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The School Building Association

ISSUETRAK

A CEFPI Brief on Educational Facility Issues

Topic: Electric Lighting and Daylighting in Schools

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CEFPI BRIEF

INTRODUCTION

When building or renovating a school, a critical planning element is the lighting system. Lighting systems are significant for two reasons, the first being the inordinate amount of energy that electric lighting can consume compared to the rest of a facility. The second reason is the effect that light (both electric light and daylight) can have on the behavior and performance of the building occupants. Lighting systems must be selected carefully to ensure that both the facilities and the people using them can operate effectively and efficiently. The best lighting decisions are made when facility planners understand the appropriate application for different types of equipment. To that end, we will examine both electric lighting and daylighting, listing criteria to determine the correct equipment for a project.

NOT ALL LIGHT (OR LIGHTING SYSTEM) IS CREATED EQUAL

It is important not make your selections based on dollars alone. Be wary of any proposed value engineering (VE) study that masquerades as a method for selecting the cheapest equipment available, considering first-cost analysis only—is Product A cheaper than Product B. While a VE study should look at first costs, it also should include maintenance costs, life cycle repair and replacement costs as part of the analysis. Unfortunately, value-engineered solutions seldom consider these more significant factors, such as life-cycle costs, represented by equipment life and energy consumption associated with equipment. And it absolutely never considers implications to the users of a facility. So if value-engineering cannot provide the answers to lighting system selection, then on what basis should decisions be made? The true value of any piece of equipment should include the impact that it has on the behavior and performance of the people using a specific space. Responsible decisions can be made only when facility planners consider all affects and outcomes associated with their equipment choices.

SELECTING AN ELECTRIC LIGHTING SYSTEM

Traditionally, selecting an electric lighting system was simple. Two-by-four lay-in troffers with fluorescent lamps were commonly used (and still are used) in school facilities. The decision to provide direct illumination with troffers was easily made because students spent much of their time sitting at desks, reading from books. Today, classrooms must support a variety of functions, including an increasing amount of time spent by students, teachers, and staff, alike, working at computer monitors. The increased use of computer monitors has introduced a new set of problems which demand a different set of solutions than have been provided traditionally.

Prismatic Lenses

While prismatic lenses offer the least expensive solution to lighting classrooms and other school facilities, bear in mind that not all prismatic lenses are the same. The cheapest lens is the standard pattern A12 (.097" thick) prismatic lens. A pattern A12 (.125" thick) is also available. With cost as the obvious advantage, the A12 lenses are very popular. In the Arizona market (all costs listed throughout reflect this market), the cost for these fixtures typically run around $90-$100 each. However, there are several problems associated with use of the A12 lenses. The lenses, which are thin, tend to sag and turn yellow. As a result, they have a relatively short life-cycle. Most importantly, because of direct glare, the A12 lenses tend to have very low visual comfort; usually levels of visual comfort well below those recommended by the Illuminating Engineering Society of North America (IESNA). Students and teachers may experience more headaches and visual fatigue with use of A12 prismatic lenses than with other electric lighting systems, thereby resulting in diminished performance and concentration.

The next choice is the pattern A19 (.156" thick) prismatic lens. Although these lenses add $6.50 to the cost of each fixture, or roughly $65 per classroom, the pattern A19 lens has a longer life-cycle. While not outstanding in terms of visual comfort, they do provide sufficiently comfortable lighting quality to meet IESNA standards.

Neither A12 or A19 lenses are appropriate for use in spaces where computers are used. They cause bright spots (reflected glare) to appear on monitors, making it difficult to read the screen. Because eyes must constantly adjust to these contrasts, visual fatigue and headaches are common when prismatic lenses are used to illuminate computer areas.

Parabolic Louvers

Parabolic louvers are usually the first option considered when people want increased visual comfort or a higher quality light than prismatic lenses, particularly in spaces with computer monitors. As is the case with lenses, there is a considerable variance in the level of visual comfort provided by different types of parabolic louvers. In some ways, the differences between parabolic louvers can be quite extreme, both in terms of cost and visual satisfaction.

The most common type of parabolic louver has cells that are 3" deep, with 18, 24, or 32 cells per fixture. These louvers generally have a “shielding zone” of 30º-45º (or shielding angle). The shielding zone determines the angle at which the lamps in a fixture are not directly visible to a viewer. By reducing the view of the lamps from most positions in a space, direct glare is reduced dramatically, usually to levels well above those recommended by the IESNA. Many people also find these louvers to be aesthetically pleasing. This type of louver adds $25-$35 to the cost of a 2' x 4' troffer, bringing the total cost per classroom to $125-$130 (again, based on Arizona prices).

