INTUITIVE AND OBJECTIVE APPROACHES TO DAYLIGHTING A NEW ENGLAND ELEMENTARY SCHOOL

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ABSTRACT

The Town of Concord, Massachusetts faced the challenge of building an entirely new school on the same site as its (still operating but eventually to be demolished) predecessor school. This new learning environment would become the home for approximately 400 kindergarten thru 5th grade elementary school children and their associated staff. It would also become the recreational and community center for the surrounding neighborhood.

Together, this community of neighbors, parents, educational professionals and town elders established two over-arching goals for their new school: First, it had to be a superb and holistic learning environment. Second, it had to be designed to achieve high performance under two sustainable building rating systems - a Silver level under LEED for Schools and a minimum of 34 points under MA-CHPS[2].

Daylighting strategies played a key role in meeting these goals and they played the essential role in integrating them. Everything from the school's placement and orientation on the site, the shape of its unique footprint, the development of the building's cross sections, the educational programming for each space, the building's mechanical / electrical systems and the architectural details / aesthetics were all about light, ambient light levels and light controls. Windows, skylights, roof monitors, clerestories, transom glazing, light shafts, and interior glazing of all sorts were strategically employed to create highly functioning and lovely daylit spaces throughout. Even an analemma and sundial worked their way into the design.

Key Words: Daylighting, Elementary School, holistic, LEED Silver, MA-CHPS, borrowed light, analemma, sundial, physical models, computer energy and light modeling simulations, day-lit, high-performance

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2 MA-CHPS is one of the two sustainable building rating systems recognized by the MSBA. Modeled after the LEED rating system, it began in California as an incentive and recognition tool to encourage sustainable design in public schools. The MSBA offers supplemental building cost reimbursement for projects achieving certain prerequisite and point totals.

INTRODUCTION

This paper will document the trail of light driven design decisions; compare the light related data garnered (thru the employment of both physical and computer models) during the design stages with comparable data gathered in the completed school; and hopefully demonstrate how day-lit environments integrate, illumine and de-light.

GOALS AND VALUES

Preceding our design work, a list of preliminary goals and values was established by the owner with the architect. After further refinement, these project goals and values guided the early planning stages. Four of these relate to the use of daylight in the design:

After review of numerous options, two concepts were analyzed by the design team, one resembling a ‘base school model’ and one prioritizing daylighting. A computer energy model was used to compare the energy consumption of the two options and potential cost savings. It was determined, through the energy modeling analysis, that the option that prioritized daylighting, Option B, would consume less energy and be less expensive to operate than Option A, the base school model.

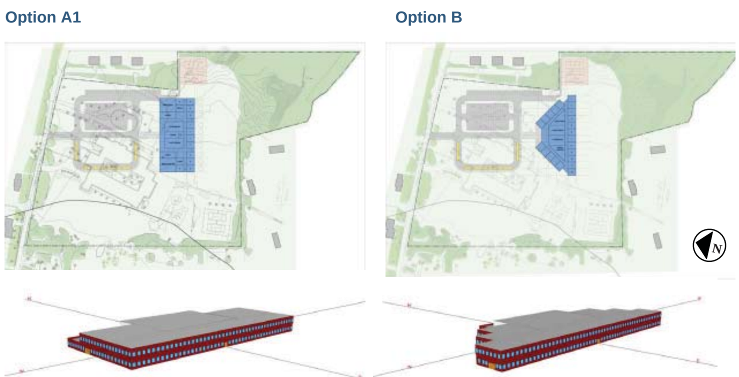

Figure 8: Site plan and isometric view of Options A1 & B

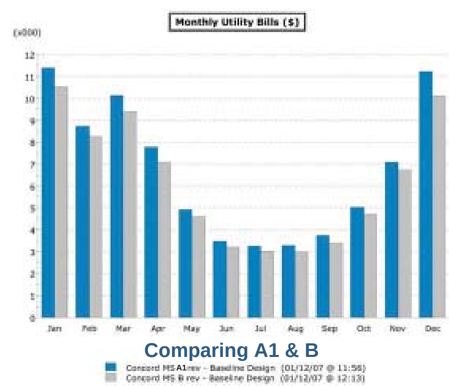

Figure 9: Energy model comparison chart of Options A1 & B

Once it was determined that Option B was worth pursuing, the integrated design team analyzed[3] and tweaked the solar orientation by comparing an all north-south exposure to a southeast and southwest exposure. Daylight modeling and energy consumption analysis of these two options indicated that maximizing northern and southern daylight and minimizing the eastern and western daylight reduced energy consumption.

