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Remote possibilities

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Fabric energy storage technology is bringing a breath of fresh air to a ground-breaking new hospital in Botswana. Engineer Paul Norton, who designed the project, explains all.

In a remote village in the north west region of Botswana, at the gateway to the Okavango Delta, a ground-breaking healthcare project is under way. The pioneering scheme is a 260-bed hospital. What sets it apart is that it is Africa's first building to use Termodeck's fabric energy storage system. What's more, it's the world's first hospital to use the system and if it's a success it could slash the building's cooling load by 40% and lead the way in radically reducing energy consumption in future healthcare facilities. No mean feat in a region where outdoor air temperatures exceed 40ºC.

The Maun District Hospital is one of five new hospitals under construction as part of a government programme to meet Botswana's growing demand for better healthcare facilities. Maun is the most remote of these, 900 km from the capital Gaborone. It's the brainchild of FMA Architects and North Atlantic Engineering Consultants, which persuaded the government of Botswana of the effectiveness of the hollow core fabric energy store technology by citing its success in Middle Eastern countries where outdoor air temperatures regularly exceed 40ºC.

The two-storey main hospital building occupies 24,000 m² and the Termodeck hollow core plank system provides indoor environmental control to almost half of this, with remaining areas such as operating theatres and the central atrium using conventional all-air systems. The major benefit of the fabric energy store approach is its contribution towards achieving a low installed cooling load. The target we aimed for at North Atlantic was 125 W/m². When compared with similar-sized hospitals in the region that employ conventional construction and services designs, Maun's approach should deliver a 40% reduction in cooling load and an equivalent saving in electrical power. Considering that almost

60% of the total supply of air delivered into the hospital is outdoor air at design temperatures approaching 40°C, this was quite a challenge.

Our starting point was the ASHRAE guide recommendations for ventilation rates in healthcare facilities. To meet these it was determined that a relatively low air-handling unit specific fan power of 2.5 W/l/s could be used because air change rates to general, non-critical in-patient areas could be reduced due to the high component of radiant coolth from the slabs.

Other energy-saving aspects of the fabric energy store system include the potential for “free cooling” the hollow core slab once outdoor air temperatures drop to 17°C. With typical outdoor diurnal temperature swings of 11-13°C in both summer and mid season, this should allow a substantial saving in cooling load; particularly for night-time charging on days when outdoor temperatures peak between 28°C to 30°C. When higher peak outdoor temperatures occur, summer night-time charging of the slabs using mechanically chilled air will benefit from higher chiller coefficients of performance, typically ranging from 3.5 to 4.4 compared with 2.5 during peak daytime temperatures.

Although the use of concrete hollow core slabs for supplying air has given rise to some concerns about air quality, independent studies undertaken by BRE have proven them unfounded. They found that concrete cores do not increase the risk of fungal growth or other hygiene problems when compared with standard approaches using sheet metal ducts, and concluded that the risk may be even lower in some circumstances. However, access points are nonetheless provided to ensure that the ‘active’ cores (typically three cores in each slab forming a labyrinth configuration) of the hollow core slabs can be easily cleaned. These include a tee piece on the supply air branch ductwork connection into the hollow core slab and a further access point on the middle core, while the core delivering air into the room can be cleaned from the supply air diffuser opening.

Four air-cooled chillers generate almost 2.1 MW of cooling, which serves the main hospital, mortuary block and selected service buildings. These circulate chilled water through 2 km of distribution pipework, feeding 35 air-handling units of which 25 serve the hollow core slab fabric energy store system.

Design supply air temperatures into the hollow core slab vary depending on the requirement of each department, typically ranging from 13°C to 19°C. The higher supply air temperatures are those associated with high air change rate departments, such as the TB wards. This high volume of supply air is predominantly conveyed in proprietary closed cell pre-insulated ductwork, with reinforced aluminium foil facings within the main hospital building.

During the winter months, a constant volume hot water system, using steam generated by a central coal-fired steam boiler plant as its primary heating medium, serves the heating coils in each of the air-handling units. This provides bulk air heating, with electric heaters at each room terminal allowing adjustment of the final supply air temperatures.

To reduce the risk of airborne cross infection, specific hospital rooms require 12 to 15 air changes per hour. It was, however, found that there was an insufficient number of active Termodeck cores in such rooms to meet the high airflow rate demand. This problem was compounded in rooms where air throws from active cores also became restrictive. Furthermore, if trying to pass all the air through the hollow core slabs there was a potential for overcooling the space. To avoid these problems, the airflow shortfall through the hollow core slab is made up by a continuous supply of air directly into the space by either sidewall or ceiling diffusers. As this air is taken from the same primary air system serving the hollow core slab, its temperature is lower than that entering the room through the slab. To prevent overcooling or underheating, low capacity electric heaters with modulating control are used to temper the air to maintain acceptable room conditions.

