deeper daylight
anidolic devices in new delhi office buildings

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Since the second half of the 20th century, buildings have been growing boxier and boxier. Mechanical air cooling systems and artificial lighting have given rise to the open floor plan, a big, plain rectangle, which provides the interior occupier infinite flexibility in organizing and reorganising the space. But for all its gains, it sacrifices access to daylight, which until the last 75 years, was imperative for an interior space.

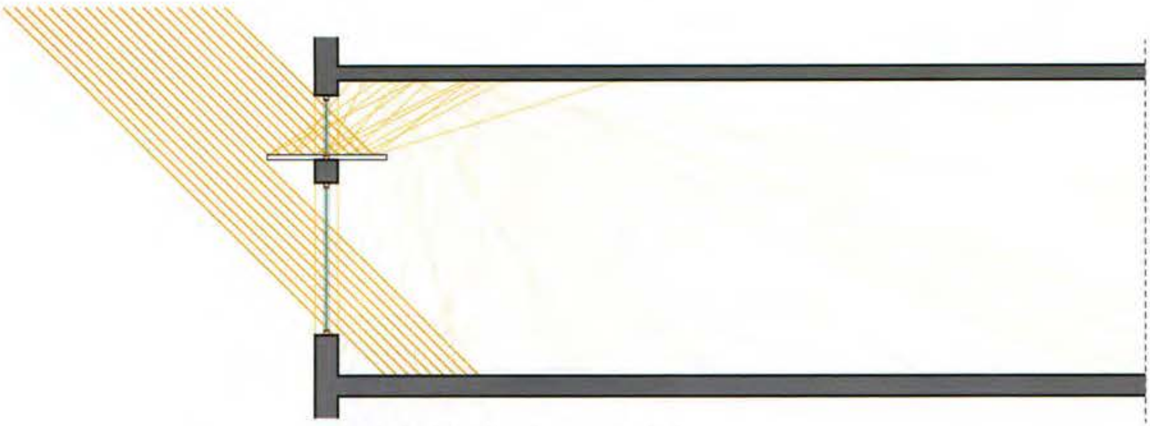
In that light, attention has been shifting back toward the introduction of daylight in the space, and toward optimised use of this free amenity, which when controlled for heat, can improve working conditions immensely.

But now that the carrot of open floor plans and flexible space has been dangled, it can be difficult to move back to the thin section buildings of earlier centuries. As an alternative, how might we evaluate tools that drive daylight deeper into the building, thus giving us the expansive floor plate and the natural light? The introduction of light shelves, anidolic ducts and light tubes, among other products, has shown that devices can work to move daylight deep inside a building, allowing the designer to create deep, naturally lit floor plans.

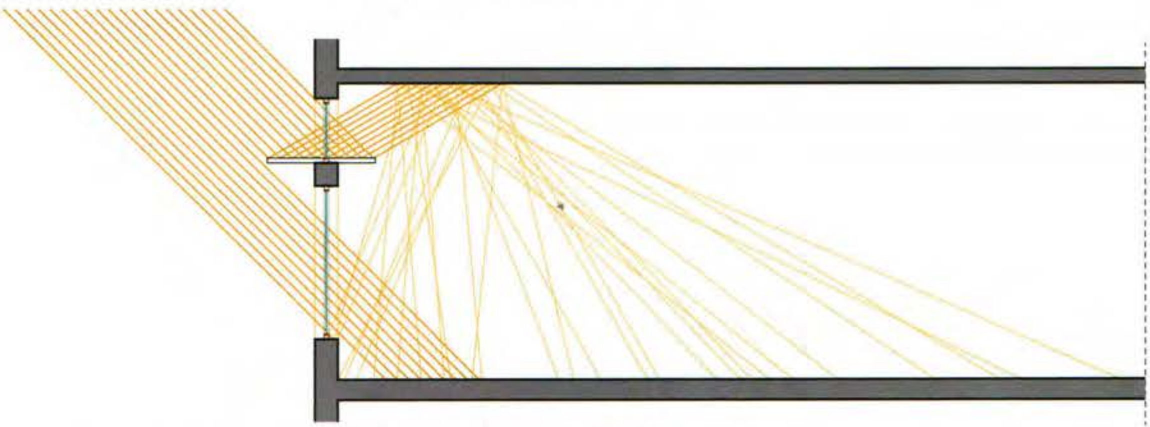
This study examines these three devices in the context of New Delhi. With the intensity of the sun present here and the heat of the climate, how well do these devices work? Are they an option for the Indian commercial climate? Are they affordable?

