CARBSE Article Series

Architecture in India today is exploding. With the rise of material availability and access to ever-increasing platforms for information dissemination, the built environment seems to running further ahead and faster afield to try out new technologies and follow up fresh trends.

Alongside feverish growth and experimentation, increasing energy demands add pressure to systems running at capacity to feed the electronic hunger of the nation. In the face of these issues, research in building performance plays an ever more important role in discovering, testing and innovating better ways to use and save energy as we move toward the future. It is a balance of finding what is new and drawing value from traditions, building up a toolbox of strategies and methods to address the state of energy in contemporary India.

This series of articles uses the research of the Centre for Advanced Research in Building Science and Energy (CARBSE) at CEPT University, Ahmedabad, to look at aspects of energy research in the built environment through a variety of lenses—in studies that analyze traditional pol houses with scientific rigour, examine the optimized possibility of stone jaali performance, and explore simulation to assess courtyard effectiveness, among others.

As an interdisciplinary research hub for the building profession, CARBSE advances the use of technically sophisticated methods to assess the built environment, from traditional architecture to contemporary buildings, and shares these findings for the benefit of both practice and research. These inputs also support the Centre's objective of improving future building practices, both through better-informed design, and through the influence of policies for the built environment.

- Melissa K Smith
courtyards in context

ahmedabad, caravan serai
square courtyard scale variations
jodhpur courtyards

hexagonal courtyard scale variations
algiers courtyards
back bay, mumbai, scales of courtyards

jaisalmer courtyards
delhi, india habitat centre

courtyard location variations
fort area, mumbai, commercial courtyards
south delhi, commercial courtyards

image source: google maps satellite photos
Commercial Courtyards
a delicate balance

Text & Graphics: Melissa K Smith
Research: Rachit Kumar, Rajan Rawal (Guide)

Commercial high-rises have been spreading like monsoon mushrooms in the urban cores of Indian cities. This rapid rise in height, clad in glass, and ripped off from abroad, is often coupled with limited operational technical knowledge, which leads to energy and comfort issues in the buildings' operation. Today, with artificial climate control and artificial lighting, these excess energy guzzlers are primarily dependent on mechanical systems for their operation.

Alongside this rapid proliferation, attention to energy efficiency is growing in India. In the face of increasing energy costs, it no longer occupies just the realm of environmentalists, but has become a commercial reality. One strategy to deal with new challenges is to look back to older forms, and adapt them to new conditions. The logic is that these tried and tested techniques must hold the climatic wisdom we have forgotten, and which we can quickly reapply to fix our problem. Along this line, many would argue that incorporating courtyards in commercial buildings could improve their energy efficiency, and since it is passive, could maybe even do it with a lower initial cost than typical construction. But these recommendations must be taken with caution. The problem is, our today aren't exactly the same as the conditions for which the traditional courtyard evolved, which means that to just throw a traditional element like that in the design mix may not address this new situation. Rather, it needs to be treated, like all design strategies, as a method to be tested and adapted for its specific purpose. In the commercial building condition, does the courtyard really work? How does it work best?

This study examines the parameters at work in the thermal performance of the courtyard, and tests whether it really is a relevant solution to the growing need for energy efficiency in contemporary commercial buildings in India. Through a method of computer simulation, it asks, how do courtyards affect the thermal performance of commercial buildings? What is the relationship between energy consumption and design parameters (building height and form, window percentage and window shading) in a courtyard building? What role does orientation play in these buildings' thermal performance? Within the limitations of building bylaws and typical plot sizes in Indian urban master plans, what are the energy saving potentials of the courtyard form?
the contemporary commercial building

Most commercial buildings today depend year round on mechanical systems for cooling and heating. One reason for this is that buildings are designed around a universal program structure which disregards variations in function according to different climate zones. Another reason—commercial buildings like glass.

The problem with a high glazing percentage in a mechanically controlled building is the accompanying heat gain from direct beam radiation, and the creation of thermal differentials in large volumes of air. Because current trends promote elaborate glass facades, the large amount of glazing directed exposed to the high altitude sun in this hot climate allows great amounts of heat penetration. Shortwave solar energy is transmitted through glazing and absorbed by solid building elements, which re-emit longwave radiation that becomes trapped inside the glass. The result: a commercial greenhouse. To keep these greenhouses comfortable, air conditioning systems take on the excess load.

