CASE STUDY

COMMUNITY IN A CUBE
RIVERSIDE ONE

LEEDS METROPOLITAN UNIVERSITY
Leeds Sustainability Institute

CeBE

Technology Strategy Board
Driving Innovation

Good Homes Alliance

The project reported here is part of the Technology Strategy Board's Building Performance Evaluation programme and acknowledgement is made of the financial support provided by that programme. Specific results and their interpretation remain the responsibility of the project team.

80 residential units, mixed-use development

One Planet Living®

Zero Carbon

Mechanical ventilation with heat recovery, communal heating, biomass

Measured air tightness (1 apartment): 5.52 $m^3h^{-1}m^{-2}$@ 50 Pa

Evaluation Team

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Introduction

Community in a Cube (CIAC) was designed to be a zero carbon mixed-use development comprising 80 residential units and retail/leisure space. Constructed between 2011-2012, CIAC is located at the Riverside One development in Middlesbrough. It is first building to be constructed in the 40 acre, £200 million regeneration project, planned to eventually be 16 buildings in total, providing residential accommodation, commercial opportunities and community spaces.

The building is located in the dock area of Middlesbrough, close to the Riverside Stadium, home to Middlesbrough Football Club. It is located close by to both the town centre and railway station, and the North Sea coast is only 10km away.

CIAC at Riverside One

CIAC incorporates the 10 One Planet Living® principles (Bioregional Quintain, 2012) and was designed to provide a lifestyle-orientated approach to sustainability by making it easy, attractive and affordable to live sustainably. Cycle storage facilities, dedicated parking, electric vehicle charging points, and a communal garden are provided.

The 9 storey building takes a cubic form, with the retail and leisure space on the ground floor, studios and 1 and 2 bedroom apartments above, and 2 bedroom, 'skyhome' apartments on the top floor.

This case study examines a one bed, 42m^2 apartment on the 5th floor of the development. This apartment was completed in December 2011, and the study ran from February 2012 to June 2013.

This evaluation was conducted under the Technology Strategy Board's (TSB) Building Performance Evaluation programme. The purpose of this programme is to assemble data from different new buildings so that conclusions about the effectiveness of different various design types and construction and operational practices can be drawn, with the aim to improve the whole sector in terms of comfort, energy use and occupant satisfaction.

To determine the effectiveness of the design and delivery strategy at the CIAC, real performance indicators were tested to compare these results with anticipated performance. The project team followed the TSB protocols for fabric and services testing, conducting the following examinations:

- Thermographic survey
- In-situ u-value tests
- Airtightness tests
- Coheating test
- Services commissioning checks
- Design and Construction review
- Occupant induction review

Additionally the BUS survey was used to capture occupant perceptions about their dwellings.

The results from this evaluation indicate that the apartments have not completely fulfilled their design intentions. Thermal bridges and heat loss through the superstructure were identified, but it also appears that some building services, particularly the MVHR system, have not been designed, constructed or commissioned effectively. Issues with heat loss through the communal heating system and MVHR system are also likely to contribute to an overheating problem.

Design and Construction

The predicted fabric and services performance figures are listed below in Table 1.

Table 1. Design Targets

Air permeability (design SAP, 2010)	3 $m^3h^{-1}m^{-2}$@ 50Pa
U-value: walls (design SAP)	0.18-0.21 W/m^2K
U-value: windows (design SAP)	1.3 W/m^2K
U-value: doors (design SAP)	0.63 W/m^2K
Y value (design SAP)	0.04 W/m^2K
MVHR heat exchanger efficiency (SAP Appendix Q)	92%
MVHR fan Specific Fan Power (SAP Appendix Q)	1.04 W/l/s

Building Fabric

The apartment has an open-plan living/kitchen area on the South and West façade of the building, a West-facing bedroom and a South-facing bathroom. An internal storage cupboard is located in the hallway which houses the communal heating heat exchanger unit. All of the apartments have dual aspect, large windows, with high ceilings and exposed concrete soffits.

Kitchen area with exposed soffit ceiling

The building has a concrete frame, with site-built timber-frame in-fill panels for external walls, with timber or brick skin cladding. Some of these panels have been constructed around the concrete columns which form part of the building structure. There is also a glass privacy panel beneath the bathroom and kitchen window. External walls have designed U-values between 0.18-0.21 W/m^2K.

The windows are double-glazed, argon filled low-e aluminium faced composite units (aluminium/insulation/timber), while the doors are timber, with designed U-values of 1.3 W/m^2K and 0.63 W/m^2K respectively.

