Daylighting and Flooring: Don't Overlook the Issue of Reflectivity

Written by Mike Kennedy of ***American School and University*** *magazine based upon the latest available research on daylighting in schools and recently completed (October 2014) research conducted by Dr. Richard Mistrick, Associate Professor of Architectural Engineering at Penn State University.*

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Schools and universities are striving to provide 21st-century learning spaces for their students and staff, and the effect that facilities have on the environment is one of the major factors that architects and administrators consider as they design, construct and renovate buildings.

A key strategy in creating environmentally friendly, energy-efficient education spaces is capturing abundant daylight and reducing the reliance on artificial light. Efforts to maximize daylighting in school facilities have taken many forms as techniques have grown more sophisticated. For example, computer simulations enable planners to make precise calculations about a school's site, the size and placement of windows, and the types of materials and equipment that will be chosen for a facility, all in an effort to deliver the most energy-efficient facility possible.

For architects and administrators who have reaped the benefits of many of these strategies and are seeking even more daylighting dividends, one characteristic to consider that some may be overlooking is the reflectivity of the flooring material selected for a space.

"It is an issue that most facility managers are just beginning to think about," says Amy Costello, Sustainability Manager for Armstrong World Industries. "They realize that the flooring can have an effect on daylighting. It's not the primary factor in daylighting, but it's something to consider."

The benefits of daylighting appeal not only to energy- conscious students, staff and community members but also to financially minded administrators and academically focused educators:

Sustainability – By capturing daylight and using it to help illuminate classrooms and other areas in an education facility, schools and universities can use less electricity and reduce their reliance on carbon-based fuels that release greenhouse gases into the atmosphere.

Budget – Harvesting natural light is less expensive than generating electricity, so daylighting strategies enable education institutions to reduce their utility bills for artificial lighting and may make it possible for them to reduce the demands on a building's HVAC system.

Academics – Studies of academic performance have shown that students in classrooms with effective daylighting strategies achieve higher tests scores than students in classrooms without effective daylighting.

Daylighting Strategies

The embrace of daylighting strategies for schools has grown considerably since a 1999 study by Heschong Mahone Group, a consulting firm based in Sacramento, Calif., that looked at the performance of more than 20,000 students in California, Washington and Colorado. The data indicated that daylighted classrooms had a positive effect on student achievement.

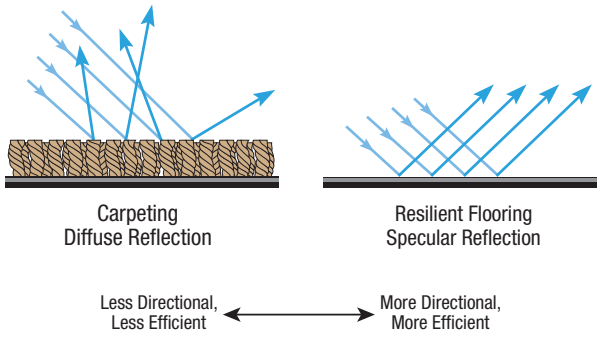
The most compelling findings were in the Capistrano (Unified) District, where students in classrooms that had the most daylighting progressed 20 percent faster on math tests and 26 percent faster on reading tests in one year, compared with students in classrooms with the least daylighting.

In the pursuit of the greatest daylighting benefits, designers have learned to integrate numerous strategies and try to come up with the right balance of characteristics to provide a comfortable, cost-effective space where students can achieve academic excellence.

