Daylighting Study

Theory

The tightly spaced structural members of the original diagrid inhibit potential panoramic views and limit natural sunlight into exterior spaces. However, the development of the perimeter truss system in Solution Area III opens up the façade in dramatic fashion. This new structural concept provides an opportunity to apply a multitude of curtain wall materials and patterns. With the perimeter truss, windows can be placed in virtually any quantity or arrangement. The freedom to specify how much glazing goes where is sufficient reason to incorporate daylighting. The Athletic Center's original design incorporates daylighting to provide natural light to interior spaces through the use of atrium skylights. Unfortunately, the remainder of the building, primarily perimeter space, was not designed with daylighting concepts in mind.

Why should daylighting be considered for these spaces? There are a number of potential benefits of properly daylighted buildings:

- Increased worker productivity. Pleasant, comfortable daylighted spaces may increase occupant and owner satisfaction and may decrease absenteeism (O'Connor, 1-1).
- Lower operating costs. In general, daylight has a higher light-to-heat ratio. As a result, reduced artificial lighting means reduced space cooling loads, which can save considerable money, especially during peak energy hours.
- Environmentally sound. Daylighted buildings reduce energy consumption and environmental pollution. In some cases they can help obtain LEED certification, giving the building owner certain tax breaks.
- Increased heat gain in winter. This decreases the required heating load and can save mechanical equipment operation costs.

There are also a number of challenges to daylighting the Athletic Center:

- Discipline coordination. Daylighting is highly integrated with other systems and requires much coordination between different disciplines. Ideally, it should have been incorporated into the building program during initial design.
- Increased building glare. Glare occurs when an object is much brighter than the surrounding visual field. It is most frequently experienced by direct sun exposure on the east or west of a building.
- Thermal discomfort. Temperature imbalance from direct ray exposure is irritating to occupants.
- Building orientation and location. This is critical to an early daylighting design. Unfortunately, the Athletic Center's footprint is considered set and cannot be moved or rotated. Neighboring buildings must be taken into account.
- Summer heat gain. Potential unnecessary heat gain will increase cooling loads and energy costs.

The purpose of this study was to design a daylighting system for the perimeter spaces of the Athletic Center and to evaluate its advantages and disadvantages. It was a qualitative study, not a more accurate (and time-consuming) detailed numerical analysis. Simple diagrams and calculations help present the information.

Solution

To begin the study, a determination of which spaces have potential to be daylighted was necessary. A typical floor layout (Figure 34) shows that the daylighted spaces served by atrium skylights (light green) are located on the interior of the building only. Private offices on the western face (orange) are well-suited for daylighting. The large public area at the northwest corner had potential as well, however it faces three directions at once and would be very difficult to properly light and control. All white areas are either back of house spaces, or they face the Shoemaker Arena and would not receive enough light. Therefore, daylighting design focused on the West offices only.

