An unconventional lady

Queensland's new Lady Cilento Children's Hospital challenges convention. With a design inspired by fauna and focused on the needs of children and their families, it reflects a rethink of the care model. **Sean McGowan** reports on how the building services design also tested conventional wisdom around smoke control.

Queensland's new children's hospital in South Brisbane is named after the pioneering Australian physician Lady Phyllis Cilento. One of Australia's largest public health infrastructure projects, it officially opened late last year.

The building's floor area covers 112,000 sq m (including 73,000 sq m of clinical space) over 16 levels to accommodate 359 hospital beds. This equates to more than 7 hectares, or the equivalent of a 56-storey high-rise boasting a floor-plate size of 2,000 sq m.

Designed by architects Conrad Gargett Lyons, the building's blueprint has moved away from the conventions of traditional hospital design.

The first sign of unconventionality is the brightly coloured, finned façade that is inspired by the locally prolific bougainvillea. And, as you move further inside the building, its originality becomes increasingly obvious.

According to the architects, the facility was designed around the concept of a living tree. Its network of trunks and branches are realised in the form of two vertical atriums and double-height spaces.

These "branches" bring natural daylight into the building, and also help patients, staff and visitors find their way.

As well as providing acute and sub-acute health services, the hospital also includes one of only four iMRI scanners in Australia. At a cost of $3 million, it weighs a massive seven tonnes.

Powering the new facility is a world-class central energy plant accommodated in its own, purpose-designed building (see Ecolibrium, October 2013).

The plant uses trigeneration technology to supply most of the hospital's power, heating, cooling and steam requirements. It also reduces the demand on the local electricity grid by 60 per cent during peak consumption periods.

LATERAL THINKING

AECOM was engaged by Queensland Health in July 2007 as consultant for the mechanical, electrical, communications, security, fire, hydraulics and fire engineering of the Lady Cilento Children's Hospital (LCCH).

The project followed a traditional schedule, with initial master planning completed first, before entering the subsequent concept design and schematic design stages.

AECOM's initial contract with Queensland Health was then transitioned to the project's managing contractor Lend Lease (formerly Abigroup) in late 2009, as the project moved closer to the construction phase.

"The initial brief from Queensland Health to the architects was to create an environment whereby children would not feel like they were in a hospital," says AECOM's Rob Dagnall, M.AIRAH, who was the original lead mechanical engineer and later took on the role of project manager for MEP services.

"From the start of the project," Dagnall says, "we realised some lateral thinking would be required, and that we would not be looking at a traditional hospital design."

Recognising that the changing shape and function of the space from the ground floor up would inhibit the use of traditional risers and plant rooms, AECOM began looking at individual solutions for the different departments and floors.

To assist this process, the team broke the hospital spaces into a number of smaller projects.

"There are over 70 departments within the hospital, all with their own individual requirements," says Dagnall. "Therefore, locations of plant rooms became critical from the onset, to try and avoid services congestion within the ceiling voids and to ensure sufficient separation between outdoor intakes and exhaust discharge points."

This would also help avoid complex controls strategies for smoke control systems.

However, due to clinical and department floor-area requirements, it was not possible to site all plant rooms where AECOM initially wished. Compromise by the entire design team was therefore required.

TARGETED HVAC

Three main types of HVAC system condition the various spaces in LCCH.

A constant-volume system is used for critical departments that operate around the clock. In these spaces, such as the emergency department, the load remains fairly even and on-floor maintenance must be kept to a minimum.

However, some variation exists between the systems deployed in these spaces. For example, the Bone Marrow Transplant

The hospital features more than 70 departments, each with its own requirements.

Area requires the entire department to be HEPA-filtered and positively pressurised to adjacent compartments. Also, its positive- and negative-pressure isolation rooms require 100 per cent outside air.

Due to the number of rooms and variations in cooling load, variable-air-volume (VAV) systems are used in outpatient areas, consulting rooms and offices where some form of localised control is required.

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Most interestingly, particularly given the Brisbane climate, is the selection of active chilled beams for inpatient wards.

"After a number of systems were reviewed and presented to Queensland Health, the decision was made to progress with active chilled beams," Dagnall says.

"The reason for this decision was that the client believed there were improved infection control benefits from a system that provides 100 per cent outside air."

To assist with infection control, as per Queensland Health's requirements, ward rooms have been designed so that bedrooms are slightly negative to the pressure in the corridor.

The chilled beam solution also offers the additional benefit of being able to provide individual temperature control to rooms. This is particularly important for children who have differing abilities to control body temperature (i.e. bariatric patients).

Dagnall says there were also the obvious energy-saving benefits to consider.

"The usual concerns were considered in relation to active chilled beams in humid environments like Brisbane, including that the beams may create condensate – often referred to as 'raining'," he says.

AECOM advised both the client and project team that a well-sealed façade would minimise infiltration. And with the correct control strategies in place, condensation could be avoided.

