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How Building Analysis Software Promoted Educated Design Decisions for the International Studies Building at Indiana University

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ABSTRACT

Over the course of designing the International Studies Building on the Bloomington campus of Indiana University, the project’s design team recognized the need for a collaborative design process through which various design decisions could be made as a result of better understanding of the project’s building science and anticipated performance characteristics. Due to monetary constraints and the time consuming and expensive process of carrying out numerous, robust whole-building simulations at several stages throughout the design process, the team decided to leverage several of the numerous accessible software platforms quickly coming to market as a result of the building design and construction industry’s focus on high performance buildings and interdisciplinary design collaboration in order to make design decisions that would positively impact the performance of the project.

1. INTRODUCTION

In our age of heightened energy and environmental consciousness, it is becoming imperative that design teams integrate applied research into the design process in order to better understand architecture and building science. Through applied research into new tools, methods of delivery, materials, and products, effective channels of communication between various disciplines can be opened – making integrated, high-performance design more attainable.

Currently, most architects must “outsource” HVAC system design, daylight/electric lighting modeling, and whole building energy modeling to mechanical engineers, who may have to subcontract building simulation modeling to energy consultants. Such an approach may severely reduce the potential for dynamic interdisciplinary collaboration among a project’s disciplines to periodic coordination meetings. Through the latter approach, opportunities to arrive at deeply integrated design solutions become either unnecessarily cumbersome or simply lost altogether. In addition, such an approach can lead to false design assumptions or inaccurate modeling input due to restricted lines of communication and a lack of mechanisms for checks and balances among team members.

However, today there is an emerging set of tools that are finally bridging the gap between digital architectural models and building simulation and energy models. For the first time, diverse disciplines among project teams can readily exchange interoperable file types and easily-accessible tools that can provide schematic building analysis data to all team members during the seminal stages of the design development process.
Indiana University’s International Studies Building (ISB) is an example of how these emerging tools can be integrated into the design process to inform critical design decisions. For the ISB specifically, research using various software platforms was applied to analyze the building in terms of solar access around the site, incident solar radiation on the envelope, passive loads through select portions of the building envelope, and interior illuminance in order to make educated decisions regarding wall and glazing types, the effectiveness of exterior shading devices, solar access to outdoor spaces, and interior daylight autonomy.

2. PROJECT BACKGROUND

The International Studies Building is proposed as an academic building for Indiana University that will feature multiple department suites. The structure is currently in the design development phase. The 4-story structure will be approximately 174,000 square feet (+/-43,055 SF per story max.). The ISB is designed to achieve LEED for New Construction, version 2.2 (LEED-NCv2.2), Silver certification.

The building is comprised of two north-to-south oriented wings, with a multi-story atrium and circulation core bridging the two wings toward the north end of the property. This results in a large, south-facing, vegetated court to the south of the atrium, flanked by the two building wings.

While there are several wall-type variations throughout the building’s exterior envelope, the most common wall-type consists of 3-5/8-inch light gauge metal stud framing (air space between the studs) along the interior face of a 10-inch concrete structural shell, which was clad with an air/vapor barrier, 2-inches of extruded polystyrene, a 2-inch air space, and 3 to 4-inch limestone veneer (varies based on location). The limestone is a locally sourced Indiana Limestone. It is anticipated that the overall project may surpass 30% regional materials per the definitions and specifications defined by the LEED-NCv2.2 rating system.

The roof assembly consists of a 5-inch concrete slab, topped with a minimum 4-inch layer of extruded polystyrene, topped with a thermoplastic polyolefin (TPO) single-ply roofing membrane. The TPO membrane is considered a high-albedo roofing product, with a solar reflective index (SRI) upwards of the LEED requirements for a cool roof assembly. Of the roughly 42,600 square feet (SF) of exposed roof surface, nearly 1,000 SF will be an extensive green roof assembly comprised of movable 1-foot by 2-foot green roof modules.

Much of the building’s perimeter glazing is accompanied by shading devices or designed elements intended to provide some degree of shading. As section 3 will describe, the design and specifications of the shading devices and glazing assemblies were determined through various investigations and analyses of the project.

3. METHODOLOGY

The design team recognized that energy performance goals of the ISB would be difficult to achieve without optimally designed and specified building assemblies and mechanical systems. The architectural team in particular, which consisted of a New York-based design firm and an Indiana-based Architect of Record and environmental design consultancy, sought to develop highly-refined, energy-efficient design solutions that were not based on broad-based rules of thumb, but on applied research into the solutions themselves. The team determined that through analyses into various proposed design responses, a deeper understanding of building science could be achieved, which would lead to informed decision-making for such choices as shading device sizes, interior finishes, glazing assemblies, envelope insulation values, and general building form.