Many issues contribute to energy consumption. Optimized mechanical controls alone can reduce consumption by almost half in a typical building, but if these measures were integrated with passive design strategies at the architectural level, they could be even more powerful. Strategies like thermal mass, external shading, orientation and massing should work with the mechanical system to reduce reliance on energy for comfort and operation.

In a commercial building, when courtyards have been implemented, little priority is typically given to energy concerns, which means that courtyards are ineffective climatically. On top of this, buildings are oriented to capture view, not shield sun, and most commercial buildings are fully conditioned with excessive amounts of glass. None of this makes an energy efficient building.

the courtyard

The courtyard is a design tool, used both traditionally and in contemporary design, which among other things can reduce the energy consumption of a building. As a thermally performative element, the courtyard has the potential for energy efficiency, for improving interior daylit spaces, for passive cooling through air movement. It can work as a microclimate modifier. As a spatial element, the courtyard offers flexibility in allowing light into the building, provides different use opportunities both daily and seasonally, and holds a capacity for many geometrical configurations present in site or in program relationships.

The thermal and spatial roles of the courtyard can complement each other beautifully. This is apparent both in traditional settings, like the palaces and houses of Rajasthan, and contemporary, like the India Habitat Centre. But when the courtyard’s role is co-opted purely for its spatial characteristics, it works at odds with expected thermal performance.

As a spatial element, the courtyard allows designers to create buildings with regular spaces on complex sites, absorbing the complexity into its void, and to handle complicated conditions formed by irregular plot lines and radial streets. It also creates secure open space, accessible only by those who can also access the building, and connects more users to an outdoor view. But when the courtyard is used in isolation from energy considerations, it can actually negatively impact the energy use of the building. For the courtyard, orientation, size and proportion, envelope construction, building type and function, and interaction of courtyard with adjacent spaces all contribute to thermal performance. This leads to excessive solar heat gain in summers, which in turn leads to high-energy consumption and more dependency on mechanical systems to achieve comfortable indoor space, which means that the operational building cost will increase.

Courtyard configuration is extremely important for a building’s energy performance, whether the building is unconditioned, or partially or fully conditioned. In this, the relationship between geometry and proportion is critical. It works in both warm humid and hot arid climates, but because the difference in moisture requires different approaches to cooling, the proportion and layout must change.
study parameters

plot aspect ratio

6 8 10 12

floors

no courtyard  courtyard with peripheral zones  courtyard with east peripheral zone  courtyard with west peripheral zone  courtyard with north peripheral zone  courtyard with south peripheral zone

space configurations

10% 30% 60% 90%

window to wall ratio

yes no

*6 Floor building models do not have courtyard

total simulations:
2 plots X 4 heights X 7 configurations X 4 wwr X 2 shades = 448
(-) [6 floor courtyard (2 plots X 1 height X 1 configuration X 4 wwr X 2 shades) = 16]

=432 simulations

THE STUDY

its structure
The specific method of study explores the thermal effect of courtyard proportion, wall to window ratio (WWR) and shading device overhangs. It does so by using a conventional building as a base, which assures that the study is dealing with issues faced by the commercial sector in real scenarios. The site constraints were developed according to the new master plan for Mohali, Punjab.

There, a typical site size is 5000sq.m, so this was selected, with two aspect ratios: 1:1, and 1:2. For building heights ranging from 6 to 12 floors, different configurations have been derived. On all of these, window-to-wall-ratios of 10%, 30%, 60% and 90%, were applied, and analyzed with two overhang situations: lots (.9m) and none.

