EVALUATING THE IMPACT OF AN ENHANCED ENERGY PERFORMANCE STANDARD ON LOAD-BEARING MASONRY DOMESTIC CONSTRUCTION

Partners in Innovation CI 39/3/663

Interim Report Number 2 – Design Process

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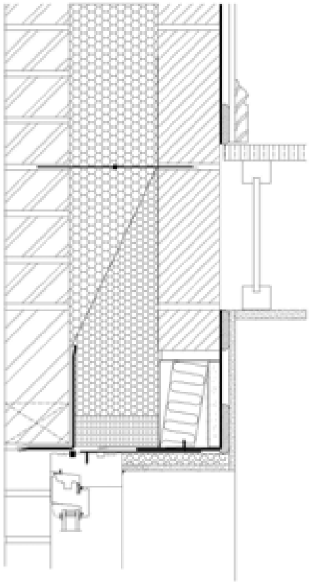
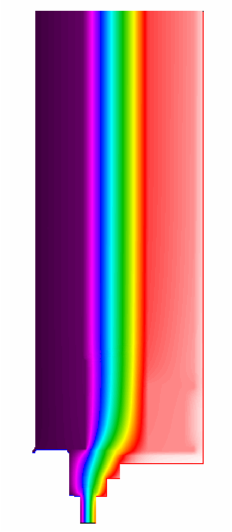
April 2004





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Executive summary

1 This interim report deals with the progress so far in the Stamford Brook project, from land acquisition, scheme inception, drafting of the environmental and energy standards, design team assembly, site layout, dwelling design and confirmation of compliance with the standard. At the time of writing (April 2004), all major design decisions have been taken and construction of the first houses is planned to start in June 2004. The design team is currently instructing the construction departments to the requirements, addressing buildability issues and setting up site staff training programmes.

2 The Dwelling Energy Standard was written by the LeedsMet research team and has requirements for fabric U values, thermal bridging, airtightness and ventilation provision. These requirements are in excess of those in ADL2002 and are intended primarily to ensure significantly lower carbon dioxide emissions from new dwellings. This standard was assimilated into the Trust's wider Environmental Performance Standard which includes additional requirements for increased use of environmentally friendly materials and reductions in domestic water use and construction waste.

3 A substantial part of the report deals with the detail design of the fabric. The research team used computer thermal modelling to simulate thermal performance through building elements and junctions and fed that information back to the design team. Through this iterative process, a set of construction details was designed that had minimal thermal bridging. Noteworthy design decisions include high performance double glazed timber windows with a whole U value of 1.3 W/m^2K, the use of plastic wall ties between the masonry leaves to minimise point thermal bridging and a the use of a parging layer on the blockwork internal surface on external walls. The parging provides the airtight layer allowing plasterboard on dabs to be used as normal. A test wall was built to assuage any buildability concerns of using plastic ties, a 142mm wide fully-filled cavity and thermally broken reveal details using separate lintels and thermal cavity closers. Another section deals with the detail design of heating and ventilation systems.

4 Deliverable 4 will report on budget and actual costs later in 2004. In the meantime, two tentative illustrations are given here which show how the budget cost has changed through iterations of the design process. The two examples given show a large drop in budget cost from initial estimates.

5 Trafford Building Control has agreed to work to the Dwelling Energy Standard in lieu of the current legislation. This will allow the research team to conduct an exercise that will involve informing and training building control officers and monitoring their compliance checking both at design stage and on site. This will be followed by a debriefing seminar that will capture their experiences and opinions. Early indications are that Trafford find the standard easy to understand and straightforward to use.

6 As the dwelling design is now largely complete, the design team are now looking towards the construction process and have formalised the design decisions into one Construction Specification that will be used by the site teams. From this, individual trade specifications are currently being drafted and these will help to form the basis of the site workforce training necessary to achieve the energy standard in practice. A pre-selection seminar was held to inform potential sub-contractors of the extra requirements of the EPS and to outline the free training, and other benefits, of being involved in the project.

7 A series of appendices are also included which support the main report. Appendix 1 shows the Dwelling Energy Standard. This, together with the second appendix, the Draft Proposed Thermal Bridging Details, forms the basic documentation in the building regulation application and proof of compliance process. Working drawings for each construction detail are included in Appendix 3. Several working papers were written to inform the design process and are included as Appendices 4 to 8. Areas covered here include lintel choice, setback of window frame, parging as an airtight masonry layer and performance of double glazed timber windows. Appendix 8 is the interview questionnaire that was used to capture the opinions of the design team before, and during, the dwelling design process. Finally, Appendix 9 is the Construction Specification written by the developers and other members of the design team which is being used as the project is now entering the construction phase.

8 The preliminary signs from the design process are that the dwellings appear to meet the requirements of the Dwelling Energy Standard (in theory at least). Although it is too early to say if the airtightness target will be achieved easily and consistently throughout the construction period,

the developers are optimistic about meeting this requirement and are determined to make best use of site staff training and site supervision to this end.

The design process: Developing the solution

Introduction

9 The origins of this project lie in a desire on behalf of the National Trust to take a proactive role in the long term development of sustainable housing schemes. In 1998, the need to sell surplus land on the Dunham Massey estate in Cheshire provided them with an opportunity to develop their ideas further. Although the Trust were concerned to raise enough capital from the sale to secure the future of the Dunham Massey Estate they also saw that by forgoing some land value they could persuade two large private sector housing developers to build to much higher standards of environmental sustainability than hitherto. The Vision was for a 710 dwelling development at Stamford Brook that not only took a significant step forward in terms of sustainable energy use, reduced CO_2 emissions and minimisation of overall environmental impact but did so in such a way that the scheme was capable of being replicated in mainstream housing development. In order to do this it was crucial that the developers were fully engaged from the outset and that the standards adopted were sufficiently in advance of current levels to make a significant improvement but not so far in advance of current practices as to label the scheme as too futuristic and, therefore not attainable by the house building industry in general. It was anticipated also that the results of the work would provide the evidence needed to enable the development, within the next 5 years, of higher housing performance standards through building regulations and planning control.

Dwelling performance standard

10 Around the same time that the Trust was developing its Vision for Stamford Brook, the research team at Leeds Metropolitan University was working on a project at St Nicholas Court in York (Lowe, Bell & Roberts 2003). This research project was a trial of proposed prototype performance standards for Parts L and F of the building regulations (Lowe Bell 1998, see Appendix 1). The houses at York were timber frame and it was felt that similar research into load-bearing masonry would be a very useful companion project. Discussion between the Trust and LeedsMet resulted in the adoption of the dwelling energy standard used at St Nicholas Court. The Trust up to that time were not precisely sure what an energy standard might look like and their thoughts were crystallised when they saw the dwelling energy standard written by the research team at LeedsMet. This standard fulfilled the Trust's broad requirements in that it 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. 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^{2}K)	0.25
U value of roofs (W/m^{2}K)	0.16
U value of floors (W/m^{2}K)	0.22
U value of windows, outer doors & roof-lights (W/m^{2}K) (no more than 25% of gross floor area)	1.3
Airtightness target (5m^3/hour/m^2/ @ 50Pa)	5
Carbon index	8.7
Maximum carbon intensity for space and water heating (kg/GJ)	70

11 Partners in Innovation (PII) funding was obtained for the research, the objective being to contribute to the development of building regulation. As such, the PII project objectives relate to the dwelling design only and, although the wider environmental objectives of the Trust provide the context to

design decisions, this report focuses on the design process as applied to the house types and housing layout.

Environmental Performance Standard (EPS)

12 The Trust's Vision and the research team's dwelling energy standard were written into an Environmental Performance Standard (EPS) in June 2001. This document was then used as the energy and environmental standard for Stamford Brook. The EPS had four main areas:

a) Minimisation of energy use and greenhouse gas emissions. This is the area covered by the dwelling energy standard written by the research team and the main area of interest in this report.

b) Minimisation of water use. Houses are to include low flush toilets, aerated low pressure taps, A-rated appliances, water metering and rainwater butts in gardens.

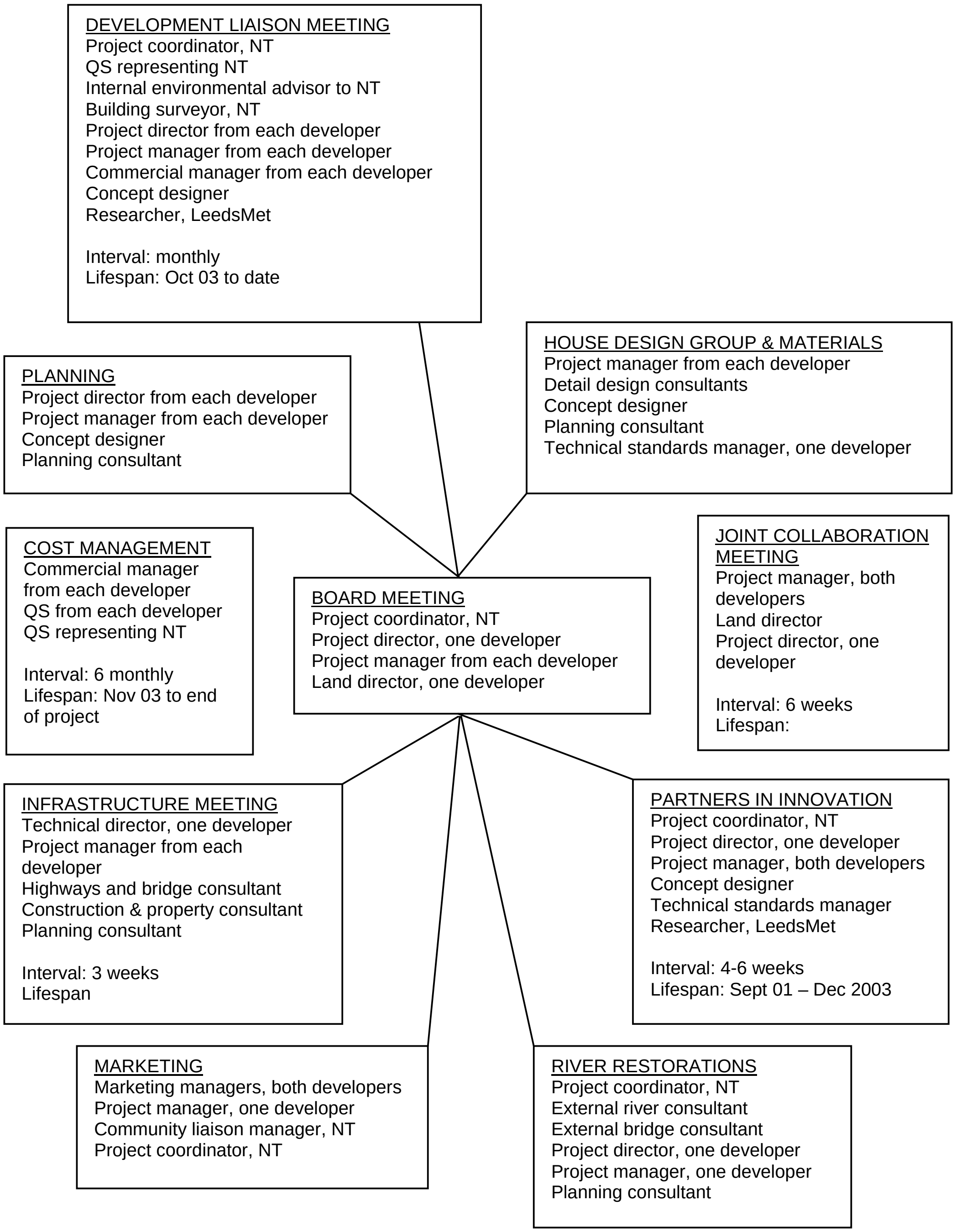
c) Minimisation of waste. Provision is to be made for compost bins, recycling boxes and a strategy for recycling household waste.

d) General environmental standards. This section specified the use of materials with a high recycled content, materials from local sources, materials with low embodied energy, low VOCs and zero ozone depletion potential. Waste on site is to be minimised during construction. House design is to optimise living space, an example being room-in-the roof houses. Durable materials and materials which can be reclaimed at the end of the building's life are to be used wherever possible.

Design team assembly

13 The Trust entered negotiations with two developers who between them held key access land to the site. Both were keen to be involved although they had reservations as to the commercial viability of the standards to be achieved. The LeedsMet research team first attended technical design meetings with the developers and the Trust in September 2001. At that time the developers were not contractually bound and project directors from each developer were involved in the design discussions which were general rather than specific. Technical meetings were held over a two year period which involved the research team, project directors and technical manager from the developers, the Trust and their internal and external environmental advisors. Input was made from the ventilation system supplier as early as January 2002.

14 The design team grew steadily in size and included external consultant advisors to the Trust, a concept designer, details designers working for each of the developers on bespoke house types, the Trust's QS and several external consultants. It became clear that the project needed to organise itself into dedicated workgroups to iron out design and cost issues and deal with the areas not covered by this report such as the river restoration. A technical working group was established which included technical people from the development team and the research team. A similar group was set up to look at costs. New team members were added as the design process progressed and expertise was required in other areas such as construction and sales. Many of the other sub-groups, such as River Restoration and Infrastructure, for example, were not relevant to the PII project and are not discussed in this report. The research group were not part of other sub-groups, such as Materials, although some decisions made in those groups were referred across groups. Once the design meetings were progressing (mid 2003) it became apparent that the wide range of environmental and thermal performance issues required co-ordination and a monthly Development Liaison meeting was held to bring together all the issues discussed in the sub-groups (see Figure 1). Each month in the Liaison Meeting, a list of all the EPS items was used as a checklist and progress in design and costing was reported to the meeting. The Liaison meeting was designed to make quick decisions possible on materials and building techniques.



DEVELOPMENT LIAISON MEETING
Project coordinator, NT
QS representing NT
Internal environmental advisor to NT
Building surveyor, NT
Project director from each developer
Project manager from each developer
Commercial manager from each developer
Concept designer
Researcher, LeedsMet

Interval: monthly
Lifespan: Oct 03 to date

PLANNING
Project director from each developer
Project manager from each developer
Concept designer
Planning consultant

HOUSE DESIGN GROUP & MATERIALS
Project manager from each developer
Detail design consultants
Concept designer
Planning consultant
Technical standards manager, one developer

COST MANAGEMENT
Commercial manager from each developer
QS from each developer
QS representing NT

Interval: 6 monthly
Lifespan: Nov 03 to end of project

BOARD MEETING
Project coordinator, NT
Project director, one developer
Project manager from each developer
Land director, one developer

JOINT COLLABORATION MEETING
Project manager, both developers
Land director
Project director, one developer

Interval: 6 weeks
Lifespan:

INFRASTRUCTURE MEETING
Technical director, one developer
Project manager from each developer
Highways and bridge consultant
Construction & property consultant
Planning consultant

Interval: 3 weeks
Lifespan

PARTNERS IN INNOVATION
Project coordinator, NT
Project director, one developer
Project manager, both developers
Concept designer
Technical standards manager
Researcher, LeedsMet

Interval: 4-6 weeks
Lifespan: Sept 01 – Dec 2003

MARKETING
Marketing managers, both developers
Project manager, one developer
Community liaison manager, NT
Project coordinator, NT

RIVER RESTORATIONS
Project coordinator, NT
External river consultant
External bridge consultant
Project director, one developer
Project manager, one developer
Planning consultant

Figure 1: Organisation structure.

Scheme design process

Site layout

15 The Trust wanted a high density development to optimise the amount of open space to give people access to light and air. They wanted a 'green' open space type development instead of a typical suburban 'sprawl'. It was important for the land to survive as land and not be completely full of bricks and mortar. The site layout centred on the river restoration, sustainable urban drainage, community woodland and open space. The two access roads, the main one from the east and the one from the south which crosses the railway line, dictated the direction of the spine road. The houses were provisionally placed in the spaces remaining, arranged in parcels of about 25 houses each. The intention was to optimise solar gain for each dwelling and a study of passive solar shading was made.

Passive solar shading

16 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 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. 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, see Figure 2.

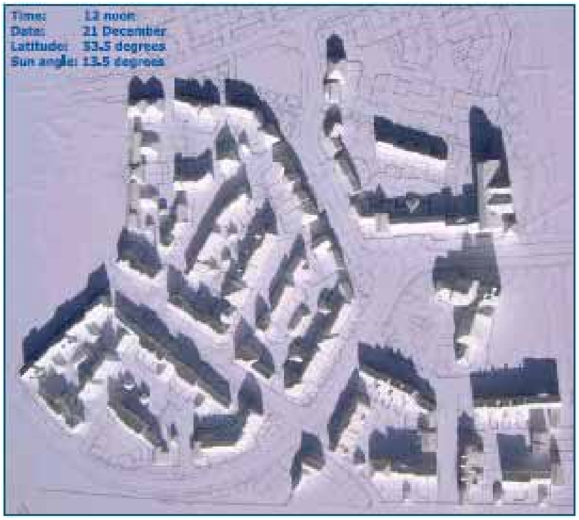


Figure 2: Solar shading study.

17 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 13.5^0 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.

Environmental objectives

18 Apart from the dwelling energy standard, many of the environmental objectives set out in the EPS did not impact the detail design of the dwellings. Requirements for water minimisation, use of

certified sustainable timber were met by the QS and purchasing departments of the developers. The EPS preferred local skills and materials wherever possible. However, as is discussed later, the exacting nature of the dwelling energy standard meant that several building components could only be sourced from non-UK-based suppliers. For some other components, non-PVC alternatives were not available.

19 Room-in-the roof lofts were desirable as they would allow utilisation of the loft space, reduce wall heights and provide a different type of space in the house. The Trust wanted a durable house and thought that wet plaster was the most durable way of incorporating energy efficiency. The Vision was not to invest in ‘add-on bits of kit’, they wanted to invest in a really efficient structure that had well-insulated fabric. A wider part of the Vision was 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.

Building regulations submission

Assessment of compliance

20 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 St. Nicholas court project. The calculator 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 was also prepared that contained the thermal bridging data, see Appendix 2. The style of the catalogue was based on the existing Robust Details (DTLR 2001) but with the addition of thermal bridging information.

