FARNSWORTH REDUX; Reconsidering an Architectural Icon as a Passive Energy House

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Abstract

To strengthen the tenuous interdisciplinary connection between aesthetic design, building construction, digital representation and architectural history, this project spans two semesters in the building technology curriculum to address these topics simultaneously. Based on the pedagogy of adapting an iconic building to today's standards, students integrated passive energy strategies into a famous but energy-flawed building; in this case the Farnsworth House by Mies Van der Rohe. Mies designed the home with a preference for concept over comfort, so the large expanses of unshaded glass and minimal insulation make it a challenge to heat and cool the house. The overall assignment was to reconsider the house as a passive energy efficient building while being aesthetically sensitive to the home's historic value.

Part One occurs in their Tech 1 course while learning about steel frame construction. Using historic details, they puzzled together the structural elements into a 3D digital model to understand the steel shapes, details and load paths. The second and third parts occur during the spring semester in the Tech 2 course on exterior envelope and passive energy systems. Part Two involved the design of a sun-shading device to control light on the south glass wall on specific dates while not disrupting the view sightlines and remaining sensitive to the design intent. Because the home's envelope was designed with minimum insulation and very inefficient windows, Part Three asked students to dramatically increase envelope efficiency by improving the insulation R-values of the roof/ceiling and floor systems, as well as replacing the fixed windows with an efficient operable system. The extended project was capped with a digital color-rendered wall-section that brought together all three parts of the project in one comprehensive drawing.

Introduction

It is an age-old concern that architecture students tend to prioritize design studio over their support courses in history, technology and representation. To be fair, it is often unclear how some of the information that is taught in these courses relates to the design challenge. To strengthen the interdisciplinary connection between aesthetic design, building construction, digital technology and architectural history, I linked several projects that span two semesters in the two introductory building tech courses to addresses these topics simultaneously by having them modify an architectural icon based on current sustainability goals. Based on an established pedagogical method of adapting and updating an existing building to today's technology standards, the project challenges the student to integrate passive energy strategies into a famous but energy *in*efficient building. The historic baseline building for this project was the Farnsworth House in Plano, Illinois by Mies Van der Rohe. Mies designed the building with a preference for concept over comfort, so the large expanses of unshaded glass and minimal insulation make it a challenge, not to mention expensive, to heat and cool the house. Students learn about the now infamous lawsuit brought by the client Edith Farnsworth on Mies over not only the huge construction cost overruns, but also the basic non-livability of the house.[1] Farnsworth claimed "I wanted to do something 'meaningful,' and all I got was this glib, false sophistication"[2] While the house has been criticized on several levels, from a lack of privacy to being built on a flood plain, the students were asked to focus on the problems with the building's thermal comfort and energy usage. The all-glass walls made the house was very cold in the winter and "Farnsworth sweltered in the summertime because Mies gave her only one door and the smallest of openable windows, and no air conditioning."[3.] So to address this condition, the overall assignment was to reconsider the house as it might be built today as a passive energy-efficient building. Many architectural critics would find it blasphemous to make any changes to such a famous work of architecture so aesthetic design changes had to be respectful of the original design intent with sensitive light-handed touches, adding another layer of challenge to the problem.

Figure 1 - Farnsworth House – South Elevation

In terms of the overall schedule of the linked projects, the first part occurs during the fall semester in their Building Tech 1 course while they are learning about steel frame construction. Using only existing historic details of the house, they were required to draw only the structural elements (steel frame and precast planks) of the building as a 3D digital model to understand the steel shapes, load paths, connection details and relationships between primary and secondary structural elements. This drawing served as the virtual and literal framework for the subsequent parts of the project. The second and third parts of the project occurred during the following spring semester in the Building Tech 2 course that focuses on the building exterior envelope and passive energy systems such as passive heating and cooling and daylighting. Part 2 involved the design of a sun-shading device to control light penetration on the southern glass wall on specific dates while, at the same time, not greatly disrupting the sightlines to the river. The home's original envelope was designed with minimum insulation and very energy-*in*efficient steel windows. So, for Part 3 students were asked to dramatically increase the energy efficiency of the exterior envelope to minimize heat transfer. They were required to replace the roof, ceiling and floor insulation systems with improved versions as well as replacing the fixed, steel-frame windows with an insulated, operable system for natural ventilation. A number of in-class lab exercises were assigned help the students understand the project requirements. The culmination of the extended project made use of their representation skills in a final color-rendered wall-section that demonstrated all parts of the project together in one comprehensive drawing.

