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Investigating Sustainable Practices in Tall Buildings

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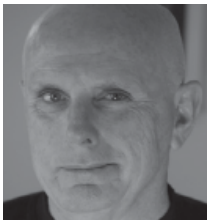

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Rosemary Kennedy
Rosemary's major research interest is sustainable compact urbanization in warm climates, particularly regarding the ability of higher density typologies to produce acceptable or even desirable amenity in terms that embrace culture, landscape and climate in appropriate design solutions.

Rosemary has received several Australian Institute of Architects commendations for architectural design, and was appointed to the prestigious position of AIA Queensland Awards Director in 2008. She has been a member of Brisbane City Council's Independent Design Advisory Panel since its inception in 2006 and advised the Queensland Minister for Arts on the Queensland International Centre for Sustainable Design in 2007.

Shane Thompson
Shane Thompson recently established a new practice, Shane Thompson Architects, after 25 years as a Director and Principal at BVN Architecture where he was instrumental in their growth nationally and their emerging international reputation for innovative practice and design. He has designed many significant public buildings and major urban renewal projects throughout Australia and is the recipient of numerous awards. His work has received the RAIA Robin Boyd Award for Lavarack Barracks, Townsville, and a RAIA Sir Zelman Cowan Award Commendation for the University of the Sunshine Coast Faculty of Arts, the two major annual categories for Australian architecture.

Shane is also a founding board member of the Australian Green Development Forum, a founding member of the International Green Cross and is a past member of the Centre for Subtropical Design Management Committee. He has been Adjunct Professor at the University of Queensland since 2004.

"The provision of natural ventilation cannot be a stand-alone design objective but must be integrated with other considerations to achieve overall positive project outcomes in terms of comfort, safety, health, privacy and so on, as well as cost-effectiveness considered over the life of the building."

In Brisbane, the high-rise residential tower is under the microscope. It is generally thought that tower types derived from cooler climates are not appropriate for the climatic conditions enjoyed in the subtropical city with its mild dry winters and warm humid summers, and that these models are over-reliant on energy-intensive air-conditioning.

According to a study of inner-urban Brisbane apartment dwellers' perceptions and experiences by Buys et al (2008) as many as 83% of people prefer natural ventilation over air-conditioning and are frustrated at the lack of control they have over air flow and thermal comfort in their own domiciles. People are concerned about indoor air quality, lack of ventilation and poor thermal comfort, and the inexorable rise in energy costs. The study also revealed that residents are well aware of the role building orientation plays in thermal comfort and daylight penetration. Natural light to dwellings is highly valued by residents for its association with feelings of more comfortable, livable and aesthetically pleasing interiors, as well as for energy saving advantages. Openness and permeability and strong connections to nature through all the senses are key values of subtropical living.

Introduction

In 2009 the Centre for Subtropical Design at Queensland University of Technology (QUT) conducted a design *charrette* which involved four creative teams – QUT, Cotee Parker, DBI, and Cox Rayner – led by architects working with landscape architects, engineers, urban designers, developers, building physicists and social scientists. The teams collaborated on design options for climate-responsive residential towers demonstrating the key principles of natural light to every habitable room and cross-ventilation to every apartment.

The site location for this intensive design research was an urban renewal area of Brisbane in close proximity to three of the city's best-serviced public transport routes with seamless connections to all major destinations in the region. The focus of the charrette was on outcomes for the eventual occupants, and to determine whether high-rise apartments that are naturally-lit and ventilated can be afforded by all members of society rather than only those who can afford sought-after premium locations on the beach front and riverfront. An integrated analysis of the buildings' expected degree of thermal comfort, effectiveness of natural ventilation, availability of day lighting, predicted energy rating, acoustic amenity, economic feasibility and building efficiency revealed strong performance benchmarked in comparison to business-as-usual across most fields.