Among those strategies:

- **Building orientation** – A building situated so that it is elongated along the east-west axis enables the building's north and south sides to be exposed to greater amounts of daylight.
- **Placement of windows** – The size, number and location of windows in a space greatly affect the amount of daylight that enters and whether it is effectively distributed to create a beneficial learning environment. School buildings should minimize the number of windows on the east and west sides and maximize the number of south-facing windows. Windows for enhancing daylighting should be placed higher on walls so daylight can penetrate deeper into the space.
- **Roof monitors** – A popped-up roof extension with vertical window glazing on top of a facility enables daylight to penetrate a space from the ceiling; baffles may be employed to diffuse the light and eliminate glare.
- **Light shelves** – Horizontal shelves placed above eye level reflect daylight toward the ceiling and enable natural light to reach deeper into a space.
- **Automatic lighting controls** – Lighting systems that take daylighting levels into account and automatically adjust artificial lighting levels enable schools and universities to illuminate facilities in the most efficient manner.
- **Computer modeling** – Building information modeling enables designers to use simulations to experiment with building design choices and determine the most energy-efficient and academically effective strategies.
- **Uniformity of materials** - higher surface smoothness uniformity increases the directional ability of light reflectance increases. *(See Figure 1)*

Figure 1: Directionability of Light Reflection



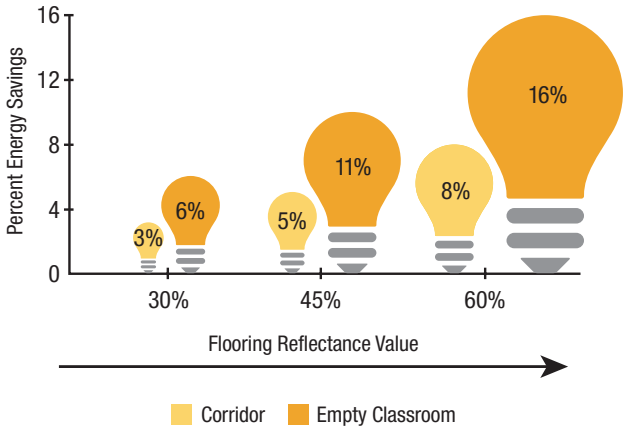
The potential savings from effective daylighting are enormous. The U.S. Environmental Protection Agency estimates that K-12 school districts in the United States spend about $8 billion annually on energy costs. Improving energy efficiency in schools could save about $2 billion of that, the agency projects.

Data from the U.S. Energy Information Administration's "Commercial Building Energy Consumption Survey" look specifically at lighting and electricity consumption in education facilities. The survey found that lighting accounts for 31 percent of electricity costs in an average education facility, and the average cost of electricity in those facilities is 82 cents per square foot.

Leveraging Flooring Reflectivity

So, after designers see the energy and cost savings that result from the daylighting strategies delineated above, or if the conditions of a specific school project do not permit designers to take advantage of all the steps that will improve energy efficiency, they may want to consider what savings they are able to realize by installing flooring material with higher light reflectance values. *(See Figure 2)*

Figure 2: Percent Energy Savings Relative to 10% Floor Reflectance for a Corridor or in an Empty Classroom*



*Direct with LED or fluorescent lighting in room with 60% reflectant ceiling and 40% reflectant walls

Boosting the reflectance values of flooring will enable more light – from either artificial or natural sources – to bounce off the floor and enable the available light to illuminate the space more efficiently.

Daylighting advocates have recognized the importance of the reflectivity of the interior surfaces of classrooms but tend to focus more on ceilings and walls because those surfaces provide more daylighting benefits.

Having high ceilings enables available light to bounce off more surfaces throughout a classroom and provide more reflected illumination. The American Society of Heating, Refrigerating, and

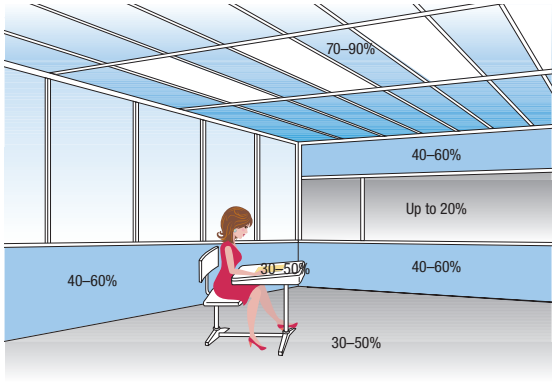
Air-Conditioning Engineers' *Advanced Energy Design Guide for K-12 School Buildings* states that a minimum 10-foot ceiling height is recommended for daylighted classrooms. It also recommends ceiling surfaces should be a light color.

