The same additional deadloads were added as in cases one and two, and seismic loads were added at the same location as in case two.

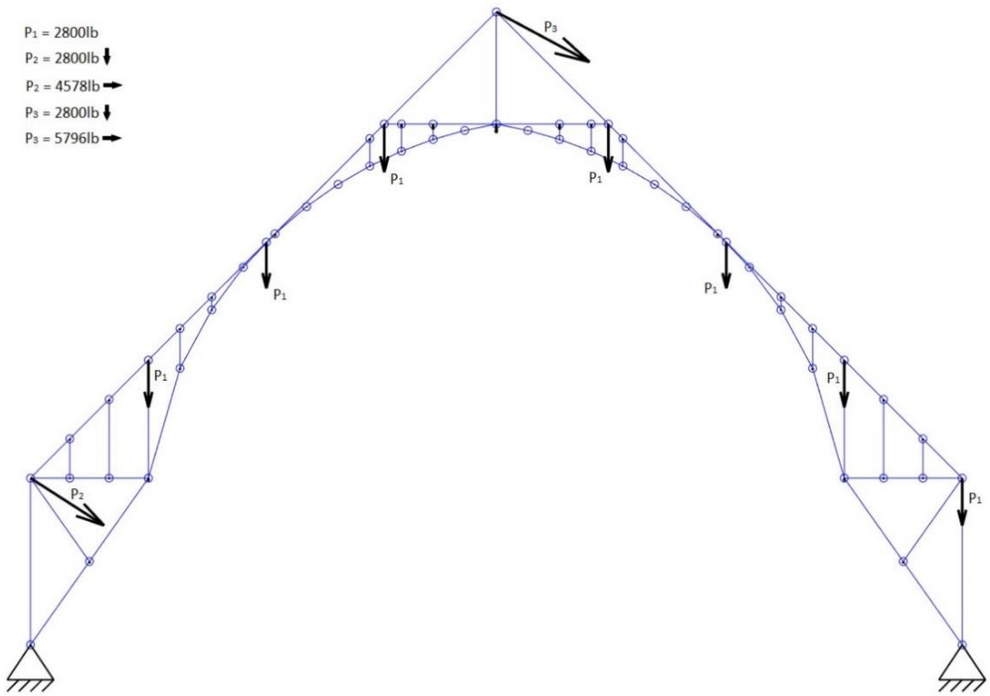


Figure 25: Truss Case 3 Loading Scenario (Gravity and Laterally Governed)

Whereas the size of the decking, purlins, and rafters were mentioned in the archive plans, no detailed plans of the truss exist, and the size of the members was not discussed. Consequently, the size of the members was left for us to measure. Because most of the members were out of reach, many of the members had to be estimated using visual inspection. To create a virtual model for *MATLAB*, a series of nodes was created. All primary members were divided up based on the location of the nodes. The structural analysis algorithm automatically creates fixed-end connections at each node. For each pin connection, an additional node was added and an infinitely small member with infinite flexibility connected the nodes. Once all the members were created at each node, 131 members were used for the computation with 106 nodes. For each member, the cross-sectional area and the moment of inertia were also defined. Two pin supports were placed on the truss at the bottom-most joints. *MATLAB* also cannot receive distributed loads in the algorithm and so all distributed loads from self-weight, sheathing, and MEP were broken up into equivalent couple point loads and moments. Upon running the program, all of the axial loads, shear forces, and bending moments, nodal displacements, and reaction forces were determined and used to test for adequacy of the members. The reaction forces were also used for the corresponding wall analysis.

4.1.4 Floor

Upon visual inspection, the floor that ran between the basement and the sanctuary contain girders that ran east-west at the same location where the trusses lie. These girders are covered by the drop-down ceiling in the basement. The girders run through the original basement ceiling and so it is impossible to see what is between the original ceiling and the floor of the sanctuary. The archive plans suggest that the floor in made up of 2x12 spruce joists running north-south spaced 16 in O.C. and 8x12 girders spaced 15.3 ft running east-west sitting on top of lally columns spaced approximately 11 ft.

Load combinations for dead and live loads were applied to the joists and girders, and each was analyzed at first based on gravity loads only. Both the girders and joists were tested for adequacy with shear, bending moment, and deflection using the same techniques as those used to analyze the roof members. In this case, the analysis was performed by hand due to the simplicity of the model.

In order to incorporate lateral loads into the floor analysis. A 2D frame model was created which included the girder, lally columns, and buttresses that ran beneath the floor. Similarly, to the truss analysis, three loading scenarios were created by three different load combinations. The first was gravity governed and used the combination D + L shown in Figure 26. The second was primarily laterally governed and used the combination D + 0.7E shown in Figure 27. The third was governed by both gravity and lateral loads and used the load combination D + 0.75L + 0.75(0.7E) + 0.75S shown in Figure 28. For lateral load analysis, seismic loads were used over wind loads because seismic loads were at a greater magnitude than the wind loads and ASCE permits the use of the greater of the two. In the model, pin connections were used at each end of the lally columns, as they are not designed to resist moment. Reaction forces calculated from *RISA 2D* from the frame analysis was used as the influence of the floor in the wall analysis.

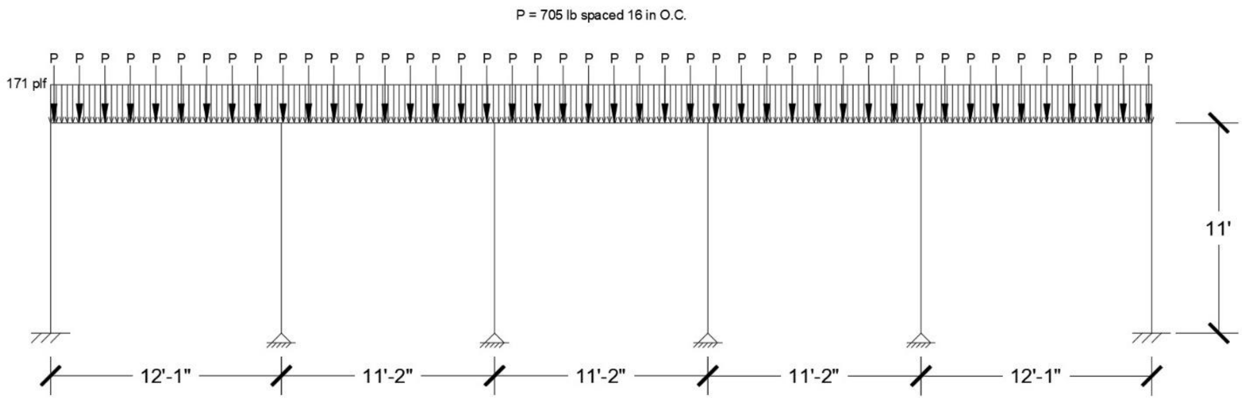


Figure 26: Gravity Governed Frame (D + L)

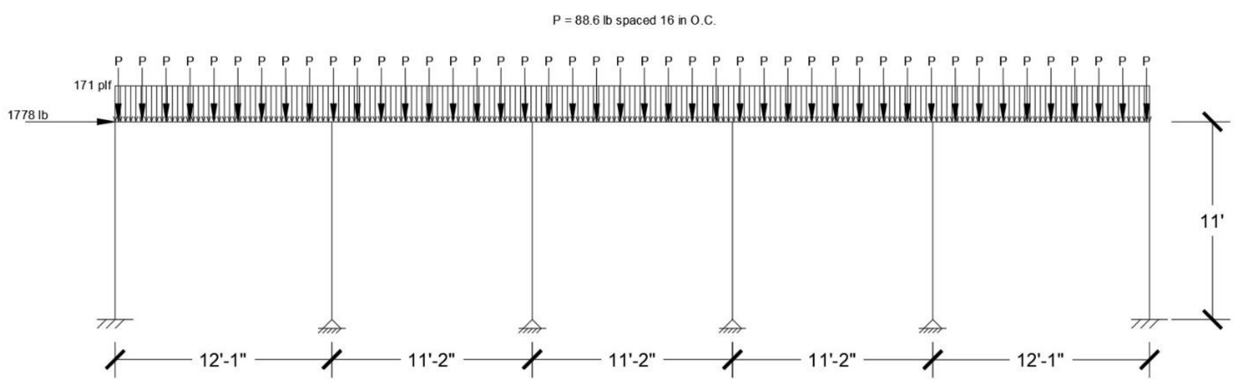


Figure 27: Seismic Governed Frame (D + 0.7E)

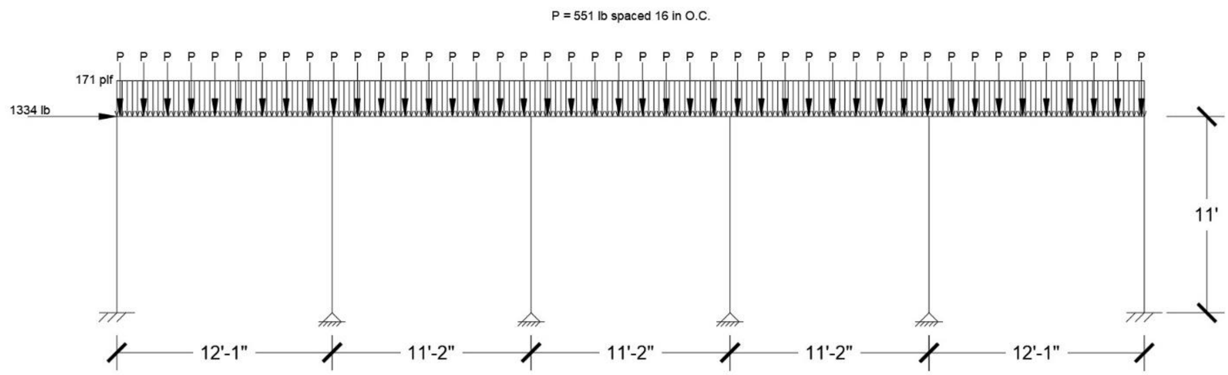


Figure 28: Gravity + Seismic Governed Frame (D + 0.75L + 0.75(0.7E) + 0.75S)

4.1.5 Walls

The walls of the church where the sanctuary are estimated to consist of the granite masonry buttress varying from 3-2 ft thick based on the height from ground level, 16in of additional granite masonry on the exterior side of the wall, several inches of brick masonry, an unknown air gap and insulation and plaster finish on the interior of the wall. The walls were analyzed at the weakest points. These weakest points primarily consisted of the section of wall in which the buttress connected to the truss and girder. A picture of the buttress can be seen in Figure 29. At first, the buttress (rectangular section) was tested to resist all loads. This was highly conservative and resulted in large amounts of tension in the masonry. A revised T-section analysis was performed to also include a larger section of the wall. These sections can be seen in Figure 30. The amount of wall permitted to be used in the section is based on a shear lag principle in American Institute of Steel Construction (AISC) chapter 16, section I3-1a stating that the effective width of the wall permitted to be used in the T-section shall not exceed one-eighth the height of the wall, or one-half the distance to the centerline of adjacent buttresses. This is because the further away from the buttress, the less the wall is resisting the load. In this case, one-eighth the height of the wall is 3.75

ft on either side of the buttress centerline. Consequently 7.5 ft of the wall can be considered to resist the buttress for the 30ft tall wall.

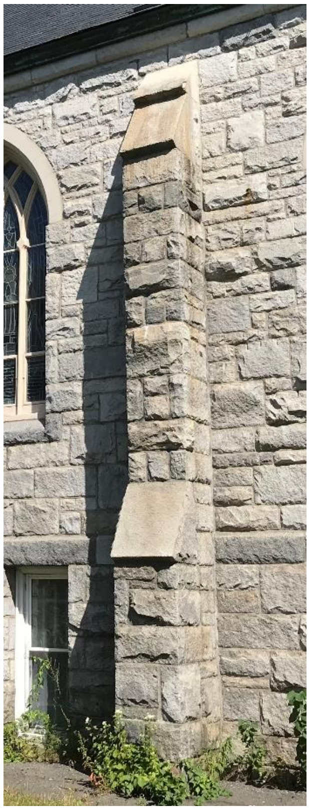


Figure 29: Church Buttress

Four primary external loads are exerted into the walls. Two of which are vertical and horizontal component loads exerted from the truss at point B in Figure 30 and the other two are the vertical and horizontal component loads exerted from the girder at point D in Figure 30. The unit weight of granite is about 169 pcf. Because the exterior is granite masonry, mortar can be factored into the weight and the unit weight of granite masonry can be estimated at about 150 pcf. For simplification, when calculating for the self-weight of the wall and external moments caused by asymmetry in the cross-section, it can be assumed that the cross-section is completely comprised of granite masonry. The footing on the other hand is referred to as bed stone in the archive plans and as a result will be assumed to be pure granite at 169 pcf.

Three points along the height of the wall were analyzed for tension and compression forces at the extreme fibers of the cross-section. Point C is located immediately above where the buttress changes from two to three feet thick, point E is at the base of the buttress, and point F is located at the base of the footing. These points can be seen in Figure 30. The reason these three specific points are used is because they represent the point at which the buttress experiences the greatest moment under each cross-section. At these three points, all forces acting vertically both internally as self-weight and externally carried over from the truss and girder are calculated to come up with a total load, P. Total moment, M, is calculated by all loads, internally by asymmetry and externally through the truss and girder, acting at a distance away from the centroid of the cross-section. The purpose of calculating the tension and compression of the extreme fibers at point C and point E is to determine the adequacy of the buttress to resist moment and axial loads, but the purpose of calculating compression and tension at point F is to determine the effective size of the footing and the ultimate loads acting on the footing to compare alongside bearing capacity.

Once P and M are calculated the maximum tension and compression stress can be calculated using the equation

$$\sigma = \frac{P}{A} \pm \frac{Mc}{I}$$

Equation 5

where P is the total load acting on the buttress at a given point, A is the cross-section over which the load acts, M is the total moment acting on the cross-section due to eccentricities, c is the distance from the centroid of the cross-section to the extreme fiber under which the most extreme compression/tension is experienced, and I is the moment of inertia of the cross-section.

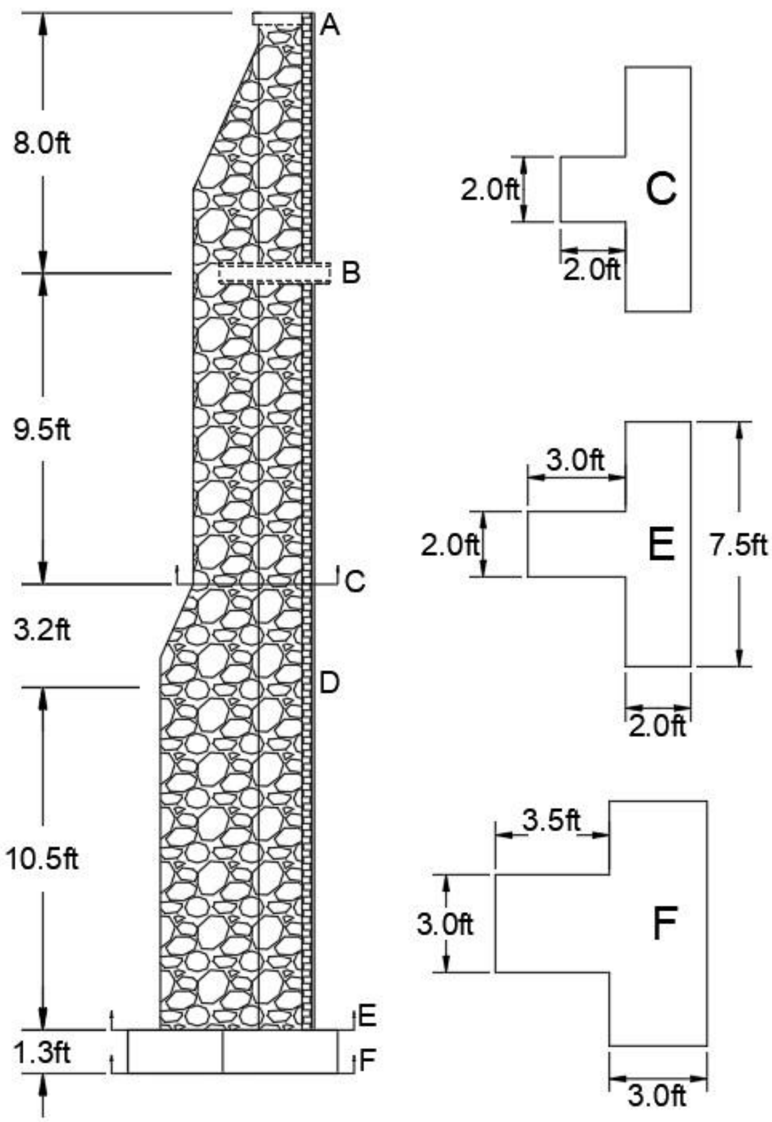


Figure 30: Buttress Dimensions and Locations Analyzed

Three different loading cases were used to analyze the walls. The first of these cases, referred to as the gravity case, correspond to the D + 0.75L + 0.75(0.6W) + 0.75S combination acting on the truss and the D + L combination acting on the girder. The second case, referred to as seismic case 1, corresponds to the D + 0.7E combination acting on the truss and girder forcing the wall to deflect away from the interior of the church. The third case, referred to as seismic case 2, corresponds to the D + 0.7E combination acting on the truss and girder forcing the wall to deflect towards the interior of the church. These cases are shown in Figure 31.

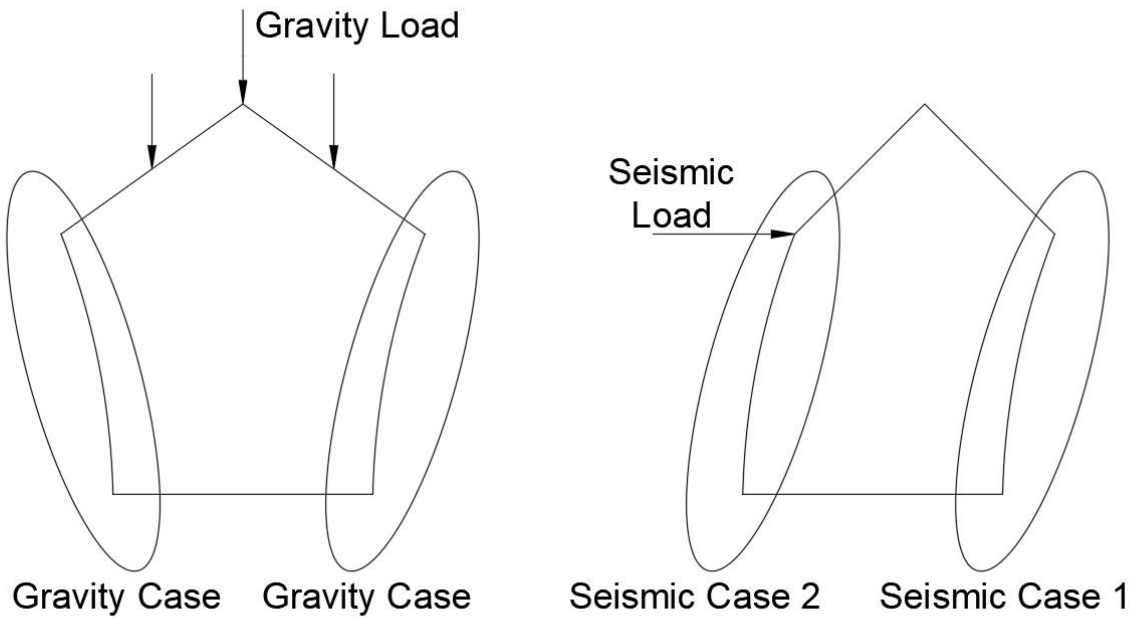


Figure 31: The Wall was Analyzed Under Three Loading Cases: A Gravity Case and Two Seismic Cases

In order to size reinforcement for the buttress, an interaction diagram can be created for the buttress acting in both compression and flexure. Several suggested values from National Concrete Masonry Association (NCMA) are used to estimate the yield strength and elastic modulus of the masonry and steel. These values are used with concrete masonry and are conservative for use with granite masonry. In this case, an entire interaction diagram does not need to be created because the axial load in the buttress will remain constant. Instead, eccentricity in the buttress will change based on how much steel is used and how far the neutral axis shifts. Equilibrium for the buttress is calculated since the tension in the section plus the axial load equals the compression block in the section. Assuming that steel will yield first, different amounts of steel can be tested, and the neutral axis can be found using iteration so that T + P = C holds true. Once the neutral axis is found, the nominal moment in the buttress can be found about the steel and can be compared with the ultimate moment the buttress experiences to find adequacy.

Reinforcement can be anchored to the existing wall by means of steel anchors or shear studs. These studs will create composite action and the steel section will be able to resist all of the tension preventing cracking. According to AISC I8.3a, the amount of sheer each stud can withstand is proportional to the surface area of the stud multiplied by the yield strength of the steel. This shear resistance can then be used with the reinforcement area of steel to determine the number of studs required for full composite action.

4.1.6 Determination of Vibration Thresholds

With I-290 and Route 9 both in proximity of the church, there was some concern that traffic induced vibrations may be affecting the church's structural integrity. In order to investigate the vibrations experienced by the church, accelerometers were placed on the walls of the towers.

Figure 32: Onset HOBO Pendant G Accelerometer[13]

These accelerometers measured the acceleration of the vibrations experienced by the church over periods of time. The accelerometers measured vibration levels in the church from May 2019 until January 2020. Throughout this time, the accelerometers performed measurements of the vibrations with intervals ranging from 1 second to 1 minute. There were two placed in Tower 1 (Right) on the North and East sides and there were two placed in Tower 2 (Left) on the South

[13] https://www.onsetcomp.com/products/data-loggers/ua-004-64

and West sides. In the towers, the accelerometers were on the second level which is about 40 feet above ground level.

Figure 33: Accelerometer Installed on Wall of the Right Tower

Vibration threshold analysis is the primary way to detect the level of vibrations a building can withstand without damage. Vibration thresholds are not the same for every building. For comparison, the human body can perceive very low levels of vibrations. Roughly, the perception threshold for steady-state vibrations is 0.03 in/s. Most vibrations become disturbing at 0.1-0.2 in/s[14].

There are three primary factors that are used when selecting the appropriate criteria to determine vibration thresholds. The first factor is building type and condition, which considers responsiveness/sensitivity to vibration input and fragility. The second factor is vibration type, which considers what types of vibrations the building might be experiencing. For example, short term vibrations or steady state/continuous vibrations. The final factor is the importance factor,

[14] Zeigler, John M. 2019. *Vibration Standards.* Accessed 2 13, 2020. https://vibrationdamage.com/Vibration_standards.htm.

which indicates additional conservatism, cultural, or economic value of the structure being analyzed.

In addition to the three key factors to keep in mind, there are four primary industry standards that were considered in this report. The first is the British Standards Institute (1993) which can be used for any vibration source. This is best to use for unreinforced or light framed structures that are experiencing cosmetic damage. The peak particle velocity for this standard is 0.3 in/s. The second is the Swiss Standards Association (1992), which can be used for any vibration source as well. This is best to use for historic and protected buildings that are experiencing any type of damage. The peak particle velocity for this standard is 0.24 in/s. The third is Deutsches Institut fur Normung DIN 4150-3 (1999) which can be used for any vibration source. This standard is best to use for buildings of great intrinsic value that are experiencing any permanent effect that reduces serviceability. The peak particle velocity for this standard is 0.25 in/s. The last is the USBM RI-8507 which is mainly for ground vibration and surface mine blasting. The source that is the best fit for the church is the Swiss Standards Association 640 312. The Swiss Standards Association is the best fit for the church because it has the four different classes of standards that are specified for different building types. Classes 1 and 2 include industrial/commercial size buildings. Class 3 includes residential buildings in brick or concrete, office buildings, schools, hospitals, churches, well designed. Lastly, class 4 includes historic buildings. With the church being built in 1910 and still containing original structural elements, it fits into either class 3 as a church or class 4 as a historic building. In the Swiss Standards Association, class 4 standards are for historic buildings which are especially fragile because of their age and material. This was the standard that was used for the church with it being over 100 years old. According to the Swiss

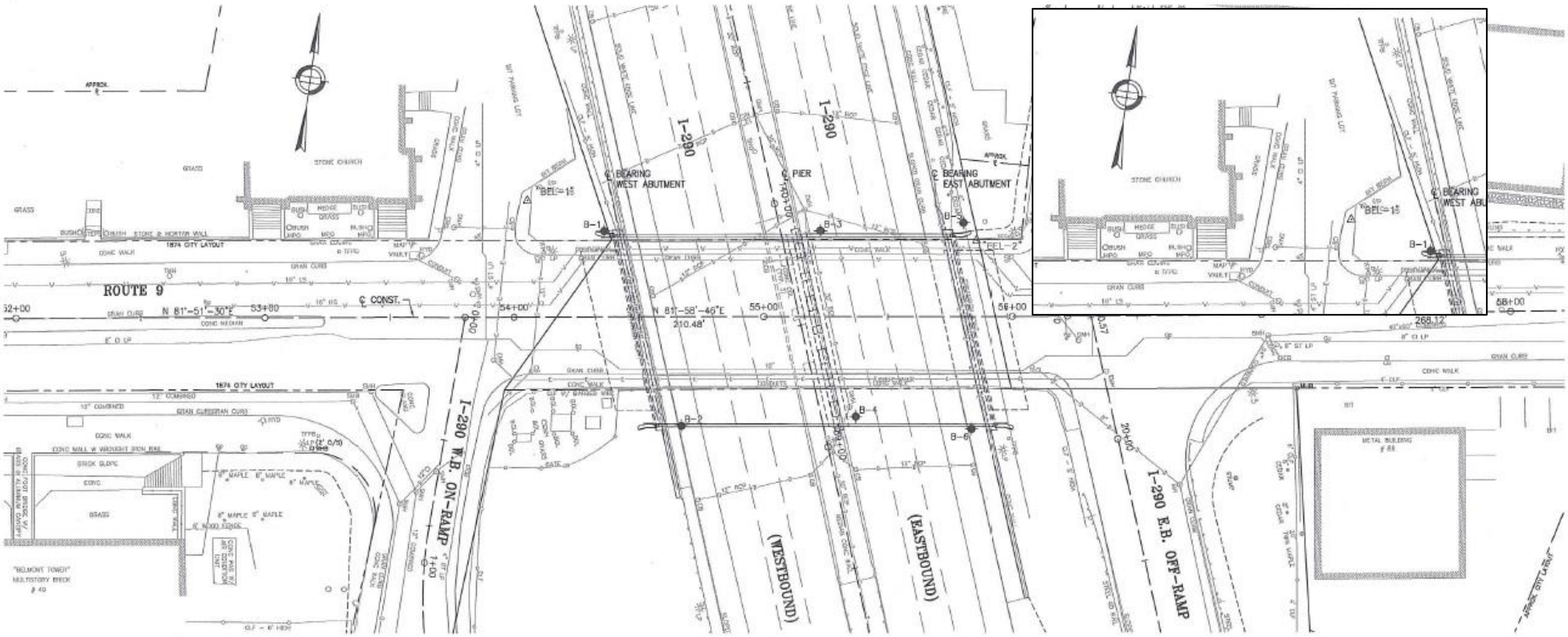
Standards Association class 4 standards, the church would experience damage if a vibration of 0.59 in/s occurred instantaneously or if a vibration of 0.24 in/s occurred continuously.

4.2 Geotechnical Analysis

It is important to analyze the foundation of the church against typical modes of failure such as through settlement and bearing capacity. This process was performed using data from a representative soil profile, which acts like a model used to represent soil conditions and properties at various depths to be used for analysis. The analysis for bearing capacity was performed using Terzaghi's method. Settlement calculations were performed using the classical method based on past maximum stress. All geotechnical calculations are shown in Appendix C.

4.2.1 Determination of Soil Conditions

The Massachusetts Department of Transportation performed a geotechnical analysis in 2008 prior to the renovation of the overpass over route I-290 adjacent to the church. This analysis was based on in-situ data received from boring logs as well as various laboratory tests. The location of the boring logs can be seen in Figure 34. The first boring hole, B-1, is located closest to the church and can best represent the soil conditions beneath the church. Estimates for friction angles and unit weights were then found based off the data obtained from B-1.



FINAL BORING LOCATIONS			
BORING	NORTHING	EASTING	SURFACE EL.
B-1	2924237.7975	576317.5008	517.0
B-2	2924164.7065	576359.2180	496.0
B-3	2924249.8698	576403.5807	495.5
B-4	2924178.0609	576428.0848	496.4
B-5	2924261.1885	576460.1177	516.0
B-6	2924179.7347	576474.8893	496.5

PROJECT FILE NO. 604065

massDOT
Massachusetts Department of Transportation
Highway Division

ROUTE 9 (BELMONT STREET)
OVER I-290
WORCESTER, MASSACHUSETTS

BORING LOCATION PLAN

SCALE: 1" = 40'

BRIDGE NO. W-44-094

WSP • SELLS
Transportation & Infrastructure
9 Trolley Crossing Road • Charlton, MA 01507 • 508.248.1970
www.wspsells.com

FIGURE NO.
1

Figure 34: Boring Locations Obtained from Massachusetts DOT

4.2.2 Foundation

The footings are described as bed stone in the archive plans and so they are assumed to be made of pure granite. The footings underneath the lally columns as well as the footings underneath the buttresses were considered for analysis both structurally for shear and bending and geotechnically for bearing and settlement. The footings below the buttresses are assumed to be 6in wider in every direction than the buttress that runs above the footing, and the footings below the lally columns are measured to be 2.5 ft x 2.5 ft x 1.3 ft by the archive plans. It is assumed that granite behaves is a similar way to concrete and so when analyzing the footings for bending and shear, it can be assumed that the footings will have the same cleavage and other failure mechanisms as concrete. Consequently, American Concrete Institute (ACI) specifications were used for analyzing the footings for shear and bending.

Based on the first-floor frame analysis, the maximum axial loads that go into the lally columns are 8071 lb. The lally columns are measured to be 3.5 in in diameter. Typically, a baseplate is used to connect the column to the footing but because the dimensions of the baseplate are unknown, it is assumed that the column connects directly to the baseplate. Based on the geometry of the footing, critical sections for one-way shear can be created based on a distance, d, from the column where d represents the depth of the footing. For two-way shear, distance d/2 from the column to the edge of the footing in all directions defines the shape of the critical section. If the shear stress for the critical section is greater than the allowable stress of the footing, then the footing will fail for shear.

To test for bearing capacity, Terzaghi's method is used. Three imperial based constants are determined as a function of the soil's friction angle and are used to determine the ultimate bearing capacity of the soil. Also, in this method is the confining pressure at the base of the footing and the depth of the ground water table. Because the confining pressure and depth of the footing is different depending on which side of the footing is being analyzed, this value is determined based on the way in which the footing is expected to fail. Based on the eccentric load acting on the buttress, the foundation will also receive a triangular distributed load which will govern how the footing wants to rotate. Also due to the eccentric load, only the effective width of the footing based on the part of the footing in compression is used in Tarzaghi's method. The ground water table is estimated to be about 28.5 feet below the surface, which is well below the embedment depth of the footing. It should also be noted that different formulae exist for Terzaghi's method for different footing shapes. In this case, the buttress footing is continuous and the lally column footing is square. The resulting equation used to find the bearing capacity for continuous footings is

$$q_{ult} = c'N_c + \sigma'_D N_q + 0.5\gamma' B N_\gamma \qquad \text{Equation 6}$$

and for square footings is

$$q_{ult} = 1.3c'N_c + \sigma'_D N_q + 0.4\gamma' B N_\gamma \qquad \text{Equation 7}$$

where q_{ult} is the ultimate bearing capacity, c' is the effective cohesion, σ'_D is the vertical effective stress at depth D, γ' is the effective unit weight of the soil, B is the footing width, and N_c, N_q, and N_γ are bearing capacity factors as a function of the friction angle.

4.3 Envelope Analysis

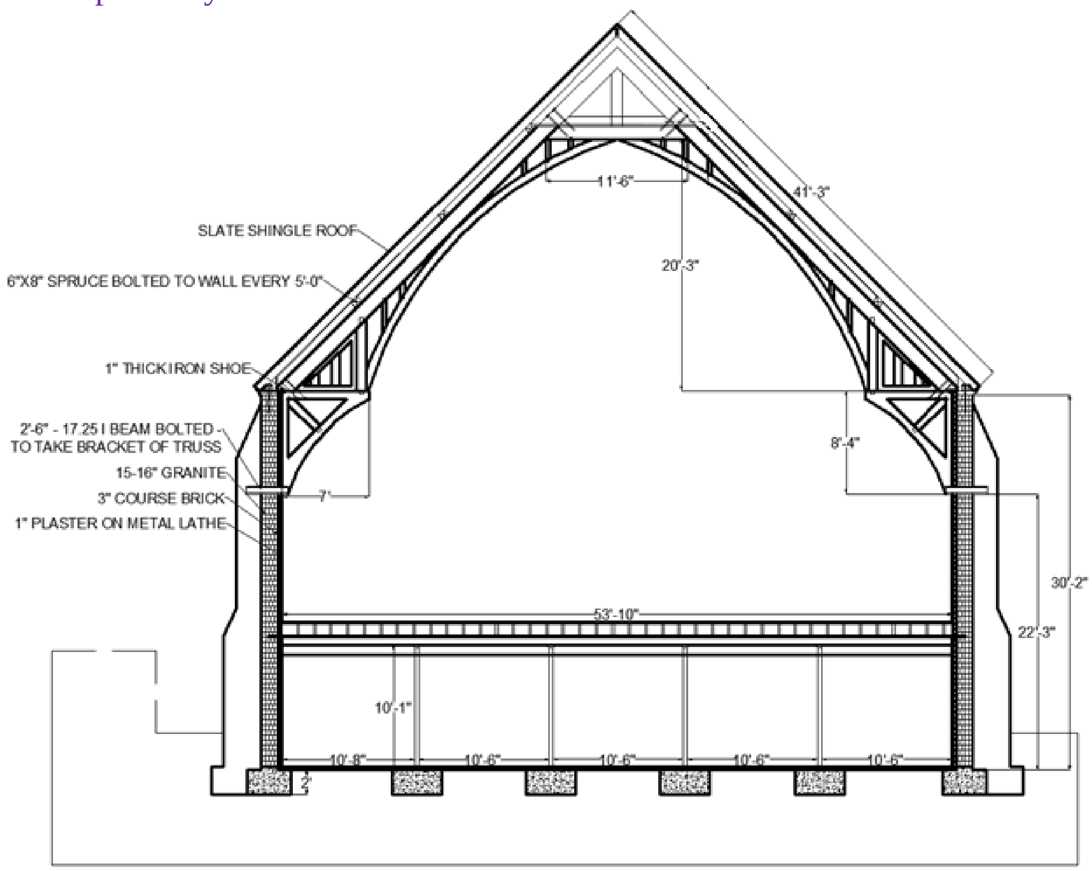


Figure 35: Section Drawing of the Worcester Gospel Church

Through site surveys, wall samples, and existing documentation our group was able to determine the construction of the church's envelope shown in Figure 35. These details were incorporated into all elements of this report and were necessary to determine structural performance, heating and cooling loads and energy analysis.

4.3.1 Walls

All walls in the sanctuary and basement are primarily solid. Locations of wall studs were not able to be determined based from site surveys as well as pre-construction plans. The preliminary architectural plans that were obtained from the Massachusetts State Archive guided this analysis assuming that the primary wall construction of the church is 15-16" masonry wall comprised of granite blocks (depending on block thickness), one course of brick (3"), and then 1" of plaster on metal lathe. There are most likely studs where the metal lathe is attached, however the air gap space is minimal. These details of the envelope were analyzed and incorporated into the structural and energy analysis of the building.

In the process of removing the portions of wall from the towers for them to "dry out", wall construction of the towers was determined. It was found that (from the outside to inside) there is 15-16" of granite stone (depending on block thickness), one course of brick (3"), a 5" air gap, studs every 24" O.C., and then 1" of plaster on metal lathe.

In late November 2019, a temperature/relative humidity sensor was placed behind the wall in the right tower in the air gap of the wall through the hole that was created in order to quantify the moisture content inside of the walls.

4.3.2 Roof

An internal visual inspection of the roof from the 1st floor access door through the Woman's restroom was attempted to determine the overall roof construction. Initial plan drawings and U-value ratings were based on long-range observations and were most likely not accurate. However, based on initial observations and plans obtained from the Massachusetts State Archive, a much better idea of the roof construction was able to be ascertained. The roof was determined to be (from outside to inside) interlaid 1/8" slate shingles overlapped, 1.125" roof decking, mounted 2x8 rafters spaced 16" O.C. running east-west, 8x10 purlins spaced 9.7 ft O.C. running north-south, and the hammer beam truss. These details were integrated into our energy and structural analysis.

4.3.3 Windows

The specifications of the stained-glass windows in the sanctuary are typical of stained glass produced around 1910. Typical U-values of these windows are consistent with modern 3mm single pane, clear glass and our analysis followed these recommendations. Since we were unable to perform exacting tests to determine the actual U-values and solar heat gain coefficients of the stained glass, ASHRAE standards for 3mm clear glass was incorporated into energy analysis. Windows in the gym and basement are double glazed window systems and were incorporated into our analysis assuming such.

4.4 Energy Analysis

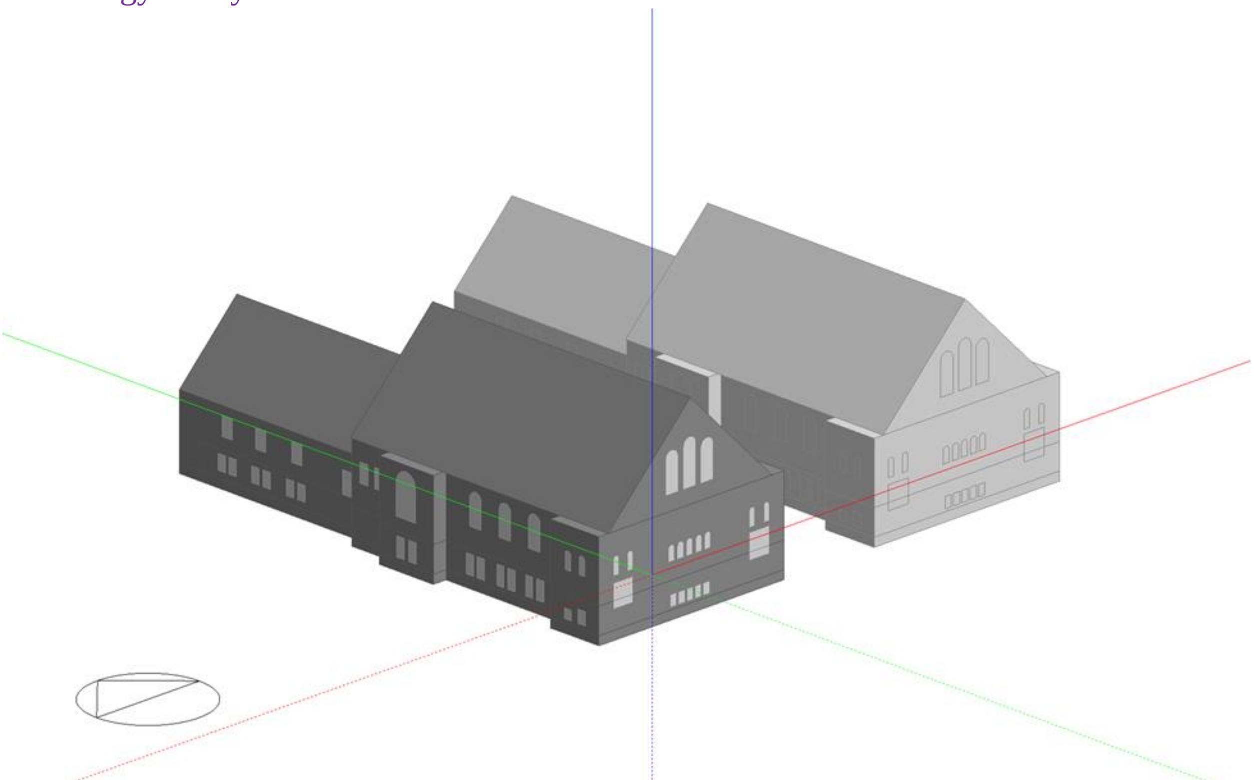


Figure 36: DesignBuilder Energy Model and ASHRAE Baseline Model

A digital model of the Church was created in the energy modeling software, *DesignBuilder*. *DesignBuilder* performs complex energy and building envelope heat loss/gain calculations based on user supplied building constructions and geometries and then establishes baselines from these criteria. A simplified model of the church was created with envelope constructions based on our observations and findings from the pre-construction plans. This software allows one to determine the heating/cooling loads of a building and the total amount of energy required to make the building comfortable based on its present condition. *DesignBuilder* requires a great deal of trial and error to ensure that complex geometries do not cause a simulation to fail. The tops of the towers of the church were not included in the simulation due to geometric/mathematical errors they introduced in the software as displayed in Figure 36. With *DesignBuilder*, potential improvements (i.e. insulation, double paned windows) can be added to the building envelope and then the energy savings due to theorized improvements can be quantified and considered. Due to the size and complex geometry of the church, a heating or cooling analysis of the church took 3-4 hours of computation time while advanced parametric and pareto front optimizations that involved many variables required days of computational time.

One of the most important factors to establish the required heating and cooling load was to create an annual local weather data set. The outdoor temperature sensor placed outside the church was used as a baseline to confirm that the annual temperature information provided by ASHRAE is valid. The ASHRAE standards are more accurate and contain more points than any data set that could have created by establishing a new localized weather data set. Annual local weather data gathered at the Worcester Airport, located approximately 4 miles away, was used in the *DesignBuilder* analysis. By establishing digital models and utilizing local weather data, an energy analysis of the building can be created based on annual conditions, and a much more accurate heating and cooling model than would otherwise be possible by using hand calculation methods can be created. By utilizing all these factors, creating accurate heating/cooling load and energy consumption figures is much more obtainable, especially in a building with such complex geometry.

4.4.1 Occupancy

DesignBuilder provides the option to input schedules as to when the building is occupied and must be heated/cooled appropriately. Based on the information that was given by Jonas Chang based on the size of the congregation and time and size of afterschool activities, an occupancy schedule of the church was created. This schedule assumes that the Sanctuary would be in use from 8am-3pm every Sunday. The basement would be partially utilized during weekday mornings for staff and primarily utilized weekday afternoons for after-school activities. The gym followed similar schedules to when there is activity in the church and during afterschool activities. These schedules determine when heating setback points are to be changed for optimal comfort, while reducing temperature in large portions of the building when they are not in use, but still active to provide adequate building conditioning. These occupancy factors also include a rough estimate of electricity that is used by lighting, computers, televisions, audio systems, etc, that contribute to the overall energy consumption of the building.

4.4.2 Walls

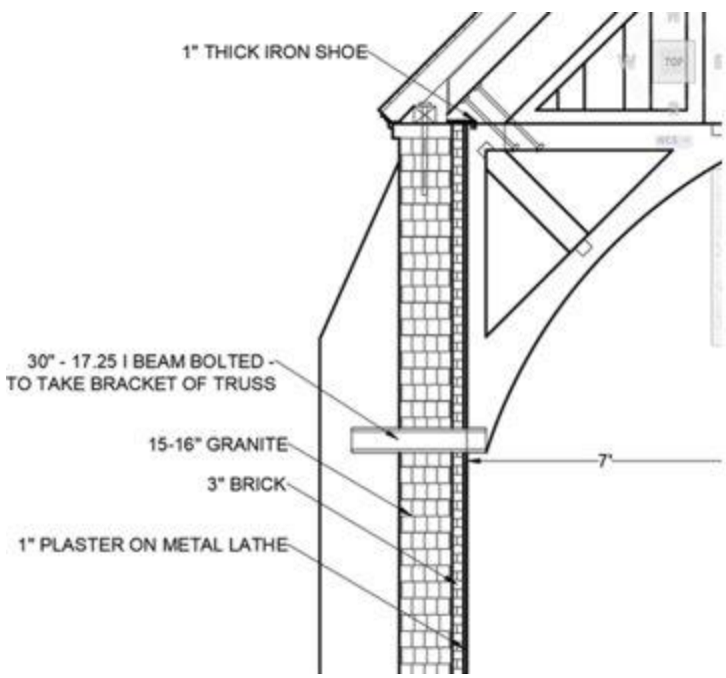


Figure 37: Determined Church Wall Construction

It was assumed in the preliminary estimates of the heating load required by the sanctuary that the walls were composed of 24” of stone. Once a better understanding of the actual building construction was established, a complete analysis was performed. The hand calculations of potential wall U-values were different compared to the *DesignBuilder* energy analysis. *DesignBuilder* includes the unique individual thermal properties of the church's building envelope elements (Figures 37 & 38) built into its software rather than using the ASHRAE standards of generic stone in the hand calculations. The *DesignBuilder* analysis is likely more accurate and allows for more complex analysis based on comprehensive weather data and thermal bridging of envelope components.

4.4.3 Roof

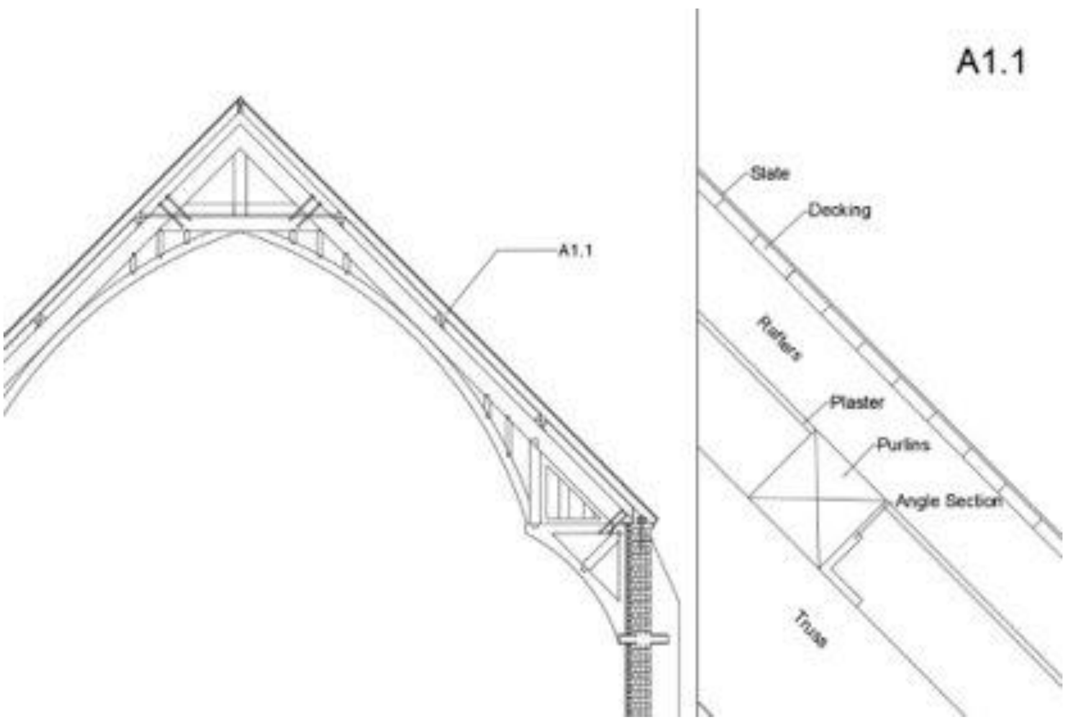


Figure 38: DesignBuilder Energy Model and ASHRAE Baseline Model

The roof deck over the sanctuary is currently uninsulated and is enclosed in an attic space that is not visible or accessible to the congregation. Adding insulation to this space was one of the first aspects considered for potential building energy improvements. Such an improvement could be implemented relatively easily compared to the other envelope suggestions in this report. A simulation was created by comparing the existing roof construction and comparing the differences if adding modern code compliant insulation was installed.

4.4.4 Windows

As discussed previously, the condition of the stained-glass windows in the sanctuary are responsible for a great deal of air infiltration as well as heat loss from the building. Repairing the windows will help greatly with these issues. Simulations were performed assuming that the windows were mechanically intact when in reality they are not. The windows were simulated by using values for 3mm clear glass which is very similar to standards associated with stained glass.[15] In this analysis, the windows in the sanctuary were simulated with double and triple glazed fenestrations to see their overall improvement to the building's energy consumption.

4.4.5 Heating Setpoints

By understanding the influence of overall heating and cooling setpoints of the building, a better understanding of maximizing comfort and energy savings. By modeling the current fuel oil boiler system, set point temperatures can be quantified to actual energy expended and the overall cost associated with these set points.

4.5 HVAC Analysis

When the church was constructed, the primary heating method of most buildings was coal, which was inexpensive and plentiful in the United States. Remnants of this heating method can be observed by the coal chute and sub-basement construction. Currently, the church's primary heating is provided by a hot water radiator and baseboard heater system fueled by oil. Hot water is pumped through pipe loops that run to baseboard heaters and radiators throughout the church and the cooled

[15] "Protective Glazing Study." National Preservation Center, March 1996. https://www.ncptt.nps.gov/wp-content/uploads/1996-06.pdf.

water is returned to the boiler to be reheated. The gym has forced air, electric heaters installed that appear to be close to 30-40 years old. There has never been any form of cooling/air conditioning installed in the building as records indicate. As identified by the church, there are significant issues with retaining heat in the building. These analyses were performed assuming that the building envelope at present is intact. Current energy consumption is likely much higher due to the defects with the roof and windows. Before installation of a new heating/cooling system is to take place, correcting these issues should be the first step to making significant building improvements. Due to many unknown factors while performing this analysis, this information should be used as a baseline to understand the heating and cooling requirements of the church. Any design of a new heating or cooling system should first be fully vetted.

4.5.1 System Sizing

Calculations to determine the total amounts of heating and cooling required were reached by using hand calculations as well as the *DesignBuilder* simulation model. Hand calculations were performed to determine the R and U values of the building envelope components. These R and U values were then used to determine the heating load for an average Worcester winter temperature of 34.7F with an internal operating temperature of 70F based on the overall wall and window areas across the church. A similar method was utilized to determine maximum cooling loads at the peak temperature times during the summer. Hand calculations for summer cooling loads were performed with different variables to ensure that the overall sizing of the system would remain in the same range. It is assumed that the *DesignBuilder* analysis is more accurate due to the utilization of complex geometries and volumes of the church as well as its ability to integrate complex ASHRAE weather data into its analysis. Hand calculations were divided into three primary sections, based on volume: The Sanctuary, Gym, and Basement.

4.5.2 Heating Load

Hand heat loss calculations were performed assuming an average Worcester winter temperature of 34.7F for the whole building divided into three zones. Initial estimates of the sanctuary heating load that were presented in A-term were calculated assuming the walls were made of 24” stone and the roof was a standard uninsulated roof deck. This was done before the original proposed building plans were obtained from the Massachusetts State Archive.

DesignBuilder calculated the total heating design load of the church for worst case winter scenarios using ASHRAE weather data beyond the hand calculations utilizing an average Worcester winter temperature. Additional steady state heat loss calculations were performed that to confirm findings determined by hand calculations. Internal heating times were determined by the occupancy schedule defined, as well as internal operating temperatures of 68F and a heating setback of 62F. This analysis included areas of the church that were not included in the hand calculations and would be assumed to remain unconditioned in the future.

4.5.3 Cooling Load

Cooling loads were determined by hand calculations determined by average and peak summer temperatures and a general understanding of the shading that the building experiences from its surroundings and other buildings utilizing ASHRAE standards. The assumed summer internal operating temperature was 74F. *DesignBuilder* was utilized to verify these numbers, but a cooling system was not integrated into the computer simulation, as one does not currently exist in the Church, and the current digital model was made so that conditions were as true to life as possible. Peak summer cooling loads were calculated to also include occupancy of the church assuming a 255 BTU/Hr addition per person in the building and an estimate of electrically powered equipment in operation adding to the heat gain.

4.5.4 Potential Heating Cooling System Options

Based on the current boiler/hot water heating system that is presently installed provides heat through baseboards located throughout the building. There were several analyses that were performed in order to determine if a new type of HVAC system would result in overall lower energy consumption and as few annual discomfort hours as possible while the building is occupied. Because of the existing hot water heating system utilizing boilers, trying to undertake a complete overhaul and reinstallation of a new heating system would be expensive based on the buildings construction. Based on energy simulations in *DesignBuilder* and research there are a few heating/cooling systems that would result in lower energy consumption compared to fuel oil and improve overall efficiency within the building.

4.5.5 Hot Water Baseboard Fuel Type Comparison

By utilizing *DesignBuilder* to establish total amounts of fuel oil required to heat the building according to the occupancy schedule and heating setpoints specified, an analysis was performed to create a reasonable comparison between the current fuel oil consumption (given that the building was conditioned appropriately during off-hours) versus using natural gas using the same occupancy schedule. Since the church is in close proximity to several large-scale public buildings (UMass Memorial Hospital, Worcester Police Station) obtaining service from a natural gas line should be relatively easy.

5.0 Results

While performing all of the calculations for structural integrity, energy usage, and HVAC options, numerical data was gathered to determine the exact details of what was analyzed. Much of this data was generated through numerical analysis aided with various software packages such as *RISA, MATLAB, and DesignBuilder*. The results and observations regarding this data are summarized and discussed in this section.

5.1 Structural Analysis

The structural analysis was performed to determine the adequacy of all major structural members, both through strength and serviceability, as well as determine if there are any vibration-induced consequences due to the adjacent roads and highways that are of any concern. The magnitude of all maximum stresses and deflection in all members were calculated and compared with their respective allowable magnitude to be used as a bases to determine adequacy.

5.1.1 Determination of Loads

All loads were determined with accordance to ASCE 7-10 standards. A summary of all of the gravity loads are presented in Table 4. Seismic loads are shown in Figure. Wind loads are shown in Figures Figur and Figure. These loads represent the design loads used to analyze all major structural members in the sanctuary.

Table 4: Gravity Loads

Load Type	Cause	Acting on	Magnitude
Dead	Slate	Roof	42 psf
Dead	Chandelier	Purlins	100 lb
Dead	MEP	Truss	5 psf
Dead	Roof Decking	Roof Decking	2.4 psf
Dead	Rafters	Rafters	2.84 plf
Dead	Purlins	Purlins	14.21 plf
Dead	Sheathing	Truss	1.683 psf
Live	Roof	Roof	20 psf
Live	Maintenance	Roof	300 lb
Live	Sanctuary	Joists	60 psf
Dead	Carpet	Joists	3 psf
Dead	Decking	Joists	2.4 psf
Dead	Joists	Joists	4.263 plf
Dead	Girders	Girders	17.05 plf
Dead	MEP	Girder	10 psf
Snow	Snow	Roof	24.5 psf

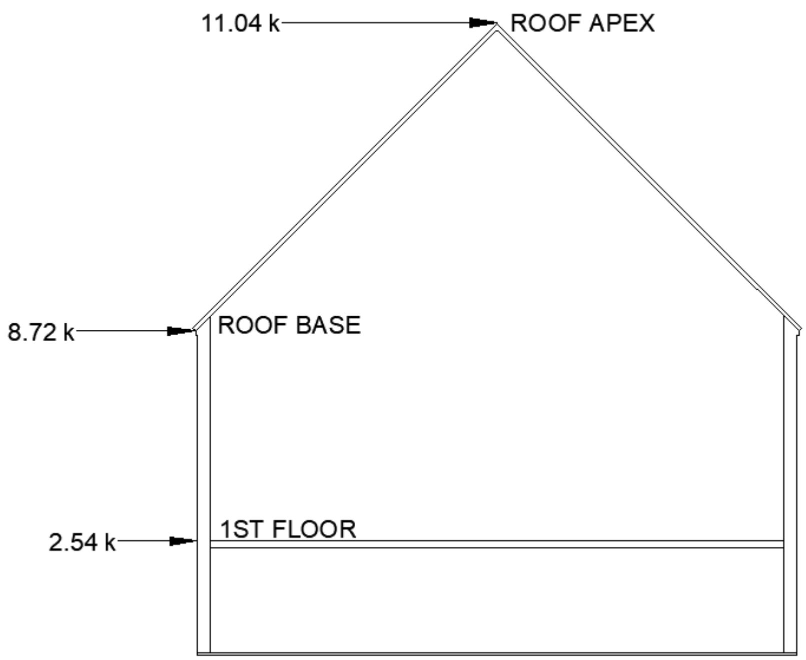


Figure 39: Seismic Loads Acting on Church

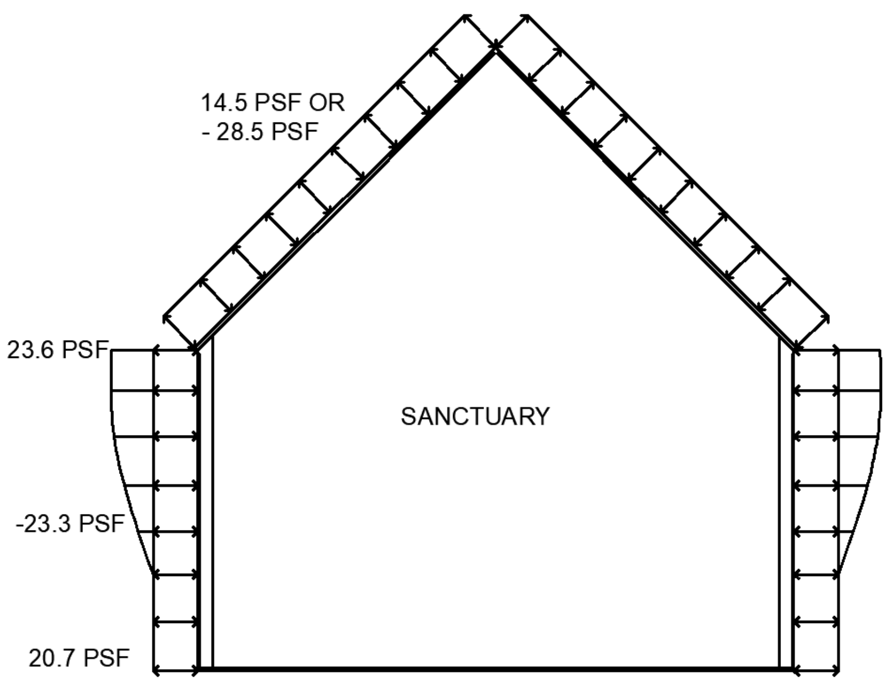


Figure 40: Wind Loads Acting on Church (Section View)

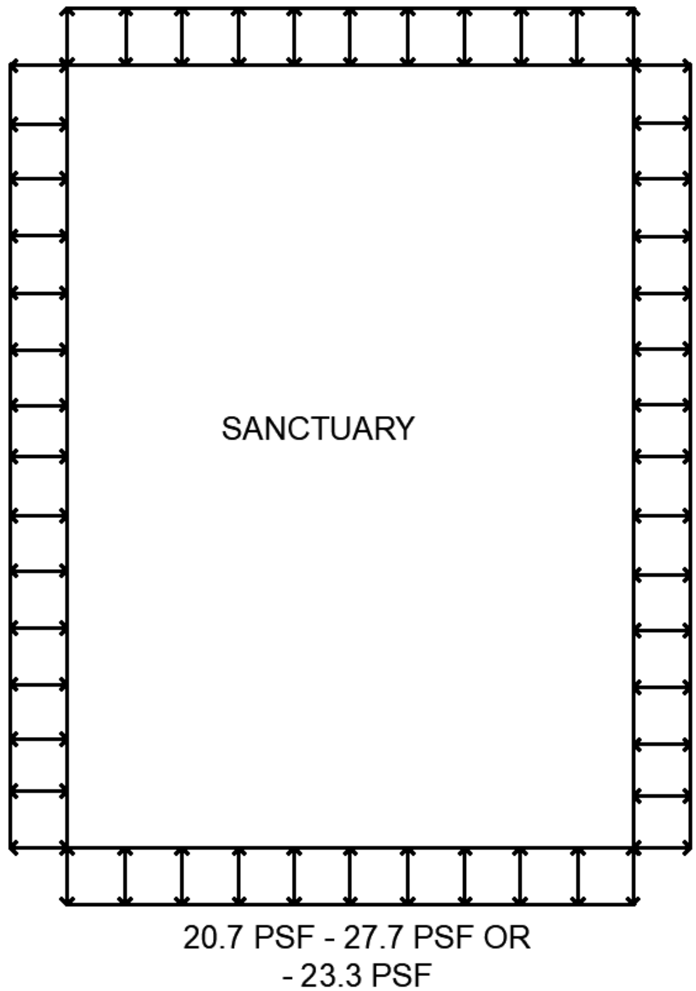


Figure 41: Wind Loads Acting on Church (Plan View)

5.1.2 Roof

A summary of the results for all members of the roof in the sanctuary are shown in

Table 5. Bending refers to bending stress/flexural stress, and shear refers to transverse shear stress. If the allowable bending stress, shear stress, compression, and deflection are greater than the ultimate bending stress, shear stress, compression, and deflection, then all members are adequate under strength and serviceability requirements under the assumed loading. In this case, all members are adequate.

Table 5: Comparison of Ultimate and Allowable Stress and Deflection Experienced by Roof Members

Members	Type	Ultimate Value	Allowable Value
Decking	Bending	287 psi	1787 psi
Decking	Compression Perpendicular to Axis	15.93 psi	425 psi
Decking	Deflection	0.006 in	0.27 in
Rafters	Bending	581 psi	1509 psi
Rafters	Shear	31.8 psi	31.8 psi
Rafters	Deflection	0.13 in	0.32 in
Purlins	Bending	749 psi	1656 psi
Purlins	Shear	41.97 psi	216 psi
Purlins	Deflection	0.374 in	0.51 in
Truss	Axial	323 psi	960 psi
Truss	Bending	1103 psi	1397 psi
Truss	Shear	98.8 psi	216 psi
Truss	Deflection	2.3 in	1.7 in

5.1.3 Hammer Beam Trusses

The hammer beam truss was analyzed under three different loading cases: gravity governed, lateral (seismic) governed, and gravity and lateral governed. The results from the MATLAB analysis are shown in the following figures. Figures Figure , Figure, and Figure summarize all of the axial loads in the truss for each case and represent the load path taken by the external forces coming from the purlins. Figures Figure , Figure, and Figure summarize all of the axial stresses in the truss for each case. Red refers to compression whereas blue refers to tension. Note that the colors used in the gravity case are proportioned with 15,000 lb and 175 psi representing the maximum loads and stress possible whereas the lateral cases with greater loads are represented with 30,000 lb and 300 psi representing the maximum loads possible.