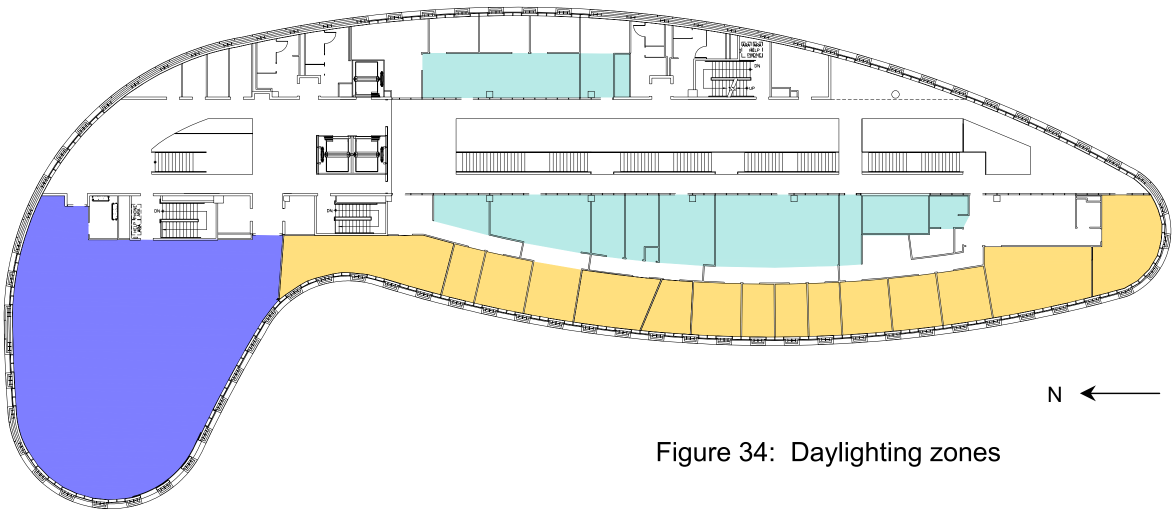


Figure 34: Daylighting zones

The next step in the study was to make building envelope decisions for five major design considerations:

1) Window quantity

To determine a reasonable quantity of glazing for daylighting use, a Net Area Glazing Calculator was used (O'Connor, 3-7). The calculated value was then multiplied by 1.25 to take into account any framing or mullions. Input assumptions were made to model a representative West office with average reflectance and double pane low-E green tinted glass. The output for the calculations is below in Table 24.

Window Area Calculations	
Average Daylight Factor	3
Room Width (ft)	13
Room Depth (ft)	14
Room Height (ft)	9
Total Area of Interior Surfaces (ft^2)	850
Area-Weighted Average Reflectance	0.5
Visible Transmittance	0.63
Vertical Angle of Sky (degrees)	90
Required Net Glazing (ft^2)	45
Required Gross Glazing (ft^2)	56

Table 24: Window area calculator output

2) Window geometry

The calculated gross glazing area was then divided by the room width and an interference factor of 0.9 to account for columns and other obstructions to the glazing. The resulting required height was 4.8 feet, a reasonable number for an average window. The height was rounded up to 5'-0" for convenience. Useable levels of daylight can be provided to a room depth approximately two times the head height of the window (Mistrick, 2). The West offices are 16' deep from the façade face; therefore window heads were located 8' from the floor. This placed the sill of the window 3' from the floor, a level which permits the occupant to look comfortably out their window. As a result, windows were designed to be continuous along the perimeter, broken only by columns. The continuity also provides a more uniform distribution of light within the space. Finally, the windows were recessed a distance of 1'-4" from the façade face. This "deep façade" approach creates a buffer zone which filters glare and blocks high sun angles. Figure 35 is a section through the typical office showing room dimensions and two key solar angles.

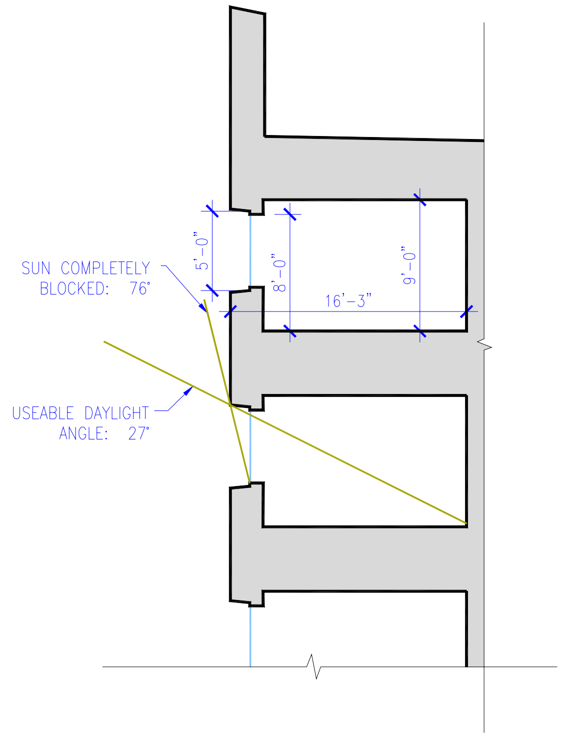


Figure 35: Typical office section

3) Glazing material

As specified in the window quantity calculations, a double pane low-E green tinted glass was selected as the glazing material. This glass works well with the geometric properties of the façade, and has a visible transmittance of about 0.63. The low emissivity also helps control winter heat loss.