"The color of the ceiling, walls, floor, and furniture has a major impact on the effectiveness of the daylighting strategy," the guide says. "When considering finish surfaces, install light colors (white is best) to ensure the daylight is reflected throughout the space."

The guide also recommends avoiding flooring material with extremely dark colors. "Darker surfaces can require more installed lighting power to meet illuminance levels resulting in higher costs and less effective daylighting," the guide states.

The National Building Information Sciences' *Whole Building Design Guide* states that it is desirable to keep ceiling reflectances at more than 80 percent, wall reflectances at more than 80 percent, wall reflectances at more than 50 percent, and floors at about 20 percent. But some school planners, recognizing the potential value of higher-reflectance flooring, have recommended flooring with higher reflectance levels. *The Illuminating Engineering Society of North America Lighting Handbook* (9th Edition) calls for the flooring in classrooms to have reflectance levels of between 30 percent and 50 percent, however incremental high reflectance increases result in incremental energy reeducations as shown in Figure 3.

Figure 3: Recommended Light Reflection of Various Classroom Surfaces



The New York City School Construction Authority (NYCSCA), responsible for building new classrooms for the nation's largest public school system, aims for classroom floors that have a light reflectance value of 45 percent, according to Arti Shah, managing architect of the NYCSCA.

"We try to incorporate as much natural light as feasible into a classroom," Shah says.

In a dense urban environment such as New York City, available space for school facilities is hard to come by, and designs for schools may not be able to incorporate the site orientation, angles and exposure to daylight that can enhance energy efficiency.

When one considers the billions of square feet of space that schools and universities occupy in the United States, even a slight reduction in electricity consumption can make a difference in an education institution's bottom line. High-reflectance flooring offers such an opportunity.

Energy Efficiency

But how much of a difference does flooring selection make in classroom lighting levels? A recent study completed at Pennsylvania State University, "Energy Saving Potential of High Reflective Flooring Material for Sustainable Interiors," provides some answers.

The research indicates that high-reflectance floor material can increase classroom daylighting levels, and where daylighting is not a factor, can result in more efficient distribution of artificial light. Either outcome would enable education institutions to reduce energy costs.

A report of the findings by Pennsylvania State University's Richard G. Mistrick, associate professor of architectural engineering, and Ling Chen, a graduate research assistant, concludes that installing higher-reflectance flooring material "can achieve a measurable level of energy savings through reduced lighting power densities for the initial design as well as increased dimming in areas where daylight-integrated photocontrol is applied."

In a classroom where the reflectance value of floor material was raised from 20 percent to 60 percent, the electricity savings "amounted to about 5 to 7 percent of the lighting energy that would be consumed with no photocontrol," the study found.

Researchers looked at high-reflectance flooring under three conditions: the effect of high-reflectance flooring on installed electric lighting; the effect of applying a 5-foot strip of high-reflectance flooring material along the exterior wall in a daylighted classroom with photocontrol; and the effect of applying high-reflectance flooring material across the entire floor of a daylighted classroom with photocontrol.

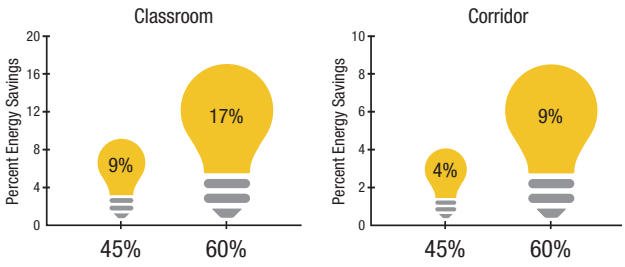
In Part I of the study, the researchers looked at a 36-by-25-foot, 10-foot-high classroom and a 40-by-6-foot, 10-foot-high corridor. Researchers measured conditions with floor reflectance values of 10, 30, 45 and 60 percent; wall reflectance values of 20, 40, 60 and 80 percent; and ceiling reflectance values of 60 and 80 percent. The study found that illumination of the spaces, measured as the Coefficient of Utilization, improves with an increase in the reflectance of the flooring.