The truss was also analyzed for deflection and is shown for each of the three cases in Figures Figure, Figure, and Figure. Under the gravity case, the truss deflects inwards and pushes out at its base. Under the lateral cases, the truss deflects to the side. It is important to note that the deflection shown in these images are exaggerated for visual purposes. The true deflection is very small—less than an inch for most member nodes.

All reactions for the truss in each case were recorded and shown in Figures Figure, Figure , and Figure. These reactions represent the magnitude and direction of the forces that are required to resist the loads acting on the truss and are equal and opposite in direction to the loads the truss exerts onto the buttress. All of the numerical details for axial loads/stresses, shear, bending, and deflection for each member can be seen in a table in appendix C.

Table 6: Comparison of Ultimate and Allowable Stress and Deflection Experienced by Truss Members (Worst Case Members—See Appendix D on Details for Members and Nodes)

Member	Type	Ultimate Value	Allowable Value
72 (Case 2)	Axial	323 psi	960 psi
36 (Case 2, Node 8)	Shear	98.8 psi	216 psi
35 (Case 2, Node 67)	Bending	1103 psi	1397 psi
39 (Case 2, Node 9)	Deflection	2.3 in	1.7 in

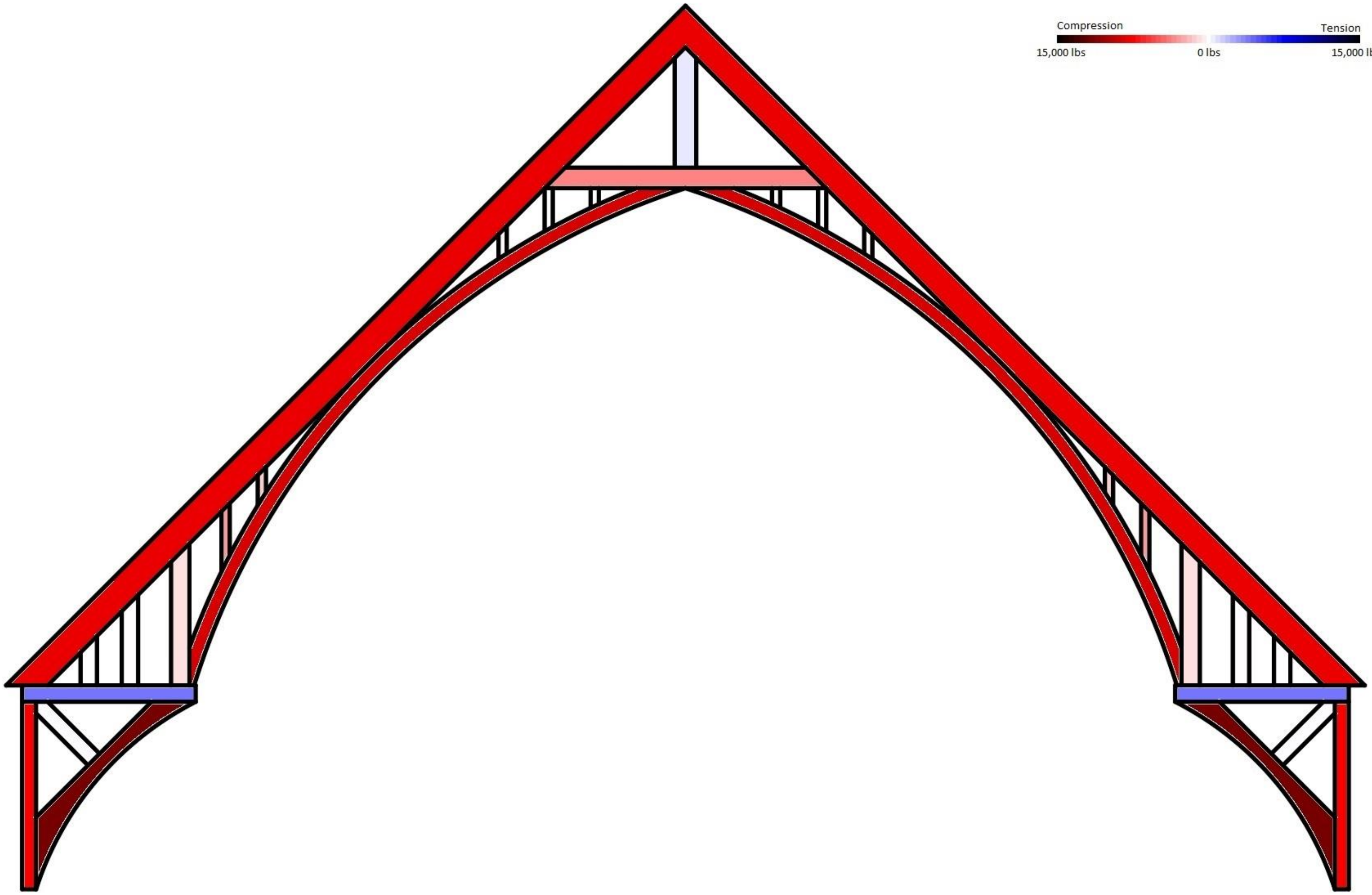


Figure 42: Member axial loads experienced under case 1 (primarily gravity governed)

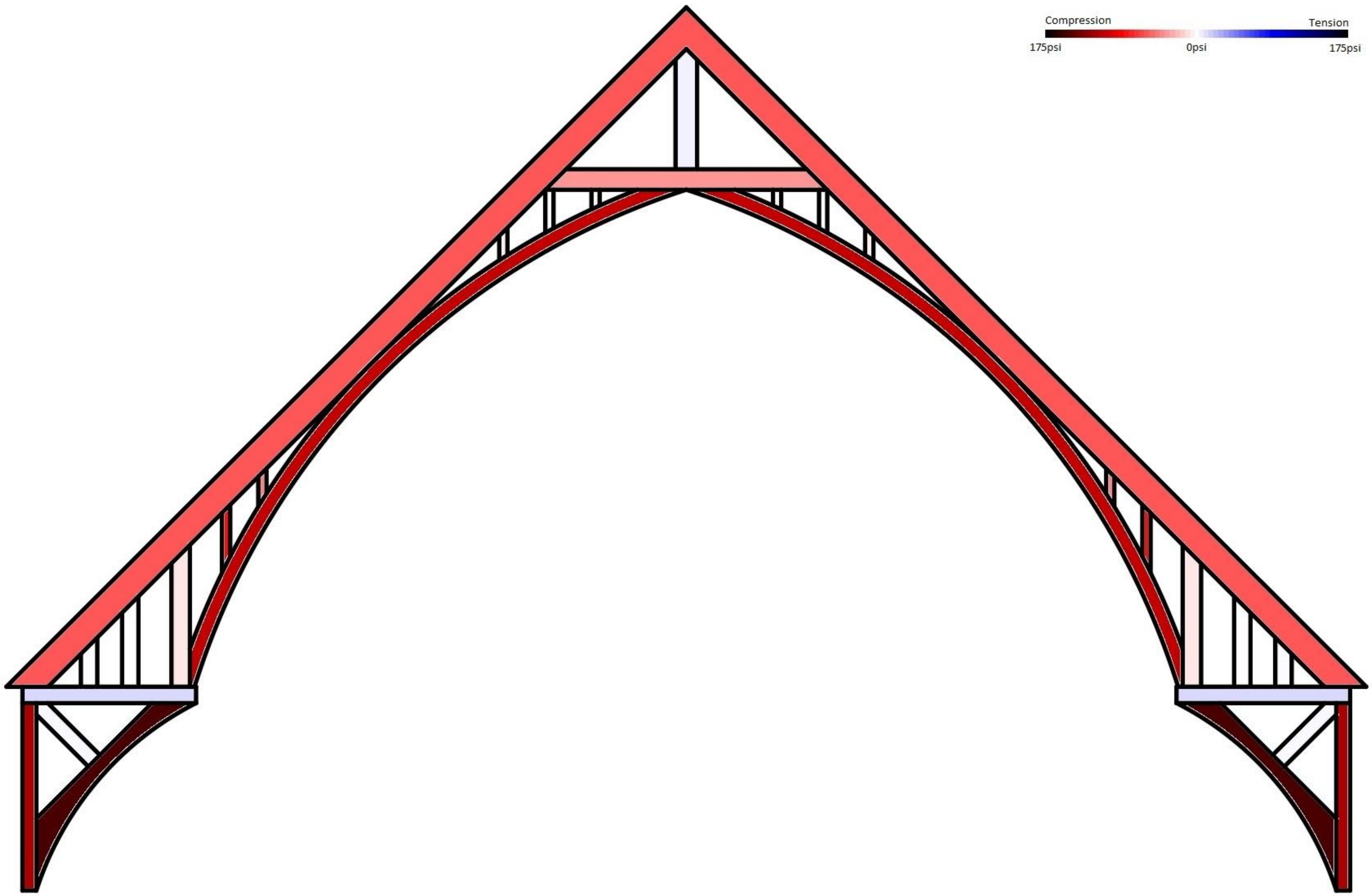


Figure 43: Member axial stress experienced under case 1 (primarily gravity governed)

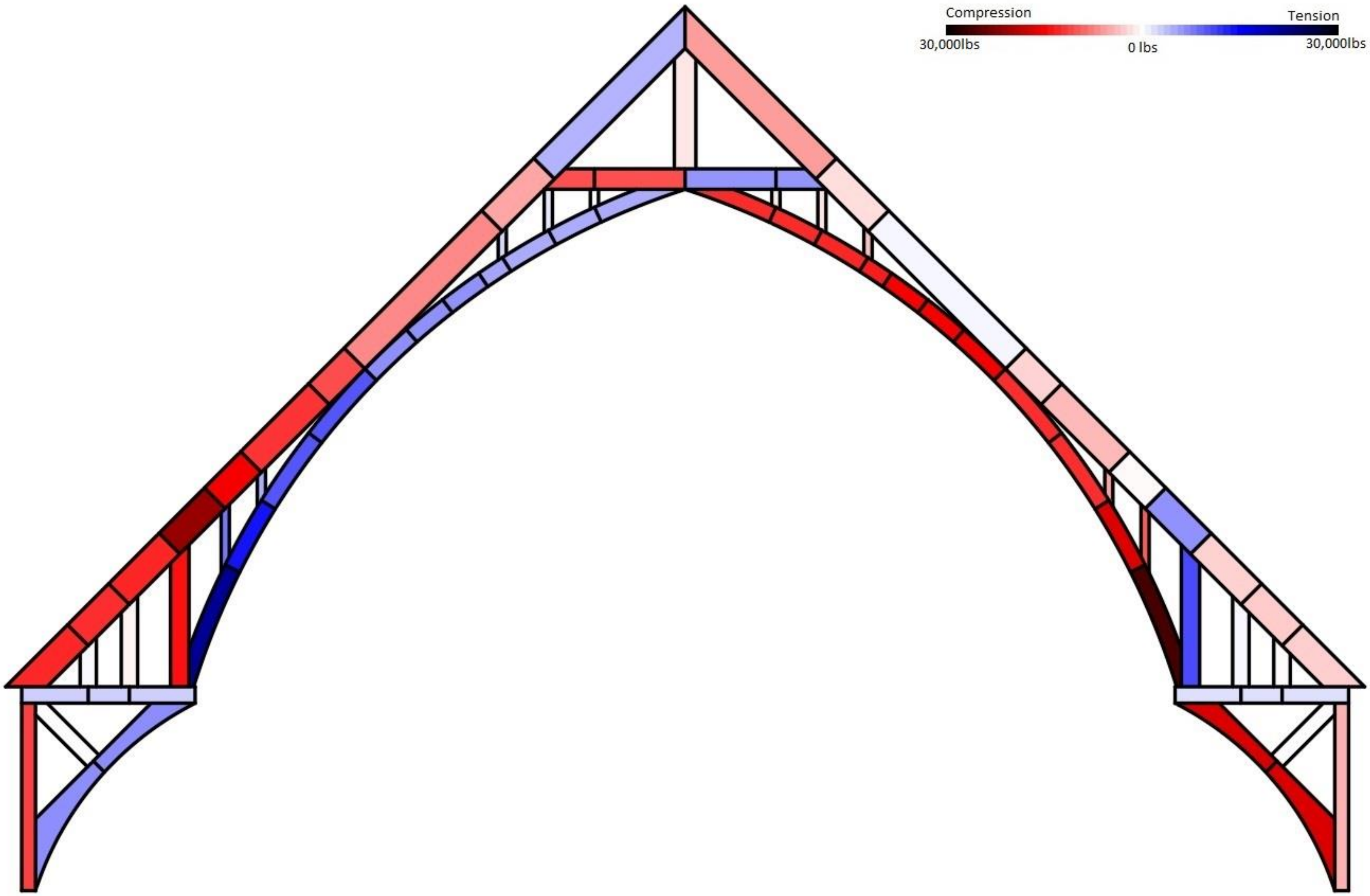


Figure 44: Member axial loads experienced under case 2 (primarily lateral governed)

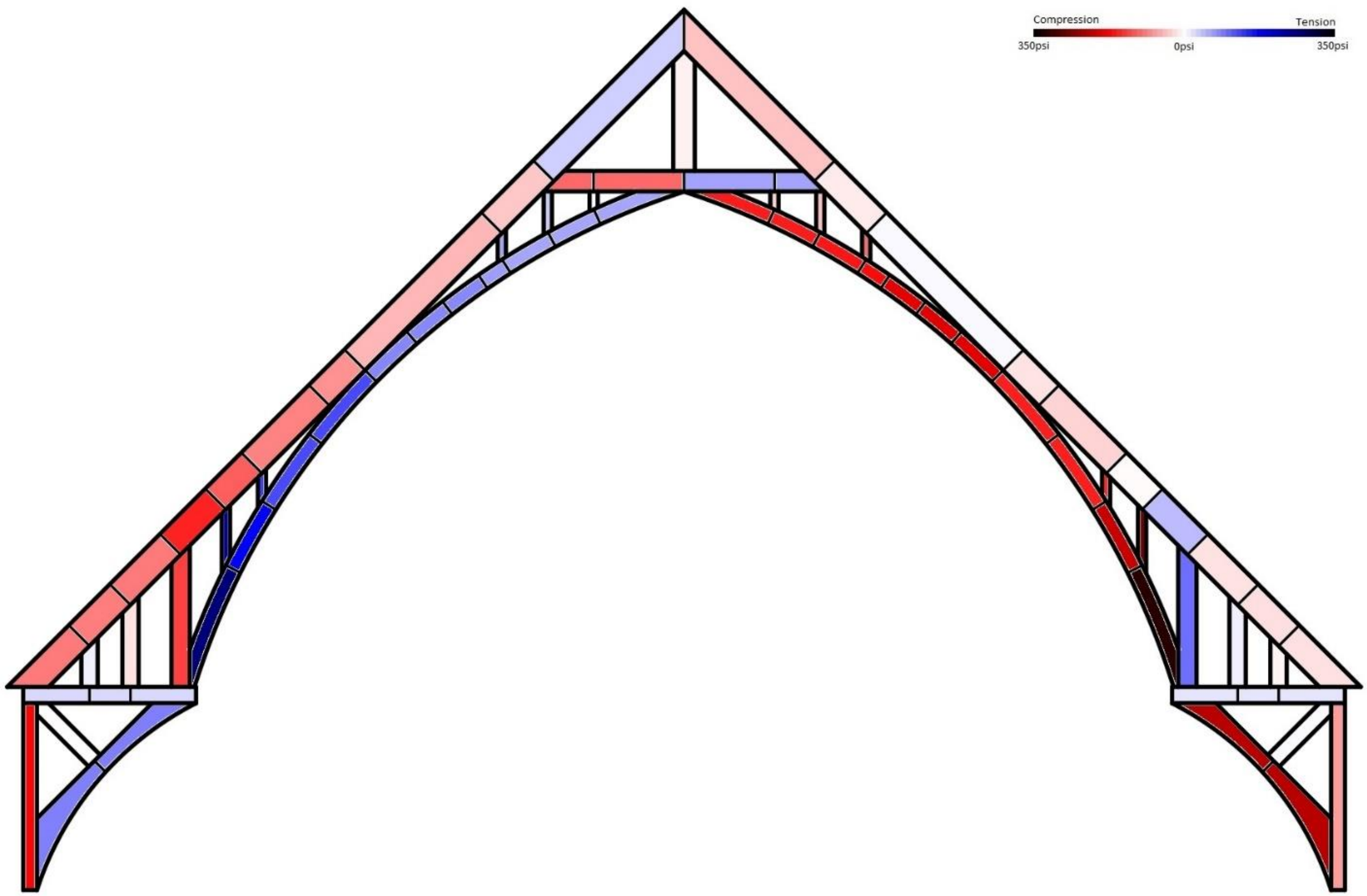


Figure 45: Member axial stress experienced under case 2 (primarily lateral governed)

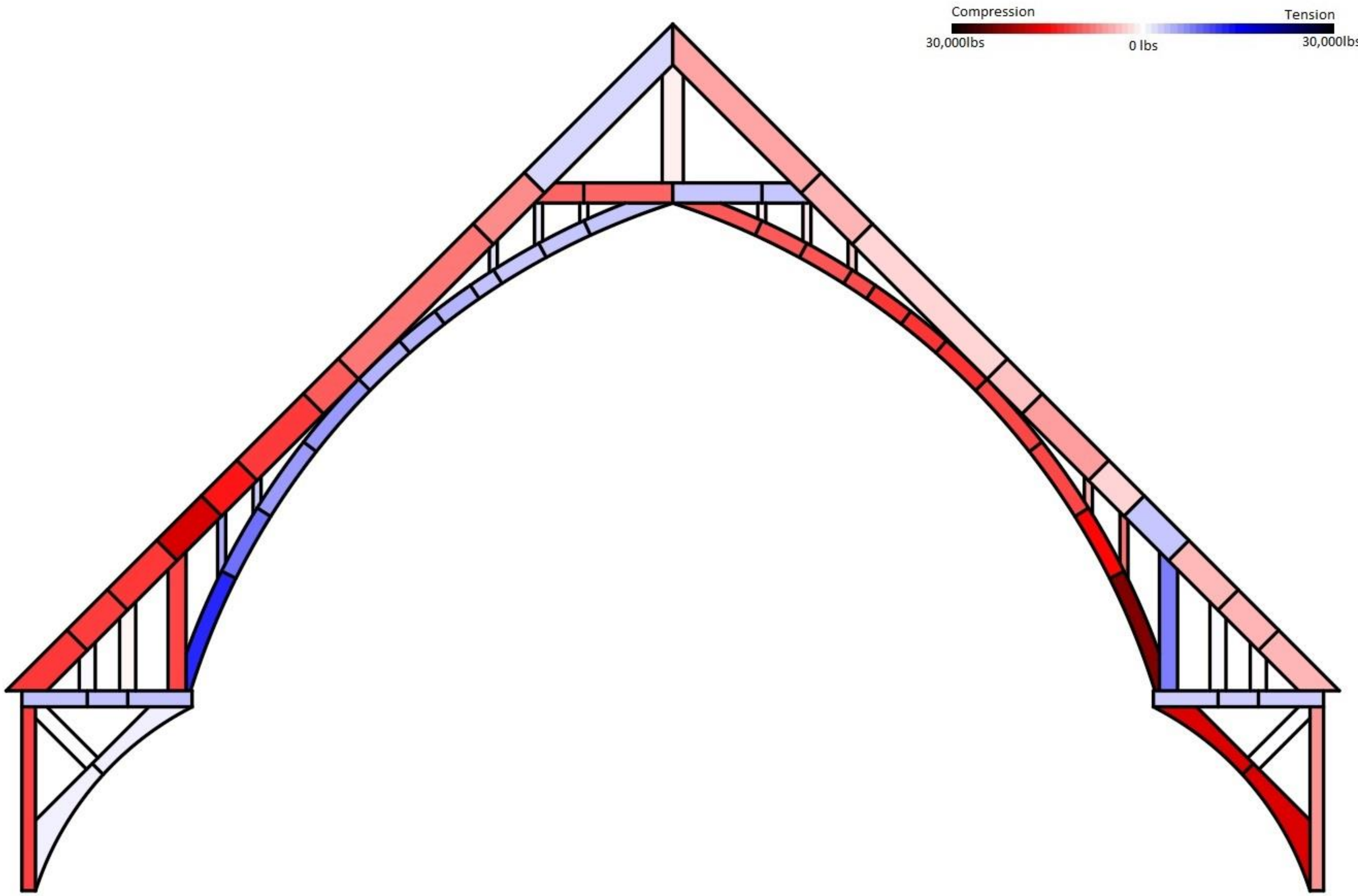


Figure 46: Member axial loads experienced under case 3 (gravity and lateral governed)

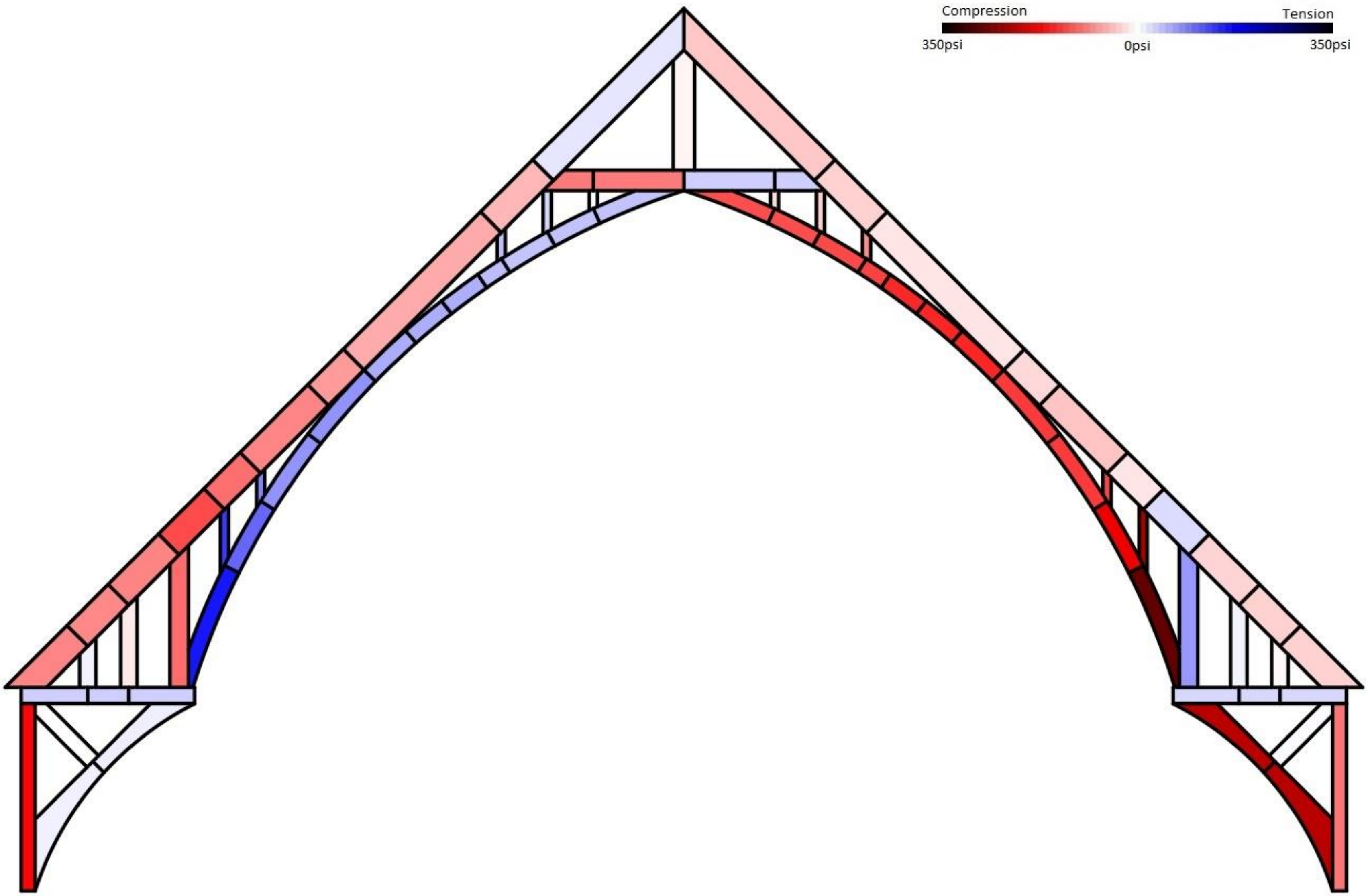


Figure 47: Member axial stress experienced under case 3 (gravity and lateral governed)

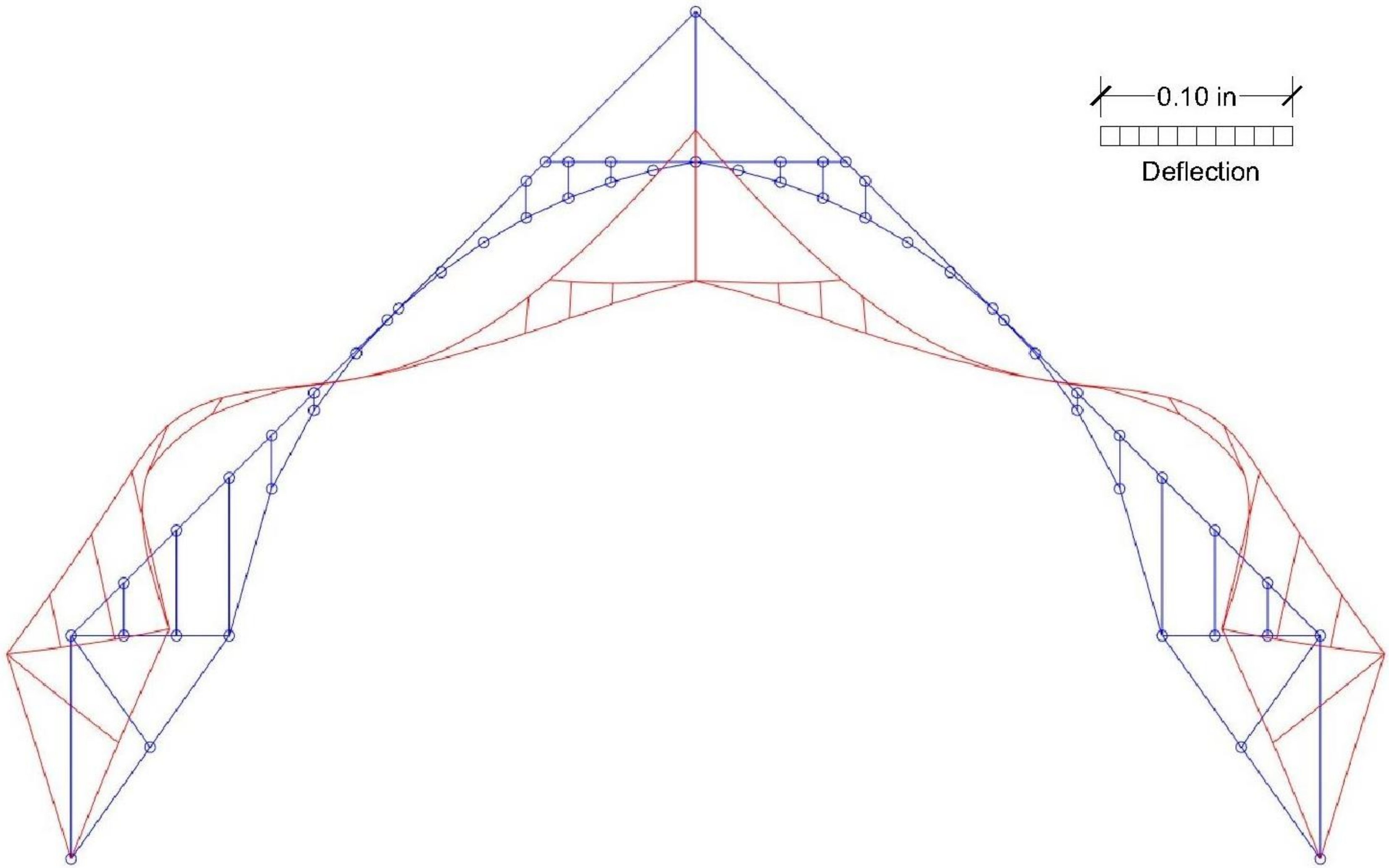


Figure 48: Truss Deflection Under Case 1 Loading Conditions (Primarily Gravity Governed)

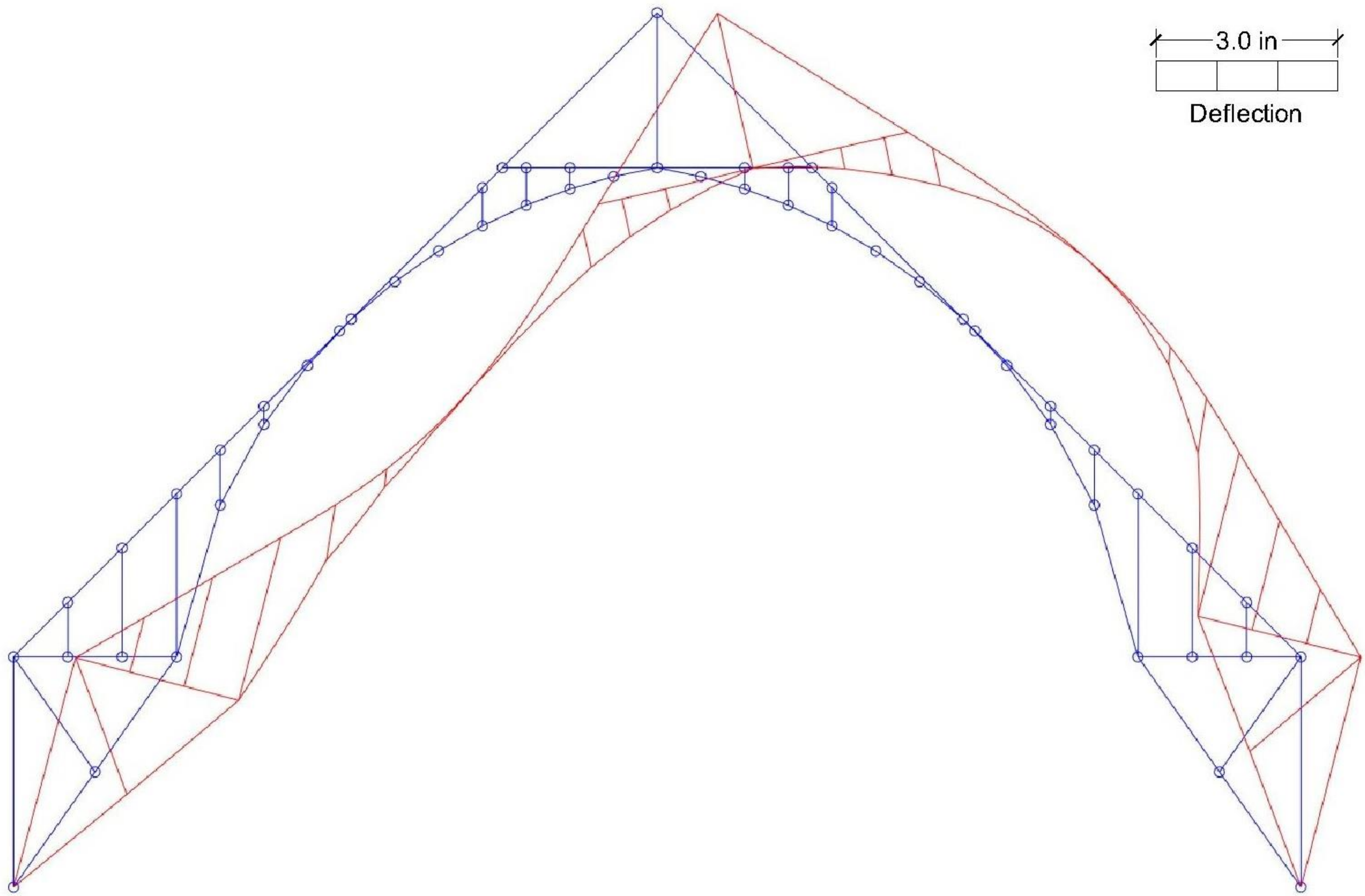


Figure 49: Truss Deflection Under Case 2 Loading Conditions (Primarily Laterally Governed)

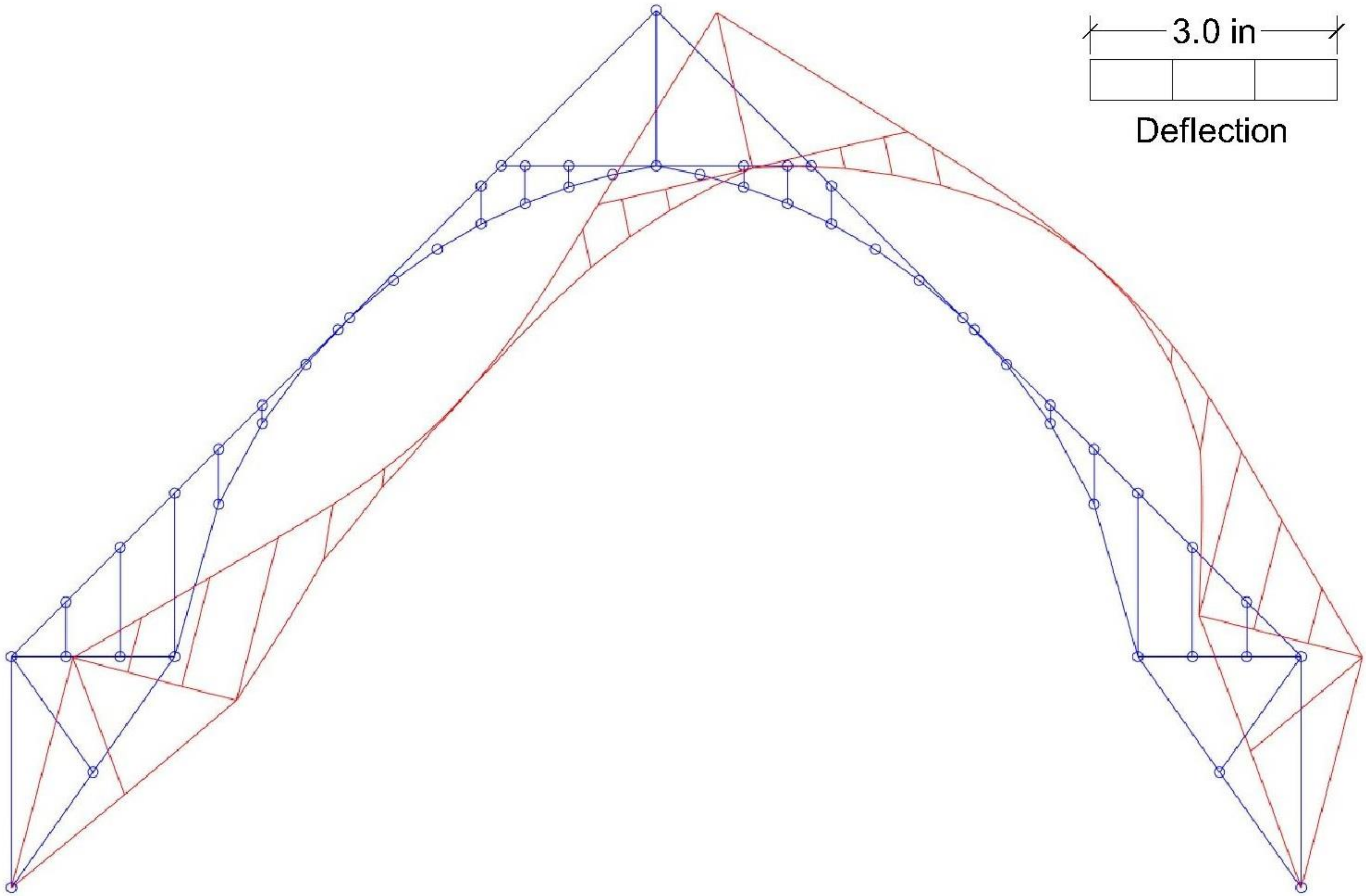


Figure 50: Truss Deflection Under Case 3 Loading Conditions (Gravity and Laterally Governed)

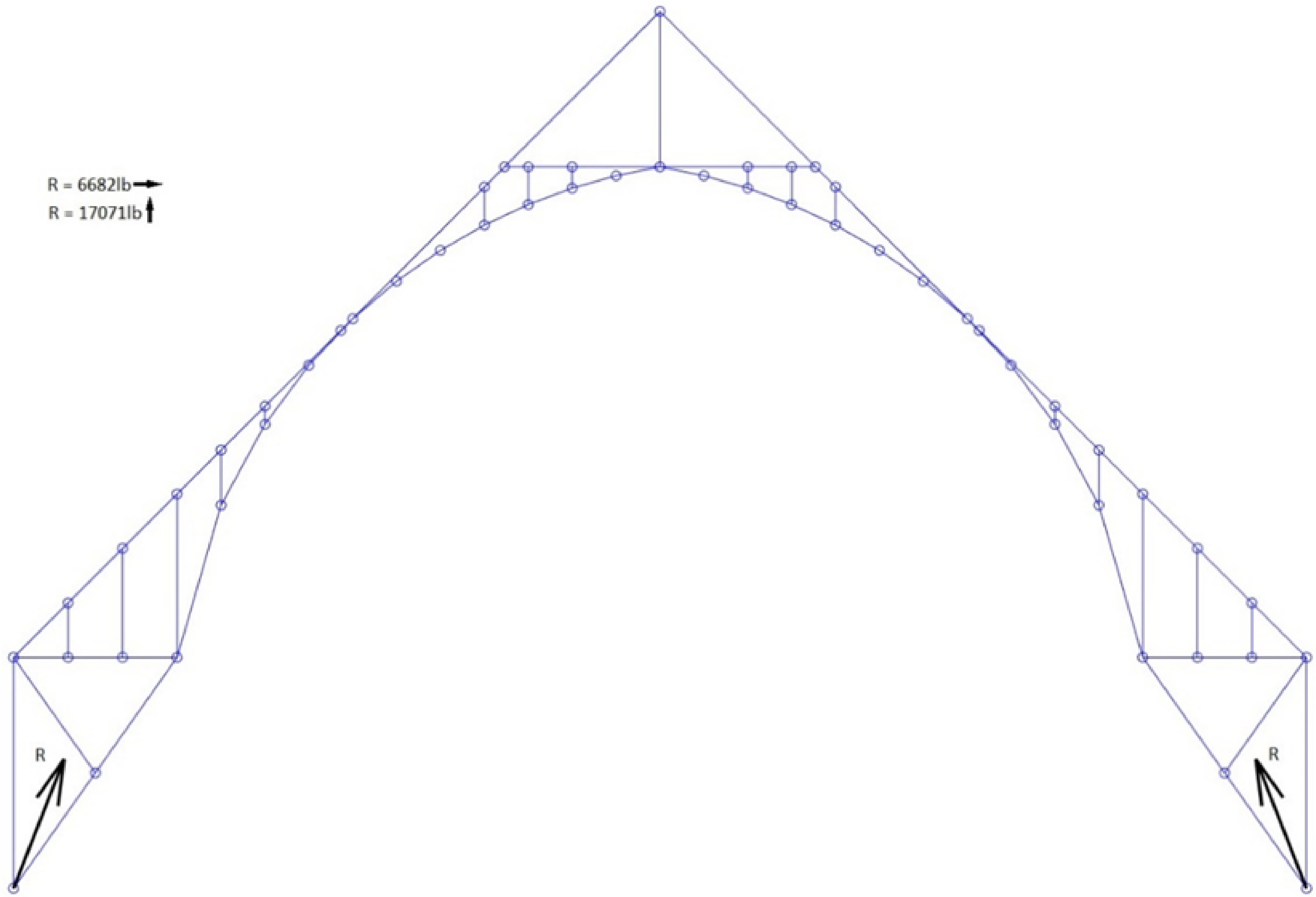


Figure 51: Truss Reactions Under Case 1 Loading Conditions (Primarily Gravity Governed)

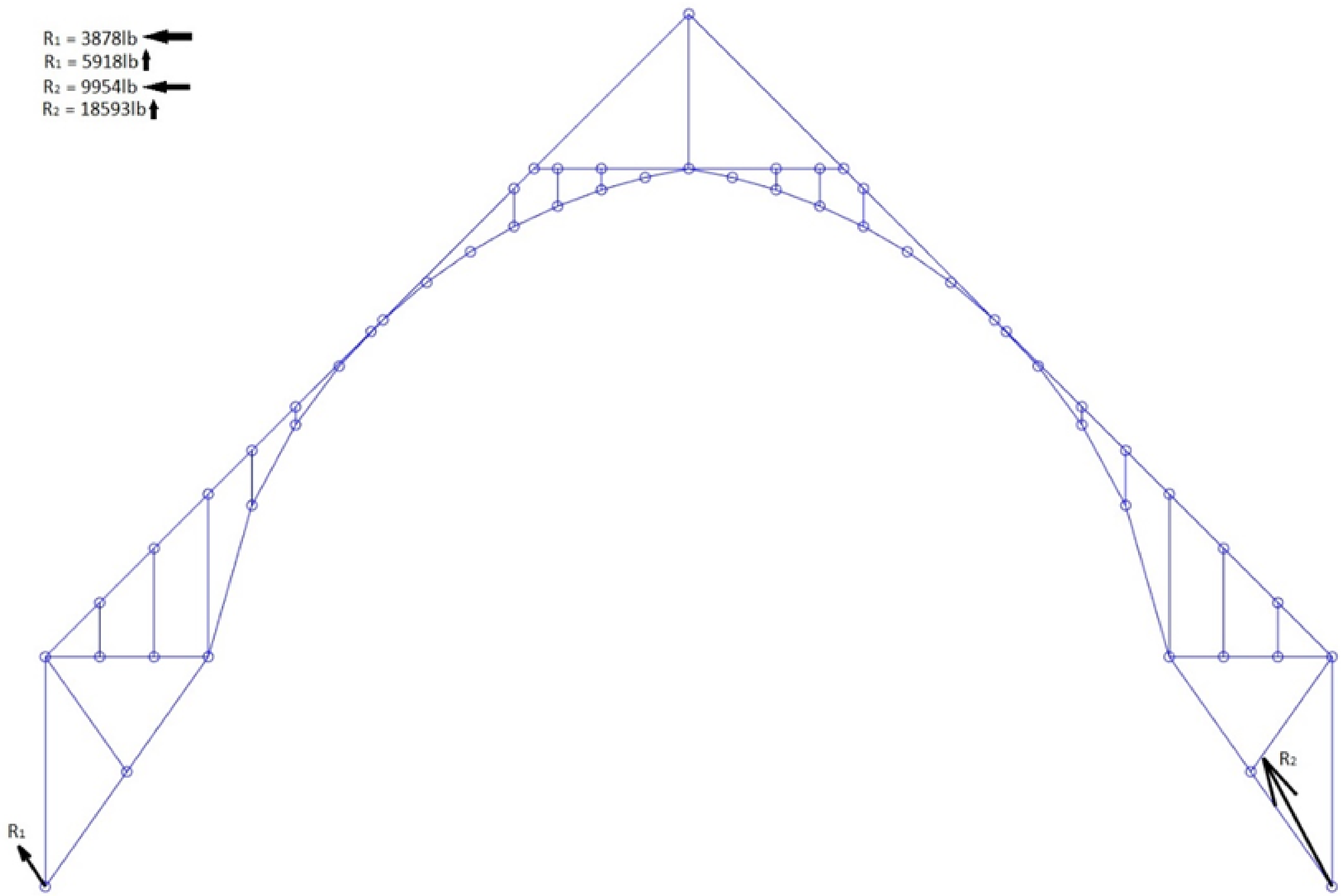


Figure 52: Truss Reactions Under Case 2 Loading Conditions (Primarily Laterally Governed)

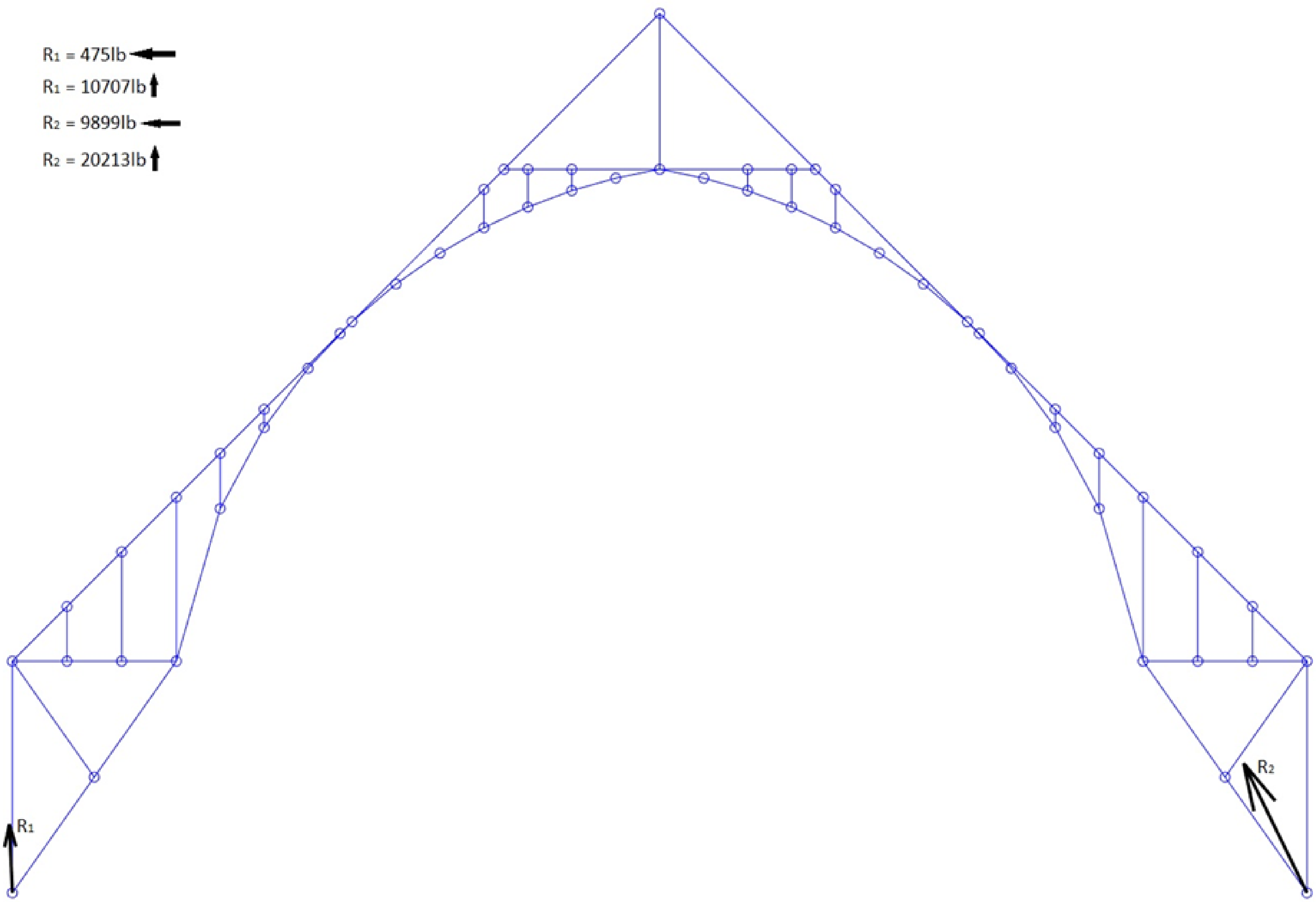


Figure 53: Truss Reactions Under Case 3 Loading Conditions (Gravity and Lateral Governed)

The adequacy results for the truss are shown in Table 6. All of the members of the truss are acceptable for strength considerations. The ultimate axial stresses, bending stresses, and shear stresses for all members in all cases are below the maximum allowable axial stresses, bending stresses, and shear stresses. For serviceability considerations on the other hand, the maximum allowable deflection of 1.7 in is below the ultimate deflection of about 2.3 in under lateral case 2. For comparison, the maximum deflection under the gravity case is 0.1 in. That means that during a major seismic event, under the most extreme circumstances, potential displacement in the roof can cause minor ceiling damage to the plaster, but the roof is in no danger of caving in. This effect though may be reduced as there is a gap between the truss and the ceiling.

Based on these results, the truss is very well designed to resist gravity loads whereas the truss is not well designed to resist lateral loads. This is likely due to the many vertical members called hammer beam posts which help to distribute the gravity loads from the upper braces to the lower braces. The lateral conditions can also create a lot of tension in some of the connections of the truss that are potentially not designed to take tension. It may be prudent to inspect the trusses and their supports at regular intervals.

5.1.4 Floor

A summary of the results for all members of the floor in between the sanctuary and basement are shown in Table 7. The members were analyzed in a very similar way to the roof members (see section 5.1.2). In this case, all members were adequate.

Table 7: Comparison of Ultimate and Allowable Stress and Deflection Experienced by Floor Members

Members	Type	Ultimate Value	Allowable Value
Joists	Bending	679 psi	1006 psi
Joists	Shear	44 psi	135 psi
Joists	Deflection	0.29 in	0.51 in
Girder	Bending	960 psi	1035 psi
Girder	Shear	78.1 psi	135 psi

Girder	Deflection	0.30 in	0.44 in

5.1.5 Walls

A summary of the results for the walls at the location of the buttresses are shown in Table 8. The maximum tension and compression refer to that experienced at the extreme fibers of the cross-section, which occurs at the most interior and most exterior parts of the cross-section.

Table 8: Maximum Tension and Compression Experienced by the Buttress within the Cross-Section at Critical Heights under Various Loading Scenarios

Case	Point	Maximum Compression (psi)	Maximum Tension (psi)
Gravity	C	61.57	0
Gravity	E	89.01	0
Gravity	F	50.86	0
Seismic 1	C	90.99	11.53
Seismic 1	E	145.10	21.72
Seismic 1	F	81.48	10.52
Seismic 2	C	46.45	27.29
Seismic 2	E	72.84	48.47
Seismic 2	F	53.17	23.89

According to the National Concrete Masonry Association (NCMA), normal type Portland cement mortar used in brick masonry found on the interior of the wall has an allowable tensile stress normal to the bed joints of 30 psi which is greater than the ultimate tensile stress of 21.72 psi under seismic case 1. Consequently, if the assumptions that were made for the wall analysis are correct and if the brick is in good condition, no reinforcement is needed for the buttress. Unfortunately, conditions of the masonry are unknown and due to moisture and neglect it is possible that overtime the mortar bonding in the brick can rupture during a seismic event and cracking can occur. In this case, assuming poor masonry conditions, tensile reinforcement should be sized for the interior of the wall to prevent cracking.

Based on this analysis, it was found that any amount of steel will work when placed 52 inches from the left most end of the buttress. The reason for this is because the location of the neutral axis is primarily governed by the location of the steel reinforcement and the buttress will not crack at all beyond the location of the neutral axis. The amount of compression the buttress is under prior to cracking is also far below the allowable yield stress of the masonry even with conservative assumptions. This allows the neutral axis to shift freely without the risk of the buttress to fail under compression. Reinforcement is still necessary though because if the cracking propagates all the way through the buttress, it will fail. Consequently, a small thin section of reinforcement is all that is necessary.

Based on the calculations found in appendix C, five ½ in studs are required for full composite action which would put the spacing of the studs at 44 in between the basement floor and the base of the truss. The maximum spacing for shear studs based on AISC section I8.2d is 36 inches requiring 7 studs to be placed 33 inches.

When analyzing the buttress for reinforcement for seismic case 2, the exterior granite masonry is in tension where the maximum tension is about 48 psi. Normal type Portland cement used for concrete masonry has an allowable tensile stress parallel to the bed joints in running bond of 60 psi. Because the granite masonry is visually in good shape, no major evidence of cracking exists on the exterior, and the granite masonry has a cross-section for mortar placement that provides for more tensile resistance than concrete masonry, the granite masonry is adequate for tensile stresses under maximum seismic loading conditions.

5.1.6 Determination of Vibration Thresholds

With I-290 and Route 9 directly adjacent to the church, there were some concerns that the vibrations may have been affecting the structure. Mentioned previously in the methodology, we found that the church would experience damage if a vibration of 0.59 in/s occurred at an instant or if a vibration of 0.24 in/s occurred continuously according to the Swiss Standards Association 640 312. Based on the data from the accelerometers in the towers and shown in Table 9 below, the highest acceleration experienced by the church was 0.025 g and the highest velocity experienced by the church was 0.08 in/s. This value does not approach the peak particle velocity of vibration the church can withstand. This means that the vibrations the church is experiencing daily is not an issue for the longevity of the structure. Although, the accelerometers that were used to obtain this data were only able to hold a limited amount of storage due to cost. There is a possibility that the true maximum acceleration may not have been recorded with these accelerometers.

For comparison, in terms of seismic loads, the peak ground acceleration for a structure to even experience very light damage is 0.039 g. With our data being within the range of the seismic data, it confirms that our accelerometer data is accurate. Also, the PPV for the church to experience physical damage, such as hairline cracking, is 0.75 in/s. This value is also much above the highest velocity experienced by the church. Our group was then able to determine that the cracks in the plaster of the church are from the moisture issues rather than vibrations.

Figure 54: Site Plan Showing the Close Proximity of the Church, I-290 and Route 9

Table 9: Max Values Experienced by Accelerometers

Accelerometer	Max Acceleration (g)	Max Velocity (in/s)
Tower 1 East	0.025	0.08
Tower 1 North	0.025	0.08
Tower 2 South	0.023	0.074
Tower 2 West	0.022	0.07

5.2 Geotechnical Analysis

There were some initial concerns geotechnically with the church and its proximity to the retaining wall and the highway. The retaining wall is of little concern to the church as most of the influence in failure caused by the soil is vertical rather than horizontal. That means that the retaining wall will cause little concern on the church but potential settlement in the church can cause extra horizontal forces that should have been considered when constructing the retaining wall.

Besides the retaining wall concern, other results from the geotechnical analysis such as bearing capacity, and settlement will be addressed in this section.

5.2.1 Determination of Soil Conditions

Based on the soil classification from the Massachusetts DOT overpass project, it was found that all soil that exists below the foundation is fine sand with a unit weight of about 120pcf and a friction angle of 34 degrees. A representative soil profile was created to show the layers of soil as well as each layer's unit weight and friction angle. This profile is shown in Figure. One consequence of fine sand is that any settlement experienced by the columns are immediate short-term settlement and no long-term settlement exists. No major evidence of cracking in the walls also suggest that there is no evidence of long-term differential settlement and as a result when sizing the footings, they only need to be tested against bearing capacity failure.

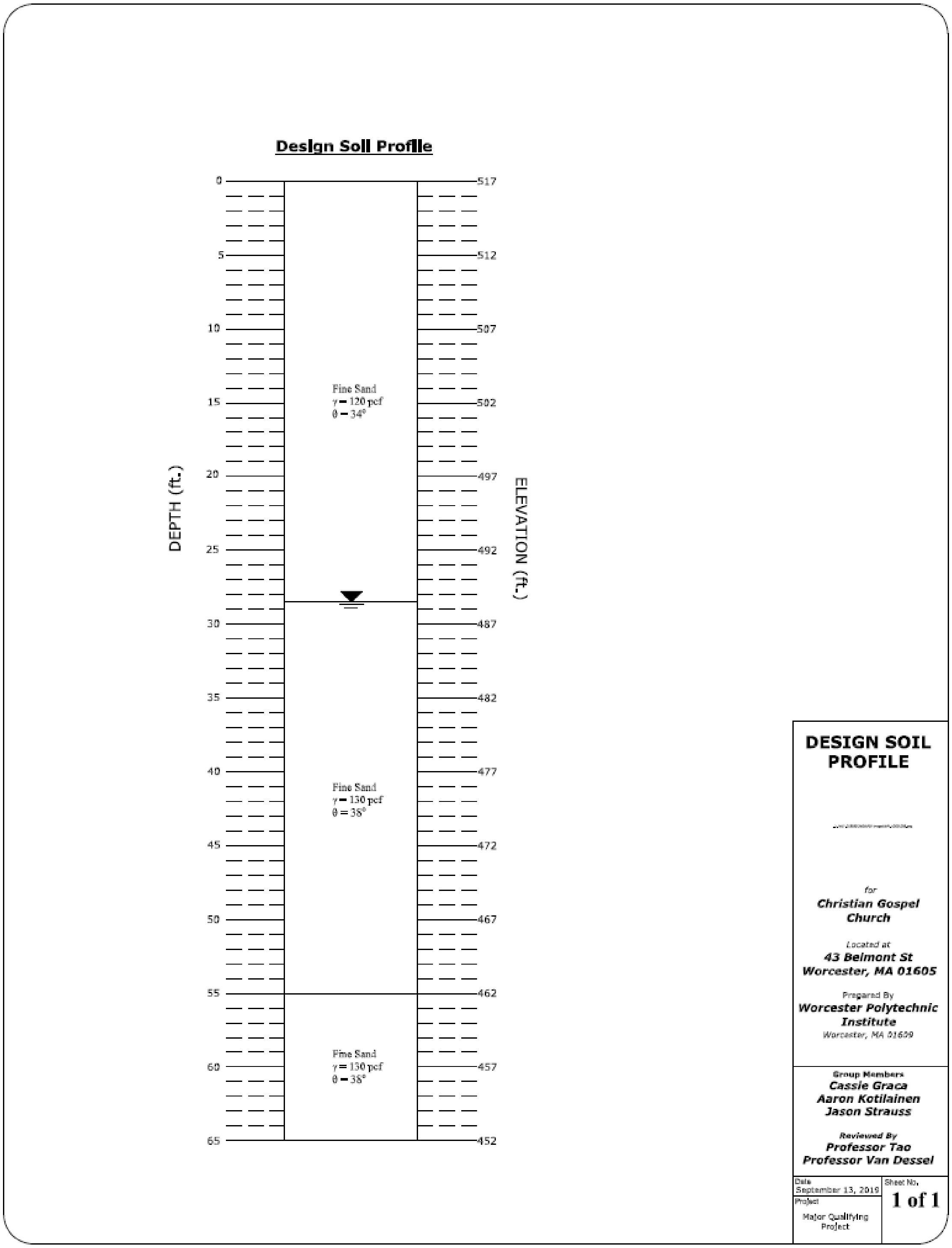


Figure 55: Design Soil Profile Estimated for the Christian Gospel Church Based on Boring Log Data from the Massachusetts Department of Transportation

5.2.2 Foundation

Upon testing the foundation for bending and shear below the buttresses, it was found that these footings are only slightly larger than the buttresses themselves, and any critical sections for shear and moment exist outside of the footings. This means that there is no risk of failure of the footings due to structural causes. The footings below the lally columns were of the same depth as the buttress footings despite only carrying about 10% of the load the buttresses carry. That means that the footings were sized very conservatively for structural failure.

To test the footings for failure due to geotechnical limitations, the factor of safety was compared with the required factor of safety. This comparison is shown in Table 10. For all the footings under all loading conditions, the footings were acceptable for bearing capacity.

Table 10: Comparison of ultimate and allowable stress experienced by the footings

Footing Location (Loading Type)	Factor of Safety	Required Factor of Safety
Buttress (Gravity)	3.14	1.6
Buttress (Seismic 1)	1.83	1.6
Buttress (Seismic 2)	3.75	1.6
Lally	10.46	1.6

5.3 Envelope Analysis

Envelope Analysis was performed through a combination of methods (*DesignBuilder* model and hand calculations). These analyses were possible through production of thorough digital models that were produced from site surveys and documentation obtained from the Massachusetts State Archive.

5.3.1 Walls

Using ASHRAE calculation methods, the U-Value of the church walls are estimated to be: 0.328 BTU/h*ft^2*F. The U-value of the tower walls with air gaps are estimated to be 0.409 BTU/h*ft^2*F.

It was assumed in the preliminary estimates of the heating load required by the sanctuary performed in the fall of 2019, that the walls were just 24” of stone. The actual wall construction is displayed in Figure 56. The hand calculations of potential wall U-values were different compared to the *DesignBuilder* energy analysis. *DesignBuilder* includes the unique individual thermal properties of the church’s building envelope elements. built into its software rather than using the assumption of full generic stone in the hand calculations. The *DesignBuilder* analysis is likely far more accurate and allows for more complex analysis based on comprehensive weather data and thermal bridging.