Part 1 - Steel Frame

The goal of the first project was to understand the connections in a steel frame building and the various modes of representing them in drawing form. The Farnsworth House is one of the most famous steel frame houses in the world where Mies took advantage of the strength of the steel frame to create a glass house with no exterior solid walls. Students were given historic details and any along with others they found may find on line, they reconstructed the frame structure in digital form as a 3D model. They were asked to consider this a puzzle by using the details as clues to piece together and draw the structure in 3D. Rhino or Revit were the main software programs used. They were asked to *only* draw the structural elements, meaning the steel beams and columns and the custom precast concrete floor and roof slabs and show details at the connections. Beams had to be drawn with the actual I, C or L shaped profile and not as abstract boxes. By drawing the details, they were able to better understand the existing construction with its faults and benefits. Required drawings included an overall axon from both above and below, a wall section at the side, a wall section at the end and 3 unique highlighted and enlarged joints; all grouped together on one comprehensive drawing sheet.

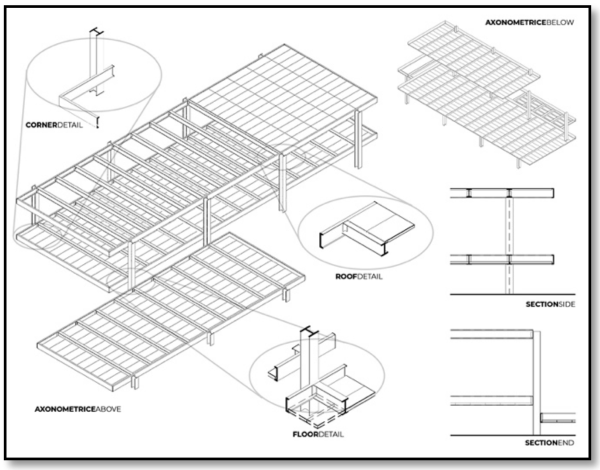

Figure 2 - Part 1 by Isaac Buxton

Part 2 - Shading Device Design

An underlying objective of Tech 2 is to understand the principles of environmental sustainability as they affect building technology and design. We especially investigate how climatic influences like sun, wind and temperature affect our buildings and how we can use them to our advantage through passive (non-mechanical) means to heat, cool and light them. Most Modern buildings in the past were not built to high energy-efficiency standards because energy was cheap. Many iconic buildings could not be built today if they had to meet current energy codes. The Farnsworth House was designed by Mies with a preference for concept over comfort, so the large expanses of single-paned, unshaded glass make it extremely difficult to control the temperature in the house in all seasons. The assignment was to reconsider the Farnsworth house as a more energy-efficient building. Even though this is a theoretical project, students still needed to be respectful of the original design intent by making as few design additions as needed. In this way they were evaluated on their design decisions as well as technical performance.

The floor to ceiling glass walls on all sides of the house constantly exposes the interior to potential overheating and sun glare. While the existing curtains can be used to control low angle sunlight on the east and west sides, closing them on the south elevation would also block the prized view to the river. So, students were asked to design a sun-shading device or combination of devices to control light on the south. At the same time, the device(s) could not greatly disrupt the view to the river from the sightlines of a person seated or standing. To be sensitive to the existing design intent and keep the shading system as invisible and unintrusive as possible, they had to use the minimum number of louvers needed to shade while maximizing views. By adjusting the size and spacing of the shading system members, they could graphically demonstrate the effectiveness of their chosen system.

To make things even across the board, standard dates were set for what was determined to be “good” sun to allow in and “bad sun” to keep out. The goal was to block 95% of the southern sun in Plano, Illinois on September 1 at noon (still a hot day of the year when the sun is at a lower angle in the sky) and allow as much sun as possible to penetrate on December 21 at noon. Since beginning students have no practical knowledge of manufacturers shading systems, they used digital CAD library of a range of a single manufacturer’s louver, overhangs and light-shelf details to choose from in and arrange in any combination. The details in a range of sizes came from Kawneer’s Versoleil Outrigger System, Versoleil Single Blade System and InLighten Interior Light Shelf systems. To achieve their goals, they could use any combination and as many of this preselected kit of parts as needed, but had to use at least 2 of the systems and not just one simple system. An AutoCad .dwg file of the possible fixtures was provided, along with their mounting hardware, to cut and paste the details into their wall section drawing as is done in the profession. One of the few allowable, and encouraged, examples of plagiarism in school.