Using prevailing office building typologies in New Delhi to derive four hypothetic models, this exercise studies the effectiveness of each deep daylighting strategy in different local daylight conditions. It also tries to evaluate the devices' cost effectiveness as retrofit devices.

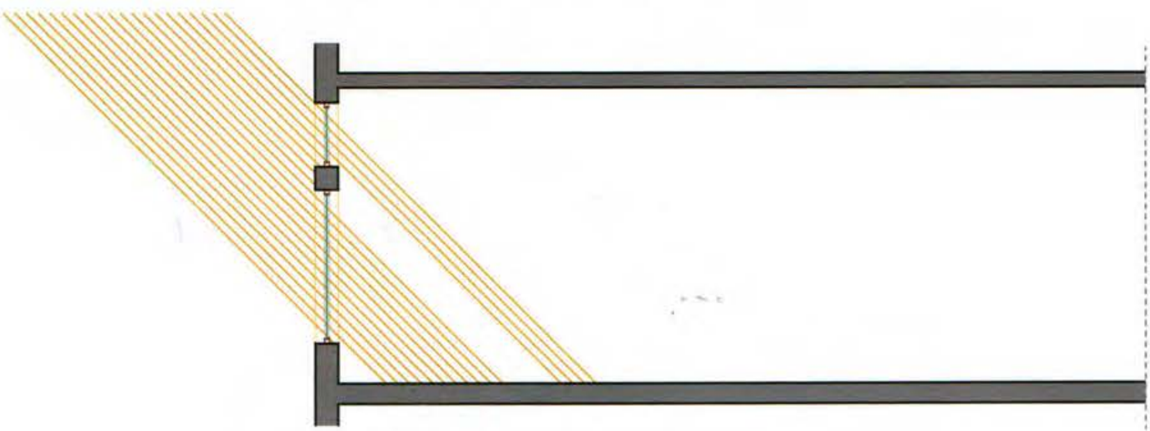
This study assessed New Delhi office buildings according to plan, bylaws, window to wall ratio, size and proportion, floor-to-floor height, lighting load and energy performance. From the aggregation of this data, base case models were derived. These models were tested with different window to wall ratios, to check the range of daylight available. Then the resulting models were analysed for their daylight performance by comparing their performance without devices to their performance with them. Finally, cost was analysed according to a market survey for device and installation taken against the electric consumption savings, to measure the payback period on each device. The simulation was done for overcast sky conditions in New Delhi, with each building's longer axis running north south.