4) Window covering

Because much of the building faces North, East, or West directions, the use of vertical blinds is employed. These blinds have an advantage over horizontal blinds by blocking low angle sunlight arriving from high azimuths. No outer window shading is used, as it would disturb the architectural intent of the perimeter.

5) Façade material

The curved shape of the Athletic Center creates potential for reflective glare from one perimeter section to another. Therefore, the building envelope surface material was designed with low specularity. Precast concrete was originally utilized to clad the diagrid members, and was found to be an excellent low specularity material. A roughened precast finish is specified for all spandrel beams and column claddings.

Also important to daylighting performance is the room design. Two factors were considered:

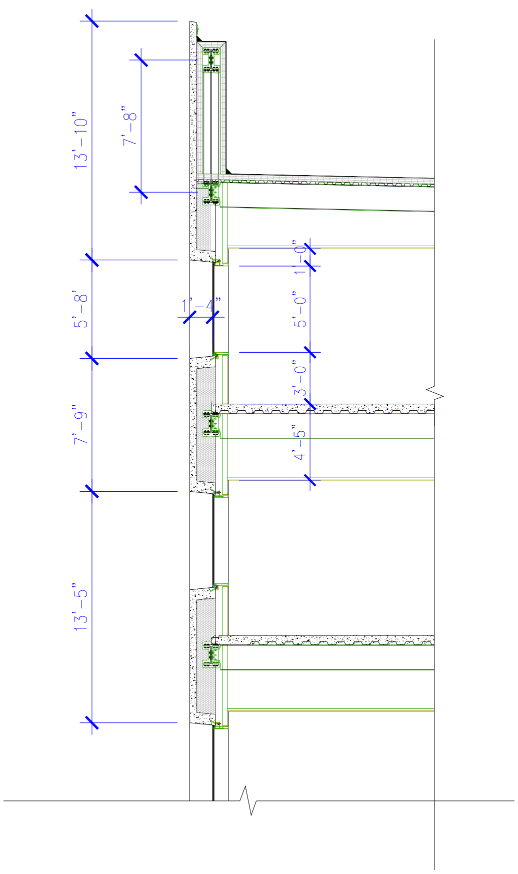
1) Control systems

Because the spaces designed for daylighting are primarily private offices, automatic controls such as photosensors were not employed. However, stepped manual control has been provided. This allows the private office or support room occupant to adjust lighting levels to suit their taste, and does not limit them to an on/off switched situation. It is also considerably less expensive than a dimmed ballast system. Operation cost reduction from the ability to step luminaire levels was not quantified for this study, but there will likely be some energy savings.

2) Interior finishes

Room surface characteristics have substantial effects on the distribution and performance of daylighted space. High reflectance and low specularity are beneficial. Therefore, offices are finished with light colors on the walls and ceilings, and other prominent objects such as the vertical blinds are matte.

Once basic design considerations were settled, curtain wall details could be worked out. The wall system was chosen to be similar to the diagrid cladding in the original design. A precast concrete spandrel beam is placed over the floor structure. It is secured to the perimeter floor beams and filled in with expanding foam insulation. Interior wall structure is built up against the precast concrete and the double pane window is set on an aluminum window frame. Sections of the curtain wall system are detailed below in Figures 36a and 36b.



