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DEVELOPING ENERGY PERFORMANCE STANDARDS FOR UK HOUSING: THE STAMFORD BROOK PROJECT

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Summary

The Stamford Brook Project is a major demonstration of sustainable housing in the UK, involving the construction of over 700 dwellings over a 5 year period. The first phase of the project is being built to a comprehensive Environmental Performance Standard. This has been developed over a period of 2 years by two large house-builders, Redrow Homes and Taylor Woodrow, in collaboration with National Trust and the Leeds Metropolitan University Buildings and Sustainability Group, with support from ODPM and DTI - the departments of state responsible for energy and industrial policy in the UK. A major component of the Environmental Performance Standard is a prototype energy performance standard [1], which was originally designed to achieve reductions in CO_2 emissions from space and water heating of more than 50% compared with 1995 Building Regulations and around 30% compared with 2002 Regulations. Evaluation of this standard is designed to support the on-going review of the Building Regulations requirements for energy performance in new UK dwellings, which in turn forms an important part of the UK's CO_2 reduction strategy, as set out in the White Paper, Our Energy Future [2].

Key features of the Stamford Brook Project are that it has a near-term technical goal and that it is based on load bearing masonry construction. These features were an attempt to maximise the relevance of the project to mainstream UK house-building and to support the process of regulatory development. The second also challenges the received wisdom that high levels of energy and environmental performance require framed construction and/or off site manufacture. Stamford Brook has been designed to demonstrate a challenging but achievable target for mass housing, and to extend, rather than supersede the most common current construction methods.

The project is being undertaken using a Participatory Action Research approach. This makes it possible to evaluate both dwelling performance and impacts on participants in the procurement process. The first batches of dwellings are expected to be completed and occupied early in 2005. Pressurisation and co-heating tests will be undertaken on completion, and energy use, internal temperatures and indoor air quality will be monitored in a sample of 10 of dwellings over the subsequent year. The purpose of this paper is to report on the experience of the design and construction processes, and on initial results of performance monitoring.

1. Introduction to the project

The Stamford Brook Project is a major demonstration of sustainable housing in the UK, involving the construction of 710 dwellings over a 5 year period. The first phase of the project is being built to a comprehensive Environmental Performance Standard. This has been developed over a period of 2 years by two large house-builders, Redrow Homes and Taylor Woodrow, in collaboration with National Trust and the Leeds Metropolitan University Buildings and Sustainability Group, with support from ODPM and DTI - the departments of state responsible for energy and industrial policy in the UK.

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The Design Team wanted to avoid off-site manufactured panels and build a durable, traditional masonry house that was familiar to the mainstream house-building industry. The intention was to invest in airtight, efficient structure that had well-insulated fabric rather than rely on 'add-on bits of kit' such as photovoltaic panels. This came from the desire to build houses that could be built almost anywhere without looking out of place – not bespoke and not regional and so it was imperative that Stamford Brook would not be seen as a one-off project.

Energy standard

A major component of the Environmental Performance Standard is a prototype energy performance standard [1], which was originally designed to achieve reductions in CO_2 emissions from space and water heating of more than 50% compared with 1995 Building Regulations and around 30% compared with 2002 Regulations. The Dwelling Energy Standard was written by the LeedsMet Research Team and has requirements for fabric U values, thermal bridging, airtightness and ventilation provision.

This standard set a demanding energy performance target but one which was seen as being achievable in mainstream house building and could anticipate future building regulatory standards. Since high levels of airtightness were expected, the standard also contains a draft standard Part F (ventilation). The key elements of the dwelling energy standard are shown in Table 1.

Table 1: Key elements of the dwelling energy standard

U value of exposed walls(W/m^2K)	0.25
U value of roofs (W/m^2K)	0.16
U value of floors (W/m^2K)	0.22
U value of windows, outer doors & roof-lights (W/m^2K) (no more than 25% of gross floor area)	1.3
Airtightness target ($m^3/hour/m^2/$ @ 50Pa)	5
Carbon index	8.7
Maximum carbon intensity for space and water heating (kg/GJ)	70

The enhanced standard was originally intended to inform a 2008 revision of Part L and as such, is still in advance of standards proposed for 2005. Nonetheless, the project is proving useful in discussions of the current consultation as there are many similarities in coping with airtightness and thermal bridging requirements and the response to whole-house carbon targets.