Building Services

Space heating is provided via a LTHW heating coil installed within a whole house MVHR unit, installed in the ceiling void in the bathroom. A wet heated towel radiator is also provided in the bathroom. A heat exchanger unit, supplied by the communal heating network, is installed in the cupboard in the hallway of the apartment. This provides LTHW to the MVHR heating coil and the bathroom towel radiator, and supplies domestic hot water to the apartment.

Communal heating system - heat exchanger unit

Communal heat is provided by a 320kW biomass boiler located on the ground floor of the building, supplied with wood pellets. A gas-fired boiler was designed as backup, with the biomass boiler as lead. However, according to operations staff, due to the low level of occupancy within the building, only the gas-fired boiler has been used so far. The biomass boiler is set to become operational once the building becomes 75% occupied.

The thermostat for the space heating system is located in the living room. This forms part of the command module, which also controls the MVHR fan speed. Time control of the space and hot water heating system, including the towel radiator, is provided with a 24 hour programmer located within the heat exchanger enclosure. The towel radiator in the bathroom is controlled by the central thermostat, and can only be activated when there is demand for space heating in the apartment.

The MVHR system incorporates a motorised heat exchanger by-pass damper (summer bypass). Boost mode is triggered by the light switch in the bathroom, the command module, and a boost switch in the kitchen. Air is supplied to the bedroom and living/kitchen area via a high level grille above the door. The method used to provide extract ventilation from the bathroom and open plan living/kitchen area is very unusual for a domestic installation - it is provided via a channel located in the plasterboard ceiling, above the window in the bathroom and above the cupboards in the kitchen. Air extracted through the channel passes into the ceiling void and is then extracted through an air valve (in the ceiling void) into the MVHR ductwork.

Design and Construction Experiences

The main changes and challenges encountered during design and construction and how they were managed are discussed in this section.

CIAC had difficulties brought about by the economic downturn, which resulted in the developer (after completion) and the Mechanical and Electrical contractor ceasing to trade. Further, it was intended that the whole Riverside One regeneration project would be undertaken over a number phases, with CIAC being just one building of many on the site. However the regeneration of this area of Middlesbrough was halted, waiting for better economic times to prevail; construction has still not commenced of any of the other 15 buildings proposed for the larger development.

This has had implications for the energy strategy. CIAC was originally designed to import heat from a larger district system, intended to supply a number of other buildings at Riverside One. As a result, the energy strategy had to be revised during construction, which had architectural implications for the building - a communal plant room with a biomass boiler and wood pellet fuel store was added at ground floor level of the building.

As previously stated, the M&E contractor stopped trading, resulting in another contractor having to takeover mid-construction. Further, an original subcontractor sadly passed away during the construction phase. This caused significant disruption to the construction programme, impacting time scales and delivery.

Another problem that was encountered was the main contractor mistakenly ordered all of the windows with trickle ventilators (trickle vents were not advised with the MVHR system). This was not picked up until the windows arrived on-site. To fix this, it was decided that all of the trickle ventilators would be sealed on-site. However observations and leakage detection revealed that the trickle ventilators, at least in the test apartment, had actually not been sealed. Consequently, one implication of this ordering error has been an increase in the background leakage rate of the apartment, as they were identified as one of the main sources of air leakage during the leakage detection test.

Additionally, the company responsible for the MVHR systems would not visit the site and take ownership of their system, which may explain the incomplete training for the MVHR installation, and the subsequent poor performance.

Design Review

A review of the design was undertaken on the test apartment. Unfortunately it was not possible to obtain a full set of design drawings, as-built drawings or the as-built SAP worksheets. Consequently, it was only possible to undertake the review with the limited amount of information that was made available.

It was found that within the reviewed documentation there was inconsistency with air permeability target. From conversations with the client, the air permeability target for the apartments was 3 $m^3h^{-1}m^{-2}$@ 50Pa, which matches with the design SAP worksheet dated 9th November 2010, done for a typical 2 bed apartment. However the design SAP worksheet dated 7th August 2011 contains an air permeability target of 10 $m^3h^{-1}m^{-2}$@ 50Pa, despite the client stating that they had not consented to any change to the target. A target of 10 $m^3h^{-1}m^{-2}$@ 50Pa seems an unrealistic, unworkable target, particularly given the inclusion of an MVHR system (a design target of 3 $m^3h^{-1}m^{-2}$@ 50Pa is usually specified if an MVHR system is to be used), and may have been included to represent a worst case SAP scenario.