"In conditions where the floor reflectance is changed from 10 percent to 60 percent, the illuminance levels' increase in a corridor could be as high as 30 percent while the magnitude in an empty classroom space could be as high as 45 percent," the study found.

The lighting improvement will be more substantial in spaces that have higher-reflectance ceilings and walls. The study determined that greatest increases in illuminance occurred in spaces where the ceiling and walls had reflectance values of 80 percent.

The study compared a floor that has 30 percent light reflectance with one that has 60 percent reflectance in an empty space that had a ceiling with 80 percent reflectance and walls with 60 percent reflectance. "The savings are roughly 9 percent for the corridor and 17 percent for the classroom," the study found. With this same scenario, switching from a 30 percent to a 45 percent light reflectance floor results in an energy saving of roughly 4 percent for corridors and 9 percent for classrooms. *(See Figure 4)*

Figure 4: Percent Lighting Savings for Classroom and Corridor*



*In a space with 80% reflectant ceiling and 60% reflectant walls

Part 2 of the study measured how lighting is affected when a 5-foot strip of high-reflectance flooring is installed along an exterior wall of a 900-square-foot classroom (36 by 25 feet and 10 feet high) in which a photocontrol system determines lighting levels. The classroom had two windows, 10 feet wide and 6 feet high, that were separated by 4 feet.

"The difference in energy savings improvements resulting from the 5-foot strip...is approximately 4 to 7 percent in an empty south-facing room, and 2 to 4 percent in empty north-facing spaces, compared with a space with a uniform 30 percent reflectance floor," the study found. "With furniture, the additional savings drop to approximately 3 percent [for the south-facing room] and 1.5 to 2 percent [for the north-facing room]."

Part 3 of the study looked at how installation of high-reflectance flooring across an entire classroom affected energy consumption. Researchers measured lighting levels with flooring of 20 percent reflectance and 60 percent reflectance, and used a classroom of the same size as the other testing — 36 by 25 feet and 10 feet high.

"With no furniture, savings from the application of a high-reflectance floor was approximately 18 to 19 percent," the study found. "With the furniture, the savings were reduced to only about 12 to 14 percent....This reduction is the result of light being trapped and, therefore, having to undergo multiple reflections under the desks and chairs."

Smart Decision-Making

Because the efficiency improvements that come from high-reflectance flooring are not as great as those that are generated by other daylighting strategies, some schools and universities may decide that other characteristics of flooring may take precedence over reflectance levels.

"The daylighting decisions are all integrated and part of the decision-making tree," says Steven Turckes, K-12 Global Education Market Leader for the Perkins + Will architectural firm. "It's not an either-or; it's a both-and. We look at durability, maintenance, longevity, aesthetics, return on investment."

The growing sophistication of the tools that planners are using to maximize daylighting and energy-efficiency in education facilities enables schools and universities to include more factors as they determine the most effective strategies, Turckes added.

Keith Johnson, an architect and an associate principal at Dull Olson Weekes Architects in Portland, Ore., has designed environmentally friendly campuses such as Sandy High School in Sandy, Ore., which has received LEED Gold certification for its sustainable elements. But in some cases, he notes, the desires of maintenance departments may override daylighting benefits. Some schools may choose flooring with lower-reflectance levels because the workers believe it is easier to clean.

Other schools may shy away from lighter-colored flooring because of worries that it will result in glares that distract students.

But Costello, the Sustainability Manager at Armstrong, notes that glare from flooring is not related to reflectance; it is a characteristic of flooring materials that have a glossy finish. Flooring is available in lighter colors with a matte finish that has high light-reflectance values, yet does not create a glare, Costello says.

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