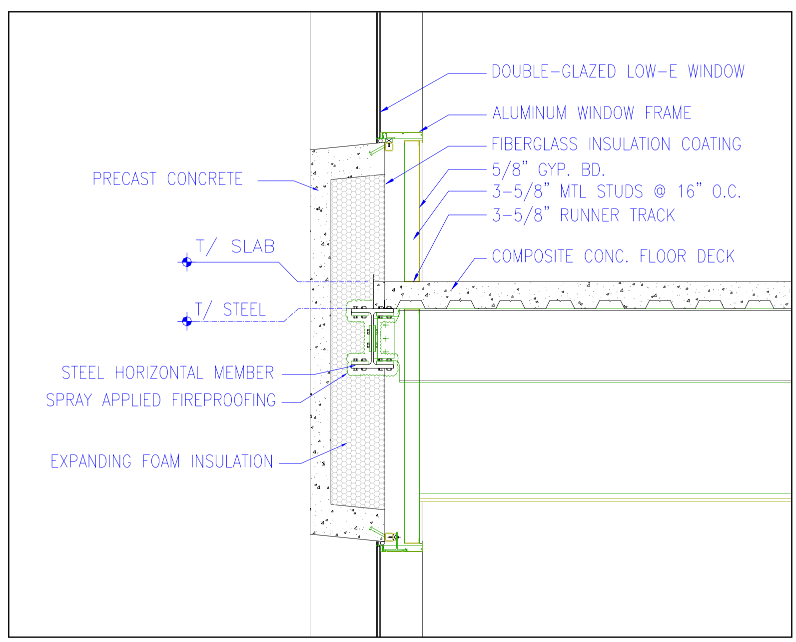


Figure 36b: Spandrel beam detail

Figure 36a: Curtain wall section

Because the exterior wall was changed in the redesign of the structural system and subsequent curtain wall design, a review of code provisions must be considered. Table 705.3 of the Ohio Basic Building Code specifies maximum unprotected or protected window areas for certain fire separation distances. Table 25 below is an abbreviated version of the code table.

	Fire Separation Distance (feet)			
Classification	**0-3**	**>3-5**	**>5-10**	**>10-15**
Unprotected	N.P.	N.P.	10%	15%
Protected	N.P.	15%	25%	45%

Table 25: OBBC Table 705.3 (abbreviated)

The code also states that buildings with an automatic sprinkler system throughout are permitted to use the protected values for unprotected windows. Because the Athletic Center is fully-sprinkled, its unprotected exterior window area may be as much as its protected area. The curtain wall design detailed above has a window area of roughly 35%. All windows have been designed unprotected, so for separation distances less than 10 feet the configuration will not work. The Athletic Center is in close proximity to the Shoemaker Center, about 10'-6" at its nearest point. This translates into a fire separation distance of 5'-3". Therefore, the windows closest to the Shoemaker Center do not meet code provisions and must be changed (Figure 37). Rather than redesigning the entire window system, the section of wall which is 20' or less from the Shoemaker Center was modified by simply introducing non-structural precast cladding panels similar to the column covers at regular intervals along the perimeter. This effectively reduces the window area to less than the 25% maximum allowed by code.

