ARCHITECTURAL BREADTH

The Roof Terrace is a very plain space as currently designed. Though its austere nature keeps it a flexible space, it also prevents it from being as useful of a space as it could potentially be. After analysis of similar spaces, I have designed an outdoor room that will provide added flexibility to the space for concerts, classes, special events, and as a general gathering space.

I accomplished this by designing a Pergola to be placed in the center of the Roof Terrace. This will define a volume of space underneath so that the uses of the Roof Terrace can be focused. The Pergola will be made of the same light oak woods as used throughout the rest of the building. The 8” hollow columns and beams will allow for wiring and housing of the lighting equipment and transformers. The top of the Pergola will be defined by 2x14 lumber at 12” on center spacing, with one box beam running across to mount lights and wiring. Because of the potential for a piano to be used in this space, a raised stage will be unnecessary. However, a lattice backdrop of wood slats will define the stage end of the Pergola. The size of the Pergola was chosen so that circulation around it would be easy if there were event tents or pavilions set up around the perimeter of the Roof Terrace. The Pergola allows for a mounting position for light in the middle of the space rather than just around the edge of the space, thus balancing out both the horizontal and the vertical illumination.

Figure 58: Daytime Rendering of Pergola

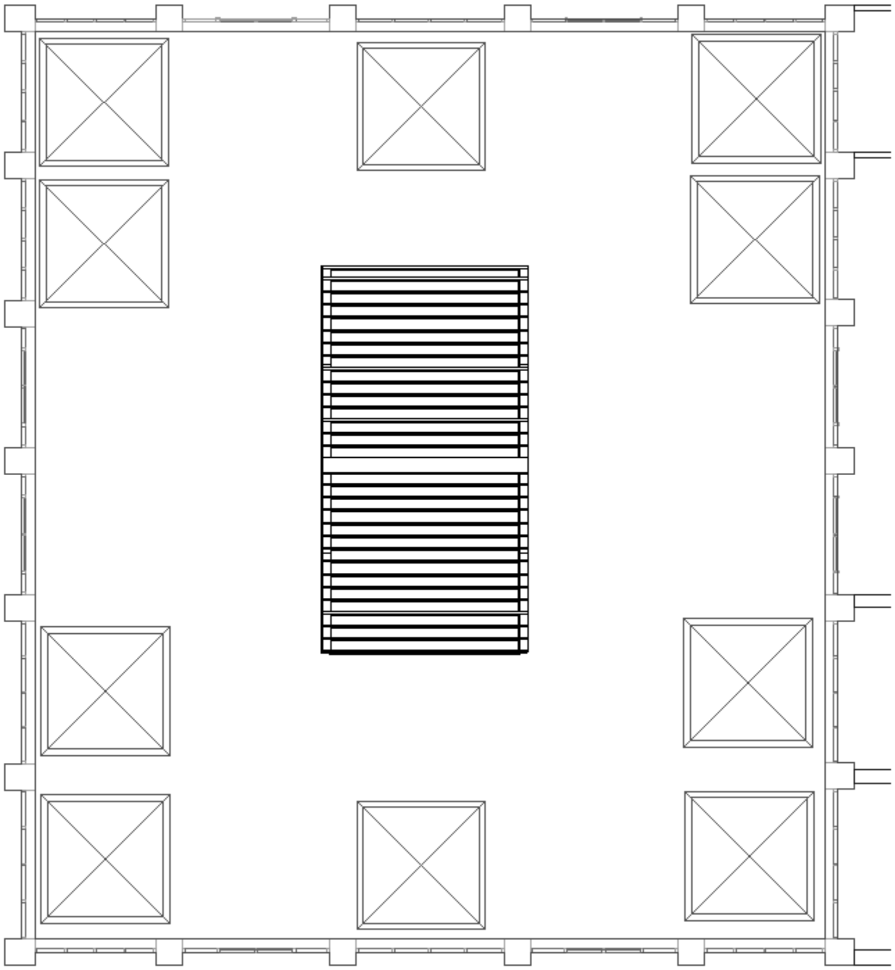


Figure 59: Roof Terrace Plan View with 10' x 10' Event Tents

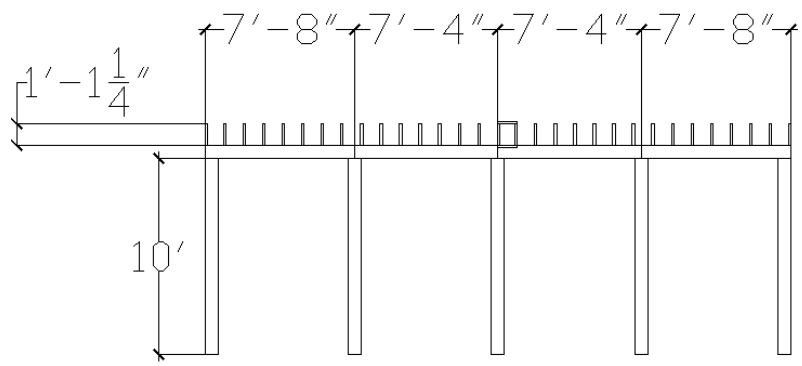


Figure 60: Pergola Side Elevation

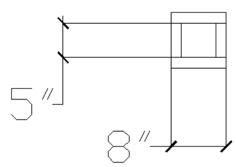


Figure 61: Column and Girder Cross Section

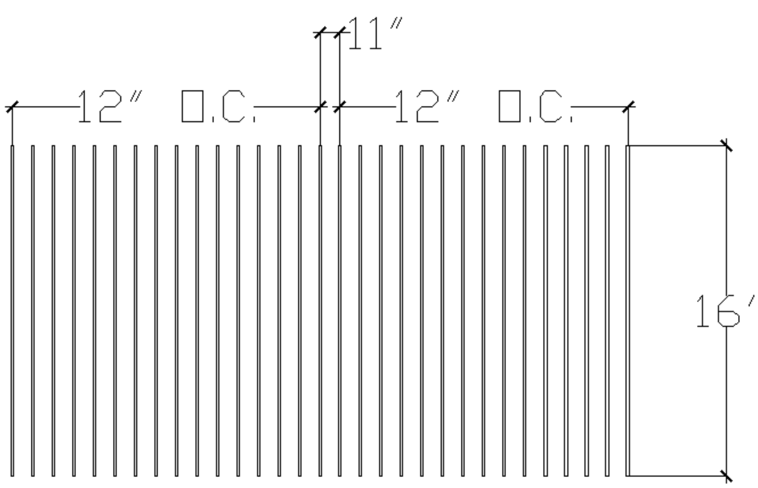


Figure 62: Pergola Beam Plan

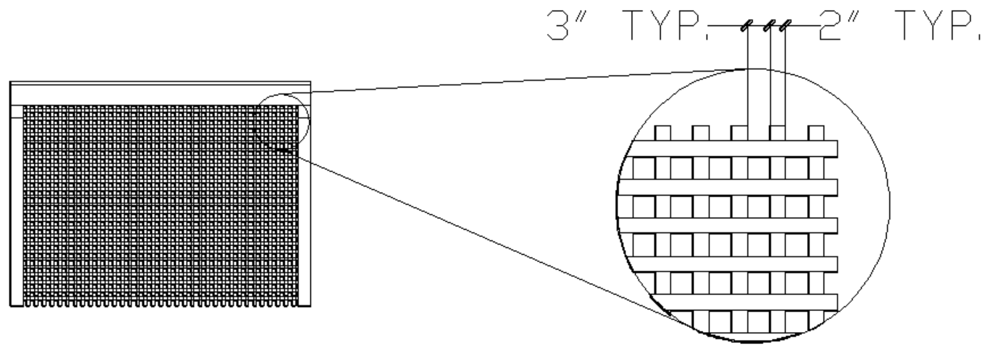


Figure 63: Pergola End Elevation

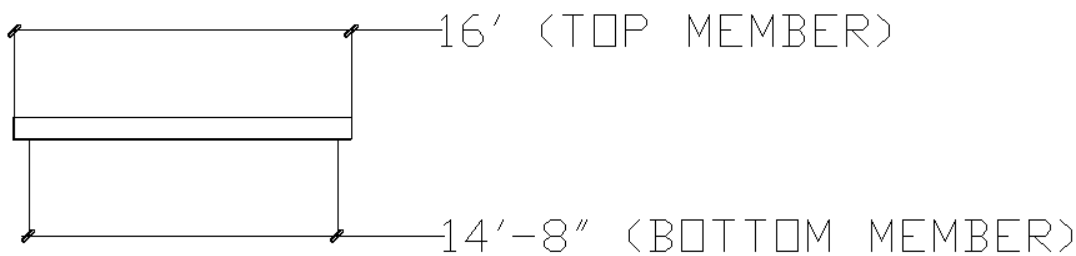


Figure 64: Pergola Lighting Box Beam Elevation

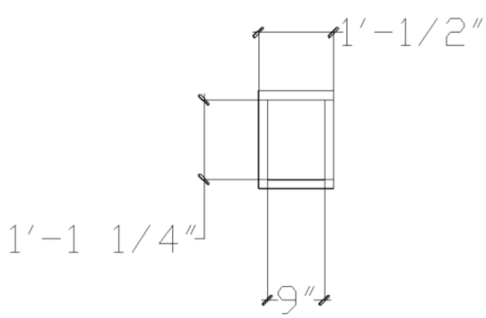


Figure 65: Pergola Lighting Box Beam Cross Section