An air tightness strategy was not clearly communicated in the documentation, with no primary air barrier identified on any of the drawings for the test apartment. In addition, no pen-on-section test has been undertaken on this apartment to the best of our knowledge, to check the continuity of the air barrier.

Additionally there is a lack of detail regarding the U-values. Construction details and U-values were not available for all of the external wall types for the test apartment. In addition, the U-value given for the timber door from the apartment to the corridor seems unrealistic; a U-value of 2.2 W/m^2K would be more representative.

As it was not possible to obtain a copy of the as-built SAP worksheet for the apartment, a design SAP worksheet was used examined for discrepancies between as-designed and constructed. The analysis revealed a number of issues associated with the SAP worksheet inputs. If the correct information had been used, it is likely that a much poorer result would have been obtained, and the apartment may even have failed to meet the regulatory Target Emission Rate. The main issues were large differences in floor area and glazing area, and the use of y value of 0.04 W/m^2K, without any documentation to prove that Enhanced Construction Details had been used.

Construction Review

Although it was only possible to undertake one set of site observations on the apartments during the construction phase, a number of issues which, if left unaddressed in construction, would likely contribute to an increase in fabric heat loss and air leakage were highlighted. These observations took place after most of the superstructure had been completed and the majority of the building was wind and watertight.

Fabric heat loss

Unsecured partial fill insulation at ground floor

- Many services were installed within the frame of the party wall, rather than through an internal service void, making it difficult to install the insulation in the party wall effectively. Insulation may not be fully installed or may be over-compressed, reducing its effectiveness both thermally and acoustically.
- Insulation was found bridging across the party wall, rather than being contained within the individual frame sections on the party wall, limiting its effectiveness.
- It is unclear how the privacy panel beneath windows in bathrooms could be adequately insulated to prevent condensation on its inner face. This could result in water pooling on the sill below it, resulting in degradation of the building fabric and increased heat loss.
- The partial fill insulation was not securely retained against the inner face of the blockwork at ground floor level, with retaining clips for insulation missing. This could cause a thermal bypass to form between the insulation and the inner leaf of blockwork.

Air leakage

- In a number of places sealant tape had either begun to lose adhesion or had only been fixed at the edge of the penetration, leaving an air gap behind, and increasing the risk of failure. If not addressed, this will likely result in increased air leakage.
- Party walls and walls to communal areas did not appear to be sealed to the concrete ceilings with the same regard to airtightness as the external walls. This may lead to air leakage between apartments.
- A number of holes from services that penetrate through party elements remained unsealed, allowing for indirect air leakage paths.

Building Fabric Evaluation

To evaluate the real building fabric performance, air pressure testing, a Coheating test, in-situ U-value tests, and a number of thermographic surveys were performed on the apartment. Fabric testing was undertaken over the period 13th February to the 16th May 2012.

Coheating Test

The Coheating test was undertaken on the test apartment between 14th February and the 4th May 2012, in accordance with the TSB adopted protocol developed by Leeds Met.

A number of significant difficulties were experienced undertaking the Coheating test on the test apartment, which contributed to the extended time of testing period. First, shortly after commencing the test, it was observed that heat was still being supplied from the communal heat main to the heat exchanger unit in the apartment. This heat supply was finally isolated by the development management on the 27th March 2012. However this was soon followed by a period of high external temperatures and high levels of solar radiation. To counteract the weather conditions, the temperature within the test apartment and the adjacent apartments was increased to 28°C on the 11th April 2012. However this warm weather, coupled with subsequent equipment failure, and the resumption of communal heat back into the apartment meant that of the 7 weeks of Coheating data that was recorded, only 9 days of usable data was obtained.

Analysis of the useable data revealed a high dependency between ΔT and solar insolation, rendering regression analysis ineffective. This is problem that can occur with performing Coheating tests outside of the winter season, when levels of solar insolation are high. An alternative analysis technique was used which involved calculating the solar aperture for the test apartment to correct the raw heat loss data. Ultimately however, because of the lack of useable data and high solar insolation, the heat loss coefficient figure obtained is not deemed to be reliable.

In-situ U-value Test

30 heat flux plates were placed in the test apartment to obtain in-situ measurements of the U-values of various elements of the building fabric. Measurements from the heat flux plates were taken at one minute intervals throughout the Coheating test. The heat flux plates were placed on a small area of each of the building elements, and could only be positioned on external elements which were subject to direct solar radiation, so figures obtained are only indicative - they may not necessarily be representative of the building U-values as a whole. As exposure to direct solar radiation will reduce the rate at which heat is lost, it is quite possible that the daily effective U-value could be higher than that measured.