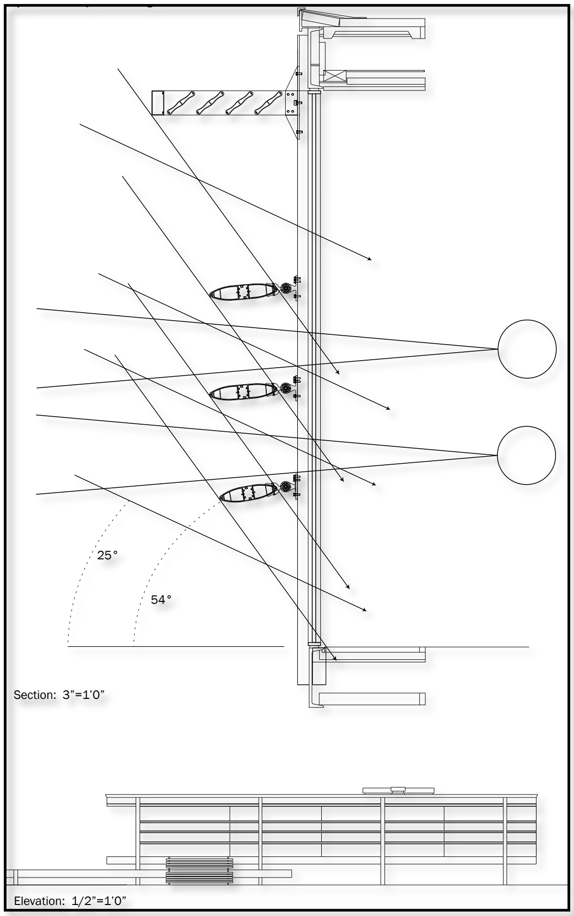

Figure 3 - Part 2 Drawing by Christopher Gartley

The final drawing for Part 2 included a full-height Wall Section showing the size and spacing of the sun screen design attached to the existing wall. Using a series of parallel lines to represent sun angles for both summer and winter sun, they had to demonstrate the screen's shading or non-shading effectiveness by showing which rays were blocked by the devices in September and how much sun was allowed to penetrate in December. Scale figures with sight lines for both a sitting and standing person of average height demonstrated how views were unobstructed. In addition to the wall section, a Building Elevation of the entire south façade showing the new sun screen was required to judge the general aesthetic impact of the design.

Support Labs for Part 2

To better understand the requirements of Project 2, two support lab exercises were completed in class. Lab Project #5 - Solar Shading Design asked students to design a bris soleil device to protect a square bay window. Two critical dates and times of the year were given for when all of the sunlight should be blocked from entering the building from which students determined the sun angles. They then had to design the width, depth and spacing of both the vertical and horizonal louvers in the eggcrate device to block all unwanted light. The depth of the horizontal and vertical louvers did not all need to be the same and the louver spacing varied with the depth of the louvers; so there are many different solutions.

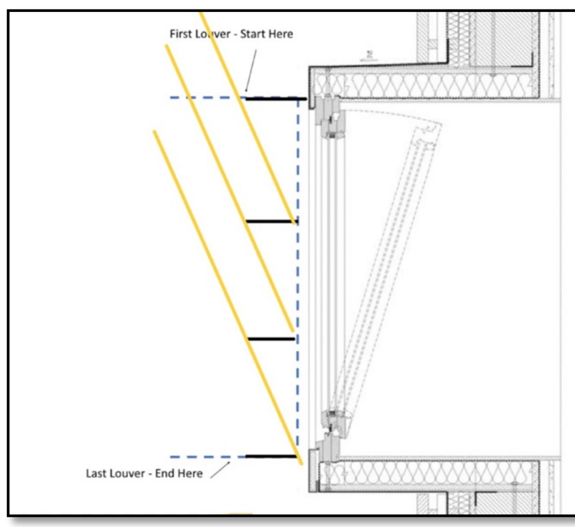

Figure 4 - Louver Design Lab by Seema Bakri

In the second support lab, students used a Sun Peg Chart to test the distance sunlight penetrates on a physical model of the Farnsworth House. A sun peg chart is an analog tool used to create accurate shadows and daylighting conditions on physical models based on date and time. Students built a simple model of the Farnsworth House (mostly floor roof and columns) and mounted a sun peg chart to its base. Using the chart they oriented the model to measure and photograph the extent of the sun's penetration into the spaces at the same assigned times of the year as the main project.