Laboratory tests were carried out to prove the case.

Performance requirements for the façade were initially set at $5m^3/hr/m^2$ at 50Pa. This requirement was deemed as best practice for limiting building air leakage in hospitals in Britain, where pressure testing is a mandatory requirement for all commercial buildings.

In Australia, however, where pressure tests were not commonplace at the time of design, this was felt to be a reasonably stringent requirement.

Commissioning results ultimately showed the façade to outperform the specified requirements, with actual leakage rates recorded at between $1–2m^3/hr/m^2$ at 50Pa.

Though extremely beneficial for the chilled beam system, such high performance created an entirely different set of challenges in designing the smoke control system.

MEETING CODE

The design team quickly ascertained that their biggest challenge, and the item of most risk, would be the smoke control strategy and compliance with all the requirements set out in AS1668.1:1998 'Part 1 – Fire and smoke control in multi-compartmental buildings'.

"Experience had told us that in large hospitals of this nature, due to the large number of fire and smoke compartments with differing sizes and locations, achieving a conventional zone pressurisation system would prove to be a challenge in terms of achieving performance requirements both during commissioning and then at each subsequent yearly test," says Dagnall.

In short, it would be extremely difficult to balance so many variables and performance requirements across so many fire and smoke compartments.

During the early stages, designers considered removing a smoke-control system altogether, and replacing it with a dual-sprinkler system to provide redundancy.

An emergency waiting lounge.

This was deemed to be a step too far for a healthcare facility, and in the end a fire-engineered smoke-control system that followed the principles of AS1668.1:1998 was selected.

The scale of the system installed at LCCH is considerable. The building features more than 60 fire compartments and 80 smoke compartments, with some floors having up to nine fire compartments each.

It also has more than 200 air-handling units (AHUs), about 1,000 motorised fire dampers, 73 smoke exhaust fans and 13 stair pressurisation fans.

Naturally, this makes for a rather complicated fire control panel, which was an obvious initial concern for QFES.

Sizing the system also proved challenging.

AECOM's Scott Cahill, M.AIRAH, worked in various roles on the project over its seven-year design-and-construct life, including acting as 2IC to the project manager during the construction phase.

A triage nurses station at the LCCH.

According to Cahill, experience had shown traditional smoke exhaust systems to be undersized when factoring in building leakage.

“Undersized systems struggle to meet the minimum requirement of 20Pa differential pressure between compartments,” Cahill says.

“This had been raised with the external peer-review process, and AECOM concurred – based on recent experience in a number of refits for clients whereby the original installed systems were not achieving 20Pa pressure differential between compartments.

“Upon reviewing the systems in detail,” Cahill says, “it appeared that systems were undersized due to the fact that building infiltration, curtain wall construction, cracks, opening, and minor penetrations had not been taken into consideration or had been underestimated.”

AN ALTERNATIVE

When reviewing commissioning results, the AECOM team members struggled to reconcile what they were seeing onsite compared to the initial detailed calculation used to size the systems.

AS1668.1:1998 STATES THAT THE FANS' CAPACITY SHOULD BE THE SUM OF:

(a) The volume of the make-up entering the largest compartment when all required exit doors serving that compartment are open

(b) For central plant system that serves multiple compartments, the volume of leakage air associated with closed air-control dampers which interconnect form other non-fire affected compartments

(c) Leakage air through minor supply and exhaust systems, lift shafts, service penetrations, building gaps and simular.

AS1668.1:1998 also states that "the exhaust quantity from the fire-affected compartment is difficult to assess accurately. The air in the compartment expands due to temperature increase, air filters into the compartment via leakage paths such as lift shafts, exhaust ducts, curtain wall construction, cracks, openings, minor penetrations and open doors to pressurised stairs."

"Essentially," says Cahill, "we were not achieving sufficient leakage between compartments."

Testing showed that less than half the specified maximum leakage rate was being achieved. The design team identified that their initial calculations had allowed for a greater amount of leakage from the façade, which meant a greater amount of make-up air than was being experienced in reality.

> "The other reason a review of AS1668.1:1998 is required? The increase in air-tight facades"

Coupled with extremely well-sealed services penetrations and door seals, it meant they needed to find a way of providing more make-up air into the fire-affected compartment itself, to achieve a reduced pressure differential between compartments and meet the door-force tests.

Cahill says a simple approach might have been to reduce the exhaust air volume from the fire-affected zone. In this case, however, it was not possible because the system would not provide the necessary smoke clearance.

"A well-sealed building, and good building installation details, had worked against us when trying to apply the principles of AS1668.1."

To achieve the same performance criteria as a deemed-to-satisfy zone-pressurisation system, AECOM employed an alternative-zone smoke-system strategy.

This used an exhaust system supplemented by minimal supply air from adjacent zones to create pressure differentials that offer the same means of escape.