Figure 10: Plan options for North facing rooms

3 Energy modeling software utilized in the daylight and electrical light analysis was: AGi32

1. "Design to Meet the Students' Educational Needs in all Respects"

Prioritizing the use of daylighting in classrooms and other spaces within a school helps to create an enhanced learning environment. At the Willard School, all twenty-eight south and north facing classrooms and a majority of other interior spaces throughout the building receive direct or shared daylight.

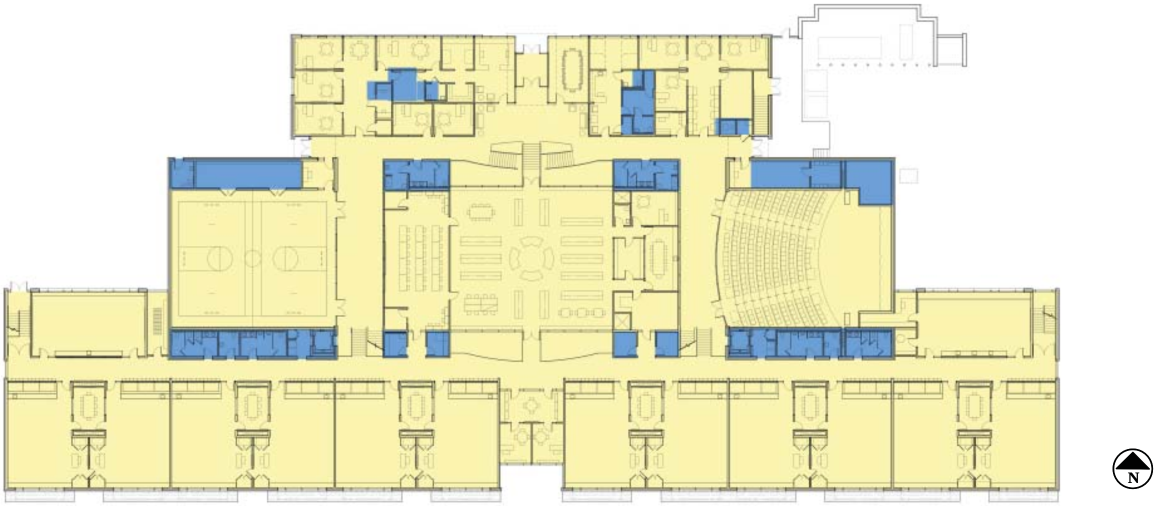

Figure 1: Almost all spaces receive natural light. Spaces colored yellow receive natural light

2. "Use the School (building and site) as an Educational Tool"

Through the use of daylighting, two timekeeping devices were integrated into the design as teaching tools. The first device is an analemma projection on the floor of a bridge that connects the media center to the classroom wings. This device consists of a small aperture precisely located in a solid panel which is placed within the light shaft of a clerestory roof monitor. A meridian line is calculated from the aperture and inscribed on the floor establishing the summer and winter solstices and equinox. With staff guidance, the students will frequently plot points at solar noon and eventually create the analemma shape. The second device is a south-facing vertical sun dial located at the playground entrance in lieu of a traditional clock face.

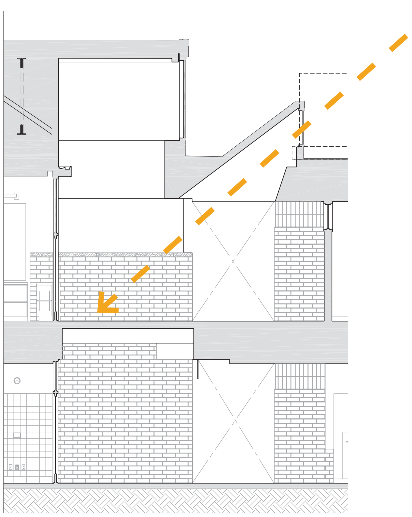

Figure 2: Section at analemma roof monitor

Figure 3: Sketch of sundial on the South Elevation

3. "Create a High-Performance School"

To achieve this goal, the Town of Concord pursued MA-CHPS credit IEQC1.2, Daylighting in Classrooms. The credit can be achieved by demonstrating with computer generated daylight models or field measurements of the as-built daylight levels within a classroom at a four foot grid. It was decided after review of the daylight modeling that the daylight calculations from the model would be submitted for the typical upper level south facing classroom; however, daylight modeling data for the typical lower level classroom was much more difficult to determine so the design team decided to field measure these rooms in the field.