Participatory action research

The project is being undertaken using a Participatory Action Research approach. This makes it possible to evaluate both dwelling performance and impacts on participants in the design, construction and occupation processes. The Research Team was actively involved in the design of robust details for the project, using thermal modeling software to minimise heat loss through thermal bridges. Since construction began (in July 2004) the team has maintained a strong site presence, monitoring the problems of moving from design to construction and working with site staff to refine buildability issues. The team is also working with sales staff, external consultants and building control.

A large number of house owners will be invited to provide utility meter data and be interviewed about their experiences of living in a low-energy home. In addition, ten specific houses will be intensively monitored for a twelve month period using wall-mounted sensors to measure energy use (gas, electric, heat meters) and indoor air quality (room temperature, humidity, CO_2, NO_2, etc). The interviews, backed up with the measured data, should provide a comprehensive picture of actual energy use and dwelling performance.

2. Experiences from the Design process

The design team consisted of a core group of representatives from the developers, the National Trust and the Research Team. Several external consultants were also present at many meetings which dealt with issues such as achieving the energy and environmental requirements, cost, buildability and health & safety. The outputs from the design process were: a masterplan, a series of robust construction details, a construction specification, a materials schedule and individual trade specifications.

Design tools

The principal tool used in the development of dwelling designs and assessing compliance with the dwelling energy standard was the ‘Domestic Performance Calculator’. This is a SAP-based excel spreadsheet which has been developed by the Research Team for use on the Stamford Brook project and includes additional formulae to allow input of: thermal bridging into the whole element U value for building elements; window energy rating; and ventilation system performance. A catalogue of construction details designed specifically for the project was also prepared, styled on the existing Robust Details [3] but with the addition of thermal bridging information. 2D thermal modeling software was used to estimate heat loss through junctions of building elements. Together, the calculator and catalogue enabled the Part L application to be submitted and allowed building control to check compliance with the enhanced ‘2008’ standard.

Passive solar shading

From the outset, it was clear that the team wanted to maximise the use of passive thermal elements like fabric rather than achieving low energy use through ‘add-ons’ such as photovoltaics. The team spent a lot of time modelling solar shading and the National Trust’s environmental consultant was instrumental in instigating midwinter sun studies to check layout, mix and density on the site layout. The concept designer initially produced Phase 1 layouts but took little account of passive solar aspects. The first study showed 50% of the properties suffered with significant solar shading but this layout had many three storey houses. A second study showed only 15% over-shading, see Figure 1. This was achieved by: repositioning and reorienting some dwellings; an improved housing mix; a shift from 3 to 2 storey house types; and more houses with lower pitched roofs. It was generally agreed that 15% represented an acceptable compromise position.

Figure 1: Solar shading study (Peter Faucet, JDDK).

For phases 2 and 3, other studies were made in early 2004. Again ground floor window over-shading was calculated for midwinter sun at the latitude of the site (Manchester has a sun angle of 13.50 at noon, midwinter) and the results showed that 72 out of 357 dwellings were over-shaded, i.e., 20%. This was higher than the target agreed after phase 1 of 15% and minor modifications are currently being made to bring the total to under 20% shaded.

Wall and reveal details

A masonry wall construction was designed for use throughout the development and all for house variants. Any later change in wall thickness would have impacted on all construction drawings and possibly affected site layout. The chosen wall construction is 345mm wide, consisting of a brick outer leaf and a medium-density concrete block inner leaf. The 142mm wide cavity is retro fully-filled with mineral fibre. Wall ties between the masonry leaves are glass-reinforced polyester. The slight additional cost of these was traded against the increase in thermal performance as steel ties were thought to contribute up to 10% additional heat loss through point thermal bridging.

Thermal modeling analysis was used to identify thermal bridges in the reveal details and improvements were found using an iterative design process. Significant heat loss was found through a combined steel lintel where the metal base plate conducts heat between the masonry leaves, as shown in Figure 2. A design was then chosen that had two separate lintels.