21 The compliance method choice of the developers was always target U value as they were most familiar with it. With the dwelling energy standard, there is an additional requirement to meet the carbon intensity of heating before the target method can be used but this was comfortably met by using a 91% efficient gas boiler. The compliance method preferred by the research team was carbon index as it gives a truer picture of overall dwelling performance than target U value and gives allowance to low carbon technologies. The domestic performance calculator gives both carbon rating and target U value as outputs so, effectively, the houses had two possible routes to compliance. The research team hoped that the developers would come to appreciate the benefits of the carbon index method. However, it soon became apparent that there were inconsistencies in the two compliance routes. The carbon index is sensitive to house form and the mid-terraced variant performs better than its corresponding detached variant of the same house type. The initial carbon rating target before the design process began was 9.1. The design process shed light on the inconsistencies between the two compliance methods so, to make the two more equitable, the carbon index requirement was relaxed to 8.7. During the work reported here, the research team did not fully appreciate the nature of these structural problems and attempted to deal with them in an ad hoc way. However, an attempt to deal with these issues more comprehensively and thoroughly has since been made as part of the review work on Part L which is currently under weigh for the 2005 revision.

22 The developers hoped that the research team would complete SAP sheets and carbon ratings for all their house types but the research team felt it was important for the developers to do their own submissions. This way, the dwelling energy standard could be assessed for workability and ease of use. The research team did agree to do several house types that were intuitively thought to be 'worst-case' types just to be sure that the designed construction details were suitable for a wide range of types. Early indications were the 'worst-performing' house types appeared to comply and some house types complied by a substantial margin.

23 The use of external consultants was proposed for the preparation of the energy performance submission on behalf of the developers. Two consultants were approached, one for each developer. The research team had meetings with them and tried to present as much information as the consultants would expect to have if the regulations had actually changed and dwelling energy standard was the actual standard. This information would normally be available to the industry through channels such as training courses, written documentation, advice from suppliers and builders merchants and knowledge acquired through peers. These meetings and discussions began in October 2003. Eventually, both developers decided to use the same consultant. As the research team was very interested in finding out reaction to the submission process and the dwelling energy standard proposals for 2008 regulations and the draft 2008 Thermal Bridging Details, two consultants could have provided a richer source of data. At the time of writing (April 2004), initial feedback from the energy consultant is that more and more builders are increasingly using external consultants and therefore any future increase in the complexity of thermal calculations is unlikely to be a major obstacle to implementation. The consultant commented that his initial reaction to the dwelling energy standard and proposed thermal bridging details for 2008 were straightforward and easy to understand and use.

24 It is planned to carry out an evaluation of the entire building regulation submission and approval process in a similar way to the St Nicholas Court project and present the results in a future report. This will include briefings with Building Control to familiarise them with the details of the dwelling

energy standard, workshops to find out any difficulties encountered and, finally, workshops to enable feedback and opinions from the building control officers. At the time of writing, submission to building control is imminent. Trafford Building Control have agreed to use the dwelling energy standard in lieu of current regulation as a proof of compliance as this standard subsumes the requirement of ADL2002 in every respect. Preparatory meetings beginning in December 2003 have enabled Trafford to understand the objectives of the EPS. The main tools for compliance with the dwelling energy standard were the standard itself, the Domestic Performance Calculator and the proposed draft thermal bridging details for 2008. Building Control's first impression was that the documentation and tools were straightforward.

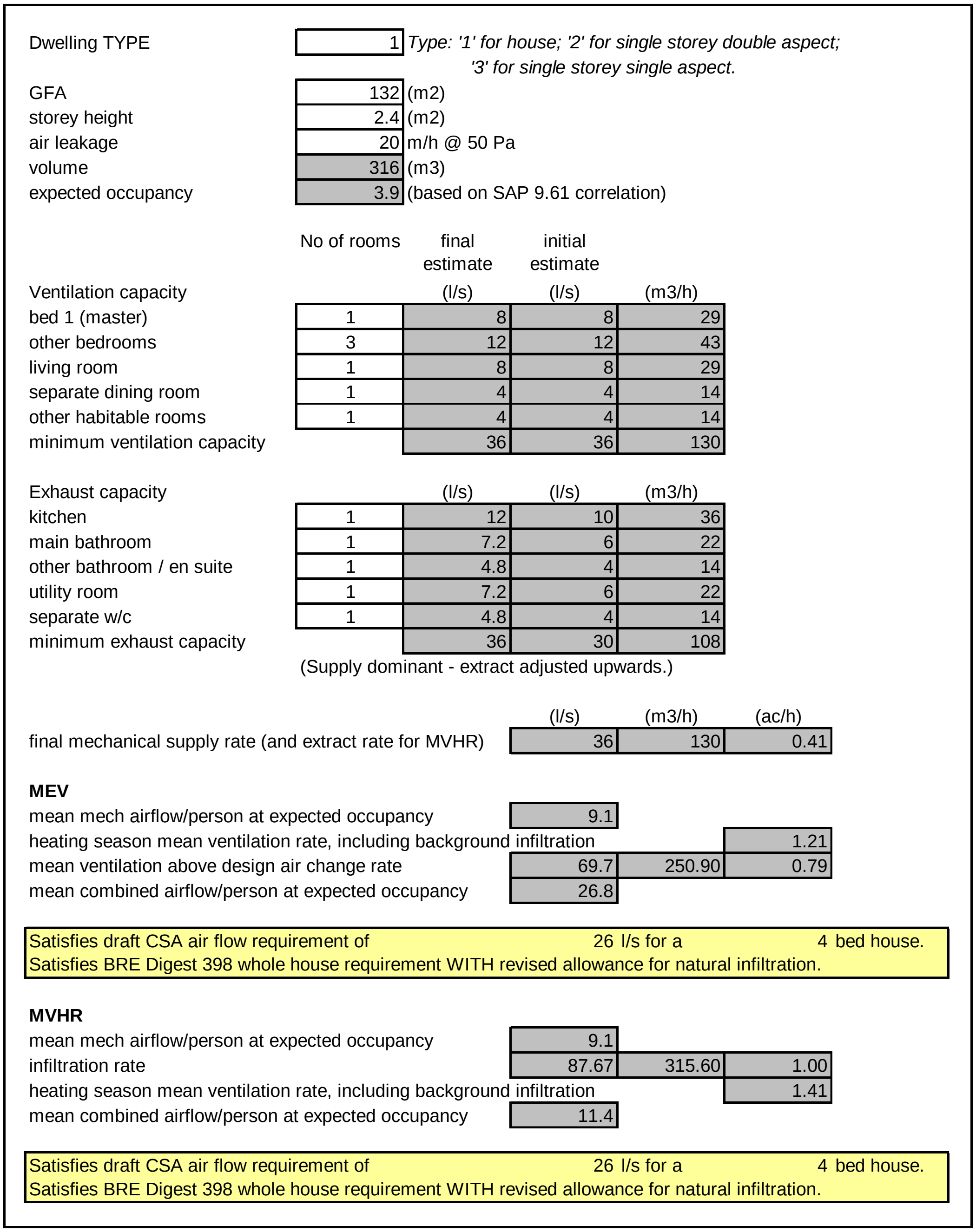
Airtightness compliance

25 The airtightness target was set at 5 $m^3/h/m^2$ @ 50 Pa which 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.

26 Airtightness was discussed at several design meetings but really only in an abstract way. The research team undertook a small number of air pressure tests on existing properties at other, existing, sites in order for the team to understand the scale of achieving 5 $m^3/h/m^2$ @ 50 Pa. These houses were built to ADL95 and without particular attention to airtightness. The details designer was present at these tests and took the opportunity to examine leaks using smoke generators to identify likely leakage points. Discussions and meetings following the tests led to the drafting of a list of a number of areas where airtightness measures could be implemented in addition to the airtight layer (the parging or the wet plaster, discussed in more detail in the 'Internal finish' section). The tests revealed airtightness levels of between 8 and 10 $m^3/h/m^2$ @ 50 Pa compared with a national average of 11.5 $m^3/h/m^2$ @ 50 Pa for this age of housing stock (Stephen 2000). This gave some reassurance that existing construction methods seemed to produce houses as good as, if not better than, the national average, but some design team members were worried that achieving 5 $m^3/h/m^2$ @ 50 Pa would be difficult.

Part F compliance

27 The research team prepared a spreadsheet to simplify the proof of compliance with part F, see Figure 3. The development of this tool was an iterative process working with the design team member from Baxi Air Management. The Canadian standards were very influential in the design of the spreadsheet and the output section additionally shows if CSA is achieved. As well as the EPS requirement, the spreadsheet also shows if BRE398 standard is achieved, for reference. The obvious (but initially) overlooked fact that houses tend to have only one kitchen regardless of house size affected the choice of flow rates through individual rooms. It is hoped that the spreadsheet will overcome some of the difficulties with BRE398 which is building dependant – BRE 398 can under-ventilate large properties and over-ventilate smaller ones.



Ventilation standard for Stamford Brook

Robert Lowe, David Roberts **February 2004**

Dwelling TYPE	1	*Type: '1' for house; '2' for single storey double aspect;* *'3' for single storey single aspect.*
GFA	132	(m2)
storey height	2.4	(m2)
air leakage	20	m/h @ 50 Pa
volume	316	(m3)
expected occupancy	3.9	(based on SAP 9.61 correlation)

	No of rooms	final estimate	initial estimate	
Ventilation capacity		(l/s)	(l/s)	(m3/h)
bed 1 (master)	1	8	8	29
other bedrooms	3	12	12	43
living room	1	8	8	29
separate dining room	1	4	4	14
other habitable rooms	1	4	4	14
minimum ventilation capacity		36	36	130

Exhaust capacity		(l/s)	(l/s)	(m3/h)
kitchen	1	12	10	36
main bathroom	1	7.2	6	22
other bathroom / en suite	1	4.8	4	14
utility room	1	7.2	6	22
separate w/c	1	4.8	4	14
minimum exhaust capacity		36	30	108

(Supply dominant - extract adjusted upwards.)

	(l/s)	(m3/h)	(ac/h)
final mechanical supply rate (and extract rate for MVHR)	36	130	0.41

MEV

mean mech airflow/person at expected occupancy	9.1		
heating season mean ventilation rate, including background infiltration			1.21
mean ventilation above design air change rate	69.7	250.90	0.79
mean combined airflow/person at expected occupancy	26.8		

Satisfies draft CSA air flow requirement of 26 l/s for a 4 bed house.
Satisfies BRE Digest 398 whole house requirement WITH revised allowance for natural infiltration.

MVHR

mean mech airflow/person at expected occupancy	9.1		
infiltration rate	87.67	315.60	1.00
heating season mean ventilation rate, including background infiltration			1.41
mean combined airflow/person at expected occupancy	11.4		

Satisfies draft CSA air flow requirement of 26 l/s for a 4 bed house.
Satisfies BRE Digest 398 whole house requirement WITH revised allowance for natural infiltration.

Figure 3: Part F compliance spreadsheet.

Eco Homes

28 Although not part of the building regulation submission itself, the introduction of an Eco Homes assessment running parallel with the other methods of compliance with the EPS is worth mentioning here as the achievement of Eco Homes credits did begin to affect design decisions. Initially, as stated, the EPS developed from the Trust's Vision and although the design team had an awareness of other environmental assessment schemes, the EPS was written, to all intents and purposes, in isolation from Eco Homes. As the design progressed, however, Eco Homes was

increasingly suggested as a nationally recognised standard that the Stamford Brook project might seek to attain in addition to the EPS. It was tacitly assumed that the standards set by the Trust would probably equate to an excellent Eco Homes rating. An approved Eco Homes assessor did a preliminary rating exercise and it was discovered that Stamford Brook did not score as highly as first hoped. The reasons for this were due to slight mismatches between the two standards and the different weightings afforded to environmental items. By this time, it had been agreed that achieving Eco Homes was desirable and that anything less than an excellent rating would not be acceptable.

29 Eco Homes became a driver in the design process but only after much of that process had been completed. Some design areas which did not initially score highly under Eco Homes were revisited and modified slightly to gain extra credit. One example was in sound insulation. Confidence in the noise reduction measures in the dwellings led the team to opt for additional sound tests to be made. Although the tests have cost implications, it was felt desirable to try and obtain the extra Eco Homes points available.

30 Discussion of various items in the specification led the team to believe that there are some expensive items in Eco Homes that seem to have little improvement in environmental impact. The Stamford Brook project might be in a position to feed back to Eco Homes some of its own environmental assessments and assist in a future revision in some areas. One such are might be I-beams. Discussion in this area will continue through the construction stage.

Detail design of fabric

31 The research team was involved early on in was the design of the construction details to be used at Stamford Brook. The details were initially loosely based on the developer's existing details and Part L 2002 Robust Details but based around a wider wall cavity. However, some details underwent several rounds of revision and eventually bore little resemblance to the existing details. The design of the details and the reasoning behind the decisions is discussed later in the report and diagrams of the details are shown in Appendix 3.

32 The research team used thermal modelling software to predict thermal performance of the building elements and junctions. The software was provided by Therm (LBNL 2004). Therm was used to calculate psi values through junctions. A psi value is the amount of thermal bridging per metre of junction. The psi values were added into the nominal elemental U value to give whole element U values. U values calculated on this basis give a more accurate representation of building thermal performance and are more difficult to achieve than those calculated according to procedures laid out in the current Part L Approved Document. Crudely, a wall with a U value of 0.25 W/m^2K calculated according to the dwelling energy standard requires 10-15% more thermal insulation than one calculated according to ADL02. The precise amount depends on the care taken to reduce thermal bridging, both within the wall, and at junctions between it and other elements of the building thermal envelope.

Wall design

33 One of the very first details for the team to get right, beginning around September 2001, was the choice of wall thickness as changing it late in the design process would have a large impact on cost. All drawings would have to be redone and site layout could be affected. It was felt that widening the cavity to accommodate greater levels of insulation would be an important factor in site layout as greater cavity width would lead to greater land use and a reduction in the number of dwellings that can be accommodated on the site. Initial estimates of dwelling loss were in the region of 4 or 5 houses per 100, losses that the developers thought they could not afford to bear This issue later raised concerns in the research team that not enough margin for error was being designed in. Some house types do not perform as well as others. The external wall, for example is a large part of the external envelope in a detached (60% in a 10×5m ×2 storey 100m^2 floor area) but a smaller part of the envelope of a mid terrace. Mid-terraces with poor U values will perform better than the detached variant of the same house type. Ultimately this means the team might have to accept a house design which does not conform to the EPS simply because there is not enough time to change it before construction begins.

34 To ensure a better agreement between nominal and 'actual' U values, the dwelling energy standard requires a whole element U value be calculated for each building element. The whole element U value of an element is the sum of the nominal U value plus all the thermal bridging heat losses through junctions between that element and other elements. Each time the detail designer amended the details, the research team made thermal simulations of those details and amended the whole element U value and fed back that information. The designer was then in a position to assess the changes. This iterative nature of the design was therefore necessary because, until the cavity width had been fixed, it was unknown how much thermal bridging heat loss there would be and therefore what the whole element U value would be. The iterative nature of the wall design impinged on window performance, ground floor design and, to a lesser extent, roof design. Initially, the developers expected cavity widths of below 100mm and could not envisage widths up to 150mm. The final cavity width was 142mm. This level of iteration was exceptional. If a requirement based on whole element U values were to find its way into an ADL, there would be a variety of mechanisms for ensuring such levels of iteration were not required in practice. The design iterations also included an element of cost assessment, although cost differences were thought to be minimal and some examples are given in the 'Costs' section.

35 Estimates of additional thermal bridging heat loss through building element junctions at this stage were thought to be around 13%. This meant that the nominal U value had to have 13% additional 'headroom' to allow for the thermal bridging to be included into the whole element U value. As an

example, to achieve a whole element U value of 0.25 W/m^{2}K, a nominal U value of 0.22 W/m^{2}K would be required.

36 By December 2001, a preliminary list of specifications had been drawn up. At this stage, two wall constructions were thought necessary, one for wet plaster and one for dry-lining. It was believed that wet plaster would not adhere well to aircrete blocks and so medium density concrete blocks (1350-1500 kg/m^3) were chosen to take wet plaster, with a cavity width of 142mm. In the case of dwellings, a thin joint aircrete blockwork option was considered since the better thermal performance meant that a narrower cavity could be used (107mm). This approach, however, was rejected on grounds of buildability and the quality management problems that would arise from two different wall specifications

37 Checks were made by the research team for driving rain exposure very early in the project. This meant that the design team could choose fully filled cavities to maximise the thermal benefit. The site falls within a sheltered to moderate exposure category[*].

Wall insulation

38 The type of wall insulation was considered very early in the project with a fully filled cavity using mineral fibre decided almost from the outset. Cavity batts were discussed at very early meetings but the developers' preferred method of cavity wall insulation was retro-blown mineral fibre. The developers' view was, based on past experience, that retro filling would be less prone to workmanship problems. Batts were thought to allow mortar droppings to build up during bricklaying and bridge the cavity allowing water ingress and thermal bridging. A demonstration at one of the meetings showed that batts absorb irregularities in wall tie spacing and angle without creating voids. This was contrary to the developers' anecdotal experience. Retro-blown fill was, however, still preferred even though the thermal performance is not as good as batts (retro blown mineral fibre insulation, λ = 0.039 W/mK, batts λ = 0.036 W/mK).

39 Concerns about the method of installing the retro fill were discussed. Normally, the installer drills holes in the block work leaf of the external walls and inserts a filling nozzle. The holes are 25mm diameter and spaced to allow the insulation to fill the entire void. These drill-holes, if not properly filled, could provide many air leakage paths from inside the dwelling to the cavity. Once dry-lining was fixed, there would be no way to check or remediate the holes. Wet plaster would, however, provide an effective method of providing an airtight layer under these circumstances. If the holes were drilled from outside, as is common in some refurbishment work, the holes would not be an airtightness problem as they would be on the other side of the airtight layer but this is not acceptable in new build on aesthetic grounds. At the time of writing, negotiations are under way with the insulation installer to ensure that drill holes are fully filled with mortar after injection.

