Demystifying High Performing Building Enclosures

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- Glazing design strategies to control solar heat gain and glare.
- Cladding design strategies to control basic environmental forces.
- Coordinating HVAC system with the enclosure system for optimal energy conservation.

Abstract

Today's technology allows us to iterate, bend, manipulate, and study almost any element of a façade system. This pushes the boundaries of what façades can do and how architecture interacts with the environment. But the design process doesn't always have to be parametric, custom, or re-written from the ground up to achieve human comfort, sustainability and high-performance.

Using a case study project in Louisville, Kentucky, this article breaks down the process of designing a high-performance, sustainable building enclosure using *accessible methods of analysis, readily available means of construction, and close coordination of building systems*, an approach which demystifies the performative design process.

Each major decision related to a building's façade has an impact on sustainability and performance. Site analysis, energy use simulations, and specific assembly performance analyses informed the building design so that it exceeds the current International Energy Conservation Code within the owner's cost model. The design team placed an equal importance on lifecycle analysis and employed strategies to ensure durability and tenant flexibility over the course of a long building lifespan.

The process to design for performance included studying various glazing strategies to control solar heat gain and glare, evaluating cladding strategies to control multiple environmental forces, and coordinating the HVAC system with the enclosure system to optimize energy conservation.

KEY WORDS:

Keywords: lifecycle analysis, energy conservation, rainscreen facade, performative design process, simulation, human comfort

1. Introduction

Figure 1: Entry Facade

Today's technology allows us to iterate, bend, manipulate, and study almost any element of a façade system. This pushes the boundaries of what façades can do and how architecture interacts with the environment. But the design process doesn't always have to be ultra-parametric, custom, or re-written from the ground up in order to achieve human comfort, sustainability, and a high level of performance. Using a case study project located on a medical campus of downtown Louisville, Kentucky, this article breaks down the process of designing a high-performance, sustainable rainscreen enclosure using accessible methods of analysis, readily available means of construction, and close coordination of building systems, an approach which simplifies and therefore demystifies the performative design process. For context, the client had affiliated general pediatric and specialty clinics practicing in several disparate locations across the medical campus. This resulted in the lack of a coherent brand and patient experience as well as wide variations in the physical properties from one clinic space to another. By consolidating services to a single new building, the organization hopes to provide state of the art care in an environment that promotes health and wellness. A high-performance building contributes to better indoor air quality and improves connections to the natural world by increasing access to daylight. Providing an environment that alleviates stress creates positive physiological change, which is especially important for healthcare facilities.[1]

2. Criteria

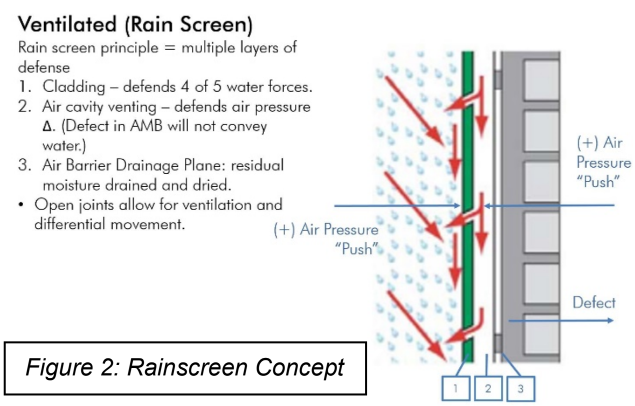


Figure 2: Rainscreen Concept

Each major decision related to a building's façade has an impact on sustainability and performance, and the owner made it clear from the outset that low maintenance, long lifespan, and low energy use were all priorities for the design of the building. Site analysis, energy use simulations, and specific assembly performance analyses informed the building design so that it exceeds the current International Energy Conservation Code within the owner's cost model. The design team placed an equal importance on lifecycle analysis and employed strategies to ensure durability and tenant flexibility over the course of a long building lifespan. A rainscreen façade system reduces required maintenance, offsets environmental pressures that often degrade facades, and lessens energy requirements for the building's mechanical systems. Glazed terracotta panels met all the criteria for the cladding; it requires virtually no maintenance, is high performing, comes at a reasonable cost, and is available in a broad range of finish options for steadfast color to engage children visiting the pediatric facility.