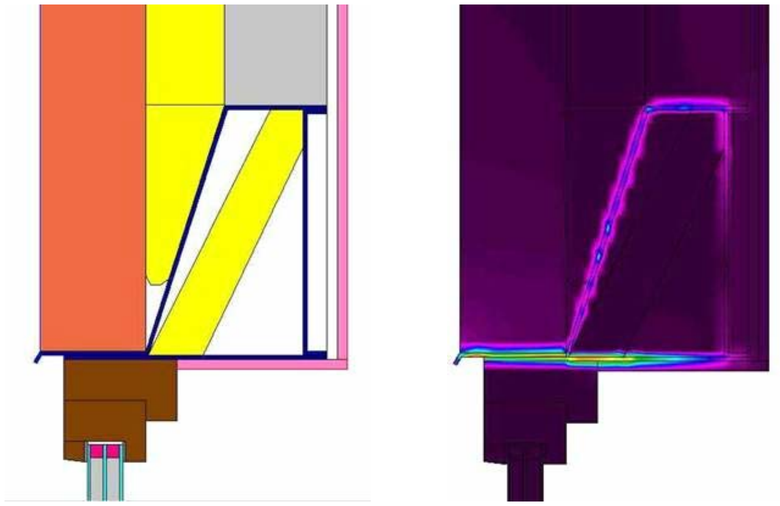

Figure 2: Section through steel combined lintel (left). Heat loss through steel lintel (right)

Early designs tackled the problem of closing the reveal cavity. Plywood reveal closer boards were trialled on a test wall but there were buildability and coursing problems due to the thickness of timber. Insulated window formers were then used. The optimum thermal performance at reveals was found when the window was directly in-line with the insulation layer although this presented fixing and weather sealing problems. A compromise was to setback the frame 75mm from the outer face of the brickwork.

The timber double-glazed windows have low-emissivity coatings, argon fill and warm edge technology, achieving a whole window U value of 1.3 W/m^2K. A study by the Research Team considered this to near the limit of what could be achieved with double glazing.

Airtight masonry layer

The airtightness target was set at 5 m/h @ 50 Pa which was thought to be in line with the thinking in the 2000 consultation document, although, at the start of 2002, it was still uncertain whether the target, when introduced, would be 5 or 10m/h. It was always intended that the first 20 houses from each developer would be exempt from the EPS contract requirement. This would give time for the builders to identify particular leakage areas and modify designs and construction techniques where necessary. The Research Team would be used in an advisory capacity during this trial period, using their blower door and smoke testing facilities.

The Research Team always favoured wet plaster as a durable way of incorporating energy efficiency because of its intrinsic airtightness properties. While the developers acknowledged this idea, they were not comfortable with wet plastering because of extended drying times (compared with dry-lining) and perceived skill shortages. The Research Team did several air pressurisation tests on houses on the developers' other sites to inform the design process. Although the houses tested were leakier than the enhanced standard requirement, smoke visualisation tests helped the design team understand where improvements could be made.

A compromise between wet plaster and dry-lining was then suggested by the developers. This was an extension of 'parging', a thin layer of Soundcoat, a product developed by British Gypsum for use on party walls for acoustic reasons. The idea was to parge the internal face of all external masonry walls to act as the primary air barrier. The parging dries in a matter of hours allowing the dry-lining operation to continue with minimal delay.

A parging trial [3] was done in December 2002 on an existing house on another site before the final decision was taken on wall finishes. The trial house was built to 1995 regulations and, apart from the parging layer, had no additional airtight measures applied other than the usual good workmanship. The parging alone halved the air permeability from around 12 to 6 m/h @ 50 Pa. The overall result on house completion was

4.5 m/h @ 50Pa, slightly within the target. This result gave the team confidence that the contractual requirements of the EPS could be met.

3. Experiences from the construction process

Site training and feedback

A series of site training sessions are being facilitated by the Research Team. Attendees include site management, building control, clerk-of-works, sub-contractor's foremen and tradesmen. Non-construction staff (sales staff and Trust members) have also been involved in order to gain a wider understanding of the problems of translating the design intentions to the construction team. The sessions were similar to the site safety induction in that they occurred as soon as new staff started on site, were classroom-based and attendance certificates were awarded. While the sessions focused on practical methods of achieving airtight construction, they also introduced the environmental objectives and the possibility of informing future revisions of building regulations. This important part of the training was to prime everyone that the research team would conduct regular work-place interviews and photograph construction details. This helped to underline that the Research Team would have a site presence and be available for assistance where necessary but would not have a supervisory of checking role. This allowed a dialogue to develop to discuss buildability issues. In fact, this two-way flow of information is proving to be one of the successes of the project.

Examples where the solving of buildability problems at the workplace has influenced the design is in the coursing of foundation brickwork to reduce thermal bridging and the insertion of Rockwool underneath cavity trays above lintels. In both cases, the input from site operatives led to improved construction details.