40 A problem of insulating around the cavity tray above a window head was identified. Suggested solutions included installing pre-shaped batts under the tray at time of construction. Post-construction testing by the research team could check the effectiveness of this approach.

Wall ties

41 The type of wall tie and the material to be used (steel or plastic) was a key issue during the early phase of the project. The contractors were very familiar with the use of steel wall ties and because of the wider cavity, initially sought to use a heavy gauge steel tie. However, concerns were expressed about the extent of the point thermal bridging that would result from this proposal. This concern was instrumental in instigating the investigation of the use of plastic ties.

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[*] Driving rain is expected to increase over the next 50-100 years and indices might change by adding 1 to existing values and the wall design took account of this. An interesting area of further research that emerged was that, although wider cavities are known to help reduce problems with driving rain, climate change could increase the severity of driving rain due to stronger rainfall or wind.

42 The research team distributed to the design team details of a Danish wall tie manufacturer in August 2002. Since then, the team has been unable to find a suitable UK manufacturer for plastic wall ties. It was hoped to use the scale of Stamford Brook to encourage the industry to supply products that were needed. Interestingly, for the wider cavity, it was found that plastic wall ties were cheaper than their stainless steel equivalents. However, the developers were naturally concerned that they were relying on one manufacturer for an essential building component - and a company based outside the UK at that. In November 2002 the use of stainless steel ties was readdressed and considered as a fall back option with the associated reduction in thermal performance of about 10%. As the wall was already near the limiting U value, this could mean a re-design of the wall structure. The plastic ties are guaranteed for use in buildings up to 15m which is appropriate for the PII at Stamford Brook as no houses are higher than 3 storeys. The landmark building is higher than this but is outside the PII.

43 Being an unfamiliar building component, several buildability concerns were raised about the use of plastic wall ties, the main one being the ability of the tie to accommodate unintentional (and frequent) mismatch between inner and outer leaf coursing (some of the team argued that there should be no mis-match in coursing). Plastic ties were thought to be safer to handle than steel ties. The design of the plastic ties allowed flexibility in accommodating mis-match between coursing as the tie by allowing a slight rotation in a green mortar bed giving room to position the tie at angles other than 90^0, although this would not be true where mortar has set. The steel ties suitable for this cavity width would have been larger cross-section and therefore stiffer but still provide this flexibility. However, this is only true assuming regular mortar bed thickness, an issue that was added to the construction specification as a matter of good workmanship.

44 The proposed tie was the 250mm Kristiansen Refus 1 glass-filled polyester tie. Both developers insisted on an independent wall tie test. Testing was performed by Ceram who produced a technical report stating that the ties conform to EN 846-6 with average values of tensile strength of 2135N compared to the required 600N. NHBC were also consulted and they insisted on a further series of checks including: durability confirmed by manufacturers, reaction between tie and insulation, confidence that replacements could be found at a future date and details of the testing procedures. The tests showed that the 4 ties/m^2 would be sufficient (not 8/m^2 as previously thought). The 250mm ties had a recommended minimum embedment of 50mm. This could have enabled up to a 150mm cavity but the detail designer preferred to retain the 142mm cavity width to allow some tolerance in tie position.

Design of window and door openings

45 The minimising of thermal bridging by providing a thermal break between inside and outside skins at window and door reveals was quickly embraced by the developers and the details designers. Thermal simulations of reveal details were made by the research team and this information was used by the detail designer to optimise the thermal design. Initial ideas for reveals used 18mm plywood timber liners to close the cavity and provide support for the window frames and plasterboard. This idea was taken further and a test wall was built on an existing site, see Figures 4 and 5. The timber liner idea was discarded as its thickness (18mm ply) caused coursing problems and potential mismatch between inner and outer leaves. The test wall was made using aerated blocks and these were cut to size by handsaw. The medium dense blocks to be used at Stamford Brook would not be as easy to shape. Alternatively, special coursing blocks could be used but these would be expensive and add to buildability problems.

Figure 4: Test wall showing 142mm cavity and plastic ties.

Figure 5: Test wall showing coursing problems caused by timber liner.

46 The design of the sill had to overcome the problem of the timber sub-sill not being wide enough to throw rainwater over the brick or stone masonry sub-sill. A wider timber section would have been less durable and would not have been compatible with the spirit of the EPS with respect to the appropriate use of materials. One method was to redesign the masonry sub-sill to slope away to

outside from under the frame. Another was to cover the timber and masonry section in aluminium sheet.

47 Catnic lintels were chosen for the internal masonry leaf above doors and windows. The internal lintel had a sole plate (toe) which extended across much of the cavity. The reason for this choice was to provide a solid structure to fix plasterboard to at the opening. This feature went against the principle of maintaining a thermal break between masonry leaves to diminish thermal bridging across the insulation layer. Thermal analysis by the research team showed this toe allowed significant heat flow through the detail (see Appendix 4). The detail designer chose to compromise on thermal performance here and keep the toe as a support for the plasterboard. This demonstrated a growing maturity in the designer’s ability to quantify and confidently trade-off thermal performance and still produce a workable detail.

48 As the detail design progressed, an insulating closer was introduced in an attempt to use a proprietary product to do more than one job – close the cavity, provide a fixing for the window frame, provide the correct size masonry opening and provide a thermal break between masonry leaves. These particular windows can not be built-in, they are pre-finished and are fitted after the scaffold is dropped. The proposed closer was undesirable from the Trust’s EPS point of view as it is made from PVC. Solutions to this problem were discussed but seemed to hinge on one major obstacle – that non-PVC products do not seem to be available at the moment for many building applications.

49 An alternative to using permanent closers is to build the masonry around a temporary profile which is removed after the mortar has set leaving the correct size opening. Removable timber profiles were considered but were thought to leave insufficiently accurately-sized openings. Although theoretically reusable, the profiles would deteriorate quickly as they are forced out of the openings by hammer. Since there are a large number of different size openings throughout the site, this was judged to be a wasteful use of timber. The ideal solution appeared to be the permanent former which gives an accurate size for bricklayers to lay to; provides a resilient fixing for the frame; provides a DPC; creates a stop for the blown insulation, gives a structure to apply parging onto; and gives support to the plasterboard. Discussions led the team to decide that the insulating aspect of the former is unnecessary because the frame would act as a stop for the retro blown insulation and that area would be insulated just as effectively. At the time of writing, the developers are trying to source a non-PVC product.

50 The ‘Conservation’ range was a major influence on the house facade design for Stamford Brook. This is a range of houses currently in production at other sites which have omitted some details that were purely decorative. These were inefficient in terms of thermal performance and material-use - one example is add-on empty gables. In March 2003, the concept designer thought flush windows with an attached surround would relieve what were now, to him, bland facades. The drawings showed timber-framed surrounds. Other team members thought that the surrounds were a poor add-on as they introduced durability and maintenance problems. Water penetration behind timbers and painting of timber were the two main issues. With the suggestion of lead flashings as an add-on to cover these weak areas, it became apparent that the design was drifting away from the concept of simple detailing and efficient materials use. Equally, all this went against work done by the details designer who wanted setback frames to minimise thermal bridging. When the research team modelled the flush frame details and calculated the effect on whole wall U value, it was found that the additional thermal bridging pushed the whole element U value beyond the 0.3 W/m^2K limiting value (see Appendix 5). Up to that point, the concept designer had not been in the design loop with the rest of the team and was not aware of the precise extent of the thermal bridging and the corresponding limitations on design. However, once the thermal bridging issue was raised, the concept designer understood immediately. Remarkably, after this incident, the concept designer and detail designers still continued to work mainly in isolation from each other. With this in mind, the Trust thought that it would be better to firm up the exteriors with the concept designer before continuing on detailed interiors with the details designer.

51 The framed surround was dropped and artstone heads and sills were mooted as a possible way forward to combine the setback frame with façade interest. Mullions, thought desirable by all, were cost prohibitive and anecdotal evidence suggested that some mullions had been known to fall out, not being load-bearing. The artstone sill had the additional advantage of providing a catchment for drip from the recessed timber sub-sill, a problem identified earlier. Other ideas to reduce blandness

around window heads were sloping tiles and protruding artstone lintels, all discarded due to problems with water drip, water ingress and buildability.

Internal finish

52 There were several reasons that the Trust was keen to build houses with a wet plastered internal wall finish. Wet plastering was seen as durable finish and one that provided a robust airtight layer that would improve dwelling energy efficiency. The Trust also wanted to revive wet plastering as a traditional skill which that seems to have been replaced by dry-lining in new build over recent years - part of the Trust's Vision was to favour traditional trades such as wet plastering to achieve sustainability in society. However, the developers were equally keen not to use wet plaster as they were concerned about the additional drying time and its effect on production. A cost was estimated for additional drying time which was based on lost interest. Another of their arguments against wet plaster was the indication that wet plaster trades were in short supply due to the reduced demand over recent decades. However, it could also be argued that other trades, notably plumbing, also suffer from a shortage of skilled workers but there was never any argument about including plumbing works.

53 The developers were very keen to develop an alternative strategy to wet plastering to achieve the airtightness standard and parging was considered as a possible way. Parging is a thin (2-4mm) layer of a plaster-type material that had been used elsewhere to improve predictability of the sound insulation properties of masonry walls (a well-built wall does not improve much with parging but a poorly built wall will improve with an application of parging). Parging is a plaster-based material which shares some of the properties of undercoat and adhesive. The parging essentially fills small gaps and voids in the blockwork. It was thought that this property would also go some way to providing an airtight layer. The developers soon realised that this method may be feasible as it is quick drying (a matter of hours), could be applied by non-skilled or semi-skilled workers and would allow the preferred dry-lining to take place almost immediately after application. As mentioned in the section on wall design, it was thought that drying and shrinkage movement of aircrete blocks would be detrimental to a solid wall finish (in this case parging) and so this strengthened the justification for using medium density blocks for the load bearing wall construction. As 100 houses are to be built using wet plaster as part of the PII project, this would simplify site organisation as medium density blocks could be used throughout the site. As a precaution it was decided to review the block situation after a number (50-100) of houses were built.

54 Once the idea to use parging as the airtight layer rather than wet plaster had been adopted in principle, an investigation of the effectiveness of parging was undertaken by the research team in December 2002. A layer of parging was applied to a house on an existing site to the inside of the external wall blockwork prior to dry lining. The house was built to 1995 building standards and apart from the parging and the usual good workmanship, no particular care was taken to improve airtightness. The house was air pressure tested immediately before and after the application and a substantial reduction in leakage was recorded. The house was tested again on completion and an air leakage of 4.5 $m^3/h/m^2$ @ 50 Pa was obtained. This would pass the EPS target of 5 $m^3/h/m^2$ @ 50Pa and it is believed that with attention to detail and stricter supervision, lower air leakage rates will be achieved at Stamford Brook on a regular basis. This important finding is presented in more detail in Appendix 6.

55 Work is currently being done on another site being constructed by one of the developers which is using spray techniques to apply parging. It is hoped that the results of this trial will be available before construction start. The design team will use findings from the trial to assess the cost, time taken, skill level and impact on air leakage.

56 The research team will take the opportunity to compare the two finishing systems. Both developers have agreed to wet plaster 50 houses each in the first phase and results of air pressure tests will be compared to see if there are differences in air leakage or differences in standard deviation in the results. Any findings will feed back into the design process.

57 The idea of machine wet plastering was also considered but as the preferred method of achieving the airtight layer became the method involving a parging layer, this idea became less important despite an offer from a (German) wet plaster machine company to train up UK-based operatives.

Window and door design

58 One of the earliest design decisions was to simplify window geometry so as to maximise solar gain and minimise thermal bridging. In practice this involves elimination of fanlight windows in favour of night-safe positions on main opening lights, and the use of larger individual lights than are common in the UK. Initial quotations from manufacturers were only able to supply window U values of 1.7 W/m^{2}K, well above the elemental requirement of 1.3 W/m^{2}K and the limiting value of 1.5 W/m^{2}K when the target method is used. However, previous work done by the research team on the St Nicholas Court project (Lowe, Bell & Roberts 2003) showed that, in theory at least, double glazed units could provide the required thermal performance (see Appendix 7). These units had warm edge spacers, argon fill and very low emissivity coatings. The preferred method of window compliance was by Domestic Window Energy Rating (DWER), a rating which gives takes solar gain (g) into account along with heat loss. The DWER of 70 was chosen as a requirement because a window is thermally neutral at DWER 70, with heat losses balancing solar gains over a heating season. (Getting maximum window performance was now essential as the wall cavity width had, to all intents and purposes, been fixed at 142mm. The whole wall U value was near the limiting U value and therefore additional building fabric performance was needed from the other building elements, roof, floors and windows).

59 By January 2001, a window manufacturer had been sourced and the possibility of their using warm edge technology and having the units rated by the British Fenestration Rating Council (BFRC) was being discussed. In order to achieve the DWER, the window manufacturer, Rationale, approached the (BFRC) who modelled the glazing systems and certified a rating. The windows achieved a rating of 70 and a U value of 1.3 W/m^{2}K, which gives compliance with the dwelling energy standard. This was thought by the design team to be a striking example of the kind of influence a large project like Stamford Brook could exert on a manufacturer or supplier.

60 One developer then decided to source an alternative window supplier as it was their company policy to obtain three quotations. One was found that could deliver the required performance but by offering triple-glazed units. Both manufacturers used sustainable timber frames. One reason for wanting double glazed units in the first place (in preference to triple) was the lower weight of the units and easier handling on site. The developer was aware of the handling and the quoted price of the triple windows appeared to include fitting, whereas the double glazed units was supply only. When site fitting costs of double glazing were included in the calculation, it seemed that the cost of each system was about the same. By this time (Oct 2003) a DWER report had been written for the double glazed system and the team realised that there would be additional modelling, tests and reports if the triple glazed system were also to be BFRC rated. This, and later confusion over the exact cost of supply and fit, led the team to adopt the double glazed system for both developers across the whole site.

61 The first choice of doors (December 01) were composite insulated with a U value of 1.79 W/m^{2}K. At the time of writing, a steel faced door with a U value of 0.55 W/m^{2}K is being considered. This would improve overall house thermal performance slightly.

Separating walls

62 The team debated whether wider external wall cavities necessarily meant wider separating wall cavities. At wide cavity widths in party walls the effect on overall terrace footprint could be sizable. As the issue was acoustic and not thermal transmittance through the wall, the research team's view was that 'normal' size separating cavity widths could be used.

63 A complication arose where staggered terraces occur and the separating wall has to carry the exposed gable. If a wide cavity is used in this situation, the same wall U value will be achieved on the exposed part. Alternatively, if narrow cavity is used, the exposed gable would then have a higher U value that the rest of the external wall. This effect is small enough to be negligible if the stagger itself is small. Terraces perform thermally better than detached due to the smaller external wall area. The team decided to have the narrow separating wall cavity only in situations where there is no terrace staggering. On this particular site there are substantial areas of open space in the community woodlands and the wildlife corridors so minimising house footprint was less of an

issue. Other sites which have a high density of terraced dwellings may be more sensitive to separating wall cavity width and more research should be done in this area.

Roof design

64 An intention of the EPS is to make efficient use of living space and room-in-the-roof is an area where the Trust thought this could be implemented. I-beams integrated with cellulose or sheep wool insulation was the Trust's system of choice. 1¾ and 2½ storey houses were thought desirable by the Trust as they saw lower materials use (in wall materials) and good use of internal space. However, the developers thought that room-in-the-roof accommodation was generally undesirable by house buyers. They thought that such a construction type would give problems accommodating furniture such as wardrobes. Conventional cold loft roofs built with trusses were preferred. If room-in-the-roof was to built, their preferred method was attic trusses. One developer did admit that they preferred not to try anything new, such as I-beam roof construction. The wider wall cavity, by comparison, was an easier change for them to make as the structure used essentially the same materials and method of build. The benefits of I-beam construction were discussed at several technical meetings as the design progressed and the desire to use (or at least trial) I-beams became more prevalent throughout the team.

65 It was hoped that a trial of I-beam roof construction in the first phase could investigate the efficiency of the system. The Trust hoped that they would then be adopted site–wide for roofs (I-beams were already chosen for use in intermediate floors). In line with the desire to minimise materials usage, flush eaves were used (no fascias / rafter feet) and clipped verges (no bargeboards).

66 By October 2002 it appeared that the main obstacle to I-beams for roofs was the perceived high cost. A third alternative, using structural insulated panels to form the roofs was considered. Such panels are normally supplied to meet current regulations but thicker ones were available to order. Thermal modelling by the research team showed that the large timber sections necessary for the interlocking structure permitted significant thermal bridging. The supplier was asked for a further design iteration to achieve the required whole element U value. The final offering still did not meet the requirement, the manufacturer preferring to use provide a nominal U value and ignore the substantial bridging. Whether this was intentional or the supplier did not know how to calculate whole roof U values was unknown. This method was then deselected by the design team.

67 The solution adopted for the room-in-the-roof, with design input from the supplier, appeared to be 241mm TJI Trusjoist I-beams. However, discussions in January 2004 showed that this decision had still not been agreed by all. The additional costs (if any) are still being calculated – the reduction in masonry in 1¾ storey houses is being accounted for.

Roof insulation, cold roof

68 Choice of roof insulation for cold roofs was discussed in some detail. The Trust wanted blown recycled cellulose (Warmcel) and the developers preferred to keep to their traditional mineral fibre quilt. A third option, sheepswool, was discarded on cost grounds. In the cold roof, 250mm of insulation was required, made up from 100mm between joists and 150mm above the joists.