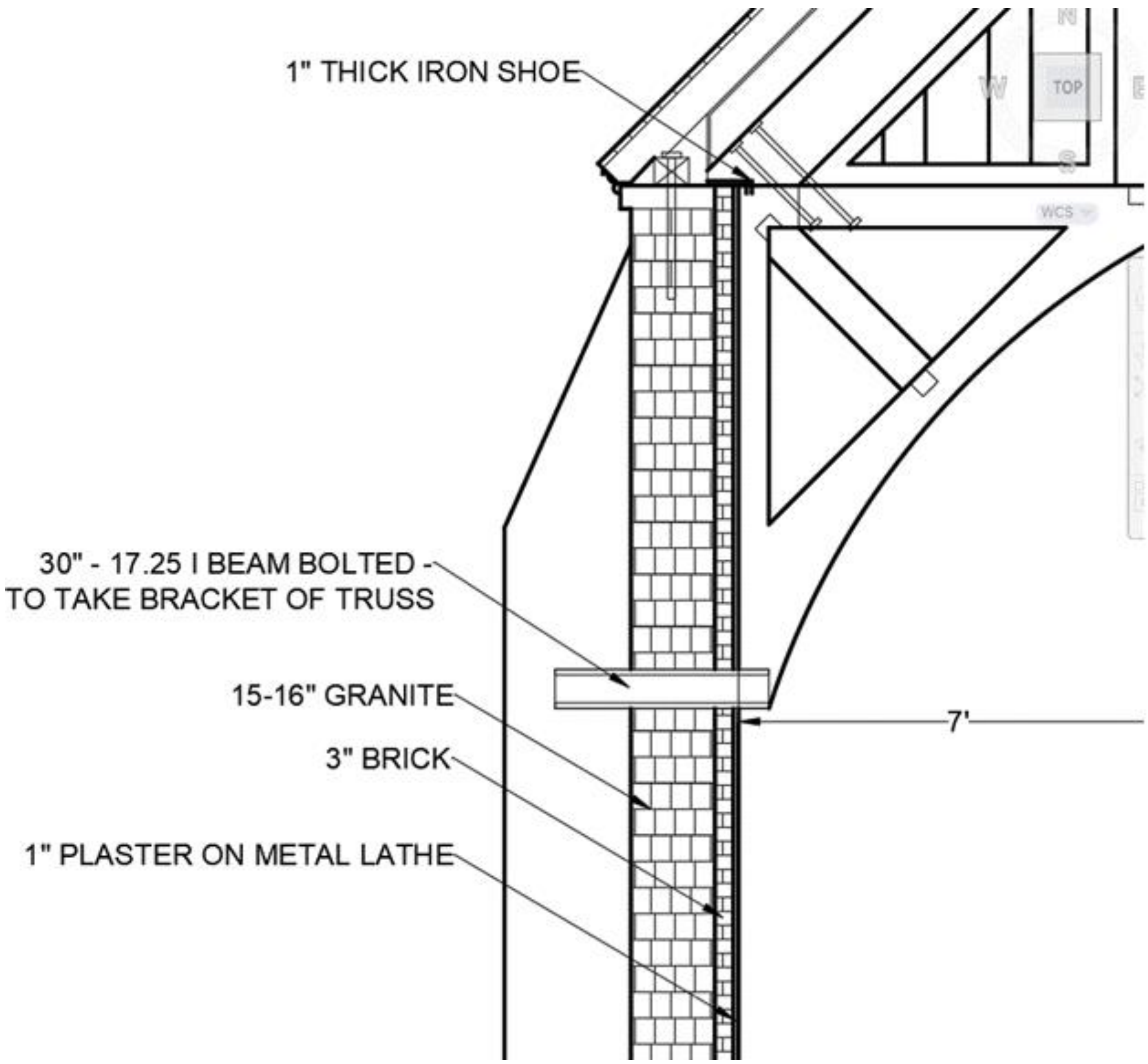


Figure 56: Sanctuary Wall Section

Based on the findings from the Relative Humidity sensor placed inside of the wall, it was found that the relative humidity levels behind the plaster was nearly at 100% as displayed by the graph in Figure 57. This reveals that the air gap in the tower is completely saturated. As discussed previously in the report, it is most likely that the leading cause of water infiltration is due to the issues with the roof and its waterproofing components. Developing a way of drying out the towers is critical in order to maintain the integrity of the building and the air holes that were cut will hopefully improve this situation until the roof can be repaired. This saturation can be visualized when viewing the walls on the mezzanine level by viewing the water staining and cracks in the plaster.

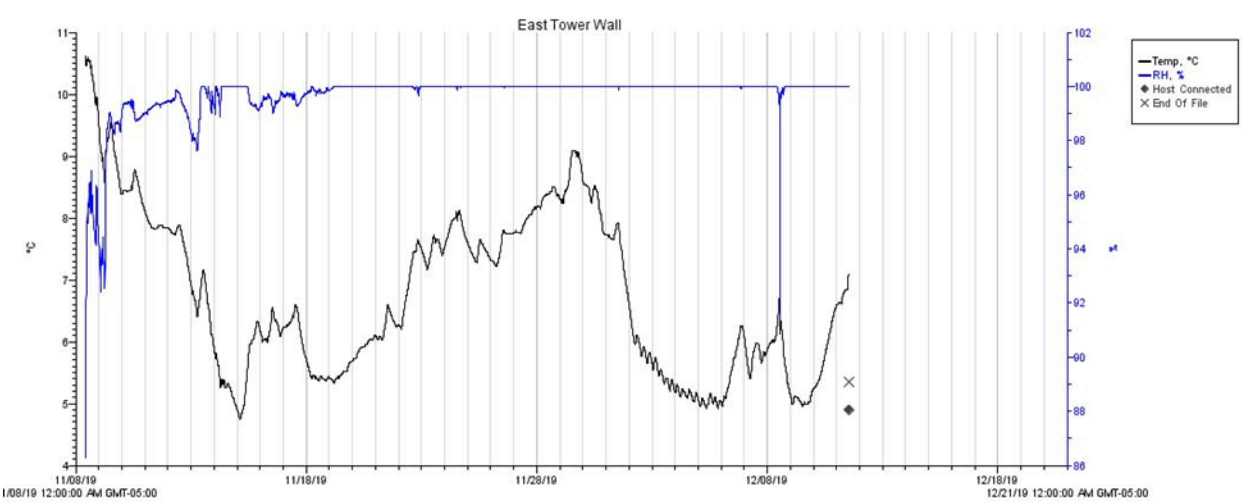


Figure 57: Temperature and Humidity Readings Inside the Right Tower Wall from November to December 2019

5.3.2 Roof

The U-Value of the roof is estimated to be between 0.237 and 0.274 BTU/h*ft^2*F based on its construction and positioning of the purlins. This U-Value assumes that the envelope of the roof is complete and does not have any defects. However, due to the holes and separation in the roof and weakening of the wood envelope, it is likely that the actual U-Value of the roof is much higher and significantly contributes to the overall heat loss of the building.

5.3.3 Windows

The U-Values used for the windows was 1.078 BTU/h*ft^2*F. The accepted ASHRAE standard for stained glass is 1.09 BTU/h*ft^2*F. During site surveys of the building, it was observed that there were many portions of stained glass that have cracks, holes, missing components, and are failing due to warping. These issues with the windows are another factor contributing to the discomfort that is being felt inside the sanctuary during services. Since there are open holes, air infiltration is prevalent and causing drafts, exacerbating heat loss, and causing excess humidity throughout the church. It should also be noted that the primary component of stained-glass windows is lead, which is used as a barrier between colors on stained glass. For safety reasons, it is recommended that patrons should not touch the windows due to health concerns and barriers to prevent access be established.

The windows throughout the gym and basement have been upgraded to double hung, double paned windows and appear to have no issues. It was estimated that the U-Value of these windows was 0.50 BTU/h*ft^2*F.

5.4 Energy Analysis

The building as currently standing (assuming an intact envelope) is within national energy consumption guidelines. Based on this analysis with the assumed occupancy settings, the building is estimated of having an annual energy consumption of 781,909 kBTU between heating and electricity consumption. 565,966 kBTUs are utilized for heating needs annually. This comparison is shown in Figure 58.

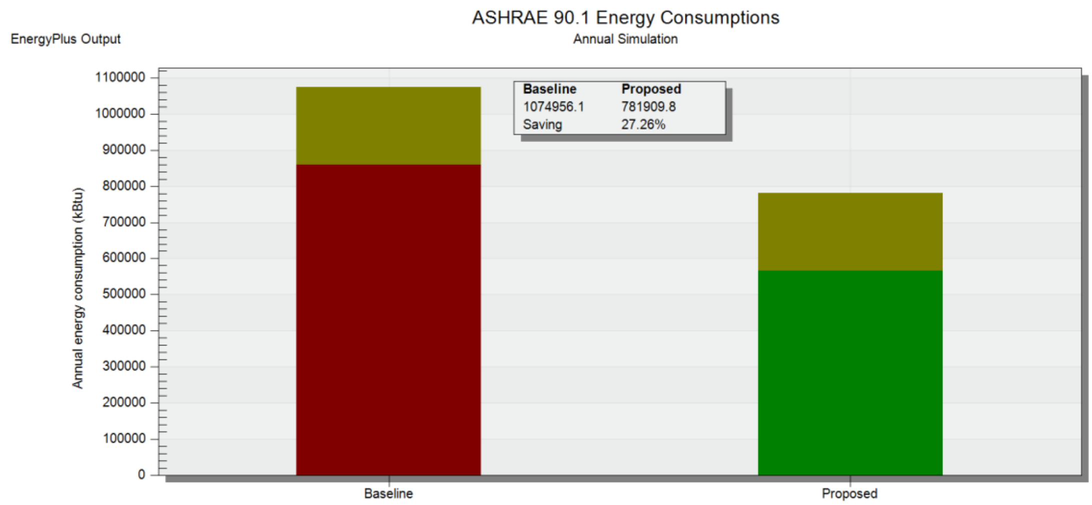


Figure 58: ASHRAE Baseline vs. Existing Building Energy Consumption Comparison

5.4.1 Walls

Based on the *DesignBuilder* and hand calculation analysis, most heat loss in the church is due to the granite massing walls. Unfortunately, due to the orientation of the church, most thermal mass effects due to sun exposure is experienced by the front of the building due to the sun path. This design choice was most likely done intentionally so that the sun would shine through the front facing stained glass windows during services. The high-rise apartment building across Belmont Street also blocks most of the sun path annually.

Adding insulation inside of the walls is not an option due to the construction of the building (i.e. no large air gaps in the walls to add blown-in insulation). However, an analysis was performed to quantify improvements by adding varying ratings of insulation on the inner surface of the church to see the improvement in heat loss (Figure 59). Adding a layer of R-20 or R-30 Insulation to the inner surface of the walls would result in approximately 147,000 BTU/Hr improvement to the buildings heat loss issue. This would result in a 26% improvement of the buildings energy consumption.

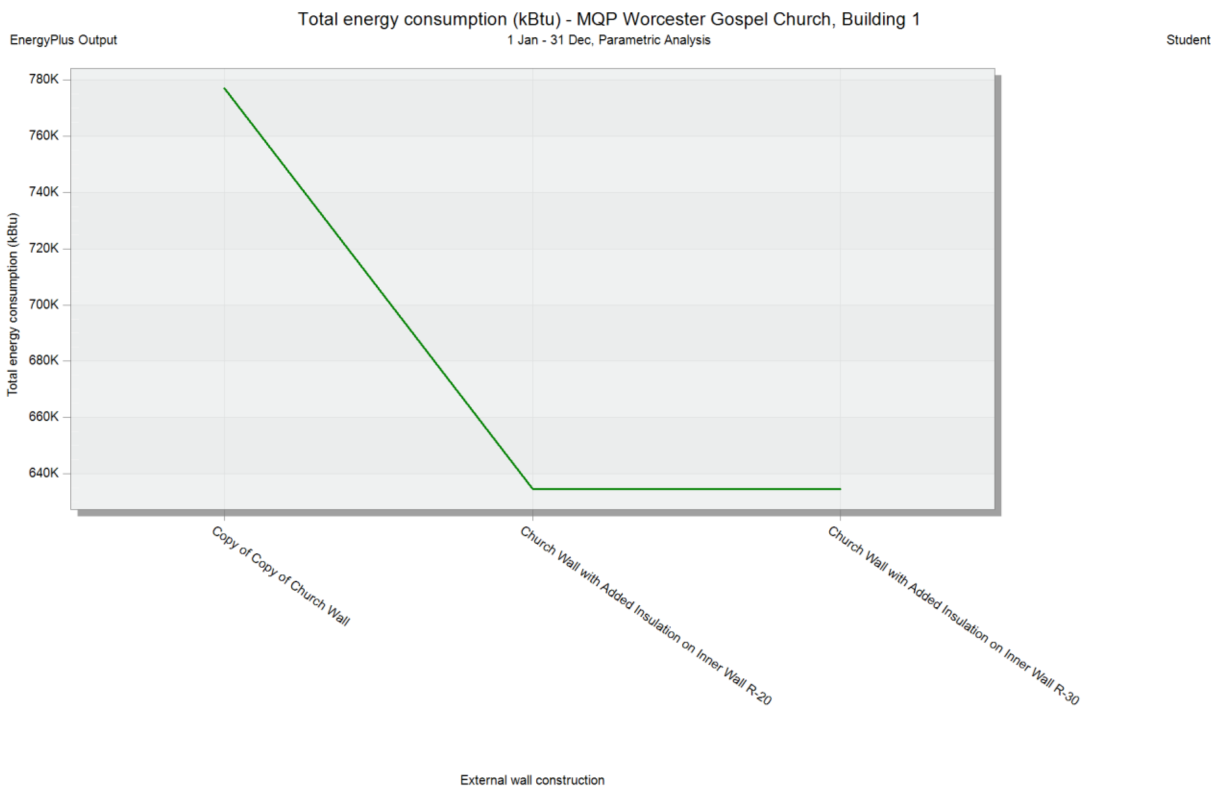


Figure 59: Existing Wall Construction vs. Proposed Wall Insulation Improvement Comparisons

Any improvements that could be made to insulate the walls would make a significant difference in annual heat loss and fuel consumption. Improvements to the insulative properties of the wall should be investigated as this will create the most noticeable improvements. However, if a similar solution is implemented, it is important to consider additional condensation effects that may occur by adding another layer of insulation on the existing wall. Any modifications to the wall envelope should be first vetted by an engineer experienced with building enclosure improvements as this would be a significant undertaking.

5.4.2 Roof

The roof deck over the sanctuary is currently uninsulated and in an attic space that is not visible or accessible to the congregation. Adding insulation to this space was one of the first things considered for potential building improvements. Such an improvement could be implemented relatively easily compared to the other envelope suggestions in this report. A simulation was created by comparing the existing roof construction and comparing the differences if adding roof code compliant insulation was installed (Figure 60). By installing R-30, R-35, or R-40 batt insulation in the roof deck would result in an approximate improvement of 47,000 BTU/Hr or an 8.3% improvement to the buildings energy consumption.

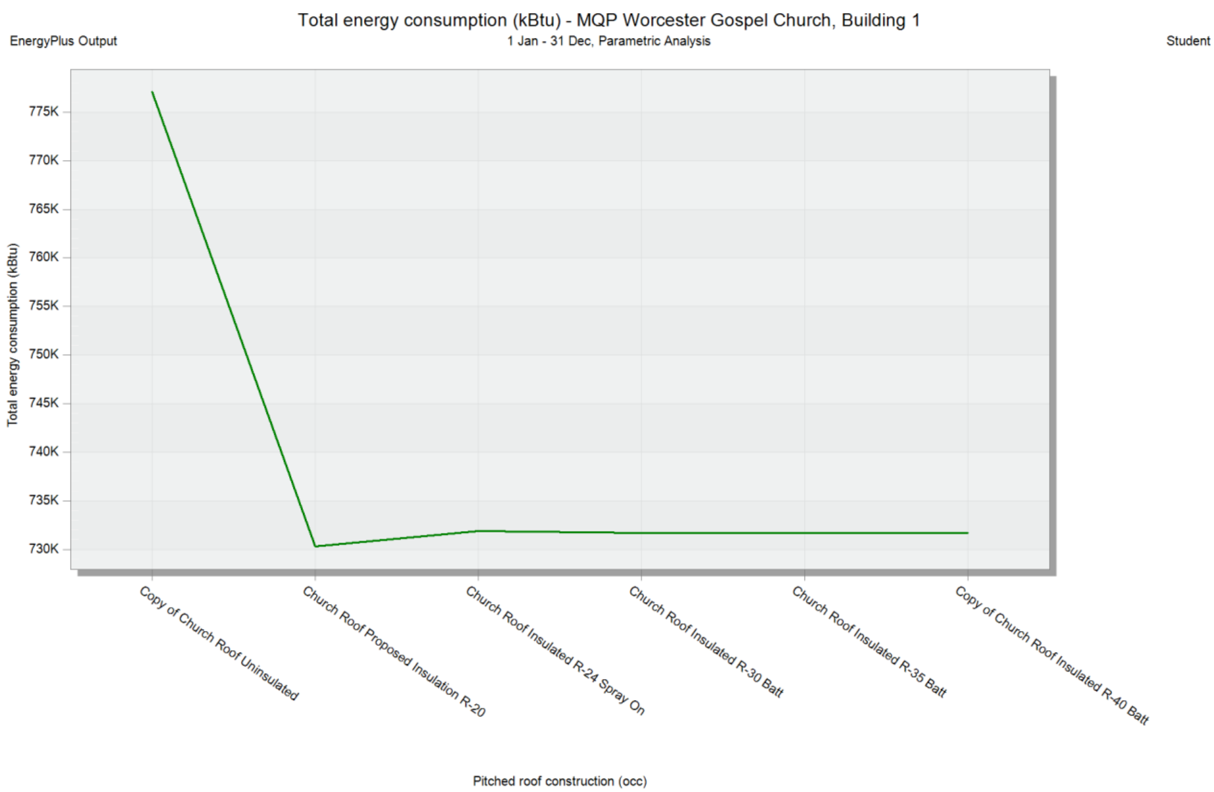


Figure 60: Existing Roof Construction Energy Consumption vs. Proposed Roof Insulation Improvements Comparisons

The most pressing issues with the roof are external due to gaps in the slate and issues with the waterproofing methods, leading to water infiltration and exacerbated heat loss. The simulation that was performed assumed that the roof's envelope is intact and will retain heat appropriately. Unfortunately, this is not the case with its current condition and its current insulative properties are unknown. It could be assumed that performing necessary roof repairs and adding insulation would result in a much greater overall energy improvement than 8.3%. It should be considered if the church is going to be reroofed, either with slate or a more cost friendly solution, to consider the addition of insulation in the roof deck at the same time to minimize labor costs.

5.4.3 Windows

It was found that a double-glazed window system of 3mm clear glass with a 13mm air gap of air or argon would result in the best energy savings over triple glazed systems if instituted in the church (Figure 61). Adding a secondary 3mm layer of glass with an air gap would result in a 17,000 BTU/Hr or a 3% improvement in annual energy consumption, while an argon filled double pane window system would result in an 19,000 BTU/Hr or a 3.4% improvement.

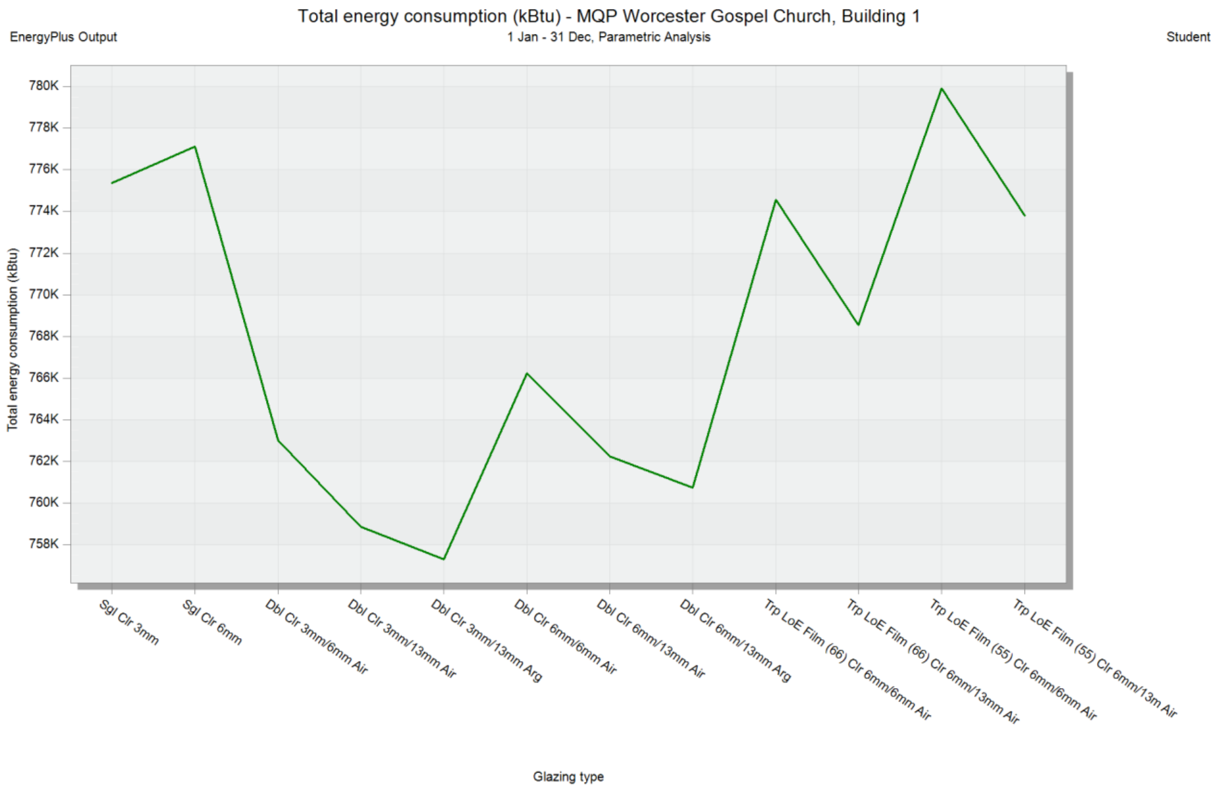


Figure 61: Existing Window Energy Consumption vs. Proposed Window Improvements Comparisons

While these improvements may not appear to be significant, the actual condition of the windows is akin to having them partially open all the time. Repairing the windows, independent of adding another layer of glass, will dramatically improve the overall discomfort that is felt in the sanctuary by reducing drafts and heat loss.

5.4.4 Heating Setpoints

Adjusting the church's heating setback to 60F from 63F results in an annual energy savings of 30,000 BTU or a 5% reduction in heat needed (Figure 62). Identifying ideal heating setback and cooling setback temperatures combined with a thorough occupancy study will result in improved occupant comfort and long-term energy savings.

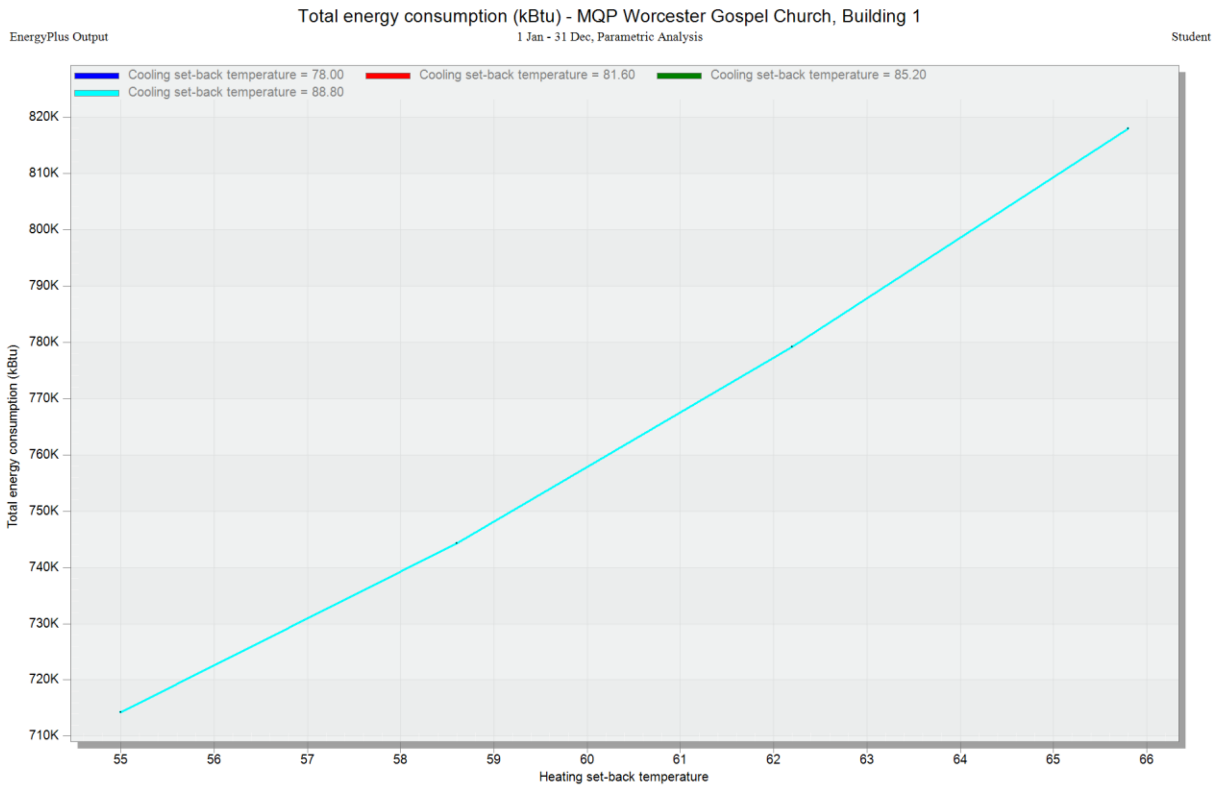


Figure 62: Heating Setback Energy Consumption Comparison

5.4.5 Overall Improvements

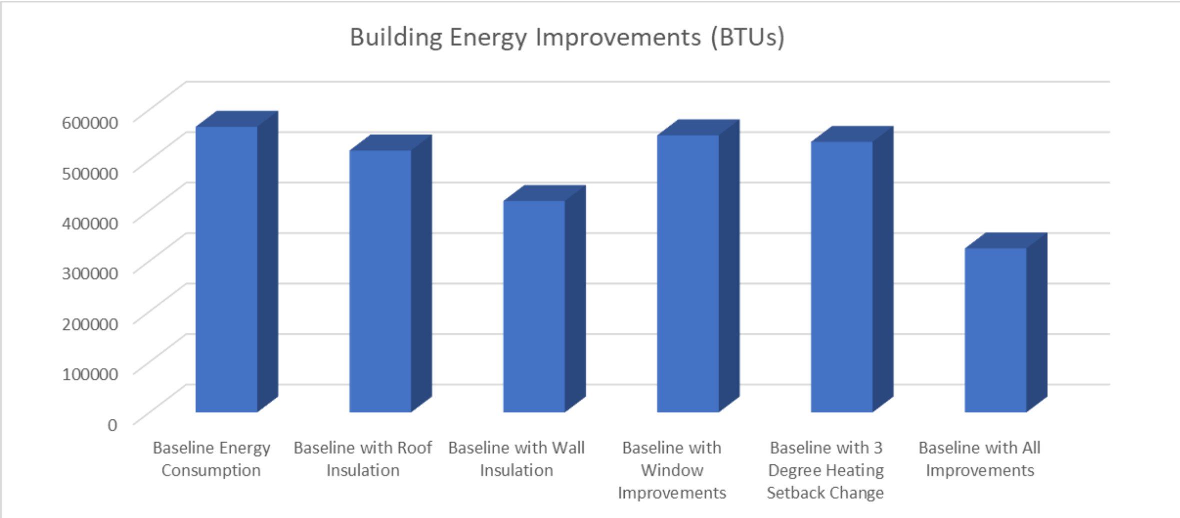


Figure 63: Overall Building Insulation Improvements Compared to Baseline Energy Consumption

Implementing all the envelope suggestions above would result in an approximate 42.7% reduction in overall energy needed to heat the building. A visual representation of the energy improvements suggested in this report is seen in Figure 63. Having the roof and windows properly repaired would bring the building up to the baseline established by *DesignBuilder*. These repairs combined with these suggested improvements would result in a greater energy reduction than postulated by this report.

5.5 HVAC Analysis

One of the primary goals of this project was to obtain values so that the church leadership would have a better understanding of the heating and cooling loads needed to properly condition their building. Potential heating and cooling systems and system improvements that could be feasibly implemented have been suggested.

5.5.1 Heating Load

Hand calculations assuming average Worcester winter temperatures resulted in the total heating load of the church in the winter of 499,311 BTU/Hr equating to a 41.6-ton system. The sanctuary with roof included was calculated having a heat loss of 230,893 BTU/Hr, equating to a 19.2-ton system. The initial 10-ton system estimate for the sanctuary that was provided by the heating contractor would have resulted in a vastly undersized system and the same heating issues repeating. The gym was calculated as having a heat loss of 70,879 BTU/Hr which equates to 5.9 tons. The entire basement, including the slab floor, was calculated as having a total heat loss of 197,540 BTU/Hr equating to 16.46 tons.

DesignBuilder calculated the total heating design load of the church for worst case winter scenarios using ASHRAE weather data beyond the conservative hand calculations. Internal heating times were determined by the occupancy schedule defined, as well as internal operating temperatures of 68F and a heating setback of 62F. The total design heating capacity of the building in worst case scenarios is 1,026,570 BTU/Hr or 85.45 tons. This number included areas of the church that were not included in the hand calculations and would be assumed to remain unconditioned in the future. The sanctuary calculated at these conditions was found to have a heat loss of 301,160 BTU/Hr equating to 25 tons. The basement was found to have a total heat loss of 414,420 BTU/Hr equating to 34.5 tons. The Gym was determined to have a heat loss of 203,080 BTU/Hr equating to 16.9 tons. These combined three zones at worst case weather scenarios results in a total system size of 76.4 tons. The total required tonnage of a new heating system required is most likely between the hand calculations and the worst-case scenarios. The total system size should be approximately 50-60 tons to appropriately heat the entire church appropriately during the winter.

5.5.2 Cooling Load

Based on hand calculations and an ASHRAE ComCheck format, the total cooling load of the church is between 364,603 BTU/Hr (average summer temperatures) and 431,097 BTU (peak summer temperatures with occupancy). These numbers translate to 30.4 tons and 35.9 tons respectively. The sanctuary was calculated to have a cooling load of 190,329 BTU/Hr or 15.7 tons (average summer temperatures) and 227,994 BTU/Hr or 19 tons (peak summer temperatures with occupancy). The basement was calculated to have a cooling load of 82,326 BTU/Hr or 6.7 tons (average summer temperatures) and 139,336 or 11.6 tons (peak summer temperatures with occupancy). The gym was calculated to have a cooling load of 63,767 BTU/Hr or 5.3 tons (average summer temperatures) and 91,948 BTU/Hr or 7.7 tons (peak summer temperatures with occupancy).

5.5.3 Hot Water Baseboard Fuel Type Comparison

It was determined by using *DesignBuilder* that the building as standing without any envelope improvements would require approximately 565,907 kBTU of fuel annually to heat. If one gallon of fuel oil contains 139,000 BTUs, the overall consumption of the church would be 4,071 gallons of fuel oil annually. Based on current market trends and the 2019-2020 national average of $2.95 per gallon results in an overall annual fuel oil cost of $12,009.45.

If the boilers in the church were upgraded to use natural gas instead of fuel oil, given that the average cost in Massachusetts of natural gas is $13.98 per 1000 cubic feet of natural gas. There are approximately one million BTUs in 1000-cubic feet of natural gas. This would require 565.907

1000-cu. ft units of natural gas annually to appropriately heat the church. This would cost the church $7,911 dollars yearly in order to heat utilizing natural gas. The conversion to natural gas would result in an annual cost savings of $4,098.45 yearly for the same amount of heat or a 34% reduction in heating costs.

If envelope improvements suggested in the energy analysis section were implemented, it would result in a 42.7% reduction in the overall amount of fuel required to heat the building. This would be 241,642 kBTUs annually compared to 565,907 kBTUs annually prior to any improvements. This would equate to 1,738 gallons of fuel oil annually or an annual cost of $5,128. If the hot water baseboard system was upgraded to natural gas, the overall heating with envelope improvements would require 241.64 1000-cu. ft units of natural gas or an annual cost of $3,378.

5.5.4 Variable Air Volume Systems

One of the primary findings in the cooling analysis was that in-wall air conditioning units would be the most efficient, however, because of the building's construction and important aesthetic value, this solution would not be feasible due to the need to make holes in the building's granite walls. A ducted VAV system would be feasible and provide heating and cooling to all areas of the church. Ducts containing hot/cold air could either be installed in the floor between the basement and first floor and vented appropriately to each zone of the church. The ducts could also be run through the Sanctuary ceiling supported by the trusses, although that would dramatically alter the aesthetics of the building. Retrofitting such a system into the existing building would be difficult but possible. A VAV system operates on the principle of variable air volume and not constant air volume like other forced air systems (Figure 64). VAV systems vary air flow with a constant temperature resulting in lower energy costs due to the reduction of the need of fans and results in more precise temperatures and less long-term wear of the system. A VAV system also offers additional passive dehumidification which is a major feature that the church requires now without any envelope repairs. It is estimated that an installation of a VAV system compared to the existing fuel oil system would result in approximately a 22,000 BTU reduction in total energy based purely on the efficiency of the system alone compared to baseboard heating.

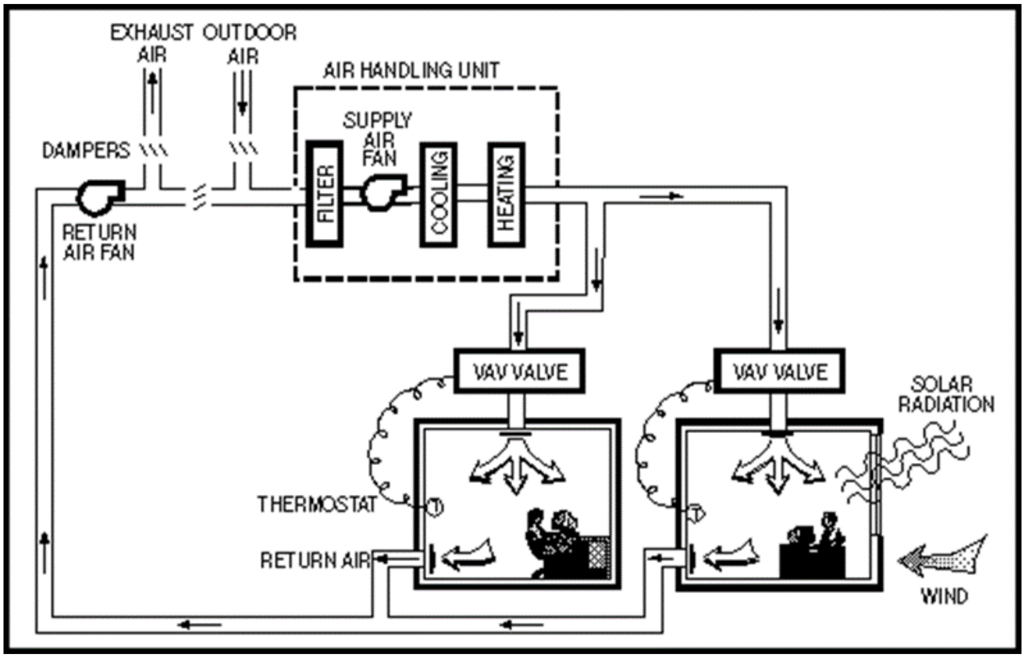


Figure 64: Example Diagram of a VAV System[16]

5.5.5 Radiative Heaters

One potential solution has been implemented in medieval churches in Europe involves the installation of infrared heaters in the sanctuary (Figure 65). Radiative heaters are very energy efficient as they directly reach occupants and surroundings due to the use of shortwave infrared heat and does not transfer heat to objects that may not necessarily need to be.

It would be possible to supplement the existing baseboard heating system with these ceiling/wall mounted radiative heaters. The existing baseboards could be used to condition the space in the winter at a stationary temperature to ensure proper humidity levels during the winter,

[16] University, Drexel. 2005. *Adventure Works Products Page.* Accessed February 25, 2020. http://www.pages.drexel.edu/~ea38/AE390/A5/products.htm.

but then utilize the radiative heaters when Sunday services are taking place. These heaters can then be left off at all other times resulting in lower overall energy costs but still warming the sanctuary.

Figure 65: Example of Radiative Heaters Installed in a Medieval Church [17]

There are many radiative heating options that operate either on electricity or natural gas. It would most likely be advantageous to convert the heat energy source of the church from fuel oil to natural gas and utilize a few methods of heating/cooling different areas of the church which would result in greater efficiency and greater cost savings.

[17] 2020. *Tansun.* Accessed January 14, 2020. https://www.tansun.com/gb_en/blog/what-is-the-best-method-for-heating-a-church.html.

Figure 66: Tansun Sorrento Triple Infrared Quartz Heater [18]

Tansun infrared heaters (Figure 66) that have been utilized in similar churches have a 6kW output approximately. This equates to 20,470 BTU/Hr. If the sanctuary requires 301,160 BTU/Hr to heat, this will require 15 infrared heaters positioned around the sanctuary. A potential placement of these heaters is suggested in Figure 67. This option is certainly feasible and would detract minimally from any aesthetic value of the church. These heaters are designed to be installed at

[18] 2020. *Tansun.* Accessed February 20, 2020. https://www.tansun.com/gb_en/infrared-heaters/sorrento/sorrento-triple.html.

higher ceiling heights and could be installed at the tops of walls to ensure maximum range of coverage.

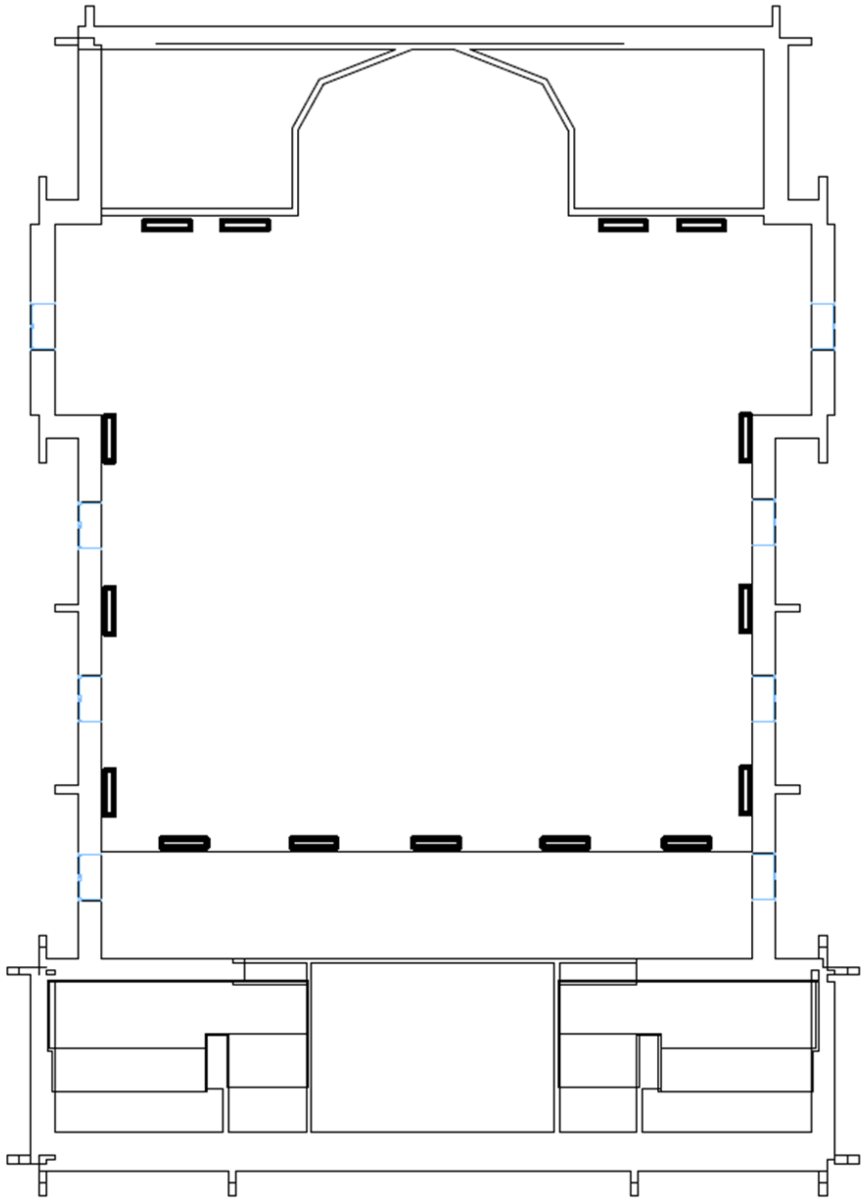


Figure 67: Suggested Placement of Infrared Heaters in the Sanctuary

Since these *Tansun* units are powered electrically, it would be advantageous to install any forms of green energy production to offset any utility costs or to appropriately size additional systems with these considerations in mind. Additionally, this brand would need to have a separate electrical service installed throughout the sanctuary since they operate at 220 volts. The current condition of the buildings electrical system requires addressing before an addition of another 220V service.

6.0 Recommendations

After analyzing the church, there are several recommendations that should be considered for structural and energy improvements. All suggestions should be discussed with a Professional Engineer and if decided to be implemented, installed by a certified contractor. These recommendations are based off of visual observations taken from many church visits as well as observations from the results of the analysis.

6.1 Structural Recommendations

Based on the structural analysis of the church, the building is structurally worthy and there are no immediate issues with the trusses, walls, roof and other load bearing members. Based on the computer analysis of the truss, diagrams have been provided for key areas of the truss to observe for any defects or changes in crack size or location. These defects could occur during a seismic event and combined with the high moisture content (relative humidity) in the church could cause issues in the future in the event of an earthquake or other significant seismic event.

6.1.1 Sub-Basement Concrete Reinforcement

The main concern structurally remains with the coal chute area located in the sub-basement next to the boilers. On inspection of this area it was observed that the concrete slabs and supporting steel members have corroded significantly. Since this area has ground directly exposed above, caution must be exercised if a cherry picker, scissor lift, or any significant weight is placed on this area. There is a potential that extra weight on this portion of the ground could cause this coal chute area to cave in.

Figure 68: Corrosion in Steel Reinforcement in the Sub-Basement Area

6.1.2 Truss I-beam

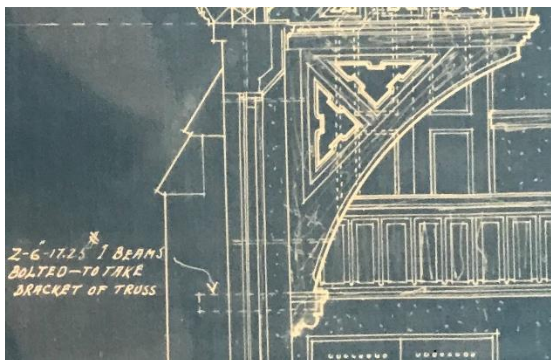


Figure 69: I-Beams as shown in the Archive Plans

From the review of section plans retrieved from the Massachusetts State Archives, it was determined that there are steel I-beams encased by wood located at the base of every truss. It is uncertain whether these I-beams are either encased with molding or embedded in wood. Due to the high humidity levels that the church has experienced as well as its age, it is recommended that a few test holes be made to inspect these I-beam members for rust and structural integrity. The shifting of these I-beam members is also causing cracking in the drywall. The holes should also be used to inspect if these cracks persist through the masonry behind the drywall and determine if there are any other underlying issues.

Figure 70: Cracking in drywall where the truss connects to the buttress

6.1.3 Buttress Reinforcement

During a seismic event, the interior brick may be responsible for providing tensile reinforcement. This brick layer should be inspected and if it is in poor condition, either the masonry should be repointed, or tensile reinforcement should be considered. A thin 1in^2 section of steel with 1/2in studs spaced 33 inches from the basement floor to the base of the truss should provide the necessary reinforcement. See Appendix C and the structural analysis section for more details.

6.2 Envelope Recommendations

A roof inspection is an immediate priority. In order to determine the extent of water infiltration coming from the roof level, an inspection from roof level was needed for this report, but this could not be accomplished since this group was unable to obtain access to a cherry picker or scissor lift. However, based on the photos sent by Jonas Chang and the observable damage, it is assumed that the condition of the roof is a major issue. These issues need to be addressed and repaired in order to prevent any further damage via water transport through the roof and the effects of annual heating and cooling cycles.

6.2.1 Potential Water Infiltration Sources

- Where the Towers meet the roof there may be an issue with the flashing/counterflashing allowing water to travel down the towers internally and make its way into the plaster. Over 100 years of weathering has most likely made these waterproofing systems not nearly as effective as originally intended. These areas of the roof should be thoroughly investigated by a roof inspection.
- There may be an issue with moisture transport occurring through the masonry construction of the granite walls. It is possible that water is being absorbed through the aggregate and being retained in the brick next to the plaster in the wall envelope. This moisture then leaches out due to heating and cooling cycles. The building should be inspected by a professional stonemason to verify the status of the masonry and determine if repointing is necessary.

6.2.2 Fenestrations

There are several stained-glass windows in the sanctuary that are broken/cracked and have warped frames. These openings are creating significant air changes in the sanctuary and creating a great deal of heat loss as can be directly felt as drafts while people are seated during church services. Correcting this issue will dramatically help with heat loss and the discomfort felt in the sanctuary. Installing another layer of glass over the existing stained glass in the sanctuary will dramatically improve the heat loss in the church. It was determined through analysis via *DesignBuilder* that adding another layer of clear glass, much like a double paned window, would reduce the energy needed by almost 20,000 BTUs.

6.2.3 Insulation

Installation of insulation on top of the granite walls would be a significant undertaking. However, based on the amount of heat being lost by the walls it is a worthwhile avenue to investigate in order to reduce energy consumption. Adding insulation to the roof deck is an option that is much more obtainable and would help dramatically with heat retention in the sanctuary.

6.3 Renewable Technology Considerations

The position of the towers of the church are directly obstructing the annual sun path. Additionally, the high-rise apartment building across Belmont Street is significantly taller than the church and contributes to blocking the sun path. This is shown in Figure 71. These obstructions will accumulate shadows on potential solar panels that could be installed on the roof and result in minimal energy being produced in the winter months when the sun is at its lowest. Due to the offset of the back wall between the church and the gym annex, shadows would be thrown over much of the roof during half of the year, making a potential installation of PV panels not advantageous from an electricity production and a maximization of return on investment (Figure 72).

Figure 71: Google Earth Image of Belmont Street and the High-Rise Apartment Building Across the Street from the Church

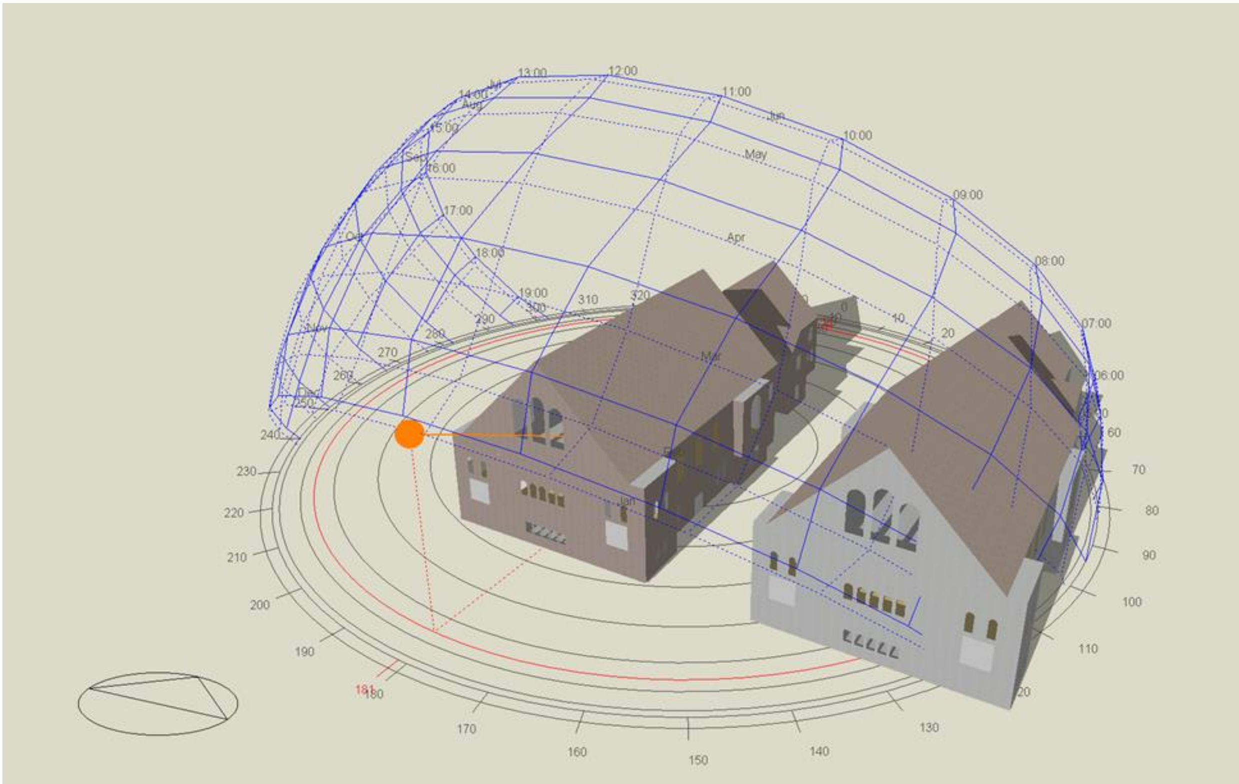


Figure 72: Simulated Sun Path in DesignBuilder

However, one consideration to keep in mind would be to add a solar parking area that have become more common in past years (Figure 73). Since the church offers their property for parking during the weekdays, it would be possible to add solar collectors to the parking areas and shield cars from sun and weather. The potential cost of this project could be offset by raising parking costs to commuters and could also be done slowly and expand as necessary and find an ideal place to place a potential solar field.

Figure 73: Example of a Solar Parking Lot[19]

Based on *Google Earth* calculations there is approximately 17,800 square feet in the top parking lot (Figure 74). The rear parking lots sun path is blocked by the building itself. An average of a 15% efficient solar panel would produce 15 watts per square feet resulting in a power production of 267 kW. Such power production would be enough to power the radiative heaters suggested in previous sections.

[19] https://solarips.com/2019/09/solar-carports-and-canopies-a-practical-solution/

Figure 74: Existing Parking Lot Behind the Church

6.4 Additional Recommendations

During a site survey investigating the roof construction via access through the ladies first floor bathroom, it was noticed that the electrical service located there is not up to code. When a light was turned on at the higher level above the ladder, there was significant amounts of smoke and a burning electrical smell. The electrical system at hand represents a fire hazard and should be addressed soon. As improvements are made to the building, upgrading the existing electrical system is critical.

Works Cited

2011. *2012 International Building Code.* 7th printing. International Code Council. https://codes.iccsafe.org/content/IBC2012/preface.

ASHRAE. 2019. *ASHRAE.* Accessed January 21, 2020. https://ashrae.iwrapper.com/ViewOnline/Standard_15-2019.

Cochran, Brice. 2018. *Hammer Beam Truss Details.* https://timberframehq.com/hammer-beam-truss-detail/.

2019. *Hammer Beam Truss Detail.* June 26. Accessed October 23, 2019. https://timberframehq.com/hammer-beam-truss-detail/.

2020. *HOBO U12 Temperature/Relative Humidity/Light/External Data Logger.* Accessed January 28, 2020. https://www.onsetcomp.com/products/data-loggers/u12-012.

Kidder, F.E. 2018. *The Hammer-Beam Truss.* Accessed January 2, 2020. https://chestofbooks.com/architecture/Construction-Superintendence/21-The-Hammer-Beam-Truss.html.

2015. *Massachusetts State Building Code.* 9th ed. https://up.codes/viewer/massachusetts/ibc-2015.

2013. *Minimum Design Loads for Buildings and Other Structures.* ASCE 7-10. 3rd printing. Reston, Virginia: American Society of Civil Engineers. www.pubs.asce.org.

2016. *National Design Specification for Wood Construction.* 2015 Ed. Leesburg, Virginia: American Wood Council. https://www.awc.org/codes-standards/publications/nds-2015.

n.d. *National Society of Professional Engineers.* Accessed January 23, 2020. https://www.nspe.org/resources/licensure/why-get-licensed.

2009. *Natitional Concrete Masonry Association.* TEK 14-7B Structural. Herndon, Virginia. https://ncma.org/resource/allowable-stress-design-of-concrete-masonry/.

“Protective Glazing Study.” National Preservation Center, March 1996. https://www.ncptt.nps.gov/wp-content/uploads/1996-06.pdf.

2020. *Swedish Lutheran Gethsemane Church.* Accessed February 5, 2020. https://www.cardcow.com/334173/swedish-lutheran-gethsemane-church-worcester-massachusetts/.

2020. *Tansun.* Accessed January 14, 2020. https://www.tansun.com/gb_en/blog/what-is-the-best-method-for-heating-a-church.html.

2020. *Tansun.* Accessed February 20, 2020. https://www.tansun.com/gb_en/infrared-heaters/sorrento/sorrento-triple.html.

n.d. *The Life of a Campus: 9 Essays on Clark Buildings Past and Present.* Clark University. https://wordpress.clarku.edu/krwilson/files/2012/05/CLU_ARCH-book.pdf.

University, Drexel. 2005. *Adventure Works Products Page.* Accessed February 25, 2020. http://www.pages.drexel.edu/~ea38/AE390/A5/products.htm.

Zeigler, John M. 2019. *Vibration Standards.* Accessed 2 13, 2020. https://vibrationdamage.com/Vibration_standards.htm.

Appendix A: Temperature/Relative Humidity Data

ASHRAE Climatic Design for Worcester, MA

2009 ASHRAE Handbook - Foundamentals (SI)

WORCESTER REGIONAL ARPT, MA, USA (WMO: 725095)

Lat:**42.27N** Long:**71.88W** Elev:**310** StdP: **97.66** Time zone:**-5.00** Period:**82-06**

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB	
			99.6%			99%			0.4%		1%			
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD
1	**-16.9**	**-14.3**	**-25.5**	**0.4**	**-14.8**	**-22.8**	**0.5**	**-12.5**	**13.6**	**-7.2**	**12.4**	**-4.9**	**6.0**	**280**

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
7	**9.0**	**29.8**	**21.8**	**28.4**	**21.1**	**26.9**	**20.2**	**23.4**	**27.7**	**22.5**	**26.4**	**21.6**	**25.2**	**4.6**	**270**

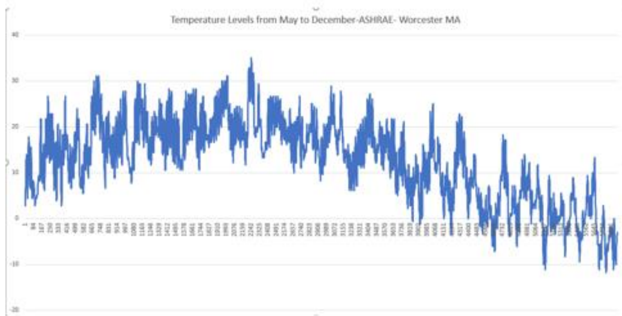
Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Hours 8 to 4 and 12.8/20.6
0.4%			1%			2%			0.4%		1%		2%		
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	
22.1	**17.4**	**25.6**	**21.2**	**16.5**	**24.6**	**20.3**	**15.6**	**23.7**	**71.2**	**27.8**	**67.5**	**26.4**	**64.1**	**25.0**	**752**

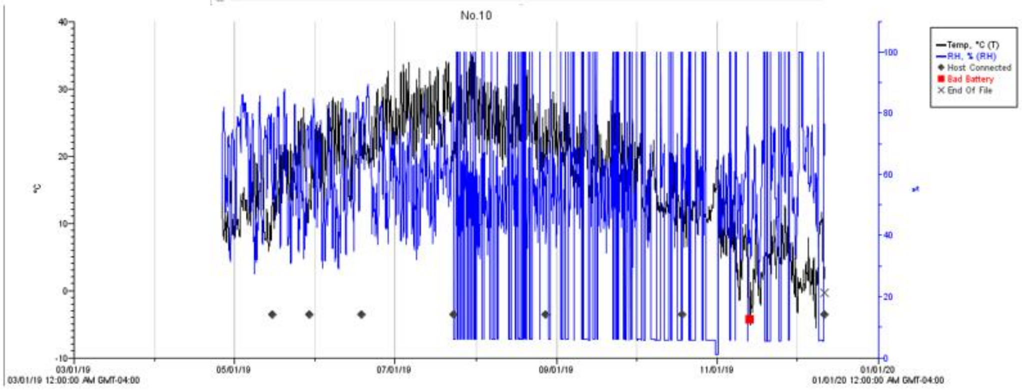
Extreme Annual Design Conditions

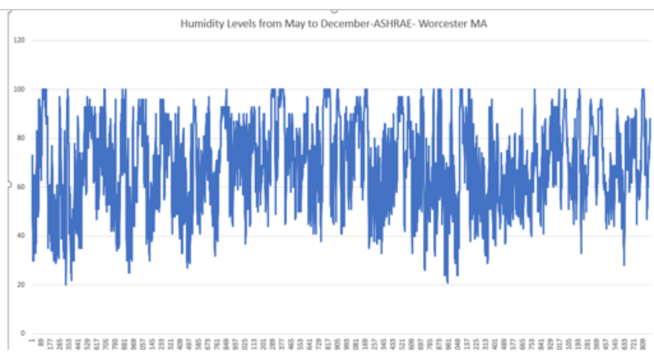
Extreme Annual WS			Extreme Max WB	Extreme Annual DB				n-Year Return Period Values of Extreme DB							
				Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
11.5	**10.2**	**8.7**	**29.4**	**-20.0**	**32.2**	**2.4**	**1.2**	**-21.7**	**33.0**	**-23.1**	**33.7**	**-24.5**	**34.4**	**-26.2**	**35.3**

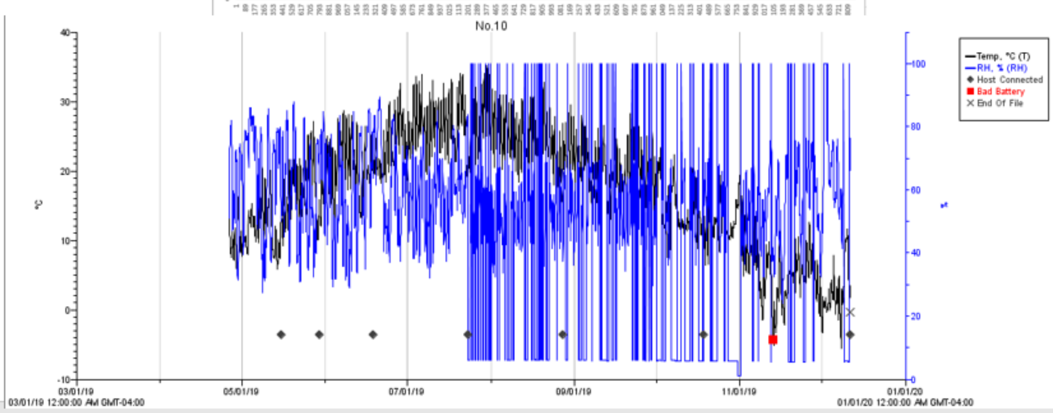
Monthly Climatic Design Conditions

			Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperatures, Degree-Days and Degree-Hours	Tavg		**8.8**	**-4.2**	**-2.7**	**1.4**	**7.6**	**13.3**	**18.3**	**21.1**	**20.3**	**16.2**	**10.1**	**4.7**	**-1.0**
	Sd			**5.88**	**5.37**	**5.35**	**4.65**	**4.28**	**3.86**	**2.93**	**3.20**	**3.87**	**4.32**	**4.92**	**5.44**
	HDD10.0		**1755**	**439**	**356**	**272**	**101**	**15**	**1**	**0**	**0**	**3**	**55**	**171**	**343**
	HDD18.3		**3726**	**697**	**589**	**526**	**323**	**166**	**48**	**9**	**17**	**86**	**258**	**409**	**600**
	CDD10.0		**1322**	**1**	**0**	**6**	**28**	**118**	**248**	**343**	**321**	**188**	**57**	**12**	**2**
	CDD18.3		**252**	**0**	**0**	**0**	**1**	**10**	**46**	**93**	**79**	**21**	**1**	**0**	**0**
	CDH23.3		**1596**	**0**	**0**	**3**	**20**	**94**	**321**	**604**	**450**	**99**	**4**	**0**	**0**
	CDH26.7		**352**	**0**	**0**	**1**	**4**	**17**	**74**	**143**	**98**	**15**	**0**	**0**	**0**
Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4%	DB		**13.3**	**13.0**	**21.0**	**26.3**	**29.1**	**30.8**	**32.0**	**31.2**	**28.7**	**23.7**	**19.9**	**16.2**
		MCWB		**11.1**	**9.0**	**13.0**	**15.5**	**19.2**	**22.3**	**23.7**	**23.3**	**21.0**	**16.6**	**15.5**	**13.6**
	2%	DB		**9.6**	**9.7**	**15.6**	**21.3**	**26.1**	**28.9**	**29.8**	**29.2**	**26.0**	**21.2**	**16.8**	**12.1**
		MCWB		**7.3**	**6.6**	**9.9**	**12.8**	**17.2**	**21.0**	**22.4**	**21.9**	**19.7**	**16.1**	**13.7**	**9.6**
	5%	DB		**6.3**	**7.3**	**12.0**	**17.9**	**23.4**	**26.9**	**28.3**	**27.5**	**24.0**	**18.9**	**14.4**	**9.2**
		MCWB		**4.3**	**4.6**	**7.7**	**11.0**	**15.8**	**19.9**	**21.3**	**21.0**	**18.6**	**14.4**	**11.7**	**6.7**
	10%	DB		**3.5**	**4.9**	**9.1**	**15.0**	**20.9**	**25.0**	**26.7**	**25.9**	**22.3**	**16.9**	**12.4**	**6.4**
		MCWB		**1.6**	**2.2**	**5.4**	**9.3**	**14.3**	**18.6**	**20.4**	**20.0**	**17.8**	**13.1**	**9.8**	**3.7**
Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures	0.4%	WB		**12.2**	**10.5**	**14.3**	**16.8**	**21.2**	**23.8**	**24.7**	**24.8**	**22.5**	**19.6**	**17.0**	**13.9**
		MCDB		**12.8**	**11.7**	**19.1**	**23.9**	**26.3**	**28.9**	**29.5**	**29.1**	**26.6**	**21.7**	**18.4**	**15.7**
	2%	WB		**7.8**	**7.4**	**11.3**	**14.4**	**18.7**	**22.4**	**23.6**	**23.2**	**21.1**	**17.2**	**14.4**	**10.2**
		MCDB		**9.0**	**8.9**	**14.2**	**19.2**	**23.6**	**26.8**	**28.0**	**26.9**	**23.9**	**19.6**	**16.0**	**11.7**
	5%	WB		**4.5**	**4.7**	**8.3**	**12.5**	**16.9**	**21.2**	**22.6**	**22.2**	**20.1**	**15.4**	**12.3**	**7.1**
		MCDB		**6.2**	**6.8**	**11.3**	**16.0**	**21.5**	**25.1**	**26.5**	**25.7**	**22.8**	**18.2**	**14.0**	**8.8**
	10%	WB		**1.7**	**2.4**	**5.7**	**10.5**	**15.4**	**20.0**	**21.6**	**21.3**	**18.9**	**13.7**	**10.2**	**4.3**
		MCDB		**3.4**	**4.5**	**8.8**	**14.1**	**19.4**	**23.5**	**25.3**	**24.5**	**21.5**	**16.3**	**12.0**	**6.0**
Mean Daily Temperature Range		MDBR		**7.7**	**8.0**	**8.7**	**9.5**	**10.0**	**9.4**	**9.0**	**8.6**	**8.6**	**8.7**	**7.8**	**7.5**
	5% DB	MCDBR		**10.7**	**9.9**	**12.9**	**13.8**	**13.2**	**11.3**	**10.5**	**10.0**	**9.8**	**10.6**	**10.5**	**10.5**
		MCWBR		**9.7**	**7.9**	**8.7**	**7.9**	**7.1**	**6.3**	**5.2**	**4.7**	**5.3**	**6.8**	**8.6**	**9.0**
	5% WB	MCDBR		**10.7**	**9.3**	**12.3**	**12.6**	**11.7**	**10.1**	**9.6**	**9.0**	**8.8**	**9.4**	**9.8**	**9.4**
		MCWBR		**10.2**	**8.4**	**9.5**	**8.7**	**7.2**	**6.4**	**5.3**	**4.8**	**5.3**	**6.8**	**8.6**	**9.0**