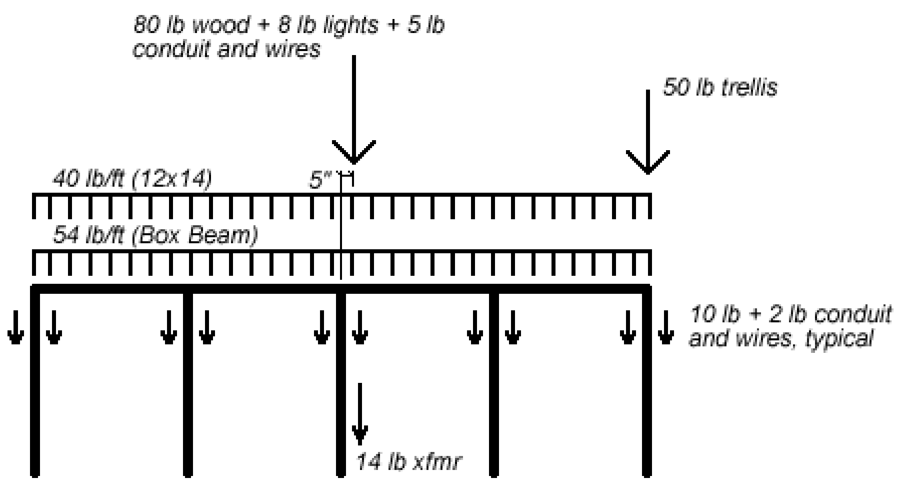
STRUCTURAL BREADTH

Since the addition discussed in my Architectural Breadth would add significant amounts of weight to the roof terrace, a redesign of the structural system may be necessary. The pergola is analyzed to see if it is capable of supporting itself and the light fixtures attached to it. Then these loads are carried through to the LH joists running under the terrace. Finally, the loads from the joists are applied to the masonry walls around the recital hall that are holding up the joists.

Wood Pergola Analysis

The cross members that support the lights have negligible weight in addition to their self weight and are thus not considered in this analysis. Snow loads were also not calculated due to their negligible effect on such small areas.

Top 2x14 members: $4.83\ \frac{\text{lb}}{\text{ft}} \times 16' = 77.28$ lb. total, 12" o.c.



Maximum moment: 5.164 lb. ft. + 203.607 lb. ft. + 186.179 lb. ft. = 394.950 lb. ft.

Maximum shear: 488.982 lb.   Maximum axial load: 529.000 lb.