The building's two atriums form the smoke-spill shafts for the smoke-control system, with all fire and smoke compartments from levels one to eight discharging into the atriums.

The smoke is then exhausted from the tops of the atriums. Smoke exhaust fans are located at the top of each (two duty, one stand-by). When a fire is detected, the motorised louvres at low level open to provide make-up air while those louvres at the top of the atrium close. The smoke exhaust fans run to ensure the discharge of smoke from the atriums.

A NEW APPROACH

Based on the experiences at the Lady Cilento Children's Hospital, AECOM believes AS1668.1:1998 needs to be reviewed for modern buildings – especially large healthcare facilities with numerous fire and smoke compartments.

According to AECOM, the reasoning is two-fold.

Firstly, a zone-pressurisation system for a large healthcare facility, particularly one such as this that has limited modularity, is very complex both to commission and more importantly, to maintain.

"Zone-pressurisation systems work very well for multi-storey commercial buildings where the fire compartment is one floor," says Cahill. "They do not work well where there are multiple fire compartments per floor and where compartments on adjacent floors are not vertically aligned."

The other reason a review of AS1668.1:1998 is required? The increase in air-tight facades.

Infiltration is being reduced due to improved building facades and construction techniques. This provides a reduction in cooling load and subsequent reduction in building energy consumption.

Obviously, this is a positive from an environmental perspective, but it has ultimately removed one of the make-up air paths from the fire-affected compartment itself.

"This means it has become difficult to achieve the minimum differential pressure, ensure compliance with door forces and still size the system for stair pressurisation relief to achieve the Lm/s," Cahill says.

"Therefore alternative make-up air paths needed to be considered, which was ultimately the solution provided for LCCH. However, we were fortunate that we had a fire engineered solution that enabled us to make these changes."

Transfer ducts between compartments with non-return dampers were utilised to increase the make-up air.

"We also experienced that the number of differing door types, sizes and doors closers had a significant impact in the door forces experienced between compartments," Dagnall says.

"There needs to be a consideration in the standards for each of these components and the subsequent requirements in regards to Australian Standards."

THE FUTURE OF ZONE PRESSURISATION

The challenges experienced in the fire and smoke control design of LCCH are not solely related to healthcare buildings. Any multi-storey building with a large footprint and multiple fire zones on each floor would likely face similar challenges.

For Cahill and the team at AECOM, it is clear that a zone-pressurisation system is not suitable in such facilities.

"A zone smoke control system that doesn't rely on specific pressure differentials between zones is preferred, which means either adopting an alternative strategy or, in the long term, modifying the requirements of AS1668.1," he says.

Lady Cilento Children's Hospital officially opened on November 29, 2014.

Feedback to date has been positive, and the effectiveness of the natural ventilation strategy – one of the main project innovations from a services perspective – will be reviewed throughout the year to see how the building performs in different seasons.

Importantly, AECOM will also be reviewing the smoke control yearly test to ensure the original commissioning results are repeatable. ■

FINDING CRACKS

Both AS1668.1:1998 for zone pressurisation and the standards in relation to fire and smoke doors are written to minimise the spread of smoke.

Where cracks exist surrounding a door, for example, a make-up air path between compartments is created. However, as soon as smoke seals are installed, the path is removed. This only serves to compound the issue when combined with an air-tight façade.

The standard also requires doors in fire walls and smoke walls to close and remain closed against system pressures.

"For double-hung doors in corridors that are required to swing in either direction and have no positive central latching arrangement, pressure differentials in excess of 20Pa were shown to cause these doors to remain slightly open," says AECOM's Scott Cahill, M.AIRAH.

Adjusting door closers to ensure the doors remained closed resulted in the door-opening forces exceeding the required 110N limit at Lady Cilento Children's Hospital (LCCH).

AECOM believes that for large and complex systems, alternatives should be considered as a deemed-to-satisfy solution in any future updates of AS1668.1.

"This would provide the end user with a solution that is simple to control and operate with minimal points of failure, which can be maintained with ease and without the need for fire engineering reports that are required to be updated with building changes," Cahill explains.

He adds that in many countries around the world, a zone-pressurisation system is not required by buildings of the size and complexity of Lady Cilento Children's Hospital.

Possible alternatives that could be considered include a simple purge system, increasing the level of fire protection provided within the building (duty/standby) or an exhaust-only system.

PROJECT AT A GLANCE

The personnel

Architect: Conrad Gargett Lyons

Building engineering services: AECOM

Client: Queensland Health

Contractor: Lend Lease (formerly Abigroup)

Mechanical contractor: AE Smith

Medical gases: Hosmed

Equipment

Air-handling units: Air Design

BMS: Dalkia (Veolia)

Chilled beams: Dadanco

Diffusers: Holyoake

Fans: Fantech

Grilles: Holyoake

Motorised fire dampers: Bullock