U-value measurements obtained on the timber panel section of external wall, at the location deemed to be least influenced by thermal bridging, ranged between 0.18 W/m^{2}K to 0.30 W/m^{2}K, with a mean of 0.25 W/m^{2}K. There is a discrepancy of 0.06 W/m^{2}K from the specified design value of 0.19 W/m^{2}K. U-values for the concrete column section of external wall ranged between 0.32 W/m^{2}K to 0.66 W/m^{2}K with a mean of 0.42 W/m^{2}K, which is 0.21 W/m^{2}K higher than the specified design value of 0.21 W/m^{2}K.

For the kitchen and bedroom windows, the measured U-value for centre pane ranged between 1.33 W/m^{2}K to 1.54 W/m^{2}K, with a mean of the 1.41 W/m^2K. The compares favourably with the specified design value of 1.3 W/m^2K.

Measurements on the internal concrete column of the building frame revealed that the superstructure could be acting as a heat transfer mechanism between apartments in other areas of the building at a lower temperature. If this is the case, then the actual heat loss from the apartment is likely to be larger than intended, as the heat loss through the superstructure into adjacent apartments has not been accounted for in design. As this apartment was built to Part L 2006, this additional heat loss was not accounted for within that edition of the Building Regulations. Part L of the Building Regulations has since been amended to account for heat loss through party walls, but not other elements of the superstructure, such as floors or ceilings.

Air Pressure Testing

Air pressurisation tests and leakage identification was undertaken on the test apartment. Tests were conducted twice: before and immediately after the Coheating test. This second test was performed to see whether the Coheating test had any impact on airtightness.

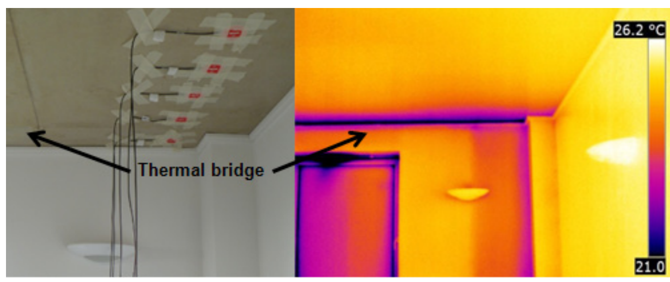
The results indicate that the apartment is of average airtightness by UK new build standards. Despite having no identified primary air barrier, it achieved mean air permeability figures of 5.43 and 5.61 $m^3h^{-1}m^{-2}$@ 50Pa (5.52 $m^3h^{-1}m^{-2}$@ 50Pa averaged over the two tests). While significantly better than the target of 10 $m^3h^{-1}m^{-2}$@ 50Pa found in one design SAP worksheet, it is also higher than the original target of 3 $m^3h^{-1}m^{-2}$@ 50Pa (which the developer thought to be the correct target). The results also indicate that there has been effectively no increase in the air permeability of the dwellings as a result of the Coheating test procedure. This suggests that the apartment had fully dried out before the Coheating test began.

Only very small amounts of air leakage were identified. These were as follows:

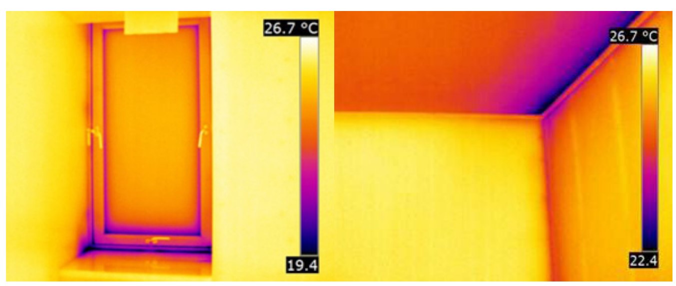
- Under the window sills at the junction between the sill and the plasterboard lining.
- Into electrical sockets on external walls.
- At the top of the closed trickle ventilators – this was the most significant area of air leakage.
- At the exposed ceiling/external wall junction.
- Into the suspended ceiling void in the bathroom.
- At the base of the wash hand basin in the bathroom.
- Through the ventilation gap in the bathroom into the suspended ceiling void.
- Through the ventilation gap in the kitchen/living area into the suspended ceiling void.
- At the external wall/party wall/ground floor junction in the bedroom.

A comparison was also made between the LeedsMet results and those undertaken by the contractor for Building Regulations compliance. This showed that the LeedsMet results were comparable with contractor's values (this is not the case in many studies).