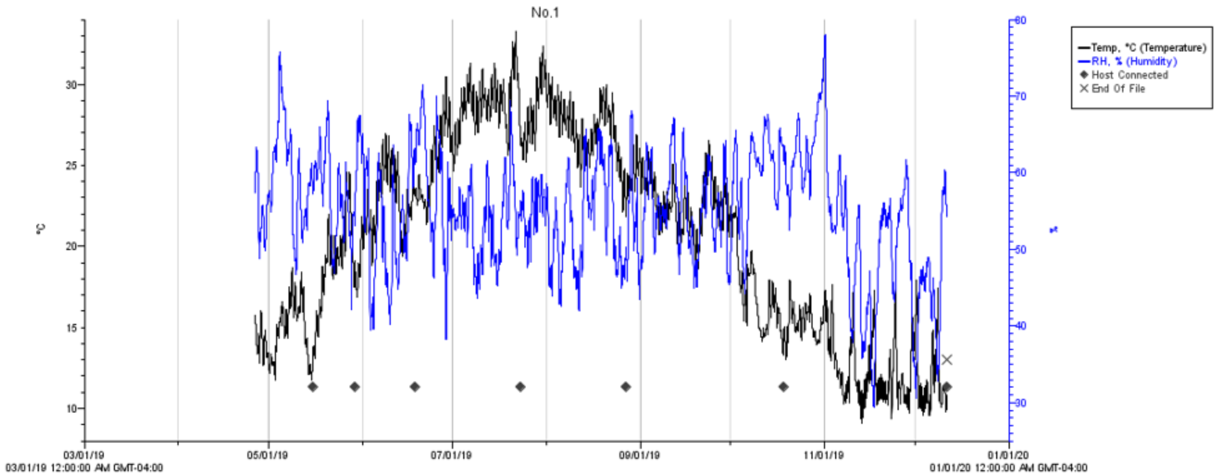

Temperature Levels from May to December-ASHRAE- Worcester MA


No.10
Temp, °C (T)
RH, % (RH)
Host Connected
Bad Battery
End Of File
03/01/19
03/01/19 12:00:00 AM GMT-04:00
05/01/19
07/01/19
09/01/19
11/01/19
01/01/20
01/01/20 12:00:00 AM GMT-04:00


Humidity Levels from May to December-ASHRAE- Worcester MA


No.10
Temp, °C (T)
RH, % (RH)
Host Connected
Bad Battery
End Of File
03/01/19
03/01/19 12:00:00 AM GMT-04:00
05/01/19
07/01/19
09/01/19
11/01/19
01/01/20
01/01/20 12:00:00 AM GMT-04:00

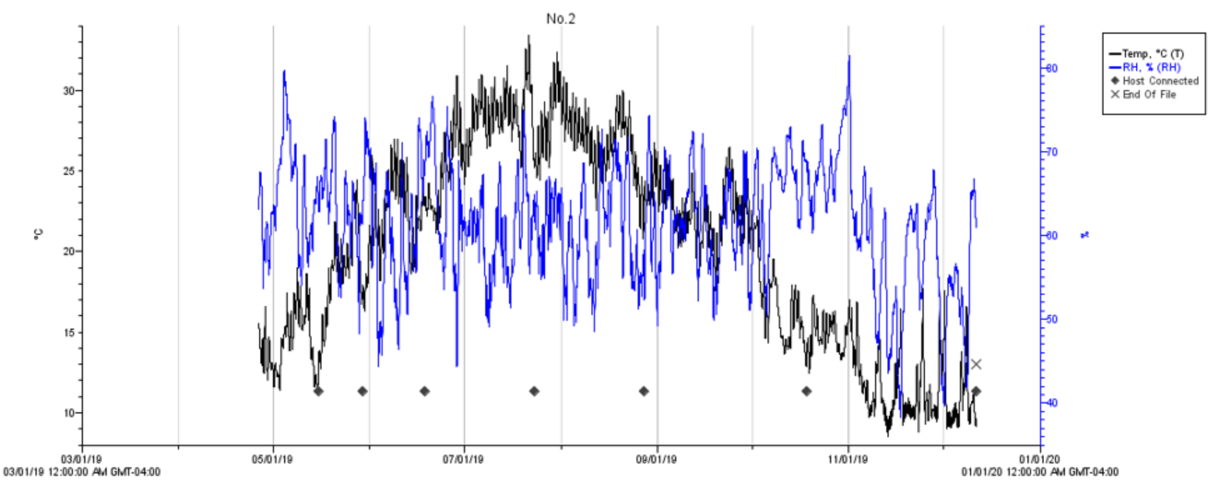
Sensor #1: Sanctuary-Back of Stage



Highest Temp Recorded: 91.87F
Lowest Temp Recorded: 48.32F

Highest RH Recorded: 77.95%
Lowest RH Recorded: 29.4%

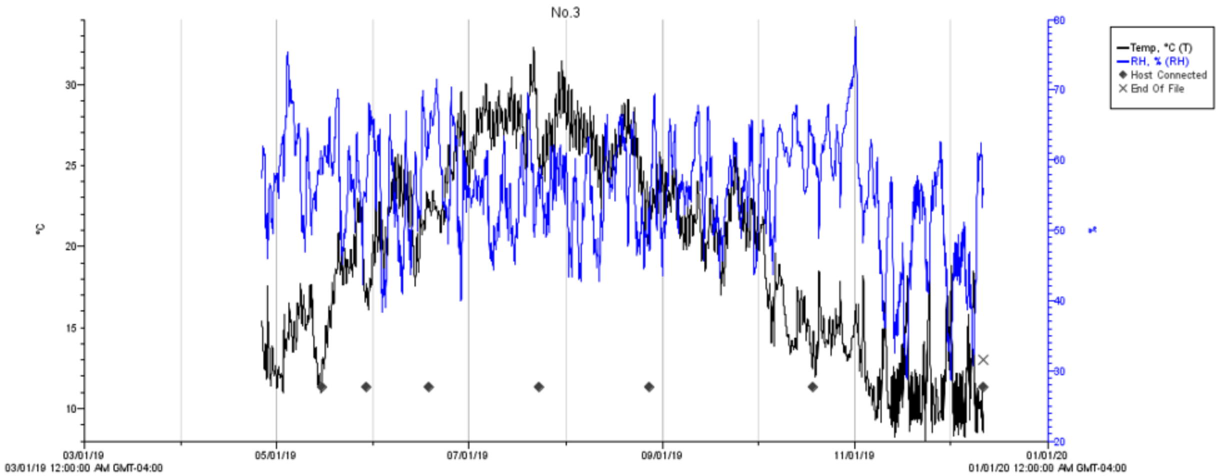
Sensor #2- Under 1st Pew-Center Aisle



Highest Temp Recorded: 92.15F
Lowest Temp Recorded: 8.54C

Highest RH Recorded: 81.46%
Lowest RH Recorded: 38.35%

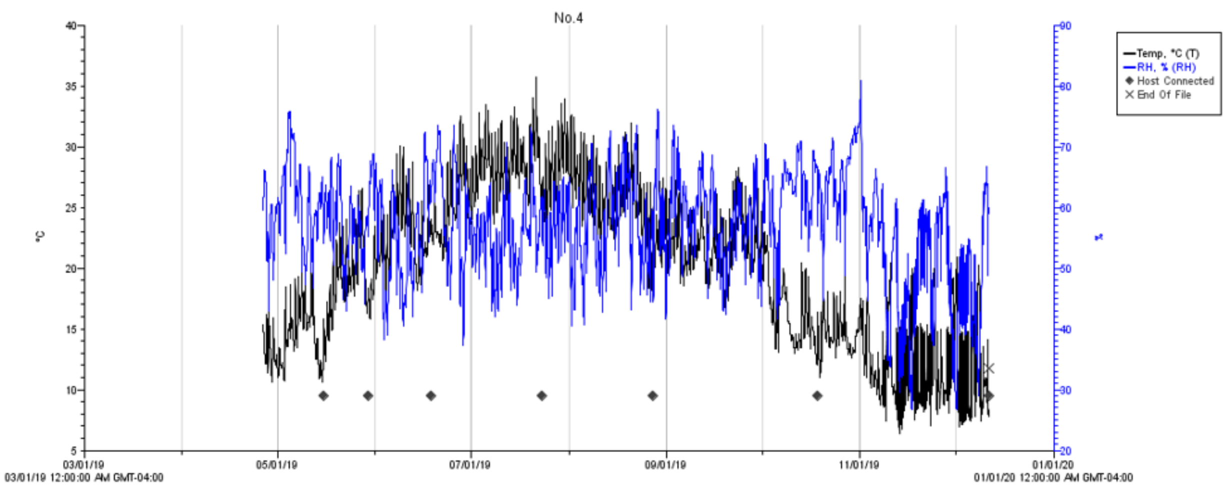
Sensor #3: Under Pew- Left Side



Highest Temp Recorded:32.30C
Lowest Temp Recorded: 8.05C

Highest RH Recorded: 78.95%
Lowest RH Recorded: 28.58%

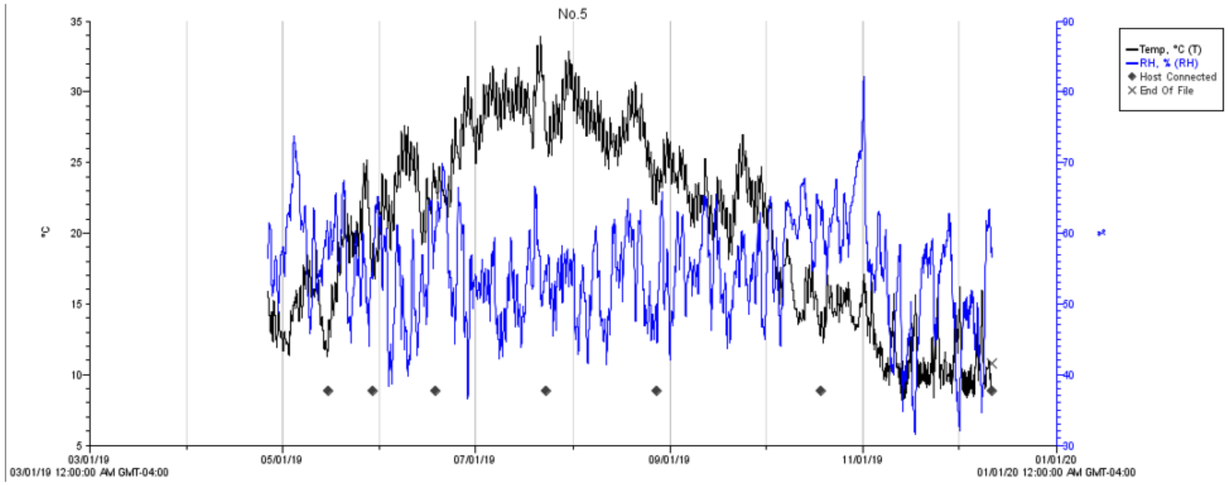
Sensor #4: On Stained Glass- Left Side



Highest Temp Recorded:35.74C
Lowest Temp Recorded: 6.33C

Highest RH Recorded: 80.84%
Lowest RH Recorded: 26.67%

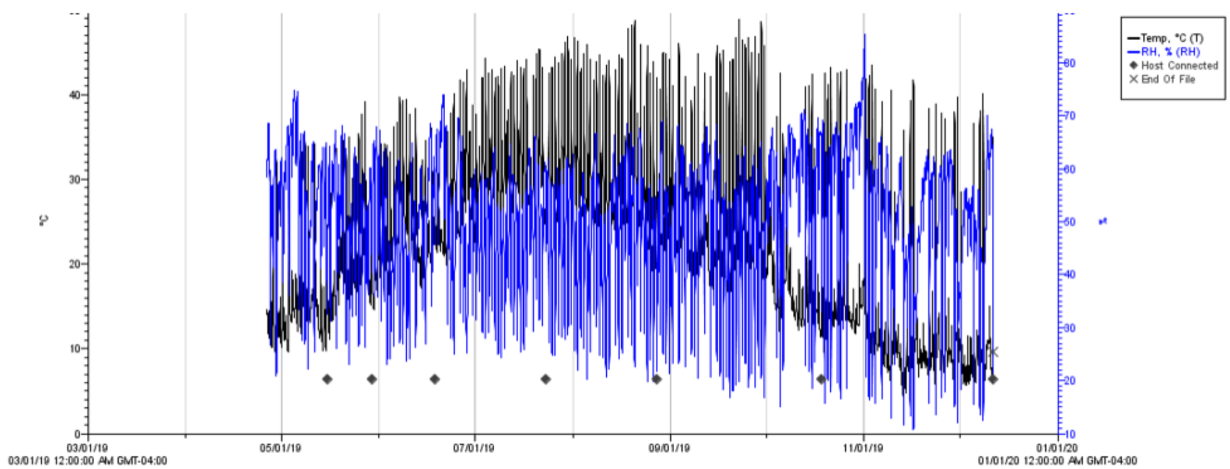
Sensor #5: Left Side Truss- Mezzanine



Highest Temp Recorded: 33.94C
Lowest Temp Recorded: 8.1C

Highest RH Recorded: 82.1%
Lowest RH Recorded: 31.53%

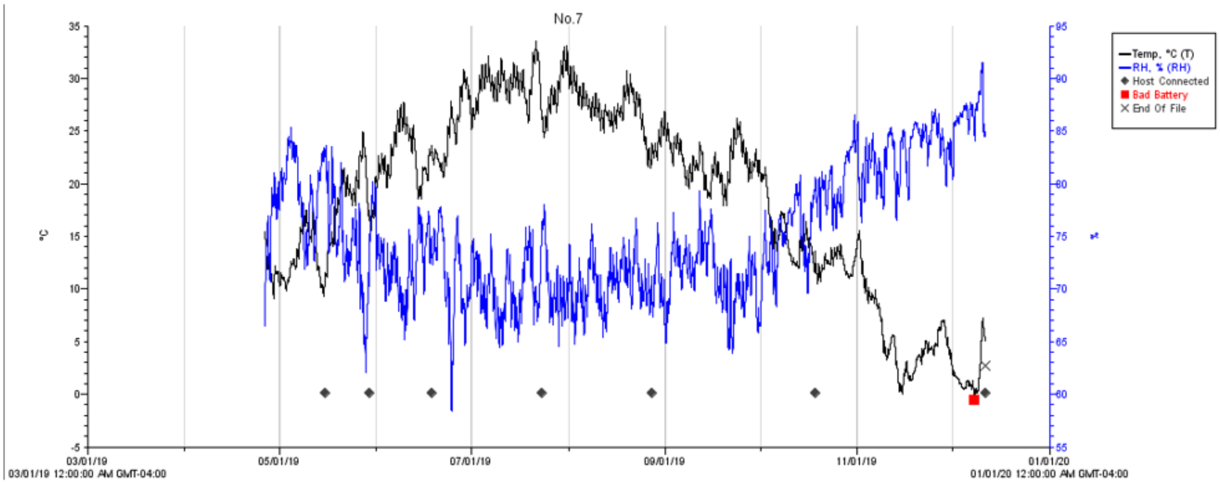
Sensor #6: On Stained Glass- Center Mezzanine



Highest Temp Recorded: 48.8C
Lowest Temp Recorded: 4.22C

Highest RH Recorded: 85.33%
Lowest RH Recorded: 10.86%

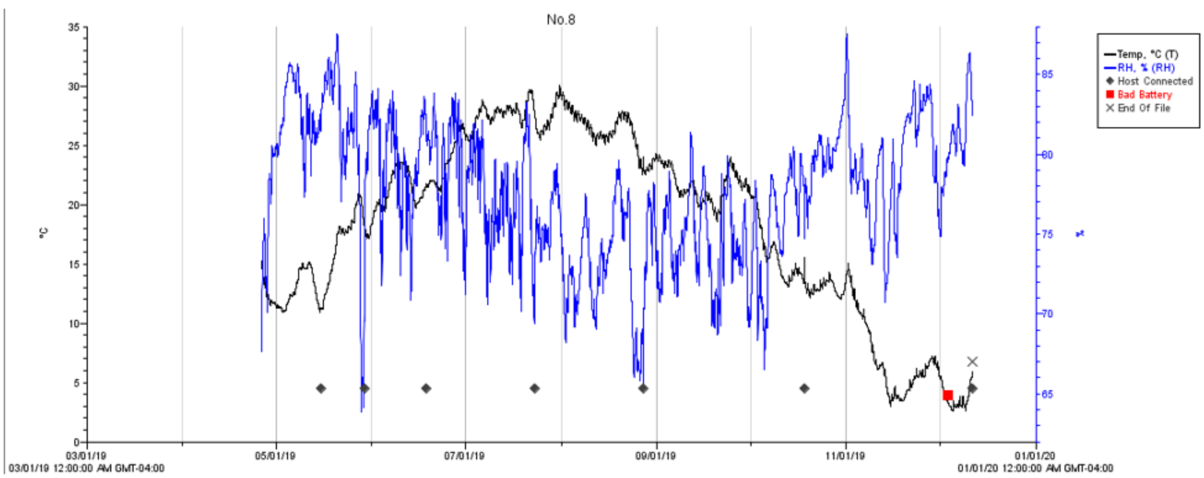
Sensor #7: Tower 1 Attic



Highest Temp Recorded: 33.57C
Lowest Temp Recorded: -0.359C

Highest RH Recorded: 91.49%
Lowest RH Recorded: 58.38%

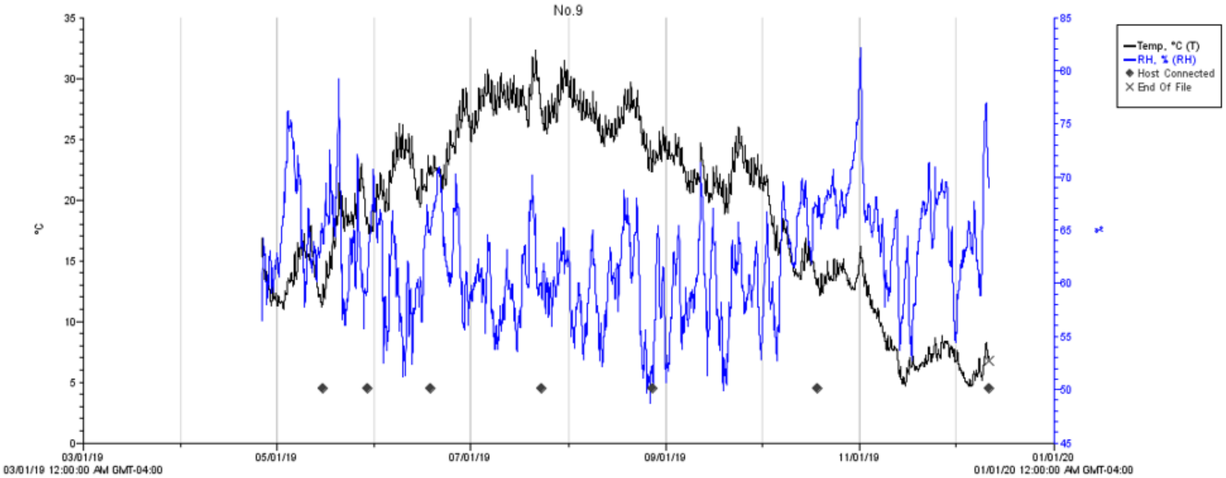
Sensor #8: Tower #1- North Side



Highest Temp Recorded:30.04C
Lowest Temp Recorded: 2.61C

Highest RH Recorded: 87.54%
Lowest RH Recorded: 63.84%

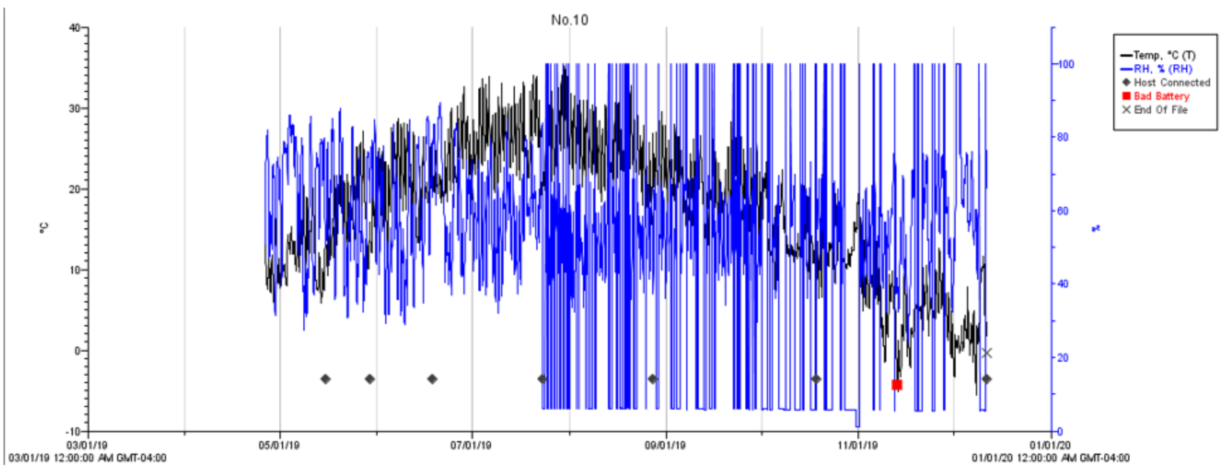
Sensor #9: Tower #2- West Side



Highest Temp Recorded: 32.33C
Lowest Temp Recorded: 4.64C

Highest RH Recorded: 82.13%
Lowest RH Recorded: 48.72%

Sensor #10: Outside Entrance



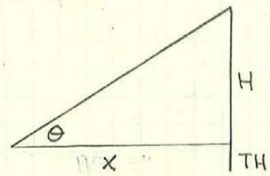
Highest Temp Recorded: 35.08C
Lowest Temp Recorded: -5.54C

Highest RH Recorded: 100%
Lowest RH Recorded: 1%

Appendix B: Accelerometer Data

Appendix C: Load and Structural Calculations

Height Measurements | MQP | 1



$\theta = 90° - 74°00'20'' = 15.99°$

$H = \tan\theta\,(x = 115'3'') = 33.035'$

$H + TH = H_{tot} = H + 64'' = 38.37'$

Gym Apex

Gym Wall height

$\theta = 5.756°$ $x = 116'1''$

$H = 11.70'$ $TH = 64''$

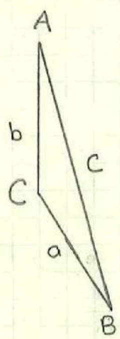
$H_{tot} = 17.03'$

Sanctuary Wall height (from ground)

$\theta = 26.12°$ $x = 45.7'$

$H = 22.41'$ $TH = 61.75''$

$H_{tot} = 27.56'$



$B = 17°57'40''$

$a = 45.7'$

$b = 29'$

$$\frac{\sin(17°57'40'')}{29'} = \frac{\sin A}{45.7'}$$

$A = 29.07°$

$C = 132.964°$

$$\frac{\sin C}{c} = \frac{\sin B}{b} \qquad c = 68.82'$$

Church Apex height

$\theta = 36.8°$ $x = 68.82'$

$H = 51.48'$ $TH = 61.75''$

$H_{tot} = 56.63'$

Gym Secondary Apex

$\theta = 35.306°$ $x = 37.6'$

$H = 26.63'$ $TH = 61.75''$

$H_{tot} = 31.77'$

$\frac{\text{apex} - \text{wall}}{\text{wall length}}$

Church Roof Slope

$$\frac{56.63' - 27.56'}{29'}$$

$= 1.00$ $\therefore 45°$ slope

Gym Roof Slope

$$\frac{38.37' - 17.03'}{21.06'}$$

$\frac{\text{apex} - \text{wall height}}{\text{wall length}}$

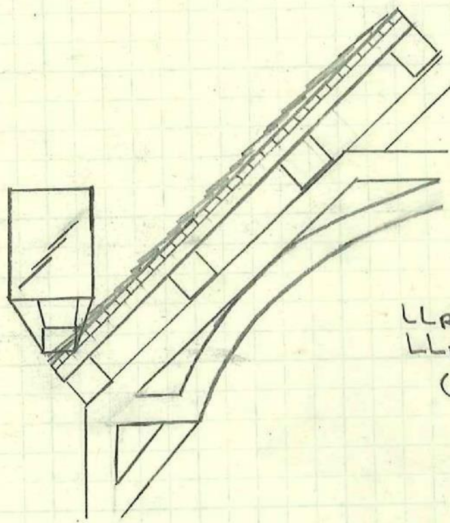
$= 1.01 \approx 1.00$ $\therefore 45°$ slope

Gym Secondary Apex base height (assuming equivelent slope)

$$\frac{31.77' - h}{8.54'} = 1.01 \qquad h = 23.1'$$

Dead Loads + Live Loads | Roof | 2

Roof from bottom to top: Truss, purlins, rafters, decking, slate



$LL_R = 300\,lb$ (concentrated)

$LL_R = 20\,psf$ (uniform)

(ASCE 7-10 Table 4-1)

Unit weight of slate: 167.99 pcf

Thickness of slate is 1/8" but it overlaps so thickness is 1/4"

$\boxed{\text{Dead load of slate} = 42.0\,psf}$ — see note on page 3

$\boxed{\text{Dead load of chandelier} = 100\,lb \text{ - applied at center of purlin}}$

$\boxed{\text{Dead load of CMEP} = 5\,psf \text{ - applied uniformly over truss}}$

Eastern Spruce Decking $G = 0.41 \rightarrow \gamma = 25.58\,pcf$

Decking is 1.125 in thick

$\boxed{\text{Dead load of decking} = 2.40\,psf}$

Spruce Rafters $G = 0.41 \rightarrow \gamma = 25.58\,pcf$

Members are 2"×8" spaced 16" O.C.

$\boxed{\text{Dead load of rafters} = 2.84\,plf \text{ or } 2.13\,psf}$

Eastern Spruce Purlins $G = 0.41 \rightarrow \gamma = 25.58\,pcf$

Members are 8"×10" spaced 9.7 ft O.C.

$\boxed{\text{Dead load of purlins} = 14.21\,plf}$

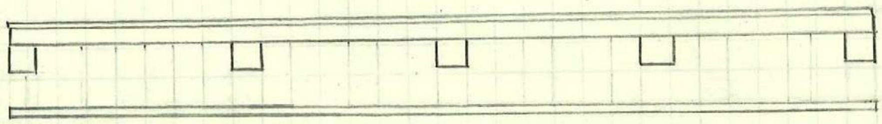
DL(slate + decking) = 44.4 psf

7/8" pine sheathing $G = 0.36 \rightarrow \gamma = 22.46\,pcf$

$\boxed{\text{Dead load of sheathing} = 1.638\,psf}$

Dead Loads + Live Loads | Floor | 3

Between 1st floor and basement



From top to bottom: carpet → decking → joists → girders → drop ceiling

LL (sanctuary) = 60psf (with fixed seating) or 300lb

DL (carpet + pad) = 3psf

DL (decking) = 2.4psf

DL (joists) = 4.263plf (2x12 spruce)

DL (girders) = 17.05plf (8x12 spruce)

DL (MEP) = 10psf (typ)

Note: Upon reviewing, the dead load due to slate is quite high but will serve as a very conservative estimate for this purpose - especially with potential differences between the original archive plans and what may be actually present

Seismic Loads | | | 4

Step 1 S_s and S_1

$S_s = 20\% \, g = 0.2g$
$S_1 = 7\% \, g = 0.07g$ } ASCE 7-10 Figures 22-1 + 22-2

Step 2

Not exempt → 2012 IBC 1613.1

Step 3 Seismic Design Category (SDC)

a) Soil Classification (Urban Land)

Site Class D → Web Soil Survey

b) S_{DS} and S_{D1} → ASCE 7-10 Table 11.4-1 + 11.4-2

$S_{DS} = (\frac{2}{3})(F_a)(S_s)$ $F_a = 1.6$ $S_{D1} = (\frac{2}{3})(F_v)(S_1)$ $F_v = 2.4$

$= (2/3)(1.6)(0.2g)$ $= (2/3)(2.4)(0.07g)$

$S_{DS} = 0.213g$ $S_{D1} = 0.112g$

c) Risk Category → ASCE 7-10 Table 1.6-1

Risk Category ~~IV~~ III

d) SDC (0.2S)

- B

SDC (1s)

- B

Step 4 Analysis Procedure

(ELF Permitted)

a) Determine fundamental period, T

$T_a = C_t h_n^x$ $C_t = 0.016(0.0466)^a$ } Table 12.8-2 ASCE

$x = 0.9$

$T_a = (0.016)(0.0466)^a$ $T = C_u T_a$ $C_u = 1.6$ → Table 12.8-1 ASCE

$T_a = 0.1N$

$= 0.1(3)$ N = # of stories

$T_a = 0.3$

$T = 1.6(0.3)$ $T = 0.48\,s$

b) Determine T_s

$$T_s = \frac{S_{D1}}{S_{DS}} = \frac{0.112g}{0.213g} = 0.53\,s$$

Step 5 Determine R, Response Modification Coefficient

Bearing Wall

- Ordinary plain masonry shear walls

$R = 1\frac{1}{2}$

Step 6 Determine Seismic Importance Factor, I_e

$I_e = 1.00$

Step 7 Determine Seismic Base Shear, V

$V = C_s W$

$C_s = \dfrac{S_{DS}}{\left(\frac{R}{I_e}\right)} = \dfrac{0.213g}{\left(\frac{1.5}{1}\right)} = 0.142$ $V = 0.142(662k)$ $V = 94.15$ kips $W = 113.98$ psf

Step 8 Distribute V over the height of the structure

$T \leq 0.5s$ so $k = 1$

$F_x = C_{vx} V$ where $C_{vx} = \dfrac{W_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k}$

↳ shear

	W_x	h_x^k	$W_x h_x^k$	C_{vx}	F_x	ΣStory Shear
Level 1	331 kips	30'	9930	0.5	47.08k	47.08
Level 2	331 kips	30'	9930	0.5	47.08k	94.15

Step 9 Redundancy Factor, ρ $W = 662$ k

$\rho = 1.0 \rightarrow 12.3.4.1$

Re-do of Sanctuary

Total DL = 388,938 lb
= 389 k

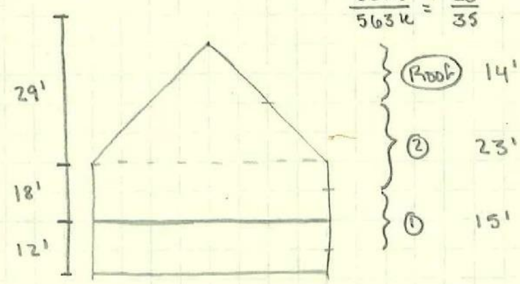
Step 7
$V = C_s W$
$= 0.142 (389 k)$
$= 55.24 k$

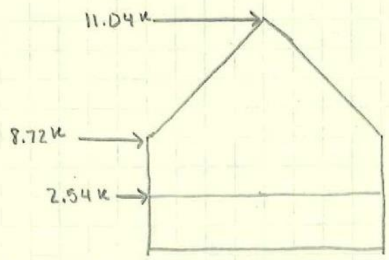
Step 8 Distribute V over height of structure
$T \leq 0.5s$ so $k = 1$

$\frac{321k}{563k} = \frac{20}{35}$

$F_x = C_{vx} V$

$R = 1.5$
$\Omega_D = 2.5$
$C_D = 1.25$





Level	W_x	h_x^k	$W_x h_x^k$	C_{vx}	F_x	Σ story shears	Per Section
Roof	105 k	14'	1470	0.21	11.6k	55.2 k	11.04 k
2	172 k	23'	3956	0.56	30.9k	43.6 k	8.72 k
1	112 k	15'	1680	0.23	12.7k	12.7 k	2.54 k
			$\boxed{7106}$				

Snow Loads

For Worcester, MA ground snow load $P_g = 50psf$ MBC* Table 1604.11 adopted with IBC

Terrain Category B (urban area)
Roof is fully exposed
$\Rightarrow$ Exposure factor $(C_e) = 0.9$ ASCE 7-10 Table 7-2

Thermal factor $(C_t) = 1.0 \Rightarrow$ heated structure (Table 7-3)

Risk Catagory III $\Rightarrow$ high risk assembly building (Table 1.5-1)

↳ Snow Importance Factor $(I_s) = 1.1$ (Table 1.5-2)

Flat roof snow load $(p_f) = 0.7 C_e C_t I_s p_g \geq 35psf$ MBC* Table 1604.11 adopted with IBC

$p_f = 0.7(0.9)(1.0)(1.1)(50psf) \geq 35psf$

$p_f = 34.7 psf \geq 35psf \Rightarrow p_f = 35psf$

For $C_t \leq 1.0$, roof is considered warm

Assuming the roof is not insulated, Slope factor $(C_s) = 0.7$ (Figure 7-2a ASCE 7-10)

Sloped roof snow load $(p_s) = C_s p_f = (0.7)(35psf) = \boxed{24.5psf}$

Note that this load acts vertically and not on the plane of the roof

*MBC: Massachusetts State Building Codes

Wind Loads

Risk Category III ⇒ High risk assembly structure (≥300 capacity)
(ASCE 7-10 Table 1.5-1)

→ Wind importance factor (I_w) = 1.0 (Table 1.5-2)

V_{ult} = 134 mph (MSBC Table 1604.11)

Directionality Factor (k_d) = 0.85 ⇒ buildings (ASCE 7-10 Table 26.6-1)

Surface Roughness Category B ⇒ urban area

Mean Roof Height (h) (Sanctuary) = 42.1ft

Mean Roof Height (h) (Gymnasium) = 27.7ft

For mean roof height greater than 30ft, exposure B applies surface roughness prevails in upwind direction at a distance greater than 2600 ft or 20 times building height, whichever greater

$20h = 20(56.63ft) = 1133ft$ ∴ 2600 ft governs

⇒ In this case, surface roughness corresponds to other buildings, and according to google maps, any distance of 2600ft from the church will result in another building

∴ exposure category B

For wind speed up effects, there exists a retaining wall where the highway is but this wall is obstructed upwind by the wall on the other side of the highway. Any other wind speed up effects can be considered negligible

$K_{zt} = 1.0$ ⇒ no wind speedup effects

G = 0.85 ⇒ Rigid Structure

Enclosure Classification: Enclosed

↳ $GC_{pi} = \pm 0.18$ (Table 26.11-1)

for z = 17.3ft (Gym wall height), K_z = 0.593

for z = 27.56ft (Sanctuary wall height), K_z = 0.680 (Table 27.3-1)

for z = 38.37ft (Gym apex), K_z = 0.750

for z = 56.63ft (Apex), K_z = 0.837

$q_z(17.3ft) = 0.00256 K_z K_{zt} K_d V^2 = 0.00256(0.593)(1.0)(0.85)(134mph)^2 = 23.17psf$

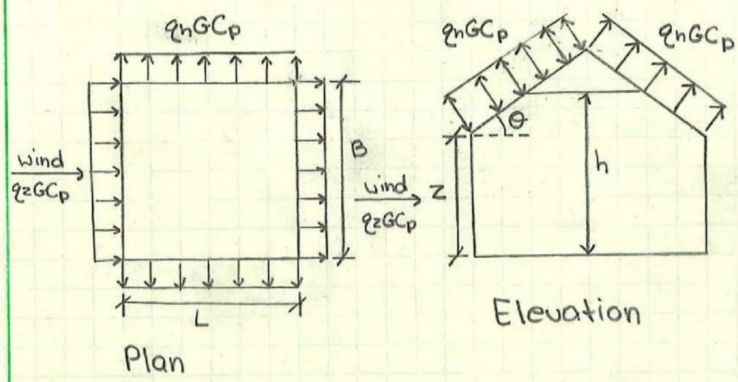
$q_z(27.56ft) = 0.00256(0.680)(1.0)(0.85)(134mph)^2 = 26.57psf$

$q_z(38.37ft) = 0.00256(0.750)(1.0)(0.85)(134mph)^2 = 29.30psf$

$q_z(56.63ft) = 0.00256(0.837)(1.0)(0.85)(134mph)^2 = 32.70psf$

Wind loads

Roof type: Gable Roof angle $(\theta) = 45°$



Wall pressure coefficient, $C_p = 0.8$ (windward wall) (27.4-1)

For sanctuary, $B = 94.54$ ft $L = 58.25$ ft $L/B = 0.616$

For gym, $B = 61.25$ ft $L = 42.125$ ft $L/B = 0.688$

$C_p = -0.5$ (Leeward Wall) $C_p = -0.7$ (Side Wall) (Figure 27.4-1)

Roof Pressure Coefficient, $C_p = 0.0, 0.355$ (windward, sanctuary)

For sanctuary, $h = 42.1$ ft $L = 58.25$ ft $h/L = 0.723$

For gym, $h = 27.7$ ft $L = 42.125$ ft $h/L = 0.658$ (Figure 27.4-1)

$C_p = 0.0, 0.368$ (windward, gym) $C_p = -0.6$ (leeward)

for $z = h_{sanctuary}$, $K_z = 0.7705$ for $z = h_{gym}$, $K_z = 0.6816$

$q_h(\text{sanctuary}) = 0.00256(0.7705)(1.0)(0.85)(134\text{mph})^2 = 30.11$ psf

$q_h(\text{gym}) = 0.00256(0.6816)(1.0)(0.85)(134\text{mph})^2 = 26.63$ psf

See attached spreadsheet for results and summary of east-west wind direction

WPI	**MWFRS Wind Loads** *ASCE 7-10* *Enclosed & Partially Enclosed Buildings of All Heights*	Job No: Designer: Jason Strauss Checker: Prof. Tao, Van Dessel
Notes:	Sanctuary East-West Direction	Date: 10/20/2019

Basic Parameters

Risk Category	III	Table 1.5-1
Basic Wind Speed, V	134 mph	Figure 26.5-1A
Wind Directionality Factor, K_d	0.85	Table 26.6-1
Exposure Category	B	Section 26.7
Topographic Factor, K_{zt}	1.00	Section 26.8
Gust Effect Factor, G or G_f	0.850	Section 26.9
Enclosure Classification	Enclosed	Section 26.10
Internal Pressure Coefficient, GC_{pi}	+/- 0.18	Table 26.11-1
Terrain Exposure Constant, α	7.0	Table 26.9-1
Terrain Exposure Constant, z_g	1,200 ft	Table 26.9-1

Wall Pressure Coefficients

Windward Wall Width, B	95 ft	
Side Wall Width, L	58 ft	
L/B Ratio	0.62	
Windward Wall Coefficient, C_p	0.80	Figure 27.4-1
Leeward Wall Coefficient, C_p	-0.50	Figure 27.4-1
Side Wall Coefficient, C_p	-0.70	Figure 27.4-1

Roof Pressure Coefficients

Roof Slope, θ	45.0°	
Median Roof Height, h	42 ft	
Velocity Pressure Exposure Coef., K_h	0.77	Table 27.3-1
Velocity Pressure, q_h	30.2 psf	Equation 27.3-1
h/L Ratio	0.72	
Windward Roof Area	0 ft²	
Roof Area Within 21 ft of WW Edge	0 ft²	

Location	*Min/Max*	*Horiz Distance From Windward Edge*			
		0 ft	*21 ft*	*42 ft*	*84 ft*
Windward Roof Coefficient Normal to Ridge, C_p	Min	0.00	0.00	0.00	0.00
	Max	0.36	0.36	0.36	0.36
Leeward Roof Coefficient Normal to Ridge, C_p	Min	-0.60	-0.60	-0.60	-0.60
	Max	-0.60	-0.60	-0.60	-0.60
Roof Coefficient Parallel to Ridge, C_p	Min	-1.08	-1.08	-0.59	-0.48
	Max	-0.18	-0.18	-0.18	-0.18

Figure 27.4-1

Structure Pressure Summary (Add Internal Pressure q_zGC_{pi} or q_hGC_{pi} as Necessary)

Height, z	K_z	q_z	*Walls*				*Roof*			Internal	
							Normal to Ridge		*Parallel to Ridge*		
			WW	*LW*	*WW + LW*	*Side*	*WW*	*LW*		Positive	Negative
0 ft	0.57	22.5 psf	15.3 psf		28.1 psf					5.4 psf	
3 ft	0.57	22.5 psf	15.3 psf		28.1 psf		Min: 0.0 psf	Min: -15.4 psf	~~Min: -27.6 psf~~	5.4 psf	
6 ft	0.57	22.5 psf	15.3 psf		28.1 psf					5.4 psf	
8 ft	0.57	22.5 psf	15.3 psf		28.1 psf					5.4 psf	
11 ft	0.57	22.5 psf	15.3 psf		28.1 psf					5.4 psf	
14 ft	0.57	22.5 psf	15.3 psf	-12.8 psf	28.1 psf	-17.9 psf				5.4 psf	-5.4 psf
17 ft	0.59	23.1 psf	15.7 psf		28.5 psf					5.4 psf	
19 ft	0.62	24.1 psf	16.4 psf		29.2 psf		Max: 9.1 psf	Max: -15.4 psf	~~Max: -4.6 psf~~	5.4 psf	
22 ft	0.64	25.1 psf	17.0 psf		29.9 psf					5.4 psf	
25 ft	0.66	25.9 psf	17.6 psf		30.4 psf					5.4 psf	
28 ft	0.68	26.7 psf	18.2 psf		31.0 psf					5.4 psf	

WPI	**MWFRS Wind Loads** *ASCE 7-10* *Enclosed & Partially Enclosed Buildings of All Heights*	Job No: Designer: Jason Strauss Checker: Prof. Tao, Van Dessel Date: 10/20/2019
	Notes: Gym East-West Direction	

Basic Parameters

Risk Category	III	Table 1.5-1
Basic Wind Speed, V	134 mph	Figure 26.5-1A
Wind Directionality Factor, K_d	0.85	Table 26.6-1
Exposure Category	B	Section 26.7
Topographic Factor, K_{zt}	1.00	Section 26.8
Gust Effect Factor, G or G_f	0.850	Section 26.9
Enclosure Classification	Enclosed	Section 26.10
Internal Pressure Coefficient, GC_{pi}	+/- 0.18	Table 26.11-1
Terrain Exposure Constant, α	7.0	Table 26.9-1
Terrain Exposure Constant, z_g	1,200 ft	Table 26.9-1

Wall Pressure Coefficients

Windward Wall Width, B	61 ft	
Side Wall Width, L	42 ft	
L/B Ratio	0.69	
Windward Wall Coefficient, C_p	0.80	Figure 27.4-1
Leeward Wall Coefficient, C_p	-0.50	Figure 27.4-1
Side Wall Coefficient, C_p	-0.70	Figure 27.4-1

Roof Pressure Coefficients

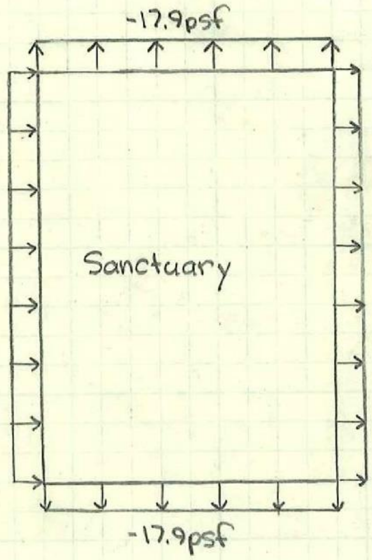
Roof Slope, θ	45.0°	
Median Roof Height, h	28 ft	
Velocity Pressure Exposure Coef., K_h	0.68	Table 27.3-1
Velocity Pressure, q_h	26.8 psf	Equation 27.3-1
h/L Ratio	0.66	
Windward Roof Area	0 ft²	
Roof Area Within 14 ft of WW Edge	0 ft²	

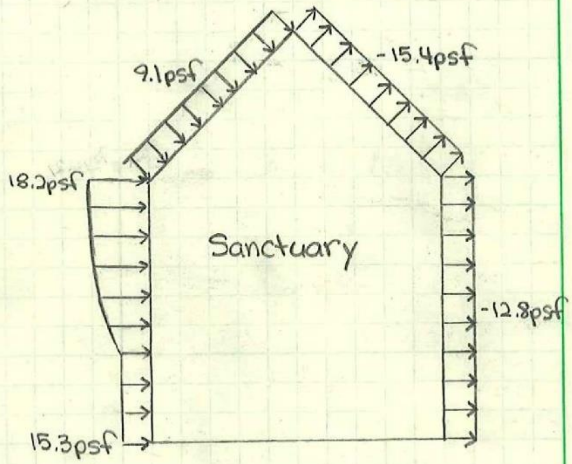
Location	*Min/Max*	*Horiz Distance From Windward Edge*			
		0 ft	*14 ft*	*28 ft*	*55 ft*
Windward Roof Coefficient Normal to Ridge, C_p	Min	0.00	0.00	0.00	0.00
	Max	0.37	0.37	0.37	0.37
Leeward Roof Coefficient Normal to Ridge, C_p	Min	-0.60	-0.60	-0.60	-0.60
	Max	-0.60	-0.60	-0.60	-0.60
Roof Coefficient Parallel to Ridge, C_p	Min	-1.03	-1.03	-0.56	-0.43
	Max	-0.18	-0.18	-0.18	-0.18

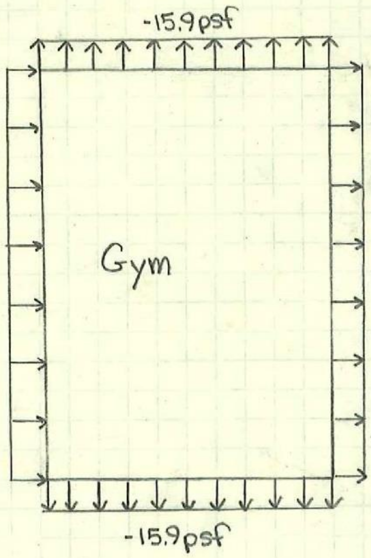
Figure 27.4-1

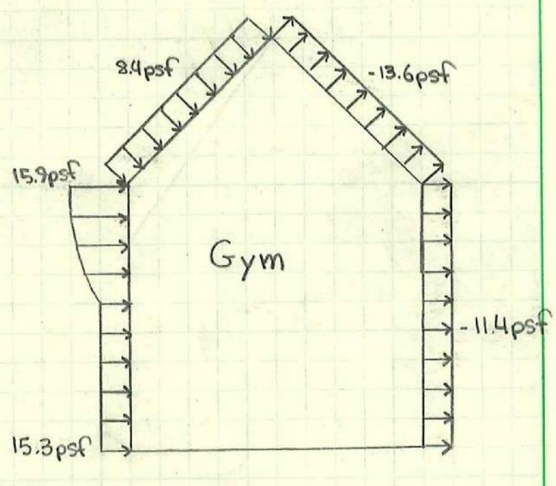
Structure Pressure Summary (Add Internal Pressure q_iGC_{pi} or q_hGC_{pi} as Necessary)

Height, z	K_z	q_z	*Walls*				*Roof*			Internal	
							Normal to Ridge		~~*Parallel to Ridge*~~		
			WW	*LW*	*WW + LW*	*Side*	*WW*	*LW*		Positive	Negative
0 ft	0.57	22.5 psf	15.3 psf		26.6 psf					4.8 psf	
2 ft	0.57	22.5 psf	15.3 psf		26.6 psf		Min:	Min:	~~Min:~~	4.8 psf	
3 ft	0.57	22.5 psf	15.3 psf		26.6 psf		0.0 psf	-13.6 psf	~~-23.3 psf~~	4.8 psf	
5 ft	0.57	22.5 psf	15.3 psf		26.6 psf					4.8 psf	
7 ft	0.57	22.5 psf	15.3 psf		26.6 psf					4.8 psf	
9 ft	0.57	22.5 psf	15.3 psf	-11.4 psf	26.6 psf	-15.9 psf				4.8 psf	-4.8 psf
10 ft	0.57	22.5 psf	15.3 psf		26.6 psf					4.8 psf	
12 ft	0.57	22.5 psf	15.3 psf		26.6 psf		Max:	Max:	~~Max:~~	4.8 psf	
14 ft	0.57	22.5 psf	15.3 psf		26.6 psf		8.4 psf	-13.6 psf	~~-4.1 psf~~	4.8 psf	
16 ft	0.58	22.7 psf	15.4 psf		26.8 psf					4.8 psf	
17 ft	0.60	23.4 psf	15.9 psf		27.3 psf					4.8 psf	









Internal pressure ranges from -5.4psf to 5.4psf (sanctuary) and from -4.8psf to 4.8psf (gym)

∴ For sanctuary, add/subtract 5.4psf to all values

∴ For gym, add/subtract 4.8psf to all values

Wind Loads	East-West		13

Use ASCE 7-10 Table 27.6-2 to confirm answers

Windward roof pressure

V=130mph Exposure C h=40ft ⇒ p=-6.9psf, 20psf

V=140mph Exposure C h=40ft ⇒ p=-8.0psf, 23.1psf

V=130mph Exposure C h=50ft ⇒ p=-7.2psf, 20.9psf

V=140mph Exposure C h=50ft ⇒ p=-8.4psf, 23.1psf

Leeward roof pressure

V=130mph Exposure C h=40ft ⇒ p=-26.5psf, -12.7psf

V=140mph Exposure C h=40ft ⇒ p=-30.7psf, -14.7psf

V=130mph Exposure C h=50ft ⇒ p=-27.8psf, -13.3psf

V=140mph Exposure C h=50ft ⇒ p=-32.2psf, -15.4psf

to convert Exposure C values to exposure B values, multiply values by adjustment factor. (0.729 for h=40ft and 0.741 for h=50ft)

Windward roof pressure

Exposure B V=130mph h=40ft ⇒ p=-5.03, 14.58
Exposure B V=140mph h=40ft ⇒ p=-5.83, 16.84 > -5.35, 15.48

Exposure B V=130mph h=50ft ⇒ p=-5.34, 15.49
Exposure B V=140mph h=50ft ⇒ p=-6.22, 17.12 > -5.69, 16.14

Leeward roof pressure

Exposure B V=130mph h=40ft ⇒ p=-19.32, -9.26
Exposure B V=140mph h=40ft ⇒ p=-22.38, -10.72 > -20.54, -9.84

Exposure B V=130mph h=50ft ⇒ p=-20.60, -9.86
Exposure B V=140mph h=50ft ⇒ p=-23.86, -11.41 > -21.90, -10.48

Linearly interpolate to find values for V=134 mph h=42.1ft

Windward p=-5.42, 15.62

Leeward p=-20.82, -9.97

These values are slightly greater than the manuel calculations but the manuel calculations have an h/L reduction factor that is not accounted for in the table - when h/L is assumed to have the greatest factor, manuel values match the table

Determining wind loads in the north-south direction requires the same analysis as the east-west direction except B and L are swapped and $\theta = 0°$

The following spreadsheets summarize the numerical results

There are two parapets on the building
① South (Front) end of church over sanctuary
② Northeast end over gym stairs

① $P_p = q_p(GC_{pn})$

$q_p = 0.00256 k_z k_{zt} k_d V^2$ $z = 60.3ft$ $k_z = 0.851$

$k_{zt} = 1.0$ $k_d = 0.85$ $V = 134mph$

$q_p = 0.00256(0.851)(1.0)(0.85)(134mph)^2 = 33.25psf$

$GC_{pn} = 1.5, -1.0$

$P_p = (33.25psf)(1.5) = 49.88psf$

$P_p = (33.25psf)(-1.0) = -33.25psf$

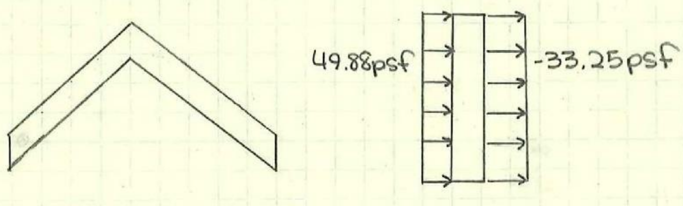
② $z = 31.77ft$ $k_z = 0.711$ $k_{zt} = 1.0$ $k_d = 0.85$ $V = 134mph$

$q_p = 0.00256(0.711)(1.0)(0.85)(134mph)^2 = 27.78psf$

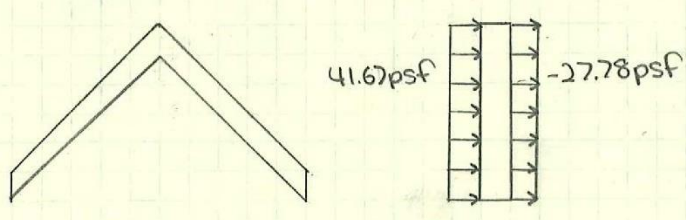
$P_p = (27.78psf)(1.5) = 41.67psf$

$P_p = (27.78psf)(-1.0) = -27.78psf$

① Front ① Side



② Front ② Side



WPI	MWFRS Wind Loads *ASCE 7-10* *Enclosed & Partially Enclosed Buildings of All Heights*	Job No:	
		Designer:	Jason Strauss
		Checker:	Prof. Tao, Van Dessel
Notes:	Sanctuary North-South Direction	Date:	10/21/2019

Basic Parameters

Risk Category	III	Table 1.5-1
Basic Wind Speed, V	134 mph	Figure 26.5-1A
Wind Directionality Factor, K_d	0.85	Table 26.6-1
Exposure Category	B	Section 26.7
Topographic Factor, K_{zt}	1.00	Section 26.8
Gust Effect Factor, G or G_f	0.850	Section 26.9
Enclosure Classification	Enclosed	Section 26.10
Internal Pressure Coefficient, GC_{pi}	+/- 0.18	Table 26.11-1
Terrain Exposure Constant, α	7.0	Table 26.9-1
Terrain Exposure Constant, z_g	1,200 ft	Table 26.9-1

Wall Pressure Coefficients

Windward Wall Width, B	58 ft	
Side Wall Width, L	95 ft	
L/B Ratio	1.62	
Windward Wall Coefficient, C_p	0.80	Figure 27.4-1
Leeward Wall Coefficient, C_p	-0.38	Figure 27.4-1
Side Wall Coefficient, C_p	-0.70	Figure 27.4-1

Roof Pressure Coefficients

Roof Slope, θ	0.0°	
Median Roof Height, h	42 ft	
Velocity Pressure Exposure Coef., K_h	0.77	Table 27.3-1
Velocity Pressure, q_h	30.2 psf	Equation 27.3-1
h/L Ratio	0.45	
Windward Roof Area	0 ft²	
Roof Area Within 21 ft of WW Edge	0 ft²	

Location	*Min/Max*	*Horiz Distance From Windward Edge*			
		0 ft	*21 ft*	*42 ft*	*84 ft*
Windward Roof Coefficient Normal to Ridge, C_p	Min	-0.90	-0.90	-0.50	-0.30
	Max	-0.18	-0.18	-0.18	-0.18
Leeward Roof Coefficient Normal to Ridge, C_p	Min	-0.90	-0.90	-0.50	-0.30
	Max	-0.18	-0.18	-0.18	-0.18
Roof Coefficient Parallel to Ridge, C_p	Min	-0.90	-0.90	-0.50	-0.30
	Max	-0.18	-0.18	-0.18	-0.18

Figure 27.4-1

Structure Pressure Summary (Add Internal Pressure q_zGC_{pi} or q_hGC_{pi} as Necessary)

Height, z	K_z	q_z	*Walls*				*Roof*			Internal	
							Normal to Ridge		*Parallel to Ridge*		
			WW	*LW*	*WW + LW*	*Side*	*WW*	*LW*		Positive	Negative
0 ft	0.57	22.5 psf	15.3 psf		24.9 psf					5.4 psf	
6 ft	0.57	22.5 psf	15.3 psf		24.9 psf		Min:	Min:	Min:	5.4 psf	
11 ft	0.57	22.5 psf	15.3 psf		24.9 psf		-23.1 psf	-23.1 psf	-23.1 psf	5.4 psf	
17 ft	0.60	23.3 psf	15.8 psf		25.4 psf					5.4 psf	
23 ft	0.65	25.3 psf	17.2 psf		26.8 psf					5.4 psf	
28 ft	0.69	26.9 psf	18.3 psf	-9.6 psf	27.9 psf	-17.9 psf				5.4 psf	-5.4 psf
34 ft	0.73	28.4 psf	19.3 psf		28.9 psf					5.4 psf	
40 ft	0.76	29.6 psf	20.2 psf		29.8 psf		Max:	Max:	Max:	5.4 psf	
45 ft	0.79	30.8 psf	20.9 psf		30.6 psf		-4.6 psf	-4.6 psf	-4.6 psf	5.4 psf	
51 ft	0.82	31.8 psf	21.7 psf		31.3 psf					5.4 psf	
57 ft	0.84	32.8 psf	22.3 psf		31.9 psf					5.4 psf	

WPI	**MWFRS Wind Loads** *ASCE 7-10* *Enclosed & Partially Enclosed Buildings of All Heights*	Job No:
		Designer: Jason Strauss
		Checker: Prof. Tao, Van Dessel
Notes:	Gym North-South Direction	Date: 10/21/2019

Basic Parameters

Risk Category	III	Table 1.5-1
Basic Wind Speed, V	134 mph	Figure 26.5-1A
Wind Directionality Factor, K_d	0.85	Table 26.6-1
Exposure Category	B	Section 26.7
Topographic Factor, K_{zt}	1.00	Section 26.8
Gust Effect Factor, G or G_f	0.850	Section 26.9
Enclosure Classification	Enclosed	Section 26.10
Internal Pressure Coefficient, GC_{pi}	+/- 0.18	Table 26.11-1
Terrain Exposure Constant, α	7.0	Table 26.9-1
Terrain Exposure Constant, z_g	1,200 ft	Table 26.9-1

Wall Pressure Coefficients

Windward Wall Width, B	42 ft	
Side Wall Width, L	61 ft	
L/B Ratio	1.45	
Windward Wall Coefficient, C_p	0.80	Figure 27.4-1
Leeward Wall Coefficient, C_p	-0.41	Figure 27.4-1
Side Wall Coefficient, C_p	-0.70	Figure 27.4-1

Roof Pressure Coefficients

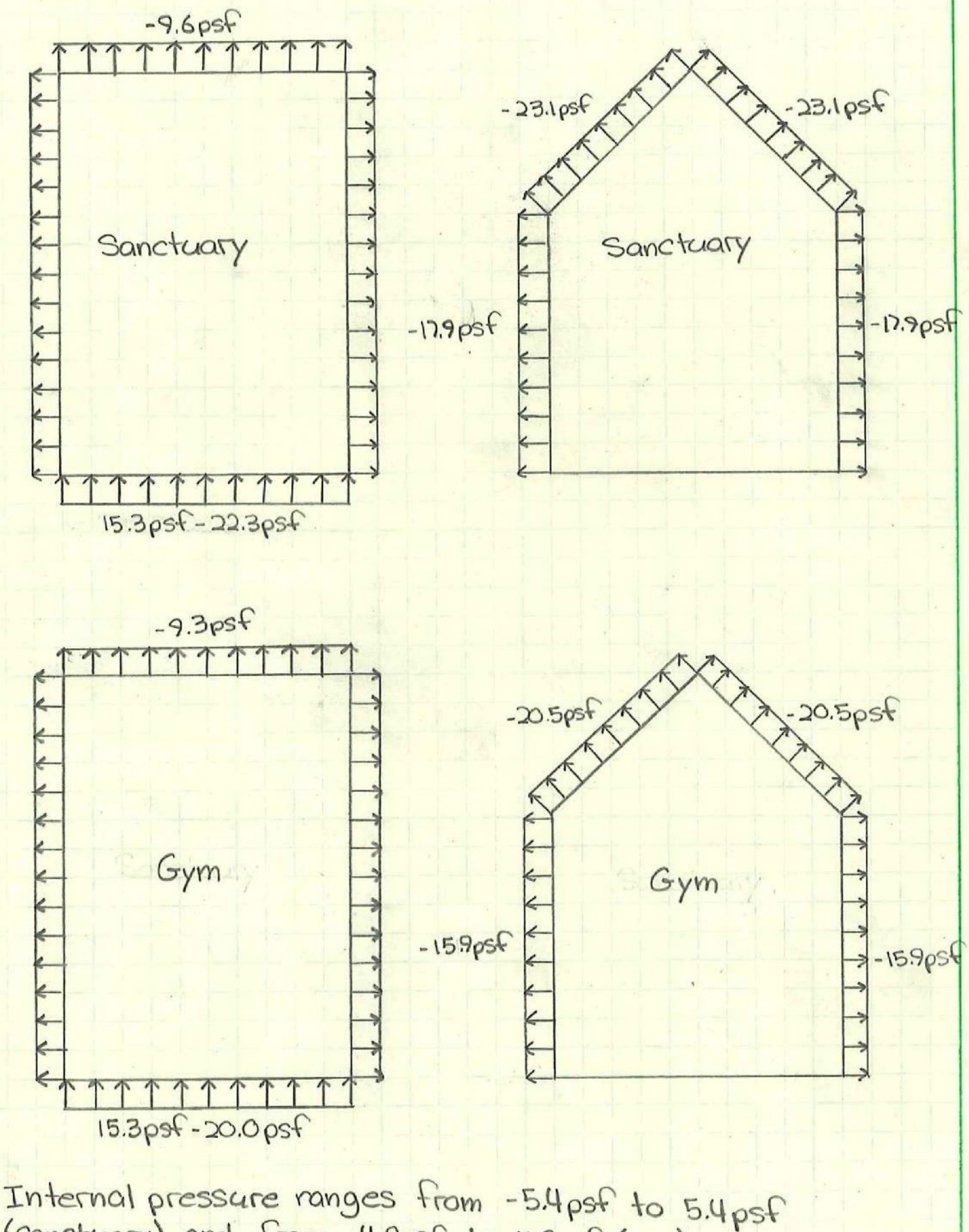
Roof Slope, θ	0.0°	
Median Roof Height, h	28 ft	
Velocity Pressure Exposure Coef., K_h	0.68	Table 27.3-1
Velocity Pressure, q_h	26.8 psf	Equation 27.3-1
h/L Ratio	0.45	
Windward Roof Area	0 ft²	
Roof Area Within 14 ft of WW Edge	0 ft²	