light shelf diffusive material



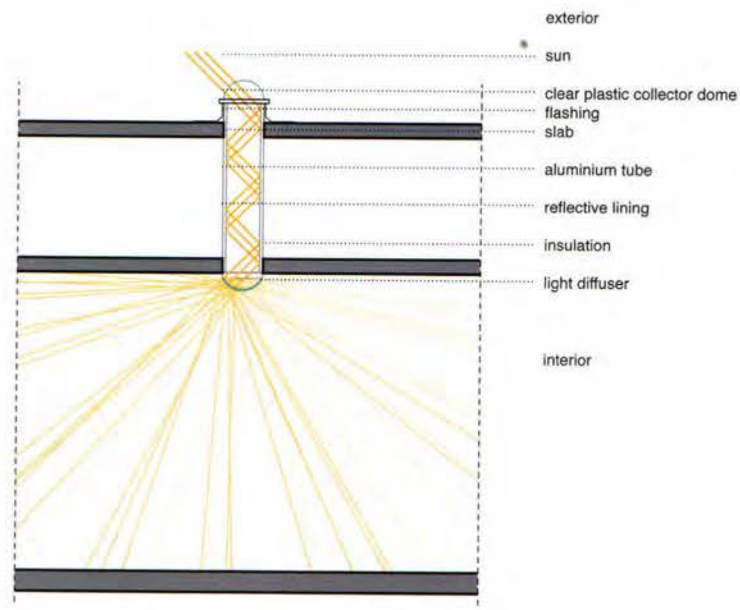
light shelf reflective material



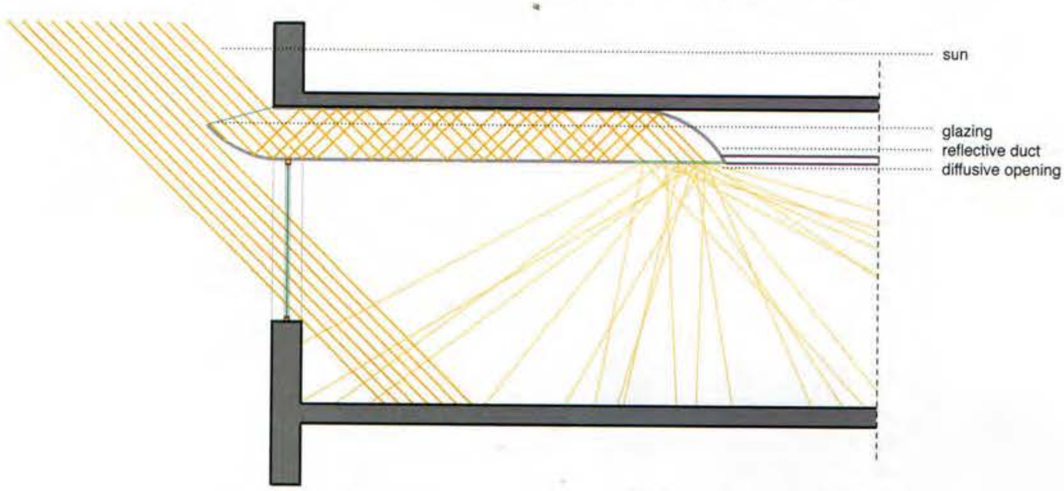
typical window clerestory

Light Shelf

A light shelf is a horizontal surface that is placed either inside or outside the window, meant to redirect light up toward the ceiling of the interior space. Several studies have been carried out on the external finishes of the light shelves. Both the efficiency of the shelf and the direction of the redirected light is influenced by both the geometry and the finish of the light shelf. A matte finish results in diffuse reflections, while a reflective surface will reflect more light, but will nearly maintain the angle of incidence, and may reflect a dirt or dust pattern onto the ceiling. A combination of the two, like a semi-specular finish or a reflecting prismatic film, can tune these effects for best results in the room. 1 The light shelf in this study is a flat horizontal plane with white stucco on the top surface, exposed to the sun, and placed equally in and outside. The total floor height is 3m and the light shelves have been installed at a height of 2.4m.