69 Two interesting discussions concerned the installation of insulation around truss struts and in eaves. Cross-laid quilt is difficult to place around intermediate truss struts without leaving gaps in the insulation layer. The actual placing of cross-laid quilt between and around struts is an awkward task for an installer and unlikely to be done well. Blown fibre such as Warmcel alleviates this problem as the loose fibres fill all the spaces around the struts and leave no voids. Restricted space makes it difficult for an insulation fitter to position the quilt effectively in the eaves. Blown fibre is also easier to install at eaves where, again, the blown material simply fills all the voids. The developers' early solution to this was to fully-fill the eaves void with sections of quilt before roof covering. This would have been done from the scaffold before roof covering and involved carrying rolls of insulation up ladders and onto scaffolds, sometimes in wind and rain. These advantages of blown insulation began to sway the developers towards Warmcel.

70 Several minor disadvantages to Warmcel were also aired. Warmcel insulation above the joists was seen as an obstacle by the developers as this meant that access in the loft was restricted - as joists

could not be seen - unless walkways were built. Although this problem also occurs with any insulation including cross-laid quilt, some of the team were only able to visualise what this actually meant with Warmcel in terms of access and storage of items such as suitcases. One team member even thought that blown fibre would pose a problem as suitcases would have loose fibre attached to them when they were taken from the loft without realising that a suitcase pressing down on top of 150mm cross laid quilt would also be a problem. Another objection was thought that using Warmcel would introduce an additional sub-contractor although in reality they would only be a substitution for the quilt installation sub-contractor.

71 One area where quilt had the edge over Warmcel was around the loft hatch. An up-stand would be needed at the loft entrance to stop loose fibres falling through the hatch, although this could easily be made from plywood or a proprietary kit which are available at low cost. Access to the loft was thought necessary for emergency repair work to equipment and walkways would need to be provided with where joists are obscured from view as they are covered with insulation. This requirement presupposes that loft spaces ought not to be accessible at all and any equipment that might need accessing for maintenance should be located in the heated part of the envelope. In previous decades, when lofts were insulated or only insulated between joists, loft access and space to position water tanks and equipment was a reasonable use of loft space. Now, and if greater levels of insulation are required in future revisions of Part L, usable loft space may be less viable.

72 The research team thought that the benefits to the construction process would become apparent to the developers after a trial period, which they agreed to. By February 2004, all had agreed to use Warmcel in cold roof construction.

Ground floor design

73 In December 2001, the ground floor was designed to be ground-bearing in-situ reinforced concrete slab with 65mm of expanded polystyrene insulation. This appeared to meet the dwelling energy standard requirement. However, ground floor U values are greatly influenced by perimeter-to-area ratio and thermal bridging through the junction with the wall. The developers already use insulation blocks in the foundation wall at slab level. The final design meant that all the ‘worst-case’ house types achieved the required whole U value apart from a very unusual dwelling, a first floor detached flat above four ground floor garages. Access to the flat was by a staircase which rose between two garages. The floor area of the staircase and store cupboard was 1m x 6m, very high perimeter-to-area ratio. This particular dwelling will have extra ground floor insulation to allow it to easily meet the requirement.

Intermediate floor

74 241mm Trusjoist I beams were adopted for intermediate floors as early as December 2001. Concrete intermediate floors were also considered but it was felt they offered less flexibility in routing services. Full house width beams free up the design possibilities of placing partition walls and this ties in well with the Trust’s Vision to provide buildings that could easily be adapted at a later date for a different use. Partitions could be moved without affecting joist layout.

75 To comply with ADE, hangers were to be used when the joists were fixed to the party wall. However, this introduced a conflict in the team as joist hangers were thought by some members to leave joists unsafe until several courses of blockwork had been laid to provide weighting and stability to the hangers. A decision was made in April 2004 to use the Simpson Strong Safety Fast system which solves this hanger safety problem and also offers joist wrapping to aid airtightness where the other end of the joist is built into the wall.

Detail design, heating and ventilation systems

Space and water heating system design

76 A wet central heating system with a condensing boiler (91% efficient) and hot water storage was chosen from the outset. As well as keeping the DHWS pipe-work runs to a minimum, 70mm insulated cylinders and insulated primary pipe-work are to be used. Information about the choice of replacement boilers will be included in the sellers packs.

77 Previous work done by the research team suggested that the good thermal performance of the envelope - giving a uniform temperature profile throughout the house - could obviate the need for radiators in upstairs rooms. The Housing Association involved in the St Nicholas Court project was willing to test this idea with the caveat that radiators should be easily fixable if needed at a later date. Capped pipe-work spurs were to be provided to radiator points to allow swift connection with minimal disruption to tenants (*see Appendix 1 in*: Lowe, Bell, Roberts, 2003). While this was an interesting benefit of designing lower energy houses, it was felt early on that house-buyers would expect radiators in bedrooms and the associated sales risks were too high to contemplate.

78 One developer has chosen to use mains pressure hot water. This has the advantage of removing pipes and tanks in the loft and their associated insulation. It would lower the number of service penetrations through roof improving airtightness. The other developer was not keen on this idea believing that water pressures seem to be continually falling as water boards strive to reduce mains leaks. They thought they could not rely on sufficient water pressure on site. This belief was challenged as low water pressures would affect all dwellings nationally and would not be acceptable to homeowners. At the time of writing (March 2004) each developer has chosen a different direction here, each designing their own hot water system. It will be interesting to see if the two strategies affect air pressure tests which will be done by the research team on completion.

Electric heating

79 One of the developers had a company policy that required the use of electricity for all energy needs in flats. This was based on safety fears relating to the use of gas, citing Ronan Point as an example. Part of the Stamford Brook development was to include some ‘landmark buildings’ – low to medium rise buildings which were intended to provide three or more floors of flats. A reduced carbon index would result from electric heating of such dwellings unless additional fabric insulation was provided or another technology employed such as heat pumps, heat recovery or solar power. The developers found it very problematic to have differing house fabric designs for flats and houses. It was decided that the landmark buildings would not form part of the PII research project on this occasion as the buildings were unusual in that they lay outside the general remit of addressing carbon rating of volume house building. However, the Trust still had the dwelling energy standard that the developers had contracted to meet. There was a discussion to have a separate standard for electric flats in the first phase. The two standards would converge in the later phases.

80 The research team prepared the dwelling energy standard as early as 1998. It was hoped then that, over the coming half decade, advances would be made in power generation and product innovation that would reduce the gap between carbon ratings of electric and gas heating systems but such a change has not yet materialised. The research team showed that electric heating could still be used and the carbon rating met provided that other complimentary (bolt-on) measures were taken. Figure 6 illustrates the point that the carbon intensity of electric heating approaches that of gas by the addition MVHR, increased airtightness and solar panels. The research team also discussed the impacts of compactness - given that flats tend to have less external surface area than houses.

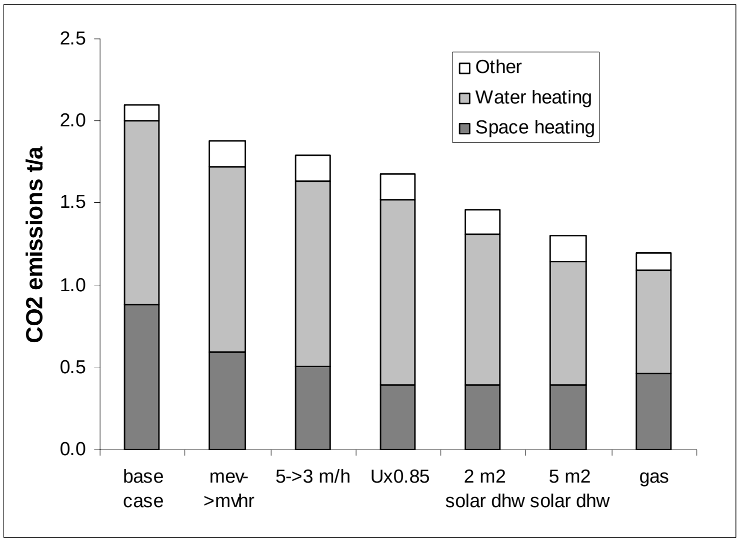

Figure 6: Technical measures for reducing carbon emissions from an electrically heated dwelling.

81 Other ideas included having a micro-CHP plant to service the landmark flats but that posed significant marketing and maintenance problems. By March 2003, the time constraints of the planning application made it difficult for the developers to choose any other system than gas heating for the flats in the landmark building. This effectively meant that the problem went away for this particular project but more work is clearly needed in this area.

Secondary heating

82 In September 2001, the developers first mentioned that focal point fires were a marketing issue and that purchasers would expect to be provided with such a feature in the standard of houses at Stamford Brook. However, focal point fires were at variance with the efficiency and airtightness intentions set by the EPS. The research team pointed out that less efficient secondary heating systems could adversely affect the carbon rating. Up to that point, secondary heating data were unknown and so not included in the preliminary carbon ratings that were made to feedback into the design process. It was only after a parametric study (using assumed efficiencies) by the research team it was realised that certain secondary heating systems (balanced flues and room-sealed fires) could be used without significant detriment to the carbon rating. The issue was not mentioned again until April 2003 when all agreed that no open flues be used and all heating appliances should be room-sealed to maintain the airtightness of the dwelling. This affected the choice of secondary heater as balanced flues can only used in detached and in semis where the fire is on an external wall. Terraced houses and semis with fires on the party wall presented a problem. One developer did not want to supply fires to those houses believing that only purchasers of detached would expect them to be included. The other developer wanted fires in all house variants and was prepared to use flue-less catalytic gas fires. A suggested compromise was an electric fire, even though that fuel has a high delivered carbon intensity. Space heating in these dwellings is small and secondary heating is only 15% of the total space heating and no flues are necessary with electric heating. It is unknown at the moment how often home-owners of airtight, highly insulated houses may utilise a secondary heating system and it may be more or may be less than the 15% assumption in the current SAP. Research team interviews with home-owners will explore this area further. In summary, focal point fires are to be used by both developers where the fire is on an external wall and the final decision between electric and flue-less fires for terraced variants for one developer is still to be reached.

Ventilation system design

83 One of the early design decisions was to use mechanical ventilation throughout the development. The main driver for this was the desire to make sure that adequate ventilation was provided to the houses that were known would be more airtight than average houses constructed at present. Although the required airtightness target was 5 $m^3/h/m^2$ @ 50 Pa, it was anticipated that some houses at Stamford Brook might be substantially more airtight than this. Natural ventilation was considered too variable to be effective and so the sales and after-sales risks were too high. The developers agreed with Baxi and decided to use the highest specification equipment for all systems This included DC motors, smooth bore ducting and high efficiency heat exchangers in MVHR systems. The Domestic Performance Calculator has additional formulae to more accurately reflect the impact of the efficiency ventilation equipment on the carbon index. Another early decision was to not connect the cooker hood to the ventilation system to avoid kitchen particulates and grease fouling the system. Cooker hoods will extract to directly outside in all houses but may have to be of the recirculating type in flats that have poor access to outside walls.

84 An important environmental step for the Trust was to prohibit the use of PVC products. Unfortunately, many building components are unavailable in forms other than PVC and so this desire was unfulfilled in some areas. One area where an alternative to PVC was available was in ventilation ducting. A supplier was sourced who could supply flame retardant high impact polystyrene CP6114 ventilation ducting and coupling products. Other types of ducting were ABS based, with and without flame retardant properties. The flame retarding material was about twice as expensive as non flame retarding. It remained unclear whether flame retarding ABS was a requirement. Since the flame retardant was available it led the team to decide that it would be best practice to use that material.

85 The ventilation system was designed to have a set-back fitted to slow down the ventilation rate when the house is unoccupied for long periods. However, the team thought that house-owners were not quite ready for this level of sophistication in ventilation control and so switches to operate the set back will not be fitted (although switches could be retro-fitted easily at a later date). This is to avoid the incorrect use of setback where under-ventilation or condensation could occur under normal occupation. Planned home owner interviews by the research team will try to assess the preferred level of user-intervention in ventilation control.

86 Another area of unwanted owner intervention was thought to be trickle vents. Some team members knew, anecdotally, that owners sometimes choose to close trickle vents in order to eliminate draughts and cold spots. If the vents were closed in an airtight naturally ventilated dwelling it could have a significant impact on air quality in that house. It is hoped that owner intervention will be minimal as the houses are expected to be more comfortable than average but the idea of using trickle vents that are still slightly open even when ‘closed’ is being discussed with the window supplier. As some rooms have more than one window frame, some trickle vents will be blocked off at the factory to avoid over-ventilation to that room. It is important to fit the correct frames to the correct rooms and so the frames will be delivered on a plot-by-plot basis and clearly marked. This design and communication requirement should improve buildability on site. Supply of trickle vents that could be adjusted by a site fitter was considered but this, again, introduced a level of complexity to buildability. In any event, these particular vents are built-in to the jambs and so could not be supplied as adjustable by the window manufacturer. It is possible that mechanical extract ventilation systems (MEV) require trickle vents with smaller cross sectional area. This, together with the more uniform pressure regime in such dwellings, would reduce the incidence of drafts caused by extreme weather conditions in MEV houses compared with naturally ventilated houses. There is no requirement for trickle vents in houses with balanced MVHR systems.

87 Noise reduction exhausts are to be fitted to all MEV units. Although Baxi considered them unnecessary as the high specification units are very quiet, this decision was taken by the developers as a precaution against possible home owner dissatisfaction. As continuous ventilation is a new concept to many house buyers, it was thought that any perception at all of the system in-use was more likely to be from noise awareness than air quality awareness. More information on this and other issues will be found when the research team interview home owners after a year of occupation.

MVHR

88 Ten plots in the first build tranche have been identified as part of the PII which will be fitted with MVHR. The possibility of a housing association MVHR trial was discussed but it was felt that more impact on the construction industry could be made if the trial was energy efficiency in speculative house building. The Trust wanted more than ten MVHR houses but as the system uses more ducting and fan equipment than MEV, the cost is higher. Five of the MVHR houses will be intensively monitored by the research team during the first year of occupation (five MEV houses will also be monitored). The intention is to feed back the findings on air quality, thermal comfort and customer perception to the team so as to inform decisions about the possible installation of MVHR in other properties. There are second order benefits with MVHR such as lower humidity, fewer cold draughts and greater freedom to place radiators on walls other than external walls. Even though the units are approved by the British Allergy Foundation to lower allergens and improve the health of asthma sufferers, the developers remain unconvinced at the moment as to how these benefits translate into marketability.

89 The placing of the MVHR equipment within the heated envelope was considered essential to achieve maximum heat exchange efficiency. (Ductwork in a cold loft was estimated to require something like 300mm of insulation around it. With a 10mm pipe, this equates to an overall height of 700mm).

90 MVHR was thought to give greater freedom in the placing of radiators within the house. Conventionally, radiators have been positioned under windows to counter localised heat loss and cold convection currents in rooms but houses with MVHR could have radiators positioned on internal walls, thereby simplifying pipe runs. Other suggestions were to use MVHR to allow smaller radiator sizes but due to the small number of house being built with MVHR and the minimal cost difference between radiator sizes, this idea was not taken any further. It was also suggested that ventilation and heating be integrated more to give a smaller space heating demand but this idea was thought ambitious and more suitable for later phases of the site.

91 It is hoped to offer MVHR as a customer option. It was first thought that this could only realistically work if a purchase was agreed before house construction giving time to fit the appropriate ductwork. MEV has extract ductwork, MVHR has extract and supply ductwork. A way round this was to design each house-type to accommodate MVHR ductwork. This was chiefly in the joist layout. MEV houses would simply omit the supply ducting. The additional cost of doing this is difficult to quantify but is believed to negligible.

Design team member interviews

92 Towards the end of the design process, the research team began a series of interviews with the other design team members to elicit their personal views on the process. The small number of interviewees (10 so far) means that the views are not necessarily representative of the construction industry but they do shed background on the reasons behind many of the design decisions that were taken. The interviews were tape recorded and then transcribed. The interview questionnaire is shown in Appendix 8. A later report will describe the process in more detail but some of the more interesting comments that have emerged so far include:

a) Airtightness is still a matter of concern to some design team members. Although the parging trial showed that the parging layer could help achieve the airtightness target even without much attention to other leakage areas, some felt that it may be difficult to achieve the target consistently in production over a long site timescale and possibly with a large turnover of staff.

b) There seem to be no insuperable technical problems designing to the EPS.

c) The construction industry can, and will, deliver whatever the regulations require (but no more or no less).

d) The regulations are necessary and fair because they provide a level playing field for the construction industry.

e) The role of the independent consultant in submitting building regulation applications will continue to grow as regulations become ever more complex and therefore specialist.

f) Unfortunately, if independent consultants are used for regulation submissions there is a danger that a breakdown in feedback may occur where the designer is unaware of what aspects of the design work and which do not.

g) Just prior to the construction phase, the main hurdle to building to the dwelling energy standard seems to be getting the message down to the trades.

h) All team members are pleased that they have managed to design low-energy houses that look ‘traditional’ and not ‘experimental’.

93 Two members began to attend meetings in early 2003 when, by that time, the existing team had established a good rapport with each other and the team was making decisions quickly and effectively. It was noted that the two new members saw only insurmountable problems where the established team saw only challenges and opportunities. This observation demonstrated the synergy within the team and how much it had grown in confidence and ability.

Costs

94 Throughout the house design period, like any other project, cost was a consideration. However, the research team considered that much of the design discussion was not actually cost-led and that design solutions were debated to get the best environmental and energy performance commensurate with acceptable costs rather than focus simply on the cheapest solution possible. This may have been because it was accepted that some increase in cost was inevitable and that the Trust wanted to purchase and fulfil as much of their 'Vision' as possible. Naturally, where two solutions had a similar environmental impact, the cheaper one was chosen.

95 A 'Summary of budget costs' spreadsheet was used to itemise all the house components that had an extra-over cost attached to them. The extra-over was the difference between achieving the current building regulations (ADL 2002) and achieving compliance with the EPS. The Summary was regularly updated as new and revised cost information and quotations came in and construction solutions were agreed upon. New versions were distributed to the team on an almost monthly basis. Initial versions were made by the developers and later versions by collaboration between them and the Trust's QS. Initially, costings were done assuming that all houses would be 100m^2 detached. At this time the precise house mix was unknown. This assumption had the effect of over-estimating items such as wall tie numbers and wall insulation as a detached has more external wall than semi and terraced variants. It was only later that the house mix became predominantly semis and mid terraces in phase 1that the truer cost became apparent.