Location	*Min/Max*	*Horiz Distance From Windward Edge*			
		0 ft	*14 ft*	*28 ft*	*55 ft*
Windward Roof Coefficient Normal to Ridge, C_p	Min	-0.90	-0.90	-0.50	-0.30
	Max	-0.18	-0.18	-0.18	-0.18
Leeward Roof Coefficient Normal to Ridge, C_p	Min	-0.90	-0.90	-0.50	-0.30
	Max	-0.18	-0.18	-0.18	-0.18
Roof Coefficient Parallel to Ridge, C_p	Min	-0.90	-0.90	-0.50	-0.30
	Max	-0.18	-0.18	-0.18	-0.18

Figure 27.4-1

Structure Pressure Summary (Add Internal Pressure q_zGC_{pi} or q_hGC_{pi} as Necessary)

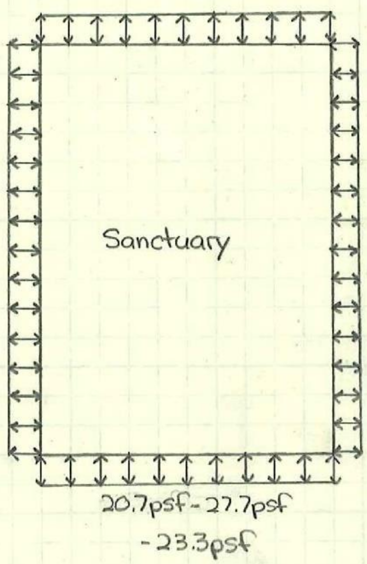
Height, z	K_z	q_z	*Walls*				*Roof*			Internal	
							Normal to Ridge		*Parallel to Ridge*		
			WW	*LW*	*WW + LW*	*Side*	*WW*	*LW*		Positive	Negative
0 ft	0.57	22.5 psf	15.3 psf		24.6 psf					4.8 psf	
4 ft	0.57	22.5 psf	15.3 psf		24.6 psf		Min:	Min:	Min:	4.8 psf	
8 ft	0.57	22.5 psf	15.3 psf		24.6 psf		-20.5 psf	-20.5 psf	-20.5 psf	4.8 psf	
12 ft	0.57	22.5 psf	15.3 psf		24.6 psf					4.8 psf	
15 ft	0.58	22.6 psf	15.4 psf		24.7 psf					4.8 psf	
19 ft	0.62	24.1 psf	16.4 psf	-9.3 psf	25.7 psf	-15.9 psf				4.8 psf	-4.8 psf
23 ft	0.65	25.4 psf	17.3 psf		26.6 psf					4.8 psf	
27 ft	0.68	26.5 psf	18.0 psf		27.3 psf		Max:	Max:	Max:	4.8 psf	
31 ft	0.71	27.6 psf	18.7 psf		28.1 psf		-4.1 psf	-4.1 psf	-4.1 psf	4.8 psf	
35 ft	0.73	28.5 psf	19.4 psf		28.7 psf					4.8 psf	
38 ft	0.75	29.4 psf	20.0 psf		29.3 psf					4.8 psf	

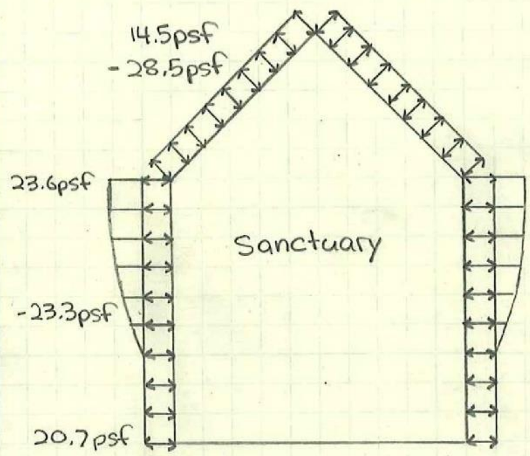


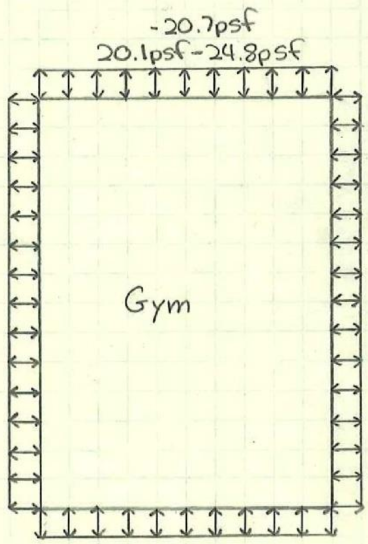
Internal pressure ranges from -5.4psf to 5.4psf (sanctuary) and from -4.8psf to 4.8psf (gym)

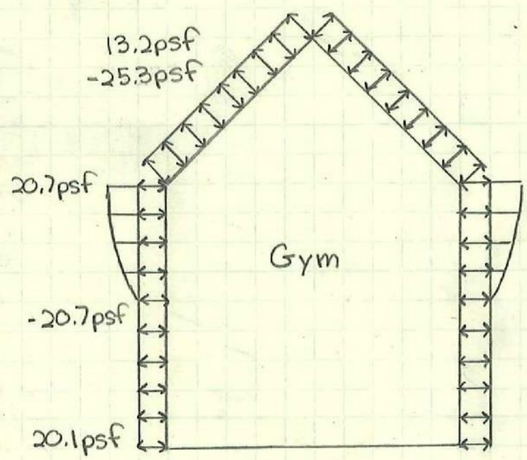
∴ For sanctuary, add/subtract 5.4psf to all values

∴ For gym, add/subtract 4.8psf to all values


Sanctuary
20.7psf - 27.7psf
-23.3psf


14.5psf
-28.5psf
23.6psf
Sanctuary
-23.3psf
20.7psf


-20.7psf
20.1psf - 24.8psf
Gym


13.2psf
-25.3psf
20.7psf
Gym
-20.7psf
20.1psf

$DL = 44.4 psf$
$SL = 24.5 psf$
$LL = 20 psf$ or $300 lb$
} acting vertically

$\sin 45° (DL, SL, LL) = F_\perp$
$DL = 31.40 psf$
$SL = 17.32 psf$
$LL = 14.14 psf$ or $212.13 lb$
} acting normal

$WL = 14.5 psf, -28.5 psf$ } acting normal to the roof

Governing Load Combinations (see excel spreadsheet)

① $50.915 psf + 0 lb$ $(D + 0.75L + 0.75(0.6W) + 0.75S)$

② $37.925 psf + 159.10 lb$ $(D + 0.75L + 0.75(0.6W) + 0.75L_r)$

③ $31.4 psf + 212.13 lb$ $(D + L_r)$

① $M_{max} = 9.56 lb\text{-}ft = 114.77 lb\text{-}in$
$\delta_{max} = 0 in$ - negligible

② $M_{max} = 47.2 lb\text{-}ft = 566.82 lb\text{-}in$
$\delta_{max} = 0.005 in$

③ $M_{max} = 60.5 lb\text{-}ft = 726.25 lb\text{-}in \rightarrow$ governs
$\delta_{max} = 0.006 in \rightarrow$ governs

$C_D = 1.25$ (for L_r)
$C_t = 1.0$ $(T \leq 100°F)$ (NDS 2.3.3)
$C_L = 1.0$ $(d \leq b)$ (NDS 3.3.3)

$C_F = 1.10$ $(b \leq 2 in)$ (NDS 4E)
$C_M = 1.0$ $(M \leq 19\%)$ (NDS 4E)
$C_{fu} = 1.0$ (incorporated) (NDS 4E)

$C_i = 1.0$ (no incising)
$C_r = 1.0$ (incorporated) (NDS 4E)

width $(b) = 12 in$ depth $(d) = 1.125 in$ length $(L) = 96 in$ (assumed)

$F_b' = 1787 psi$ $f_b = 287 psi$ $FS = 6.23$

$\delta_{allow} = 0.27 in$ $\delta = 0.006 in$ $FS = 45$

$F_{c\perp}' = 425 psi$ $f_{c\perp} = 15.93 psi$ $FS = 27$

DL = 44.4psf + 2.84plf, SL = 24.5psf, Lr = 20psf or 300lb (acting vertically)

with 16in spacing,

DL = 62.04plf
SL = 32.67plf
Lr = 26.67plf or 300lb
WL = 13.67plf, -26.87plf ↓
WL = 13.67plf, -26.87plf →

WL = 14.5psf, -28.5psf } acting normal
WL = 10.253psf, -20.15psf } vertical
WL = 10.253psf, -20.15psf } horizontal

Governing load combinations

① 94.71plf + 0lb (D+S)
② 92.69plf (vertical) + 6.15plf (horizontal) (D+0.75L+0.75(0.6W)+0.75S)
③ 68.19plf + 225lb (vertical) + 6.15plf (horizontal) (D+0.75L+0.75(0.6W)+0.75Lr)
④ 62.04plf + 300lb (vertical) (D+Lr)

① M_{max} = 789.51 lb-ft = 9474.12 lb-in
V_{max} = 325.19 lb
δ_{max} = 0.112in

② M_{max} = 823.93 lb-ft = 9887.16 lb-in
V_{max} = 339.37lb
δ_{max} = 0.117in

③ M_{max} = 1005.95lb-ft = 12071.34 lb-in
V_{max} = 334.79 lb
δ_{max} = 0.132in

④ M_{max} = 1032.16 lb-ft = 12,385.92lb-in
V_{max} = 319.07lb
δ_{max} = 0.132in

C_D = 1.25 C_F = 1.2 (for b = 2in, d = 8in) (NDS 4A) C_i = 1.0
C_t = 1.0 C_r = 1.15 (for rafters) (NDS 4.3.9)
C_L = 1.0 CM = 1.0
C_{fu} = 1.0

width (b) = 2in depth(d) = 8in length (L) = 116.54in

F_b' = 1509psi f_b = 581psi FS = 2.6

δ_{allow} = 0.32in δ = 0.13in FS = 2.5

F_v' = 168.8psi f_v = 31.8psi FS = 5.3

D+Lr from center rafter = 601.2 lb + 100 lb
Load from all other rafters = 301.2 lb
} case ① assuming D+Lr is worst case

D+S from center rafter = 459.9 lb + 100 lb
Load from all other rafters = 459.9 lb
} case ② assuming D+S is worst case

Center rafter load = 450.1 lb + 100 lb↓ + 29.9 lb→
All other rafters = 450.1 lb↓ + 29.9 lb→
} case ③ assuming $D+0.75L+0.75(0.6W)+0.75S$

Center rafter load = 556.1 lb + 100 lb↓ + 29.9 lb→
All other rafters = 331.1 lb↓ + 29.9 lb→
} case ④ assuming $D+0.75L+0.75(0.6W)+0.75L_r$

Additional sheathing dead load = 1.638 psf → 15.90 plf (9.71 ft spacing)
Self weight dead load = 14.21 plf
Due to 45° angle, $F_\perp = \sin 45°(D, L_r, S, W)$

① (center = 495.8 lb) + (All other = 213.0 lb) + (21.29 plf)
② (center = 395.9 lb) + (All other = 325.2 lb) + (21.29 plf)
③ (center = 410.1 lb) + (All other = 339.4 lb) + (21.29 plf)
④ (center = 485.1 lb) + (All other = 255.3 lb) + (21.29 plf)

---

① M_{max} = 6357.4 lb-ft = 76289 lb-in
V_{max} = 1591.5 lb
δ_{max} = 0.276 in

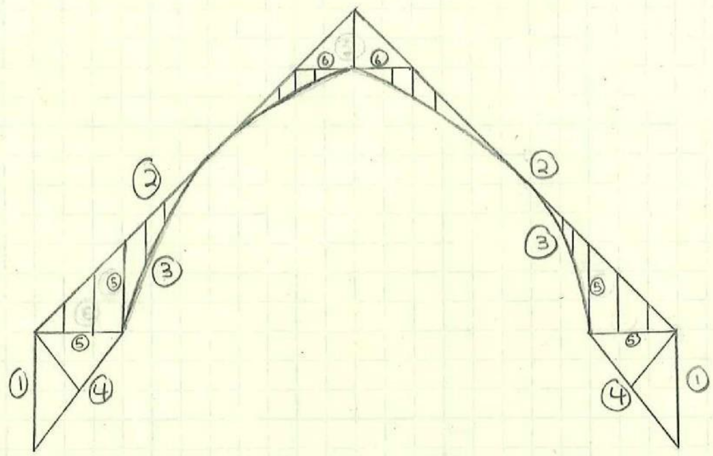
② M_{max} = 8011.3 lb-ft = 96136 lb-in
V_{max} = 2148.2 lb
δ_{max} = 0.360 in

③ M_{max} = 8322.4 lb-ft = 99869 lb-in
V_{max} = 2233.2 lb
δ_{max} = 0.374 in
} governing load combination $D+0.75L+0.75(0.6W)+0.75S$

④ M_{max} = 7083.2 lb-ft = 84998 lb-in
V_{max} = 1816.0 lb
δ_{max} = 0.313 in

F_b' = 1656 psi f_b = 749.0 psi FS = 2.21
F_v' = 216 psi f_v = 41.87 psi FS = 5.16
δ_{allow} = 0.51 in δ = 0.374 in FS = 1.36

C_D = 1.6 (wind) C_L = 1.0
C_M = 1.0 C_F = 1.0 (4D)
C_t = 1.0 C_{fu} = 1.0 (4D)
C_i = 1.0 C_r = 1.15



remaining members are assumed 6x6

All members are spruce ⇒ E = 1400000 psi

① 6in × 11in ② 10in × 14in ③ 8in × 10in ④ 7in × 11in ⑤ 9in × 12in ⑥ 10in × 10in

① $C_D = 1.6$ $C_M = 1.0$ $C_t = 1.0$ $C_F = 1.0$ $C_{fu} = 1.0$ $C_i = 1.0$ $C_r = 1.0$ $C_L = 0.99$

② $C_D = 1.6$ $C_M = 1.0$ $C_t = 1.0$ $C_F = 0.98$ $C_{fu} = 1.0$ $C_i = 1.0$ $C_r = 1.0$ $C_L = 0.99$

$C_F = (12/d)^{1/9} = 0.98$ (for d > 12in) (Table 4D)

③ $C_D = 1.6$ $C_M = 1.0$ $C_t = 1.0$ $C_F = 1.0$ $C_{fu} = 1.0$ $C_i = 1.0$ $C_r = 1.0$ $C_L = 0.99$

④ $C_D = 1.6$ $C_M = 1.0$ $C_t = 1.0$ $C_F = 1.0$ $C_{fu} = 1.0$ $C_i = 1.0$ $C_r = 1.0$ $C_L = 0.99$

⑤ $C_D = 1.6$ $C_M = 1.0$ $C_t = 1.0$ $C_F = 1.0$ $C_{fu} = 1.0$ $C_i = 1.0$ $C_r = 1.0$ $C_L = 0.99$

⑥ $C_D = 1.6$ $C_M = 1.0$ $C_t = 1.0$ $C_F = 1.0$ $C_{fu} = 1.0$ $C_i = 1.0$ $C_r = 1.0$ $C_L = 0.99$

for ② Two equal concentrated loads at 1/3 points with lateral support at 1/3 points $\ell_e = 1.68\,\ell_u$ where $\ell_u = 29.13\text{ft}$

$\ell_e = 1.68\,\ell_u = 1.68(29.13\text{ft}) = 48.94\text{ft}$

slenderness ratio $R_B = \sqrt{\dfrac{\ell_e d}{b^2}} = \sqrt{\dfrac{(48.94\text{ft})(12\text{in/ft})(14\text{in})}{(10\text{in})^2}} = 9.07$

$F_{bE} = \dfrac{1.2E_{min}}{R_B^2} = \dfrac{1.2(510{,}000\text{psi})}{9.07^2} = 7439\text{psi}$ $\quad F_b^* = 900\text{psi}(1.6)(0.98) = 1411.2\text{psi}$

$C_L = \dfrac{1+(F_{bE}/F_b^*)}{1.9} - \sqrt{\left(\dfrac{1+(F_{bE}/F_b^*)}{1.9}\right)^2 - \dfrac{F_{bE}/F_b^*}{0.95}} = 3.3 - 2.31 = 0.99$

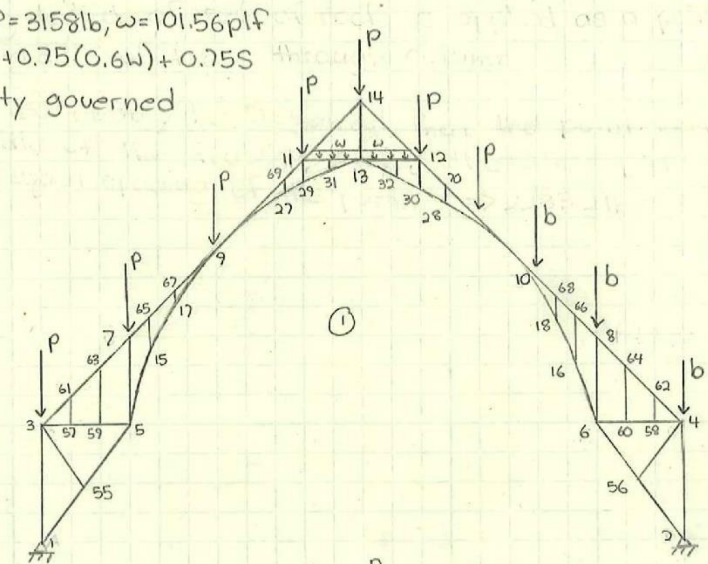
case ① carry over purlins → truss = 3158 lb

Sheathing DL or horizontal section of truss = 1.638psf → 25.06plf (15.3ft space)

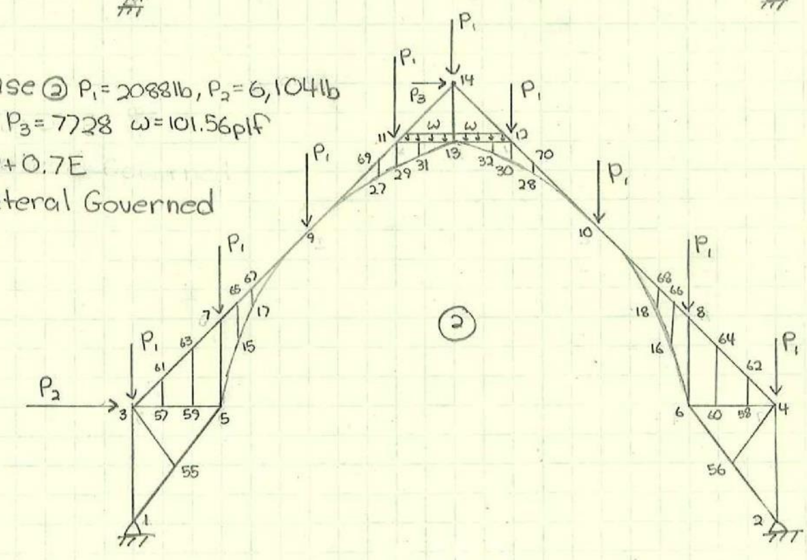
MEP DL on horizontal section of truss = 5psf → 76.5plf

self weight ① 11.72plf ② 24.87plf ③ 14.21plf ④ 13.68plf ⑤ 19.19plf ⑥ 17.76plf

case ① P = 3158 lb, ω = 101.56 plf
D + 0.75L + 0.75(0.6W) + 0.75S
Gravity governed



case ② P_1 = 2088 lb, P_2 = 6,104 lb
P_3 = 7728 ω = 101.56 plf
D + 0.7E
Lateral Governed

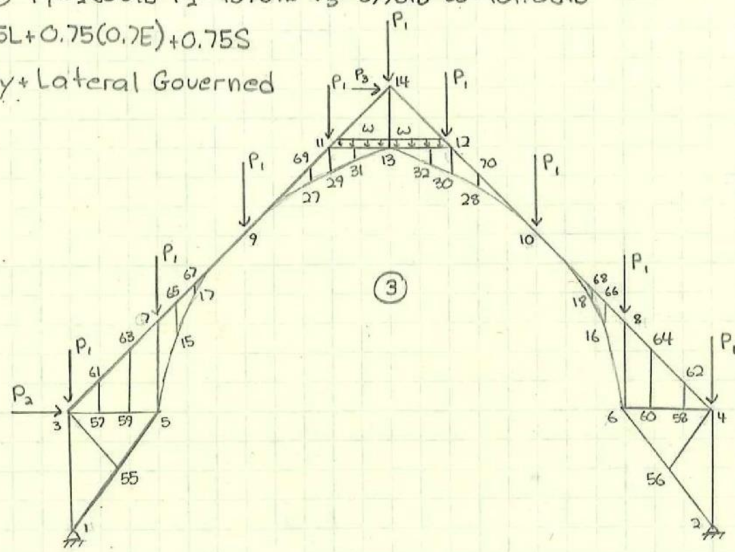


case ② carry over load rafters → purlins = 301.2 lb
case ② carry over load purlins → truss = 2088 lb

Case ③ $P_1 = 2800 lb$ $P_2 = 4578 lb$ $P_3 = 5796 lb$ $\omega = 101.56 lb$

D+0.75L+0.75(0.7E)+0.75S

Gravity + Lateral Governed



case ③ carry over load rafters → purlins = 420.2 lb
case ③ carry over load purlins → truss = 2800 lb

① Greatest axial stress = 150 psi (members 7 and 10)
② Greatest axial stress = 323 psi (member 72), -265 psi (member 59)
③ Greatest axial stress = 282 psi (member 72), -160 psi (member 59)

① Greatest shear stress = 18.9 psi (members 33 and 36, joints 7 and 8)
② Greatest shear stress = 98.8 psi (member 36, joint 8)
③ Greatest shear stress = 81.0 psi (member 36, joint 8)

① Greatest bending stress = 169 psi (members 34 and 37)
② Greatest bending stress = 1103 psi (member 35)
③ Greatest bending stress = 865 psi (member 38)

$F_t' = 960 psi$ $f_t = 323 psi$ $FS = 2.97$
$F_v' = 216 psi$ $f_v = 98.8 psi$ $FS = 2.19$
$F_b' = 1397 psi$ $f_b = 1103 psi$ $FS = 1.27$

$\delta_{allow} \approx 1.7 in$ $\delta_{max} \approx 2.3 in$ (seismic)
$\delta_{max} \approx 0.1 in$ (gravity)

∴ During a seismic event, potential displacement can cause ceiling damage

Loads

Dead load = 3psf + 2.4psf = 5.4psf
Self weight dead load = 4.263plf
LL = 60 psf or 300lb

16 in spacing
15ft 5in length

Governing load combinations

① 65.4psf (not including self weight) (D + $L_{uniform}$)
② 5.4psf + 300lb (not including self weight) (D + $L_{concentrated}$)

① $65.4psf(16in)(\frac{1}{12}ft/in) + 4.263plf = 91.46\ plf$
② $5.4psf(16in)(\frac{1}{12}ft/in) + 4.263plf + 300lb = 11.5plf + 300lb$

① $M_{max} = \frac{\omega L^2}{8} = \frac{(91.46plf)(15\frac{5}{12}ft)^2}{8} = 2717\ lb\text{-}ft = 32{,}606\ lb\text{-}in$

$V_{max} = \frac{\omega L}{2} = \frac{(91.46plf)(15\frac{5}{12}ft)}{2} = 705\ lb$

$\delta_{max} = \frac{5\omega L^4}{384EI} = \frac{5(91.46plf)(\frac{1}{12}ft/in)((15\frac{5}{12}ft)(12in/ft))^4}{384(1400000psi)(288in^4)} = 0.288in$

② $M_{max} = 1498\ lb\text{-}ft = 17{,}976\ lb\text{-}in$

$V_{max} = 239\ lb$

$\delta_{max} = 0.134in$

Scenario ① will govern

$C_D = 1.0$ (live) $C_F = 1.0$
$C_n = 1.0$ $C_{fu} = 1.0$
$C_t = 1.0$ $C_i = 1.0$
$C_L = 1.0$ $C_r = 1.15$

$F'_b = 1006.25psi$ $f_b = 679.29psi$ FS = 1.48
$F'_v = 135.00psi$ $f_v = 44.06psi$ FS = 3.06
$\delta_{allow} = 0.51in$ $\delta = 0.29in$

∴ joists are adequate

Floor Analysis	Sanctuary	Girder	26

Loads

Deadload + liveload = $\underbrace{705\text{lb (spaced 16in)}}_{\text{carry over from joists}} + \underbrace{10\text{psf}}_{\text{MEP}} + \underbrace{17.05\text{plf}}_{\text{self weight}}$

Load combination

$D+L = 10\text{psf}\underbrace{(15^{5}/_{12}\text{ft})}_{\text{girder spacing}} + 17.05\text{plf} + 705\text{lb (spaced 16in)} = 171\text{ plf} + 705\text{lb}$

$M_{max} = 15355.8$ lb-ft $= 184{,}267$ lb-in

$V_{max} = 5000$lb

$\delta_{max} = 0.299$in

$F_b' = 1035$psi $f_b = 960$psi FS = 1.08

$F_v' = 135$psi $f_v = 78.1$psi FS = 1.73

$\delta_{allow} = 0.442$in $\delta = 0.299$in

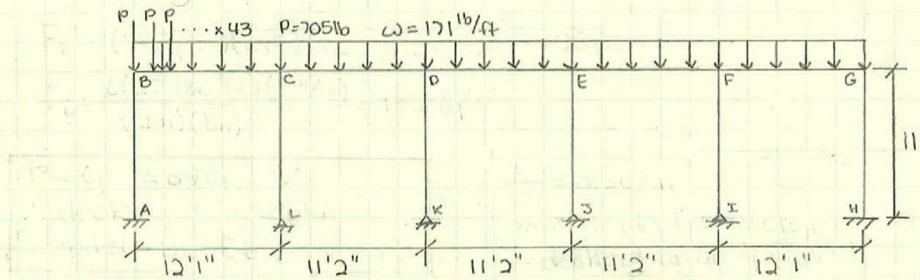
$C_D = 1.0$ $C_F = 1.0$

$C_M = 1.0$ $C_{fu} = 1.0$

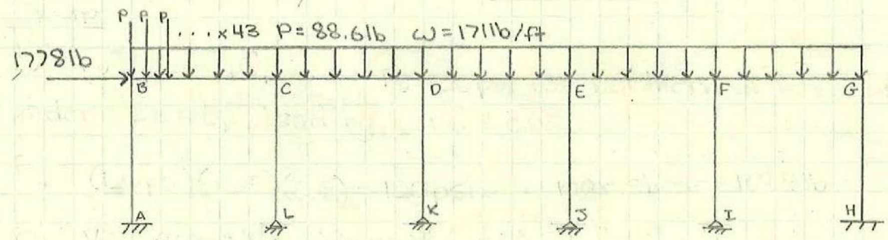
$C_t = 1.0$ $C_i = 1.0$

$C_L = 1.0$ $C_r = 1.15$

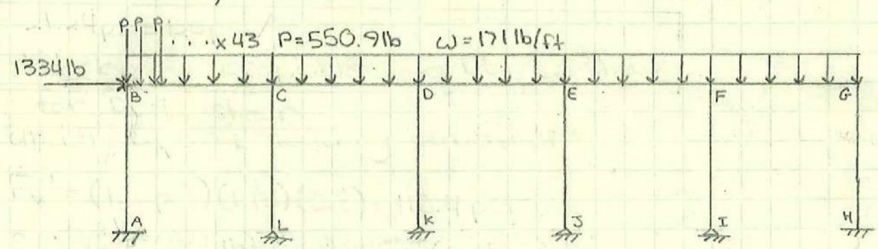
Case ① Gravity Only D+L



Case ② Seismic D+0.7E



Case ③ Gravity + Lateral D+0.75L+0.75(0.7E)+0.75S



case ① H_A=710.5 lb→ M_A=1175 lb-ft ↺ V_A=4600 lb↑
Max lally = 8071 lb compression

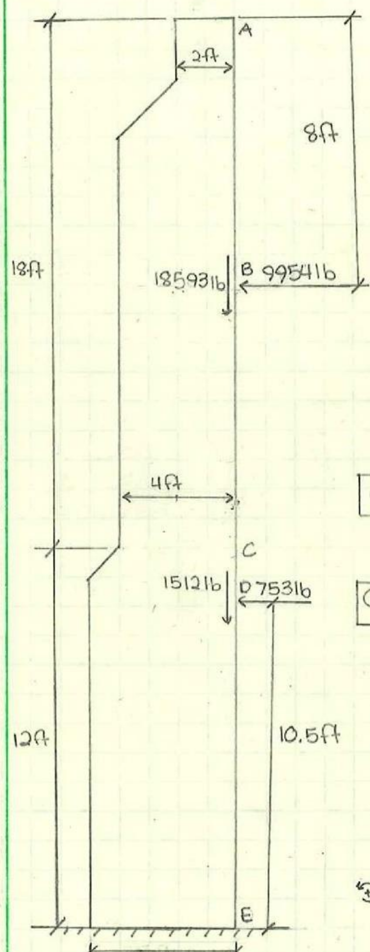
Both buttresses experience same force

case ② H_A=1025 lb← M_A=14,170 lb-ft ↺ V_A=14871 lb↑
H_H=753 lb← M_H=5163 lb-ft ↺ V_H=15121 lb↑
Max lally = 2761 lb compression

case ③ H_A=357 lb← M_A=11,314 lb-ft ↺ V_A=3811 lb↑
H_H=977 lb← M_H=3194 lb-ft ↺ V_H=3835 lb↑
Max lally = 6755 lb compression

Pure granite $= 169\ ^{lb}/_{ft^3}$

Assume weight $\approx 150\ ^{lb}/_{ft^3}$ with mortar and voids



weight above point C

$(150\ ^{lb}/_{ft^3})(2ft)(2ft)(2ft) + (150\ ^{lb}/_{ft^3})(\frac{1}{2})(2ft)(4ft+2ft)(2ft) + (150\ ^{lb}/_{ft^3})(14ft)(4ft)(2ft)$

$= 1200lb + 1800lb + 16800lb = 19800lb$

$P_{total} = 19800lb + 18{,}593lb = 38{,}393\ lb$

$\circlearrowleft @C,\ M_o = (9954lb)(10ft) - (18593\ lb)(2ft) - (1200lb)(1ft) - (1800lb)(0.5ft)$

$M_o = 60254\ lb\text{-}ft$

$\sigma_{tension} = \frac{P}{A} - \frac{6M_o}{BL^2} = \frac{38{,}393lb}{(2ft)(4ft)} - \frac{6(60{,}254lb\text{-}ft)}{(2ft)(4ft)^2}$

$\boxed{@C\ \sigma_{tension} = 6499\ psf = 45.1\ psi}$

$\sigma_{compression} = \frac{P}{A} + \frac{6M_o}{BL^2} = \frac{38{,}393lb}{(2ft)(4ft)} + \frac{6(60{,}254lb\text{-}ft)}{(2ft)(4ft)^2}$

$\boxed{@C\ \sigma_{compression} = 16{,}097\ psf = 112\ psi}$

Above is based on worst case seismic event

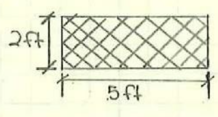
Weight above point E

$(19800lb) + (150\ ^{lb}/_{ft^3})(1ft)(4ft+5ft)(\frac{1}{2})(2ft) + (150\ ^{lb}/_{ft^3})(5ft)(11ft)(2ft)$

$= 19800lb + 1350\ lb + 16500lb = 37650lb$

$P_{total} = 37650lb + 18593lb + 1512lb = 57{,}755\ lb$

$\circlearrowleft M_o = (9954lb)(22ft) + (753lb)(10.5ft) - (18593lb)(2.5ft) - (1512lb)(2.5ft) - (1200lb)(1.5ft) - (1800lb)(1ft) - (16800lb)(0.5ft) - (1350lb)(0.25ft) = 164{,}295\ lb\text{-}ft$

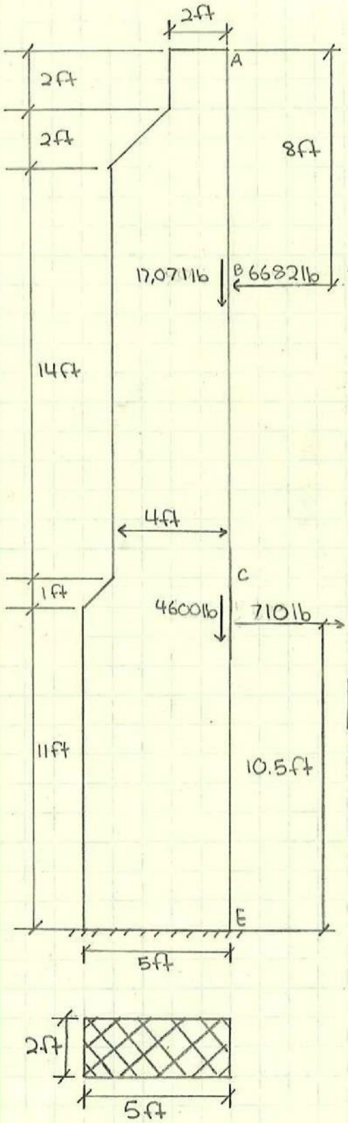


$\sigma_{tension} = \frac{P}{A} - \frac{6M_o}{BL^2} = \frac{57755lb}{(2ft)(5ft)} - \frac{6(164{,}295\ lb\text{-}ft)}{(2ft)(5ft)^2}$

$\boxed{@E\ \sigma_{tension} = 13{,}940\ psf = 96.8\ psi}$

$\sigma_{compression} = \frac{P}{A} + \frac{6M_o}{BL^2} = \frac{57755\ lb}{(2ft)(5ft)} + \frac{6(164{,}295\ lb\text{-}ft)}{(2ft)(5ft)^2}$

$\boxed{@E\ \sigma_{compression} = 25{,}491\ psf = 177\ psi}$



weight above point C = 19800lb

$P_{total} = 19800lb + 17044lb = 36844lb$

$\circlearrowleft M_o = (6602lb)(10ft) - (17044lb)(2ft) - (1200lb)(1ft) - (1800lb)(0.5ft) = 29832\,lb\text{-}ft$

$\sigma_{tension} = \frac{P}{A} - \frac{6M_o}{BL^2} = \frac{36844lb}{(2ft)(4ft)} - \frac{6(29832lb\text{-}ft)}{(2ft)(4ft)^2}$

$\boxed{@C,\ \sigma_{tension} = 988psf = 6.86psi}$

$\sigma_{compression} = \frac{P}{A} + \frac{6M_o}{BL^2} = \frac{36844lb}{(2ft)(4ft)} + \frac{6(29832lb\text{-}ft)}{(2ft)(4ft)^2}$

$\boxed{@C,\ \sigma_{compression} = 10,199psf = 70.83psi}$

Weight above point E = 37650lb

$P_{total} = 37650lb + 17,071lb + 4600lb = 59320lb$

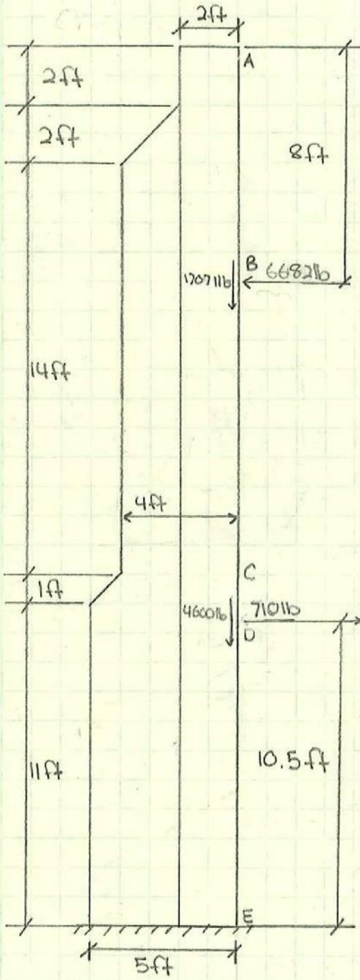
$\circlearrowleft M_o = 6682lb(22ft) - (710lb)(10.5ft) - (17,071lb)(2.5ft) - (4600lb)(2.5ft) - (1200lb)(1.5ft) - (1800lb)(1ft) - (16800lb)(0.5ft) - (1350lb)(0.25ft) = 73015\,lb\text{-}ft$

$\sigma_{tension} = \frac{P}{A} - \frac{6M_o}{BL^2} = \frac{59320lb}{(2ft)(5ft)} - \frac{6(73015lb\text{-}ft)}{(2ft)(5ft)^2}$

$\boxed{@E,\ \sigma_{tension} = 2830psf = 19.65psi}$

$\sigma_{compression} = \frac{P}{A} + \frac{6M_o}{BL^2} = \frac{59320lb}{(2ft)(5ft)} + \frac{6(73015lb\text{-}ft)}{(2ft)(5ft)^2}$

$\boxed{@E,\ \sigma_{compression} = 14,694psf = 102.04psi}$



$$\bar{x} = \frac{(2ft)(3ft)(1.5ft) + (2ft)(7.5ft)(4ft)}{(2ft)(3ft) + (2ft)(7.5ft)} = 3.286ft$$

$$I_x = \frac{(2ft)(3ft)^3}{12} + (2ft)(3ft)(3.286ft - 1.5ft)^2$$

$$+ \frac{(7.5ft)(2ft)^3}{12} + (2ft)(7.5ft)(4ft - 3.286ft)^2$$

$$I_x = 4.5ft^4 + 19.14ft^4 + 5ft^4 + 7.65ft^4 = 36.29ft^4$$

Above based on 3ft × 2ft buttress

Below based on 2ft × 2ft buttress

$$\bar{x} = \frac{(2ft)(2ft)(1ft) + (2ft)(7.5ft)(3ft)}{(2ft)(2ft) + (2ft)(7.5ft)} = 2.579ft$$

$$I_x = \frac{(2ft)(2ft)^3}{12} + (2ft)(2ft)(2.579ft - 1ft)^2$$

$$+ \frac{(7.5ft)(2ft)^3}{12} + (2ft)(7.5ft)(3ft - 2.579ft)^2$$

$$I_x = 1.33ft^4 + 9.97ft^4 + 5ft^4 + 2.66ft^4 = 18.96ft^4$$

Weight above point C = 19800lb

$+ (150pcf)(5.5ft)(2ft)(18ft) = 19800lb + 29700lb$

$= 49500lb$

$P_{total} = 49500lb + 17071lb = 66571lb$

$\circlearrowright M_o = (66821lb)(10ft) - (17071lb)(4ft - 2.579ft)$

$-(1200lb)(3ft - 2.579ft) - (29{,}700lb)(3ft - 2.579ft)$

$+(1800lb)(0.079ft) + (16800lb)(0.579ft)$

$M_o = 394231b\text{-}ft$

$$\sigma_{tension} = \frac{P}{A} - \frac{M_o c}{I} = \frac{66571lb}{19ft^2} - \frac{(39423lb\text{-}ft)(4ft - 2.579ft)}{18.96ft^4}$$

$\sigma_{tension} = -549\ psf$ ∴ no tension above point C

Weight above point E = 37650lb

$+(150pcf)(5.5ft)(2ft)(30ft) = 37650lb + 49500lb$

$= 87150lb$

$P_{total} = 87150lb + 17071lb + 4600lb = 108821lb$

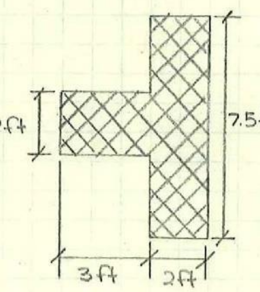
$\circlearrowright M_o = (66821lb)(22ft) - (7101lb)(10.5ft) - (49500lb)$

$(4ft - 3.286ft) - (17071lb + 4600lb)(1.714ft)$

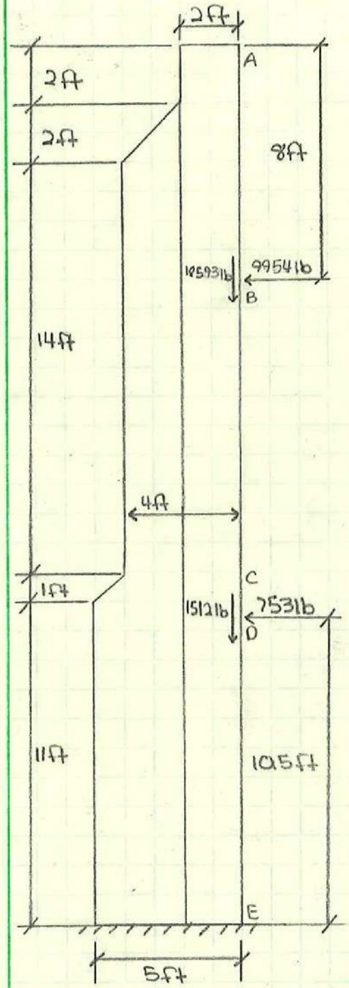
$-(1200lb)(0.714ft) - (1800lb)(0.214ft)$

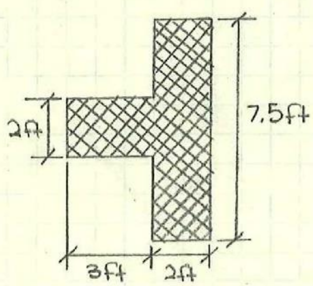
$+(16800lb)(0.286ft) + (1350lb)(0.536ft)$

$+(16500lb)(0.786ft) = 843171lb\text{-}ft$



$$\sigma_{tension} = \frac{P}{A} - \frac{M_o c}{I} = \frac{108821lb}{21ft^2} - \frac{(843171lb\text{-}ft)(5ft - 3.286ft)}{36.29ft^4} = -1200psf$$ ∴ no tension in buttress





2ft×2ft buttress : $\bar{x} = 2.579\,ft$ $I_x = 18.96\,ft^4$

3ft×2ft buttress : $\bar{x} = 3.286\,ft$ $I_x = 36.29\,ft^4$

weight above point C = 49,500 lb

$P_{total} = 49{,}500\,lb + 18593\,lb = 68093\,lb$

$\circlearrowright M_o = (9954\,lb)(10\,ft) - (18593\,lb)(1.421\,ft) - (1200\,lb)(0.421\,ft) - (29700\,lb)(0.421\,ft) + (1800\,lb)(0.079\,ft) + (16800\,lb)(0.579\,ft) = 69980\,lb\text{-}ft$

$$\sigma_{tension} = -\frac{P}{A} - \frac{M_o c}{I} = -\frac{68093\,lb}{19\,ft^2} - \frac{(69980\,lb\text{-}ft)(1.421\,ft)}{18.96\,ft^4}$$

$\boxed{\sigma_{tension} = 1661\,psf = 11.53\,psi}$

$\boxed{\sigma_{compression} = 13103\,psf = 90.99\,psi}$

Weight above point E = 87150 lb

$P_{total} = 87150\,lb + 18593\,lb + 1512\,lb = 107255\,lb$

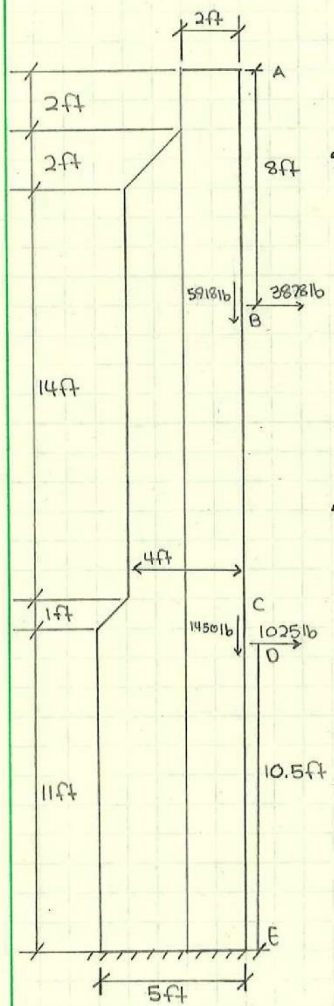
$\circlearrowright M_o = (9954\,lb)(22\,ft) + (753\,lb)(10.5\,ft) - (49500\,lb)(0.714\,ft) - (18593\,lb + 1512\,lb)(1.714\,ft) - (1200\,lb)(0.714\,ft) - (1800\,lb)(0.214\,ft) + (16800\,lb)(0.286\,ft) + (1350\,lb)(0.536\,ft) + (16500\,lb)(0.786\,ft)$

$M_o = 174347\,lb\text{-}ft$

$$\sigma_{tension} = -\frac{P}{A} - \frac{M_o c}{I} = -\frac{107255\,lb}{21\,ft^2} - \frac{(174347\,lb\text{-}ft)(1.714\,ft)}{36.29\,ft^4}$$

$\boxed{\sigma_{tension} = 3127\,psf = 21.72\,psi}$

$\boxed{\sigma_{compression} = 20894\,psf = 145.10\,psi}$



$2ft \times 2ft$ buttress: $\bar{x} = 2.579ft$ $I_x = 18.96ft^4$

$3ft \times 2ft$ buttress: $\bar{x} = 3.286ft$ $I_x = 36.29ft^4$

weight above point C = 49500lb

$P_{total} = 49500lb + 5918lb = 55418lb$

$\circlearrowright M_o = (3878lb)(10ft) + (5918lb)(1.421ft) + (29700lb)(0.421ft) - (1800lb)(0.079ft) + (1200lb)(0.421ft) - (16800lb)(0.579ft)$

$M_o = 50329\ lb\text{-}ft$

$\sigma = \frac{P}{A} \pm \frac{M_o c}{I} = \frac{55418lb}{19ft^2} \pm \frac{(50329lb\text{-}ft)(2ft \pm 0.579ft)}{18.96ft^4}$

$\boxed{\sigma_{tension} = 3929psf = 27.29psi}$

$\boxed{\sigma_{compression} = 6689psf = 46.45psi}$

Weight above point E = 87150lb

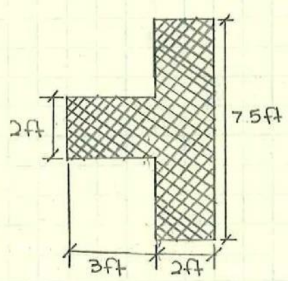
$P_{total} = 87150lb + 5918lb + 1450lb = 94518lb$

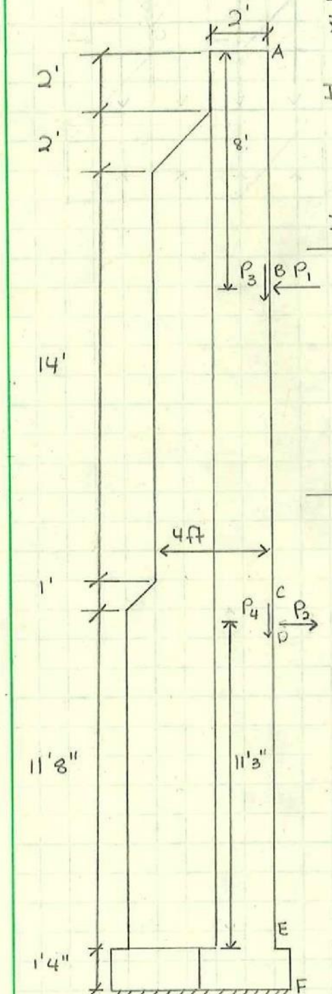
$\circlearrowright M_o = (3878lb)(22ft) + (1025lb)(10.5ft) + (5918lb)(1.714ft) + (1450lb)(1.714ft) + (49500lb)(0.714ft) + (1200lb)(0.714ft) + (1800lb)(0.214ft) - (16800lb)(0.286ft) - (1350lb)(0.536ft) - (16500lb)(0.786ft) = 126795\ lb\text{-}ft$

$\sigma = \frac{P}{A} \pm \frac{M_o c}{I} = \frac{94518lb}{21ft^2} \pm \frac{(126795lb\text{-}ft)(2.5ft \pm 0.786ft)}{36.29ft^4}$

$\boxed{\sigma_{tension} = 6980psf = 48.47psi}$

$\boxed{\sigma_{compression} = 10489psf = 72.84psi}$





Foundation center of mass

$$\bar{x} = \frac{(3ft)(3.0ft)(1.50ft)+(3ft)(7.5ft)(4.5ft)}{(3ft)(3.0ft)+(3ft)(7.5ft)} = \frac{114.75ft^3}{31.5ft^2} = 3.64ft$$

$$I_x = \frac{(3ft)(3.0ft)^3}{12} + (3ft)(3.0ft)(3.64ft-1.5ft)^2$$

$$+\frac{(7.5ft)(3ft)^3}{12} + (7.5ft)(3ft)(4.5ft-3.64ft)^2$$

$$I_x = 6.75ft^4 + 41.22ft^4 + 16.875ft^4 + 16.64ft^4 = 81.49ft^4$$

Weight above point F

$= (150pcf)(7.5ft)(2ft)(30.67ft) + (150pcf)\frac{1}{2}(2ft)(2ft)(2ft)$
$+ (150pcf)(2ft)(2ft)(14ft) + (150pcf)(2ft)(1ft)\frac{1}{2}(2ft+3ft)$
$+ (150pcf)(3ft)(11.67ft)(2ft) + (169pcf)(3ft)(7.5ft)(1.33ft)$
$+ (169pcf)(3ft)(3.0ft)(1.33ft) = 96341 lb$

$P_{total} = 96341lb + 17071lb + 4600lb = 118012 lb$

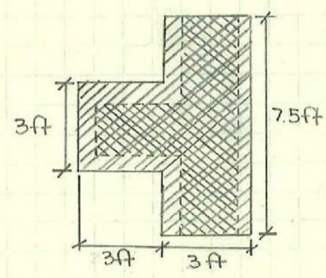
$\circlearrowright M_o = (6682lb)(24ft) - (710lb)(12.58ft) - (17071lb)(1.86ft)$
$- (4600lb)(1.86ft) - (69008lb)(0.86ft) - (5057lb)(0.86ft)$
$+ (603lb)(0.80ft) + (8400lb)(1.14ft) + (750lb)(1.39ft)$
$+ (10503lb)(1.64ft) + (2023lb)(2.14ft) = 80085 lb\text{-}ft$

$$\sigma_{tension} = \frac{P}{A} - \frac{M_o C}{I} = \frac{118012lb}{31.5ft^2} - \frac{(80085lb\text{-}ft)(2.36ft)}{81.49ft^4} = -1427 psf$$

∴ Entire footing acts on the soil (no tension)

$$\sigma_{compression} = \frac{P}{A} + \frac{M_o C}{I} = \frac{118012lb}{31.5ft^2} + \frac{(80085lb\text{-}ft)(3.64ft)}{81.49ft^4}$$

$= 7324psf = 50.86psi$



$P_1 = 6682lb$
$P_2 = 710lb$
$P_3 = 17071lb$
$P_4 = 4600lb$

$\bar{x} = 3.64ft \quad I_x = 81.49ft^4$

$P_{total} = 96341\,lb + 18593\,lb + 1512\,lb = 116446\,lb$

$\circlearrowleft M_o = (9954\,lb)(24ft) + (753\,lb)(12.58ft) - (18593\,lb)(1.86ft)$
$- (1512\,lb)(1.86ft) - (69008\,lb)(0.86ft) - (50571\,lb)(0.86ft)$
$+ (600\,lb)(0.80ft) + (8400\,lb)(1.14ft) + (750\,lb)(1.39ft)$
$+ (10503\,lb)(1.64ft) + (2023\,lb)(2.14ft) = 179930\,lb\text{-}ft$

$\sigma_{tension} = \frac{P}{A} - \frac{M_o c}{I} = \frac{116446\,lb}{31.5ft^2} - \frac{(179930\,lb\text{-}ft)(2.36ft)}{81.49ft^4}$

$= 1514\,psf = 10.52\,psi$

∴ Eccentricity is beyond kern distance

$\sigma_{compression} = \frac{P}{A} + \frac{M_o c}{I} = \frac{116446\,lb}{31.5ft^2} + \frac{(179930\,lb\text{-}ft)(3.64ft)}{81.49ft^4}$

$= 11734\,psf = 81.48\,psi$

∴ Effective width of foundation is 5.32 ft

$P_{total} = 96341\,lb + 5918\,lb + 1450\,lb = 103709\,lb$

$\circlearrowleft M_o = (3878\,lb)(24ft) + (1025\,lb)(12.58ft) + (5918\,lb)(1.86ft)$
$+ (1450\,lb)(1.86ft) + (69008\,lb)(0.86ft) + (50571\,lb)(0.86ft)$
$- (600\,lb)(0.80ft) - (8400\,lb)(1.14ft) - (750\,ft)(1.39ft)$
$- (10503\,lb)(1.64ft) - (2023\,lb)(2.14ft) = 150714\,lb\text{-}ft$

$\sigma_{tension} = \frac{P}{A} - \frac{M_o c}{I} = \frac{103709\,lb}{31.5ft^2} - \frac{(150714\,lb\text{-}ft)(3.64ft)}{81.49ft^4}$

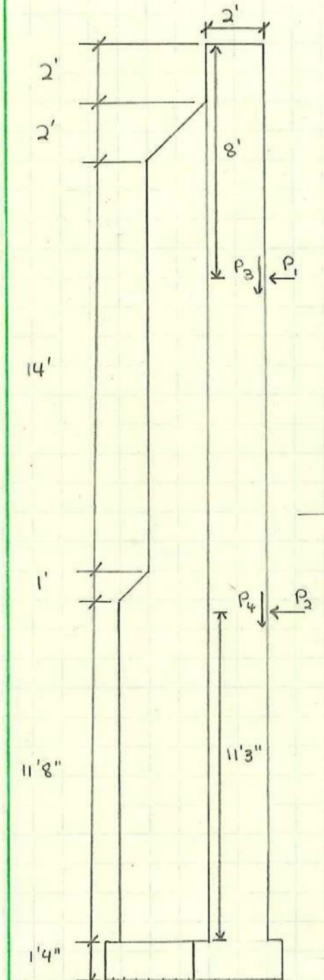
$= 3440\,psf = 23.89\,psi$

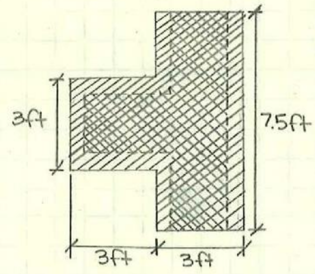
∴ Eccentricity is beyond kern distance

$\sigma_{compression} = \frac{P}{A} + \frac{M_o c}{I} = \frac{103709\,lb}{31.5ft^2} + \frac{(150714\,lb\text{-}ft)(2.36ft)}{81.49ft^4}$

$= 7652\,psf = 53.17\,psi$

∴ Effective width of foundation is 4.14ft





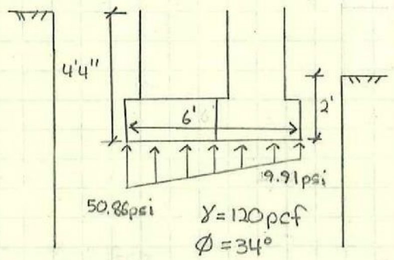
$P_1 = 9954\,lb$, $P_2 = 753\,lb$, $P_3 = 18593\,lb$, $P_4 = 1512\,lb$ } seismic case one

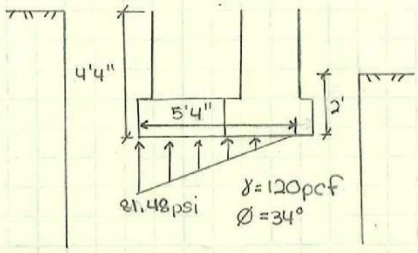
$P_1 = -3878\,lb$, $P_2 = -1025\,lb$, $P_3 = 5918\,lb$, $P_4 = 1450\,lb$ } seismic case two

① Gravity

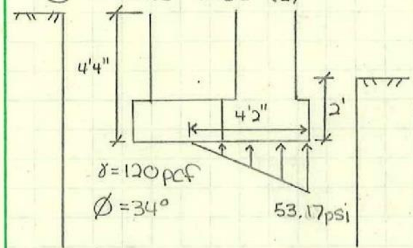
② Seismic Case (1)

Note: $D_w = 35ft$





③ Seismic Case (2)



① $\phi = 34° \rightarrow N_c = 52.6,\ N_q = 36.5,\ N_\gamma = 39.6$

$q_{ult} = c'N_c + \sigma'_D N_q + 0.5\gamma' B N_\gamma$

$q_{ult} = 0(52.6) + (120pcf)(2ft)(36.5) + 0.5(120pcf)(6ft)(39.6) = 23{,}016psf$

$q_{ult} = 159.83psi$

$\boxed{FS = 3.14}$

② $q_{ult} = c'N_c + \sigma'_D N_q + 0.5\gamma' B N_\gamma$

$q_{ult} = 0(52.6) + (120pcf)(2ft)(36.5) + 0.5(120pcf)(5.33ft)(39.6) = 21{,}424psf$

$q_{ult} = 148.78psi$ $\boxed{FS = 1.83}$

③ $q_{ult} = c'N_c + \sigma'_D N_q + 0.5\gamma' B N_\gamma$

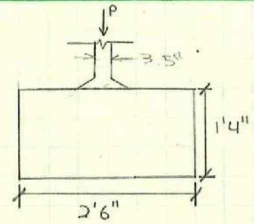
$q_{ult} = 0(52.6) + (120pcf)(4.33ft)(36.5) + 0.5(120pcf)(4.11ft)(39.6) = 28{,}731psf$

$q_{ult} = 199.52psi$ $\boxed{FS = 3.75}$

Use linear formulation to determine effective foundation widths for ② and ③

② $m = \dfrac{81.48psi + 10.52psi}{6ft} = 15.33\,psi/ft$ $\quad 0 = 15.33\,psi/ft\,(x) - 81.48\,psi$ $\quad x = 5.32ft = 5'4"$

③ $m = \dfrac{53.17psi + 23.89psi}{6ft} = 12.84\,psi/ft$ $\quad 0 = 12.84\,psi/ft\,(x) - 53.17\,psi$ $\quad x = 4.14ft = 4'2"$



Note: Plans called for bedstone footing
→ assume that bedstone refers to granite with $f'_g \approx 19000$ psi (19 ksi) and $f_y = 700$ psi ← tension
→ assume that granite has the same cleavage/failure mechanisms as concrete
→ ACI design provisions will be used

P = 8071 lb (see floor analysis - frame)
footing is square

$b_o = \pi(3.5in + 16in) = 61.26in$

$$V_g = \min \begin{Bmatrix} 4 \\ 2+\frac{4}{\beta} \\ \frac{\alpha_s d}{b_o}+2 \end{Bmatrix} \lambda \sqrt{f'_g}\, b_o d$$

$\beta = 1$ for square footings
$\alpha_s = 40$ for interior loaded columns
$d = 16$ inches
$\lambda = 1$ (refers to lightweight vs. normalweight conc.)

$V_g = 4(1)\sqrt{19000psi}\,(21.99in)(16in) = 194^k$

$\boxed{\phi V_g = 0.75V_g = 145^k}$

$V_u = q_u\left(b^2 - (\pi r^2)\right)$ $\quad b = 30in \quad q_u = \frac{P}{b^2} = 8.97$ psi $\quad r = \frac{16in+3.5in}{2} = 9.75in$

$V_u = 8.97psi\left((30in)^2 - \pi(9.75in)^2\right) = 5394\,lb = 5.4^k$

$\phi V_g \geq V_u \quad \boxed{145^k \geq 5.4^k}$ ✓ ∴ footing acceptable for two-way shear

$V_g(\text{1-way}) = 2\lambda\sqrt{f'_g}\,bd = 2(1)\sqrt{19000psi}\,(30in)(16in)\left(\frac{1^k}{1000lb}\right) = 132^k \quad \phi V_g = 99.2^k$

$V_u(\text{1-way}) = q_u\left(\frac{b}{2} - (d + r_{col})\right)b = (8.97psi)(15in - 17.75in)(30in) = -0.74^k$

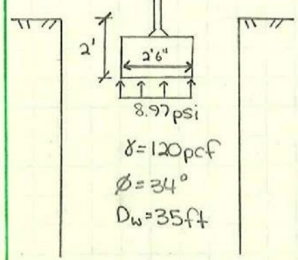
footing is too thick to experience one-way shear failure → critical section exists outside the footing

$M_u = q_u\left(\frac{1}{2}\right)\left(\frac{b}{2} - r_{col}\right)^2 b$

$M_u = (8.97psi)\left(\frac{1}{2}\right)\left(\frac{30in}{2} - 1.75in\right)^2(30in) = 23.6$ k-in

$\phi M_g = 0.9(700psi)\frac{1}{2}(8in)^2(30in) = 604.8$ k-in

$\phi M_g \geq M_u$ ∴ granite tensile yield strength is high enough to support column loads without reinforcement



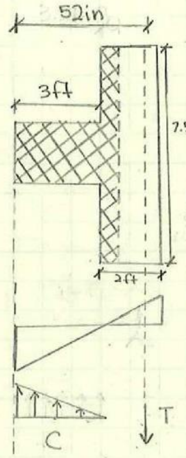
$\phi = 34° \rightarrow N_c = 52.6,\ N_q = 36.5,\ N_\gamma = 39.6$

$q_{ult} = 1.3c'N_c + \sigma'_D N_q + 0.4\gamma' B N_\gamma$

$q_{ult} = 1.3(0)(52.6) + (120\,pcf)(2ft)(36.5)$
$+ 0.4(120\,pcf)(2.5ft)(39.6) = 13512\,psf = 93.83\,psi$

$\boxed{FS = 10.46}$

According to National Concrete Masonry Association (NCMA), normal type portland cement mortar used in brick masonry found on the interior of the wall has an allowable tensile stress normal to the bed joints of 30psi which is greater than the ultimate tensile stress of 21.72psi. Theoretically, no reinforcement is needed, but due to possible poor conditions of the masonry due to moisture and neglect, lets assume the brick masonry is beyond the modulus of rupture and cracking occurs.