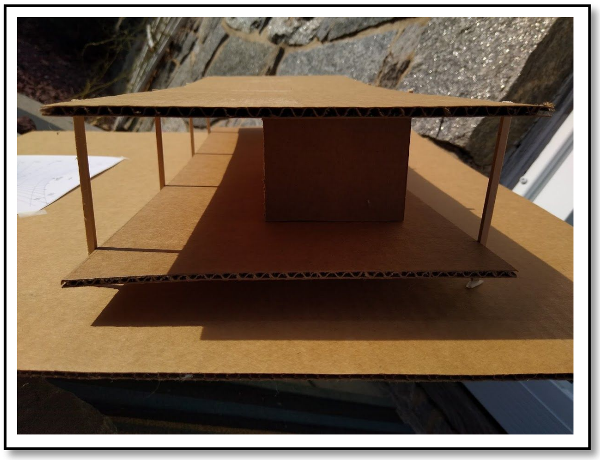

Figure 5 - Sun Peg Lab by Jessica Forsell

Part 3 - Envelope Redesign

In Project 1, students designed a passive shading system to minimize solar heat gain in the summer. For Project 2 they redesigned the exterior envelope to dramatically increase its energy efficiency and minimize heat transfer. The current envelope was designed with minimum insulation and very energy-*in*efficient steel windows because it was done at a time when energy was cheap. We no longer have that luxury so need to maximize the R-value of the envelope. Since this is an historic building that needs to maintain its classic appearance, the steel structure, decks and interiors finish systems had to remain exactly the same. Students could only make changes to the window system, the roof and within the thickness of the existing ceiling and floor plenums by replacing existing materials with updated versions that are more energy efficient and sustainable. Instructions for each the 4 areas they could modify are listed below.

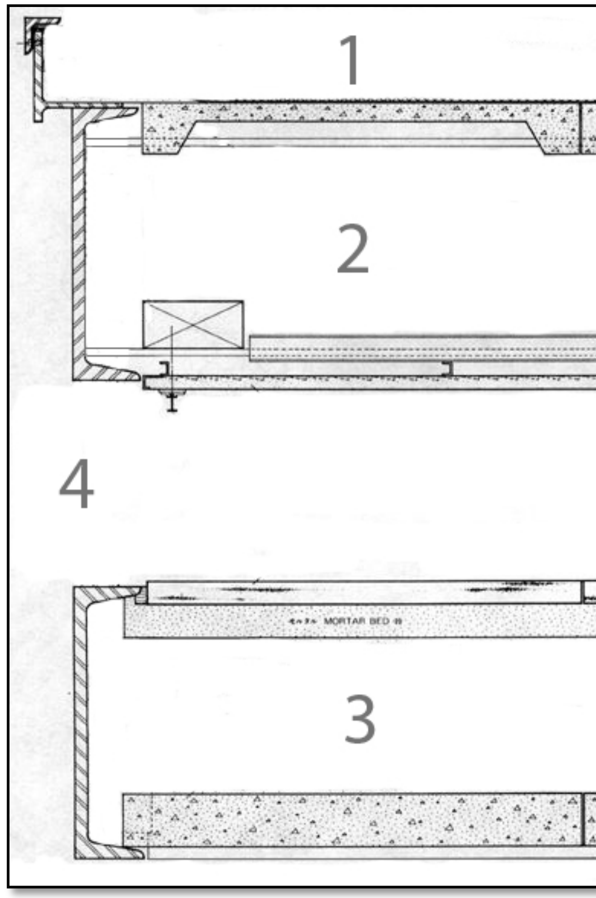

Figure 6 - Farnsworth Section Details Edited

1. ROOF – Select a sustainable flat roof system that will minimize heat island effect and provide a method to slope the roof to the central drain. If insulation is used to create a slope, it should be included in the roof R-value numbers.

2. ROOF/CEILING INSULATION - Design a highly insulated roof system with minimal thermal bridging. Insulation must add up to a minimum R-30 for the total roof, including any insulation used for roof slope. Using the R-value chart provided, label your materials and thicknesses and show the calculations of how you achieved your ratings.

3. FLOOR INSULATION – Since the floor is open to the weather below, you need to design a highly insulated floor with minimal thermal bridging. The insulation

system must be able to support the weight of the travertine floor and mortar bed which limits/ determines your insulation choices. Insulation must add up to a minimum R-25 for the total floor and you must show your calculations.

4. FENESTRATION – Floor to ceiling glass walls are critical to the home's concept so must be retained. However, the original steel mullions with their narrow sightlines are not thermally-broken and single-pane glass is very inefficient and so must be sensitively replaced. The fixed windows also prevent any fresh air movement so you must add some operable windows to increase natural ventilation.