Thermographic survey



Thermal bridge into communal area



Heat loss at base of window (L); Thermal bridge along external wall edge (R)

Infra-red thermographic images were taken on a number of days to examine fabric performance under different weather conditions. The survey revealed the following:

- Thermal bridging was occurring at the junction between floor and external wall.

- The windows were ineffectively sealed, resulting heat loss due to air infiltration.
- Cold air infiltration was observed through closed trickle vents in the windows in the test apartment. These vents were supposed to be permanently sealed by the contractor.
- Heat gains were coming from the communal heating heat exchanger unit, and the uninsulated communal heat main pipework was transferring heat to the hallway and bedroom.
- Heat transfer between apartments was occurring through the uninsulated party floors.
- The concrete frame of the building was acting as a conduit for heat transfer throughout the superstructure.

Real Performance

The table below compares the design targets with the measured values for the fabric tested apartment. Overall the apartment, as constructed, does not perform as well as intended in design.

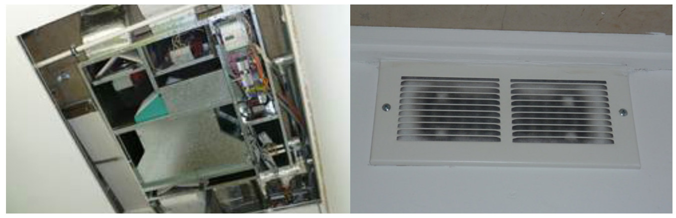
Table 2. Performance Gap

	Predicted	Measured [Leeds Met]
Air permeability	3 $m^3h^{-1}m^{-2}$@ 50Pa [design SAP, 2010]	5.52 $m^3h^{-1}m^{-2}$@ 50Pa
Wall [timber panel section]	0.19 W/m^2K [design SAP]	0.18-0.30 W/m^2K 0.25 W/m^2K [mean]
Wall [concrete column section]	0.21 W/m^2K [design SAP]	0.32-0.66 W/m^2K 0.42 W/m^2K [mean]
Window [kitchen & bedroom, centre-pane]	1.24 W/m^2K [design SAP]	1.33-1.54 W/m^2K 1.41 W/m^2K [mean]

Building Services Evaluation

MVHR

The MVHR installation was examined and measurements taken in the test and adjacent apartments. Based on these observations, the air flow rate measurements, and the limited commissioning information provided, it does not appear that these systems have been commissioned correctly in-situ.



MVHR unit and wall-mounted diffuser with filter

Examination of documentation and of the unit in test apartment revealed the following:

- A commissioning checklist was provided which provided details on fan speed operation and settings, but no information was found which gave the commissioned duct flow rates, either whole house rates or individual room flow rates.
- All of the rectangular, plastic ductwork visible in the ceiling void appears to have been installed correctly. The extract and supply valves have been installed as they are shown on the construction drawings.
- The supply air diffusers incorporate a thin filter which can only be accessed by unscrewing the grille from the wall. The purpose of these filters is not known - the MVHR unit also contains supply and extract filters. A borescopic examination of a small area of supply and extract ductwork showed a significant build-up of particulates on the filter of the supply diffuser to the bedroom and inside of the ductwork. Although the apartment had not been occupied, the MVHR had been left running, and these particulates likely accumulated during construction.
- The supply diffusers in the bedroom and living/kitchen area are located directly above the doors. There is a risk that these rooms will be inadequately ventilated as the type of diffuser used is not capable of supplying air deep into these rooms.
- The extract air grilles (which are the same as fitted for supply air) have been crudely taped onto the end of the rectangular extract ductwork. Access to these grilles is through small hatches in the plasterboard ceiling. However this access provides very little working room, making it difficult to

make any fine adjustments to set air flow rates.

- The main filters within the MVHR unit casing (installed in the bathroom ceiling void) cannot be easily changed or cleaned as they can only be accessed by unscrewing the base plate from the unit. Further, there is also no filter change, maintenance or service indicator light on the unit. Due to the difficult filter access, it is unlikely that the occupants would change the MVHR system filters themselves. However, the maintenance team at CIAC is currently responsible for replacing the MVHR filters on a yearly basis.
- The condensate from the MVHR unit ran upwards, away from the unit, which will likely result in a build-up of condensate within the pipework and possibly within the unit itself.

Duct air flow was measured in the test apartment in October 2012. Supply air measurements showed very low flow rates in both the living/kitchen area and bedroom at fan speeds 2 and 3 (boost) and no measurable flow at all at the trickle fan speed. These readings indicate that the system is not delivering the required flow rates to these individual rooms. Further, due to the way the extract system was constructed with the linear slots and poor access to the grilles in the ceiling void, it was not possible to obtain any extract readings using the flow hood. As no test points exist in the ductwork to undertake duct flow measurements, this suggests that the MVHR unit was not commissioned in-situ.