$f'_m = 1500psi$ (NCMA) - conservative for granite masonry

using ASD, $f_m = 0.45 f'_m = 675psi$

- ensures behavior of buttress is elastic (stage 2)

$E_m = 900 f'_m$ (NCMA) $= 1,350,000 psi$

$\varepsilon_{m,max} = \frac{f_m}{E_m} = \frac{675psi}{1350000psi} = 0.0005$

$F_s = 24,000 psi$ (NCMA for grade 60 steel)

$E_s = 29,000,000 psi$ (AISC)

$\varepsilon_s = \frac{F_s}{E_s} = \frac{24000psi}{29000000psi} = 0.000828$

P=107255 lb (total load on buttress at point E on page 32)

$d \geq 52$ in from left end

buttress width = 2ft (24in) wall length permitted due to shear lag = 7.5ft

buttress depth = 3ft (36 in) wall depth = 2ft (24in)

Choose $A_{st} = 1in^2 \Rightarrow T = F_s A_s = 24,000psi(1in^2) = 24,000 lb$

$C = P + T = 107,255 lb + 24,000 lb = 131,255 lb$

Through iteration, neutral axis determined to be 18.193in from left end

$\frac{\varepsilon_s}{d - 18.193in} = \frac{\varepsilon_m}{18.193in} = \frac{0.000828}{33.807in}$ $\varepsilon_m = 0.00045 \leq 0.0005$ ✓

∴ For $1in^2$ steel, steel will yield before masonry

$F_m = E_m \varepsilon_m = 1350000psi(0.00045) = 601.22psi \leq 675psi$ ✓

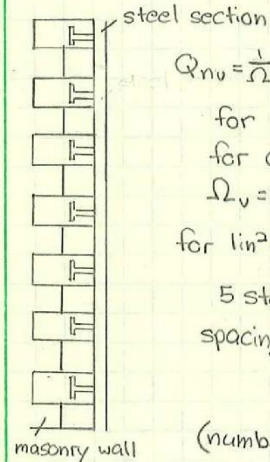
$C = \frac{1}{2}(18.193in)(24in)(601.22psi) = 131,255 lb$ ✓

$M_n = C\left(d - \frac{18.193in}{3}\right) = 131255lb\left(52in - \frac{18.193in}{3}\right) = 6029296$ lb-in $= 502441$ lb-ft

$M_u = 174347$ lb-ft ≤ 502441 lb-ft ✓

$1in^2$ steel is adequate for reinforcement. Infact, any amount of steel is adequate with d=52in. Steel is theoretically not needed for strength purposes, as masonry is capable of supporting extra compression loads due to eccentricity. Consequently, the purpose of the reinforcement is to keep cracking from propagating through the buttress.

One way to reinforce the interior masonry without major construction is to install a thin section of steel to the exterior of the brick face along the height of the wall (from the truss to floor) using sheer studs or steel anchors to create composite action.



(AISC - section I8.3a)

$$Q_{nv} = \frac{1}{\Omega_v} F_u A_{sa} = \frac{1}{2.31}(60ksi)(0.196\,in^2) = 5.09\,k/stud$$

for grade 60 steel, $F_u = 60ksi$

for 0.5" diameter studs, $A_{sa} = 0.196\,in^2$

$\Omega_v = 2.31$ for ASD

for $1in^2$ steel section, number of studs $= \frac{A_s F_s}{Q_{nv}} = \frac{1in^2(24000psi)}{5090\,lb/stud}$

5 studs are needed for full composite action

$$spacing = \frac{22ft\,(12^{in}/ft)}{5+1\ studs} \leq 36\,inches \quad (I8.2d)$$

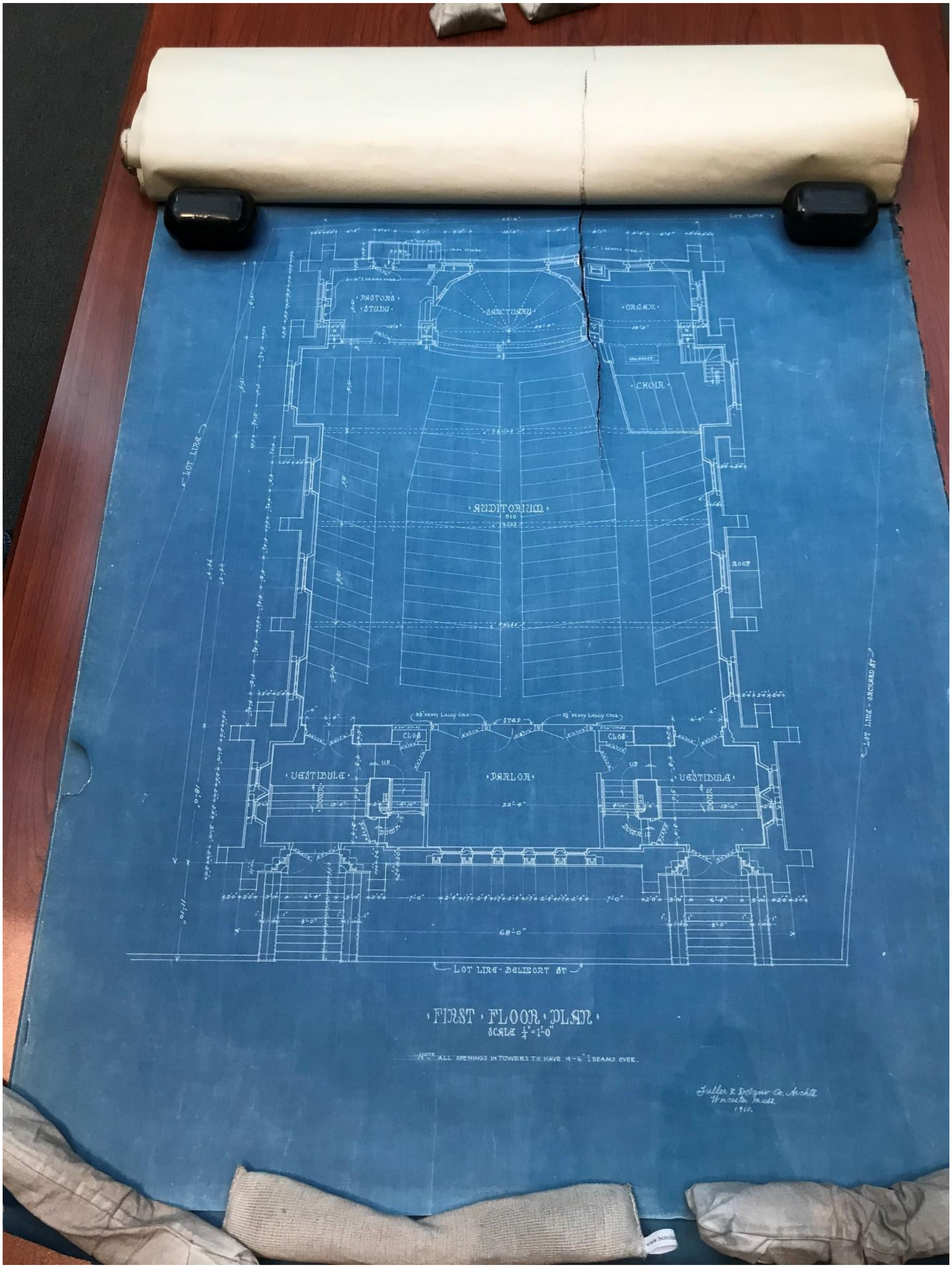
$44\,in \nleq 36\,in$ ← height of wall below truss

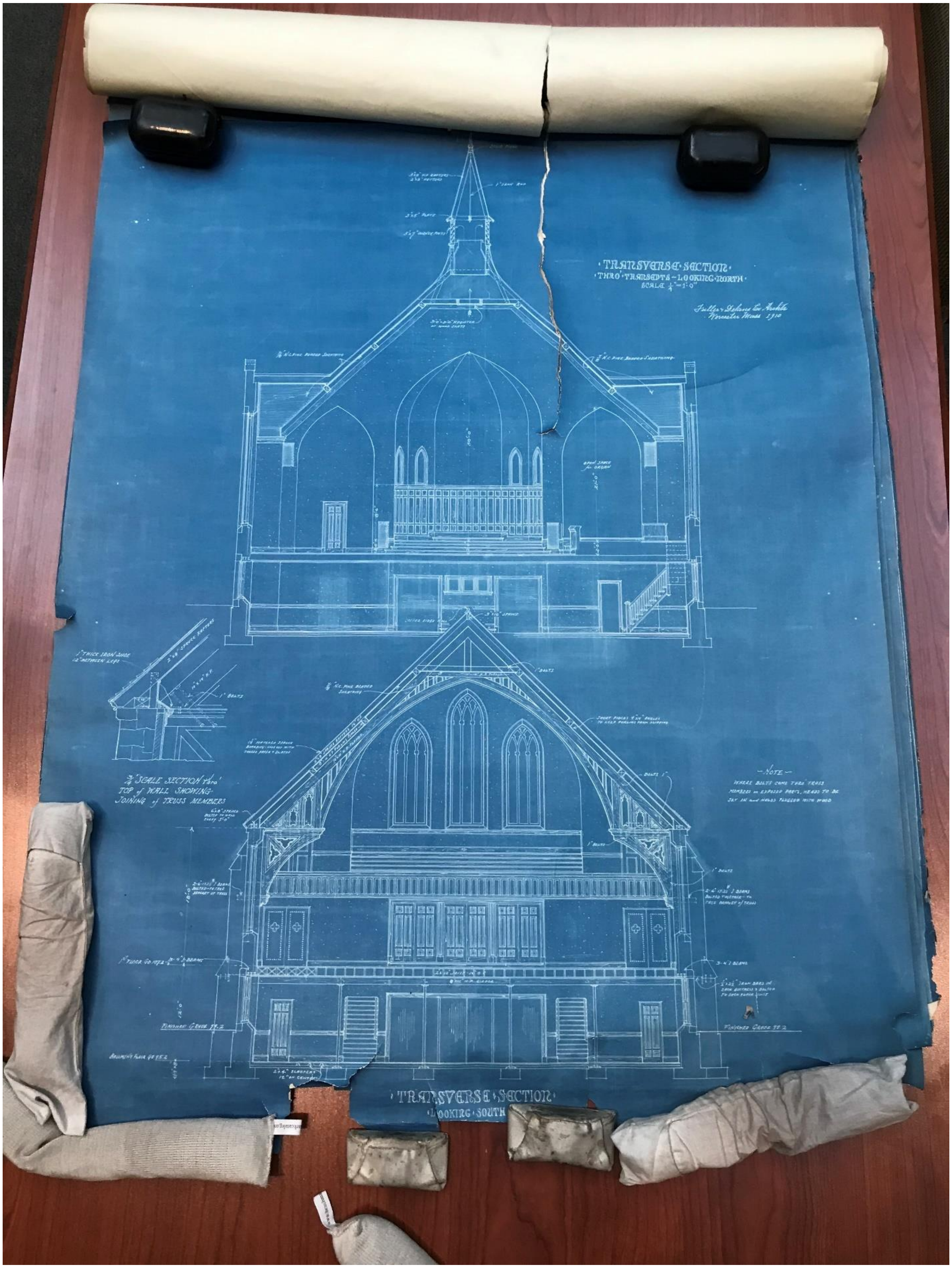
$$(number\ of\ studs) + 1 = \frac{22ft\,(12^{in}/ft)}{36in} = 7.3$$

$\boxed{\text{7 studs are required spaced 33 inches}}$ ← requirements do not change if $< 1in^2$ reinforcement was decided to be used

Note: For seismic case 2, the exterior granite masonry is in tension where σ_{max} is 48.47psi. Normal type portland cement used for concrete masonry has an allowable tensile stress parallel to the bed joints in running bond of 60psi. Granite masonry has a cross-section of mortar placement that provides for more tensile strength than concrete masonry. Because the granite masonry is also in good shape and no evidence of major cracking already exists, the granite masonry is adequate for tensile stresses under maximum seismic loading conditions.

Appendix D: Massachusetts State Archive Plans

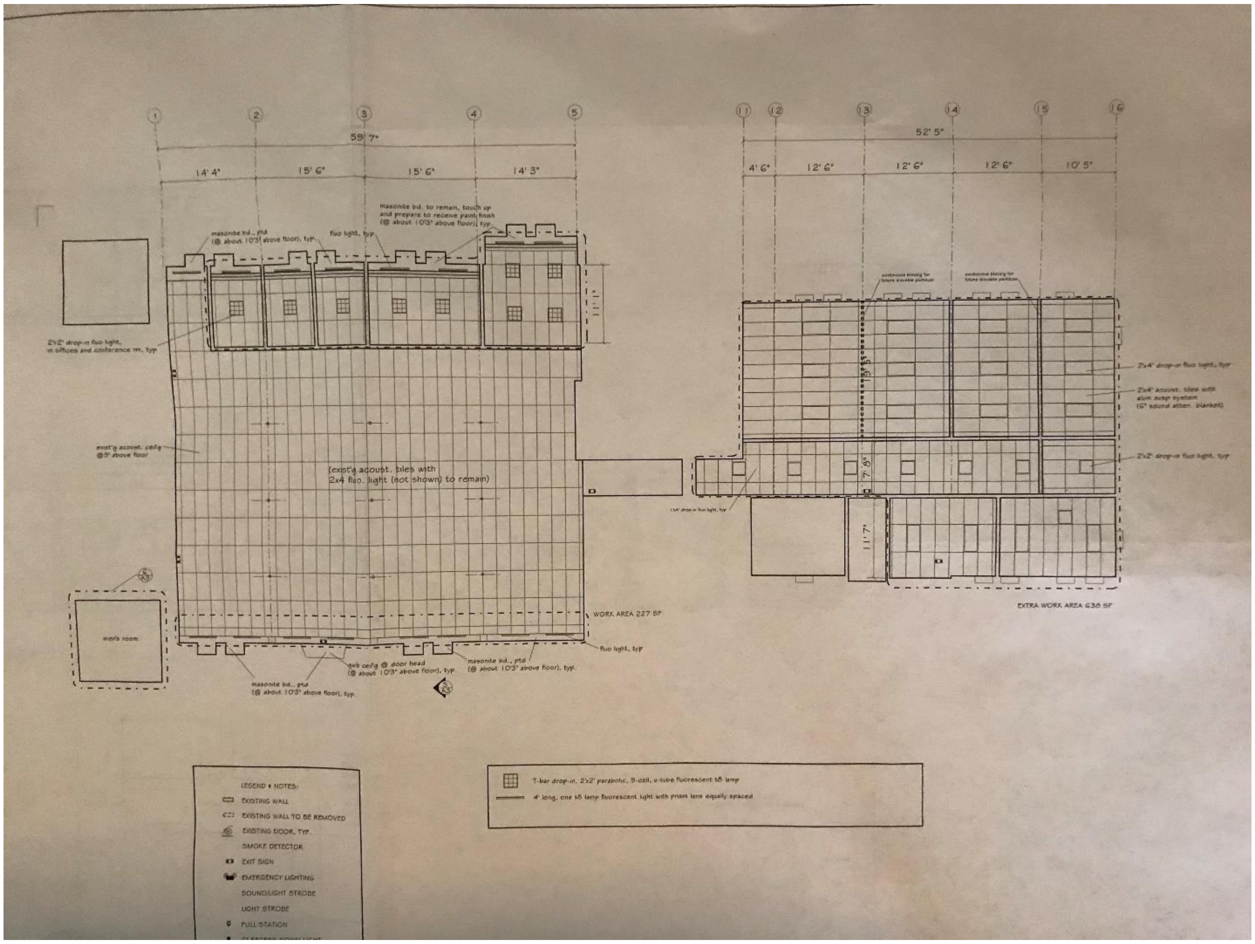

PASTOR'S STUDY
SANCTUARY
ORGAN
CHOIR
AUDITORIUM
ROOF
CLOS
CLOS
VESTIBULE
PARLOR
VESTIBULE
LOT LINE
LOT LINE - ORCHARD ST
68'-0"
LOT LINE - BELMONT ST
FIRST FLOOR PLAN
SCALE 1/4" = 1'-0"
NOTE ALL OPENINGS IN TOWERS TO HAVE 4-6" I BEAMS OVER.
Fuller & Delano Co. Archts
Worcester Mass.
1910.

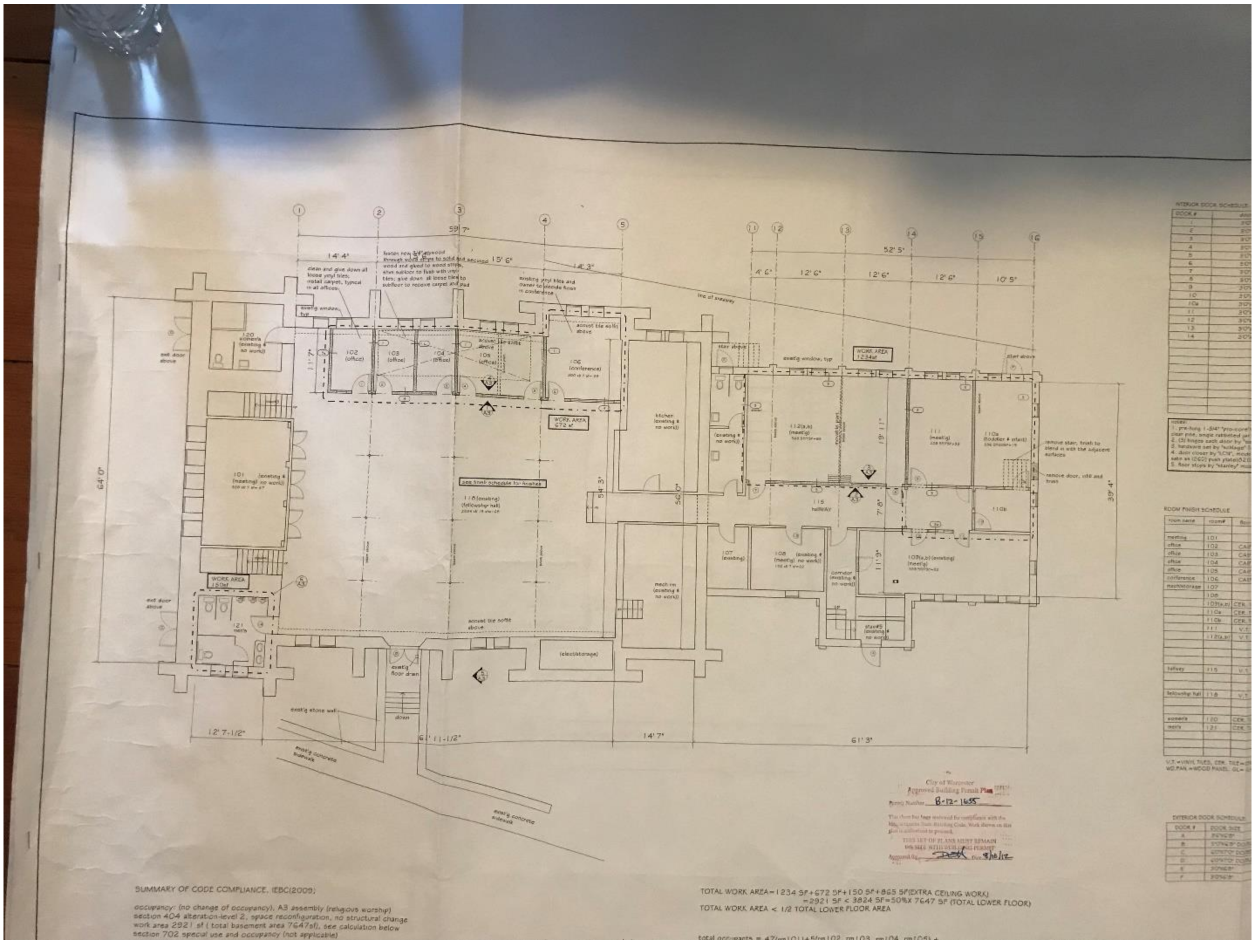


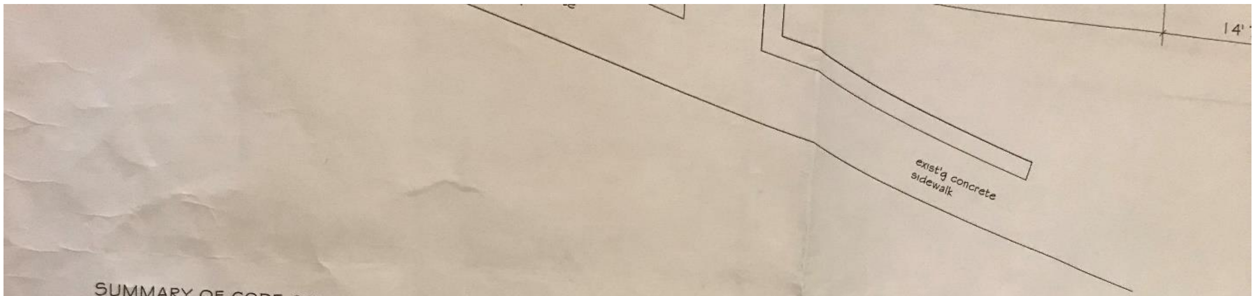
·TRANSVERSE·SECTION·
·THRO'·TRANSEPTS–LOOKING·NORTH·
SCALE 1/4"=1'-0"
Fuller & Delano Co. Archts
Worcester Mass 1910
TRANSVERSE·SECTION
LOOKING·SOUTH


PLAN AT A & B.
PLAN AT C.
SECTION OF TOWER
PLAN AT D-D.
PLAN AT E-E.
PLAN OF GALLERY.
SCALE 1/4 IN.=1FT.

Appendix E: Renovation Floor Plans







SUMMARY OF CODE COMPLIANCE, IEBC(2009)

occupancy: (no change of occupancy), A3 assembly (religious worship)
section 404 alteration-level 2, space reconfiguration, no structural change
work area 2921 sf (total basement area 7647sf), see calculation below
section 702 special use and occupancy (not applicable)
section 703 referring to building elements and materials; constrution type V(2), combustabe and not protected, fire rating not required at interior partitions; specifically in vertical opening and stair well; there shall be no work involved in vertical opening/shaft and stair well, see plan
section 703.4(section 602) referring to interior finish in exit corridor; work area is less than 50% of the floor, finish requirement is not applied to exit corridor outside of work area.
section 606 structural (no structural alteration)
section 607 energy conservation (not new construction, not applicable)
section 704.2.2 referring to sprinkler system; work area is less than 50% of the floor area, thus sprinker is not required.
(section 603 referring to maintein current level)
section 705referring to means of egress, see calculation of egress width, exterior door schedule and floor plan
(section 604, similar to section 705)
section 706 referring to accessibility; specifically to escalators, stairs, dwelling and sleeping units; not applicable to this case.
(section 605, similar to section 706)
section 707 referring to structure, there is no structural alteration involved in this work.
(section 606, similar to section 707)
section 708, section 709 and section 710 shall design and build by electrician and HVAC contractor
section 7011, referring to energy conservation, this is not a new construction, thus it's not applicable.
end of chapter 7

City of Worcester
Approved Building Permit Plan
Permit Number B-12-1655

This sheet has been reviewed for compliance with the Massachusetts State Building Code. Work shown on this plan is authorized to proceed.

THIS SET OF PLANS MUST REMAIN ON SITE WITH BUILDING PERMIT

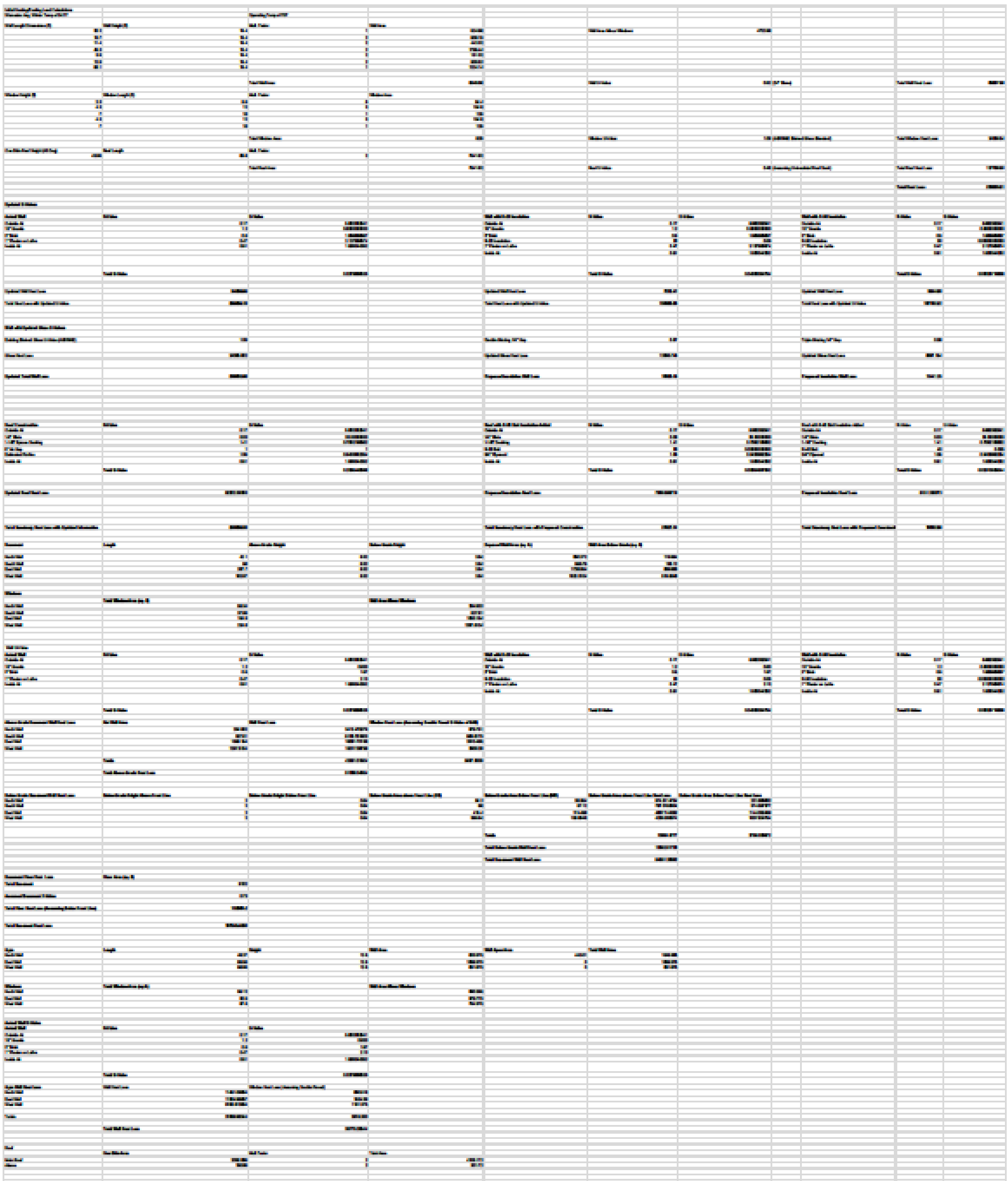
Approved By DEH Date 8/10/12

TOTAL WORK AREA=1234 SF+672 SF+150 SF+865 SF(EXTRA CEILING WORK)
=2921 SF < 3824 SF=50%X 7647 SF (TOTAL LOWER FLOOR)
TOTAL WORK AREA < 1/2 TOTAL LOWER FLOOR AREA

total occupants = 47(rm101)+5(rm102, rm103, rm104, rm105) +
29(rm106)+168(fellowship hall)+189(rm 108, 109, 111, 112)+
15(rm 111,infant and toddler)
=453

egress width required=0.2"xtotal occupant=0.2"x453=91"=7'7"
total exit door width provided=3'6"(DOOR A)+5'0"(DOOR B)=8'6"

Appendix F: Heating/Cooling Load Calculations



Inside 75 F
Outside 95 F

Cooling Load

SANCTUARY

	Orien-tation	Wall Lngth	Wall Area	Wall Grp	Wall U	Glass Area	Glass U	Glass SC	Room Area	Roof U	Peak Mnth	Peak Hour	Total SST BTUH	Table CLTD	Wall CLTD	Wall BTUH	Glass SHGF	Glass CLF	Glass Table	Glass CLTD	Glass Solar BTUH	Glass Trans BTUH	Roof CLTD	Roof BTUH	Transm Heat Loss	Wall LM Corr	Horiz LM Corr	Tbl Tcd Corr
N	N		724.56	A7	0.319	0	1.09	1.00			8	17		11	11	2,542	150	0.61	10	13	-	-						
E	E	86.4	1676.16	A7	0.319	280.8	1.09	1.00			8	17	42,505	24	24.0	12,833	150	0.81	10	13	25,693	3,979						
S	S	68	1319.2	A7	0.319	84.4	1.09	1.00			8	17	13,538	16	16.0	6,733	150	0.81	10	13	5,893	913						
W	W	86.4	1676.16	A7	0.319	280.8	1.09	1.00			8	17	38,297	18	18.0	8,626	150	0.81	10	13	25,693	3,979						
Roof									7541.82	0.229	8	17	84,989										55	84989				
Total													180,329															

BASEMENT

	Orien-tation	Wall Lngth	Wall Area	Wall Grp	Wall U	Glass Area	Glass U	Glass SC	Room Area	Roof U	Peak Mnth	Peak Hour	Total SST BTUH	Table CLTD	Wall CLTD	Wall BTUH	Glass SHGF	Glass CLF	Glass Table	Glass CLTD	Glass Solar BTUH	Glass Trans BTUH	Roof CLTD	Roof BTUH	Transm Heat Loss	Wall LM Corr	Horiz LM Corr	Tbl Tcd Corr
N	N	42.1	459.836	A7	0.319	55.24	0.5	1.00			8	17	7,072	11	11	1,649	150	0.61	10	13	5,054	360						
E	E	207.7	2217.920	A7	0.319	164.8	0.5	1.00			8	17	33,808	24	24.0	17,748	150	0.81	10	13	15,088	1,072						
S	S	68	756.88	A7	0.319	37.95	0.5	1.00			8	17	7,593	16	16.0	3,873	150	0.81	10	13	3,472	247						
W	W	183.97	2041.845	A7	0.319	224.8	0.5	1.00			8	17	33,756	18	18.0	11,726	150	0.81	10.00	13	20,569	1,461						
Roof																												
Total													80,326															

GYM

	Orien-tation	Wall Lngth	Wall Area	Wall Grp	Wall U	Glass Area	Glass U	Glass SC	Room Area	Roof U	Peak Mnth	Peak Hour	Total SST BTUH	Table CLTD	Wall CLTD	Wall BTUH	Glass SHGF	Glass CLF	Glass Table	Glass CLTD	Glass Solar BTUH	Glass Trans BTUH	Roof CLTD	Roof BTUH	Transm Heat Loss	Wall LM Corr	Horiz LM Corr	Tbl Tcd Corr
N	N	48.27	603.375	A7	0.319	56.12	0.5	1.00			8	17	7,617	11	11	2,117	150	0.61	10	13	5,135	365						
E	E	85.55	1069.375	A7	0.319	92.6	0.5	1.00			8	17	17,263	24	24.0	8,187	150	0.81	10	13	8,473	602						
S	S																											
W	W	68.95	861.875	A7	0.319	67.5	0.5	1.00			8	17	11,664	18	18.0	4,949	150	0.81	10	13	6,176	439						
Roof									4406.550	0.229	8	17	55,503										55	55503				
Total													91,848															

Appendix G: DesignBuilder Energy Analysis

Table of Contents

Program Version: **EnergyPlus, Version 8.9.0-40101eaafd, YMD=2019.12.26 10:45**

Tabular Output Report in Format: **HTML**

Building: **Building**

Environment: **MQP WORCESTER GOSPEL CHURCH (01-01:31-12) ** WORCESTER MA USA TMY2-94746 WMO#=725095**

Simulation Timestamp: **2019-12-26 10:47:47**

Table of Contents

Report: **Annual Building Utility Performance Summary**

For: **Entire Facility**

Timestamp: **2019-12-26 10:47:47**

Values gathered over 8760.00 hours

Site and Source Energy

	Total Energy [kBtu]	Energy Per Total Building Area [kBtu/ft2]	Energy Per Conditioned Building Area [kBtu/ft2]
Total Site Energy	781896.00	21.63	22.48
Net Site Energy	781896.00	21.63	22.48
Total Source Energy	1278240.02	35.36	36.74
Net Source Energy	1278240.02	35.36	36.74

Site to Source Energy Conversion Factors

	Site=>Source Conversion Factor
Electricity	3.167
Natural Gas	1.084
District Cooling	1.056
District Heating	3.613
Steam	0.250
Gasoline	1.050
Diesel	1.050
Coal	1.050
Fuel Oil #1	1.050
Fuel Oil #2	1.050
Propane	1.050
Other Fuel 1	1.000
Other Fuel 2	1.000

Building Area

	Area [ft2]
Total Building Area	36151.86
Net Conditioned Building Area	34787.98
Unconditioned Building Area	1363.88

End Uses

	Electricity [kBtu]	Natural Gas [kBtu]	Additional Fuel [kBtu]	District Cooling [kBtu]	District Heating [kBtu]	Water [gal]
Heating	45.85	0.00	565906.76	0.00	0.00	0.00
Cooling	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	215626.78	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00
Fans	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	316.61	0.00	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00	0.00	0.00
Humidification	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00	0.00	0.00
Generators	0.00	0.00	0.00	0.00	0.00	0.00
Total End Uses	215989.24	0.00	565906.76	0.00	0.00	0.00

Note: Additional fuel appears to be the principal heating source based on energy usage.

End Uses By Subcategory

	Subcategory	Electricity [kBtu]	Natural Gas [kBtu]	Additional Fuel [kBtu]	District Cooling [kBtu]	District Heating [kBtu]	Water [gal]
Heating	Boiler	0.00	0.00	565906.76	0.00	0.00	0.00

	Boiler Parasitic	45.85	0.00	0.00	0.00	0.00	0.00
Cooling	General	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	General	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	General	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	General	215626.78	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	General	0.00	0.00	0.00	0.00	0.00	0.00
Fans	Ventilation (simple)	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	General	316.61	0.00	0.00	0.00	0.00	0.00
Heat Rejection	General	0.00	0.00	0.00	0.00	0.00	0.00
Humidification	General	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	General	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	General	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	General	0.00	0.00	0.00	0.00	0.00	0.00
Generators	General	0.00	0.00	0.00	0.00	0.00	0.00

Normalized Metrics

Utility Use Per Conditioned Floor Area

	Electricity Intensity [kBtu/ft2]	Natural Gas Intensity [kBtu/ft2]	Additional Fuel Intensity [kBtu/ft2]	District Cooling Intensity [kBtu/ft2]	District Heating Intensity [kBtu/ft2]	Water Intensity [gal/ft2]
Lighting	0.00	0.00	0.00	0.00	0.00	0.00
HVAC	0.01	0.00	16.27	0.00	0.00	0.00
Other	6.20	0.00	0.00	0.00	0.00	0.00

Total	6.21	0.00	16.27	0.00	0.00	0.00

Utility Use Per Total Floor Area

	Electricity Intensity [kBtu/ft2]	Natural Gas Intensity [kBtu/ft2]	Additional Fuel Intensity [kBtu/ft2]	District Cooling Intensity [kBtu/ft2]	District Heating Intensity [kBtu/ft2]	Water Intensity [gal/ft2]
Lighting	0.00	0.00	0.00	0.00	0.00	0.00
HVAC	0.01	0.00	15.65	0.00	0.00	0.00
Other	5.96	0.00	0.00	0.00	0.00	0.00
Total	5.97	0.00	15.65	0.00	0.00	0.00

Electric Loads Satisfied

	Electricity [kBtu]	Percent Electricity [%]
Fuel-Fired Power Generation	0.000	0.00
High Temperature Geothermal*	0.000	0.00
Photovoltaic Power	0.000	0.00
Wind Power	0.000	0.00
Power Conversion	0.000	0.00
Net Decrease in On-Site Storage	0.000	0.00
Total On-Site Electric Sources	0.000	0.00
Electricity Coming From Utility	215989.240	100.00
Surplus Electricity Going To Utility	0.000	0.00
Net Electricity From Utility	215989.240	100.00

Total On-Site and Utility Electric Sources	215989.240	100.00
Total Electricity End Uses	215989.240	100.00

On-Site Thermal Sources

	Heat [kBtu]	Percent Heat [%]
Water-Side Heat Recovery	0.00	
Air to Air Heat Recovery for Cooling	0.00	
Air to Air Heat Recovery for Heating	0.00	
High-Temperature Geothermal*	0.00	
Solar Water Thermal	0.00	
Solar Air Thermal	0.00	
Total On-Site Thermal Sources	0.00	

Water Source Summary

	Water [gal]	Percent Water [%]
Rainwater Collection	0.00	-
Condensate Collection	0.00	-
Groundwater Well	0.00	-
Total On Site Water Sources	0.00	-
-	-	-
Initial Storage	0.00	-
Final Storage	0.00	-

Change in Storage	0.00	-
-	-	-
Water Supplied by Utility	0.00	-
-	-	-
Total On Site, Change in Storage, and Utility Water Sources	0.00	-
Total Water End Uses	0.00	-

Setpoint Not Met Criteria

	Degrees [deltaF]
Tolerance for Zone Heating Setpoint Not Met Time	2.00
Tolerance for Zone Cooling Setpoint Not Met Time	2.00

Comfort and Setpoint Not Met Summary

	Facility [Hours]
Time Setpoint Not Met During Occupied Heating	105.83
Time Setpoint Not Met During Occupied Cooling	0.00
Time Not Comfortable Based on Simple ASHRAE 55-2004	1524.00

Note 1: An asterisk (*) indicates that the feature is not yet implemented.

Table of Contents

Life-Cycle Cost Report

| Entire Facility |

Table of Contents

Report: **Input Verification and Results Summary**

For: **Entire Facility**

Timestamp: **2019-12-26 10:47:47**

General

	Value
Program Version and Build	EnergyPlus, Version 8.9.0-40101eaafd, YMD=2019.12.26 10:45
RunPeriod	MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)
Weather File	WORCESTER MA USA TMY2-94746 WMO#=725095
Latitude [deg]	42.27
Longitude [deg]	-71.9
Elevation [ft]	987.58
Time Zone	-5.0
North Axis Angle [deg]	0.00
Rotation for Appendix G [deg]	0.00
Hours Simulated [hrs]	8760.00

ENVELOPE

Window-Wall Ratio

	Total	North (315 to 45 deg)	East (45 to 135 deg)	South (135 to 225 deg)	West (225 to 315 deg)
Gross Wall Area [ft2]	16155.05	3456.29	4659.51	3451.93	4587.32
Above Ground Wall Area [ft2]	16155.05	3456.29	4659.51	3451.93	4587.32
Window Opening Area [ft2]	1526.72	114.24	543.54	303.36	565.57
Gross Window-Wall Ratio [%]	9.45	3.31	11.67	8.79	12.33
Above Ground Window-Wall Ratio [%]	9.45	3.31	11.67	8.79	12.33

Conditioned Window-Wall Ratio

	Total	North (315 to 45 deg)	East (45 to 135 deg)	South (135 to 225 deg)	West (225 to 315 deg)
Gross Wall Area [ft2]	15257.42	2749.11	4659.51	3261.47	4587.32
Above Ground Wall Area [ft2]	15257.42	2749.11	4659.51	3261.47	4587.32
Window Opening Area [ft2]	1526.72	114.24	543.54	303.36	565.57
Gross Window-Wall Ratio [%]	10.01	4.16	11.67	9.30	12.33
Above Ground Window-Wall Ratio [%]	10.01	4.16	11.67	9.30	12.33

Skylight-Roof Ratio

	Total
Gross Roof Area [ft2]	12853.41
Skylight Area [ft2]	0.00
Skylight-Roof Ratio [%]	0.00

PERFORMANCE

Zone Summary

	Area [ft2]	Conditioned (Y/N)	Part of Total Floor Area (Y/N)	Volume [ft3]	Multipliers	Above Ground Gross Wall Area [ft2]	Underground Gross Wall Area [ft2]	Window Glass Area [ft2]	Opening Area [ft2]	Lighting [Btu/h-ft2]	People [ft2 per person]	Plug and Process [Btu/h-ft2]
GYM:ZONE3	5947.27	Yes	Yes	67651.14	1.00	2409.34	0.00	194.17	194.17	0.0000	200.02	2.3772
GYM:ZONE1	141.11	Yes	Yes	1764.01	1.00	420.04	0.00	23.49	23.49	0.0000	200.02	2.3772
GYM:ZONE2	63.83	Yes	Yes	797.93	1.00	213.15	0.00	5.57	5.57	0.0000	200.02	2.3772
CHURCHROOF:ZONE1	867.38	No	Yes	13043.81	1.00	707.17	0.00	0.00	0.00	0.0000		0.0000
CHURCHROOF:ZONE4	248.25	No	Yes	1713.02	1.00	95.23	0.00	0.00	0.00	0.0000		0.0000
CHURCHROOF:ZONE2	248.25	No	Yes	1713.02	1.00	95.23	0.00	0.00	0.00	0.0000		0.0000
FIRSTFLOOR:ZONE3	322.68	Yes	Yes	6295.56	1.00	790.50	0.00	40.40	40.40	0.0000	50.00	2.3772
FIRSTFLOOR:ZONE4	324.03	Yes	Yes	6321.00	1.00	799.82	0.00	40.44	40.44	0.0000	50.00	2.3772

FIRSTFLOOR:ZONE2	9178.84	Yes	Yes	163243.84	1.00	4162.38	0.00	645.87	645.87	0.0000	50.00	2.3772
FIRSTFLOOR:ZONE6	244.82	Yes	Yes	4774.30	1.00	389.19	0.00	31.49	36.09	0.0000	50.00	2.3772
FIRSTFLOOR:ZONE7	244.82	Yes	Yes	4774.30	1.00	480.82	0.00	31.49	36.08	0.0000	50.00	2.3772
FIRSTFLOOR:ZONE1	114.80	Yes	Yes	2238.72	1.00	3.78	0.00	0.00	0.00	0.0000	50.00	2.3772
BASEMENTXABOVEGRADE:ZONE1	782.30	Yes	Yes	4364.75	1.00	443.66	0.00	79.25	79.25	0.0000	200.02	2.3772
BASEMENTXABOVEGRADE:ZONE2	424.56	Yes	Yes	2368.80	1.00	374.95	0.00	0.00	0.00	0.0000	200.02	2.3772
BASEMENTXABOVEGRADE:ZONE3	509.71	Yes	Yes	2843.86	1.00	273.15	0.00	35.99	35.99	0.0000	200.02	2.3772
BASEMENTXABOVEGRADE:ZONE4	8398.23	Yes	Yes	46857.00	1.00	971.19	0.00	95.64	95.64	0.0000	200.02	2.3772
BASEMENTXABOVEGRADE:ZONE5	207.99	Yes	Yes	1160.48	1.00	117.73	0.00	0.00	0.00	0.0000	200.02	2.3772
BASEMENTXABOVEGRADE:ZONE6	354.38	Yes	Yes	1977.25	1.00	190.27	0.00	0.00	0.00	0.0000	200.02	2.3772
BASEMENTXABOVEGRADE:ZONE7	651.13	Yes	Yes	3632.92	1.00	241.04	0.00	0.00	0.00	0.0000	200.02	2.3772
BASEMENTXABOVEGRADE:ZONE8	1541.77	Yes	Yes	8602.15	1.00	452.72	0.00	53.20	53.20	0.0000	200.02	2.3772
BASEMENTXABOVEGRADE:ZONE9	454.91	Yes	Yes	2538.14	1.00	133.58	0.00	26.65	26.65	0.0000	200.02	2.3772
BASEMENTXABOVEGRADE:ZONE10	280.46	Yes	Yes	1564.80	1.00	66.96	0.00	0.00	0.00	0.0000	200.02	2.3772
BASEMENTXABOVEGRADE:ZONE11	796.96	Yes	Yes	4446.53	1.00	208.68	0.00	0.00	0.00	0.0000	200.02	2.3772
BASEMENTXABOVEGRADE:ZONE12	161.72	Yes	Yes	902.28	1.00	202.84	0.00	8.98	8.98	0.0000	200.02	2.3772

BASEMENTXABOVEGRADE:ZONE13	964.32	Yes	Yes	5380.31	1.00	298.89	0.00	40.32	40.32	0.0000	200.02	2.3772
BASEMENTXABOVEGRADE:ZONE14	601.26	Yes	Yes	3354.66	1.00	443.03	0.00	15.40	15.40	0.0000	200.02	2.3772
BASEMENTXABOVEGRADE:ZONE15	575.73	Yes	Yes	3212.24	1.00	430.56	0.00	19.16	19.16	0.0000	200.02	2.3772
BASEMENTXABOVEGRADE:ZONE16	1500.33	Yes	Yes	8370.92	1.00	739.16	0.00	130.02	130.02	0.0000	200.02	2.3772
Total	36151.86			375907.72		16155.05	0.00	1517.54	1526.72	0.0000	109.43	2.2875
Conditioned Total	34787.98			359437.87		15257.42	0.00	1517.54	1526.72	0.0000	105.30	2.3772
Unconditioned Total	1363.88			16469.86		897.63	0.00	0.00	0.00	0.0000		0.0000
Not Part of Total	0.00			0.00		0.00	0.00	0.00	0.00			

Table of Contents

Report: **Demand End Use Components Summary**

For: **Entire Facility**

Timestamp: **2019-12-26 10:47:47**

End Uses

	Electricity [kBtuh]	Natural Gas [kBtuh]	Fuel Oil #1 [kBtuh]	District Cooling [kBtuh]	Steam [kBtuh]	Water [gal/min]
Time of Peak	18-FEB-09:09	-	03-FEB-09:20	-	-	-
Heating	0.02	0.00	1140.64	0.00	0.00	0.00
Cooling	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	0.00	0.00	0.00	0.00	0.00	0.00

Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	78.62	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00
Fans	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	0.14	0.00	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00	0.00	0.00
Humidification	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00	0.00	0.00
Generators	0.00	0.00	0.00	0.00	0.00	0.00
Total End Uses	78.78	0.00	1140.64	0.00	0.00	0.00

End Uses By Subcategory

	Subcategory	Electricity [kBtuh]	Natural Gas [kBtuh]	Fuel Oil #1 [kBtuh]	District Cooling [kBtuh]	Steam [kBtuh]	Water [gal/min]
Heating	Boiler	0.00	0.00	1140.64	0.00	0.00	0.00
	Boiler Parasitic	0.02	0.00	0.00	0.00	0.00	0.00
Cooling	General	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting	General	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	General	0.00	0.00	0.00	0.00	0.00	0.00

Interior Equipment	General	78.62	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	General	0.00	0.00	0.00	0.00	0.00	0.00
Fans	Ventilation (simple)	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	General	0.14	0.00	0.00	0.00	0.00	0.00
Heat Rejection	General	0.00	0.00	0.00	0.00	0.00	0.00
Humidification	General	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	General	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	General	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	General	0.00	0.00	0.00	0.00	0.00	0.00
Generators	General	0.00	0.00	0.00	0.00	0.00	0.00

Table of Contents

Report: **Component Sizing Summary**

For: **Entire Facility**

Timestamp: **2019-12-26 10:47:47**

ZoneHVAC:Baseboard:RadiantConvective:Water

	Design Size Maximum Water Flow Rate [gal/min]	U-Factor times Area [Btu/h-F]
GYM:ZONE3 WATER RADIATOR	20.26	2708.46
GYM:ZONE1 WATER RADIATOR	1.47	190.83
GYM:ZONE2 WATER RADIATOR	0.772107	97.62
FIRSTFLOOR:ZONE3 WATER RADIATOR	3.41	450.03

FIRSTFLOOR:ZONE4 WATER RADIATOR	3.51	463.11
FIRSTFLOOR:ZONE2 WATER RADIATOR	31.27	4184.36
FIRSTFLOOR:ZONE6 WATER RADIATOR	1.77	230.30
FIRSTFLOOR:ZONE7 WATER RADIATOR	2.03	264.99
FIRSTFLOOR:ZONE1 WATER RADIATOR	0.598264	74.59
BASEMENTXABOVEGRADE:ZONE1 WATER RADIATOR	2.79	367.23
BASEMENTXABOVEGRADE:ZONE2 WATER RADIATOR	1.86	242.70
BASEMENTXABOVEGRADE:ZONE3 WATER RADIATOR	1.75	228.00
BASEMENTXABOVEGRADE:ZONE4 WATER RADIATOR	15.21	2031.67
BASEMENTXABOVEGRADE:ZONE5 WATER RADIATOR	0.699907	88.04
BASEMENTXABOVEGRADE:ZONE6 WATER RADIATOR	1.13	145.85
BASEMENTXABOVEGRADE:ZONE7 WATER RADIATOR	1.68	218.90
BASEMENTXABOVEGRADE:ZONE8 WATER RADIATOR	3.82	504.85
BASEMENTXABOVEGRADE:ZONE9 WATER RADIATOR	1.23	158.69
BASEMENTXABOVEGRADE:ZONE10 WATER RADIATOR	0.680585	85.48
BASEMENTXABOVEGRADE:ZONE11 WATER RADIATOR	1.77	231.29
BASEMENTXABOVEGRADE:ZONE12 WATER RADIATOR	0.901499	114.82
BASEMENTXABOVEGRADE:ZONE13 WATER RADIATOR	2.36	310.13

BASEMENTXABOVEGRADE:ZONE14 WATER RADIATOR	2.32	304.41
BASEMENTXABOVEGRADE:ZONE15 WATER RADIATOR	2.26	295.98
BASEMENTXABOVEGRADE:ZONE16 WATER RADIATOR	4.75	630.32

User-Specified values were used. Design Size values were used if no User-Specified values were provided.

PlantLoop

	Maximum Loop Flow Rate [ft3/min]	Plant Loop Volume [ft3]
HW LOOP	14.74	29.49

User-Specified values were used. Design Size values were used if no User-Specified values were provided.

Pump:VariableSpeed

	Design Flow Rate [ft3/min]	Design Power Consumption [Btu/h]
HW LOOP SUPPLY PUMP	14.74	676.34

User-Specified values were used. Design Size values were used if no User-Specified values were provided.

Boiler:HotWater

	Design Size Nominal Capacity [Btu/h]	Design Size Design Water Flow Rate [gal/min]
BOILER	996952.59	110.29

User-Specified values were used. Design Size values were used if no User-Specified values were provided.

Table of Contents

Report: **Adaptive Comfort Summary**

For: **Entire Facility**

Timestamp: **2019-12-26 10:47:47**

Time Not Meeting the Adaptive Comfort Models during Occupied Hours

	ASHRAE55 90% Acceptability Limits [Hours]	ASHRAE55 80% Acceptability Limits [Hours]	CEN15251 Category I Acceptability Limits [Hours]	CEN15251 Category II Acceptability Limits [Hours]	CEN15251 Category III Acceptability Limits [Hours]

Table of Contents

Report: **Climatic Data Summary**

For: **Entire Facility**

Timestamp: **2019-12-26 10:47:47**

SizingPeriod:DesignDay

	Maximum Dry Bulb [F]	Daily Temperature Range [deltaF]	Humidity Value	Humidity Type	Wind Speed [ft/min]	Wind Direction
SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	85.82	15.84	71.24	Wetbulb [F]	0.00	0.00
WINTER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)	1.94	0.00	1.94	Wetbulb [F]	2677.30	0.00

Weather Statistics File

	Value
None	

Table of Contents

Report: **Envelope Summary**

For: **Entire Facility**

Timestamp: **2019-12-26 10:47:47**

Opaque Exterior

	Construction	Reflectance	U-Factor with Film [Btu/h-ft2-F]	U-Factor no Film [Btu/h-ft2-F]	Gross Area [ft2]	Net Area [ft2]	Azimuth [deg]	Tilt [deg]	Cardinal Direction
GYM:ZONE3_WALL_2_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	373.79	327.07	90.00	90.00	E
GYM:ZONE3_WALL_3_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	526.30	470.30	0.00	90.00	N
GYM:ZONE3_WALL_4_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	861.96	765.57	270.00	90.00	W
GYM:ZONE3_WALL_7_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	131.89	109.07	90.00	90.00	E
GYMROOF:ZONE1_WALL_1_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	443.15	443.15	0.00	90.00	N
GYMROOF:ZONE1_WALL_7_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	72.26	72.26	90.00	90.00	E
GYMROOF:ZONE1_ROOF_0_0_0	COPY OF CHURCH ROOF	0.40	0.226	0.274	747.06	747.06	90.00	45.00	

	UNINSULATED								
GYMROOF:ZONE1_ROOF_0_0_1	COPY OF CHURCH ROOF UNINSULATED	0.40	0.226	0.274	1203.54	1203.54	90.00	45.00	
GYMROOF:ZONE1_ROOF_4_0_0	COPY OF CHURCH ROOF UNINSULATED	0.40	0.226	0.274	2052.79	2052.79	270.00	45.00	
GYMROOF:ZONE1_ROOF_5_0_0	COPY OF CHURCH ROOF UNINSULATED	0.40	0.226	0.274	150.88	150.88	0.00	45.00	
GYMROOF:ZONE1_ROOF_6_0_0	COPY OF CHURCH ROOF UNINSULATED	0.40	0.226	0.274	150.88	150.88	180.00	45.00	
GYM:ZONE1_WALL_2_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	212.52	189.03	90.00	90.00	E
GYM:ZONE1_WALL_3_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	103.76	103.76	0.00	90.00	N
GYM:ZONE1_WALL_5_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	103.76	103.76	180.00	90.00	S
GYM:ZONE2_WALL_2_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	143.76	138.19	90.00	90.00	E
GYM:ZONE2_WALL_3_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	69.38	69.38	0.00	90.00	N

GYM:ZONE2_ROOF_1_0_0	CZ5 NON-RES ROOF INS ENTIRELY ABOVE DECK R-19.9C.I. (3.5C.I.) U-.O48 (.273)	0.30	0.048	0.050	63.83	63.83	180.00	0.00	
CHURCHROOF:ZONE1_WALL_1_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	387.07	387.07	0.00	90.00	N
CHURCHROOF:ZONE1_WALL_1_0_1	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	320.11	320.11	0.00	90.00	N
CHURCHROOF:ZONE1_EXTFLOOR_2_0_0	CZ5 NON-RES EXTERNAL FLOOR STEEL-JOIST R-3O.1 (5.3) U-.O38 (.214)	0.30	0.038	0.040	7.20	7.20	0.00	180.00	
CHURCHROOF:ZONE1_EXTFLOOR_2_0_1	CZ5 NON-RES EXTERNAL FLOOR STEEL-JOIST R-3O.1 (5.3) U-.O38 (.214)	0.30	0.038	0.040	7.20	7.20	0.00	180.00	
CHURCHROOF:ZONE1_ROOF_0_0_0	COPY OF CHURCH ROOF UNINSULATED	0.40	0.226	0.274	613.33	613.33	90.00	45.00	
CHURCHROOF:ZONE1_ROOF_3_0_0	COPY OF CHURCH ROOF UNINSULATED	0.40	0.226	0.274	613.33	613.33	270.00	45.00	

CHURCHROOF:ZONE4_WALL_3_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	95.23	95.23	180.00	90.00	S
CHURCHROOF:ZONE4_ROOF_0_0_0	COPY OF CHURCH ROOF UNINSULATED	0.40	0.226	0.274	351.08	351.08	90.00	45.00	
CHURCHROOF:ZONE2_WALL_4_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	95.23	95.23	180.00	90.00	S
CHURCHROOF:ZONE2_ROOF_3_0_0	COPY OF CHURCH ROOF UNINSULATED	0.40	0.226	0.274	351.08	351.08	270.00	45.00	
FIRSTFLOOR:ZONE3_WALL_3_1_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	91.02	91.02	0.00	90.00	N
FIRSTFLOOR:ZONE3_WALL_4_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	351.21	330.99	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_5_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	348.27	291.84	180.00	90.00	S
FIRSTFLOOR:ZONE3_ROOF_6_2_0	PITCHED ROOF - UNINSULATED - HEAVYWEIGHT (DATA MODIFIED WHEN LOADED TO FILE)	0.30	0.520	0.875	61.66	61.66	180.00	0.00	
FIRSTFLOOR:ZONE4_WALL_3_1_0	COPY OF COPY OF	0.40	0.440	0.704	97.53	97.53	0.00	90.00	N

	CHURCH WALL								
FIRSTFLOOR:ZONE4_WALL_4_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	351.15	330.93	90.00	90.00	E
FIRSTFLOOR:ZONE4_WALL_5_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	351.15	290.48	180.00	90.00	S
FIRSTFLOOR:ZONE4_ROOF_0_2_0	PITCHED ROOF - UNINSULATED - HEAVYWEIGHT (DATA MODIFIED WHEN LOADED TO FILE)	0.30	0.520	0.875	81.01	81.01	180.00	0.00	
FIRSTFLOOR:ZONE2_WALL_13_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	78.01	78.01	0.00	90.00	N
FIRSTFLOOR:ZONE2_WALL_14_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	391.99	303.02	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_15_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	91.00	91.00	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_16_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	856.13	733.49	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_19_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	626.99	577.81	180.00	90.00	S

FIRSTFLOOR:ZONE2_WALL_22_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	856.13	733.49	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_23_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	78.01	78.01	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_24_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	391.99	303.02	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_25_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	78.01	78.01	0.00	90.00	N
CHURCHROOF:ZONE3_WALL_3_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	714.14	540.67	180.00	90.00	S
CHURCHROOF:ZONE3_EXTFLOOR_1_0_0	CZ5 NON-RES EXTERNAL FLOOR STEEL-JOIST R-3O.1 (5.3) U-.O38 (.214)	0.30	0.038	0.040	51.19	51.19	0.00	180.00	
CHURCHROOF:ZONE3_EXTFLOOR_1_0_1	CZ5 NON-RES EXTERNAL FLOOR STEEL-JOIST R-3O.1 (5.3) U-.O38 (.214)	0.30	0.038	0.040	21.95	21.95	0.00	180.00	
FIRSTFLOOR:ZONE2_ROOF_36_3_0	PITCHED ROOF - UNINSULATED - HEAVYWEIGHT (DATA	0.30	0.520	0.875	70.36	70.36	180.00	0.00	

	MODIFIED WHEN LOADED TO FILE)							
FIRSTFLOOR:ZONE2_ROOF_36_3_1	PITCHED ROOF - UNINSULATED - HEAVYWEIGHT (DATA MODIFIED WHEN LOADED TO FILE)	0.30	0.520	0.875	70.36	70.36	180.00	0.00	
CHURCHROOF:ZONE3_ROOF_0_0_0	CZ5 NON-RES ROOF INS ENTIRELY ABOVE DECK R-19.9C.I. (3.5C.I.) U-.O48 (.273)	0.30	0.048	0.050	414.05	414.05	90.00	45.00	
CHURCHROOF:ZONE3_ROOF_0_0_1	CZ5 NON-RES ROOF INS ENTIRELY ABOVE DECK R-19.9C.I. (3.5C.I.) U-.O48 (.273)	0.30	0.048	0.050	2722.07	2722.07	90.00	45.00	
CHURCHROOF:ZONE3_ROOF_4_0_0	CZ5 NON-RES ROOF INS ENTIRELY ABOVE DECK R-19.9C.I. (3.5C.I.) U-.O48 (.273)	0.30	0.048	0.050	1249.03	1249.03	270.00	45.00	
CHURCHROOF:ZONE3_ROOF_4_0_1	CZ5 NON-RES ROOF INS	0.30	0.048	0.050	1887.09	1887.09	270.00	45.00	

	ENTIRELY ABOVE DECK R-19.9C.I. (3.5C.I.) U-.O48 (.273)								
FIRSTFLOOR:ZONE6_WALL_1_2_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	24.50	24.50	0.00	90.00	N
FIRSTFLOOR:ZONE6_WALL_1_2_1	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	83.86	83.86	0.00	90.00	N
FIRSTFLOOR:ZONE6_WALL_3_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	280.83	244.74	270.00	90.00	W
FIRSTFLOOR:ZONE7_WALL_1_3_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	90.01	90.01	0.00	90.00	N
FIRSTFLOOR:ZONE7_WALL_1_3_1	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	109.98	109.98	0.00	90.00	N
FIRSTFLOOR:ZONE7_WALL_2_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	280.83	244.74	90.00	90.00	E
FIRSTFLOOR:ZONE1_WALL_1_2_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	3.78	3.78	0.00	90.00	N
BASEMENTXABOVEGRADE:ZONE1_WALL_3_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	248.72	182.73	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE1_WALL_4_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	81.99	68.73	0.00	90.00	N

BASEMENTXBELOWGRADE:ZONE10_WALL_2_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	84.94	84.94	90.00	90.00	E
BASEMENTXBELOWGRADE:ZONE10_WALL_3_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	28.00	28.00	0.00	90.00	N
BASEMENTXBELOWGRADE:ZONE10_EXTFLOOR_0_0_0	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	391.15	391.15	0.00	180.00	
BASEMENTXABOVEGRADE:ZONE2_WALL_2_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	141.42	118.61	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE2_WALL_3_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	69.04	69.04	0.00	90.00	N
BASEMENTXABOVEGRADE:ZONE2_WALL_8_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	69.04	69.04	180.00	90.00	S
BASEMENTXBELOWGRADE:ZONE9_WALL_2_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	48.29	48.29	90.00	90.00	E
BASEMENTXBELOWGRADE:ZONE9_WALL_3_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	23.58	23.58	0.00	90.00	N
BASEMENTXBELOWGRADE:ZONE9_WALL_8_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	23.58	23.58	180.00	90.00	S
BASEMENTXBELOWGRADE:ZONE9_EXTFLOOR_0_0_0	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	71.17	71.17	0.00	180.00	

BASEMENTXBELOWGRADE:ZONE9_EXTFLOOR_0_0_1	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	141.11	141.11	0.00	180.00	
BASEMENTXABOVEGRADE:ZONE3_WALL_3_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	203.62	167.63	0.00	90.00	N
BASEMENTXBELOWGRADE:ZONE11_WALL_3_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	69.54	69.54	0.00	90.00	N
BASEMENTXBELOWGRADE:ZONE11_EXTFLOOR_0_0_0	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	254.85	254.85	0.00	180.00	
BASEMENTXABOVEGRADE:ZONE4_WALL_12_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	53.48	53.48	270.00	90.00	W
BASEMENTXABOVEGRADE:ZONE4_WALL_15_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	35.77	35.77	180.00	90.00	S
BASEMENTXABOVEGRADE:ZONE4_WALL_19_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	35.77	35.77	180.00	90.00	S
BASEMENTXABOVEGRADE:ZONE4_WALL_22_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	365.18	282.49	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE4_WALL_23_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	33.27	33.27	180.00	90.00	S
BASEMENTXABOVEGRADE:ZONE4_WALL_24_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	167.20	135.30	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE4_WALL_25_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	33.27	33.27	0.00	90.00	N