Common Issues Affecting the Quest for Natural Light and Ventilation

Charrette participants identified an array of marketing, regulatory, technical, contextual

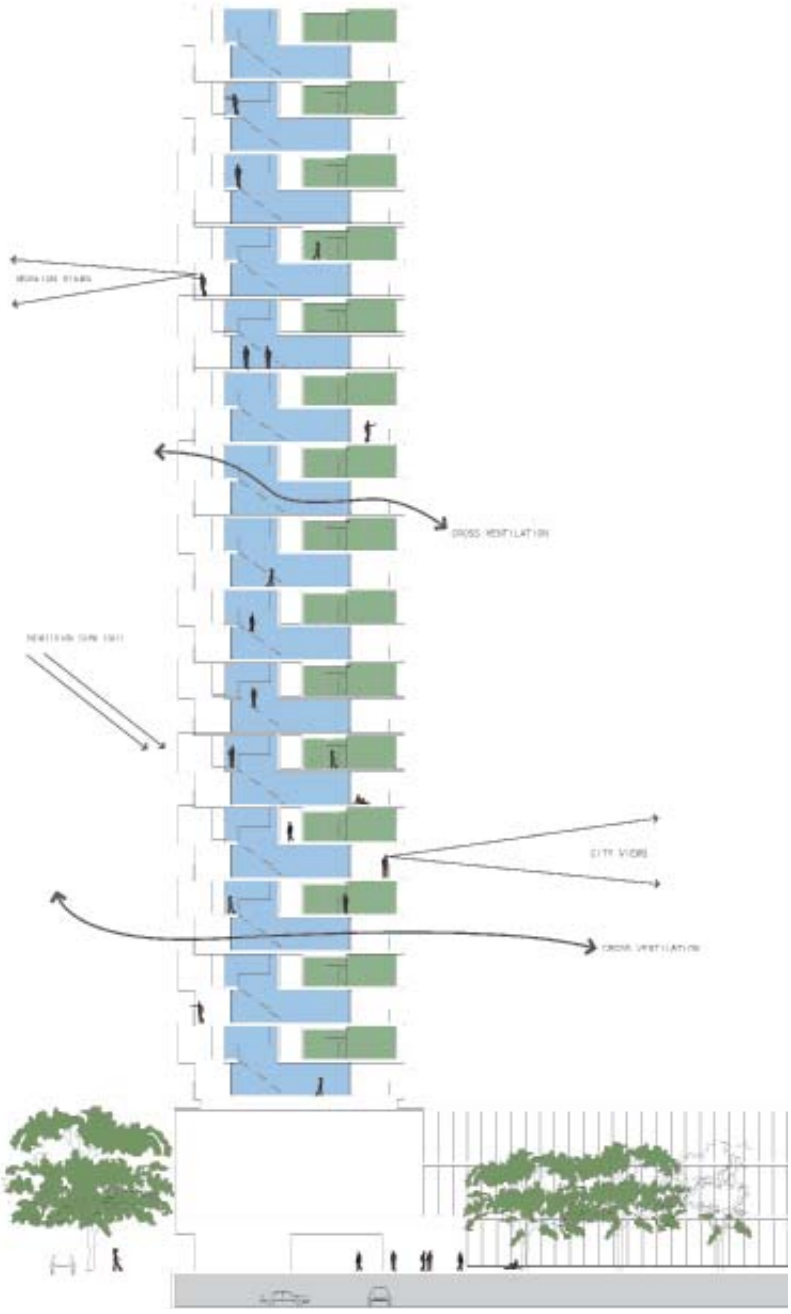

Figure 1. QUT Interlocking section, Brisbane © CSD

and cultural issues which compromise the availability of natural light and ventilation in high-rise residential buildings. Most telling are the perennial tensions between construction costs, ideal building form, energy ratings, and marketing values.

Three dimensional form – shape and height

Structural requirements for towers tend to dictate concentrated, square floor plans in response to wind loads, yet natural ventilation usually requires a narrow rectangular floor plan resulting in a slender profile as buildings become taller.