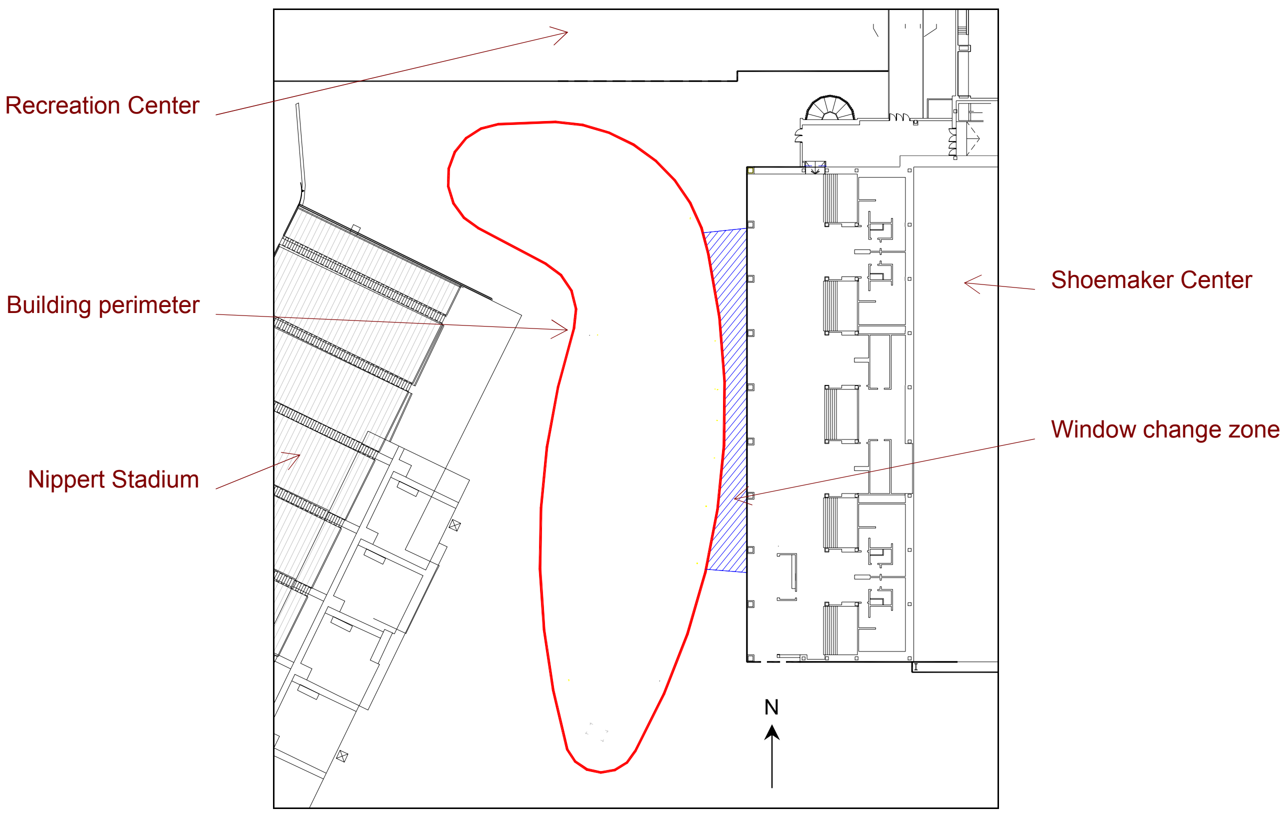


Figure 37: Window change zone

Conclusions

The opportunity to incorporate perimeter daylighting into the Athletic Center was made relatively easy by the structural redesign of Solution Area III. However, the number of spaces which could utilize daylighting was limited. A daylighting program for private offices on the West side of the building was made, taking geometry and material considerations into account. A chart is provided below to summarize the advantages and disadvantages of the perimeter daylighting system relative to the original diagrid system (Table 26).

Issue	Result	Reason
Worker productivity	Advantage	Increased daylight makes offices more comfortable and satisfying
Operating costs	Either	Daylighted offices will benefit from reduced artificial costs; however the other spaces could experience increased mechanical conditioning loads from the additional window area.
Initial cost	Advantage	No additional controls or special equipment is needed for the proposed design. Also, the continuous façade design decreases construction costs due to simple, repetitive pieces.
Environmental Impact	Either	Energy consumption could go either way, base on the same reasoning as for operating costs
Design coordination	Disadvantage	More coordination is needed between disciplines, as well as during the initial design stages.
Glare	Disadvantage	Larger windows placed at the normal viewing height create more opportunity for glare, especially on West side. Vertical blinds help control direct sunlight.
Thermal discomfort	Disadvantage	Increased windows lead to radiation discomfort, especially during winter months. Direct sunlight may be an issue.
Heat gain	Either	Heat gain during winter months is desirable, but during summer months it is a problem.
Views	Advantage	Large, continuous windows at eye level open up views of the Athletic Center surroundings.

Table 26: Daylighting advantages and disadvantages

Given the considerations above, it is safe to conclude that perimeter daylighting for the Athletic Center is certainly possible, but not necessarily feasible. The inherent constraints on building shape and orientation severely decrease the effectiveness of any perimeter daylighting system. Implementation of daylighting for the private office spaces on the west side of the building is a tossup, depending largely on the design intent of the architect and preferences of the building owner.