De²RHECC

Design and Delivery of Robust Hospital Environments in a Changing Climate

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Project duration: October 2009 – February 2013

Project website: http://www.robusthospitals.org.uk - for details of all our papers and our film

Key project aim: *to design and test economical refurbishment strategies for the NHS acute hospital estate that will be resilient to summertime overheating in changing climates while meeting the ambitious & legally binding carbon reduction targets set of the NHS*

Key work to date: *two years' temperature data collected in representative buildings on partner NHS Trusts' campuses; calibrated models of the buildings made and tested to the 2080s; refurbishment strategies devised and designed; strategies tested for summer performance up to the 2080s; strategies fully costed and assessed for buildability/infection control implications*

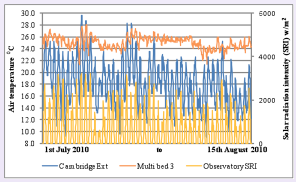
Principal findings: *that refurbishment can deliver excellent results in typical years (and in some cases, extreme years) for lower cost than new construction. That passive strategies that use the 'stuff' of architecture to moderate the internal environment should be investigated before designing 'business as usual' buildings that attempt to deal with energy use through technological means*

Impact includes: *citation in the National Climate Change Risk Assessment; links with UK practitioners, policymakers & PFI teams; international contacts including Kaiser Permanente (Oakland, California), Mercy Healthcare (Victoria, Australia).*

Addenbrooke;s Hospital, Cambridge – published in *Building and Environment*

This building is a typical recurrent UK hospital type (at least 50 survive in England), a medium-rise ward tower dating from the late 1960s. It shows that this particular type may have more resilience in the current climate than might have been expected, that it will remain resilient into the 2030s, and that relatively non-invasive measures would extend and increase its resilience whilst saving energy. Hybrid solutions – passive in the first instance, with longer-term mechanical capabilities – are the best bet.

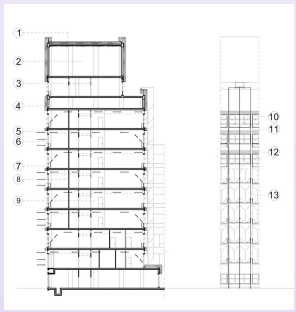
The first step in our work was to 'diagnose' the building based on measured performance and predicted future performance.



This graph shows temperatures in a multi-bed ward space in the Tower, summer 2010

Level	Space	Maximum temperature, °C (24 hours)	Minimum temperature, °C (24 hours)	Mean temperature, °C (24 hours)	Mean night time temperature, °C (23:00 to 6:00)	Mean night time temperature, °C (23:00 to 6:00)	Annual cooling (kh)	Hours over 25°C (24 hours)	Hours over 28°C (24 hours)	Hours over 32°C (23:00 to 6:00)	Hours over 26°C (23:00 to 6:00)
6	Multi-bed 6MB7	28.4	21.9	25.3	24.6	6.5	935	6	528	43	
	Nurse station (NS)	29.3	24.4	27.1	26.4	4.9	1898	110	460	339	
							(95.5%)	(10%)	(100%)	(73.7%)	
8	Multi-bed 8MB10	28.5	21.6	25.0	24.6	7.1	693	2	358	98	
							(46.7%)	(0.2%)	(73.5%)	(18.3%)	
	Multi-bed 8MB4	28.1	21.2	25.5	24.7	6.9	583	1	358	17	
							(52.6%)	(0.1%)	(76.1%)	(3.7%)	
	Nurse station (NS)	29.1	25.9	26.1	25.9	5.2	998	15	435	285	
							(89.7%)	(1.4%)	(99.8%)	(64.4%)	

Five refurbishment options have been devised by the research team, tested and costed. Two are shown here as examples:

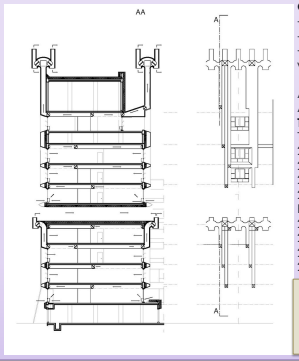


Option 4
- Replaces existing mechanical system with natural ventilation, ducts threaded across the ward to allow cross-ventilation without infection risk
- Building fabric is insulated; windows are shaded against solar gain on main S side
- Windows are openable

Annual predicted energy demands: 20 GJ/100m³ (well below target of 55-65 GJ/ 100m³ and the current performance of 101GJ/100m³

Annual predicted emissions: 44 kg CO_2/m² Cost per sq.m. = £1069.89

Total hours above 28°C:	**above Cat I limit**
Typical year:	
2005 – 0	0
2030 – 3	22
2050 – 18	24
2080 – 96	123
Extreme year	
2005 – 8	22
2030 – 199	187
2050 – 582	478
2080 – 1060	861



Option 5
- Natural ventilation achieved passively with stacks added to the exterior
- Stacks also serve to shade the windows which now sit within deep reveals
- Perimeter Heating, BMS controlled perimeter dampers and manually operable windows, transfer ducts as 4 coupled to stacks, slabs exposed between.

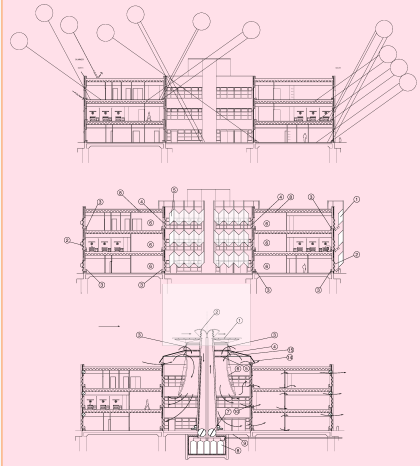
Annual predicted energy demands: 32 GJ/100m³
Annual predicted emissions: 67 kg CO_2/m²

Total hours above 28°C:	**above Cat I limit**
Typical year:	
2005 – 0	0
2030 – 0	0
2050 – 2	6
2080 – 11	20
Extreme year	
2005 – 0	0
2030 – 102	69
2050 – 491	374
2080 – 1014	767

Addenbrooke's is just one of the hospitals featured in our **project film**, a broadcast-quality documentary that will be available via our website from winter 2012. The film features contributions from David Pencheon (NHS SDU), Paul Morrell (Govt Chief Construction Advisor), Greg Chant-Hall (Skanska), Ian Hinitt (Bradford Teaching Hospitals NHS Foundation Trust, plus animations of our results

The Rosie Maternity Hospital – paper currently in progress

This is a typical low-rise courtyard-type hospital dating from the early 1980s. The building overheats on account of its main patient spaces facing south, but also because of heating pipes embedded in the concrete slab floors which make the north side of the building hotter still.



Section through the existing hospital showing central court, summer sun angles

The team's Option 2, with shading added to vulnerable elevations, plus additional insulation, additional opening windows, greater connections between corridor and central court

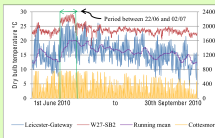
Our Option 4 implements Passive Downdraught Cooling: a natural option for improved cooling and ventilation

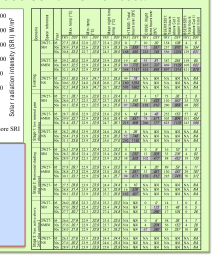
We are currently modelling these options to test their performance to 2080

Glenfield Hospital, Leicester – paper under review

More than 100 'Nucleus' type hospitals were constructed between the late 1970s and early 1990s, using a distinctive set of cruciform templates. The result was a shallow mat-plan building, low-rise, with good natural ventilation and lighting plus some additional mechanical ventilation. Trusts, driven by the perceived need to maintain medical adjacencies, are filling the courts to create deep-plan buildings.