Wind velocities and air movement conundrum

Air movement is essential to moderate humidity, but the effects of wind at upper levels of tall buildings can make cross-ventilation difficult and use of balconies uncomfortable.

Figure 2. QUT Detail of articulated façade © CSD

Tensions between yield and form

Expectations of yield – maximizing building economies and efficiencies, and minimizing non-saleable floor space, particularly shared circulation space – have led to the ubiquitous double-loaded corridor apartment building model which is the least supportive of effective cross-ventilation for individual dwellings.

Apartment size

Popular smaller dwellings such as studios and one or two-bedroom apartments are inherently shallow in plan. This can increase external wall area to floor area ratios, particularly if bathrooms are located on external walls for natural light and ventilation. Rather than accept the resultant upward effect on construction costs, developers tend to favor deeper planned apartments with internalized bathrooms.

Figure 3. DBI's Typical part plan © DBI Design

Regulations associated with tall buildings

Regulatory requirements for tall multi-residential buildings include the need for fire sprinklers, multiple fire stairs with pressurization, more than one elevator, and relief mechanical ventilation to elevator lobbies. Economies of scale dictate taller, deeper plan buildings.

Aspect vs outlook

Developers assume that the market prefers unobstructed views over good solar orientation. This same assumption also leads to fully transparent glass balustrade designs for balconies. These marketing strategies soon lose their gloss for occupants when the ultimate usefulness of this valuable outdoor space is restricted for want of privacy or thermal comfort.

Parking

Normally, tall buildings containing a large number of dwellings require multiple car-parking levels, either in basements or in podiums. Basements are a very expensive method of storing vehicles (currently around AU$50,000 per car), and podium car-parks tend to deactivate the streetscape. Attempts to disguise parking by affixing apartments to the street frontage of a podium ignore day lighting and cross ventilation of such dwellings. Ironically, despite their capital-intensity, car parks are often under utilized.

Figure 4. DBI's rough façade and roof garden © DBI Design

Privacy and noise

The openness associated with natural ventilation seems contradictory to acoustic privacy and the need to prevent noise transfer between dwellings, particularly from balcony to balcony.

Security

Doors and windows left open for cross-ventilation are perceived to be a security risk.

Traffic noise and air quality

Noisy and polluting traffic is a challenge for acceptance of natural ventilation of dwellings in urban environments where multi-residential buildings are required.

Building energy ratings systems

The rating systems "points chase" in the quest for energy efficient design necessitates air-conditioning and is working directly against place-responsive design. A high ratio of external glazing to floor area, and natural ventilation both have a downward effect on building energy ratings.

Strategies for Achieving Effective Natural Ventilation for Multi-residential Towers in the Subtropics

The designers prioritized cross-ventilation as the most important design strategy and worked to achieve the optimal balance between this and thermal mass, day-lighting, acoustic amenity, privacy, operable openings and glazing and shading to influence the occupant's experience for the better. There was also an expressed desire to adopt readily available and implementable technologies to demonstrate the ease with which the designs could be taken up by the industry. These two principles underscore a holistic approach which showed how a building's operation could be improved by design to achieve positive social, environmental and economical change in the design, procurement and operation of residential towers.

Nevertheless, the architectural forms generated by the four teams, for buildings ranging from 15–30 stories, showed diverse solutions. All achieve the developer's objective of city views yet favor solar orientation in the search for an efficient balance between climate-responsiveness and cost-effectiveness. Layered façades and sheltered outdoor spaces develop a rich transition from outdoor to indoor spaces.

Building configuration

The innovative interlocking configuration (see Figure 1) by the QUT team led by Professor Paul Sanders creates a double-loaded type

that effectively halves the extent of corridors, with positive cost-benefit. Apartments are arranged over two levels with a double-height living space that blurs the line between interior and external space and results in an articulated composition of solid and void, and effective shading and ventilation (see Figure 2).