In addition to enhanced lighting controls including automatic daylight harvesting provided for selected areas and occupancy sensors provided for many spaces, other energy-saving features included: demand-controlled ventilation, building envelope enhancements (wall and roof insulation and window performance exceeding minimum requirements; overhangs for south facing windows), high efficiency condensing boilers with optimized hot water loop temperature, energy recovery units including variable frequency drives for the energy recovery wheel control (and better control of the discharge air), and very significantly reduced lighting power density (0.87 watts/sf) for the lighting system in the entire building.

The Town of Concord reports[4] that the gas and electric bills indicate the new Willard School is consuming over 30% less energy than the Town's two other elementary schools which were recently built to the same program. They are the same size as Willard.

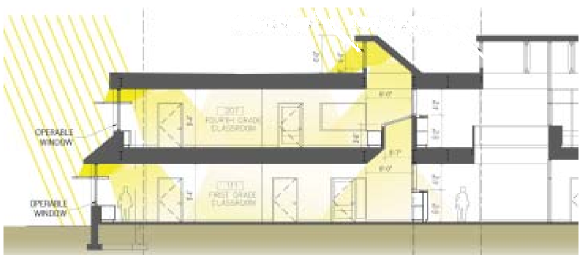

Figure 4: Daylighting section through classrooms

Figure 5: Daylighting model of classroom

4. "Organize the School so That it Functions Optimally and There is an Enhanced Sense of Community"

- o All grade level classrooms face south.
- o The special classrooms: Art, Music, and Collaborative Classrooms, all face north.
- o The Gymnasium, Auditorium, Library and Cafeteria are daylit from above by clerestories.
- o The Administrative suites all face north, the direction of entry, pick-up / drop-off, and parking.

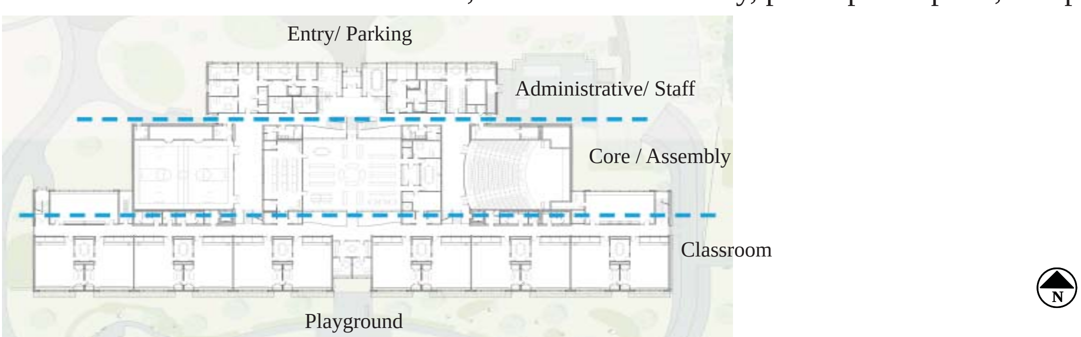

Figure 6: Building organization

4 E-mail from Town of Concord's School Facilities Manager

THE SITE'S SOLAR ORIENTATION

Building and site planning schemes were created to show options that allowed for the new school building and parking area to be built while the existing school was operational.

Figure 7: Building and Site planning options

DAYLIGHTING DESIGN ELEMENTS AT CLASSROOMS

At each phase of the design process beginning with the early conceptual planning and through construction documentation, daylighting elements were refined, detailed and tuned to optimize the quantity and quality of daylight within the building. The combination of daylight monitors, clerestory glazing and sunshade/light shelves were used in different ways throughout.