3. Design Strategies

3.1 Glazing Design Strategies

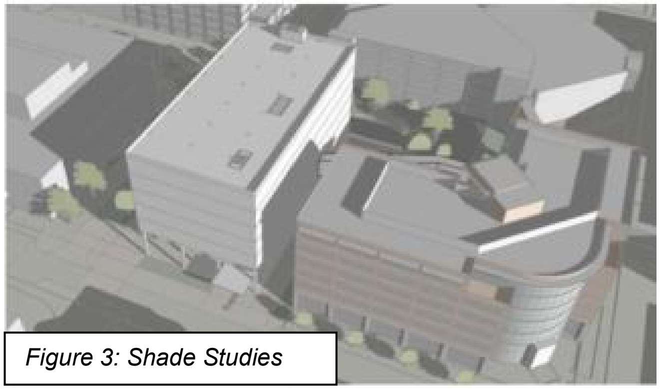


Figure 3: Shade Studies

We used several common software programs to forecast the building's performance: Sketchup, Revit, and Sefaira. We also worked closely with our HVAC designers to fine tune the exterior features to optimize human comfort and energy conservation. As mentioned above, the site is urban and therefore close to neighboring buildings. In order to get a sense of how the neighbors would cast shadows on our building, we used a simple model in Sketchup for several time lapse studies covering all seasons. This highlighted the areas of the facades that would need close attention. We then looked through the lens of Sefaira for a more granular approach to window to wall ratios (WWR). The inflection curves obtained through iteration confirmed our intuition that the biggest challenges would be concentrated glare on the East and West facades and thermal radiation on the South façade. Due to internal programming and site constraints, we couldn't follow the recommended WWRs. We then looked at using solar screens to reduce glare and solar heat gain. The primary focus was on perforated vertical panels. Once again, Sefaira confirmed our intuition that vertically oriented panels would be far more effective than typical horizontal shading devices. We used Grasshopper scripts to design the panels and discovered that partial punches in the panels could do a great job of further controlling daylight. Unfortunately, in the end, the panels were not aesthetically acceptable to the owner. We turned instead to high performance glazing for control: East, West and high Southern glazing exposures received the highest performance ratings. We maintained performance coatings on the Northern exposure to reduce radiant heat loss in the winter. Note that we went through this exercise of fine tuning glazing performance to keep within budget while optimizing comfort and energy use.