96 A theme which emerged regularly at meetings was bulk buying. The fact that the Stamford Brook project was so large (710 dwellings) was thought by the Trust's QS to have sufficient buying power to obtain significant bulk discounts. The developers, though, preferred to let their own supply contracts on a parcel by parcel basis (typically 25 houses at a time) in order to provide flexibility in choice of supplier. The developers were keen not to be 'tied' to suppliers over long periods. Each developer did agree to try and share suppliers if their quotes were more competitive. A letter of intent to renew contracts to suppliers as each parcel became available was touted as a compromise but, again, the effectiveness of this strategy was difficult to ascertain. How much the promise of extra work affected quotes is difficult to quantify. The corollary was that some suppliers could also not guarantee their prices over such a long timescale (4-5 years).

97 Midway through the design period, budgetary constraints meant that not all of the Trust's EPS items could be afforded and each item was weighed against others in an attempt to decide which to keep and which to reject. This was a difficult choice as all the items remaining in the EPS had by then already been through a rigorous and well-debated selection process. By January 2004, though, the Trust decided to include all the EPS items even though this took the cost of the project over budget. The hope was that over the course of the project, actual costs would be lower than budget costs. If not, some items could be omitted in later phases in order to meet the overall budget. It was also thought that revision of actual building regulations would change the benchmark from which the extra-over costs were calculated. For instance, if the regulations in 2005 required window U values of 1.3W/m^{2}K (the EPS standard), then there would be no extra-over for that item from that time onwards.

98 An interesting phenomenon occurred as budget cost was analysed over time. The estimated cost of many items in the EPS did appear to fall and some fell substantially from first estimates. A full report of budget and actual costs will be prepared by the research team later in the project but, in the meantime, two tentative examples are given below to give a flavour of the findings so far. Examples for plastic wall ties and cavity wall insulation are shown in Figures 7 and 8 respectively.

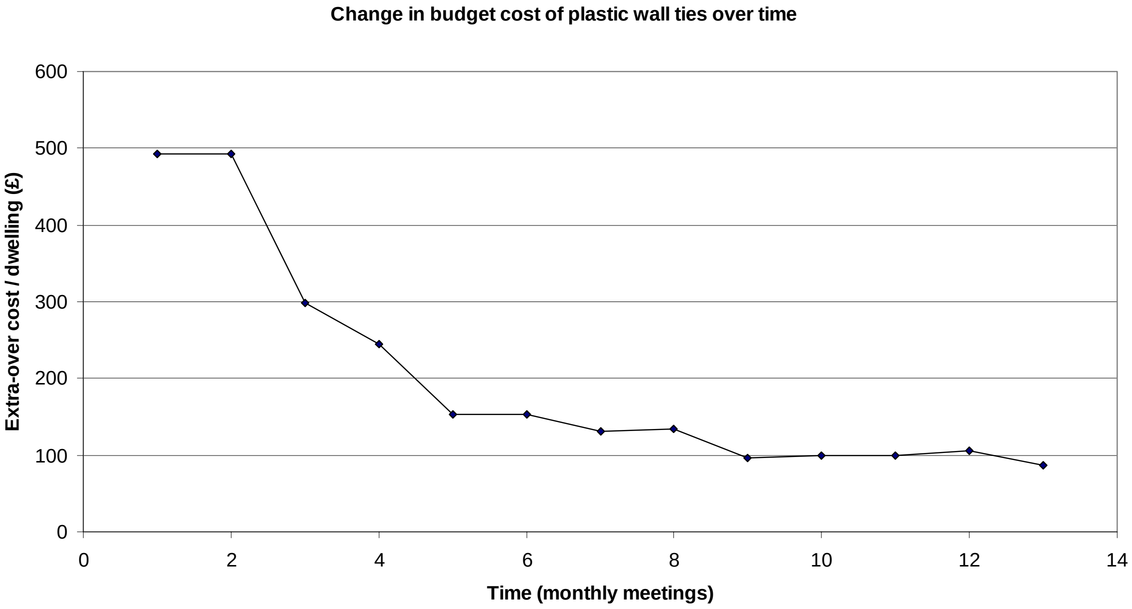

Figure 7: Change in budget cost of plastic wall ties.

99 Figure 7 shows a graph of how the budget cost of plastic wall ties changed at each revision (approximately monthly) of the Summary of Budget Costs. The cost is the additional cost taking into account the saving made by not using steel ties. Although first estimates were inevitably high and the way of calculating the figures varied slightly, there was still a marked downward trend as estimates were refined, buildability issues resolved and uncertainty removed. (All figures are normalised to show the cost of using tie spacing of 8/m^2).

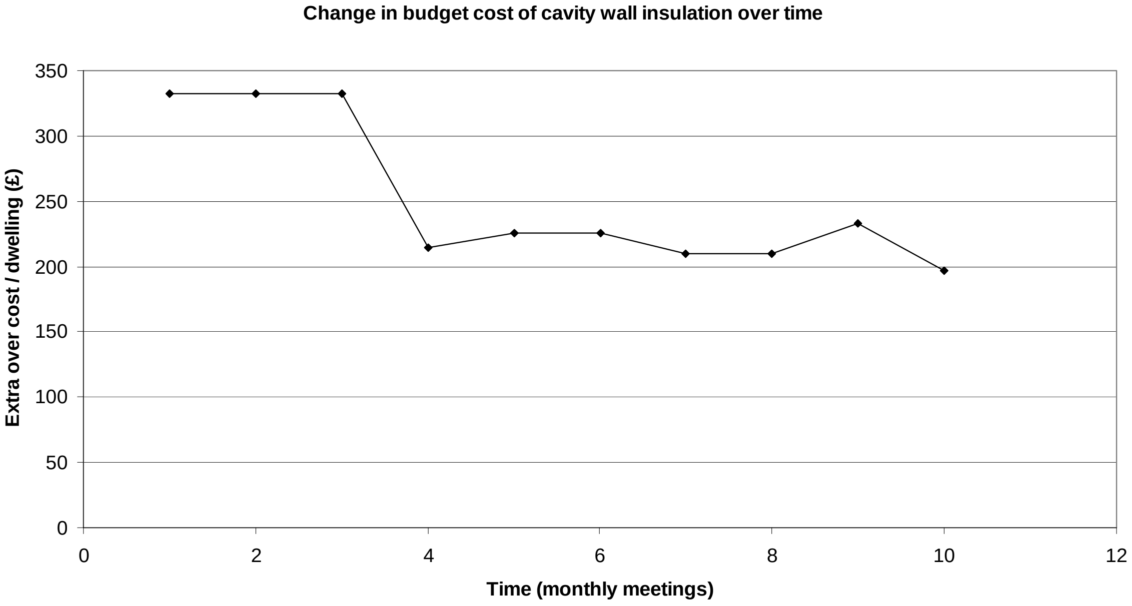

Figure 8: Change in budget cost of cavity wall insulation.

100 Figure 8 shows a large fall in budget cost of cavity wall insulation from initial estimates and then more conservative changes but still with a general trend downward. Initially, the costs were an average of both developers because of the way they were calculated (points 1 to 8). The last two points (9 and 10) show the cost for each developer separated out. The extra-over cost for each developer was slightly different as each had a different baseline from which costs were calculated. The five-fold reduction in cost for plastic wall ties is probably extreme, since at the start of the project, the developers had had no previous experience of them. The cost of cavity wall insulation shows a smaller, though significant reduction.

Construction phase

Construction specification

101 As the design stage moved forward, several design items became firmer in terms of their precise specification. At the time writing (April 2004), the design team is starting to entrust the design to the construction departments. The design process at this point has been progressing for two and a half years and now the team acknowledged that the remaining problems appeared to be buildability issues and getting the message across to the site staff and the trades. For this, a Construction Specification was written (see Appendix 9). This specification itemised all the trades, products and materials and specified what was to be built and how. Individual trade specifications are also being drafted which detail every aspect of the individual trades. These largely are made up from existing trade specifications with addenda that cover the environmental and energy objectives and methods of achieving airtightness through workmanship, sealing gaps and service penetrations. As the two developers used different construction details before the Stamford Brook project, it was suggested that two developers continue separately and design their own addenda to meet the requirements of EPS. However, it was felt that it was better to develop one Construction Specification as the new details and materials were largely the same. In any event, each developer was contributing to the writing of the specification. Other contributors included the research team at LeedsMet, Baxi, National Trust and the Trust's QS.

Sub contractors

102 It quickly became apparent that sub-contractor appointment would be more involved than usual. Not only was it important to meet the fabric requirement set by the dwelling energy standard but there were additional restrictions imposed on materials usage/substitution from the wider environmental objectives of the Trust contained in the EPS. The airtightness target itself and the air pressurisation testing meant that assured workmanship would be needed in all trades, especially plumbing, bricklaying and plastering In addition, there would be a larger supervisory content, both from site management and also from sub-contractors to their operatives.

103 A 'sub-contractor pre-selection seminar' was held in March 2004 where the design team made presentations to sub-contractors who will shortly be invited to tender. Although one of the main drivers for the seminar was to allow time for the subcontractors to become familiar with the project to avoid over-inflated quotations, it quickly became apparent to the team that this was an ideal opportunity to use the seminar to begin a dialogue with the subcontractors and help identify those who were sympathetic to the objectives of the EPS and would those who would benefit personally from the experience of working to a much higher energy and environmental standard. The presentations were made by representatives of the Trust, each developer and the research team. The Trust outlined the history of the scheme and the environmental intentions of the Trust. The developers presented information on which construction aspects would be different and what they were looking for in terms a commitment to sustainable building. The research team presented information on the airtightness testing and the long term monitoring aspect of the research project. They also gave the overall message that the project gave an opportunity to any sub-contractors involved to gain useful experience and expertise in sustainable building.

Materials and products

104 Many materials were difficult to source from local or even UK-based manufacturers. Examples include: low flush toilets from Sweden, doors from Canada and wall ties from Denmark. This put the developers in a difficult situation because products they require usually become available when there is a demand for them, such as when the building regulations change, for example. The project was working to the higher dwelling energy standard but the supply industry could only offer materials that were expected for use under current legislation. The exceptions were materials available from other countries where standards are currently higher than the UK. This too was limited because building methods differ between countries - there is a greater proportion of solid wall to cavity wall masonry in Germany than the UK, for example. Another example is windows. Triple glazing is available that meets and exceeds the U value requirement but double glazed

windows were preferred if the standard could be met. This was thought to be achievable but only of warm edge technology was used in addition to the familiar gas-filled low emissivity units.

105 This problem of sourcing appropriate materials was over-estimated by the some members of the team as some of the products needed are widely available in the UK. Cavity wall insulation is an example of material that always has been readily available, all that is required here is a greater thickness of it. I beams have been available for some time but it may be the cost and the developer's unfamiliarity rather than the lack of product that is the barrier to their widespread use.

Acknowledgments

106 The Stamford Brook project is funded/resourced by the Department for Communities and Local Government (under Partners In Innovation project - CI 39/3/663), the National Trust (land owners) and the developers (Redrow Homes and Bryant Homes) with contributions from The National House Building Council, the Concrete Block Association, Vent-Axia, and Construction Skills. The contribution from all partners is gratefully acknowledged.

107 The research is led by the Buildings and Sustainability Group in the Centre for the Built Environment at Leeds Metropolitan University in collaboration with the Bartlett School of Graduate Studies at University College London.

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Appendix 1: Dwelling energy standard

A Trial of Dwelling Energy Performance Standards for 2008:

Prototype standards for energy and ventilation performance

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Foreword

The draft performance standards contained in this report have been developed as a research tool for PII project PII 39/3/604 (A Trial of Dwelling Energy Performance Standards for 2008). The objective of this project is to assess the impact on dwelling occupants, designers, building control authorities and house builders & developers of an energy and greenhouse gas emission performance standard that is significantly higher than that contained in current UK Building Regulations.

Two prototype standards are defined. The first deals with energy and greenhouse gas emission standards and relates to Part L of the Building Regulations for England and Wales. The second addresses provisions for ventilation and relates to Part F of the Building Regulations for England and Wales. The coordination of these two performance standards is an attempt to ensure that the energy performance is not pursued at the expense of indoor air quality and public health.

The standards developed in this project have been designed as prototypes for regulatory standards that could be adopted in the next comprehensive revision of the Building Regulations, expected in or shortly after 2008. It is our hope that the evaluation of the impact of these standards, through PII 39/3/604, will make a significant contribution to such a review.

Nevertheless, this document has no official status and should not be interpreted as indicating any intent on the part of Government regarding possible future regulatory changes.

Prototype performance standard for the minimisation of energy use and greenhouse gas emissions in housing

Objectives of the requirements

The primary objective of this prototype standard is to ensure that carbon dioxide emissions resulting from space heating, ventilation and water heating in dwellings built to these requirements, are significantly less than from dwellings constructed to the 2002 Edition of the Building Regulations Approved Document L1 (DTLR, 2001). This objective is met primarily by requiring:

more highly insulated buildings, free from serious thermal bridging

a high level of air-tightness

heating and ventilating systems that minimise carbon dioxide emissions.

This standard must be read in conjunction with the prototype performance standard for ventilation in the second part of this document. Taken together, these will also ensure that dwellings are adequately ventilated, and that they are free from combustion products from heating appliances.

1. General

Buildings shall be designed to minimise carbon dioxide emissions, to avoid unnecessary energy use, and to achieve a healthy indoor environment.*

Because of the risk of condensation and additional heat loss, thermal bridging must, as far as possible, be avoided in external construction elements, including windows and doors. The energy effect of thermal bridges must be taken into account in calculating the thermal transmittance (U value) for each construction element.

Buildings and construction elements, including windows and doors, shall be so constructed that heat losses are not significantly increased as a result of moisture or air movement.†

U values and transmission heat loss coefficients for opaque elements of the building thermal envelope shall be calculated in accordance with:

BS EN ISO 6946: 1997

BS EN ISO 10211-1: 1995

BS EN ISO 14683: 1999

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[*] Much of this preamble has been taken, with minor modifications, from Section 8 of the 1995 edition of the Danish Building Regulations (Danish Ministry of Housing 1995).

[†] This would normally require the provision of an air barrier adjacent to the internal face of thermal insulation, and the provision of an external wind proof layer.

with the additional provisions of Appendix A. For any given construction, U values thus calculated will tend to be higher than those calculated according to the requirements of Approved Document L (DOE & Welsh Office 1994) and Approved Document L1 (DTLR 2001).*

Thermal performance of windows shall be calculated or measured in accordance with CEN standards prEN ISO 10077-2, EN 673/ISO 10292, BS EN 410:1998. Product-specific performance data used in preference to generic values shall be BFRC certified.

2. Performance targets for dwellings

Compliance with this standard can be demonstrated by one of three methods:

Elemental Method.

Target U Value Method

Carbon Rating Method

2.1 Elemental Method

Compliance will be shown if the performance targets for fabric heat loss, air leakage and heating system performance, as set out in sections 2.1.1 to 2.1.4 are met. If you do not satisfy each and all of these requirements, you may not use the Elemental Method. You will have either to use the Target U Value Method or the Carbon Rating Method instead.

2.1.1 Fabric heat loss

The performance targets will be satisfied if the thermal transmittance of each element of the dwelling is no greater than shown in Table 1†.

Table 1 Standard U values for dwellings (W/m2K)	
exposed walls	0.25
Roofs	0.16
Floors	0.22
windows, outer doors & rooflights (no more than 25% of gross floor area)	1.3

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[*] This has been taken into account in selecting limiting the U values shown in Tables 1 and 2.

[†] The U values listed here differ slightly from those given in the first version of this document (October 1999). The change was made to bring this document into line with the proposals for possible future changes presented in the Part L Consultation Document (DETR 2000:p 180-183).

As an alternative to the specification of U values for fenestration, certified annual window energy ratings may be used (see 2.1.2 below).

2.1.2 Alternative method for assessing window performance

As an alternative to specification of U values, windows with an annual energy rating of 70 or better may be specified. Annual energy ratings must be certified by the British Fenestration Rating Council. Where annual energy ratings are used, total window area, including glazed doors, may vary up to 35% of gross floor area[*].

2.1.3 Air leakage

A dwelling shall have an air leakage rate, measured by pressurisation test at 50 Pa, and expressed as an average over the internal surface area of the dwelling, of no more than 5 m/h[†]. For this purpose, all elements should be included in the area, including those shared with adjacent dwellings (party walls, and floors between separate dwellings) [‡],[§].

Air leakage shall be tested at discretion of the Building Control Officer[**]. Where a dwelling fails a test;

measures shall be taken to remedy the failure in the dwelling that failed the test;

further tests may be undertaken in houses constructed by the same builder to ensure compliance.

2.1.4 Carbon intensity of space and water heating

Carbon intensity of space and water heating shall not exceed 70 kg of CO_2 per Gigajoule of useful heat.[††]

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[*] The BFRC window energy rating system provides a rigorous framework for the calculation of whole window U values and solar heat gain fractions, and for combining these quantities into an annual energy rating that indicates the impact of increasing the window area of a typical dwelling by 1 m^2. A window with an energy rating of 70 will be approximately energy-neutral in a typical new dwelling - solar gains from such a window cancel out heat losses. This means that the annual space heating energy for a typical dwelling fitted with such windows is not strongly affected by the total area of window. It therefore makes sense to allow a wider range of glazing ratios. It does not make sense, at this level, to attempt to provide for trading-off between solar gain through windows and heat loss through the opaque parts of the building fabric.

[†] The value specified in the first version of this document was 3 m/h. The increase to 5 m/h brings the current version into line with the Part L Consultation Document (DETR 2000:p 182). Below 5 m/h, energy use in dwellings with extract-only ventilation systems is insensitive to air leakage. However, energy consumption in dwellings with balanced heat recovery ventilation (MVHR) continues to fall, all the way down to zero air leakage.