light tube diffusive material



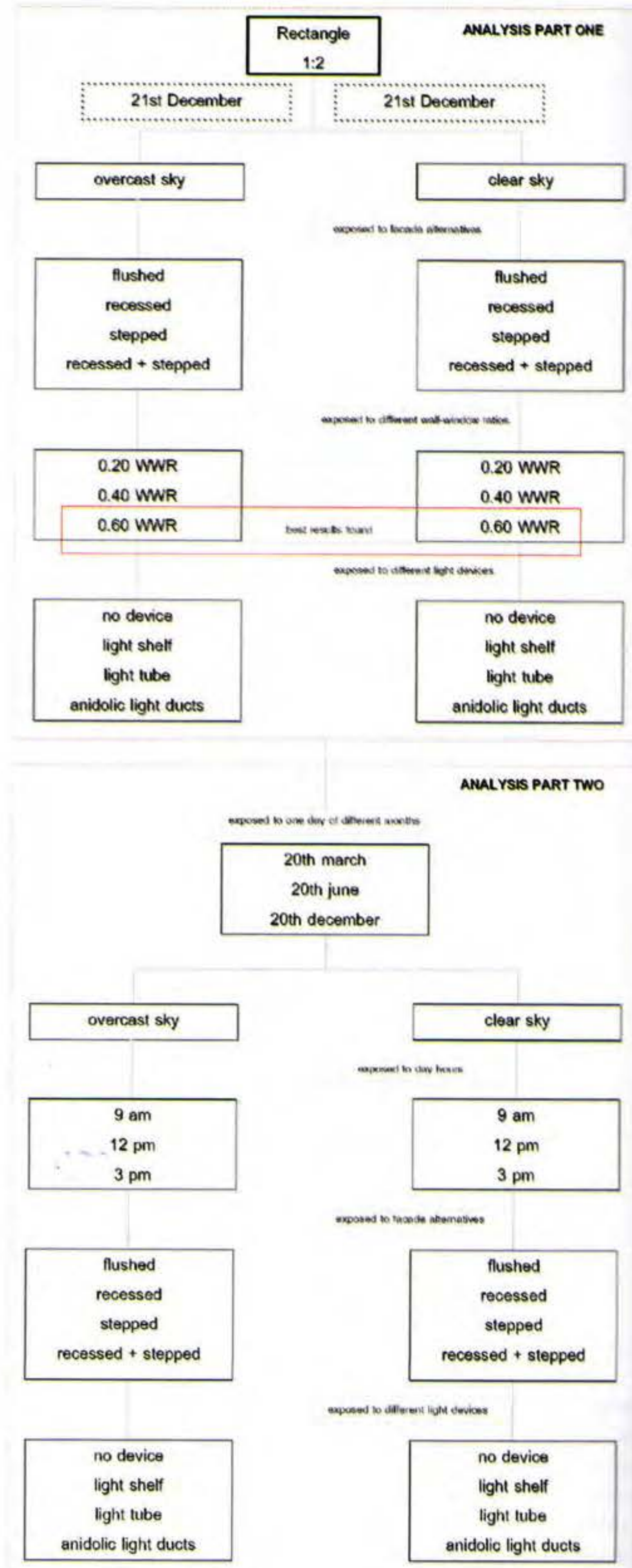
light duct diffusive material

Vertical Light Tube

Vertical light tubes use a collector at the exterior surface of a building, and transmit light to an emitter inside the building through a tube or pipe. This, for example, could be a tube whose interior surface is reflective. Inside, the emitter functions like a surface mounted light fixture. For this study, commercially available light tubes (Solatube 20DS) have been selected. These are hollow vertical tubes with a dome that collects sunlight. The inner surfaces of the tubes have been coated with highly reflective material, and at the bottom of the tube is a diffuser.

Anidolic Light Ducts

Anidolic ceiling systems collect diffuse daylight (from overcast or partly cloudy skies), and use a compound parabolic concentrator to redirect the light through a specular duct to the back of a deep room. In this case, an anidolic light duct with a highly reflective optical mirror has been studied. The device redirects the light entering from the external scoop located at the upper part of the facade, followed by a funnel (anidolic ceiling), and an exit aperture.



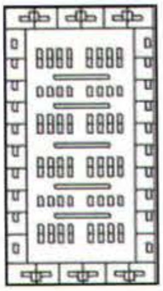
Method

All the devices were selected based on their availability in the Indian commercial market, and then analyzed with the software Radiance. First, a pilot study tested the appropriateness of the study, through the test of a light shelf on typical window to wall ratios in the Bhikaji Cama Place, a typical Delhi building. The reference model was the existing base case, and the pilot study showed that light shelves would bring light deeper into the building.

With pilot in place, the study took two sky conditions: overcast and clear, and looked at a series of hypothetical building types at noon on one day, December 21st, while varying the window to wall ratios (WWR) from .2 to .6. Because .6 showed the best results, this WWR was taken forward and tested for four critical days at three times per day: 9am, 12pm and 3pm.

The study also analyzed the possibilities for energy savings by calculating average energy loads for a 'no device' case, and then comparing them with the 'device' cases by deducting the amount of energy needed to achieve the daytime light levels that each of the different devices obtained. Finally, this was compared with the cost of the product to find the payback period, and return on investment for each device.