An inherent characteristic of the fabric energy store system is slow response to sudden changes in room heat gains. To overcome this problem in rooms with six or fewer air changes per hour, primary system air passing through the hollowcore slab is diverted directly into the room through sidewall or ceiling diffusers. The primary system air is typically 5-6°C below that exiting the hollowcore slab into the room, so this accommodates such intermittent fluctuations in load. To divert the air, duct-mounted motorised dampers operate in a fully open or closed mode. Room temperature controllers allow the occupant to adjust control set points and divert air directly into the room. There is a facility to boost air temperature using an electric heater, but the BEMS will be restrict use of this to colder months. To prevent the hollow core slab from being continuously bypassed, the dampers reset after a pre-determined time to a default position whereby all supply air entering the room passes through the slab.

All of the air systems serving the fabric energy store are self-balancing. The use of extensive duct looping, in conjunction with air pressure-powered constant volume regulators on duct branches, maintains room supply air quantities within acceptable tolerances. In addition to making the system much easier to balance, this also takes up any variations in system pressure caused by the opening and closing of diverting dampers.

The project is scheduled for completion in February 2008 and although testing of the system is still some way off, the team is confident of its success. Operation of the building will be monitored for a year after occupation, while the FES is fine-tuned to fully exploit energy savings from associated systems.

This is a groundbreaking project in many ways and hopefully it will persuade design teams to consider FES systems part of the solution to reducing overall building energy consumption when tackling future healthcare facilities.

Building Design

The building form and orientation assist in moderating the effects of the semi-arid climate on indoor temperature. The longest axis of the building runs east-west through an enclosed central atrium, which forms the access hub to adjoining blocks. Each block wraps around open courtyards, providing views into landscaped areas and offering solar shading during the day.

The building fabric is designed to be thermally efficient to ensure the cooling load imposed on the hollow core slab stays within its inherent operating limits. Extruded polystyrene thermal insulation with thicknesses of 100 mm and 150 mm correspondingly achieve U-values of 0.3 W/m²K for brick cavity walls and 0.2 W/m²K for the main roof area. In addition, 100 mm thick insulation extends below ground level within the cavity of the external walls to minimise temperature fluctuations under the ground-floor slab.

Windows and doors are double-glazed using a solar control outer pane and a low emissivity inner pane to achieve a U-value of 2.1 W/m²K, including frame and a 0.17 shading coefficient.

Thermal bridging is minimised by incorporating thermal breaks into door and window frames and low profile sealing plates to close off the insulated brick wall cavities around window and door openings. Extensive use of internal masonry partition walls provides additional thermal mass that contributes to the fabric energy storage medium. This combined with the modest areas of glazing provides a thermally efficient structure without detracting from its aesthetics.

Slab manufacture

Costs, quality control and the logistics of transporting 2800 pre-cast concrete slabs to such a remote location led the main contractor to manufacture the hollow core slabs on site. Using proprietary hollow core extrusion machinery, alternating between two 90 m long casting beds, production was completed in 12 months. The slabs are typically 1.2 m wide and 250 mm thick, with five 190 mm diameter cores and spans from 5 m to 7.5 m. Slab customisation, erection, core cleaning and pressure testing were all completed on time. The slab soffits are of such quality that they only needed minor attention and painting.

Using the fabric energy store system required a high level of co-ordination with other disciplines. Selected “non-active” cores of slabs, not used as air passages, are employed as ducts for cables routed from the central corridor ceiling voids to light fittings and smoke detectors in adjacent areas. Similarly, cores of the slab are used to convey exhaust air from “dirty” utility rooms, toilets, bathrooms and cleaners’ rooms, reducing the number of services crossovers.

Source:
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Postscript:
Paul Norton is chief mechanical engineer at North Atlantic Engineering Consultants, Botswana. Email pauln@northatlantic.bw

First floor plan showing the areas served by the FES system (PDF)

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- Ground floor plan showing the areas served by the FES system (PDF)

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- Schematic showing the operation of the FES system in a room requiring additional cooling (PDF)

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- Schematic showing the operation of the FES system in a typical room (PDF)

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- Schematic showing the operation of the FES system in a room requiring a continuous direct air supply (PDF)

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