[‡] Air leakage can, in principle, be expressed either as a leakage per m^3 of building volume or as a leakage per m^2 of envelope area. For a 2 storey detached building with gross floor area of 100 m^2, the resulting numerical values are very similar. The question of test methodology will need to be resolved (see for example, Lowe et al (2000).

[§] There is a view that building elements that are intrinsically airtight, or which under normal conditions have no temperature difference across them, should not be included in the envelope area for the purpose of estimating air leakage. In practice, such elements are often not airtight, and allow the passage of air from within the heated volume of one or both dwellings to the outside, as well as allowing the transmission of sound and odours between dwellings (see Part E Consultation Document, DETR 2001b). This provision will encourage a minimum level of airtightness for such elements, but will avoid unduly penalising compact built forms with low external surface area.

[**] It is expected that typically 10% of dwellings will be tested.

[††] This limiting value can be met by a gas-fired condensing heating system with an annual thermal efficiency of 85%, a rated output of 6 kW and an auxiliary electrical requirement (for boiler fan and circulation pump of 200 W). This level of performance represents good practice at the time of writing, and would be a plausible minimum standard by 2008.

The carbon intensity of useful space and water heat is a recent concept that combines the effects of the carbon intensity of delivered energy, with the conversion efficiency of systems within the dwelling. It treats all heating system and fuel choice options in a consistent and transparent way, based on their carbon dioxide emissions per unit of useful heat output. Carbon intensities of useful space and water heat may be found or calculated according to the rules in Appendix B.

This section is intended to apply to all systems within the dwelling, that are designed to provide space and water heating, and that are not portable appliances. Where space and water heating are provided by a number of separate systems, the weighted average of the carbon intensities for each system shall satisfy the requirement*. This provision would apply eg. where space heating is provided by a primary and a secondary system, and where space and water heating are provided separately. Methods for calculating carbon intensities for useful heat are set out in Appendix B.

Where a heat recovery system is provided which incorporates a device to recover heat from outgoing air or water, this may be allowed for in deriving the carbon intensity for heating.

2.2 Target U Value Method

The dwelling will satisfy this standard if the average U value of the thermal envelope is less than the target U value and if elemental U values are less than those set out in Table 2. The target U value shall be calculated from the following equation:

$$U_{target} = 0.25 - 0.09 \cdot A_{roof}/A_{total} - 0.03 \cdot A_{ground\ floor}/A_{total} + 0.263 \cdot A_{floor}/A_{total}$$

The average U value of the dwelling shall include 1-d transmission according to BS EN ISO 6946: 1997 and 2-d transmission according to BS EN ISO 14683: 1999 and/or BS EN ISO 10211-1: 1995. In equation form:

$$U_{mean} = \frac{\Sigma U_i.A_i + \Sigma \psi_j.l_j}{\Sigma A_i}$$

where:

A_i are the surface areas of plane elements of the dwelling calculated according to internal dimensions (m2)

U_i are the U values for these elements calculated according to BS EN ISO 6946: 1997 (W/m2K)

ψ_j are the linear thermal transmittances for 2-d thermal bridges not included in the computation of Ui and for junctions between major elements of the thermal envelope as indicated in BS EN ISO 14683: 1999 (W/mK)

l_j are the lengths of 2-d thermal bridges and junctions (m)

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[*] To avoid the need to calculate weighted averages, it will be sufficient to show that the carbon intensity of each separate heating system within the dwelling satisfies the criterion.

In addition, the dwelling shall comply with the upper limit on air leakage set out in 2.1.3 and the limit on carbon intensity of space and water heating set out in 2.1.4. If you do not satisfy all of these requirements, the Carbon Rating Method should be used.

Table 2 Maximum elemental U values, not to be exceeded as a result of trade-offs (W/m2K)	
exposed walls	0.3
roofs	0.19
floors	0.26
windows, glazed outer doors & rooflights	1.56

2.3 Carbon Rating Method

The dwelling will comply with this standard if the Carbon Index for space and water heating, as calculated using the Standard Assessment Procedure[*], is 9.1 or greater[†]. The provisions relating to maximum elemental U values (Table 2) and to air leakage (section 2.1.3) must also be satisfied.

2.4 Prevention of summer overheating

To reduce the incidence of overheating in Summer, it is necessary to place upper limits on unprotected window areas[‡]. Limits are expressed in terms of the effective fenestration ratio, feff, for each façade.

feff = g.z.f

where:

g total solar heat gain coefficient of fenestration calculated according to BS EN 410, or certified by the British Fenestration Rating Council

z shading factor (effect of additional solar protection not accounted for in calculation of g)

f fenestration ratio f = Af/(Aw+Af)

Af area of fenestration on given facade

Aw net wall area on given facade

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[*] The Carbon Index was added to a modified SAP as part of the revised Approved Document L1, which is due to come into force in 2002. The modified version is included in the new approved document (DTLR 2001).

[†] This limiting carbon index is achievable with default elemental U values in typical two storey semi-detached dwellings with a gas condensing boiler with an efficiency of 83%. In detached houses, a boiler efficiency in the high 80s would be required.

[‡] This section has been adapted from the current German Building Regulations (Bundesministerium für Wirtschaft 1994). The appropriateness of the limiting values for the UK climate, particularly in the case of medium and low thermal mass dwellings, will need to be confirmed by further work. This work should take into account the likely effects of Climate Change over the next half century. The value given in the German Building Regulations is assumed to apply to dwellings of high thermal mass only.

For all facades clockwise between NE and NW, the effective fenestration ratio shall not exceed the values set out below:

feff ≤ 0.25 for dwellings with high thermal mass (masonry external walls, partitions and floors)

feff ≤ 0.2 for dwellings with intermediate thermal mass (masonry external walls and ground floor)

feff ≤ 0.15 for dwellings with low thermal mass (timber framed external walls and partition walls):

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EN ISO 10211-1: 1996 Thermal bridges in building construction – Heat flows and surface temperatures – Part 1: General calculation methods.

EN 673 ISO 10292 Glass in building: Determination of thermal transmittance (U value) – Calculation method.

BS EN 410 Glass in building: Determination of total solar energy transmittance: Calculation method.

BS EN ISO 14683: 1999 Thermal bridges in building constructions – Linear thermal transmittance – Simplified methods and design values

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Hauser, G. & Stiegel, H. 1996 Wärmebrücken-Atlas für den Mauerwerksbau. Wiesbaden & Berlin: Bauverlag.

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Appendix A. Calculation of elemental U values

The principle to be used in calculating the U value for a building element is that the U value should account for the whole heat flow from the inside to the outside of the dwelling through that element.

Thus:

$U = \Phi/A$

where:

Φ is the total heat flow, measured at the inside surface of the element, for a temperature difference of 1K

A is the area of the element, measured at the inside surface

The U value thus defined, is an average over the whole surface area of the element*. For the purposes of these regulations, total heat flux should include contributions from:

point thermal bridges such as wall ties;

linear thermal bridges within elements (such as structural timber in timber framed walls);

linear thermal bridges associated with window and door reveals;

linear junctions between major elements of the thermal envelope (horizontal junctions between walls and ground floor, horizontal junctions between walls and roofs, vertical junctions between adjacent walls).

The effects of point thermal bridges and linear thermal bridges within elements may be accounted for using BS EN ISO 6946: 1997. The effects of other linear thermal bridges may be estimated using the linear transmission coefficients from an approved encyclopaedia of thermal bridges† or alternatively, they may be calculated by 2 dimensional simulation using the methods described in EN ISO 10211-1‡.

Appendix B. Carbon intensity of space and water heating

Carbon emissions for space and water heating in a building are determined both by the performance of the building thermal envelope, and by the performance of the heating system. The latter depends on the fuels used, the thermal efficiency of the system, and the methods used to control its operation.

These factors can be combined to give the carbon intensity for space and water heating. The carbon intensity of space and water heating is the ratio of total carbon dioxide emissions from a heating system, to the total useful heat output for space and water heating, over a typical year's operation.

---

[*] These definitions of U value and elemental area is consistent with the approach taken by the most widely available 2 dimensional finite element packages. Consistency of approach between hand calculation methods and simulation packages is essential.

[†] See for example, Hauser & Stiegel (1992 & 1996).

[‡] It is, at present, impractical to take into account 3 dimensional heat flows by finite element simulation. While software packages exist, they are relatively expensive and not widely available. It is simple enough to handle minor thermal bridges, such as those caused by wall ties in a masonry wall, by the methods laid out in BS EN ISO 6946: 1997. The additional impact of heat losses at junctions between any three major elements of the thermal envelope (vertices) are an order of magnitude smaller than the effect of edges and, unless poorly detailed, may be safely neglected at this stage.

To a first approximation, the carbon intensity of space and water heating can be estimated from the following equation:

$$ch = cd/\eta$$

where:

ch = carbon intensity of useful heat (kg(CO2)/GJ)

cd = carbon intensity of delivered energy (kg(CO2)/GJ)

η = thermal efficiency or coefficient of performance of heating system*

Values for the carbon intensity of delivered energy may be taken from Table 15, and values for system thermal efficiencies may be taken from Tables 4a to 4c of SAP98 Appendix D.

The concept of carbon intensity of space and water heat is intended to include the effects of auxiliary electricity consumption in systems whose main source of energy is non-electrical – for example mains gas fired boilers. In the case of a gas-fired central heating system, the ratio of the heat output of the boiler to the electrical power required to operate the system can referred to as the heat-to-power ratio. For such a system

$$ch = cd, gas/\eta + cd,el/p$$

where:

cd, gas = carbon intensity of delivered gas

cd,el = carbon intensity of delivered electricity

p = heat-to-power ratio of the system

This concept may be extended to include the effect of electrical heat pumps and systems with heat recovery (eg. mvhr systems). The heat-to-power ratio of such systems is normally referred to as the coefficient-of-performance (cop). For such systems, the first term in the above equation is zero (they use no gas), and the equation may be re-written:

$$ch = cd,el/cop$$

Where space and water heating are provided by a number of separate sub-systems, carbon intensity may be calculated according to the following general equation:

$$ch = \Sigma\ fi\ .\ ch,i$$

where:

---

[*] The carbon intensities of delivered energy presented in SAP98 are based on the gross calorific values of the respective fuels. The numerical values of the carbon intensities of useful heat are not affected by choice of definition of calorific value for fuels. However the values of thermal efficiency and carbon intensity of delivered energy used in calculating carbon intensities of useful heat must be based on a consistent definition of calorific value.

fi = fraction of total space and water heat provided by the i-th sub-system

ch,i = the carbon intensity of useful heat output for the i-th sub-system

The following carbon intensities for space and water heating have been determined using the procedures described above.

Table B1 Carbon intensities for space and water heating (kg (CO2)/GJ)	
direct resistance, on-peak electric heating	142
electric heat pump, annual COP 2.5	57
gas fired condensing boiler, thermal efficiency 85% (based on gross cv), heat-to-power ratio 30.	68

Prototype performance standard for ventilation and indoor air quality

Objectives of the requirements

The primary objectives of this part of the prototype standard are to ensure:

that buildings are constructed so as to ensure satisfactory indoor air quality in normal use, while at the same time limiting energy use for space heating. This standard , together with the associated prototype standard relating to energy performance in part 1, will ensure that buildings in normal use will be adequately ventilated, free from condensation and mould, and in the case of dwellings, that excessive summertime temperatures can be avoided.

These objectives are to be met primarily by:

requiring the provision of adequate means of ventilation

preventing over-ventilation under adverse weather conditions

eliminating sources of air pollutants from the indoor environment

1. Ventilation

Adequate fresh air shall be supplied through direct openings to the outside or by means of a mechanical ventilation system.

Ventilation systems shall be designed in accordance with appropriate codes of practice, which will ensure that they are properly designed and constructed with respect to health and safety (including fire), energy conservation and indoor climate (including air quality and thermal comfort). Mechanical ventilation systems shall be so constructed and installed that they do not supply the ventilated space with substances, including micro-organisms, which make the indoor climate unsatisfactory with respect to health.

Air transfer, including recirculation of air between rooms, may only take place from rooms with fresher air to rooms with staler air.

Ventilation systems shall be designed and constructed to allow proper and safe cleaning and maintenance of ducts, fans and filters*.

Ventilation systems shall be equipped with measuring points for checking operating conditions and energy consumption*.

---

[*] Current Danish Regulations add that they shall be properly operated and maintained. This may be desirable, but may not be enforceable in UK dwellings.

1.1 Dwellings

Provision shall be made in dwellings for[†]:

rapid ventilation

background ventilation

1.1.1 Rapid ventilation

Habitable rooms, kitchens and bathrooms shall be provided with means for rapid ventilation, to remove indoor air contaminants and to limit overheating in Summer[‡]. In habitable rooms, such means may include one or more ventilation openings (eg. an opening window) with some part of each opening at high level (typically 1.75 m above floor level). In kitchens, a capability to boost the rate of mechanical extraction (during cooking) to 30 l/s from a point above the hob, should be provided in addition to ventilation openings.

Opening areas in habitable rooms should be a minimum of 1/20 of floor area.

1.1.2 Background ventilation

Means shall be provided to ensure the continuous air flow rates set out in Tables 1a & 1b. Where the total air flow through the dwelling, calculated on this basis, is less than 5 litres of fresh air per second per person (5 l/s/p) at design occupancy, individual room ventilation rates shall be increased in proportion to provide a total air flow through the dwelling of 5 l/s/p. Background ventilation shall be provided in a manner that limits over-ventilation under adverse weather conditions (high winds and/or large inside-outside temperature differences).

Table 1a Minimum air supply requirements for category A rooms (litres/second)[§]	
double bedroom	10
single bedroom	5
living room	5
dining room	5
other habitable room	5

---

[*] This is particularly important in the case of balanced, ducted MVHR systems, where poor commissioning and maintenance can both significantly degrade performance.

[†] This document uses the basic structure of the current Approved Document (ADF95), but explicitly acknowledges the need for rapid ventilation to control overheating in Summer.

[‡] This paragraph follows the provisions of the current Part F1, except where superseded by requirements for continuous mechanical ventilation.

[§] The figures in Tables 1a and 1b have been taken from CSA F326 M91 (1993 amendment), except for the extract rate for kitchens, which has been taken from the Current Danish Building Regulations. Ventilation of kitchens is complicated by the need to provide high flow rates for relatively short periods of time, and by the need to avoid fouling ductwork in ducted systems.

Table 1b Minimum air extract requirements for category B rooms (litres/second)	
kitchen	20
bathroom	10
separate wc	10

The total air flow rate through the dwelling shall be the larger of the sum of air supply requirements according to Table 1a and air extract requirements according to Table 1b. The excess in either case shall be distributed, pro rata, over the category A or B rooms, as appropriate.

Background ventilation should be provided by a primary ventilation system, which may be:

a mechanical extract system combined with means for the direct admission of outside air to rooms (eg. trickle vents)*;

a balanced mechanical ventilation system;

any other system that can be shown to provide equivalent air quality to the above, while limiting over-ventilation under adverse weather conditions.

1.1.3 Design of ventilation systems

Where domestic mechanical ventilation systems are fitted with air-to-air heat recovery devices, supply and extract air flows must be balanced.

Background ventilation systems shall be equipped with controls to allow the total air flow rate to be reduced to 50% of the minimum set out in Tables 1a & 1b, to allow for periods when the dwelling may be unoccupied.†

1.1.4 Provision of secondary means of ventilation

In the case of habitable rooms, bathrooms, wc's and kitchens, additional means shall be provided to ensure adequate background ventilation under conditions when the primary ventilation system is not operational‡. Such means shall include a window with a secure opening position corresponding to a free area of 8000 mm2 per 10 m2 of floor area, with an absolute minimum of 8000 mm2.

---

[*] The provision of continuously operating extract fans allows trickle vents to be significantly smaller than are allowed under the current UK Building Regulations. Current Danish Regulations require "fresh air valves" with a minimum area of 3000 mm^2 per 25 m^2 of floor area in habitable rooms. This is in the region of one fifth of the area required by the current UK Regulations. Smaller fixed vents, coupled with airtight construction (see part 1), reduce the effect of weather on ventilation rates in the dwelling.

[†] An obvious technical development would be to connect such controls to systems for measuring air quality in the dwelling. Relative humidity and carbon dioxide concentration, taken together, would form an appropriate measure of air quality.

[‡] This allows for the provision of adequate ventilation when the primary ventilation system is under repair, during power cuts, and for other unforeseen eventualities. The opening areas specified have been taken from the current Approved Document Part F1. Details for secure opening of windows are provided in the current Approved Document.

2. Elimination of contaminants from indoor air

Provisions will be made to eliminate products of combustion, formaldehyde, methane and radon from the indoor environment.*

2.1 Products of combustion

There will be a general presumption against the use of open-flued appliances in dwellings. The only exception to this will be gas cooking appliances (hobs and ovens).† Provision must be made to allow the extraction of air from the vicinity of such appliances during the cooking process (see paragraph 1.1.1).

2.2 Formaldehyde emissions

Emissions of formaldehyde will be controlled at source, through regulations to limit the emission rates from wood products (chipboard, hardboard, MDF etc.) used in the indoor environment.

2.3 Radon, methane and other gaseous emissions from sub-soil

Radon and other emissions from the ground, will be controlled by requiring airtight ground floor and basement constructions in susceptible areas of the UK. Other measures, including the provision of balanced as opposed to extract ventilation, may be required at the discretion of the Building Control Officer.

References

BRE 1994 Continuous Mechanical Ventilation in Dwellings: Design Installation and Operation. BRE Digest 398. Watford: BRE.

CSA F326 M91 Residential Mechanical Ventilation Systems 1993 amendment. Toronto, Canadian Standards Association.

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[*] Indoor air quality requires both the provision of ventilation and the control of sources of airborne contaminants. It seems appropriate to extend the scope of the current Part F1 to include the latter. This section is not complete, but gives an indication of what would be needed.