C factors:

F_b: $C_m = 0.85$, $C_f = 1.1$

F_v: $C_m = 0.97$, $C_f = 1.1$

F_c: $C_m = 0.8$, $C_f = 1.0$

Assuming #2, Mixed Oak (chosen for aesthetic quality over structural quality):

Raw $F_b = 800$ psi

Raw $F_c = 625$ psi

Raw $F_v = 170$ psi

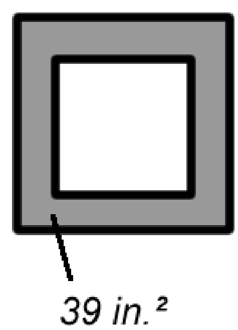
$S = 85.333 \text{ in.}^3 - 20.833 \text{ in.}^3 = 64.500 \text{ in.}^3$

Horizontal:

$$f_b = \frac{M}{S} = \frac{394.9495 \text{ lb. ft.} \cdot 12 \text{ in./ft.}}{64.5 \text{ in.}^3} = 73.476 \text{ psi}$$

$$F_b = (0.85)(1.1)(800 \text{ psi}) = 748 \text{ psi}$$

$$f_b < F_b$$



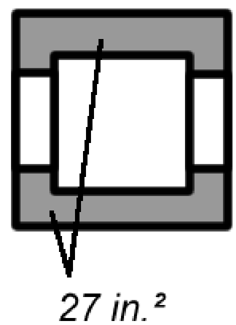
Assume 8" across, 1.5" thick

$$f_v = 1.5\frac{V}{A} = \frac{488.982 \text{ lb.}}{39 \text{ in.}^2} = 18.807 \text{ psi}$$

$$F_v = (0.97)(1.1)(625 \text{ psi}) = 666.875 \text{ psi}$$

$$f_v < F_v$$

Vertical:



Assume 8" across, 1.5" thick, two 4" junction boxes

$$f_C = \frac{P}{A} = \frac{529.000 \text{ lb.}}{27 \text{ in.}^2} = 19.592 \text{ psi}$$

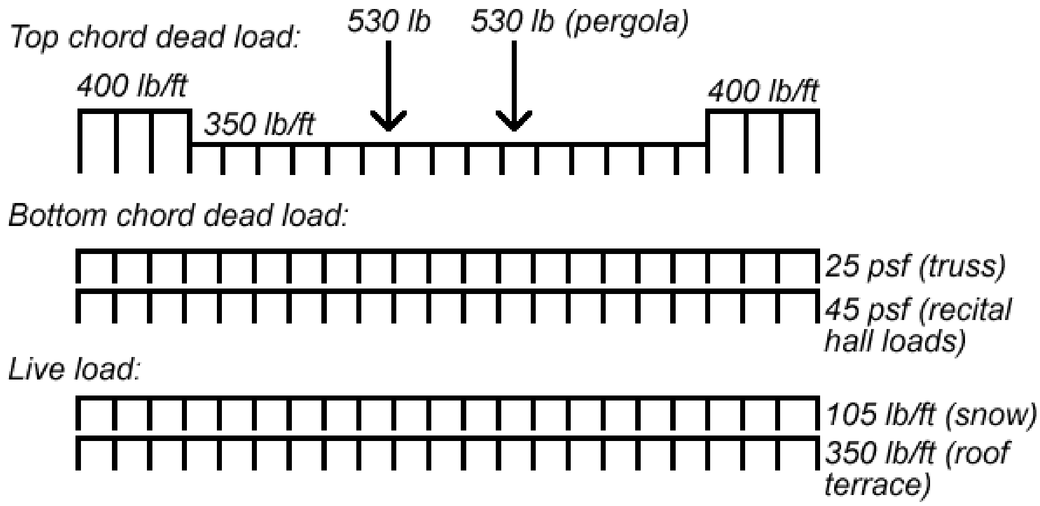
$$F_C = (0.8)(1.0)(170 \text{ psi}) = 136 \text{ psi}$$

$$f_C < F_C$$

The pergola is by far strong enough to support itself and the lighting equipment on it.

Joist Analysis

The original size of the joist is a 36 LH 15 at 64' long. There is plenty of room below the joist if the depth needs to be increased to handle the loads of the pergola.