The design proposal from DBI (see Figures 3 and 4) maintains a rational structural grid and very efficient towers above a podium. Apartments take advantage of an open core for cross-ventilation yet wall-to-floor ratios represent increased value for developers. The proposal is very strong on social sustainability making many well-thought-out meaningful moves to support choice and sustainable behaviors. For example, the simple but effective strategy of shared outer lobbies means that apartments can be expanded or contracted in size to provide flexibility of tenure, households and longer term residence for people of all ages (see Figure 3).

Cottee Parker Architects' team drew inspiration from the Queensland vernacular house with its verandas front and back and leafy backdrop for the apartments and arranged them around open cores featuring external sky gardens (see Figures 5, 6, and 7). Increased wall-to-floor ratios are balanced by an efficient core design.

Cox Rayner Architect's single-loaded tower over a podium introduces a significant conceptual departure with an external core, and an emphasis on integrated planting and water systems based on the theme not just a landscape, but an ecosystem (see Figures 8, 9, and 10). Apartments all face north, and the city-facing sky lobbies are re-imagined as

Figure 5. Cottee Parker's north facing towers © Cottee Parker Architects

Figure 6. Cottee Parker's typical plan © Cottee Parker Architects

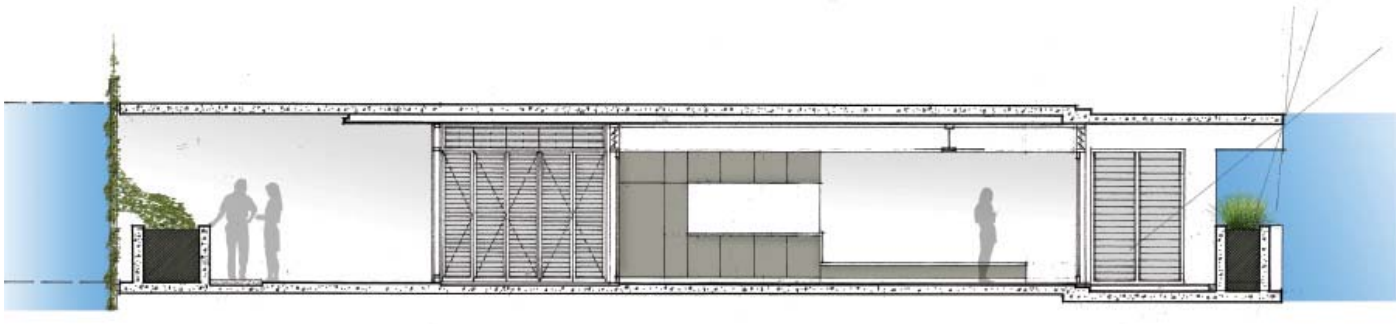

Figure 7. Cottee Parker's typical apartment section © Cottee Parker Architects

sheltered outdoor places that people can occupy for a variety of purposes – not just for passing through as quickly as possible.

Wind and air movement conundrum

Balconies and outdoor living are synonymous with the subtropical lifestyle. Eighty-seven percent of Brisbane's inner urban apartment dwellers identified their balcony as their favorite living space (Buys et al, 2008), using them for a variety of out-of-doors purposes day to day including relaxing, clothes drying, gardening and so on – activities which may be compromised by poor design in tall buildings as wind forces on the façades of buildings become exponentially stronger with building height. The main issue is to ensure that design accounts for the characteristics of the local wind availability, including ways of moderating strong winds and inducing air movement to alleviate comfort on hot days in low velocity conditions.

DBI Design's concept of the rough façade (see Figure 4) has many advantages for slowing air flow and reducing turbulent vortices across the façade while creating high and low pressure zones that induce cross-flow through apartments. These wind walls are multi-functional, providing useful sun-shading, acoustic shielding and reducing sound transmission between dwelling units as well. Strategies developed by other designs demonstrate this principle as well (see Figures 2 and 5).