BASEMENTXBELOWGRADE:ZONE2_WALL_2_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	124.71	109.67	90.00	90.00	E
BASEMENTXBELOWGRADE:ZONE2_WALL_3_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	11.36	11.36	180.00	90.00	S
BASEMENTXBELOWGRADE:ZONE2_WALL_4_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	57.10	57.10	90.00	90.00	E
BASEMENTXBELOWGRADE:ZONE2_WALL_5_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	11.36	11.36	0.00	90.00	N
BASEMENTXBELOWGRADE:ZONE2_WALL_21_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	18.26	18.26	270.00	90.00	W
BASEMENTXBELOWGRADE:ZONE2_WALL_24_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	12.22	12.22	180.00	90.00	S
BASEMENTXBELOWGRADE:ZONE2_WALL_28_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	12.22	12.22	180.00	90.00	S
BASEMENTXBELOWGRADE:ZONE2_EXTFLOOR_0_0_0	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	80.41	80.41	0.00	180.00	
BASEMENTXBELOWGRADE:ZONE2_EXTFLOOR_0_0_1	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	77.41	77.41	0.00	180.00	
BASEMENTXBELOWGRADE:ZONE2_EXTFLOOR_0_0_2	SOLID BASEMENT GROUND	0.40	0.191	0.242	77.41	77.41	0.00	180.00	

	FLOOR UNINSULATED								
BASEMENTXBELOWGRADE:ZONE2_EXTFLOOR_0_0_3	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	73.30	73.30	0.00	180.00	
BASEMENTXBELOWGRADE:ZONE2_EXTFLOOR_0_0_4	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	998.71	998.71	0.00	180.00	
BASEMENTXBELOWGRADE:ZONE2_EXTFLOOR_0_0_5	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	181.05	181.05	0.00	180.00	
BASEMENTXBELOWGRADE:ZONE2_EXTFLOOR_0_0_6	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	2014.96	2014.96	0.00	180.00	
BASEMENTXBELOWGRADE:ZONE2_EXTFLOOR_0_0_7	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	695.87	695.87	0.00	180.00	
BASEMENTXABOVEGRADE:ZONE5_WALL_2_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	87.76	87.76	90.00	90.00	E
BASEMENTXBELOWGRADE:ZONE8_WALL_2_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	29.97	29.97	90.00	90.00	E
BASEMENTXBELOWGRADE:ZONE8_EXTFLOOR_0_0_0	SOLID BASEMENT GROUND FLOOR	0.40	0.191	0.242	104.00	104.00	0.00	180.00	

	UNINSULATED								
BASEMENTXABOVEGRADE:ZONE6_WALL_2_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	95.66	95.66	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE6_WALL_3_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	46.17	46.17	0.00	90.00	N
BASEMENTXBELOWGRADE:ZONE7_WALL_2_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	32.67	32.67	90.00	90.00	E
BASEMENTXBELOWGRADE:ZONE7_WALL_3_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	15.77	15.77	0.00	90.00	N
BASEMENTXBELOWGRADE:ZONE7_EXTFLOOR_0_0_0	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	177.19	177.19	0.00	180.00	
BASEMENTXABOVEGRADE:ZONE7_WALL_2_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	119.79	119.79	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE7_WALL_3_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	59.89	59.89	0.00	90.00	N
BASEMENTXBELOWGRADE:ZONE6_WALL_2_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	40.91	40.91	90.00	90.00	E
BASEMENTXBELOWGRADE:ZONE6_WALL_3_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	20.45	20.45	0.00	90.00	N
BASEMENTXBELOWGRADE:ZONE6_EXTFLOOR_0_0_0	SOLID BASEMENT GROUND FLOOR	0.40	0.191	0.242	325.57	325.57	0.00	180.00	

	UNINSULATED								
BASEMENTXABOVEGRADE:ZONE8_WALL_4_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	337.48	284.28	270.00	90.00	W
BASEMENTXBELOWGRADE:ZONE16_WALL_4_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	115.25	115.25	270.00	90.00	W
BASEMENTXBELOWGRADE:ZONE16_EXTFLOOR_0_0_0	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	770.89	770.89	0.00	180.00	
BASEMENTXABOVEGRADE:ZONE9_WALL_5_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	99.57	72.92	270.00	90.00	W
BASEMENTXBELOWGRADE:ZONE15_WALL_5_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	34.00	34.00	270.00	90.00	W
BASEMENTXBELOWGRADE:ZONE15_EXTFLOOR_0_0_0	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	227.46	227.46	0.00	180.00	
BASEMENTXABOVEGRADE:ZONE10_WALL_5_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	49.91	49.91	270.00	90.00	W
BASEMENTXBELOWGRADE:ZONE13_WALL_5_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	17.04	17.04	270.00	90.00	W
BASEMENTXBELOWGRADE:ZONE13_EXTFLOOR_0_0_0	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	140.23	140.23	0.00	180.00	

BASEMENTXABOVEGRADE:ZONE11_WALL_4_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	35.77	35.77	0.00	90.00	N
BASEMENTXABOVEGRADE:ZONE11_WALL_5_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	119.79	119.79	270.00	90.00	W
BASEMENTXBELOWGRADE:ZONE12_WALL_4_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	12.22	12.22	0.00	90.00	N
BASEMENTXBELOWGRADE:ZONE12_WALL_5_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	40.91	40.91	270.00	90.00	W
BASEMENTXBELOWGRADE:ZONE12_EXTFLOOR_0_0_0	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	398.48	398.48	0.00	180.00	
BASEMENTXABOVEGRADE:ZONE12_WALL_3_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	64.60	55.62	0.00	90.00	N
BASEMENTXABOVEGRADE:ZONE12_WALL_4_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	86.60	86.60	270.00	90.00	W
BASEMENTXBELOWGRADE:ZONE14_WALL_3_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	22.06	22.06	0.00	90.00	N
BASEMENTXBELOWGRADE:ZONE14_WALL_4_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	29.57	29.57	270.00	90.00	W
BASEMENTXBELOWGRADE:ZONE14_EXTFLOOR_0_0_0	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	80.86	80.86	0.00	180.00	

BASEMENTXABOVEGRADE:ZONE13_WALL_5_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	222.80	182.49	180.00	90.00	S
BASEMENTXBELOWGRADE:ZONE4_WALL_5_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	76.09	76.09	180.00	90.00	S
BASEMENTXBELOWGRADE:ZONE4_EXTFLOOR_0_0_0	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	482.16	482.16	0.00	180.00	
BASEMENTXABOVEGRADE:ZONE14_WALL_2_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	149.73	134.33	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE14_WALL_3_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	41.59	41.59	0.00	90.00	N
BASEMENTXABOVEGRADE:ZONE14_WALL_6_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	138.92	122.27	180.00	90.00	S
BASEMENTXBELOWGRADE:ZONE5_WALL_2_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	51.13	51.13	90.00	90.00	E
BASEMENTXBELOWGRADE:ZONE5_WALL_3_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	14.20	14.20	0.00	90.00	N
BASEMENTXBELOWGRADE:ZONE5_WALL_6_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	47.44	47.44	180.00	90.00	S
BASEMENTXBELOWGRADE:ZONE5_EXTFLOOR_0_0_0	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	300.63	300.63	0.00	180.00	

BASEMENTXABOVEGRADE:ZONE15_WALL_4_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	38.81	38.81	0.00	90.00	N
BASEMENTXABOVEGRADE:ZONE15_WALL_5_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	149.74	130.58	269.52	90.00	W
BASEMENTXABOVEGRADE:ZONE15_WALL_6_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	132.40	115.74	180.00	90.00	S
BASEMENTXBELOWGRADE:ZONE3_WALL_4_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	13.26	13.26	0.00	90.00	N
BASEMENTXBELOWGRADE:ZONE3_WALL_5_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	51.14	51.14	269.52	90.00	W
BASEMENTXBELOWGRADE:ZONE3_WALL_6_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	45.21	45.21	180.00	90.00	S
BASEMENTXBELOWGRADE:ZONE3_EXTFLOOR_0_0_0	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	287.87	287.87	0.00	180.00	
BASEMENTXABOVEGRADE:ZONE16_WALL_4_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	33.27	33.27	0.00	90.00	N
BASEMENTXABOVEGRADE:ZONE16_WALL_5_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	167.20	134.60	270.00	90.00	W
BASEMENTXABOVEGRADE:ZONE16_WALL_6_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	38.81	38.81	180.00	90.00	S
BASEMENTXABOVEGRADE:ZONE16_WALL_7_0_0	COPY OF CHURCH WALL	0.40	0.440	0.704	311.70	214.28	270.00	90.00	W

BASEMENTXBELOWGRADE:ZONE1_WALL_4_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	11.36	11.36	0.00	90.00	N
BASEMENTXBELOWGRADE:ZONE1_WALL_5_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	57.10	57.10	270.00	90.00	W
BASEMENTXBELOWGRADE:ZONE1_WALL_6_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	13.26	13.26	180.00	90.00	S
BASEMENTXBELOWGRADE:ZONE1_WALL_7_0_0	COPY OF COPY OF CHURCH WALL	0.40	0.440	0.704	106.45	106.45	270.00	90.00	W
BASEMENTXBELOWGRADE:ZONE1_EXTFLOOR_0_0_0	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	427.21	427.21	0.00	180.00	
BASEMENTXBELOWGRADE:ZONE1_EXTFLOOR_0_0_1	SOLID BASEMENT GROUND FLOOR UNINSULATED	0.40	0.191	0.242	322.96	322.96	0.00	180.00	

Exterior Fenestration

	Construction	Glass Area [ft2]	Frame Area [ft2]	Divider Area [ft2]	Area of One Opening [ft2]	Area of Multiplied Openings [ft2]	Glass U-Factor [Btu/h-ft	Glass SHGC	Glass Visible Transmittance	Frame Conductance [Btu/h-ft2-F]	Divider Conductance [Btu/h-ft2-F]	Shade Control	Parent Surface	Azimuth [deg]	Tilt [deg]	Cardinal Direction

							2-F]								
GYM:ZONE3_WALL_2_0_0_0_0_1_WIN	1001	23.36	0.00	0.00	23.36	23.36	1.017	0.819	0.881			No	GYM:ZONE3_WALL_2_0_0	90.00	90.00	E
GYM:ZONE3_WALL_2_0_0_1_0_0_WIN	1001	23.36	0.00	0.00	23.36	23.36	1.017	0.819	0.881			No	GYM:ZONE3_WALL_2_0_0	90.00	90.00	E
GYM:ZONE3_WALL_3_0_0_0_0_3_WIN	1001	14.00	0.00	0.00	14.00	14.00	1.017	0.819	0.881			No	GYM:ZONE3_WALL_3_0_0	0.00	90.00	N
GYM:ZONE3_WALL_3_0_0_1_0_2_WIN	1001	14.00	0.00	0.00	14.00	14.00	1.017	0.819	0.881			No	GYM:ZONE3_WALL_3_0_0	0.00	90.00	N
GYM:ZONE3_WALL_3_0_0_2_0_1_WIN	1001	14.00	0.00	0.00	14.00	14.00	1.017	0.819	0.881			No	GYM:ZONE3_WALL_3_0_0	0.00	90.00	N
GYM:ZONE3_WALL_3_0_0_3_0_0_WIN	1001	14.00	0.00	0.00	14.00	14.00	1.017	0.819	0.881			No	GYM:ZONE3_WALL_3_0_0	0.00	90.00	N
GYM:ZONE3_WALL_4_0_0_1_0_2_WIN	1001	22.88	0.00	0.00	22.88	22.88	1.017	0.819	0.881			No	GYM:ZONE3_WALL_4_0_0	270.00	90.00	W
GYM:ZONE3_WALL_4_0_0_2_0_1_WIN	1001	22.88	0.00	0.00	22.88	22.88	1.017	0.819	0.881			No	GYM:ZONE3_WALL_4_0_0	270.00	90.00	W
GYM:ZONE3_WALL_4_0_0_3_0_0_WIN	1001	22.88	0.00	0.00	22.88	22.88	1.017	0.819	0.881			No	GYM:ZONE3_WALL_4_0_0	270.00	90.00	W
GYM:ZONE3_WALL_7_0_0_0_0_0_WIN	1001	22.	0.00	0.00	22.82	22.82	1.017	0.8	0.881			No	GYM:ZONE3_WALL_7_0_0	90.00	90.	E

		82						19							00	
GYM:ZONE1_WALL_2_0_0_0_0_0_WIN	1001	23.49	0.00	0.00	23.49	23.49	1.017	0.819	0.881			No	GYM:ZONE1_WALL_2_0_0	90.00	90.00	E
GYM:ZONE2_WALL_2_0_0_0_0_0_WIN	1001	5.57	0.00	0.00	5.57	5.57	1.017	0.819	0.881			No	GYM:ZONE2_WALL_2_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE3_WALL_4_0_0_0_0_0_WIN	1001	0.11	0.00	0.00	0.11	0.11	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_4_0_0_1_0_0_WIN	1001	4.77	0.00	0.00	4.77	4.77	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_4_0_0_2_0_0_WIN	1001	0.58	0.00	0.00	0.58	0.58	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_4_0_0_3_0_0_WIN	1001	0.73	0.00	0.00	0.73	0.73	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_4_0_0_4_0_0_WIN	1001	0.82	0.00	0.00	0.82	0.82	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_4_0_0_5_0_0_WIN	1001	0.84	0.00	0.00	0.84	0.84	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_4_0_0_6_0_0_WIN	1001	0.79	0.00	0.00	0.79	0.79	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_4_0_0_7_0_0_WIN	1001	0.67	0.00	0.00	0.67	0.67	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.	W

								19							00	
FIRSTFLOOR:ZONE3_WALL_4_0_0_8_0_0_WIN	1001	0.51	0.00	0.00	0.51	0.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_4_0_0_9_0_0_WIN	1001	0.30	0.00	0.00	0.30	0.30	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_4_0_0_11_0_1_WIN	1001	0.11	0.00	0.00	0.11	0.11	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_4_0_0_12_0_1_WIN	1001	4.77	0.00	0.00	4.77	4.77	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_4_0_0_13_0_1_WIN	1001	0.58	0.00	0.00	0.58	0.58	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_4_0_0_14_0_1_WIN	1001	0.73	0.00	0.00	0.73	0.73	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_4_0_0_15_0_1_WIN	1001	0.82	0.00	0.00	0.82	0.82	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_4_0_0_16_0_1_WIN	1001	0.84	0.00	0.00	0.84	0.84	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_4_0_0_17_0_1_WIN	1001	0.79	0.00	0.00	0.79	0.79	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_4_0_0_18_0_1_WIN	1001	0.67	0.00	0.00	0.67	0.67	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.	W

								19							00	
FIRSTFLOOR:ZONE3_WALL_4_0_0_19_0_1_WIN	1001	0.51	0.00	0.00	0.51	0.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_4_0_0_20_0_1_WIN	1001	0.30	0.00	0.00	0.30	0.30	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_4_0_0	269.52	90.00	W
FIRSTFLOOR:ZONE3_WALL_5_0_0_0_0_1_WIN	1001	0.11	0.00	0.00	0.11	0.11	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE3_WALL_5_0_0_1_0_1_WIN	1001	4.76	0.00	0.00	4.76	4.76	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE3_WALL_5_0_0_2_0_1_WIN	1001	0.58	0.00	0.00	0.58	0.58	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE3_WALL_5_0_0_3_0_1_WIN	1001	0.73	0.00	0.00	0.73	0.73	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE3_WALL_5_0_0_4_0_1_WIN	1001	0.81	0.00	0.00	0.81	0.81	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE3_WALL_5_0_0_5_0_1_WIN	1001	0.84	0.00	0.00	0.84	0.84	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE3_WALL_5_0_0_6_0_1_WIN	1001	0.79	0.00	0.00	0.79	0.79	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE3_WALL_5_0_0_7_0_1_WIN	1001	0.67	0.00	0.00	0.67	0.67	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.	S

								19							00	
FIRSTFLOOR:ZONE3_WALL_5_0_0_8_0_1_WIN	1001	0.51	0.00	0.00	0.51	0.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE3_WALL_5_0_0_9_0_1_WIN	1001	0.30	0.00	0.00	0.30	0.30	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE3_WALL_5_0_0_11_0_2_WIN	1001	0.11	0.00	0.00	0.11	0.11	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE3_WALL_5_0_0_12_0_2_WIN	1001	4.76	0.00	0.00	4.76	4.76	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE3_WALL_5_0_0_13_0_2_WIN	1001	0.58	0.00	0.00	0.58	0.58	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE3_WALL_5_0_0_14_0_2_WIN	1001	0.73	0.00	0.00	0.73	0.73	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE3_WALL_5_0_0_15_0_2_WIN	1001	0.81	0.00	0.00	0.81	0.81	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE3_WALL_5_0_0_16_0_2_WIN	1001	0.84	0.00	0.00	0.84	0.84	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE3_WALL_5_0_0_17_0_2_WIN	1001	0.79	0.00	0.00	0.79	0.79	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE3_WALL_5_0_0_18_0_2_WIN	1001	0.67	0.00	0.00	0.67	0.67	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.	S

								19							00	
FIRSTFLOOR:ZONE3_WALL_5_0_0_19_0_2_WIN	1001	0.51	0.00	0.00	0.51	0.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE3_WALL_5_0_0_20_0_2_WIN	1001	0.30	0.00	0.00	0.30	0.30	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE3_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE4_WALL_4_0_0_0_0_0_WIN	1001	0.11	0.00	0.00	0.11	0.11	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE4_WALL_4_0_0_1_0_0_WIN	1001	4.77	0.00	0.00	4.77	4.77	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE4_WALL_4_0_0_2_0_0_WIN	1001	0.58	0.00	0.00	0.58	0.58	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE4_WALL_4_0_0_3_0_0_WIN	1001	0.73	0.00	0.00	0.73	0.73	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE4_WALL_4_0_0_4_0_0_WIN	1001	0.82	0.00	0.00	0.82	0.82	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE4_WALL_4_0_0_5_0_0_WIN	1001	0.84	0.00	0.00	0.84	0.84	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE4_WALL_4_0_0_6_0_0_WIN	1001	0.79	0.00	0.00	0.79	0.79	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE4_WALL_4_0_0_7_0_0_WIN	1001	0.67	0.00	0.00	0.67	0.67	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.	E

								19							00	
FIRSTFLOOR:ZONE4_WALL_4_0_0_8_0_0_WIN	1001	0.51	0.00	0.00	0.51	0.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.000	E
FIRSTFLOOR:ZONE4_WALL_4_0_0_9_0_0_WIN	1001	0.30	0.00	0.00	0.30	0.30	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.000	E
FIRSTFLOOR:ZONE4_WALL_4_0_0_11_0_1_WIN	1001	0.11	0.00	0.00	0.11	0.11	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.000	E
FIRSTFLOOR:ZONE4_WALL_4_0_0_12_0_1_WIN	1001	4.77	0.00	0.00	4.77	4.77	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.000	E
FIRSTFLOOR:ZONE4_WALL_4_0_0_13_0_1_WIN	1001	0.58	0.00	0.00	0.58	0.58	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.000	E
FIRSTFLOOR:ZONE4_WALL_4_0_0_14_0_1_WIN	1001	0.73	0.00	0.00	0.73	0.73	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.000	E
FIRSTFLOOR:ZONE4_WALL_4_0_0_15_0_1_WIN	1001	0.82	0.00	0.00	0.82	0.82	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.000	E
FIRSTFLOOR:ZONE4_WALL_4_0_0_16_0_1_WIN	1001	0.84	0.00	0.00	0.84	0.84	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.000	E
FIRSTFLOOR:ZONE4_WALL_4_0_0_17_0_1_WIN	1001	0.79	0.00	0.00	0.79	0.79	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.000	E
FIRSTFLOOR:ZONE4_WALL_4_0_0_18_0_1_WIN	1001	0.67	0.00	0.00	0.67	0.67	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.	E

								19							00	
FIRSTFLOOR:ZONE4_WALL_4_0_0_19_0_1_WIN	1001	0.51	0.00	0.00	0.51	0.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE4_WALL_4_0_0_20_0_1_WIN	1001	0.30	0.00	0.00	0.30	0.30	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_4_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE4_WALL_5_0_0_0_0_1_WIN	1001	0.11	0.00	0.00	0.11	0.11	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE4_WALL_5_0_0_1_0_1_WIN	1001	4.77	0.00	0.00	4.77	4.77	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE4_WALL_5_0_0_2_0_1_WIN	1001	0.58	0.00	0.00	0.58	0.58	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE4_WALL_5_0_0_3_0_1_WIN	1001	0.73	0.00	0.00	0.73	0.73	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE4_WALL_5_0_0_4_0_1_WIN	1001	0.82	0.00	0.00	0.82	0.82	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE4_WALL_5_0_0_5_0_1_WIN	1001	0.84	0.00	0.00	0.84	0.84	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE4_WALL_5_0_0_6_0_1_WIN	1001	0.79	0.00	0.00	0.79	0.79	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE4_WALL_5_0_0_7_0_1_WIN	1001	0.67	0.00	0.00	0.67	0.67	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.	S

								19							00	
FIRSTFLOOR:ZONE4_WALL_5_0_0_8_0_1_WIN	1001	0.51	0.00	0.00	0.51	0.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE4_WALL_5_0_0_9_0_1_WIN	1001	0.30	0.00	0.00	0.30	0.30	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE4_WALL_5_0_0_11_0_2_WIN	1001	0.11	0.00	0.00	0.11	0.11	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE4_WALL_5_0_0_12_0_2_WIN	1001	4.77	0.00	0.00	4.77	4.77	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE4_WALL_5_0_0_13_0_2_WIN	1001	0.58	0.00	0.00	0.58	0.58	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE4_WALL_5_0_0_14_0_2_WIN	1001	0.73	0.00	0.00	0.73	0.73	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE4_WALL_5_0_0_15_0_2_WIN	1001	0.82	0.00	0.00	0.82	0.82	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE4_WALL_5_0_0_16_0_2_WIN	1001	0.84	0.00	0.00	0.84	0.84	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE4_WALL_5_0_0_17_0_2_WIN	1001	0.79	0.00	0.00	0.79	0.79	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE4_WALL_5_0_0_18_0_2_WIN	1001	0.67	0.00	0.00	0.67	0.67	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.	S

								19							00	
FIRSTFLOOR:ZONE4_WALL_5_0_0_19_0_2_WIN	1001	0.51	0.00	0.00	0.51	0.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE4_WALL_5_0_0_20_0_2_WIN	1001	0.30	0.00	0.00	0.30	0.30	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE4_WALL_5_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_14_0_0_0_0_0_WIN	1001	0.86	0.00	0.00	0.86	0.86	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_14_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_14_0_0_1_0_0_WIN	1001	38.94	0.00	0.00	38.94	38.94	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_14_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_14_0_0_2_0_0_WIN	1001	6.11	0.00	0.00	6.11	6.11	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_14_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_14_0_0_3_0_0_WIN	1001	7.23	0.00	0.00	7.23	7.23	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_14_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_14_0_0_4_0_0_WIN	1001	7.65	0.00	0.00	7.65	7.65	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_14_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_14_0_0_5_0_0_WIN	1001	7.59	0.00	0.00	7.59	7.59	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_14_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_14_0_0_6_0_0_WIN	1001	6.98	0.00	0.00	6.98	6.98	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_14_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_14_0_0_7_0_0_WIN	1001	5.86	0.00	0.00	5.86	5.86	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE2_WALL_14_0_0	270.00	90.	W

								19							00	
FIRSTFLOOR:ZONE2_WALL_14_0_0_8_0_0_WIN	1001	4.36	0.00	0.00	4.36	4.36	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_14_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_14_0_0_9_0_0_WIN	1001	2.61	0.00	0.00	2.61	2.61	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_14_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_14_0_0_10_0_0_WIN	1001	0.79	0.00	0.00	0.79	0.79	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_14_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_0_0_0_WIN	1001	0.42	0.00	0.00	0.42	0.42	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_1_0_0_WIN	1001	18.56	0.00	0.00	18.56	18.56	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_2_0_0_WIN	1001	2.51	0.00	0.00	2.51	2.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_3_0_0_WIN	1001	3.06	0.00	0.00	3.06	3.06	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_4_0_0_WIN	1001	3.37	0.00	0.00	3.37	3.37	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_5_0_0_WIN	1001	3.42	0.00	0.00	3.42	3.42	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_6_0_0_WIN	1001	3.19	0.00	0.00	3.19	3.19	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.	W

								19							00	
FIRSTFLOOR:ZONE2_WALL_16_0_0_7_0_0_WIN	1001	2.72	0.00	0.00	2.72	2.72	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_8_0_0_WIN	1001	2.04	0.00	0.00	2.04	2.04	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_9_0_0_WIN	1001	1.23	0.00	0.00	1.23	1.23	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_10_0_0_WIN	1001	0.37	0.00	0.00	0.37	0.37	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_11_0_1_WIN	1001	0.42	0.00	0.00	0.42	0.42	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_12_0_1_WIN	1001	18.56	0.00	0.00	18.56	18.56	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_13_0_1_WIN	1001	2.51	0.00	0.00	2.51	2.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_14_0_1_WIN	1001	3.06	0.00	0.00	3.06	3.06	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_15_0_1_WIN	1001	3.37	0.00	0.00	3.37	3.37	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_16_0_1_WIN	1001	3.42	0.00	0.00	3.42	3.42	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.	W

								19							00	
FIRSTFLOOR:ZONE2_WALL_16_0_0_17_0_1_WIN	1001	3.19	0.00	0.00	3.19	3.19	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_18_0_1_WIN	1001	2.72	0.00	0.00	2.72	2.72	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_19_0_1_WIN	1001	2.04	0.00	0.00	2.04	2.04	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_20_0_1_WIN	1001	1.23	0.00	0.00	1.23	1.23	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_21_0_1_WIN	1001	0.37	0.00	0.00	0.37	0.37	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_22_0_2_WIN	1001	0.42	0.00	0.00	0.42	0.42	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_23_0_2_WIN	1001	18.56	0.00	0.00	18.56	18.56	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_24_0_2_WIN	1001	2.51	0.00	0.00	2.51	2.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_25_0_2_WIN	1001	3.06	0.00	0.00	3.06	3.06	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_26_0_2_WIN	1001	3.37	0.00	0.00	3.37	3.37	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.	W

								19							00	
FIRSTFLOOR:ZONE2_WALL_16_0_0_27_0_2_WIN	1001	3.42	0.00	0.00	3.42	3.42	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_28_0_2_WIN	1001	3.19	0.00	0.00	3.19	3.19	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_29_0_2_WIN	1001	2.72	0.00	0.00	2.72	2.72	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_30_0_2_WIN	1001	2.04	0.00	0.00	2.04	2.04	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_31_0_2_WIN	1001	1.23	0.00	0.00	1.23	1.23	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_16_0_0_32_0_2_WIN	1001	0.37	0.00	0.00	0.37	0.37	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_16_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE2_WALL_19_0_0_1_0_0_WIN	1001	4.51	0.00	0.00	4.51	4.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_2_0_0_WIN	1001	0.65	0.00	0.00	0.65	0.65	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_3_0_0_WIN	1001	0.78	0.00	0.00	0.78	0.78	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_4_0_0_WIN	1001	0.84	0.00	0.00	0.84	0.84	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.	S

								19							00	
FIRSTFLOOR:ZONE2_WALL_19_0_0_5_0_0_WIN	1001	0.84	0.00	0.00	0.84	0.84	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_6_0_0_WIN	1001	0.78	0.00	0.00	0.78	0.78	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_7_0_0_WIN	1001	0.66	0.00	0.00	0.66	0.66	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_8_0_0_WIN	1001	0.49	0.00	0.00	0.49	0.49	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_9_0_0_WIN	1001	0.29	0.00	0.00	0.29	0.29	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_12_0_1_WIN	1001	4.51	0.00	0.00	4.51	4.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_13_0_1_WIN	1001	0.65	0.00	0.00	0.65	0.65	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_14_0_1_WIN	1001	0.78	0.00	0.00	0.78	0.78	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_15_0_1_WIN	1001	0.84	0.00	0.00	0.84	0.84	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_16_0_1_WIN	1001	0.84	0.00	0.00	0.84	0.84	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.	S

								19							00	
FIRSTFLOOR:ZONE2_WALL_19_0_0_17_0_1_WIN	1001	0.78	0.00	0.00	0.78	0.78	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_18_0_1_WIN	1001	0.66	0.00	0.00	0.66	0.66	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_19_0_1_WIN	1001	0.49	0.00	0.00	0.49	0.49	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_20_0_1_WIN	1001	0.29	0.00	0.00	0.29	0.29	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_23_0_2_WIN	1001	4.51	0.00	0.00	4.51	4.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_24_0_2_WIN	1001	0.65	0.00	0.00	0.65	0.65	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_25_0_2_WIN	1001	0.78	0.00	0.00	0.78	0.78	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_26_0_2_WIN	1001	0.84	0.00	0.00	0.84	0.84	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_27_0_2_WIN	1001	0.84	0.00	0.00	0.84	0.84	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_28_0_2_WIN	1001	0.78	0.00	0.00	0.78	0.78	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.	S

								19							00	
FIRSTFLOOR:ZONE2_WALL_19_0_0_29_0_2_WIN	1001	0.66	0.00	0.00	0.66	0.66	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_30_0_2_WIN	1001	0.49	0.00	0.00	0.49	0.49	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_31_0_2_WIN	1001	0.29	0.00	0.00	0.29	0.29	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_34_0_3_WIN	1001	4.51	0.00	0.00	4.51	4.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_35_0_3_WIN	1001	0.65	0.00	0.00	0.65	0.65	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_36_0_3_WIN	1001	0.78	0.00	0.00	0.78	0.78	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_37_0_3_WIN	1001	0.84	0.00	0.00	0.84	0.84	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_38_0_3_WIN	1001	0.84	0.00	0.00	0.84	0.84	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_39_0_3_WIN	1001	0.78	0.00	0.00	0.78	0.78	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_40_0_3_WIN	1001	0.66	0.00	0.00	0.66	0.66	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.	S

								19							00	
FIRSTFLOOR:ZONE2_WALL_19_0_0_41_0_3_WIN	1001	0.49	0.00	0.00	0.49	0.49	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_42_0_3_WIN	1001	0.29	0.00	0.00	0.29	0.29	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_45_0_4_WIN	1001	4.51	0.00	0.00	4.51	4.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_46_0_4_WIN	1001	0.65	0.00	0.00	0.65	0.65	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_47_0_4_WIN	1001	0.78	0.00	0.00	0.78	0.78	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_48_0_4_WIN	1001	0.84	0.00	0.00	0.84	0.84	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_49_0_4_WIN	1001	0.84	0.00	0.00	0.84	0.84	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_50_0_4_WIN	1001	0.78	0.00	0.00	0.78	0.78	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_51_0_4_WIN	1001	0.66	0.00	0.00	0.66	0.66	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_19_0_0_52_0_4_WIN	1001	0.49	0.00	0.00	0.49	0.49	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.	S

								19							00	
FIRSTFLOOR:ZONE2_WALL_19_0_0_53_0_4_WIN	1001	0.29	0.00	0.00	0.29	0.29	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_19_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE2_WALL_22_0_0_0_0_0_WIN	1001	0.42	0.00	0.00	0.42	0.42	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_1_0_0_WIN	1001	18.56	0.00	0.00	18.56	18.56	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_2_0_0_WIN	1001	2.51	0.00	0.00	2.51	2.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_3_0_0_WIN	1001	3.06	0.00	0.00	3.06	3.06	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_4_0_0_WIN	1001	3.37	0.00	0.00	3.37	3.37	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_5_0_0_WIN	1001	3.42	0.00	0.00	3.42	3.42	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_6_0_0_WIN	1001	3.19	0.00	0.00	3.19	3.19	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_7_0_0_WIN	1001	2.72	0.00	0.00	2.72	2.72	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_8_0_0_WIN	1001	2.04	0.00	0.00	2.04	2.04	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.	E

								19							00	
FIRSTFLOOR:ZONE2_WALL_22_0_0_9_0_0_WIN	1001	1.23	0.00	0.00	1.23	1.23	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_10_0_0_WIN	1001	0.37	0.00	0.00	0.37	0.37	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_11_0_1_WIN	1001	0.42	0.00	0.00	0.42	0.42	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_12_0_1_WIN	1001	18.56	0.00	0.00	18.56	18.56	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_13_0_1_WIN	1001	2.51	0.00	0.00	2.51	2.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_14_0_1_WIN	1001	3.06	0.00	0.00	3.06	3.06	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_15_0_1_WIN	1001	3.37	0.00	0.00	3.37	3.37	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_16_0_1_WIN	1001	3.42	0.00	0.00	3.42	3.42	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_17_0_1_WIN	1001	3.19	0.00	0.00	3.19	3.19	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_18_0_1_WIN	1001	2.72	0.00	0.00	2.72	2.72	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.	E

								19							00	
FIRSTFLOOR:ZONE2_WALL_22_0_0_19_0_1_WIN	1001	2.04	0.00	0.00	2.04	2.04	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_20_0_1_WIN	1001	1.23	0.00	0.00	1.23	1.23	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_21_0_1_WIN	1001	0.37	0.00	0.00	0.37	0.37	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_22_0_2_WIN	1001	0.42	0.00	0.00	0.42	0.42	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_23_0_2_WIN	1001	18.56	0.00	0.00	18.56	18.56	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_24_0_2_WIN	1001	2.51	0.00	0.00	2.51	2.51	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_25_0_2_WIN	1001	3.06	0.00	0.00	3.06	3.06	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_26_0_2_WIN	1001	3.37	0.00	0.00	3.37	3.37	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_27_0_2_WIN	1001	3.42	0.00	0.00	3.42	3.42	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_28_0_2_WIN	1001	3.19	0.00	0.00	3.19	3.19	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.	E

								19							00	
FIRSTFLOOR:ZONE2_WALL_22_0_0_29_0_2_WIN	1001	2.72	0.00	0.00	2.72	2.72	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_30_0_2_WIN	1001	2.04	0.00	0.00	2.04	2.04	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_31_0_2_WIN	1001	1.23	0.00	0.00	1.23	1.23	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_22_0_0_32_0_2_WIN	1001	0.37	0.00	0.00	0.37	0.37	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_22_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_24_0_0_0_0_0_WIN	1001	0.86	0.00	0.00	0.86	0.86	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_24_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_24_0_0_1_0_0_WIN	1001	38.94	0.00	0.00	38.94	38.94	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_24_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_24_0_0_2_0_0_WIN	1001	6.11	0.00	0.00	6.11	6.11	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_24_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_24_0_0_3_0_0_WIN	1001	7.23	0.00	0.00	7.23	7.23	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_24_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_24_0_0_4_0_0_WIN	1001	7.65	0.00	0.00	7.65	7.65	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_24_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_24_0_0_5_0_0_WIN	1001	7.59	0.00	0.00	7.59	7.59	1.017	0.8	0.881			No	FIRSTFLOOR:ZONE2_WALL_24_0_0	90.00	90.	E

								19							00	
FIRSTFLOOR:ZONE2_WALL_24_0_0_6_0_0_WIN	1001	6.98	0.00	0.00	6.98	6.98	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_24_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_24_0_0_7_0_0_WIN	1001	5.86	0.00	0.00	5.86	5.86	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_24_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_24_0_0_8_0_0_WIN	1001	4.36	0.00	0.00	4.36	4.36	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_24_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_24_0_0_9_0_0_WIN	1001	2.61	0.00	0.00	2.61	2.61	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_24_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE2_WALL_24_0_0_10_0_0_WIN	1001	0.79	0.00	0.00	0.79	0.79	1.017	0.819	0.881			No	FIRSTFLOOR:ZONE2_WALL_24_0_0	90.00	90.00	E
CHURCHROOF:ZONE3_WALL_3_0_0_0_0_0_WIN	1001	0.69	0.00	0.00	0.69	0.69	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_1_0_0_WIN	1001	29.81	0.00	0.00	29.81	29.81	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_2_0_0_WIN	1001	3.53	0.00	0.00	3.53	3.53	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_3_0_0_WIN	1001	4.49	0.00	0.00	4.49	4.49	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_4_0_0_WIN	1001	5.08	0.00	0.00	5.08	5.08	1.017	0.8	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.	S

								19							00	
CHURCHROOF:ZONE3_WALL_3_0_0_5_0_0_WIN	1001	5.25	0.00	0.00	5.25	5.25	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_6_0_0_WIN	1001	4.98	0.00	0.00	4.98	4.98	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_7_0_0_WIN	1001	4.30	0.00	0.00	4.30	4.30	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_8_0_0_WIN	1001	3.27	0.00	0.00	3.27	3.27	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_9_0_0_WIN	1001	2.00	0.00	0.00	2.00	2.00	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_10_0_0_WIN	1001	0.61	0.00	0.00	0.61	0.61	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_11_0_1_WIN	1001	0.58	0.00	0.00	0.58	0.58	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_12_0_1_WIN	1001	25.12	0.00	0.00	25.12	25.12	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_13_0_1_WIN	1001	3.21	0.00	0.00	3.21	3.21	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_14_0_1_WIN	1001	3.98	0.00	0.00	3.98	3.98	1.017	0.8	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.	S

								19							00	
CHURCHROOF:ZONE3_WALL_3_0_0_15_0_1_WIN	1001	4.44	0.00	0.00	4.44	4.44	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_16_0_1_WIN	1001	4.54	0.00	0.00	4.54	4.54	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_17_0_1_WIN	1001	4.27	0.00	0.00	4.27	4.27	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_18_0_1_WIN	1001	3.66	0.00	0.00	3.66	3.66	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_19_0_1_WIN	1001	2.76	0.00	0.00	2.76	2.76	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_20_0_1_WIN	1001	1.68	0.00	0.00	1.68	1.68	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_21_0_1_WIN	1001	0.51	0.00	0.00	0.51	0.51	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_22_0_2_WIN	1001	0.58	0.00	0.00	0.58	0.58	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_23_0_2_WIN	1001	25.12	0.00	0.00	25.12	25.12	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_24_0_2_WIN	1001	3.21	0.00	0.00	3.21	3.21	1.017	0.8	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.	S

								19							00	
CHURCHROOF:ZONE3_WALL_3_0_0_25_0_2_WIN	1001	3.98	0.00	0.00	3.98	3.98	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_26_0_2_WIN	1001	4.44	0.00	0.00	4.44	4.44	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_27_0_2_WIN	1001	4.54	0.00	0.00	4.54	4.54	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_28_0_2_WIN	1001	4.27	0.00	0.00	4.27	4.27	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_29_0_2_WIN	1001	3.66	0.00	0.00	3.66	3.66	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_30_0_2_WIN	1001	2.76	0.00	0.00	2.76	2.76	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_31_0_2_WIN	1001	1.68	0.00	0.00	1.68	1.68	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
CHURCHROOF:ZONE3_WALL_3_0_0_32_0_2_WIN	1001	0.51	0.00	0.00	0.51	0.51	1.017	0.819	0.881			No	CHURCHROOF:ZONE3_WALL_3_0_0	180.00	90.00	S
FIRSTFLOOR:ZONE6_WALL_3_0_0_0_0_1_WIN	1001	15.19	2.30	0.55	18.04	18.04	1.017	0.819	0.881	1.673	1.673	No	FIRSTFLOOR:ZONE6_WALL_3_0_0	270.00	90.00	W
FIRSTFLOOR:ZONE6_WALL_3_0_0_1_0_0_WIN	1001	15.	2.30	0.55	18.04	18.04	1.017	0.8	0.881	1.673	1.673	No	FIRSTFLOOR:ZONE6_WALL_3_0_0	270.00	90.	W

		19						19							00	
FIRSTFLOOR:ZONE7_WALL_2_0_0_0_0_1_WIN	1001	15.19	2.30	0.55	18.04	18.04	1.017	0.819	0.881	1.673	1.673	No	FIRSTFLOOR:ZONE7_WALL_2_0_0	90.00	90.00	E
FIRSTFLOOR:ZONE7_WALL_2_0_0_1_0_0_WIN	1001	15.19	2.30	0.55	18.04	18.04	1.017	0.819	0.881	1.673	1.673	No	FIRSTFLOOR:ZONE7_WALL_2_0_0	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE1_WALL_3_0_0_0_0_3_WIN	1001	16.50	0.00	0.00	16.50	16.50	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE1_WALL_3_0_0	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE1_WALL_3_0_0_1_0_2_WIN	1001	16.50	0.00	0.00	16.50	16.50	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE1_WALL_3_0_0	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE1_WALL_3_0_0_2_0_1_WIN	1001	16.50	0.00	0.00	16.50	16.50	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE1_WALL_3_0_0	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE1_WALL_3_0_0_3_0_0_WIN	1001	16.50	0.00	0.00	16.50	16.50	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE1_WALL_3_0_0	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE1_WALL_4_0_0_0_0_0_WIN	1001	13.26	0.00	0.00	13.26	13.26	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE1_WALL_4_0_0	0.00	90.00	N
BASEMENTXABOVEGRADE:ZONE3_WALL_3_0_0_0_0_1_WIN	1001	21.07	0.00	0.00	21.07	21.07	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE3_WALL_3_0_0	0.00	90.00	N
BASEMENTXABOVEGRADE:ZONE3_WALL_3_0_0_1_0_0_WIN	1001	14.92	0.00	0.00	14.92	14.92	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE3_WALL_3_0_0	0.00	90.00	N
BASEMENTXABOVEGRADE:ZONE4_WALL_22_0_0_0_0_4_WIN	1001	15.	0.00	0.00	15.93	15.93	1.017	0.8	0.881			No	BASEMENTXABOVEGRADE:ZONE4_WALL_22_0_0	90.00	90.	E

		93						19							00	
BASEMENTXABOVEGRADE:ZONE4_WALL_22_0_0_1_0_3_WIN	1001	15.93	0.00	0.00	15.93	15.93	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE4_WALL_22_0_0	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE4_WALL_22_0_0_3_0_1_WIN	1001	15.93	0.00	0.00	15.93	15.93	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE4_WALL_22_0_0	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE4_WALL_22_0_0_4_0_0_WIN	1001	15.93	0.00	0.00	15.93	15.93	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE4_WALL_22_0_0	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE4_WALL_24_0_0_0_0_1_WIN	1001	15.95	0.00	0.00	15.95	15.95	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE4_WALL_24_0_0	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE4_WALL_24_0_0_1_0_0_WIN	1001	15.95	0.00	0.00	15.95	15.95	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE4_WALL_24_0_0	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE8_WALL_4_0_0_0_0_3_WIN	1001	13.30	0.00	0.00	13.30	13.30	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE8_WALL_4_0_0	270.00	90.00	W
BASEMENTXABOVEGRADE:ZONE8_WALL_4_0_0_1_0_2_WIN	1001	13.30	0.00	0.00	13.30	13.30	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE8_WALL_4_0_0	270.00	90.00	W
BASEMENTXABOVEGRADE:ZONE8_WALL_4_0_0_2_0_1_WIN	1001	13.30	0.00	0.00	13.30	13.30	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE8_WALL_4_0_0	270.00	90.00	W
BASEMENTXABOVEGRADE:ZONE8_WALL_4_0_0_3_0_0_WIN	1001	13.30	0.00	0.00	13.30	13.30	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE8_WALL_4_0_0	270.00	90.00	W
BASEMENTXABOVEGRADE:ZONE9_WALL_5_0_0_0_0_1_WIN	1001	13.	0.00	0.00	13.33	13.33	1.017	0.8	0.881			No	BASEMENTXABOVEGRADE:ZONE9_WALL_5_0_0	270.00	90.	W

		33						19							00	
BASEMENTXABOVEGRADE:ZONE9_WALL_5_0_0_1_0_0_WIN	1001	13.33	0.00	0.00	13.33	13.33	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE9_WALL_5_0_0	270.00	90.00	W
BASEMENTXABOVEGRADE:ZONE12_WALL_3_0_0_0_0_0_WIN	1001	8.98	0.00	0.00	8.98	8.98	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE12_WALL_3_0_0	0.00	90.00	N
BASEMENTXABOVEGRADE:ZONE13_WALL_5_0_0_0_0_4_WIN	1001	8.06	0.00	0.00	8.06	8.06	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE13_WALL_5_0_0	180.00	90.00	S
BASEMENTXABOVEGRADE:ZONE13_WALL_5_0_0_1_0_3_WIN	1001	8.06	0.00	0.00	8.06	8.06	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE13_WALL_5_0_0	180.00	90.00	S
BASEMENTXABOVEGRADE:ZONE13_WALL_5_0_0_2_0_2_WIN	1001	8.06	0.00	0.00	8.06	8.06	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE13_WALL_5_0_0	180.00	90.00	S
BASEMENTXABOVEGRADE:ZONE13_WALL_5_0_0_3_0_1_WIN	1001	8.06	0.00	0.00	8.06	8.06	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE13_WALL_5_0_0	180.00	90.00	S
BASEMENTXABOVEGRADE:ZONE13_WALL_5_0_0_4_0_0_WIN	1001	8.06	0.00	0.00	8.06	8.06	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE13_WALL_5_0_0	180.00	90.00	S
BASEMENTXABOVEGRADE:ZONE14_WALL_2_0_0_0_0_1_WIN	1001	8.80	0.00	0.00	8.80	8.80	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE14_WALL_2_0_0	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE14_WALL_2_0_0_1_0_0_WIN	1001	6.60	0.00	0.00	6.60	6.60	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE14_WALL_2_0_0	90.00	90.00	E
BASEMENTXABOVEGRADE:ZONE15_WALL_5_0_0_0_0_1_WIN	1001	7.52	0.00	0.00	7.52	7.52	1.017	0.8	0.881			No	BASEMENTXABOVEGRADE:ZONE15_WALL_5_0_0	269.52	90.	W

								19							00	
BASEMENTXABOVEGRADE:ZONE15_WALL_5_0_0_1_0_0_WIN	1001	11.64	0.00	0.00	11.64	11.64	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE15_WALL_5_0_0	269.52	90.00	W
BASEMENTXABOVEGRADE:ZONE16_WALL_5_0_0_0_0_1_WIN	1001	16.30	0.00	0.00	16.30	16.30	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE16_WALL_5_0_0	270.00	90.00	W
BASEMENTXABOVEGRADE:ZONE16_WALL_5_0_0_1_0_0_WIN	1001	16.30	0.00	0.00	16.30	16.30	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE16_WALL_5_0_0	270.00	90.00	W
BASEMENTXABOVEGRADE:ZONE16_WALL_7_0_0_0_0_5_WIN	1001	16.24	0.00	0.00	16.24	16.24	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE16_WALL_7_0_0	270.00	90.00	W
BASEMENTXABOVEGRADE:ZONE16_WALL_7_0_0_1_0_4_WIN	1001	16.24	0.00	0.00	16.24	16.24	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE16_WALL_7_0_0	270.00	90.00	W
BASEMENTXABOVEGRADE:ZONE16_WALL_7_0_0_2_0_3_WIN	1001	16.24	0.00	0.00	16.24	16.24	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE16_WALL_7_0_0	270.00	90.00	W
BASEMENTXABOVEGRADE:ZONE16_WALL_7_0_0_3_0_2_WIN	1001	16.24	0.00	0.00	16.24	16.24	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE16_WALL_7_0_0	270.00	90.00	W
BASEMENTXABOVEGRADE:ZONE16_WALL_7_0_0_4_0_1_WIN	1001	16.24	0.00	0.00	16.24	16.24	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE16_WALL_7_0_0	270.00	90.00	W
BASEMENTXABOVEGRADE:ZONE16_WALL_7_0_0_5_0_0_WIN	1001	16.24	0.00	0.00	16.24	16.24	1.017	0.819	0.881			No	BASEMENTXABOVEGRADE:ZONE16_WALL_7_0_0	270.00	90.00	W
Total or Average						1526.72	1.017	0.8	0.881							

								19								
North Total or Average						114.244	1.017	0.819	0.881							
Non-North Total or Average						1412.48	1.017	0.819	0.881							

Interior Fenestration

	Construction	Area of One Opening [ft2]	Area of Openings [ft2]	Glass U-Factor [Btu/h-ft2-F]	Glass SHGC	Glass Visible Transmittance	Parent Surface
Total or Average			0.00	-	-	-	

Exterior Door

	Construction	U-Factor with Film [Btu/h-ft2-F]	U-Factor no Film [Btu/h-ft2-F]	Gross Area [ft2]	Parent Surface
GYM:ZONE3_WALL_4_0_0_0_0_3_DOOR	CZ5 NON-RES OPAQUE DOOR SWINGING U-.7 (3.975)	0.729	1.919	27.77	GYM:ZONE3_WALL_4_0_0

FIRSTFLOOR:ZONE3_WALL_5_0_0_22_0_0_DOOR	CZ5 NON-RES OPAQUE DOOR SWINGING U-.7 (3.975)	0.729	1.919	36.25	FIRSTFLOOR:ZONE3_WALL_5_0_0
FIRSTFLOOR:ZONE4_WALL_5_0_0_22_0_0_DOOR	CZ5 NON-RES OPAQUE DOOR SWINGING U-.7 (3.975)	0.729	1.919	40.45	FIRSTFLOOR:ZONE4_WALL_5_0_0
BASEMENTXABOVEGRADE:ZONE2_WALL_2_0_0_0_0_0_DOOR	CZ5 NON-RES OPAQUE DOOR SWINGING U-.7 (3.975)	0.729	1.919	22.80	BASEMENTXABOVEGRADE:ZONE2_WALL_2_0_0
BASEMENTXABOVEGRADE:ZONE4_WALL_22_0_0_2_0_2_DOOR	CZ5 NON-RES OPAQUE DOOR SWINGING U-.7 (3.975)	0.729	1.919	18.96	BASEMENTXABOVEGRADE:ZONE4_WALL_22_0_0
BASEMENTXBELOWGRADE:ZONE2_WALL_2_0_0_0_0_0_DOOR	CZ5 NON-RES OPAQUE DOOR SWINGING U-.7 (3.975)	0.729	1.919	15.04	BASEMENTXBELOWGRADE:ZONE2_WALL_2_0_0
BASEMENTXABOVEGRADE:ZONE14_WALL_6_0_0_0_0_0_DOOR	CZ5 NON-RES OPAQUE DOOR SWINGI	0.729	1.919	16.65	BASEMENTXABOVEGRADE:ZONE14_WALL_6_0_0

	NG U-.7 (3.975)				
BASEMENTXABOVEGRADE:ZONE15_WALL_6_0_0_0_0_0_DOOR	CZ5 NON-RES OPAQUE DOOR SWINGING U-.7 (3.975)	0.729	1.919	16.65	BASEMENTXABOVEGRADE:ZONE15_WALL_6_0_0

Table of Contents

Report: **Lighting Summary**

For: **Entire Facility**

Timestamp: **2019-12-26 10:47:47**

Interior Lighting

	Zone	Lighting Power Density [Btu/h-ft2]	Zone Area [ft2]	Total Power [Btu/h]	End Use Subcategory	Schedule Name	Scheduled Hours/Week [hr]	Hours/Week > 1% [hr]	Full Load Hours/Week [hr]	Return Air Fraction	Conditioned (Y/N)	Consumption [kWh]
Interior Lighting Total		0.0000	0.00	0.00								0.00

Daylighting

	Zone	Control Name	Daylighting Method	Control Type	Fraction Controlled	Lighting Installed in Zone [Btu/h]	Lighting Controlled [Btu/h]
None							

Exterior Lighting

	Total Watts	Astronomical Clock/Schedule	Schedule Name	Scheduled Hours/Week [hr]	Hours/Week > 1% [hr]	Full Load Hours/Week [hr]	Consumption [kWh]
Exterior Lighting Total	0.00						0.00

[Table of Contents](#)

Report: **Equipment Summary**

For: **Entire Facility**

Timestamp: **2019-12-26 10:47:47**

Central Plant

	Type	Nominal Capacity [Btu/h]	Nominal Efficiency [Btuh/Btuh]	IPLV in SI Units [Btuh/Btuh]	IPLV in IP Units [Btu/W-h]
BOILER	Boiler:HotWater	996952.59	0.89		

Cooling Coils

	Type	Design Coil Load [Btu/h]	Nominal Total Capacity [Btu/h]	Nominal Sensible Capacity [Btu/h]	Nominal Latent Capacity [Btu/h]	Nominal Sensible Heat Ratio	Nominal Efficiency [Btuh/Btuh]	Nominal Coil UA Value [Btu/h-F]	Nominal Coil Surface Area [ft2]
None									

DX Cooling Coils

	DX Cooling Coil Type	Standard Rated Net Cooling Capacity [ton]	Standard Rated Net COP [Btuh/Btuh]	EER [Btu/W-h]	SEER [Btu/W-h]	IEER [Btu/W-h]
None						

DX Cooling Coil ASHRAE 127 Standard Ratings Report

	DX Cooling Coil Type	Rated Net Cooling Capacity Test A [ton]	Rated Electric Power Test A [W]	Rated Net Cooling Capacity Test B [ton]	Rated Electric Power Test B [W]	Rated Net Cooling Capacity Test C [ton]	Rated Electric Power Test C [W]	Rated Net Cooling Capacity Test D [ton]	Rated Electric Power Test D [W]
None									

DX Heating Coils

	DX Heating Coil Type	High Temperature Heating (net) Rating Capacity [Btu/h]	Low Temperature Heating (net) Rating Capacity [Btu/h]	HSPF [Btu/W-h]	Region Number
None					

Heating Coils

	Type	Design Coil Load [Btu/h]	Nominal Total Capacity [Btu/h]	Nominal Efficiency [Btuh/Btuh]
None				

Fans

	Type	Total Efficiency [Btuh/Btuh]	Delta Pressure [psi]	Max Air Flow Rate [ft3/min]	Rated Electric Power [W]	Rated Power Per Max Air Flow Rate [W-min/ft3]	Motor Heat In Air Fraction	End Use	Design Day Name for Fan Sizing Peak	Date/Time for Fan Sizing Peak

None										

Pumps

	Type	Control	Head [psi]	Water Flow [gal/min]	Electric Power [W]	Power Per Water Flow Rate [W-min/gal]	Motor Efficiency [Btuh/Btuh]
HW LOOP SUPPLY PUMP	Pump:VariableSpeed	Intermittent	2.90	110.292138	198.22	1.80	0.90

Service Water Heating

	Type	Storage Volume [ft3]	Input [Btu/h]	Thermal Efficiency [Btuh/Btuh]	Recovery Efficiency [Btuh/Btuh]	Energy Factor
None						

[Table of Contents](#)

Report: **HVAC Sizing Summary**

For: **Entire Facility**

Timestamp: **2019-12-26 10:47:47**

Zone Sensible Cooling

	Calculated Design Load [Btu/h]	User Design Load [Btu/h]	User Design Load per Are	Calculated Design Air Flow	User Design Air Flow [ft3/min]	Design Day Name	Date/Time Of Peak {TIMESTAMP}	Thermostat Setpoint Temperature at Peak	Indoor Temperature at Peak Load [F]	Indoor Humidity Ratio at Peak Load [lbWat	Outdoor Temperature at Peak Load [F]	Outdoor Humidity Ratio at Peak Load [lbWat	Minimum Outdoor Air Flow Rate	Heat Gain Rate from DO

			a [Btu/h-ft2]	[ft3/min]				Load [F]		er/lbAir]		er/lbAir]	[ft3/min]	AS [Btu/h]
GYM:ZONE3	28146.39	32368.35	5.44	953.607	1096.648	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	7/31 16:20:00	84.99	84.99	0.01371	84.45	0.01371	505.660	0.00
GYM:ZONE1	1165.83	1340.70	9.50	39.499	45.423	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	7/31 09:00:00	84.99	84.99	0.01371	77.11	0.01371	11.998	0.00
GYM:ZONE2	403.56	464.10	7.27	13.673	15.724	SUMMER DESIGN DAY IN MQP WOR	7/31 16:50:00	84.99	84.99	0.01371	83.81	0.01371	5.427	0.00

						CESTER GOSPEL CHURCH (O1-O1:31-12) JUL								
FIRSTFLOOR:ZONE3	4165.52	4790.35	14.85	141.129	162.298	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	7/31 15:30:00	84.99	84.99	0.01371	85.34	0.01371	51.635	0.00
FIRSTFLOOR:ZONE4	3932.15	4521.97	13.96	133.222	153.205	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	7/31 14:00:00	84.99	84.99	0.01371	85.82	0.01371	51.851	0.00
FIRSTFLOOR:ZONE2	47410.60	54522.19	5.94	1606.284	1847.227	SUMMER DESIGN	7/31 16:20:00	84.99	84.99	0.01371	84.45	0.01371	1468.770	0.00

						DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL							
FIRSTFLOOR:ZONE6	2917.18	3354.76	13.70	98.835	113.660	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	7/31 16:20:00	84.99	84.99	0.01371	84.45	0.01371	39.176	0.00
FIRSTFLOOR:ZONE7	2162.95	2487.39	10.16	73.281	84.274	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	7/31 09:00:00	84.99	84.99	0.01371	77.11	0.01371	39.176	0.00

FIRSTFLOOR:ZONE1	1237.68	1423.33	12.40	41.933	48.223	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	7/31 18:30:00	84.99	84.99	0.01371	80.83	0.01371	18.370	0.00
BASEMENTXABOVEGRADE:ZONE1	4246.25	4883.18	6.24	143.864	165.444	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	7/31 09:40:00	84.99	84.99	0.01371	78.90	0.01371	66.514	0.00
BASEMENTXABOVEGRADE:ZONE2	737.31	847.91	2.00	24.980	36.098	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31	7/31 16:10:00	84.99	84.99	0.01371	84.66	0.01371	36.098	0.00

						-12) JUL								
BASEMENTXABOVEGRADE:ZONE 3	480.43	552.49	1.08	16.277	43.337	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	7/31 15:50:00	84.99	84.99	0.01371	85.03	0.01371	43.337	0.00
BASEMENTXABOVEGRADE:ZONE 4	10862.27	12491.61	1.49	368.017	714.050	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	7/31 16:30:00	84.99	84.99	0.01371	84.24	0.01371	714.050	0.00
BASEMENTXABOVEGRADE:ZONE 5	411.25	472.93	2.27	13.933	17.684	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL	7/31 16:40:00	84.99	84.99	0.01371	84.02	0.01371	17.684	0.00

						CHURCH (O1-O1:31-12) JUL								
BASEMENTXABOVEGRADE:ZONE 6	393.56	452.59	1.28	13.334	30.131	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	7/31 16:30:00	84.99	84.99	0.01371	84.24	0.01371	30.131	0.00
BASEMENTXABOVEGRADE:ZONE 7	622.33	715.68	1.10	21.085	55.362	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	7/31 15:40:00	84.99	84.99	0.01371	85.19	0.01371	55.362	0.00
BASEMENTXABOVEGRADE:ZONE 8	5428.93	6243.27	4.05	183.934	211.524	SUMMER DESIGN DAY IN MQP WOR	7/31 17:20:00	84.99	84.99	0.01371	83.07	0.01371	131.087	0.00

						CESTER GOSPEL CHURCH (O1-O1:31-12) JUL								
BASEMENTXABOVEGRADE:ZONE 9	2628.17	3022.40	6.64	89.043	102.400	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	7/31 17:20:00	84.99	84.99	0.01371	83.07	0.01371	38.678	0.00
BASEMENTXABOVEGRADE:ZONE 10	321.24	369.42	1.32	10.884	23.846	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	7/31 16:40:00	84.99	84.99	0.01371	84.02	0.01371	23.846	0.00
BASEMENTXABOVEGRADE:ZONE 11	851.36	979.06	1.23	28.844	67.760	SUMMER DESIGN	7/31 16:10:00	84.99	84.99	0.01371	84.66	0.01371	67.760	0.00

						DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL								
BASEMENTXABOVEGRADE:ZONE 12	302.19	347.52	2.15	10.238	13.750	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	7/31 18:30:00	84.99	84.99	0.01371	80.83	0.01371	13.750	0.00
BASEMENTXABOVEGRADE:ZONE 13	3085.72	3548.58	3.68	104.545	120.227	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	7/31 13:40:00	84.99	84.99	0.01371	85.56	0.01371	81.990	0.00

BASEMENTXABOVEGRADE:ZONE 14	1633.62	1878.66	3.12	55.347	63.649	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	7/31 10:50:00	84.99	84.99	0.01371	81.78	0.01371	51.121	0.00
BASEMENTXABOVEGRADE:ZONE 15	2287.09	2630.15	4.57	77.487	89.110	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) JUL	7/31 17:00:00	84.99	84.99	0.01371	83.60	0.01371	48.951	0.00
BASEMENTXABOVEGRADE:ZONE 16	12604.08	14494.69	9.66	427.030	491.084	SUMMER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31	7/31 17:10:00	84.99	84.99	0.01371	83.34	0.01371	127.564	0.00

						-12) JUL								

The Design Load is the zone sensible load only. It does not include any system effects or ventilation loads.