Similar training sessions are being held with sales staff at Stamford Brook who are building relationships between the Research Team and the house buyers. From this, house buyers have been identified who are willing to participate in the year long period of intensive dwelling monitoring. The feedback from these sessions is also beginning to shed light on the environmental and energy features of the dwellings that are attractive (or not) from the customer point of view.

Sequencing of work items

It was found that some adjustment to the sequencing of trades was required to achieve the airtight construction methods. As one example, the wall insulation is injected through 25mm diameter holes drilled in the inner leaf of external walls. These holes are then mortar-filled to avoid potential air leakage paths from the inside of the dwelling to the cavity. The parging layer is then applied. In a few cases, the parging was sequenced before the insulation leaving the punctured airtight layer vulnerable to accidental omissions of mortar-fill or failure. Once the dry-lining was fixed there would be no way to remediate this. The developers decided to sequence all future wall insulation before parging to lessen this risk of leakage through drill holes.

Another example was the parging layer behind staircases on external walls. Parging of a complete house is not possible prior to stair fitting due to access problems to upper floors. The developers decided to parge the area behind where the stairs would be. Other work done by the Research Team has identified significant air leakage behind stair stringers, although it is difficult to quantify the difference this area of blockwork makes to overall airtightness. However, the developers took the view that it was worth working slightly out of sequence to seal this area.

A third example is the timing of fixing of upper floor ceilings. Metal stud partitioning was chosen instead of timber studwork. The metal system has several access holes in the head piece which unfortunately allow air to leak from inside the wall to the loft space. One developer trialled plasterboarding the entire upper floor ceiling before fixing the partitions. This made the plasterboard operation easier and provided an air barrier at each partition/ceiling junction. However, the partition erector and the electrician had to work inside the loft space to make their fixings. This was unacceptable in terms of buildability and health and safety. A revised approach is now being used where the metal studding with timber head plates is fixed before plasterboard ceilings.

4. Initial results of performance monitoring

The project is now entering the post-construction, pre-occupation testing phase where the first 20 dwellings completed will be tested for air leakage and thermal bridging, using air pressurisation tests and infra red surveys, respectively. In addition, two dwellings (one from each developer) will have a co-heating test to compare the designed thermal performance against actual. In the co-heating test, the house will be electrically heated above ambient for a two week period and internal and external temperature measurements and energy-use logged. The thermostatically-controlled internal thermal environment will be compared with fluctuations in ambient temperature. This, combined with energy use, will enable actual heat loss to be calculated. As the fabric temperature of the dwellings needs time to stabilize, measurements from the second week will be used.

Air pressure test results

At the time of writing (February 2005) the first dwellings are almost ready for occupation and the first three pressurisation tests have been done. The two houses tested achieved an air permeability of 3.3 and 2.0 m/h @ 50 Pa. The first apartment tested achieved 1.75 m/h @ 50Pa. This remarkable level of airtightness is comfortably within the 5m/h target for the project and substantially better than the average of 13 m/h @ 50 Pa inferred by the BRE report [4]. At this level of performance, it could be argued, that a target of 10 or even 7 m/h @ 50 Pa would seem a reasonable regulatory requirement for the proposed 2005 revision of Part L. Some project members were initially worried that the airtightness target would be difficult to achieve. However, these concerns were quickly assuaged, judging by sample comments from construction team members present at the tests which included: "…this was actually quite easy to achieve…", "…all we have really done is build as we are supposed to…". These initial results have given the construction team confidence that the target will be comfortably met in all 710 dwellings, provided that levels of site supervision are maintained and the site training is continued with sub-contractors and operatives starting work on site.

5. Conclusions

1) 710 dwellings at Stamford Brook are being constructed to an Environmental Performance Standard that exceeds the standard proposed in the 2005 consultation. The design team has designed a set of fabric elements that meet elemental U values and a set of robust construction details that meet the thermal bridging requirements.

2) Air permeabilities of the first dwellings constructed have measured between 1.75 and 3.3 m/h @ 50Pa which is well with the project target of 5 m/h and substantially better than the 10 m/h currently proposed in the 2005 Part L consultation. This level of airtightness has been achieved in masonry dwellings using a slightly modified dry-lining internal finishing.

3) A two-way site training programme has been developed which explains the environmental and energy requirements to site staff and encourages feedback from the construction process to improve performance, cost and buildability. This programme, together with the documentation from the design process (robust details, construction specification, etc) should enable other developers on other sites to achieve the same levels of airtightness and thermal performance in dwellings.

Acknowledgements

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Peter Fauset, JDDK.

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