The design team did not have access to expensive state-of-the-art software, so it had to develop a methodology that utilized the team’s preferred 3-D modeling software (Google SketchUp), one affordably priced building simulation software platform (Autodesk Ecotect Analysis), and a collection of free, readily-accessible programs available through either research institutions or the U.S. Department of Energy. It is important to note that the methodology for conducting the various design analyses for ISB did not consist of the more typical, linear process of developing architectural documents to send to the mechanical engineer for an “outsourced” process of robust modeling analysis. Rather, the design team needed more simple, accessible methods and tools that could provide quick feedback for schematic design analyses. Thankfully, the design industry has witnessed a recent emergence of software platforms
that have the ability to provide such tools to a design team so that they can proceed with some degree of confidence that certain design options will perform better than certain alternatives.

What follows is a brief definition of the methodology employed for the schematic design analysis of the ISB. There are several other commercial and non-commercial tools that can provide similar types of analyses. The purpose here is to offer one possible process through which an architectural firm may be able to leverage commonly-purchased design software to conduct useful investigations to the energy performance of numerous design options.

2.1 Investigate the Building Form
The first step taken by the design team was an investigation into the building form. Specifically, software tools such as Google SketchUp and Autodesk Ecotect Analysis, which have the ability to simulate specific sun angles based on latitudinal and longitudinal coordinates, were used to execute solar access studies to compare how incident solar radiation strikes various building surfaces (useful for orienting prospective solar panel arrays and assessing the need for shading devices on different sides of the building), to determine how direct solar radiation reaches the various spaces in and around the ISB during different seasons (including the south-facing vegetated courtyard), and to assess to what degree the building form obstructs solar access from adjacent structures (Figure 1).

The results of the initial investigations into building forms enabled the design team to test hypotheses and confidently proceed with one, ultimate formal design solution.

2.2 Inventory of Assembly Types and Their Thermal Properties
After the formal composition of the design solution was established, a period of design development was carried out, as typical for any building project. As the design team established the project’s various assembly types (e.g. exterior/interior walls, windows, curtainwalls, foundation assemblies, roof assemblies, and so on), an inventory was amassed using an electronic spreadsheet.

This inventory of opaque assembly types featured a layered breakdown of every opaque assembly’s material composition. For each material, the following properties were identified in order to assess the assembly’s thermal properties:

- Thickness (inches)
- Thickness (decimal feet)
- Density (lb/ft³)
- Resistance (R) per inch thickness or thickness listed (°F ft² h/Btu-in)
- Specific heat (Btu/lb °F)
- Heat capacity (Btu/ft² °F)
- R-Value (°F ft² h/Btu)

Each glazing type was also cataloged. The properties of each glazing type were either provided by the glazing manufacturer, or the design team determined the assembly’s properties by using the software Optics, version 5, developed and available for free through the Lawrence Berkeley National Laboratory (LBNL). Optics5, as it is commonly referred to as, utilizes the International Glazing Database (IGDB) to provide users the ability to assemble and analyze the optical properties of designed glazing systems. Optics5 also allows users to export a text-based script of a glazing assembly that can be imported into a program called Radiance, which is a highly accurate ray-tracing software system developed by LBNL and licensed at no cost in source form. Radiance was developed with primary support from the U.S. Department of Energy and additional support from the Swiss Federal Government.

2.3 Define the Issues and Identify the Proper Tools
As mentioned above, there are many software platforms emerging within the field of building design and construction that are allowing design teams to investigate the performance of structures in ways never before accessible. However, few programs can be considered all-inclusive in their capabilities. For instance, some are designed specifically for daylighting analysis, others are meant to assess solar access, one program may have been developed to simulate energy production from solar panels, while yet another may be used to simulate the acoustical properties of a space. The list goes on.
As with any project, before any analysis could commence for the International Studies Building, the design team had to determine what the issues were that needed to be analyzed. Not all programs are interoperable. Many can’t receive the same file type. Thus, answering this question is critical before building any sort of analysis model.

In the case of the ISB, beyond the aforementioned solar access study, the team wished to assess interior illuminance from daylight as well as the passive gains through the building envelope. The team also anticipates the need for a comprehensive energy model in order to execute a whole-building simulation as outlined by the LEED-NCv2.3 rating system.

2.4 Building the Model

Based on the analyses the team wished to conduct, the design team determined that it needed to create an energy/building analysis model that utilizes the green building variation of the Extensible Markup Language (or XML) schema. The XML schema consists of a set of rules for designing text formats to structure and coordinate information. The XML schema is an outgrowth of the popular HTML code commonly used to develop web sites. XML supports information transaction between various software applications, thus leading to an efficient and effective way to communicate information. The green building variation of the XML schema is known as gbXML. This version of the schema permits a detailed description of a single building or a set of buildings for the purposes of building system, energy, and resource analyses (GSA, 2009).