The total load is 58,110 lbs. which can be supported by a size 44 LH 17 joist. The additional 8 inches of depth will not impact the systems or structures below.

Figure 66: North-facing Construction Photograph Showing Original Joists Above Recital Hall

Masonry Analysis

A dual 10" masonry wall system with #5 @16" o.c. reinforcements surrounds the recital hall. The mass of the wall helps to isolate the recital hall acoustically from the rest of the building. The air gap creates an additional discontinuity to prevent acoustic conduction to the recital hall. The joists of the roof terrace are only supported by the interior wall. The wall uses ASTM C90, grade n1 (min 2800 psi) block with C270 Type S mortar (with f'_m = 2000 psi). The grout for the block cells is 3000 psi. The joists apply 8300 lb/ft of load on the masonry wall.

For this wall construction:

A_{avg} = 82.0 in.^{2}/ft

I_{avg} = 759.7 in.^{4}/ft

S_{avg} = 157.9 in.^{3}/ft

r_{avg} = 3.04 in.

$$\frac{h}{r} = \frac{394.32 \text{ in.}}{3.04 \text{ in.}} = 129.71$$

Since 129.71 > 99, the equation to find the ΦP_n of the wall is:

$$\Phi P_n = (0.9)\cdot(0.80)\cdot\left[0.80f'_m(A_n - A_s) + f_yA_s\right]\left(\frac{70r}{h}\right)^2$$

$$\Phi P_n = (0.9)\cdot(0.80)\cdot[0.80(2000)(82.0 - 0.31) + 60\cdot 0.31]\left(\frac{70\cdot 3.04}{394.32}\right)^2$$

$$\Phi P_n = 27{,}411.24 \text{ lb./ft.}$$

Since 27,411.24 lb./ft. > 8300 lb./ft., the masonry wall is more than capable of supporting the additional loads as originally designed.

FINAL THOUGHTS

The lighting of The Pennsylvania Academy of Music offers both aesthetic and functional qualities. It does not try to place its own accent on the architecture, instead it tries to actually accent the architecture. Lighting is also quite interconnected with the engineering of the energy distribution. So in this chain, when the architecture changes, so does the electrical distribution. Similar can keep being added on either end of this chain. My architectural and structural breadth topics helped me experience additional links on this metaphorical chain. Only when you can become so closely involved with a project like this do you realize how profoundly the slightest change in one system can change something that at first glance seems unrelated – even on the other side of the building. Through this experience, I have gotten to experience firsthand how intricate and interdependent the different fields within the design of buildings actually are.

In addition to this appreciation of architecture and related systems, I have gained experience in stretching my abilities to learn and discover techniques and applications that I haven't learned before and apply techniques that I haven't had the opportunity to apply yet. This is true of all four fields I have looked at in this project. I learned what to look for when designing a portion of architecture when adding to the Roof Terrace. I learned how to analyze masonry walls when figuring out what impact this addition made to the building. I experienced firsthand how much of an impact simple changes in the lighting system can affect the utility of a space. I learned how far reaching a simple change in an electrical system can spread. Above all, I learned how to pay attention to all of these at once while aiming for the goals and criteria that I had set aside for the project.

REFERENCES AND ACKNOWLEDGEMENTS

References:

National Electric Code 2005. National Fire Protection Association, 2005.

Hughes, David. *Electrical Systems in Buildings*. New York: Delmar Publishers Inc., 1988.

Rea, Mark S., ed. *The IESNA Lighitng Handbook*. New York: Illuminating Engineering Society of North America, 2000.

Saferian, Haig. *Hardscaping: High Style, Low Maintenance Outdoor Spaces*. New York: McGraw Hill Professional, 2004.

Special thanks:

James Rockwell of The Pennsylvania Academy of Music

Duane Schrempp of Philip Johnson Alan Ritchie Architects

Imran Malik of Cosentini

Lee Brandt of Horton Lees Brogden Lighting Design

Dr. Mistrick

Ted Dannerth

Professors Parfitt and Holland

All of my friends I've made along the way.