The typical two story classroom wing incorporates all of these strategies to create balanced daylit spaces. In addition to the exploration of the plan and section in drawing form, both physical and computer generated daylight models were created. Several schemes were developed and compared to test different configurations of window opening sizes at the exterior wall as well as interior walls at the roof monitor and the glazed light wells. A device, similar to a heliodon, was built to maintain the proper orientation of the sun and a light meter was used to measure the foot-candles within the model.

Figure 11: Daylighting Scale Model

Figure 12: Daylighting Scale Model & Light meter (typical upper level south facing classroom looking north)

Figure 13: Daylighting Scale Model (Typical upper level south facing classroom looking south)

At the exterior wall, options were explored to determine the size for the window openings as well as the different depths for the exterior sunshade and interior light shelf. The sunshade plays a critical role in controlling the penetration of direct sunlight into the classrooms. The light shelf is primarily a reflective plane which redirects the light from the transom glass to the ceiling. It also aids in controlling the direct sunlight into the space. Base cabinets at the exterior wall also function as a light shelf, reflecting more light into the space and up to the ceiling.

Figure 14: Sunshades at South Facade of classroom wing looking east

Figure 15: Interior light shelf at classroom

The classroom daylight monitor was explored in form, size and relationship to the spaces below. The monitor's roof overhang, amount of glazing, and geometry were also developed and tested in both physical and computer generated models. To evaluate the efficiency of the roof monitor the design team considered how much light the upper level and lower level classroom received. The overall size and configuration of the monitor were optimized to maintain a balance of light at the front and back of the upper level classroom; while the slope of the roof monitor indicated how much light would be driven down through the light well into the lower level classroom. The light-colored roofing membrane reflects light into the monitor.

Figure 16: Building section through the south facing classroom wing and roof monitor and light well

Figure 17: Exterior view of south facing classroom wing looking northeast showing clerestory roof monitor at back of upper level

Figure 18: Upper level south facing classroom light well and clerestory monitor ceiling opening

Figure 19: Upper level classroom corridor looking at slot in ceiling for shared clerestory daylight

Figure 20: Lower level south facing classroom looking up at light well and curved ceiling transition

Figure 21: Lower level classroom corridor looking through transom glass into lower level south facing classroom light well

DAYLIGHT DESIGN ELEMENTS AT CORE / ASSEMBLY SPACES

In the gymnasium and auditorium, a combination of north and south facing clerestory windows and large light shelves work together to daylight the interior spaces. In the auditorium motorized room darkening shades were added to control the varying lighting conditions that the space requires. Supplemental artificial lighting was placed on top of the light shelves to maintain the same indirect quality of artificial light at night to the daylight during the day.

Figure 22: Section through Core / Assembly spaces looking south

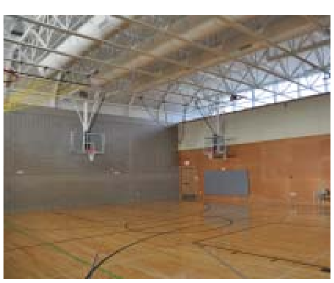

Figure 23: Gym looking through north clerestory and light shelf

Figure 24: Gym looking east towards gallery space

Figure 25: Auditorium looking at southeast clerestory and light shelf

The daylighting strategy at the media center and cafeteria employs clerestories, but not light shelves. Consequently, daylight surrounds and engulfs these spaces. With large glazed interior wall systems at the north and south of these spaces, the daylight is shared and controlled. Additionally, a small dome shaped skylight was placed in the center or the media center roof and the ceiling space carved into a cone shape to promote more daylight distribution into the center of the space. The transparent nature of these spaces creates strong visual relationship to the adjacent circulation of the program space and coherently pulls the entire building together around this central core.

Figure 26: Lobby and stair up to media center and down to cafeteria

Figure 27: Media center circulation desk with skylight with conical shaped light well above

Figure 28: South of media center and cafeteria looking up into the clerestories

Figure 29: North of cafeteria looking through cafeteria and south entry to outdoor play area

CONCLUSION

Once the extensive use of windows (for view and psychological benefit) was assumed, energy modeling was utilized to assist in the design of the facade to effectively harvest daylight, enabling the electric lighting to be turned off in the classrooms, thereby saving energy.