The ISB project was not designed using a building information modeling (BIM) software platform, thus the design team had to determine an alternative route to create a useful gbXML file type. As mentioned above, the design team was using Google SketchUp for 3-D modeling and solar access studies. In the absence of any gbXML export capabilities afforded by BIM software, the team decided to utilize the Demeter plug-in for SketchUp, version 6, to build a gbXML file. The Demeter plug-in is freely accessible and was developed by Greenspace Research. More recent advancements of the plug-in are available as part of the LiveEnergy Modeller suite of building energy analysis tools.

2.5 Tools for Analysis

Autodesk Ecotect Analysis was utilized as the graphic user interface (GUI) from which the gbXML file could be edited and then exported to a number of software programs for further analysis (Figure 2). The programs utilized for the ISB analyses included:

- Radiance – For interior illuminance simulations.
- Ecotect – For passive gains/losses simulations.
- COMcheck – A free software program available through the U.S. Department of Energy used for checking a building’s compliance with specified design criteria. The ISB team input raw data from the assembly database to verify that the building’s envelope met the minimum requirements set forth by the applicable building energy code.

It is anticipated that when the whole-building simulation needs to be conducted, the gbXML file will be imported into either Trane Trace 700 or eQuest. Preliminary trials have verified that the gbXML file created for the ISB can be successfully imported into Trane Trace 700.

4. RESULTS

By leveraging the various tools and software outlined above, the design team was able to work their engineers in a more productive manner. Collaborative efforts were more fruitful and through the various analyses the design team became much better acquainted with the building science at play in the proposed design of the ISB. By way of example, consider the following issue regarding the balancing of daylighting considerations with energy considerations that the ISB team was confronted with while attempting to determine which glazing assemblies to specify for the project:

Multiple glazing types were considered for the International Studies Building. Per LEED specifications, all frequently occupied spaces need to achieve a minimum of 25 footcandles at the work surface level and a maximum of 500 footcandles throughout the space on September 21st at both 9:00 AM and 3:00 PM. However, specifying the
proper glazing for a project is much more than finding an assembly with a high visible light transmittance (VT) value. In addition, the U-value and solar heat gain coefficient (SHGC) must be carefully considered from the standpoint of energy performance (Figures 3 through 5).

Over the course of the team’s design investigations, it was discovered that many forms of high-performance glazing reduced the VT to such a level that the minimum 25fc could not be achieved in certain spaces. In fact, it was determined that in order to meet the minimum daylighting requirements outlined by LEED, the project would have to forfeit considerable energy savings by specifying less energy-efficient glazing properties that would afford the high VT values needed to achieve 25fc as specified. The project’s budget would simply not support a more advanced, and more expensive, high performance glazing assembly that could provide both the low SHGC and high VT values need to achieve both goals successfully. The design team also recognized that regardless of the stringent LEED daylight criteria, the project is designed to provide ample daylight in most frequently occupied spaces at the locations where desks and workstations requiring such light would be located. Therefore, the team favored high performance glazing assemblies with consequently low VT values.

5. CONCLUSION

Over the course of executing the various analyses carried out by the International Studies Building design team, the most important discovery was the process itself. The entire premise of this manuscript is to exemplify one process through which it can demonstrated that building analysis tools are becoming accessible to design teams in ways never before possible. With the emergence of BIM software and the aforementioned tools (and many others), the bridge between architectural models and energy models is being forged. Interoperability of various platforms is being established and interdisciplinary collaboration is becoming easier and more effective than it has ever been.

Of course the building science behind the analyses conducted for the International Studies Building is very well understood and documented. The quality and refinement of the investigations are admittedly schematic. However, by utilizing such tools early in the design process, the entire design team can better understand the consequences of various design decisions. A deeper understanding of building science can begin to inform decision making within an integrated project delivery approach. Such understanding will be invaluable to an industry ever more committed to high performance and efficient resource use.

REFERENCES


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Figure 1: Presentation graphic from the solar access study conducted during the schematic design phase.

Figure 2: Graphic output from Autodesk Ecotect Analysis depicting the gbXML file of the ISB project.
Figure 3: An example of two glazing types compared for an analysis of a specified west-facing office in the ISB.

Figure 4: Illuminance rendering comparing the two glazing types. Please note the open space beyond the bulkhead.
Figure 5: Graphic output from a comparison of how the two glazing types affect the overall passive gains within the office space. For each glazing type, the design team reconciled daylighting potential with energy performance.