1:2



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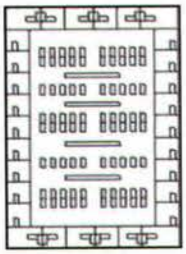
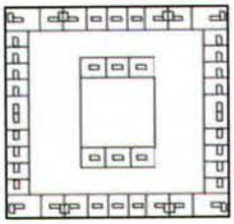
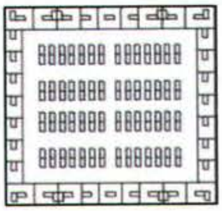


3:3

[with courtyard]

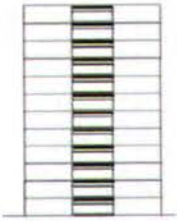


1:1

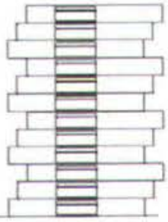


facade types

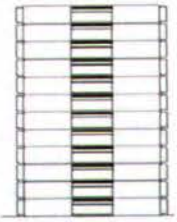
flush



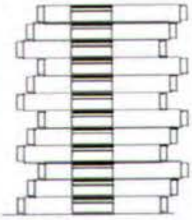
stepped

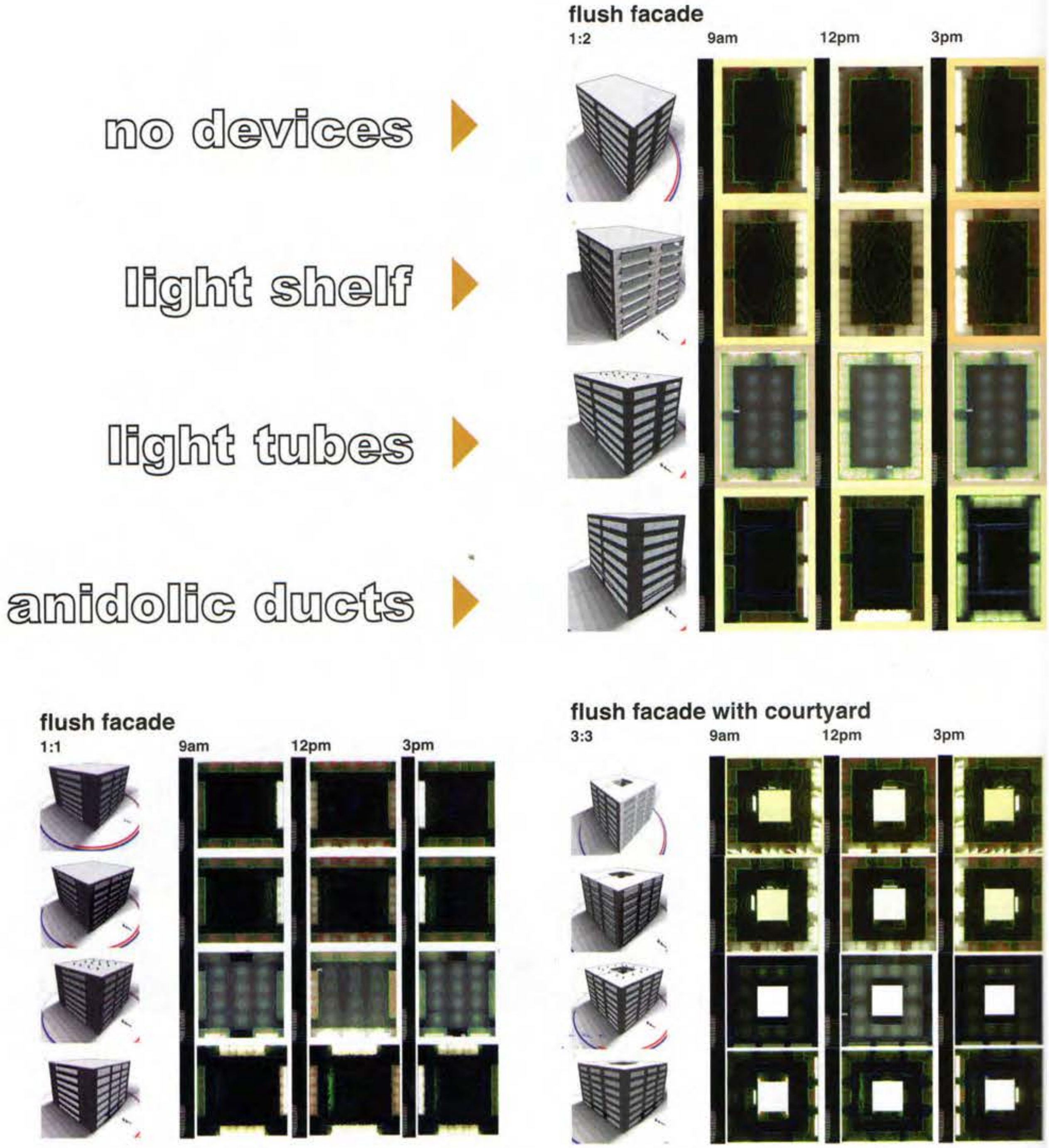


recessed

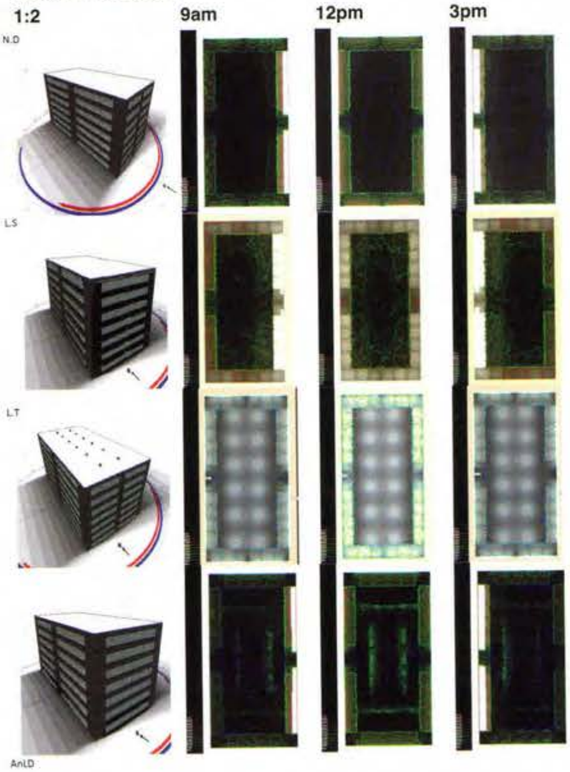


recessed and stepped

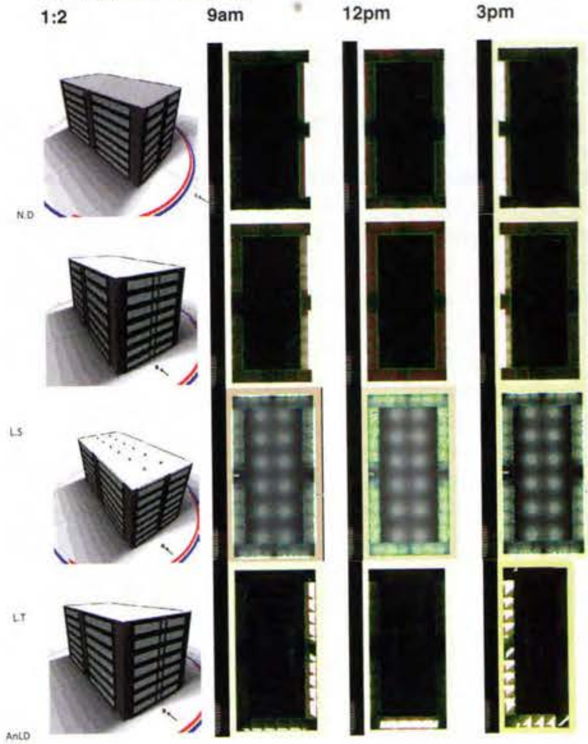



flush facade
1:2
9am
12pm
3pm
no devices
light shelf
light tubes
anidolic ducts
flush facade
1:1
9am
12pm
3pm
flush facade with courtyard
3:3
9am
12pm
3pm