The problem with these louvers is the shadow that they cast on walls. Owing to the shielding they provide, shadows are cast at an angle equal to the shielding angle. This means that when a fixture is two feet from a wall, a louver with a shielding angle of 45º will cast a shadow extending two-feet below the ceiling line. The shadows and low glare tend to make fixtures “disappear.” The ceiling area looks dark, thereby creating a “cave-effect,” which makes the space look and feel dark even though there is plenty of illumination on work surfaces. The presence of computer monitors causes an additional problem. Although these louvers restrict direct glare, indirect glare on computer monitors may occur, thus causing severe eyestrain and headaches.

To eliminate the problem of reflected glare on computer monitors, a slightly different type of louver can be used. These louvers appear similar to the 3" deep louvers, but they are 4" deep and have an additional metal extension that forms a “V” around the lamps. These figures meet the IESNA recommendations (RP-24) for parabolic louvers in spaces where computers are used frequently. The benefit to visual comfort is not without a price, though. Louvered fixtures that meet RP-24 can cost as much as $160-$180 apiece.

In addition to the relatively high cost of fixtures with these louvers, another serious concern exists. Owing to the depth of the louvers, a severe shadow is cast on walls. With a shielding angle of 60o, fixtures located just two feet from a wall will cast a shadow nearly 3'-6" below the ceiling line. These dramatic shadows can create an environment which feels very dark although, once again, illumination levels on work surfaces is high. Considering both the high cost and the dark, gloomy atmosphere they create, these deep louvers are really best suited for spaces in which computers are used frequently and where the ceiling is too low to permit use of an indirect lighting system.

Indirect Lighting

Indirect lighting is a term that describes illumination systems which reflect light (primarily off a ceiling and sometimes off walls) to illuminate a space. The idea is to use the ceiling and walls as diffusers to provide soft, even lighting throughout a space. Researchers have found consistently that spaces illuminated with indirect lighting systems are reported to cause less eyestrain, visual fatigue, and fewer headaches than direct lighting provided by fixtures using either prismatic lenses or parabolic louvers.

Achieving good conditions with indirect lighting systems requires careful design using some basic principles. The success of indirect lighting depends on creating lighting with little contrast. Because good indirect lighting has no bright spot, but rather a soft glow, there is no reflected glare on computer monitors and no direct glare from the lighting source. To achieve this effect, indirect lighting should be suspended at a distance of 18"-24" below the ceiling. Rows of fixtures should be spaced at 10'-0" apart, although 12'-0" is acceptable when the suspension length is 24" or more. And while designers sometimes believe they don’t have the ceiling height necessary to suspend indirect fixtures properly, a little creativity can resolve this problem. Ceilings in classrooms are usually at least 9'-0" in height. Because the 6" that normally would be used above the ceiling for troffers is not required, ceilings can be raised 6" to provide the minimum 18" suspension length. The bottom of indirect fixtures will then be 8'-0" above the floor.

Energy Savings Using Indirect Lighting

If first cost is the only concern, then indirect lighting cannot compete with prismatic-lensed troffers. Prices for indirect fixtures can run as inexpensively as $30-$35 per linear foot, however. At this price, they can compete on a cost basis directly with RP-24 parabolic louvers. They also can compete with 3" deep parabolic louvers if the operating cost is considered. Because indirect lighting eliminates shadows, spaces appear brighter than when lit with direct lighting, thereby requiring less lighting. Classroom spaces with direct lighting are illuminated to 50-100 foot-candles (fc), but when indirect lighting is used, only 35 fc are required—and it still appears brighter. Since less light is required, energy savings are possible. The energy savings are usually sufficient to pay for the incremental cost to upgrade from standard parabolic louvers in just a few years.

SELECTING A DAYLIGHTING SYSTEM

Selecting a daylighting system that will meet the needs of both the owner and the building occupants can be as challenging as selecting an electrical lighting system. There are many alternatives, each one associated with particular costs and benefits. But, rather than exploring all of them here, we offer a brief overview of some of the less commonly recognized and/or appreciated aspects of windows and skylights.

Windows

Occasionally, windows are targeted for elimination from design solutions. There are two primary reasons cited—one is an increasing concern about vandalism and violence by facility owners, and the other is a concern that students should "pay attention to the teacher and not be distracted" by things going on outside the classroom Bolstering the anti-window argument is the fact that much of a building's energy loss through the envelope is transferred through windows. In this instance, as is so often the case, there is a good measure of fallacy mixed with fact.