During the four month monitoring period, the maximum indoor temperatures in the case study spaces varied between 26.6 °C and 29.3 °C. Nurse stations were found to be the hottest areas. During this period the performance of most of the monitored spaces was reasonably within the thermal comfort threshold of HTM03-01. The simulation results demonstrate that light- touch low carbon interventions could produce comfortable conditions in bedrooms into the 2050s.



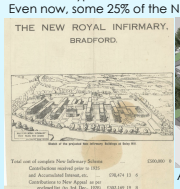


A note on Adaptive Comfort Standards…

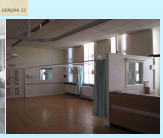
The Department of Health's HTM03-01 document provides guidance on temperatures, but our work suggests that the adaptive standard BS EN 15251 is a better way of evaluting performance. A paper on this topic by the team has been published in *Building and Environment*.

Bradford Royal Infirmary – our work published in the journal *BSERT*

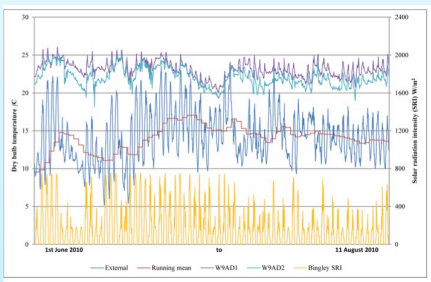
The Nightingale Wards are classic open-plan 'dormitory' type wards for 24 patients, built in 1927-34. This type of ward runs counter to Department of Health ideas about privacy and dignity, and infection control, but emerges as being resilient in both the current and future climate, thanks to its thermal mass, high ceilings, and large operable windows. Ventilation was a key factor in the origins of the Nightingale ward type. Though compromised by reduced window opening areas (for patient safety) a new window design, with appropriate decorative guards, could restore the original greater opening area. The team is also working on the benefits of slow-moving patient-operated ceiling fans. These wards remain popular for certain types of care, for example geriatric medicine; we argue that for that reason, and on financial ground, they should not be written off. Even now, some 25% of the NHS hospital estate pre-dates 1948.



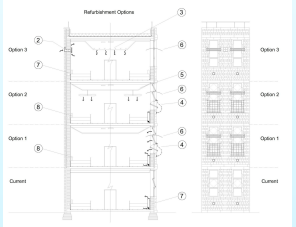
A still from the animation in our film



As built, 1928 (left) and as now (2012, right), with partitions and suspended ceilings. Though thus altered, the design remains remarkably resilient



Monitored performance, 2010. We now have a vast database of spaces on our case study sites



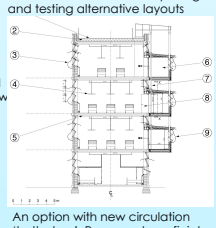
Three refurb options. The building is insulated and the windows shaded. Window guards in options 1 and 2 allow greater opening area. Opt. 2 has slow moving fans. Option 3 uses radiant heat/cooling

Option	Mean temperature (°C) (24 hours)	Maximum temperature (°C) (24 hours)	Mean temperature (°C) (23:00 to 6:00)	Mean night time temperature (°C) (23:00 to 6:00)	BEMS: Total hours above 28°C	CIBSE: Night time hours above 26°C	BSEN15251: Cat I hours above Cat I limit	BSEN15251: Cat II hours above Cat II limit
				2010				
Existing	29.0	33.0	21.6	22.3	4	3	179	43
Opt-1	27.4	27.2	21.9	22.8	0	0	196	23
Opt-2	26.2	27.2	21.9	22.8	0	0	192	16
Opt-3	26.8	27.0	20.6	22.3	0	0	na	na

Predicted performance, 2010 climate, for our redesign options

Our modelling shows that the refurbished wards remain comfortable into the 2080s in typical years. In extreme years, measured against the fixed HTM03-01 criteria, some overheating is experienced, but against the adaptive standard BS EN 15251, the wards are fine.

We have become interested in ways that the ward environment can be improved without compromising its resilience and are currently designing and testing alternative layouts



An option with new circulation 'bolted on'. Preserves beneficial cross-ventilation & capacity