Additionally, air temperature and velocity were measured on the supply and extract air diffusers in other apartments during the Coheating test. The following was found:

- In dwellings of identical size and configuration, quite different air flow velocity readings were taken.
- The extract air flow readings measured in all apartments tested are greater than the corresponding supply airflow readings - in 2 dwellings by a considerable margin. This suggests that the MVHR units are not balanced, which has implications for heat exchanger efficiency.

Heating System

The communal heating and the apartment space heating and hot water systems were examined. The following was found:

- No commissioning information was provided for the heat exchanger unit within the apartment.
- The majority of the pipework within the test apartment was well insulated, with the exception of missing insulation over isolation valves and at drain-off points.
- Insulation on communal pipework located outside the test apartment was not always continuous, particularly at isolation valves.
- The temperature within the cupboard that houses the heat exchangers was very warm despite the fact that the heat exchanger had been isolated and there was no call for heat.
- Communal corridors were noticeably ‘warm’ on cold days, even though no source of space heating was provided to these areas and the lighting had not been activated.

Occupant Engagement

The information given to occupants when they moved into the properties was evaluated as part of this study, as was the occupant induction.

Occupant Guides

New occupants are given two documents: the ‘Information for New Tenants’ guide, and the ‘Homeowners Manual’. These documents are designed to provide the occupants with information about systems and services both within their home and the CIAC development as a whole.

The ‘Homeowners Manual’ appeared to be hard to use, with too much background information provided on the development, several spelling and grammatical errors, poor quality images, and the location of information often misrepresented in the contents page. Contact details, which were only generic emergency and wellbeing services, were scattered throughout the document, rather than being in one location as indicated by the contents page. Key instructions were highlighted in red boxes, however these were mainly concerned with safety, and when related to energy, health and wellbeing, were often too vague. For example, the manual stated, “By keeping your home at a reasonably even temperature at all times during the drying out period and ensuring it is sufficiently ventilated you should minimise any problems associated with shrinkage and condensation.” Generally, information in this document is laid out in large blocks of text, which could make reading this guide tedious. It is unlikely a resident would engage with this document.

Within ‘The Homeowners Manual’, the ‘Information for New Tenants’ guide was provided on a CD. This guide is mainly composed of user manuals for appliances and services within the dwelling, in addition to providing some contact details and usage guidance for the operation of the home. The guide appears fairly difficult to use as well, with its large size, unattractive presentation and poor quality images. However, when a topic is located, the instructions are often concise and easy to follow.

Occupants were also directed to the CIAC residents’ website, which provides information on the development and allows them to contact the maintenance and management teams, in addition to checking their bills, and receive live updates on CIAC development, amongst other things. The CIAC user website was the most useful handover material examined. The website is appealingly designed and easy to navigate. Occupants have direct access to contact details for maintenance teams, and the community aspect of the development is engendered, with residents able to access a shared notice board to arrange events and discuss community related topics.

Induction

Induction, or occupant handover, is the process by which new occupants are walked around a dwelling, in this case by a member of CIAC sales staff, and introduced to the various systems and appliances. The induction on a new owner/occupier for a single bedroom property was observed during this study.

Induction was found to be thorough, with most aspects of the development not only indicated but explained and demonstrated. This was particularly true of the building services. The occupants were shown all fuses, shut off valves and modes of operation for each system and were encouraged to try everything themselves. Building and system maintenance schedules were all thoroughly discussed, with the exception of the cooker hood extract filter. The occupant was also informed that the trickle vents might blow open in high winds, allowing water ingress, and were informed that the best solution was to seal the vent.

Aftercare was also covered in depth, the building maintenance team mentioned several times, and their contact details and hours of work provided. Occupants were encouraged to consult their handover packs, the resident website and to contact the building manager if they have queries after the handover.

Occupant Perceptions

During the time when the occupant perceptions were being examined, many of the apartments in the development were still unoccupied. Additionally, the majority of occupied apartments were inhabited by temporary overseas workers, who were attending a 6 month training course in the area.   At the time of the BUS survey distribution (discussed below) there were only 9 permanent occupants.

Because of the low occupation and difficulty engaging directly with occupants, the CIAC building manager was interviewed to gather any feedback that they had received. It was found that occupants had complained of:

- Overheating in apartments
- Trickle vents blowing open during periods of high winds, allowing water to enter (advice was given to seal the vents permanently)
- Building access

- The look of the exposed concrete ceilings in the apartments.