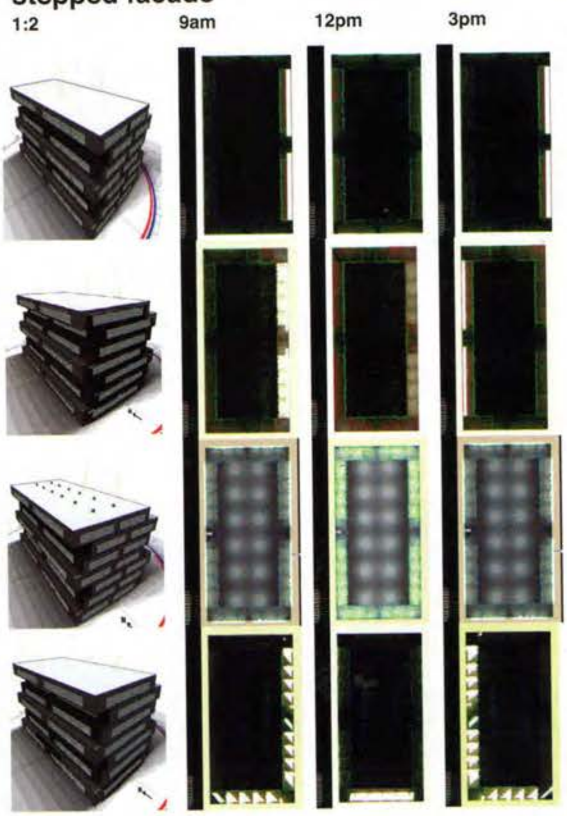
flush facade



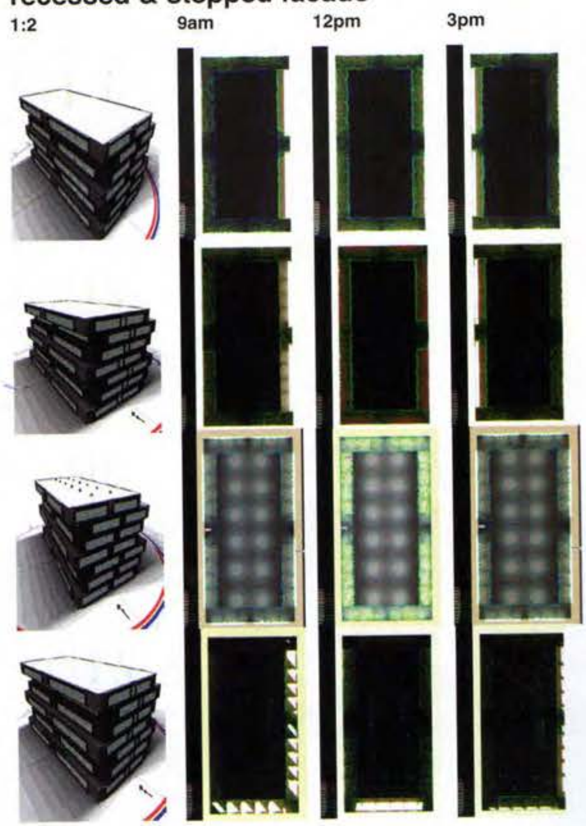
recessed facade



stepped facade



recessed & stepped facade



Conclusion

The study results showed that light shelves are least effective under an overcast sky, but perform well in a clear sky. Light tubes performed the best in both conditions. And while integrating daylighting devices increased the amount of daylight in the building, varied geometries in the façades tended to decrease it.

Both light tubes and ducts produced excellent daylight results in overcast as well as sunny sky conditions. However, both devices are also costly, with a long payback period. Anidolic ducts illuminate the area near a duct's opening well. Light tubes are better at focusing light in a particular area because they deflect light only minimally. Light shelves, unlike the prior two, do not work well under overcast sky conditions. Even in clear skies, they do not allow light to penetrate very deeply into the section of the building. However, they do create a uniform daylight distribution, and also protect areas near the windows from direct sunlight and glare. And because they are less costly, despite less effect, they have a shorter payback period.

These devices also perform differently at different times of day. Light shelves and anidolic ducts are best at grabbing low angle daylight in the morning and afternoon. Light tubes perform best at noon, but they also provide adequate light earlier and later.

All things considered, according to this study, light shelves are the best option. They are cheaper, can double as a shading device, and can be easily retrofitted on a building. Their limitation in overcast skies is not so important in the context of New Delhi, which has a clear sky for seventy to eighty percent of the year. One could potentially also combine options and use more than one device in a building to target specific light conditions in different areas. ■

(Endnotes)

1 Littlefair, P.J., 1996. Designing with Innovative Daylighting. Construction Research Communication Ltd, London, UK.

Melissa Smith is an architect and city planner at **banduk**smith**studio**, an architecture, urban design and research practice in Ahmedabad. Her work navigates architecture and the city, dealing with issues of material, energy and change in the built environment and its inhabitants. She also teaches at CEPT University, and consults for CARBSE.

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