Because the focus is on the thermal behavior of the courtyard buildings under different conditions, the models are simplified, to either central or no courtyard, and four adjacent zones. The whole building is taken into account when simulating for models simply with and without courtyard. Perimeter zones are excluded in simulations of a particular zone's energy consumption. Each space is separated completely from any environmental thermal changes by three adiabatic walls, as well as adiabatic ground and top floors. The fourth wall facing the courtyard is glazed. Adjacent space floor-to-floor height is 4m, and the internal environment of all the spaces are modeled as fully conditioned, with a constant temperature of 24 DC, and suspended fluorescent lighting with energy use per square meter of space floor area of 11.8.
Building Data
Activity Light office work
Sector Commercial Building
Occupancy 0.2 people/m²
Metabolic Activity Office
Winter Clothing Business suit, thermals, jacket
Summer Clothing Trousers & shirts, light business suit
Holidays Holidays per year 104 (five working days in a week)

Other Gains
Computers Heat Gains 10 (W/ m²)
Radiant Fraction 0.200
Office Equipment Heat Gain 16 (W/ m²)
Radiant Fraction 0.200

Environmental Control
Heating Setpoint Temperature Heating (°C) 18.0
Heating SetBack(°C) 10.0
Cooling Setpoint Temperature Cooling (°C) 24.0
Cooling SetBack(°C) 28.0
Humidity Control Humidification Setpoint 10.0
Dehumidification Setpoint 90.0
Minimum Fresh Air Fresh Air 8.00 (l/s- person)
Mech Vent per area 1.00 (l/s- m²)
Lighting Target Illuminance 300 lux

† window to wall ratio
† courtyard configurations
the results

Results showed that just by adding a courtyard, in a commercial building that adheres to current planning norms, the problem of excess energy consumption is not solved. Rather, because the configuration of the building mass and void significantly affects the thermal performance, the parameters that produce the courtyard must be carefully designed if it needs to be thermally effective.

The thermal load of the building increases with the increase in height of the building from 8 floors to 12 floors. This may be because to maintain 100% FAR, as the height of the building increases, the footprint must decrease, which means that the courtyard size increases. Therefore, the courtyard of a 12-floor building would be larger than that of an 8-floor building. In general, the energy performance of courtyard building showed that it was more energy efficient in a low-rise building.

The change in the aspect ratio of the courtyard form does not appear to have a significant effect on the building's thermal performance. This may be because of the efficient orientation taken for a rectangular building, which results in equal mutual shading areas by courtyard adjacent walls for both square and rectangle forms.

Regarding adjacent courtyard zones, the east zone is shown to be most critical. The east zone is the main source for heat gain from the early sun, which increases thermal load at the beginning of the day. This is problematic because in a sealed environment, a huge amount of heat gets trapped within the building during night hours, and leads to high thermal building loads. Shading is shown to be most effective in south and east zones, and its efficiency increases, as one would expect, with an increase in the window to wall ratio.

In the study's current configuration, the results show that a building with a courtyard consumes more energy than a building without one. This might be because a large courtyard area results in high sun exposure and excessive heat gains. It means that shaded or partially shaded courtyards might be a good idea. It also means that the configuration of the courtyard is critical in finding the sweet spot between allowing air to ventilate and letting the sun beam in. At present, because these forms were derived from an existing building code, they are limited in their possibility to push the boundaries of urban form and its capacity to aid in building thermal performance. Further studies could test the geometry further, and find better ways to write our cities' codes, which support energy efficiency from the outset, and allow an urban form that befits its climatic context.

recommendations for the future

These results begin to tell the story of a design element that certainly has the potential to improve the thermal performance of a building, but which needs to be tuned according to each site and program in order to be effective. While the designer does have a fair degree of flexibility without affecting the design's energy performance, there are also certain strategies that can immediately change the condition. It is a complex relationship between spatial characteristics and thermal performance which must be delicately balanced. This balance is further stretched by the change in seasonal requirements. It is certainly possible that the best form of a courtyard for marginal seasons does not work in overall annual performance. At this point, the designer needs to make strategic decisions about how the program can work with the courtyard configuration to achieve the best performance both for the building's use, and in its thermal effectiveness.

Today, as standard commercial practices continue to concentrate their energy saving efforts on increasing the efficiency of mechanized conditioning systems, the courtyard strategy needs more detailed research and application. Development, and a misplaced perception of progress, is increasing building enclosures, and harshly defining the line between inside and out. This design direction fails to take advantage of passive design features integrated with the form and the envelope of the building, which can both improve the interior environment and reduce building energy consumption. Instead, along with advances in the efficiency of conditioning systems, designers and researchers need to work to create and analyze design strategies that benefit from the climate, and don't just fight against them.

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