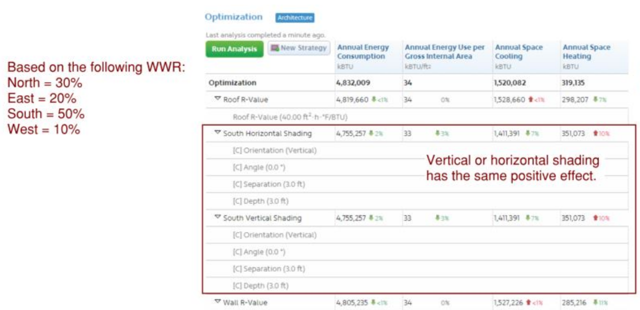


Figure 4: Window to Wall Ratios

3.2 Cladding Design Strategies

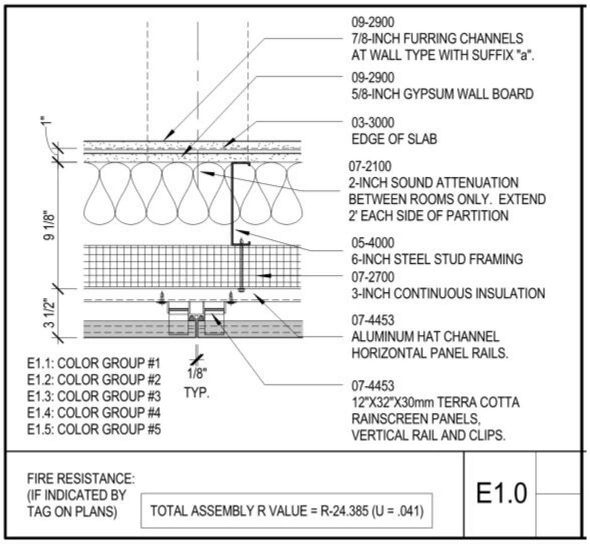
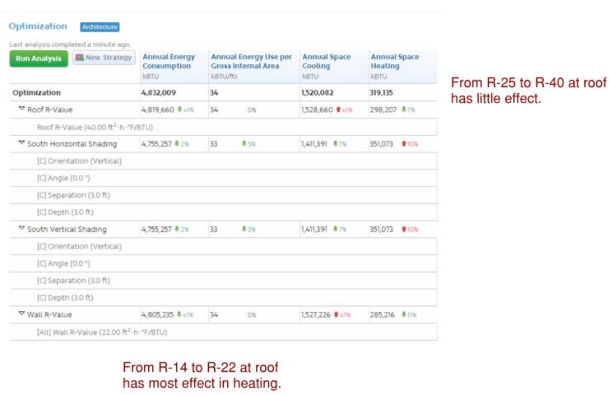


Figure 5: Assembly Detail

We also used Sefaira to study energy loss through conduction within the opaque façade assemblies. The iterative inflection curves (as part of a cost/benefit analysis) determined that providing more insulation than the prescribed IECC 2012 values would not achieve appreciable energy conservation values. As a cost savings measure, we designed all of the insulation to be continuous and outboard of the wall framing. This was a benefit to the energy model. Per ASHRAE provisions, the insulation between wall framing members only counts as 50% of the full R- value of the product. There are currently no provisions otherwise, even if the continuous insulation (C.I.) eliminates the dew point within the stud cavity. Our office standard is for 2 inches of polyisocyanurate C.I. with 1.5 inches of spray applied urethane insulation between the wall framing. The final design was to use 3 inches C.I. Through conversations with the Construction Manager, we decided to provide all insulation as C.I., and eliminate the spray applied insulation between framing members. This would create cost savings and decrease construction time by eliminating another trade. The C.I. we specified has a laminated foil facing that acts as air barrier, moisture barrier, impermeable vapor retarder and drainage plane for the rainscreen cladding. The sealing and continuity of the air barrier was critical to the HVAC design, as we will discuss later.



Optimization Architecture

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Run Analysis / New Strategy	Annual Energy Consumption kBTU	Annual Energy Use per Gross Internal Area kBTU/ft²		Annual Space Cooling kBTU	Annual Space Heating kBTU
Optimization	4,832,009	34		1,520,082	319,135
Roof R-Value	4,819,660 <1%	34	0%	1,528,660 <1%	298,207 7%
Roof R-Value (40.00 ft²·h·°F/BTU)					
South Horizontal Shading	4,755,257 2%	33	3%	1,411,391 7%	351,073 10%
[C] Orientation (Vertical)					
[C] Angle (0.0 °)					
[C] Separation (3.0 ft)					
[C] Depth (3.0 ft)					
South Vertical Shading	4,755,257 2%	33	3%	1,411,391 7%	351,073 10%
[C] Orientation (Vertical)					
[C] Angle (0.0 °)					
[C] Separation (3.0 ft)					
[C] Depth (3.0 ft)					
Wall R-Value	4,805,235 <1%	34	0%	1,527,226 <1%	285,216 11%
[All] Wall R-Value (22.00 ft²·h·°F/BTU)					

Figure 6: Conduction Studies

The rainscreen cladding is a combination of custom metal panels and glazed terracotta panels. Open jointed rainscreen cladding design has two benefits, the first of which is air pressure equalization. The open joints allow the air pressure within the cavity behind the cladding to be equal to the wind driving rain onto it, thus counteracting the kinetic forces. This allows the rain to harmlessly drain from the face of cladding. If rain does get behind the cladding or if condensate forms within the air cavity, it will fall from the drainage plane and weep out of the wall assembly. Secondly, thermal benefits are obtained by venting built up heat and having multiple air films within the assembly.