Research published in the Journal of Environmental Psychology[1] states that "windowless classrooms should be avoided for permanent use." This premise is supported by medical doctors who, in the Archives of Internal Medicine,[2] report a biological need for windows. Rather than being a distraction which disrupts the learning process, windows provide a necessary relief, requiring "soft" attention. The type of soft attention associated with window gazing is less consuming than the focused attention used to draw pictures or "doodle" in a notebook. It is much easier for students to refocus their attention back on the teacher when engaged in tasks requiring soft attention rather than those requiring more focused attention.

When vandalism or violence is a potential problem, classrooms can be designed to focus inward toward an interior courtyard. Classrooms can have windows facing the courtyard which are protected from the street. Skylights located on the far side of the room from the windows can supplement light from the windows, if desired.

And while it's true that windows are not as good at conserving energy as are insulated walls, their energy loss is not as severe as one might think. Schools are usually interior load-dominated buildings. That means that the HVAC system must contend with more energy generated inside the building than energy transferred from the exterior (as is the case with external-load dominated buildings). As a result, the additional load associated with having windows is not sufficient to offset the benefits they provide. Furthermore, windows that are well designed need not have a major detrimental impact on energy consumption. In hot climates, windows can face north, or, for south-facing windows, be shaded to reduce direct solar penetration into spaces. In cold climates, south-facing windows can be designed with overhangs that allow light and warmth to enter a space when the weather is cold yet shade the windows when the weather is hot. Double-glazed windows with thermal breaks are a good investment in all but the most temperate of climates.

Skylights

In instances where it may not be feasible to have windows, skylights provide an excellent alternative. The Orcutt/Winslow Partnership uses "enhanced" skylights that have highly reflective shafts (to bring daylight down from the roof level) and diffusers that extend below the ceiling to deliver uniform illumination. Although the first-cost of skylights may be high, that cost should be compared against the cost of windows. Skylights cost $3200 per classroom versus $1200 per classroom for windows, but using the incremental cost reduces the payback for skylights to 7-8 years. (Windows on one wall would not enable energy savings to be attained through daylighting). Further, the payback does not include savings from reduced HVAC sizing and solar loads.

Skylights provide outstanding color rendering and high levels of illumination. Numerous studies from The National Institute of Mental Health indicate that illumination levels typically provided in schools and offices (i.e., 50-100 fc) can cause people to become lethargic, irritable, and depressed. Illumination levels provided by the skylights (150-200 fc) have been found to reverse these effects, helping to keep students alert. The cost of providing 150-200 fc with electric lighting would be prohibitive.

SUMMARY AND CONCLUSIONS

When it comes to lighting selections and costs, there is no standard answer. While we would like clear-cut answers, there are many different systems and innumerable ways to design lighting—the advantages and disadvantages of each system must be considered on a project-specific basis. This becomes a particularly difficult job when you go beyond mere cost comparisons to address such necessary yet subjective issues as comfort and quality. This article only begins to scratch the surface by addressing some of the most common equipment used in schools, helping you to learn more about your potential lighting options. A lighting designer should be consulted to ensure that your decisions are, in fact, the best for your particular project. The following table should assist you in weighing the advantages and disadvantages discussed.

Lighting System	Lens	Advantages	Disadvantages	Application
Prismatic lenses	A12	Low cost	High glare, low comfort	Low budget, NO computers
	A19	Slightly less glare and more comfort than A12 lenses	Slightly higher cost, NO computers	Small budget, NO computers
Parabolic Louvers	3" deep	Reduces glare	Cost	Computer spaces, low ceiling, aesthetics
	RP-24	Eliminates glare	High cost	
Indirect Lighting	None	Excellent visual comfort, especially in computer spaces	Cost	Computer spaces, high ceilings
Windows	Glass	View, daylight	Vandalism	Classrooms and offices
Skylights	Acrylic	Daylight, color quality, savings, high light levels	First cost	Classrooms, media center, energy gymnasium, offices

[1] Kuller, R. & Lindsten, C., “Health and Behavior of Children in Classrooms With and Without Windows,” Journal of Environmental Psychology 12 (1992): 305-317.

[2] Wilson, L. M., “Intensive Care Delirium: The Effect of Outside Deprivation on a Windowless Unit,” Archives of Internal Medicine 130 (1972): 225-226.

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