Conversely, residents spoke highly of the building aesthetics. Users reported great satisfaction in the design, location and apartment views.

Additionally, initial feedback for the developer suggested overheating was occurring in the communal corridors. The cause of this was identified as poorly insulated communal heating pipework. This was to be addressed, with insulation to be applied to previously uninsulated sections.

It was also discovered that some occupants were concerned their apartment thermostat set-point of 28°C was not actually getting the apartment to that temperature – that they could not heat their apartments to the high set point temperature they desired.

BUS Survey

The BUS questionnaire gauges occupant satisfaction with their dwelling and helps to inform the research team about occupant issues, which can then be cross referenced with measured data to ascertain potential reasons for poor performance.

Of the 57 BUS questionnaires distributed to residents, only 3 were completed and returned – a return rate of 5.3%. This sample size is too small to be considered statistically significant, so responses can only be examined anecdotally, and cannot be considered conclusive.

While most features were found to be good or acceptable, respondents consistently reported that they found the indoor temperature too hot. Remarks included, “No cooling option for the flat. Leaving windows open attracts insects that live around the water.” A reluctance to use windows during hot weather is an issue that may require future resolution if similar complaints are received.

Key Observations

1. Despite a number of attempts to counteract some of these problems which occurred during the Coheating test, it was not possible to derive a reliable heat loss figure for the apartment. However, a number of lessons were learned concerning the application of this test:
    - Testing apartments is inherently problematic and careful consideration needs to be given to any heat loss that may occur through any party elements of the construction and to any unoccupied spaces (such as stairwells, communal areas, etc.).
    - Access may need to be gained to a significant number of adjacent apartments to undertake a Coheating test, which will have implications for the amount of equipment required.
    - Apartments that incorporate a large proportion of South-facing glazing in relation to envelope area are likely to have rooms that are susceptible to overheating if tested either at the beginning or towards the end of the Coheating testing season.
    - The Coheating test, as it stands, is not a 'fit and forget' test. It is imperative that the data obtained from the test is downloaded and analysed on a regular basis so that any testing issues can be identified and appropriate interventions undertaken to minimise the amount of data that is compromised.

    Some of these experiences and lessons have been incorporated into the latest iteration of the Leeds Metropolitan University Whole House Heat Loss (Coheating) testing methodology[1].
2. Although the apartment tested is of average airtightness by UK standards, it is leakier than it should be when an MVHR system is installed.
3. With the exception of the windows, external elements U-values measured in-situ failed to perform close to their design specification. Measurement of the party elements revealed a possible heat loss issue of 'heat stealing', as only acoustic insulation is incorporated in these elements.
4. Some areas of unexpected heat loss were identified during the thermal imaging surveys, most notably at the separating/external wall junction on the West elevation, through the trickle ventilators and through the concrete frame of the building. Thermal imaging also revealed heat gains from the poorly insulated heat exchanger units in the apartments, as well uninsulated communal heating pipework sections.
5. Communal heating systems installed within apartments can make it difficult to isolate the flow of heat to the one apartment only without having an impact on surrounding apartments. The services should be designed so that the heat main can be isolated to individual apartments outside the apartment footprint (in a communal area).
6. Significant issues have been identified with the MVHR system related to its design, layout, the type of air supply and extract diffusers used, and filter access. These issues, coupled with the duct flow measurements (and the inability to some measure flow rates because of the installation), suggest that the MVHR system is not performing as intended and was never commissioned in-situ. As such, it is not possible to determine whether the MVHR system is providing sufficient ventilation to each of the rooms of the study apartment. Initial feedback from the occupants suggests that this is the case, as they perceived there to be stale regions of air within the apartment. In addition, the lack of appropriate ventilation to the apartments, particularly during the summer, is also likely to contribute to overheating within the apartments. Taking into consideration all of the issues identified with the MVHR system, there appears to have been a lack of integration between the conceptual design and installation and commissioning.