As with the shading devices, sophomore students have little to no knowledge of available window mullion options so a detail library was provided to select from. Kawneer aluminum mullions or more historically-correct Hopes steel windows details, both thermally broken with narrow profiles, were provided in Auto Cad format to from which to cut and paste. All the manufacturers' .dwg drawings for swing-in (casements and hoppers), swing out (casements and awnings), fixed, and/or combinations of operable and fixed details were provided so the students could select the correct 3 or 4 details to match their proposed design of operable and fixed windows shown on their elevation. Window type selection depended on access to the handle, sight lines and if a shading device was in the way of its operation. They were encouraged to consider lining up horizontal mullions with elements of your shading device to maximize view sight lines.

Support Labs for Project 3

Three separate lab exercises were assigned in class to help them understand the requirements for the project. In the Insulation Calculation Lab they were given 2 different wall sections (Light Wood Framing and Masonry Cavity) with two different strategies for insulation use. Using the thermal resistance ratings chart provided, they had to calculate the total R-value of each wall section to determine which was most efficient. They were required to show their calculations and results on the sheet so they could understand where they made any mistakes (and some were way off target). Common mistakes included using nominal material dimensions rather than actual, not multiplying by material thickness, and forgetting to count air films.

The Curtain Wall Details lab project asked students to identify and locate various fixed, operable and combination window mullions details. Elevations were provided for both an aluminum storefront system and a steel window system along with all the details. This lab required students to identify subtle differences between the mullions based on if it was fixed, operable, attached to the structure, and/or spandrel or vision glass, and match it to its correct location on the elevation.