Thermal comfort and energy efficiency

Brisbane's macro climate is said to be within the comfort zone for 80% of the year. Most people perceive it to require cooling predominantly, however conditions are too hot only 2% of time and are actually too cool to cold almost 18% of the time.

Lighting and air-conditioning is non-essential in shared circulation areas in residential buildings yet typically account for consuming upwards of 30% of energy. The charrette outcomes present viable alternatives for both shared and private areas.

The point of difference which challenges rating systems is the re-conceptualization of the external wall, or the line of enclosure. For air-conditioned buildings, the need for air-tight and moisture-tight barriers is crucial for energy efficiency. The normal definition of the line of enclosure is the point at which the interior is separated from the exterior by an air and moisture barrier. Hyde (2000, 162) points out that the problem with this definition is the meaning of barrier. In warm climates, for free-running naturally ventilated buildings, the barrier need not necessarily be air-tight to maintain thermal comfort. Each of the designs presented offer integrated strategies for natural ventilation and lighting that minimize summer heat gain and maximize winter heat gain for substantially-reduced energy demand.

Each design team created a detailed energy model for analysis using IES Virtual Environment. All façade thermal properties, natural ventilation and control strategies were modeled as accurately as the software permitted. The same models were used to determine annual energy consumption, daylight and thermal comfort within interiors.

For example, the thermal comfort model for the QUT design was analyzed using the ASHRAE Standard 55-2004 for naturally conditioned zones revealed that the units are within the 80% acceptable limit for most days during summer. Extensive shading design (see Figure 2) may require some review in balance with the glazing properties as day lighting levels within the units are lower than they could be.

Parking

Despite the potential for higher densities to reduce car-dependency, regulated parking requirements increase as residential density increases. Innovative strategies dealing with parking range from reducing excavation and material costs through compact car-stackers, pay-by-use arrangements and ventilated podiums fronted by a separate street-facing habitable zone (see Figure 10).

Conclusion

Most of the world's urban population growth is occurring in subtropical and tropical zones. Designs that oblige people to use air-conditioning for indoor thermal comfort exacerbate the use of fossil fuel energy and

Figure 8. Cox Rayner's north elevation © Cox Rayner

Figure 9. Cox Rayner's sky lobby view © Cox Rayner

Figure 10. Street-facing apartments to podium edge © Cox Rayner

… satellite

> "Building the satellite city will be a shot in the arm for developing nearby districts in the Moscow region."
>
> *Vladimir Avdeyev, partner at Russian commercial property firm S. A. Ricci, on the plan to expand Moscow. From "Moscow to Double in Size," Russia Beyond the Headlines, August 10, 2011*

CO_2 emissions, are also implicated in significant long term cost imposition on occupants as the costs of energy rises inexorably. Residential tower developments are often procured through the investor marketing process. Thus, many occupants of high-rise apartment buildings are likely to be renters, and the lack of choice as to whether living costs can be kept down by choosing to control thermal comfort and ventilation through passive systems may become more and more influential on the feasibility of a tower development.

The design capacity exists in Australia – architects and engineers are motivated to innovate and design attractive, livable, naturally-ventilated buildings. The main challenge to changing the dominant development paradigm is in the junction between urban land economics and quality of urban living – and the recognition that concepts of price (up-front cost) and value (impact on occupant's experience) are not the same.

Importantly, the provision of natural ventilation cannot be a stand-alone design objective but must be integrated with other considerations to achieve overall positive project outcomes in terms of comfort, safety, health, privacy and so on, as well as cost-effectiveness considered over the life of the building.

Best practice design for the natural ventilation for multi-story residential buildings has clear benefits, especially in terms of minimizing energy demand. Dilemmas remain over towers' intensive embodied energy, dependency on elevators for vertical transportation and expensive construction process. ■

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Cox Rayner Architects - Brendan Gaffney, URBIS, Gamble MacKinnon Green, Arup

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