[†] This requirement over-rides the provisions of the current Approved Document J. It acknowledges the mortality and ill-health that currently result from such appliances, and the fact that such problems will be more difficult to eliminate in buildings that are significantly more airtight than current practice. Bringing Part J into line with this proposal will considerably simplify it. In practice, open-flued appliances would be unlikely to meet the performance requirements of the draft prototype standard on energy performance (Lowe and Bell 2001).

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DOE & WELSH OFFICE 1994 Building Regulations Approved Document, Part F1: Means of Ventilation. London: HMSO.

Appendix 2: Thermal bridging catalogue (Proposed Draft Details)

DRAFT PROPOSED THERMAL BRIDGING DETAILS 2008

Evaluating the Impact of an Enhanced Energy Performance Standard on Load-bearing Masonry Domestic Construction

PII Contract CI 39/3/663

David Roberts

September 2003

LEEDS METROPOLITAN UNIVERSITY

Introduction

This catalogue is a draft proposal for one method of including thermal bridging into the U value calculation to be used as part of Building Regulation Part L compliance in or around 2008.

The construction details included are based on Bryant and Redrow designs made with additional design input from the research team at Leeds Metropolitan University under the PII project:

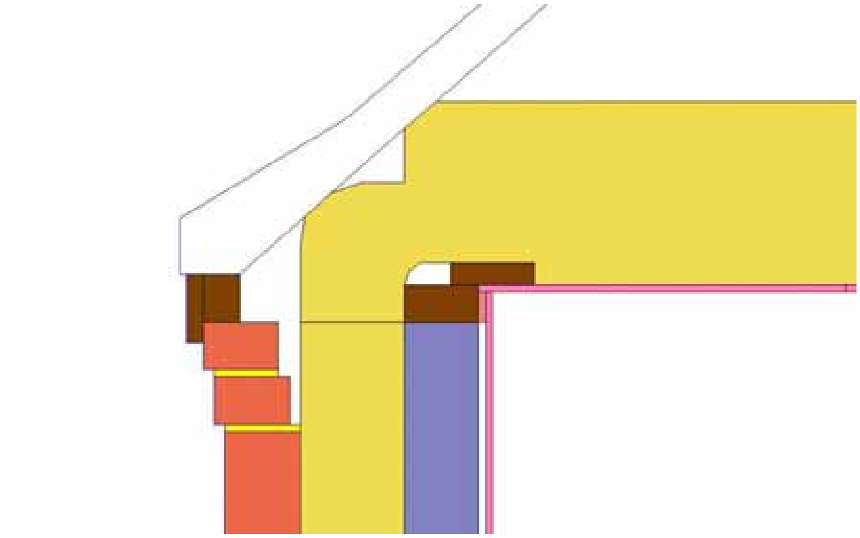
> “Evaluating the Impact of an Enhanced Energy Performance Standard on Load-bearing Masonry Domestic Construction (ref. CI 39/3/663).”

Only details relevant to the project have been included: a limited range of masonry details and no timber frame details are shown.

Each detail is illustrated in a comparable manner to the existing 2002 Part L Robust Details with the addition of thermal performance data to be used to calculate actual U values (nominal U values plus additional thermal bridging heat loss). This similarity in presentation is purely to allow additional thermal performance data to be expressed within a format that is already familiar to the Construction Industry and is not intended to be an official Government publication. Nor is it suggested that this format will officially be adopted in or after 2008. The catalogue is merely a research tool for this particular PII project only.

The catalogue can be used to select the correct thermal performance data for a particular construction detail. That value can then be entered in the ‘Domestic Energy Calculator’ which is a SAP-based Excel spreadsheet which accompanies this catalogue.

Cold roof junction at eaves. Pitched roof. Ventilated loft. Eaves.



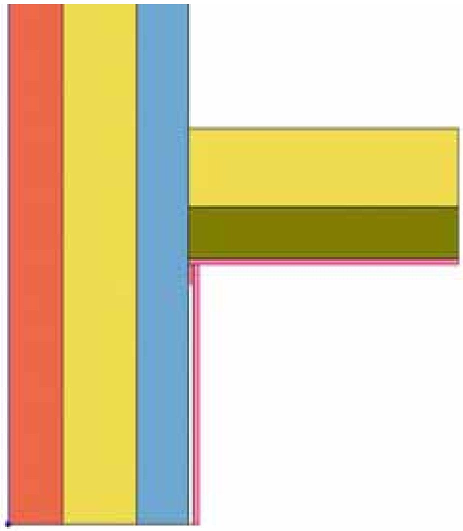
Thermal performance data		
Nominal U value of cold roof	0.1416	*(W/m^{2}K)*
Psi value of junction	0.0432	*(W/mK)*

Notes

1.
2.
3.
4.

Masonry: Cavity Wall Insulation: Full-Fill

Cold roof junction at gables. Gable – cold roof.



Thermal performance data		
Nominal U value of cold roof	0.1416	*(W/m^{2}K)*
Psi value of junction	0.1049	*(W/mK)*

Notes

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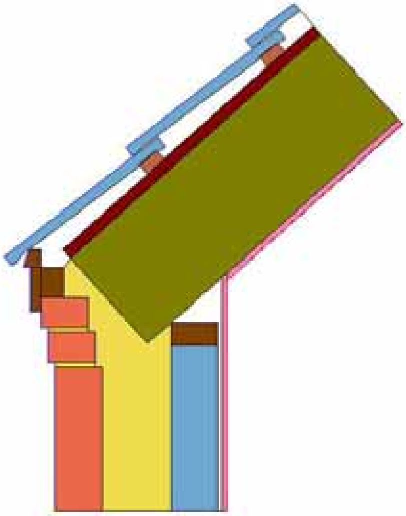
Masonry: Cavity Wall Insulation: Full-Fill

Warm 'room in the roof' junction at eaves.



Thermal performance data		
Nominal U value of warm roof	0.1519	*(W/m^{2}K)*
Psi value of junction	0.0421	*(W/mK)*

Notes

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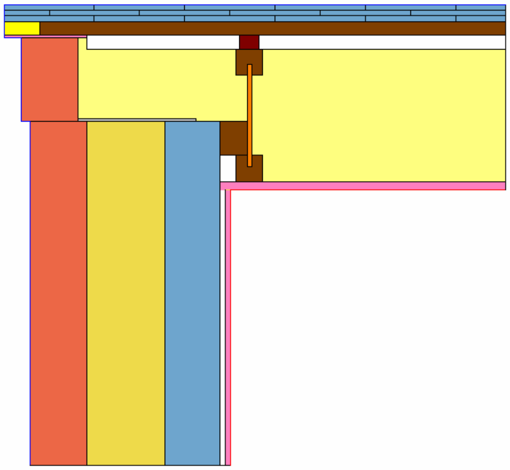
Masonry: Cavity Wall Insulation: Full-Fill

Warm 'room in the roof' junction at gables.



Thermal performance data		
Nominal U value of warm roof	0.1519	*(W/m^{2}K)*
Psi value of junction	0.1069	*(W/mK)*

Notes

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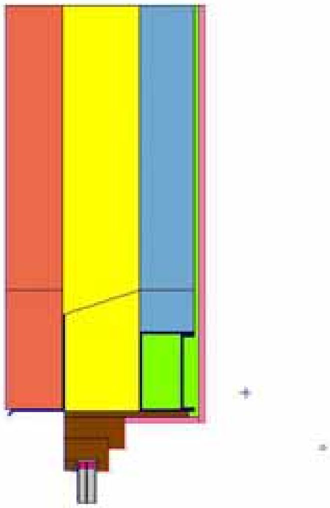
3.

Wall junction with heads. Windows and doors. Separate steel lintels.

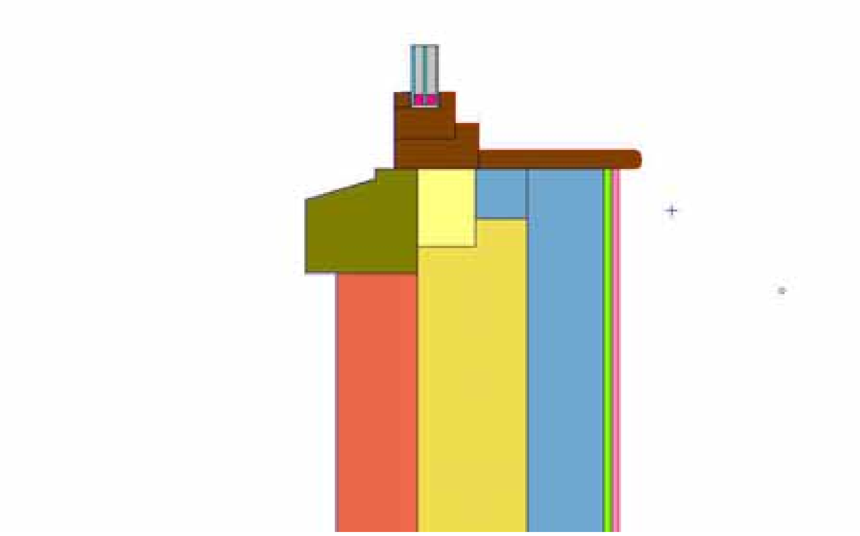


Thermal performance data		
Nominal U value of wall	0.2299	*(W/m²K)*
Psi value of junction	0.0159	*(W/mK)*

Notes

1. Fully fill area between cavity tray and top of cavity-closing liner with blown insulation.
2.
3.
4.

Wall junction with sills. Windows and doors. Sills.



Thermal performance data		
Nominal U value of wall	0.2299	*(W/m^{2}K)*
Psi value of junction	0.0222	*(W/mK)*

Notes

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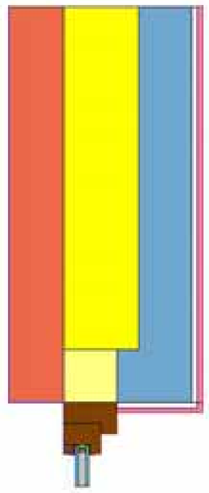
2.
3.

Masonry: Cavity Wall Insulation: Full-Fill

Wall junction with jambs. Windows and doors. Jambs.



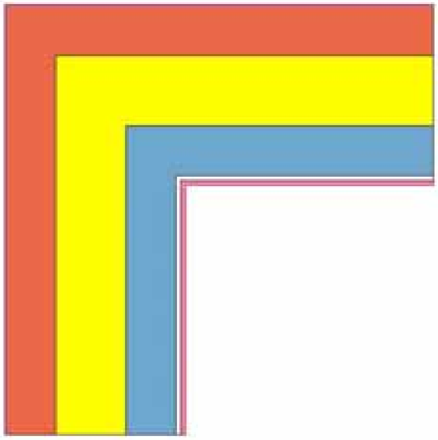
Thermal performance data		
Nominal U value of wall	0.2299	*(W/m^2K)*
Psi value of junction	0.0183	*(W/mK)*

Notes

1. Rockclose cavity closer 100mm wide.
2.
3.

Masonry: Cavity Wall Insulation: Full-Fill

Wall-wall junction (external).



Thermal performance data		
Nominal U value of wall	0.2299	*(W/m^{2}K)*
Psi value of junction	0.0704	*(W/mK)*

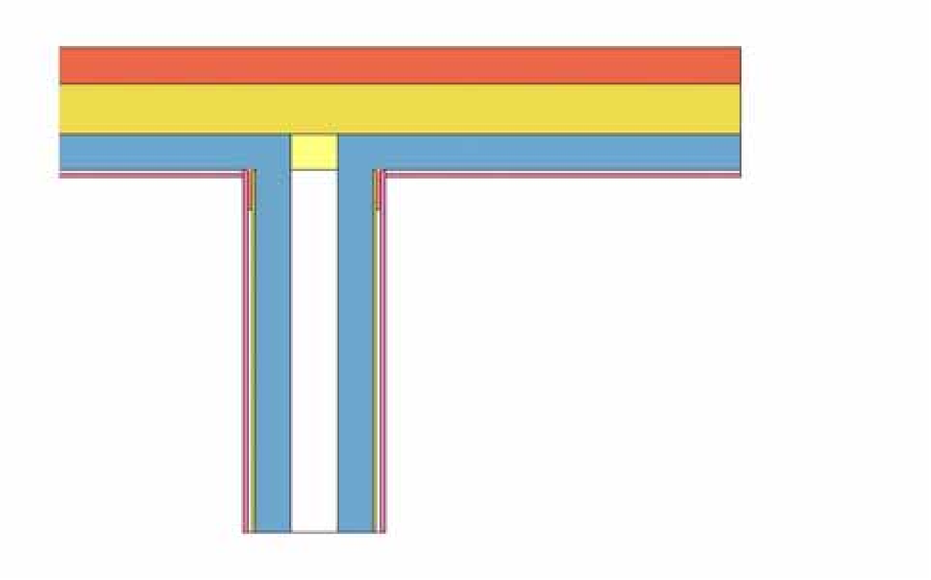
Notes

1. Use the same psi value for each external wall-wall junction, even if built at angles other than 90 degrees.

2. Psi values of internal corners are equal and opposite to external corners. If a house has an internal corner, it must have an additional external corner. As an example: a regular detached house has four corners. The same house in an L-shaped configuration has five external corners and one internal. In this case, the internal corner cancels out the additional external corner and so the junction length is made up of four of the corners only.

3.

Wall junction with separating (party) wall.



Thermal performance data		
Nominal U value of wall	0.2299	*(W/m^2K)*
Psi value of junction	0.0000	*(W/mK)*

Notes

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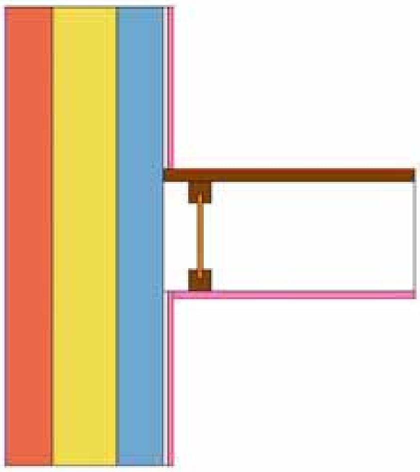
2.
3.

Masonry: Cavity Wall Insulation: Full-Fill

Wall junction with intermediate floors. I-beam.



Thermal performance data		
Nominal U value of wall	0.2299	*(W/m^2K)*
Psi value of junction	0.0034	*(W/mK)*

Notes

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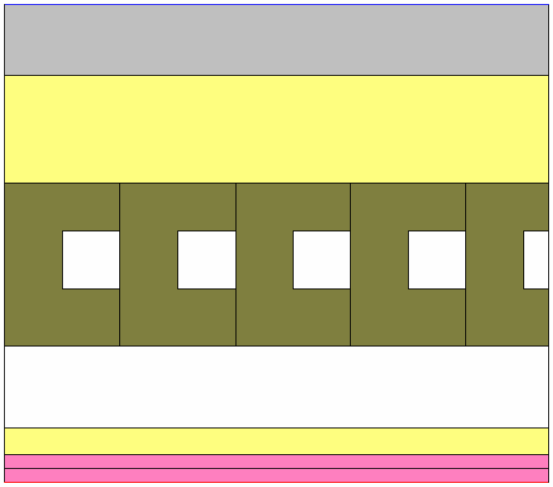
2.
3.

Masonry: Cavity Wall Insulation: Full-Fill

Floor above integral garage. Concrete.



Thermal performance data		
Nominal U value of floor above integral garage	0.2091	*(W/m^{2}K)*
Psi value of junction		*(W/mK)*

Notes

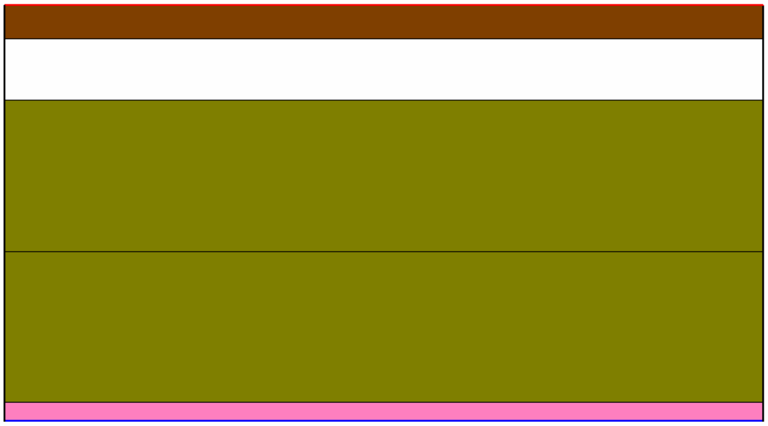
1. Bison concrete sound slab 150mm deep with a density of 308kg/m^2.

2. Gyproc Gyplyner concealed metal framed ceiling system with a 75mm void with a min 25mm isowool acoustic partition roll with 2 x layers of 12.5mm soundbloc board.

3. 100mm Rockwool Rockfloor insulation with a min density of 36kg/m 3 with 65mm sand cement screed on top with anti crack mesh.

4. The insulation is to be turned up the inside wall separating the screed edge from the wall, min 25mm thick, with a layer of 30mm Gyproc Thermal board to the internal blockwork face.

Floor above integral garage. I-beam.