Zone Sensible Heating

	Calculated Design Load [Btu/h]	User Design Load [Btu/h]	User Design Load per Area [Btu/h-ft2]	Calculated Design Air Flow [ft3/min]	User Design Air Flow [ft3/min]	Design Day Name	Date/Time Of Peak {TIMESTAMP}	Thermostat Setpoint Temperature at Peak Load [F]	Indoor Temperature at Peak Load [F]	Indoor Humidity Ratio at Peak Load [lbWater/lbAir]	Outdoor Temperature at Peak Load [F]	Outdoor Humidity Ratio at Peak Load [lbWater/lbAir]	Minimum Outdoor Air Flow Rate [ft3/min]	Heat Gain Rate from DOAS [Btu/h]
GYM:ZONE3	145964.94	182456.18	30.68	2568.568	3210.710	WINTER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)	1/15 06:00:00	68.00	68.00	0.00093	1.94	0.00090	505.660	0.00
GYM:ZONE1	10601.52	13251.90	93.91	186.557	233.196	WINTER DESIGN DAY IN MQP WORCESTER GOSP	1/15 06:00:00	68.00	68.00	0.00093	1.94	0.00090	11.998	0.00

						EL CHURCH (O1-O1:31-12)							
GYM:ZONE2	5563.45	6954.31	108.95	97.901	122.376	WINTER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)	1/15 06:00:00	68.00	68.00	0.00093	1.94	0.00090	5.427	0.00
FIRSTFLOOR:ZONE3	24554.57	30693.21	95.12	432.091	540.113	WINTER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)	1/15 06:00:00	68.00	68.00	0.00097	1.94	0.00090	51.635	0.00
FIRSTFLOOR:ZONE4	25258.35	31572.94	97.44	444.475	555.594	WINTER DESIGN DAY IN MQP WORCESTER	1/15 06:00:00	68.00	68.00	0.00097	1.94	0.00090	51.851	0.00

						GOSPEL CHURCH (O1-O1:31-12)								
FIRSTFLOOR:ZONE2	225299.71	281624.64	30.68	3964.634	4955.792	WINTER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)	1/15 06:00:00	68.00	68.00	0.00098	1.94	0.00090	1468.770	0.00
FIRSTFLOOR:ZONE6	12728.80	15911.00	64.99	223.991	279.988	WINTER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)	1/15 06:00:00	68.00	68.00	0.00097	1.94	0.00090	39.176	0.00
FIRSTFLOOR:ZONE7	14597.24	18246.56	74.53	256.870	321.087	WINTER DESIGN DAY IN MQP WORCEST	1/15 06:00:00	68.00	68.00	0.00097	1.94	0.00090	39.176	0.00

						ER GOSPEL CHURCH (O1-O1:31-12)								
FIRSTFLOOR:ZONE1	4310.81	5388.51	46.94	75.858	94.822	WINTER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)	1/15 06:00:00	68.00	68.00	0.00097	1.94	0.00090	18.370	0.00
BASEMENTXABOVEGRADE:ZONE1	20100.10	25125.12	32.12	353.705	442.131	WINTER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)	1/15 24:00:00	68.00	68.00	0.00098	1.94	0.00090	66.514	0.00
BASEMENTXABOVEGRADE:ZONE2	13396.92	16746.14	39.44	235.748	294.684	WINTER DESIGN DAY IN MQP WOR	1/15 24:00:00	68.00	68.00	0.00098	1.94	0.00090	36.098	0.00

						CESTER GOSPEL CHURCH (O1-O1:31-12)								
BASEMENTXABOVEGRADE:ZONE 3	12604.99	15756.23	30.91	221.812	277.265	WINTER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)	1/15 24:00:00	68.00	68.00	0.00098	1.94	0.00090	43.337	0.00
BASEMENTXABOVEGRADE:ZONE 4	109584.76	136980.96	16.31	1928.380	2410.475	WINTER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)	1/15 24:00:00	68.00	68.00	0.00098	1.94	0.00090	714.050	0.00
BASEMENTXABOVEGRADE:ZONE 5	5043.21	6304.01	30.31	88.746	110.933	WINTER DESIGN DAY IN MQP	1/15 24:00:00	68.00	68.00	0.00098	1.94	0.00090	17.684	0.00

						WORCESTER GOSPEL CHURCH (O1-O1:31-12)								
BASEMENTXABOVEGRADE:ZONE 6	8173.92	10217.40	28.83	143.838	179.797	WINTER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)	1/15 24:00:00	68.00	68.00	0.00098	1.94	0.00090	30.131	0.00
BASEMENTXABOVEGRADE:ZONE 7	12114.52	15143.15	23.26	213.181	266.476	WINTER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)	1/15 24:00:00	68.00	68.00	0.00098	1.94	0.00090	55.362	0.00
BASEMENTXABOVEGRADE:ZONE 8	27503.28	34379.11	22.30	483.980	604.974	WINTER DESIGN DAY IN	1/15 24:00:00	68.00	68.00	0.00098	1.94	0.00090	131.087	0.00

						MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)								
BASEMENTXABOVEGRADE:ZONE 9	8867.52	11084.40	24.37	156.043	195.054	WINTER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)	1/15 24:00:00	68.00	68.00	0.00098	1.94	0.00090	38.678	0.00
BASEMENTXABOVEGRADE:ZONE 10	4903.98	6129.97	21.86	86.296	107.870	WINTER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)	1/15 24:00:00	68.00	68.00	0.00098	1.94	0.00090	23.846	0.00
BASEMENTXABOVEGRADE:ZONE 11	12782.47	15978.09	20.05	224.935	281.169	WINTER DESIGN DAY	1/15 24:00:00	68.00	68.00	0.00098	1.94	0.00090	67.760	0.00

						IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)								
BASEMENTXABOVEGRADE:ZONE 12	6495.78	8119.73	50.21	114.307	142.884	WINTER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)	1/15 24:00:00	68.00	68.00	0.00098	1.94	0.00090	13.750	0.00
BASEMENTXABOVEGRADE:ZONE 13	17027.55	21284.43	22.07	299.636	374.545	WINTER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)	1/15 24:00:00	68.00	68.00	0.00098	1.94	0.00090	81.990	0.00
BASEMENTXABOVEGRADE:ZONE 14	16719.54	20899.42	34.76	294.216	367.770	WINTER DESIGN	1/15 24:00:00	68.00	68.00	0.00098	1.94	0.00090	51.121	0.00

						DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)								
BASEMENTXABOVEGRADE:ZONE 15	16265.68	20332.09	35.32	286.230	357.787	WINTER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)	1/15 24:00:00	68.00	68.00	0.00098	1.94	0.00090	48.951	0.00
BASEMENTXABOVEGRADE:ZONE 16	34250.04	42812.55	28.54	602.703	753.379	WINTER DESIGN DAY IN MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12)	1/15 24:00:00	68.00	68.00	0.00098	1.94	0.00090	127.564	0.00

The Design Load is the zone sensible load only. It does not include any system effects or ventilation loads.

System Design Air Flow Rates

	Calculated cooling [ft3/min]	User cooling [ft3/min]	Calculated heating [ft3/min]	User heating [ft3/min]	Adjusted cooling [ft3/min]	Adjusted heating [ft3/min]	Adjusted main [ft3/min]	Calculated Heating Air Flow Ratio []	User Heating Air Flow Ratio []
None									

Plant Loop Coincident Design Fluid Flow Rate Adjustments

	Previous Design Volume Flow Rate [ft3/min]	Algorithm Volume Flow Rate [ft3/min]	Coincident Design Volume Flow Rate [ft3/min]	Coincident Size Adjusted	Peak Sizing Period Name	Peak Day into Period {TIMESTAMP}[day]	Peak Hour Of Day {TIMESTAMP}[hr]	Peak Step Start Minute {TIMESTAMP}[min]
None								

Coil Sizing Summary

	Coil Type	HVAC Type	HVAC Name	Coil Final Gross Total Capacit	Coil Final Gross Sensible Capa	Coil Final Reference Air Volume Fl	Coil Final Reference Plant Fluid Vol	Coil U-value Times Area Va	Design Day Name at Sensible I	Date/Time at Sensible Ideal Loads P	Design Day Name at Air Flow	Date/Time at Air Flow Ideal Loads P	Coil Total Capacity at Ideal L	Coil Sensible Capacity at Ide	Coil Air Volume Flow Rate at Ideal	Coil Entering Air Drybulb at I	Coil Entering Air Wetbulb at I	Coil Entering Air Humidity Ratio at Ideal Loads Peak [lb Water/lbDr	Coil Leaving Air Drybulb at I	Coil Leaving Air Wetbulb at Id	Coil Leaving Air Humidity Ratio at	Outdoor Air Drybulb at Ideal	Outdoor Air Humidity Ratio at Ideal Loads Peak [lb Water/lbDr	Outdoor Air Wetbulb at Ideal	Outdoor Air Flow Percentage at Ideal Load	Zone Air Drybulb at Ideal Lo	Zone Air Humidity Ratio at Ideal Loads Peak [lb Water/lbDryAir]	Zone Air Relative Humidity at Ide	Zone Sensible Heat Gain at Id	Zone Latent Heat Gain at I	Coil Total Capacity at Rating Conditi	Coil Sensible Capacity at Rating Con

				y[Btu/h]	city[Btu/h]	owRate[ft3/min]	umeFlowRate[ft3/min]	lue[Btu/h-F]	dealLoadsPeak	eak	IdealLoadsPeak	eak	oadsPeak[Btu/h]	alLoadsPeak[Btu/h]	LoadsPeak[ft3/min]	dealLoadsPeak[F]	dealLoadsPeak[F]	yAir]	dealLoadsPeak[F]	ealLoadsPeak[F]	IdealLoadsPeak[F]	LoadsPeak[F]	yAir]	LoadsPeak[F]	sPeak[%]	adsPeak[F]		alLoadsPeak[%]	ealLoadsPeak[Btu/h]	dealLoadsPeak[Btu/h]	ons[Btu/h]	ditions[Btu/h]
None																																

Table of Contents

Report: **System Summary**

For: **Entire Facility**

Timestamp: **2019-12-26 10:47:47**

Economizer

	High Limit Shutoff Control	Minimum Outdoor Air [ft3/min]	Maximum Outdoor Air [ft3/min]	Return Air Temp Limit	Return Air Enthalpy Limit	Outdoor Air Temperature Limit [F]	Outdoor Air Enthalpy Limit [F]
None							

Demand Controlled Ventilation using Controller:MechanicalVentilation

	Controller:MechanicalVentilation Name	Outdoor Air Per Person [ft3/min-person]	Outdoor Air Per Area [ft3/min-ft2]	Outdoor Air Per Zone [ft3/min]	Outdoor Air ACH [ACH]	Outdoor Air Method	Outdoor Air Schedule Name	Air Distribution Effectiveness in Cooling Mode	Air Distribution Effectiveness in Heating Mode	Air Distribution Effectiveness Schedule Name
None										

Time Not Comfortable Based on Simple ASHRAE 55-2004

	Winter Clothes [hr]	Summer Clothes [hr]	Summer or Winter Clothes [hr]
GYM:ZONE3	1510.17	1524.00	1510.17
GYM:ZONE1	1523.33	1524.00	1523.33
GYM:ZONE2	1523.17	1524.00	1523.17
FIRSTFLOOR:ZONE3	1479.33	1524.00	1479.33
FIRSTFLOOR:ZONE4	1477.17	1524.00	1477.17
FIRSTFLOOR:ZONE2	1428.67	1523.33	1428.67
FIRSTFLOOR:ZONE6	1491.17	1524.00	1491.17
FIRSTFLOOR:ZONE7	1497.83	1524.00	1497.83
FIRSTFLOOR:ZONE1	1478.17	1524.00	1478.17
BASEMENTXABOVEGRADE:ZONE1	1510.50	1524.00	1510.50
BASEMENTXABOVEGRADE:ZONE2	1524.00	1524.00	1524.00
BASEMENTXABOVEGRADE:ZONE3	1524.00	1524.00	1524.00
BASEMENTXABOVEGRADE:ZONE4	1488.67	1524.00	1488.67
BASEMENTXABOVEGRADE:ZONE5	1524.00	1524.00	1524.00
BASEMENTXABOVEGRADE:ZONE6	1524.00	1524.00	1524.00

BASEMENTXABOVEGRADE:ZONE7	1517.83	1524.00	1517.83
BASEMENTXABOVEGRADE:ZONE8	1506.67	1524.00	1506.67
BASEMENTXABOVEGRADE:ZONE9	1507.00	1524.00	1507.00
BASEMENTXABOVEGRADE:ZONE10	1518.50	1524.00	1518.50
BASEMENTXABOVEGRADE:ZONE11	1505.50	1524.00	1505.50
BASEMENTXABOVEGRADE:ZONE12	1524.00	1524.00	1524.00
BASEMENTXABOVEGRADE:ZONE13	1448.17	1524.00	1448.17
BASEMENTXABOVEGRADE:ZONE14	1511.00	1524.00	1511.00
BASEMENTXABOVEGRADE:ZONE15	1514.67	1524.00	1514.67
BASEMENTXABOVEGRADE:ZONE16	1486.00	1524.00	1486.00
CHURCHROOF:ZONE1	0.00	0.00	0.00
CHURCHROOF:ZONE4	0.00	0.00	0.00
CHURCHROOF:ZONE2	0.00	0.00	0.00
Facility	1524.00	1524.00	1524.00

Aggregated over the RunPeriods for Weather

Time Setpoint Not Met

	During Heating [hr]	During Cooling [hr]	During Occupied Heating [hr]	During Occupied Cooling [hr]
GYM:ZONE3	273.00	210.50	90.83	0.00
GYM:ZONE1	162.50	173.83	57.33	0.00
GYM:ZONE2	242.00	134.83	96.50	0.00
FIRSTFLOOR:ZONE3	8.33	195.83	0.00	0.00
FIRSTFLOOR:ZONE4	7.50	203.83	0.00	0.00
FIRSTFLOOR:ZONE2	48.00	216.00	0.00	0.00

FIRSTFLOOR:ZONE6	25.17	166.17	0.00	0.00
FIRSTFLOOR:ZONE7	19.50	149.83	0.00	0.00
FIRSTFLOOR:ZONE1	145.00	153.50	0.00	0.00
BASEMENTXABOVEGRADE:ZONE1	36.50	264.67	0.00	0.00
BASEMENTXABOVEGRADE:ZONE2	36.00	137.83	0.00	0.00
BASEMENTXABOVEGRADE:ZONE3	50.50	149.00	0.00	0.00
BASEMENTXABOVEGRADE:ZONE4	91.33	176.00	0.00	0.00
BASEMENTXABOVEGRADE:ZONE5	78.17	134.33	0.00	0.00
BASEMENTXABOVEGRADE:ZONE6	77.50	113.83	0.00	0.00
BASEMENTXABOVEGRADE:ZONE7	76.67	123.83	0.00	0.00
BASEMENTXABOVEGRADE:ZONE8	66.17	183.83	0.00	0.00
BASEMENTXABOVEGRADE:ZONE9	66.17	208.50	0.00	0.00
BASEMENTXABOVEGRADE:ZONE10	126.50	126.83	0.00	0.00
BASEMENTXABOVEGRADE:ZONE11	90.83	134.83	0.00	0.00
BASEMENTXABOVEGRADE:ZONE12	28.17	146.00	0.00	0.00
BASEMENTXABOVEGRADE:ZONE13	37.33	222.83	0.00	0.00
BASEMENTXABOVEGRADE:ZONE14	23.50	176.50	0.00	0.00
BASEMENTXABOVEGRADE:ZONE15	23.00	172.17	0.00	0.00
BASEMENTXABOVEGRADE:ZONE16	31.67	293.00	0.00	0.00
CHURCHROOF:ZONE1	0.00	0.00	0.00	0.00
CHURCHROOF:ZONE4	0.00	0.00	0.00	0.00
CHURCHROOF:ZONE2	0.00	0.00	0.00	0.00
Facility	423.83	345.83	105.83	0.00

Aggregated over the RunPeriods for Weather

[Table of Contents](#)

Report: **Outdoor Air Summary**

For: **Entire Facility**

Timestamp: **2019-12-26 10:47:47**

Average Outdoor Air During Occupied Hours

	Average Number of Occupants	Nominal Number of Occupants	Zone Volume [ft3]	Mechanical Ventilation [ACH]	Infiltration [ACH]	AFN Infiltration [ACH]	Simple Ventilation [ACH]
GYM:ZONE3	29.73	29.73	67651.14	0.000	0.315	0.000	0.000
GYM:ZONE1	0.71	0.71	1764.01	0.000	0.314	0.000	0.073
GYM:ZONE2	0.32	0.32	797.93	0.000	0.314	0.000	0.054
FIRSTFLOOR:ZONE3	6.45	6.45	6295.56	0.000	0.309	0.000	0.011
FIRSTFLOOR:ZONE4	6.48	6.48	6321.00	0.000	0.309	0.000	0.017
FIRSTFLOOR:ZONE2	183.56	183.56	163243.84	0.000	0.313	0.000	0.098
FIRSTFLOOR:ZONE6	4.90	4.90	4774.30	0.000	0.310	0.000	0.002
FIRSTFLOOR:ZONE7	4.90	4.90	4774.30	0.000	0.309	0.000	0.000
FIRSTFLOOR:ZONE1	2.30	2.30	2238.72	0.000	0.311	0.000	0.001
BASEMENTXABOVEGRADE:ZONE1	3.91	3.91	4364.75	0.000	0.516	0.000	0.000
BASEMENTXABOVEGRADE:ZONE2	2.12	2.12	2368.80	0.000	0.514	0.000	0.000
BASEMENTXABOVEGRADE:ZONE3	2.55	2.55	2843.86	0.000	0.516	0.000	0.000
BASEMENTXABOVEGRADE:ZONE4	41.99	41.99	46857.00	0.000	0.519	0.000	0.017
BASEMENTXABOVEGRADE:ZONE5	1.04	1.04	1160.48	0.000	0.516	0.000	0.000
BASEMENTXABOVEGRADE:ZONE6	1.77	1.77	1977.25	0.000	0.516	0.000	0.000

BASEMENTXABOVEGRADE:ZONE7	3.26	3.26	3632.92	0.000	0.516	0.000	0.000
BASEMENTXABOVEGRADE:ZONE8	7.71	7.71	8602.15	0.000	0.518	0.000	0.002
BASEMENTXABOVEGRADE:ZONE9	2.27	2.27	2538.14	0.000	0.518	0.000	0.002
BASEMENTXABOVEGRADE:ZONE10	1.40	1.40	1564.80	0.000	0.518	0.000	0.000
BASEMENTXABOVEGRADE:ZONE11	3.98	3.98	4446.53	0.000	0.517	0.000	0.001
BASEMENTXABOVEGRADE:ZONE12	0.81	0.81	902.28	0.000	0.513	0.000	0.000
BASEMENTXABOVEGRADE:ZONE13	4.82	4.82	5380.31	0.000	0.520	0.000	0.058
BASEMENTXABOVEGRADE:ZONE14	3.01	3.01	3354.66	0.000	0.515	0.000	0.002
BASEMENTXABOVEGRADE:ZONE15	2.88	2.88	3212.24	0.000	0.514	0.000	0.002
BASEMENTXABOVEGRADE:ZONE16	7.50	7.50	8370.92	0.000	0.517	0.000	0.015

Values shown for a single zone without multipliers

Minimum Outdoor Air During Occupied Hours

	Average Number of Occupants	Nominal Number of Occupants	Zone Volume [ft3]	Mechanical Ventilation [ACH]	Infiltration [ACH]	AFN Infiltration [ACH]	Simple Ventilation [ACH]
GYM:ZONE3	29.73	29.73	67651.14	0.000	0.005	0.000	0.000
GYM:ZONE1	0.71	0.71	1764.01	0.000	0.005	0.000	0.000
GYM:ZONE2	0.32	0.32	797.93	0.000	0.005	0.000	0.000
FIRSTFLOOR:ZONE3	6.45	6.45	6295.56	0.000	0.005	0.000	0.000
FIRSTFLOOR:ZONE4	6.48	6.48	6321.00	0.000	0.005	0.000	0.000

FIRSTFLOOR:ZONE2	183.56	183.56	163243.84	0.000	0.005	0.000	0.000
FIRSTFLOOR:ZONE6	4.90	4.90	4774.30	0.000	0.005	0.000	0.000
FIRSTFLOOR:ZONE7	4.90	4.90	4774.30	0.000	0.005	0.000	0.000
FIRSTFLOOR:ZONE1	2.30	2.30	2238.72	0.000	0.005	0.000	0.000
BASEMENTXABOVEGRADE:ZONE1	3.91	3.91	4364.75	0.000	0.008	0.000	0.000
BASEMENTXABOVEGRADE:ZONE2	2.12	2.12	2368.80	0.000	0.008	0.000	0.000
BASEMENTXABOVEGRADE:ZONE3	2.55	2.55	2843.86	0.000	0.008	0.000	0.000
BASEMENTXABOVEGRADE:ZONE4	41.99	41.99	46857.00	0.000	0.008	0.000	0.000
BASEMENTXABOVEGRADE:ZONE5	1.04	1.04	1160.48	0.000	0.008	0.000	0.000
BASEMENTXABOVEGRADE:ZONE6	1.77	1.77	1977.25	0.000	0.008	0.000	0.000
BASEMENTXABOVEGRADE:ZONE7	3.26	3.26	3632.92	0.000	0.008	0.000	0.000
BASEMENTXABOVEGRADE:ZONE8	7.71	7.71	8602.15	0.000	0.008	0.000	0.000
BASEMENTXABOVEGRADE:ZONE9	2.27	2.27	2538.14	0.000	0.008	0.000	0.000
BASEMENTXABOVEGRADE:ZONE10	1.40	1.40	1564.80	0.000	0.008	0.000	0.000
BASEMENTXABOVEGRADE:ZONE11	3.98	3.98	4446.53	0.000	0.008	0.000	0.000
BASEMENTXABOVEGRADE:ZONE12	0.81	0.81	902.28	0.000	0.008	0.000	0.000
BASEMENTXABOVEGRADE:ZONE13	4.82	4.82	5380.31	0.000	0.008	0.000	0.000
BASEMENTXABOVEGRADE:ZONE14	3.01	3.01	3354.66	0.000	0.008	0.000	0.000
BASEMENTXABOVEGRADE:ZONE15	2.88	2.88	3212.24	0.000	0.008	0.000	0.000
BASEMENTXABOVEGRADE:ZONE16	7.50	7.50	8370.92	0.000	0.008	0.000	0.000

Values shown for a single zone without multipliers

Table of Contents

Report: **Object Count Summary**

For: **Entire Facility**

Timestamp: **2019-12-26 10:47:47**

Surfaces by Class

	Total	Outdoors
Wall	336	110
Floor	139	29
Roof	128	18
Internal Mass	0	0
Building Detached Shading	0	0
Fixed Detached Shading	0	0
Window	299	299
Door	8	8
Glass Door	0	0
Shading	0	0
Overhang	0	0
Fin	0	0
Tubular Daylighting Device Dome	0	0
Tubular Daylighting Device Diffuser	0	0

HVAC

	Count
HVAC Air Loops	0
Conditioned Zones	25
Unconditioned Zones	3
Supply Plenums	0
Return Plenums	0

Input Fields

	Count
IDF Objects	0
Defaulted Fields	0
Fields with Defaults	0
Autosized Fields	0
Autosizable Fields	0
Autocalculated Fields	0
Autocalculatable Fields	0

Table of Contents

Report: **Sensible Heat Gain Summary**

For: **Entire Facility**

Timestamp: **2019-12-26 10:47:47**

Annual Building Sensible Heat Gain Components

	HVAC Zone Eq & Other Sensible Air Heating [kBtu]	HVAC Zone Eq & Other Sensible Air Cooling [ton-hrs]	HVAC Terminal Unit Sensible Air Heating [kBtu]	HVAC Terminal Unit Sensible Air Cooling [ton-hrs]	HVAC Input Heated Surface Heating [kBtu]	HVAC Input Cooled Surface Cooling [ton-hrs]	People Sensible Heat Addition [kBtu]	Lights Sensible Heat Addition [kBtu]	Equipment Sensible Heat Addition [kBtu]	Window Heat Addition [kBtu]	Interzone Air Transfer Heat Addition [kBtu]	Infiltration Heat Addition [kBtu]	Opaque Surface Conduction and Other Heat Addition [kBtu]	Equipment Sensible Heat Removal [kBtu]	Window Heat Removal [kBtu]	Interzone Air Transfer Heat Removal [kBtu]	Infiltration Heat Removal [kBtu]	Opaque Surface Conduction and Other Heat Removal [kBtu]
GYM:ZONE3	150452.201	0.000	0.000	0.000	0.000	0.000	15266.634	0.000	36863.044	24334.226	0.000	347.227	0.206	0.000	-13026.71	0.000	-62701.84	-151534.78
GYM:ZONE1	11075.403	0.000	0.000	0.000	0.000	0.000	364.727	0.000	874.666	3895.978	0.000	21.862	0.115	0.000	-1525.74	0.000	-1826.38	-12880.52
GYM:ZONE2	6325.431	0.000	0.000	0.000	0.000	0.000	165.989	0.000	395.643	715.999	0.000	12.787	0.009	0.000	-377.27	0.000	-767.08	-6471.49
FIRSTFLOOR:ZONE3	7412.776	0.000	0.000	0.000	0.000	0.000	3686.654	0.000	2000.083	8075.595	0.000	62.228	0.000	0.000	-2496.92	0.000	-4391.26	-14349.16
FIRSTFLOOR:ZONE4	7505.850	0.000	0.000	0.000	0.000	0.000	3702.229	0.000	2008.450	8157.156	0.000	59.198	0.000	0.000	-2398.36	0.000	-4498.76	-14535.77
FIRSTFLOOR:ZONE2	75562.309	0.000	0.000	0.000	0.000	0.000	98637.413	0.000	56893.327	117843.864	0.000	839.494	0.000	0.000	-45564.41	0.000	-136002.67	-168209.33
FIRSTFLOOR:ZONE6	4583.354	0.000	0.000	0.000	0.000	0.000	2769.766	0.000	1517.497	4608.512	0.000	55.831	0.037	0.000	-198	0.000	-356	-7981.43

															3.68		9.85	
FIRSTFLOOR:ZONE7	5146.103	0.000	0.000	0.000	0.000	0.000	2792.558	0.000	1517.497	4790.385	0.000	69.778	0.076	0.000	-1790.52	0.000	-3477.15	-9048.66
FIRSTFLOOR:ZONE1	1888.510	0.000	0.000	0.000	0.000	0.000	1277.366	0.000	711.571	0.000	0.000	28.514	0.009	0.000	0.000	0.000	-1951.32	-1954.64
BASEMENTXABOVEGRADE:ZONE1	7768.669	0.000	0.000	0.000	0.000	0.000	2223.770	0.000	4848.936	10843.037	0.000	65.053	0.147	0.000	-4810.13	0.000	-6037.01	-14902.33
BASEMENTXABOVEGRADE:ZONE2	5424.054	0.000	0.000	0.000	0.000	0.000	1227.518	0.000	2631.571	0.000	0.000	81.784	0.033	0.000	0.000	0.000	-2765.11	-6599.82
BASEMENTXABOVEGRADE:ZONE3	5245.658	0.000	0.000	0.000	0.000	0.000	1458.663	0.000	3159.330	2669.777	0.000	75.368	0.079	0.000	-2250.69	0.000	-3496.04	-6862.07
BASEMENTXABOVEGRADE:ZONE4	46496.138	0.000	0.000	0.000	0.000	0.000	23256.367	0.000	52054.833	15626.505	0.000	902.066	0.000	0.000	-5959.14	0.000	-63716.94	-68659.82
BASEMENTXABOVEGRADE:ZONE5	2237.892	0.000	0.000	0.000	0.000	0.000	595.463	0.000	1289.206	0.000	0.000	38.201	0.008	0.000	0.000	0.000	-1438.73	-2722.03
BASEMENTXABOVEGRADE:ZONE6	3644.155	0.000	0.000	0.000	0.000	0.000	1014.562	0.000	2196.587	0.000	0.000	71.266	0.028	0.000	0.000	0.000	-2370.69	-4555.88
BASEMENTXABOVEGRADE:ZONE7	5218.627	0.000	0.000	0.000	0.000	0.000	1854.693	0.000	4035.917	0.000	0.000	118.989	0.025	0.000	0.000	0.000	-4340.51	-6887.71
BASEMENTXABOVEGRADE:ZONE8	11377.367	0.000	0.000	0.000	0.000	0.000	4314.610	0.000	9556.390	8894.790	0.000	156.982	0.000	0.000	-358	0.000	-118	-188

															7.77		56.35	56.02
BASEMENTXABOVEGRADE:ZONE9	3581.490	0.000	0.000	0.000	0.000	0.000	1276.810	0.000	2819.695	4426.496	0.000	41.572	0.000	0.000	-1818.53	0.000	-3588.38	-6739.15
BASEMENTXABOVEGRADE:ZONE10	2285.706	0.000	0.000	0.000	0.000	0.000	790.351	0.000	1738.383	0.000	0.000	46.275	0.000	0.000	0.000	0.000	-2065.04	-2795.67
BASEMENTXABOVEGRADE:ZONE11	5557.380	0.000	0.000	0.000	0.000	0.000	2250.932	0.000	4939.782	0.000	0.000	128.053	0.000	0.000	0.000	0.000	-5550.95	-7325.19
BASEMENTXABOVEGRADE:ZONE12	2498.880	0.000	0.000	0.000	0.000	0.000	470.839	0.000	1002.364	693.930	0.000	31.898	0.000	0.000	-535.12	0.000	-1045.00	-3117.79
BASEMENTXABOVEGRADE:ZONE13	5869.937	0.000	0.000	0.000	0.000	0.000	2637.124	0.000	5977.143	9369.479	0.000	75.052	0.000	0.000	-2714.97	0.000	-7869.28	-13344.49
BASEMENTXABOVEGRADE:ZONE14	6039.768	0.000	0.000	0.000	0.000	0.000	1725.501	0.000	3726.789	2724.381	0.000	86.157	0.000	0.000	-859.57	0.000	-4042.92	-9400.11
BASEMENTXABOVEGRADE:ZONE15	5857.870	0.000	0.000	0.000	0.000	0.000	1653.908	0.000	3568.571	3322.230	0.000	80.841	0.000	0.000	-1115.71	0.000	-3855.31	-9512.41
BASEMENTXABOVEGRADE:ZONE16	12013.662	0.000	0.000	0.000	0.000	0.000	4231.902	0.000	9299.507	21144.137	0.000	95.469	0.000	0.000	-8284.84	0.000	-11908.65	-26591.18
CHURCHROOF:ZONE1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1419.280	7616.498	0.000	0.000	0.000	-9035.78	0.000
CHURCHROOF:ZONE4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	84.372	1743.912	0.000	0.000	0.000	-182	0.000

																	8.28	
CHURCHROOF:ZONE2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	136.261	1691.154	0.000	0.000	0.000	-1827.41	0.000
Total Facility	401069.191	0.000	0.000	0.000	0.000	0.000	179646.347	0.000	215626.783	252136.476	0.000	5231.855	11052.335	0.000	-101100.06	0.000	-367824.70	-595837.45

Peak Cooling Sensible Heat Gain Components

	Time of Peak {TIMESTAMP}	HVAC Zone Eq & Other Sensible Air Heating [Btu/h]	HVAC Zone Eq & Other Sensible Air Cooling [ton]	HVAC Terminal Unit Sensible Air Heating [Btu/h]	HVAC Terminal Unit Sensible Air Cooling [ton]	HVAC Input Heated Surface Heating [Btu/h]	HVAC Input Cooled Surface Cooling [ton]	People Sensible Heat Addition [Btu/h]	Lights Sensible Heat Addition [Btu/h]	Equipment Sensible Heat Addition [Btu/h]	Window Heat Addition [Btu/h]	Interzone Air Transfer Heat Addition [Btu/h]	Infiltration Heat Addition [Btu/h]	Opaque Surface Conduction and Other Heat Addition [Btu/h]	Equipment Sensible Heat Removal [Btu/h]	Window Heat Removal [Btu/h]	Interzone Air Transfer Heat Removal [Btu/h]	Infiltration Heat Removal [Btu/h]	Opaque Surface Conduction and Other Heat Removal [Btu/h]
GYM:ZONE3	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GYM:ZONE1	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GYM:ZONE2	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FIRSTFLOOR:ZONE3	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FIRSTFLOOR:ZONE4	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

FIRSTFLOOR: ZONE2	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FIRSTFLOOR: ZONE6	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FIRSTFLOOR: ZONE7	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FIRSTFLOOR: ZONE1	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BASEMENTXABOVEGRADE: ZONE1	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BASEMENTXABOVEGRADE: ZONE2	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BASEMENTXABOVEGRADE: ZONE3	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BASEMENTXABOVEGRADE: ZONE4	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BASEMENTXABOVEGRADE: ZONE5	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BASEMENTXABOVEGRADE: ZONE6	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BASEMENTXABOVEGRADE: ZONE7	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BASEMENTXABOVEGRADE: ZONE8	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BASEMENTXABOVEGRADE: ZONE9	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

BASEMENTXABOVEGRADE:ZONE10	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BASEMENTXABOVEGRADE:ZONE11	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BASEMENTXABOVEGRADE:ZONE12	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BASEMENTXABOVEGRADE:ZONE13	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BASEMENTXABOVEGRADE:ZONE14	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BASEMENTXABOVEGRADE:ZONE15	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BASEMENTXABOVEGRADE:ZONE16	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHURCHROOF:ZONE1	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHURCHROOF:ZONE4	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHURCHROOF:ZONE2	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Facility	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Peak Heating Sensible Heat Gain Components

	Time of Peak {TIM	HVAC Zone Eq &	HVAC Zone Eq &	HVAC Terminal Uni	HVAC Terminal Uni	HVAC Input He	HVAC Input Co	People Sensible	Lights Sensible He	Equipment Sensible	Window Heat Ad	Interzone Air Transf	Infiltration Heat Add	Opaque Surface Conduct	Equipment Sensible	Window Heat Re	Interzone Air Transf	Infiltration Heat Re	Opaque Surface Conduct

	ESTAMP}	Other Sensible Air Heating [Btu/h]	Other Sensible Air Cooling [ton]	t Sensible Air Heating [Btu/h]	t Sensible Air Cooling [ton]	ated Surface Heating [Btu/h]	oled Surface Cooling [ton]	Heat Addition [Btu/h]	at Addition [Btu/h]	Heat Addition [Btu/h]	dition [Btu/h]	er Heat Addition [Btu/h]	ition [Btu/h]	ion and Other Heat Addition [Btu/h]	Heat Removal [Btu/h]	moval [Btu/h]	er Heat Removal [Btu/h]	moval [Btu/h]	ion and Other Heat Removal [Btu/h]
GYM:ZONE3	02-FEB-09:01	174451.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4241.28	5510.57	0.00	0.00	0.00	0.00	0.00	0.00	-8619.4	-175583.6
GYM:ZONE1	02-FEB-09:01	12499.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.63	3307.44	0.00	0.00	0.00	0.00	0.00	0.00	-258.1	-15649.9
GYM:ZONE2	02-FEB-09:01	6686.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	45.52	31.14	0.00	0.00	0.00	0.00	0.00	0.00	-105.8	-6657.4
FIRSTFLOOR:ZONE3	03-FEB-00:01	31147.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-399.1	0.00	-425.3	-30323.5
FIRSTFLOOR:ZONE4	03-FEB-00:01	32063.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-395.8	0.00	-427.3	-31240.9
FIRSTFLOOR:ZONE2	03-FEB-00:01	277896.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-7496.1	0.00	-12568.5	-257832.0
FIRSTFLOOR:ZONE6	03-FEB-00:01	15741.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-351.0	0.00	-410.1	-14979.9
FIRSTFLOOR:ZONE7	03-FEB-00:01	18239.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-312.4	0.00	-370.4	-17556.4

FIRSTFLOOR:ZONE1	03-FEB-00:01	5087.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-258.9	-4828.4
BASEMENTXABOVEGRADE:ZONE1	03-FEB-00:01	24030.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1023.5	0.00	-795.4	-22212.0
BASEMENTXABOVEGRADE:ZONE2	03-FEB-00:01	16157.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-412.3	-15745.4
BASEMENTXABOVEGRADE:ZONE3	03-FEB-00:01	15115.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-467.1	0.00	-503.6	-14144.7
BASEMENTXABOVEGRADE:ZONE4	03-FEB-00:01	130886.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1230.2	0.00	-8125.1	-121530.9
BASEMENTXABOVEGRADE:ZONE5	03-FEB-00:01	6018.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-210.5	-5807.7
BASEMENTXABOVEGRADE:ZONE6	03-FEB-00:01	9787.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-348.3	-9439.3
BASEMENTXABOVEGRADE:ZONE7	03-FEB-00:01	14757.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-550.2	-14207.7
BASEMENTXABOVEGRADE:ZONE8	03-FEB-00:01	32294.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-798.5	0.00	-1718.0	-29777.7
BASEMENTXABOVEGRADE:ZONE9	03-FEB-00:01	10407.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-396.0	0.00	-510.2	-9501.0

BASEMENTXABOVEGRADE:ZONE10	03-FEB-00:01	5770.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-304.1	-5466.6
BASEMENTXABOVEGRADE:ZONE11	03-FEB-00:01	15480.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-703.6	-14777.3
BASEMENTXABOVEGRADE:ZONE12	03-FEB-00:01	7902.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-103.4	0.00	-153.1	-7645.7
BASEMENTXABOVEGRADE:ZONE13	03-FEB-00:01	20092.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-592.3	0.00	-1062.3	-18437.6
BASEMENTXABOVEGRADE:ZONE14	03-FEB-00:01	20516.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-163.1	0.00	-496.7	-19856.4
BASEMENTXABOVEGRADE:ZONE15	03-FEB-00:01	19961.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-201.6	0.00	-471.6	-19288.5
BASEMENTXABOVEGRADE:ZONE16	03-FEB-00:01	41648.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1503.4	0.00	-1333.0	-38812.5
CHURCHROOF:ZONE1	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHURCHROOF:ZONE4	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHURCHROOF:ZONE2	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Facility	03-FEB-09:01	771505.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4134.82	8371.68	0.00	450.92	0.00	0.00	-703.4	0.00	-91165.4	-692594.4

Table of Contents

Report: **Standard 62.1 Summary**

For: **Entire Facility**

Timestamp: **2019-12-26 10:47:47**

System Ventilation Requirements for Cooling

	Sum of Zone Primary Air Flow - Vpz-sum [ft3/min]	System Population - Ps	Sum of Zone Population - Pz-sum	Occupant Diversity - D	Uncorrected Outdoor Air Intake Airflow - Vou [ft3/min]	System Primary Airflow - Vps [ft3/min]	Average Outdoor Air Fraction - Xs	System Ventilation Efficiency - Ev	Outdoor Air Intake Flow - Vot [ft3/min]	Percent Outdoor Air - %OA	Environment Name of Peak System Population - Ps	Date and Time of Last Peak System Population - Ps
None												

System Ventilation Requirements for Heating

	Sum of Zone Primary Air Flow - Vpz-sum [ft3/min]	System Population - Ps	Sum of Zone Population - Pz-sum	Occupant Diversity - D	Uncorrected Outdoor Air Intake Airflow - Vou [ft3/min]	System Primary Airflow - Vps [ft3/min]	Average Outdoor Air Fraction - Xs	System Ventilation Efficiency - Ev	Outdoor Air Intake Flow Vot [ft3/min]	Percent Outdoor Air - %OA	Environment Name of Peak System Population - Ps	Date and Time of Last Peak System Population - Ps
None												

Zone Ventilation Parameters

	AirLoop Name	People Outdoor Air Rate - Rp [ft3/min-person]	Zone Population - Pz	Area Outdoor Air Rate - Ra [ft3/min-ft2]	Zone Floor Area - Az [ft2]	Breathing Zone Outdoor Airflow - Vbz [ft3/min]	Cooling Zone Air Distribution Effectiveness - Ez-clg	Cooling Zone Outdoor Airflow - Voz-clg [ft3/min]	Heating Zone Air Distribution Effectiveness - Ez-htg	Heating Zone Outdoor Airflow - Voz-htg [ft3/min]
None										

System Ventilation Parameters

	People Outdoor Air Rate - Rp [ft3/min-person]	Sum of Zone Population - Pz-sum	Area Outdoor Air Rate - Ra [ft3/min-ft2]	Sum of Zone Floor Area - Az-sum [ft2]	Breathing Zone Outdoor Airflow - Vbz [ft3/min]	Cooling Zone Outdoor Airflow - Voz-clg [ft3/min]	Heating Zone Outdoor Airflow - Voz-htg [ft3/min]
None							

Zone Ventilation Calculations for Cooling Design

	AirLoop Name	Box Type	Zone Primary Airflow - Vpz [ft3/min]	Zone Discharge Airflow - Vdz [ft3/min]	Minimum Zone Primary Airflow - Vpz-min [ft3/min]	Zone Outdoor Airflow Cooling - Voz-clg [ft3/min]	Primary Outdoor Air Fraction - Zpz	Primary Air Fraction - Ep	Secondary Recirculation Fraction- Er	Supply Air Fraction- Fa	Mixed Air Fraction - Fb	Outdoor Air Fraction - Fc	Zone Ventilation Efficiency - Evz
None													

System Ventilation Calculations for Cooling Design

	Sum of Zone Primary Airflow - Vpz-sum [ft3/min]	System Primary Airflow - Vps [ft3/min]	Sum of Zone Discharge Airflow - Vdz-sum [ft3/min]	Sum of Min Zone Primary Airflow - Vpz-min [ft3/min]	Zone Outdoor Airflow Cooling - Voz-clg [ft3/min]	Zone Ventilation Efficiency - Evz-min

None						

Zone Ventilation Calculations for Heating Design

	AirLoop Name	Box Type	Zone Primary Airflow - Vpz [ft3/min]	Zone Discharge Airflow - Vdz [ft3/min]	Minimum Zone Primary Airflow - Vpz-min [ft3/min]	Zone Outdoor Airflow Heating - Voz-htg [ft3/min]	Primary Outdoor Air Fraction - Zpz	Primary Air Fraction - Ep	Secondary Recirculation Fraction- Er	Supply Air Fraction- Fa	Mixed Air Fraction - Fb	Outdoor Air Fraction - Fc	Zone Ventilation Efficiency - Evz
None													

System Ventilation Calculations for Heating Design

	Sum of Zone Primary Airflow - Vpz-sum [ft3/min]	System Primary Airflow - Vps [ft3/min]	Sum of Zone Discharge Airflow - Vdz-sum [ft3/min]	Sum of Min Zone Primary Airflow - Vpz-min [ft3/min]	Zone Outdoor Airflow Heating - Voz-htg [ft3/min]	Zone Ventilation Efficiency - Evz-min
None						

Table of Contents

Report: **LEED Summary**

For: **Entire Facility**

Timestamp: **2019-12-26 10:47:47**

Sec1.1A-General Information

	Data

Weather File	MQP WORCESTER GOSPEL CHURCH (O1-O1:31-12) ** WORCESTER MA USA TMY2-94746 WMO#=725095
Total gross floor area [ft2]	36151.86
Principal Heating Source	Additional Fuel

EAp2-1. Space Usage Type

	Space Area [ft2]	Regularly Occupied Area [ft2]	Unconditioned Area [ft2]	Typical Hours/Week in Operation [hr/wk]
GYM:ZONE3	5947.27	5947.27	0.00	29.23
GYM:ZONE1	141.11	141.11	0.00	29.23
GYM:ZONE2	63.83	63.83	0.00	29.23
FIRSTFLOOR:ZONE3	322.68	322.68	0.00	29.23
FIRSTFLOOR:ZONE4	324.03	324.03	0.00	29.23
FIRSTFLOOR:ZONE2	9178.84	9178.84	0.00	29.23
FIRSTFLOOR:ZONE6	244.82	244.82	0.00	29.23
FIRSTFLOOR:ZONE7	244.82	244.82	0.00	29.23
FIRSTFLOOR:ZONE1	114.80	114.80	0.00	29.23
BASEMENTXABOVEGRADE:ZONE1	782.30	782.30	0.00	29.23
BASEMENTXABOVEGRADE:ZONE2	424.56	424.56	0.00	29.23
BASEMENTXABOVEGRADE:ZONE3	509.71	509.71	0.00	29.23
BASEMENTXABOVEGRADE:ZONE4	8398.23	8398.23	0.00	29.23
BASEMENTXABOVEGRADE:ZONE5	207.99	207.99	0.00	29.23
BASEMENTXABOVEGRADE:ZONE6	354.38	354.38	0.00	29.23

BASEMENTXABOVEGRADE:ZONE7	651.13	651.13	0.00	29.23
BASEMENTXABOVEGRADE:ZONE8	1541.77	1541.77	0.00	29.23
BASEMENTXABOVEGRADE:ZONE9	454.91	454.91	0.00	29.23
BASEMENTXABOVEGRADE:ZONE10	280.46	280.46	0.00	29.23
BASEMENTXABOVEGRADE:ZONE11	796.96	796.96	0.00	29.23
BASEMENTXABOVEGRADE:ZONE12	161.72	161.72	0.00	29.23
BASEMENTXABOVEGRADE:ZONE13	964.32	964.32	0.00	29.23
BASEMENTXABOVEGRADE:ZONE14	601.26	601.26	0.00	29.23
BASEMENTXABOVEGRADE:ZONE15	575.73	575.73	0.00	29.23
BASEMENTXABOVEGRADE:ZONE16	1500.33	1500.33	0.00	29.23
CHURCHROOF:ZONE1	867.38	0.00	867.38	0.00
CHURCHROOF:ZONE4	248.25	0.00	248.25	0.00
CHURCHROOF:ZONE2	248.25	0.00	248.25	0.00
Totals	36151.86	34787.98	1363.88	

EAp2-2. Advisory Messages

	Data
Number of hours heating loads not met	105.83
Number of hours cooling loads not met	0.00
Number of hours not met	105.83

EAp2-3. Energy Type Summary

	Utility Rate	Virtual Rate [$/unit energy]	Units of Energy	Units of Demand

None				

EAp2-4/5. Performance Rating Method Compliance

	Electric Energy Use [kWh]	Electric Demand [W]	Natural Gas Energy Use [therm]	Natural Gas Demand [Btu/h]	Additional Fuel Use [kBtu]	Additional Fuel Demand [Btu/h]	District Cooling Use [ton-hrs]	District Cooling Demand [ton]	District Heating Use [kBtu]	District Heating Demand [Btu/h]
Heating -- Boiler	0.00	0.00	0.00	0.00	565906.76	1139827.01	0.00	0.00	0.00	0.00
Heating -- Boiler Parasitic	13.43	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling -- Not Subdivided	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Lighting -- Not Subdivided	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting -- Not Subdivided	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment -- General	63151.85	23025.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment -- Not Subdivided	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fans -- Ventilation (simple)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pumps -- Not Subdivided	92.73	198.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Heat Rejection -- Not Subdivided	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Humidification -- Not Subdivided	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery -- Not Subdivided	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems -- Not Subdivided	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration -- Not Subdivided	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Generators -- Not Subdivided	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

EAp2-6. Energy Use Summary

	Process Subtotal [kBtu]	Total Energy Use [kBtu]
Electricity	215626.78	215989.24
Natural Gas	0.00	0.00
Additional	0.00	565906.76
Total	215626.78	781896.00

EAp2-7. Energy Cost Summary

	Process Subtotal [$]	Total Energy Cost [$]

Electricity	0.00	
Natural Gas	0.00	
Additional	0.00	
Total	0.00	

Process energy cost based on ratio of process to total energy.

L-1. Renewable Energy Source Summary

	Rated Capacity [kW]	Annual Energy Generated [kBtu]
Photovoltaic	0.00	0.00
Wind	0.00	0.00

EAp2-17a. Energy Use Intensity - Electricity

	Electricty [kWh/ft2]
Interior Lighting (All)	0.00
Space Heating	0.00
Space Cooling	0.00
Fans (All)	0.00
Service Water Heating	0.00
Receptacle Equipment	1.75
Miscellaneous (All)	1.75
Subtotal	1.75

EAp2-17b. Energy Use Intensity - Natural Gas

	Natural Gas [kWh/ft2]
Space Heating	0.00
Service Water Heating	0.00
Miscellaneous (All)	0.00
Subtotal	0.00

EAp2-17c. Energy Use Intensity - Additional

	Additional [kBtu/ft2]
Subtotal	15.63
Miscellaneous	15.63

EAp2-18. End Use Percentage

	Percent [%]
Interior Lighting (All)	0.00
Space Heating	72.38
Space Cooling	0.00
Fans (All)	0.00
Service Water Heating	0.00
Receptacle Equipment	27.58
Miscellaneous	0.04

Schedules-Equivalent Full Load Hours (Schedule Type=Fraction)

	Equivalent Full Load Hours of Operation Per Year [hr]	Hours > 1% [hr]
WINTER HEATING (NORTHERN HEMISPHERE)	1560.	1560.
ASHRAE 90.1 OCCUPANCY - OFFICE	2654.	5998.
ASHRAE 90.1 SERVICE HOT WATER - OFFICE	1595.	8760.

Schedules-SetPoints (Schedule Type=Temperature)

	First Object Used	Month Assumed	11am First Wednesday [F]	Days with Same 11am Value	11pm First Wednesday [F]	Days with Same 11pm Value
GYM:ZONE3 HEATING SETPOINT SCHEDULE	GYM:ZONE3 DUAL SP	January	68.00	365	-58.0	365
GYM:ZONE3 COOLING SETPOINT SCHEDULE	GYM:ZONE3 DUAL SP	July	75.99	365	84.99	365
GYM:ZONE1 HEATING SETPOINT SCHEDULE	GYM:ZONE1 DUAL SP	January	68.00	365	-58.0	365
GYM:ZONE1 COOLING SETPOINT SCHEDULE	GYM:ZONE1 DUAL SP	July	75.99	365	84.99	365
GYM:ZONE2 HEATING SETPOINT SCHEDULE	GYM:ZONE2 DUAL SP	January	68.00	365	-58.0	365
GYM:ZONE2 COOLING SETPOINT SCHEDULE	GYM:ZONE2 DUAL SP	July	75.99	365	84.99	365
FIRSTFLOOR:ZONE3 HEATING SETPOINT SCHEDULE	FIRSTFLOOR:ZONE3 DUAL SP	January	-58.0	365	-58.0	365
FIRSTFLOOR:ZONE3 COOLING SETPOINT SCHEDULE	FIRSTFLOOR:ZONE3 DUAL SP	July	75.99	365	84.99	365

FIRSTFLOOR:ZONE4 HEATING SETPOINT SCHEDULE	FIRSTFLOOR:ZONE4 DUAL SP	January	-58.0	365	-58.0	365
FIRSTFLOOR:ZONE4 COOLING SETPOINT SCHEDULE	FIRSTFLOOR:ZONE4 DUAL SP	July	75.99	365	84.99	365
FIRSTFLOOR:ZONE2 HEATING SETPOINT SCHEDULE	FIRSTFLOOR:ZONE2 DUAL SP	January	-58.0	365	-58.0	365
FIRSTFLOOR:ZONE2 COOLING SETPOINT SCHEDULE	FIRSTFLOOR:ZONE2 DUAL SP	July	75.99	365	84.99	365
FIRSTFLOOR:ZONE6 HEATING SETPOINT SCHEDULE	FIRSTFLOOR:ZONE6 DUAL SP	January	-58.0	365	-58.0	365
FIRSTFLOOR:ZONE6 COOLING SETPOINT SCHEDULE	FIRSTFLOOR:ZONE6 DUAL SP	July	75.99	365	84.99	365
FIRSTFLOOR:ZONE7 HEATING SETPOINT SCHEDULE	FIRSTFLOOR:ZONE7 DUAL SP	January	-58.0	365	-58.0	365
FIRSTFLOOR:ZONE7 COOLING SETPOINT SCHEDULE	FIRSTFLOOR:ZONE7 DUAL SP	July	75.99	365	84.99	365
FIRSTFLOOR:ZONE1 HEATING SETPOINT SCHEDULE	FIRSTFLOOR:ZONE1 DUAL SP	January	-58.0	365	-58.0	365
FIRSTFLOOR:ZONE1 COOLING SETPOINT SCHEDULE	FIRSTFLOOR:ZONE1 DUAL SP	July	75.99	365	84.99	365
BASEMENTXABOVEGRADE:ZONE 1 HEATING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 1 DUAL SP	January	-58.0	365	-58.0	365
BASEMENTXABOVEGRADE:ZONE 1 COOLING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 1 DUAL SP	July	75.99	365	84.99	365
BASEMENTXABOVEGRADE:ZONE 2 HEATING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 2 DUAL SP	January	-58.0	365	-58.0	365
BASEMENTXABOVEGRADE:ZONE 2 COOLING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 2 DUAL SP	July	75.99	365	84.99	365
BASEMENTXABOVEGRADE:ZONE 3 HEATING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 3 DUAL SP	January	-58.0	365	-58.0	365

BASEMENTXABOVEGRADE:ZONE 3 COOLING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 3 DUAL SP	July	75.99	365	84.99	365
BASEMENTXABOVEGRADE:ZONE 4 HEATING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 4 DUAL SP	January	-58.0	365	-58.0	365
BASEMENTXABOVEGRADE:ZONE 4 COOLING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 4 DUAL SP	July	75.99	365	84.99	365
BASEMENTXABOVEGRADE:ZONE 5 HEATING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 5 DUAL SP	January	-58.0	365	-58.0	365
BASEMENTXABOVEGRADE:ZONE 5 COOLING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 5 DUAL SP	July	75.99	365	84.99	365
BASEMENTXABOVEGRADE:ZONE 6 HEATING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 6 DUAL SP	January	-58.0	365	-58.0	365
BASEMENTXABOVEGRADE:ZONE 6 COOLING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 6 DUAL SP	July	75.99	365	84.99	365
BASEMENTXABOVEGRADE:ZONE 7 HEATING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 7 DUAL SP	January	-58.0	365	-58.0	365
BASEMENTXABOVEGRADE:ZONE 7 COOLING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 7 DUAL SP	July	75.99	365	84.99	365
BASEMENTXABOVEGRADE:ZONE 8 HEATING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 8 DUAL SP	January	-58.0	365	-58.0	365
BASEMENTXABOVEGRADE:ZONE 8 COOLING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 8 DUAL SP	July	75.99	365	84.99	365
BASEMENTXABOVEGRADE:ZONE 9 HEATING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 9 DUAL SP	January	-58.0	365	-58.0	365

BASEMENTXABOVEGRADE:ZONE 9 COOLING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 9 DUAL SP	July	75.99	365	84.99	365
BASEMENTXABOVEGRADE:ZONE 10 HEATING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 10 DUAL SP	January	-58.0	365	-58.0	365
BASEMENTXABOVEGRADE:ZONE 10 COOLING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 10 DUAL SP	July	75.99	365	84.99	365
BASEMENTXABOVEGRADE:ZONE 11 HEATING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 11 DUAL SP	January	-58.0	365	-58.0	365
BASEMENTXABOVEGRADE:ZONE 11 COOLING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 11 DUAL SP	July	75.99	365	84.99	365
BASEMENTXABOVEGRADE:ZONE 12 HEATING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 12 DUAL SP	January	-58.0	365	-58.0	365
BASEMENTXABOVEGRADE:ZONE 12 COOLING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 12 DUAL SP	July	75.99	365	84.99	365
BASEMENTXABOVEGRADE:ZONE 13 HEATING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 13 DUAL SP	January	-58.0	365	-58.0	365
BASEMENTXABOVEGRADE:ZONE 13 COOLING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 13 DUAL SP	July	75.99	365	84.99	365
BASEMENTXABOVEGRADE:ZONE 14 HEATING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 14 DUAL SP	January	-58.0	365	-58.0	365
BASEMENTXABOVEGRADE:ZONE 14 COOLING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 14 DUAL SP	July	75.99	365	84.99	365
BASEMENTXABOVEGRADE:ZONE 15 HEATING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 15 DUAL SP	January	-58.0	365	-58.0	365

BASEMENTXABOVEGRADE:ZONE 15 COOLING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 15 DUAL SP	July	75.99	365	84.99	365
BASEMENTXABOVEGRADE:ZONE 16 HEATING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 16 DUAL SP	January	-58.0	365	-58.0	365
BASEMENTXABOVEGRADE:ZONE 16 COOLING SETPOINT SCHEDULE	BASEMENTXABOVEGRADE:ZONE 16 DUAL SP	July	75.99	365	84.99	365

Table of Contents

Report: **Life-Cycle Cost Report**

For: **Entire Facility**

Timestamp: **2019-12-26 10:47:47**

Life-Cycle Cost Parameters

	Value
Name	LIFE-CYCLE COST ANALYSIS EXAMPLE 1
Discounting Convention	EndOfYear
Inflation Approach	ConstantDollar
Real Discount Rate	0.0294
Nominal Discount Rate	-- N/A --
Inflation	-- N/A --
Base Date	January 2011
Service Date	January 2013
Length of Study Period in Years	25
Tax rate	0.0000

Depreciation Method	None

Use Price Escalation

	RESIDENTIAL-ELEC
Resource	Electricity
Start Date	January 2010
1	0.979000
2	1.013800
3	1.012700
4	1.009600
5	1.017700
6	1.027900
7	1.034400
8	1.032700
9	1.038200
10	1.045400
11	1.049400
12	1.056400
13	1.058700
14	1.054900
15	1.056600
16	1.063000
17	1.070700

18	1.085700
19	1.095300
20	1.106300
21	1.116500
22	1.122700
23	1.129200
24	1.134900
25	1.141400

Use Adjustment

	ELECADJUSTMENT
	Electricity
January 2013	1.000000
January 2014	1.002200
January 2015	1.002300
January 2016	1.002400
January 2017	1.002500
January 2018	1.002600
January 2019	1.002700
January 2020	1.000000
January 2021	1.000000
January 2022	1.000000
January 2023	1.000000

January 2024	1.000000
January 2025	1.000000
January 2026	1.000000
January 2027	1.000000
January 2028	1.000000
January 2029	1.000000
January 2030	1.000000
January 2031	1.000000
January 2032	1.000000
January 2033	1.000000
January 2034	1.000000
January 2035	1.000000

Cash Flow for Recurring and Nonrecurring Costs (Without Escalation)

	ANNUALMAINT	ESTIMATEDSALVAGE
	Recurring	Nonrecurring
January 2011	0.00	0.00
January 2012	0.00	0.00
January 2013	2000.00	0.00
January 2014	2000.00	0.00
January 2015	2000.00	0.00
January 2016	2000.00	0.00
January 2017	2000.00	0.00

January 2018	2000.00	0.00
January 2019	2000.00	0.00
January 2020	2000.00	0.00
January 2021	2000.00	0.00
January 2022	2000.00	0.00
January 2023	2000.00	0.00
January 2024	2000.00	0.00
January 2025	2000.00	0.00
January 2026	2000.00	0.00
January 2027	2000.00	0.00
January 2028	2000.00	0.00
January 2029	2000.00	0.00
January 2030	2000.00	0.00
January 2031	2000.00	-2000.0
January 2032	2000.00	0.00
January 2033	2000.00	0.00
January 2034	2000.00	0.00
January 2035	2000.00	0.00

Energy and Water Cost Cash Flows (Without Escalation)

January 2011	
January 2012	
January 2013	

January 2014	
January 2015	
January 2016	
January 2017	
January 2018	
January 2019	
January 2020	
January 2021	
January 2022	
January 2023	
January 2024	
January 2025	
January 2026	
January 2027	
January 2028	
January 2029	
January 2030	
January 2031	
January 2032	
January 2033	
January 2034	
January 2035	

Capital Cash Flow by Category (Without Escalation)

	Construction	Salvage	OtherCapital	Total
January 2011	0.00	0.00	0.00	0.00
January 2012	0.00	0.00	0.00	0.00
January 2013	0.00	0.00	0.00	0.00
January 2014	0.00	0.00	0.00	0.00
January 2015	0.00	0.00	0.00	0.00
January 2016	0.00	0.00	0.00	0.00
January 2017	0.00	0.00	0.00	0.00
January 2018	0.00	0.00	0.00	0.00
January 2019	0.00	0.00	0.00	0.00
January 2020	0.00	0.00	0.00	0.00
January 2021	0.00	0.00	0.00	0.00
January 2022	0.00	0.00	0.00	0.00
January 2023	0.00	0.00	0.00	0.00
January 2024	0.00	0.00	0.00	0.00
January 2025	0.00	0.00	0.00	0.00
January 2026	0.00	0.00	0.00	0.00
January 2027	0.00	0.00	0.00	0.00
January 2028	0.00	0.00	0.00	0.00
January 2029	0.00	0.00	0.00	0.00
January 2030	0.00	0.00	0.00	0.00
January 2031	0.00	-2000.0	0.00	-2000.0
January 2032	0.00	0.00	0.00	0.00
January 2033	0.00	0.00	0.00	0.00

January 2034	0.00	0.00	0.00	0.00
January 2035	0.00	0.00	0.00	0.00

Operating Cash Flow by Category (Without Escalation)

	Energy	Water	Maintenance	Repair	Operation	Replacement	MinorOverhaul	MajorOverhaul	OtherOperational	Total
January 2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
January 2012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
January 2013	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2014	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2015	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2016	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2017	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2018	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2019	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00

January 2020	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2021	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2022	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2023	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2024	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2025	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2026	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2027	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2028	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2029	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2030	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2031	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00

January 2032	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2033	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2034	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00
January 2035	0.00	0.00	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	2000.00

Monthly Total Cash Flow (Without Escalation)

	January	February	March	April	May	June	July	August	September	October	November	December
2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2013	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2014	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2016	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2017	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2018	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2019	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2021	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2022	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2023	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

2024	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2026	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2027	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2028	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2029	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2030	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2031	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2032	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2033	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2034	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2035	2000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Present Value for Recurring, Nonrecurring and Energy Costs (Before Tax)

	Category	Kind	Cost	Present Value	Present Value Factor
ANNUALMAINT	Maintenance	Recurring	2000.00	31230.01	15.6150
ESTIMATEDSALVAGE	Salvage	Nonrecurring	-2000.0	-1088.3	0.5442
TOTAL				30141.67	

Present Value by Category

	Present Value
Construction	0.00
Salvage	-1088.3

Other Capital	0.00
Energy	0.00
Water	0.00
Maintenance	31230.01
Repair	0.00
Operation	0.00
Replacement	0.00
Minor Overhaul	0.00
Major Overhaul	0.00
Other Operational	0.00
Total Energy	0.00
Total Operation	31230.01
Total Capital	-1088.3
Grand Total	30141.67

Present Value by Year

	Total Cost	Present Value of Costs
January 2011	0.00	0.00
January 2012	0.00	0.00
January 2013	2000.00	1833.49
January 2014	2000.00	1781.12
January 2015	2000.00	1730.25
January 2016	2000.00	1680.83

January 2017	2000.00	1632.83
January 2018	2000.00	1586.20
January 2019	2000.00	1540.89
January 2020	2000.00	1496.88
January 2021	2000.00	1454.13
January 2022	2000.00	1412.60
January 2023	2000.00	1372.26
January 2024	2000.00	1333.07
January 2025	2000.00	1294.99
January 2026	2000.00	1258.01
January 2027	2000.00	1222.08
January 2028	2000.00	1187.18
January 2029	2000.00	1153.27
January 2030	2000.00	1120.33
January 2031	0.00	0.00
January 2032	2000.00	1057.25
January 2033	2000.00	1027.06
January 2034	2000.00	997.72
January 2035	2000.00	969.23
TOTAL		30141.67

Appendix H: Massachusetts DOT Church Pre-Construction Condition Survey

Appendix I: Massachusetts DOT Geotechnical Report

Appendix J: Roof Photos