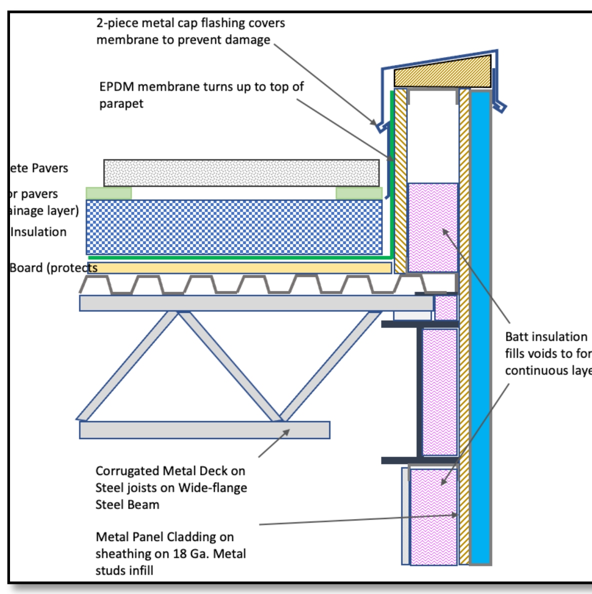

Figure 7 - Roof Parapet Lab Example Solution

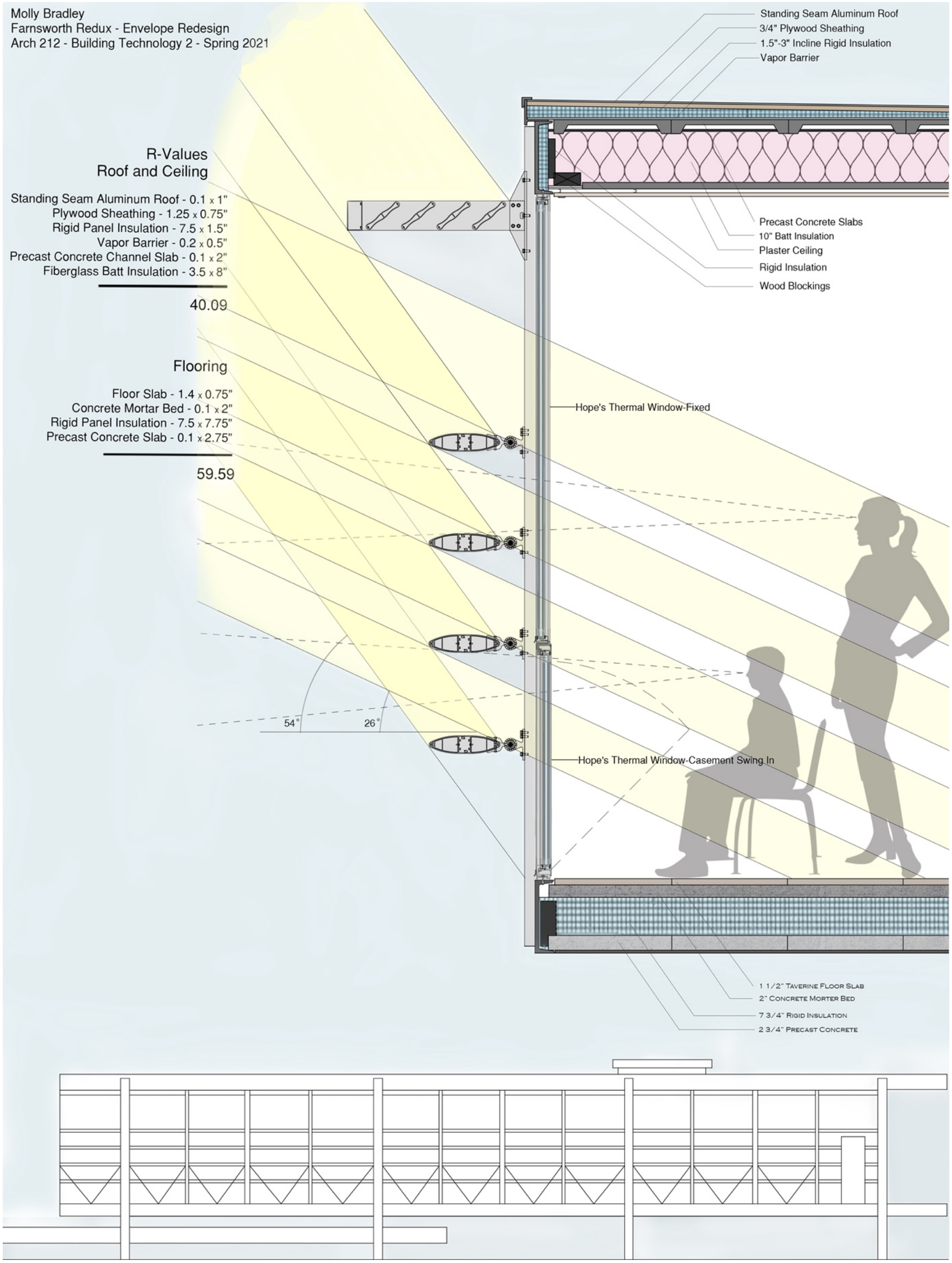

Figure 8 - Final Cumulative Drawing Example by Molly Bradley

The third Roof Eave Details Lab required students to complete two roof eave details for both a Flat Roof with Parapet / Inverted Roof Membrane Assembly (IRMA) Roof System and a Cantilevered Roof Eave with standing seam metal roof. The structural assembly was provided and the students had to complete the envelope by placing the provided list of insulating and waterproofing materials in their correct order. Because this class was run remotely using a PowerPoint file, students would drag and drop certain construction elements to the correct position and then draw the remaining materials in the right locations.

Cumulative Final Drawing

To bring together all 3 parts of the project, a final color-rendered wall section was used to summarize all the information. A black and white line drawing wall section leaves out a lot of information. Students often have trouble understanding what is cut in section and what is in elevation so draw lines without understanding what they are drawing. Therefore, I require them to add color, shading and material texture to render the material close to how it would look if the wall was actually cut open in section as a way to clearly identify and distinguish between the various materials. They also added color and shading to their building elevation to demonstrated how sensitively they had designed the new shading devices and windows for the historic building.

Conclusion

The Farnsworth House served as a good history lesson of what can happen when an architect's ego supersedes client needs. It demonstrated to students why (channeling Vitruvious) they not only need, a delightful building but also one that is functional and well-built; or why we need to consider the whole building while designing and not just the aesthetic idea. "The Farnsworth House was meant to be the pure expression of an idea. By reducing architecture to "almost nothing",[4] but it came at the high cost of personal comfort. Through this extended project we hope students will gain a greater appreciation of the value of their non-design support courses and understand how they all intertwine; how history, technology, representation and design must all be considered simultaneously to produce a quality work of architecture.

Notes

1 Alex Beam, *BROKEN GLASS; Mies van der Rohe, Edith Farnsworth and the Fight Over a Modernist Masterpiece*, Random House, 2020
2 Jackie Craven, *Mies van der Rohe Gets Sued - The Battle with Farnsworth; The troubled story of the glass-walled Farnsworth House*, https://www.thoughtco.com/mies-van-der-rohe-edith-farnsworth-177988, Nov. 4 2019
3 Beam
4 Craven