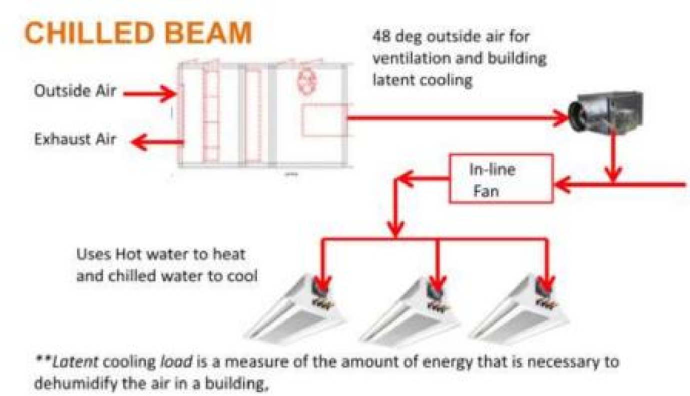

Figure 7: Active Chilled Beams

3.3 HVAC Design Strategies

The primary HVAC system in the building is Active Chilled Beams. As a radiant heating and cooling system, air delivery is only required for ventilation purposes – to bring in outside air. With ductwork needed only for ventilation air, the ducts became much smaller, which allowed the floor to floor heights to be reduced. As floor to floor heights were reduced, so too was the structural frame and overall façade areas. We used these savings to offset the cost of the active chilled beam system. Active chilled beam systems are far more energy efficient than a typical air delivery system. However, radiant cooling systems have one major variable that must be considered—humidity inside the building envelope. If not properly accounted for, condensate can form on the coils, essentially creating rain on the inside of the building! The solution to this is a robust air barrier. If the air barrier is not continuous, infiltration will carry moisture into the building. The vapor retarder must also be impermeable, so that no air borne water vapor can be inadvertently driven inwards. The laminated foil facing integral to the continuous insulation protects both the indoor environment and the ACB system from excess humidity.

4. Conclusion

This process to design for performance included studying various glazing strategies to control solar heat gain and glare, evaluating cladding strategies to control multiple environmental forces, and coordinating the HVAC system with the enclosure system to optimize energy conservation. The building is in the closeout phase of construction and opening to see patients as this paper is being written, so actual energy consumption data has not yet been recorded. As currently modeled, the building is forecast to have an energy use intensity (EUI) of 35 (kBtu/SF) versus the code minimum of 58.7, equaling a 33% improvement. We will be performing a post occupancy evaluation on the building to measure design success, both in terms of energy performance and occupant comfort. Occupant comfort and user satisfaction will be tracked against early design survey responses from user groups in their previous clinic locations. The careful process of using software to analyze external and internal factors, coordinating closely with consultants, and using accessible means of construction made a high-performance, sustainable building enclosure both approachable and affordable for the owner.

Design Energy and Emission Results		
Metric	**Design Project**	**Median Property**
ENERGY STAR Score (1-100)	**97**	50
Energy Reduction (from Median)(%)	**-72.2**	0
Source Energy Use Intensity (kBtu/ft²/yr)	**82**	297
Site Energy Use Intensity (kBtu/ft²/yr)	**35**	128
Source Energy Use (kBtu/yr)	**13,975,748**	50,224,993
Site Energy Use (kBtu/yr)	**6,031,936**	21,677,117
Energy Costs ($)	**123,271**	443,001
Total GHG Emissions (Metric Tons CO2e)	**785**	2,824

Figure 8: Modelled EUI

Project completed in collaboration with Stanley Beaman & Sears/EYP, Uzun + Case, Carman, CMTA

References:

1. Mazzi, A. (2017). Discovering Health: The collaborative and wellness-oriented pediatric care environment.