1 http://www.leedsmet.ac.uk/as/cebe/projects/iea_annex58/whole_house_heat_loss_test_method(Coheating).pdf

7. The reluctance of residents to use windows to cool apartments should be investigated as it could have overheating consequences. Large, unintentional heat gains will limit the ability of the resident to control their apartment temperature, and the MVHR system does not appear capable of dealing with this issue. To cool the apartment, the resident is often left with opening the windows as their only effective solution – which some appear reluctant to do.
8. The review of the materials and occupant induction process showed the documents given to the occupant were overly long and difficult to engage with - style and layout were found to be lacking. The 'Homeowners Manual' does not appear to be a well-designed or functional document, but could easily be improved with editing and removal of large sections of text, such as the in-depth background about the development. In contrast, the induction was good, with all aspects of the apartment covered in full, but verbal advice did sometimes conflict with written advice. The best aspect of the induction materials is the CIAC homeowner website, which allows residents to check their energy usage, contact the maintenance team, and provides useful information about the development with a news feed.
9. Due to occupation patterns at the time of the survey and a low response rate of 5.3%, the BUS survey was of limited value. However, even with low response rate, occupant feedback suggests overheating to be an issue. This is consistent with the review of apartment services. This may be lessened with the remedial work to super insulate the communal pipework.
10. Interviews with CIAC management and maintenance staff were undertaken to gain insight into occupant perceptions. Based on CIAC staff responses, overall the feedback has been positive from residents.

Key Lessons

1. Errors in the data that is used as input into SAP is not unusual, as was found in this study. A study of input errors in the application of SAP for new dwellings found errors in 56 out of 82 assessments (68%), and that when corrected, about 20% of the dwellings failed to meet the regulatory target emission rate (Trinick, Elliott, Green Shepherd and Orme, 2009). This CIAC study, along with the work undertaken by Trinick et al. (2009), highlights the requirement for much greater control of SAP and the need for a quality control process that will minimise these input errors.
2. SAP should be developed so that it takes into consideration the heat loss through party elements such as floors and ceilings.
3. A number of the construction issues identified could be avoided if appropriate quality control processes were in place to monitor insulation and airtightness measures during construction. These issues have the potential to have a significant adverse effect on the thermal and acoustic performance of the test apartment, and may even result in the degradation of the building fabric due to the formulation of condensation. It would have been beneficial if the CIAC development had adopted a dedicated onsite airtightness and thermal insulation champion.
4. A number of the design intentions were not fulfilled in construction. This may be in part be due to number of key stakeholders involved in the project ceasing trading either during or immediately after completion of the project as a result of the economy. This is likely to have resulted in some of the design information not being passed on from one contractor to another. To avoid the loss of design information in future projects, a method for storing and documenting the design information at key stages of the process should be adopted.

5. In order to minimise air leakage and achieve a level of airtightness appropriate for incorporation of MVHR, it is advised that an airtightness strategy is adopted. This is likely to comprise:
    - A properly designed and properly executed primary air barrier.
    - Adoption of a formal and well-communicated airtightness target (≤ 3 $m^3h^{-1}m^{-2}$@ 50Pa if an MVHR system is to be used).
    - Annotated Design and Construction issue plans and details to include information on airtightness.
    - The inclusion of an airtightness testing strategy into the construction programme that enables dwellings to be pressure tested at different stages of construction.
    - A well-communicated construction strategy and training programme for on-site personnel.
6. The commissioning information that was available varied considerably and there does not appear to be any standardised method of commissioning particular services. The development of a standardised method would be useful and would enable comparability between dwellings. For MVHR systems this should include the following:
    - Supply and extract valve duct flow measurements at boost and trickle operation.
    - A check on the selection and positioning of air valves to ensure that there is adequate cross flow and to minimise the risk of short circuiting of the air flow.
    - A check on the condensate drain to ensure that it is installed correctly.
    - Indicator lights should also be provided on MVHR systems to alert the occupants when the unit requires servicing, to inform them if the unit has malfunctioned and to inform the occupants when the filters need changing.
    - A check to ensure that the filters and the ductwork are free from particulates.

    A number of these suggestions are proposed in the new NHBC Standards chapter for MVHR (see NHBC, 2013).
7. The MVHR testing and borescopic survey revealed a potential issue with particulate accumulation. To avoid the build-up of particulates in MVHR systems the following recommendations should be examined with a look to implementing them in future developments and MVHR maintenance regimes:
    - Measures should be taken during construction to ensure that MVHR systems and ductwork are sealed to minimise the ingress of particulates.
    - Domestic MVHR systems should be re-commissioned on a regular basis, with the filters cleaned/replaced as necessary and ductwork inspected to see that it remains clean and free from particulates.
    - Domestic ductwork for MVHR systems should be tested to determine the amount of duct leakage. This should be repeated on a regular basis, to determine if any deterioration of the leakage of the ductwork has taken place over time.
    - All domestic ductwork for MVHR systems should be designed to enable the ductwork to be cleaned. In some cases this may include the provision of service hatches within the building fabric.

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