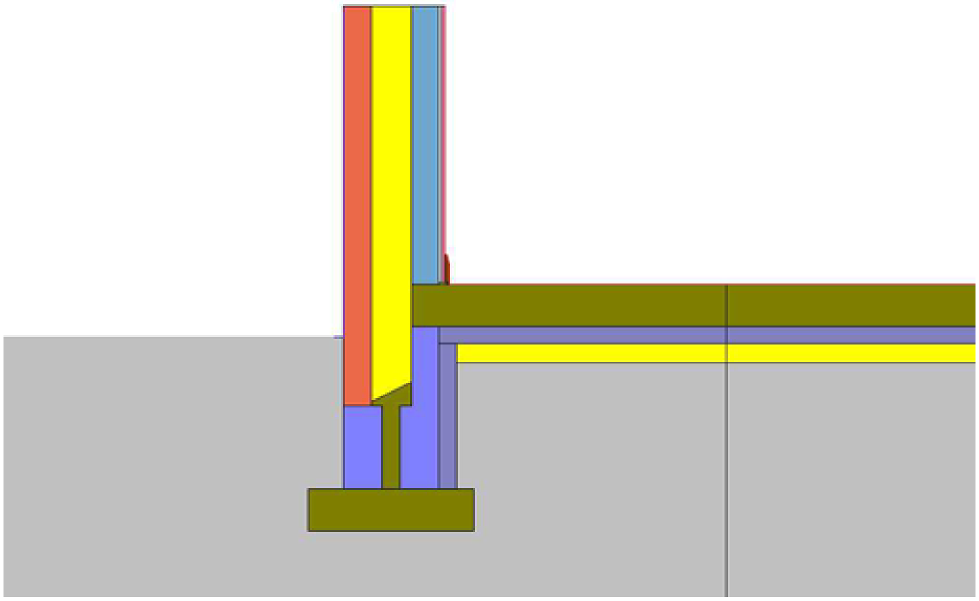


Thermal performance data		
Nominal U value of floor above integral garage	0.1826	*(W/m^{2}K)*
Psi value of junction		*(W/mK)*

Notes

1. 22mm chipboard
2. 241 TJI I beams at 600 ctrs
3. 2x100mm insulation quilt (k=0.042W/mK) between beams
4. 12.5mm Fireline plasterboard

In-situ suspended ground floor slab. Insulation below slab.



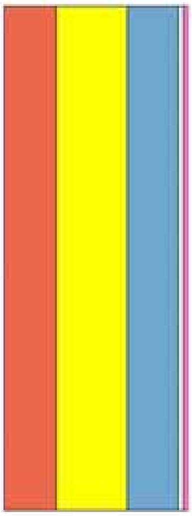
Thermal performance data		
Nominal U value of ground floor	0.1878	*(W/m^{2}K)*
Psi value of junction	0.1011	*(W/mK)*

Notes

1.
2.
3.

Masonry: Cavity Wall Insulation: Full-Fill

Wall.



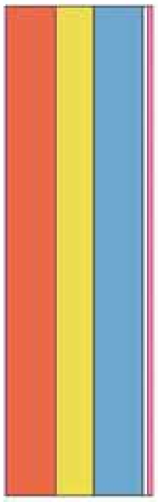
Thermal performance data		
Nominal U value of wall	0.2299	*(W/m^{2}K)*

Notes

1. Plastic wall ties.
2. 103mm facing brick.
3. 142mm fully filled cavity using Rockwool blown Energy Saver (λ = 0.039 W/mK).
4. 100mm medium dense blockwork (λ = 0.47-0.51 W/mK).
5. 9.5mm plasterboard drylining.

Masonry: Cavity Wall Insulation: Full-Fill

Wall at staggered terraces using separating wall cavity width (77mm).



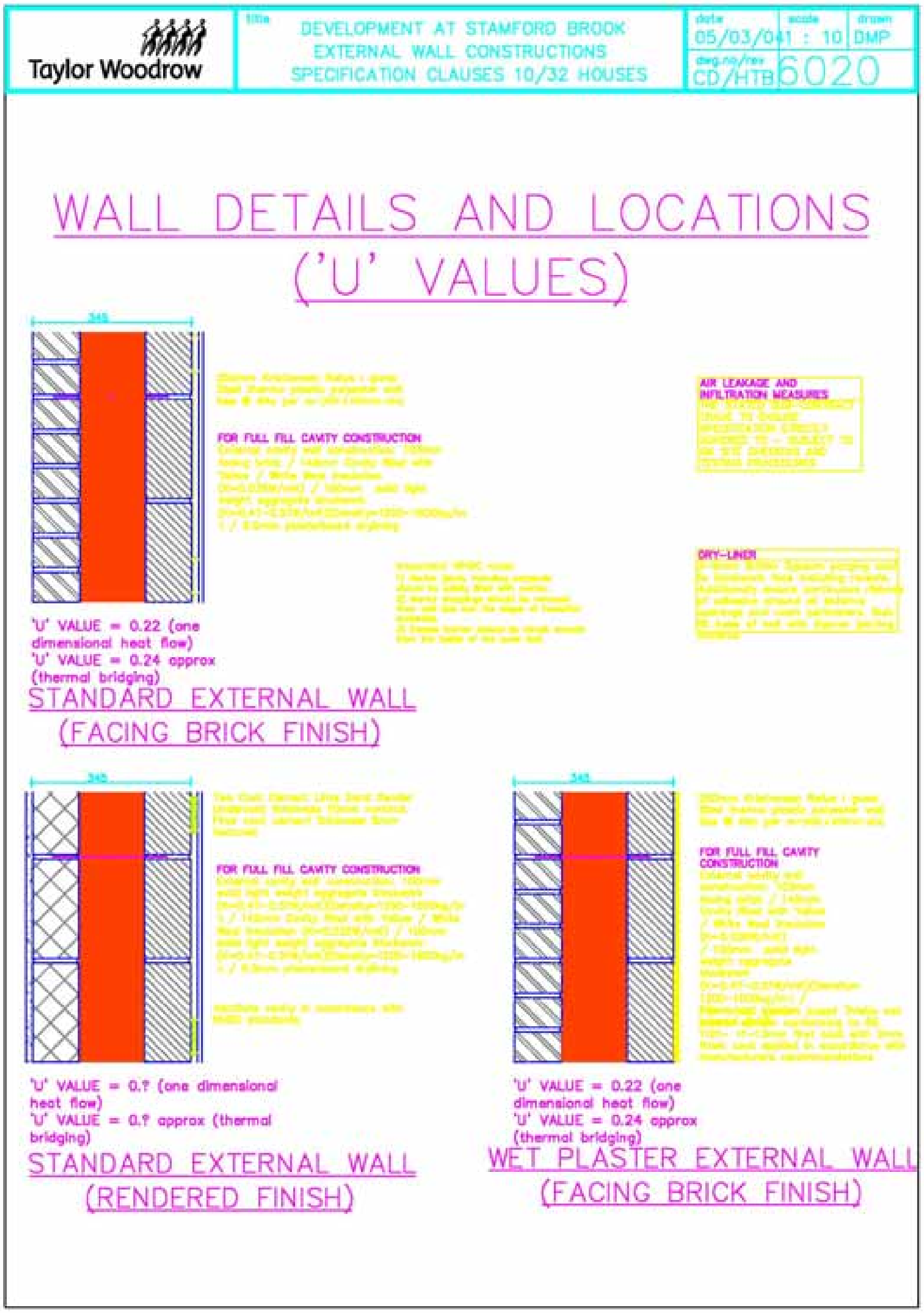
Thermal performance data		
Nominal U value of wall (type 3)	0.3727	*(W/m^{2}K)*

Notes

1. This wall (type 3) to be used for those walls in staggered terraces that have the same cavity width as the separating wall (77mm).
2. Plastic wall ties.
3. 103mm facing brick.
4. 142mm fully filled cavity using Rockwool blown Energy Saver (λ = 0.039 W/mK).
5. 100mm medium dense blockwork (λ = 0.47-0.51 W/mK).
6. 9.5mm plasterboard drylining.

Masonry: Cavity Wall Insulation: Full-Fill

Appendix 3: Detail drawings


Taylor Woodrow
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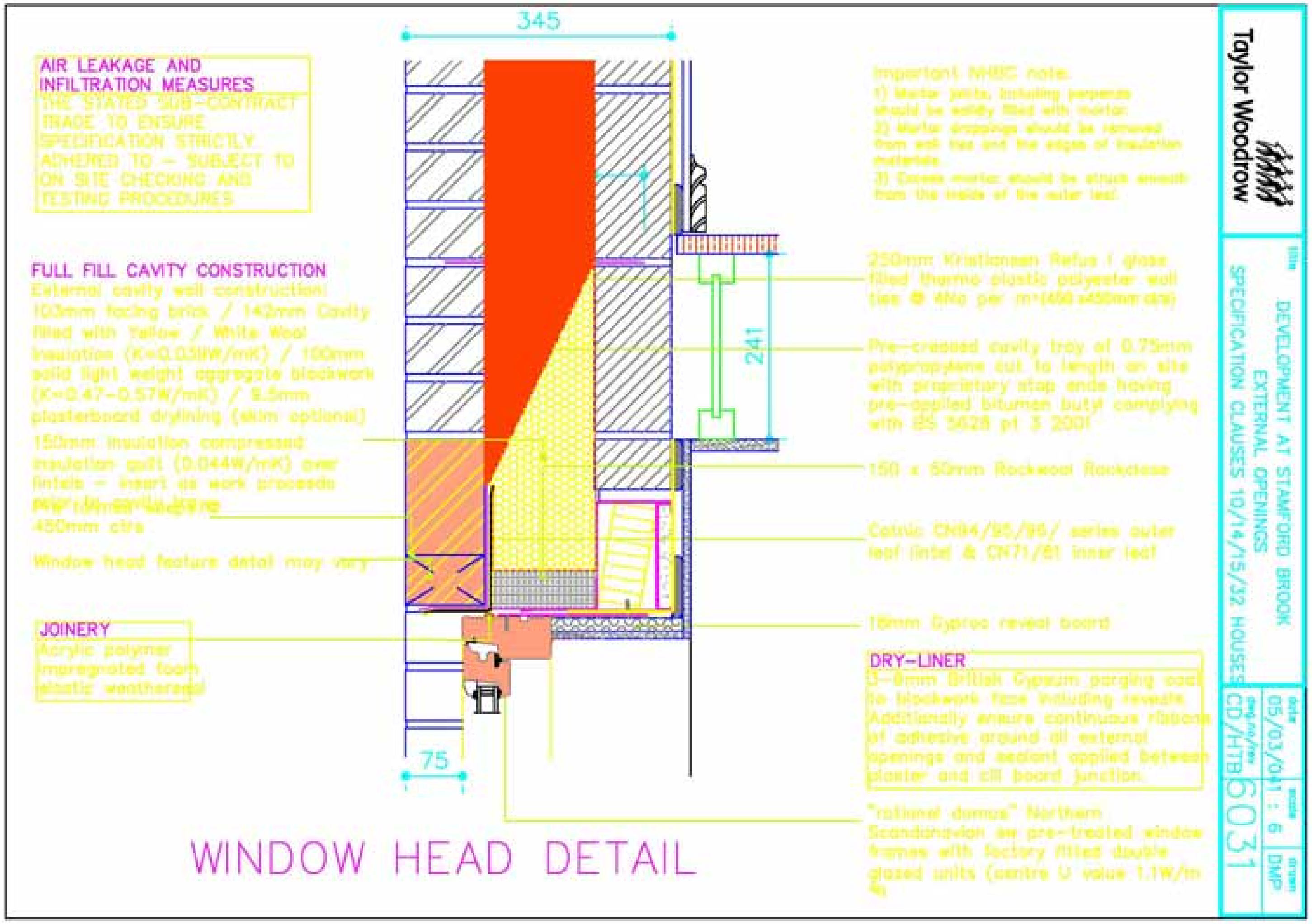
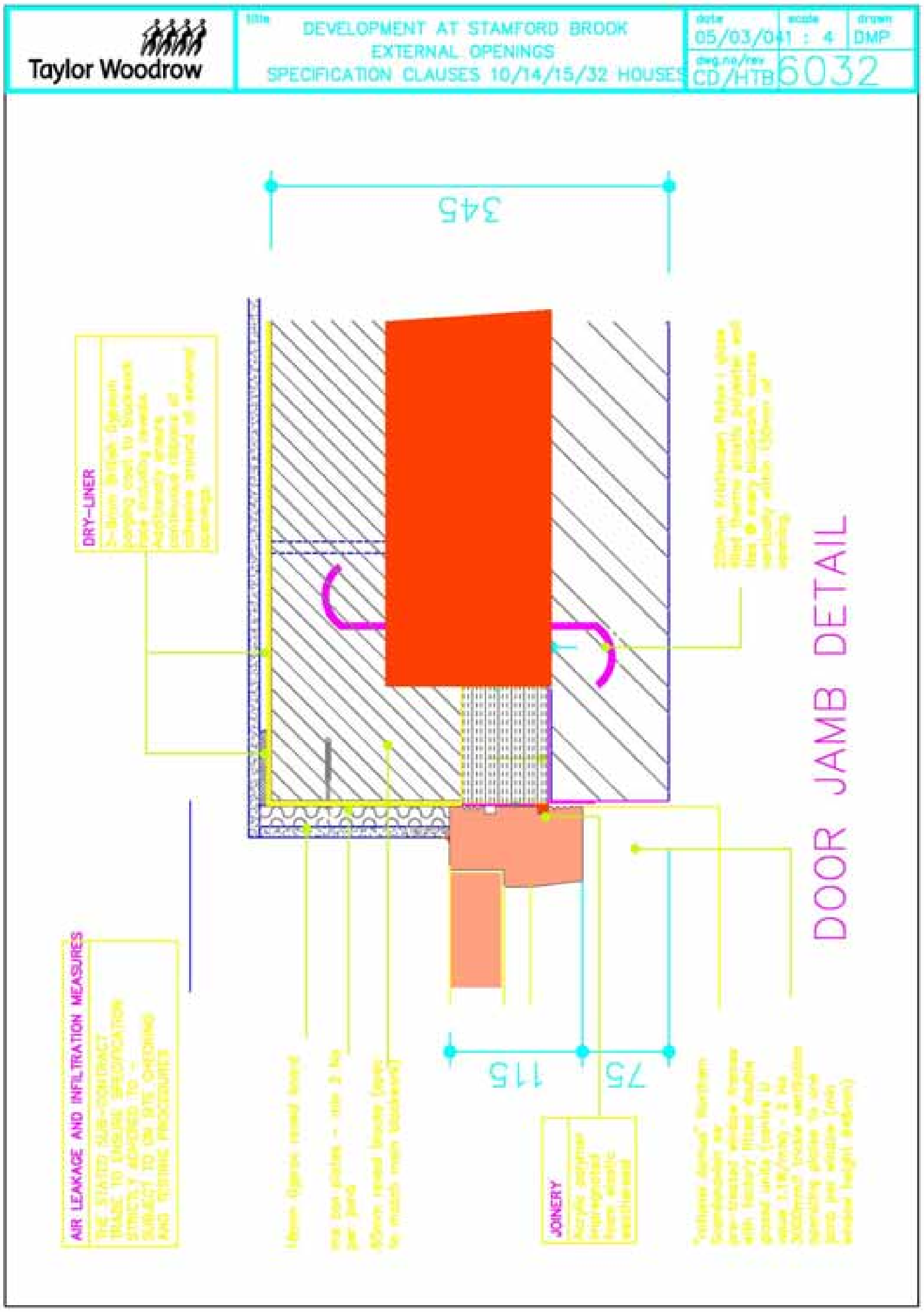
DEVELOPMENT AT STAMFORD BROOK
EXTERNAL WALL CONSTRUCTIONS
SPECIFICATION CLAUSES 10/32 HOUSES
date
05/03/04
scale
1 : 10
drawn
DMP
dwg.no/rev
CD/HTB6020
WALL DETAILS AND LOCATIONS
('U' VALUES)
345
FOR FULL FILL CAVITY CONSTRUCTION
AIR LEAKAGE AND INFILTRATION MEASURES
DRY-LINER
'U' VALUE = 0.22 (one dimensional heat flow)
'U' VALUE = 0.24 approx (thermal bridging)
STANDARD EXTERNAL WALL
(FACING BRICK FINISH)
345
FOR FULL FILL CAVITY CONSTRUCTION
'U' VALUE = 0.? (one dimensional heat flow)
'U' VALUE = 0.? approx (thermal bridging)
STANDARD EXTERNAL WALL
(RENDERED FINISH)
345
FOR FULL FILL CAVITY CONSTRUCTION
'U' VALUE = 0.22 (one dimensional heat flow)
'U' VALUE = 0.24 approx (thermal bridging)
WET PLASTER EXTERNAL WALL
(FACING BRICK FINISH)


Taylor Woodrow
title
DEVELOPMENT AT STAMFORD BROOK
EXTERNAL OPENINGS
SPECIFICATION CLAUSES 10/14/15/32 HOUSES
date
05/03/04
scale
1 : 6
drawn
DMP
dwg.no/rev
CD/HTB 6031
345
241
75
AIR LEAKAGE AND INFILTRATION MEASURES
THE STATED SUB-CONTRACT TRADE TO ENSURE SPECIFICATION STRICTLY ADHERED TO – SUBJECT TO ON SITE CHECKING AND TESTING PROCEDURES
FULL FILL CAVITY CONSTRUCTION
External cavity wall construction: 103mm facing brick / 142mm Cavity filled with Yellow / White Wool Insulation (K=0.038W/mK) / 100mm solid light weight aggregate blockwork (K=0.47–0.57W/mK) / 9.5mm plasterboard drylining (skim optional)
150mm insulation compressed insulation quilt (0.044W/mK) over lintels – insert as work proceeds
PVC 10mm weepholes @ 450mm ctrs
Window head feature detail may vary
JOINERY
Acrylic polymer impregnated foam plastic weatherseal
Important NHBC note:
1) Mortar joints, including perpends should be solidly filled with mortar.
2) Mortar droppings should be removed from wall ties and the edges of insulation materials.
3) Excess mortar should be struck smooth from the inside of the outer leaf.
250mm Kristiansen Refus I glass filled thermo plastic polyester wall ties @ 4No per m² (450 x 450mm ctrs)
Pre-creased cavity tray of 0.75mm polypropylene cut to length on site with proprietary stop ends having pre-applied bitumen butyl complying with BS 5628 pt 3 2001
150 x 50mm Rockwool Rockclose
Catnic CN94/95/96/ series outer leaf lintel & CN71/81 inner leaf
18mm Gyproc reveal board
DRY-LINER
3–8mm British Gypsum parging coat to blockwork face including reveals. Additionally ensure continuous ribbons of adhesive around all external openings and sealant applied between plaster and cill board junction.
"rational domus" Northern Scandinavian are pre-treated window frames with factory fitted double glazed units (centre U value 1.1W/m²K)
WINDOW HEAD DETAIL



Taylor Woodrow

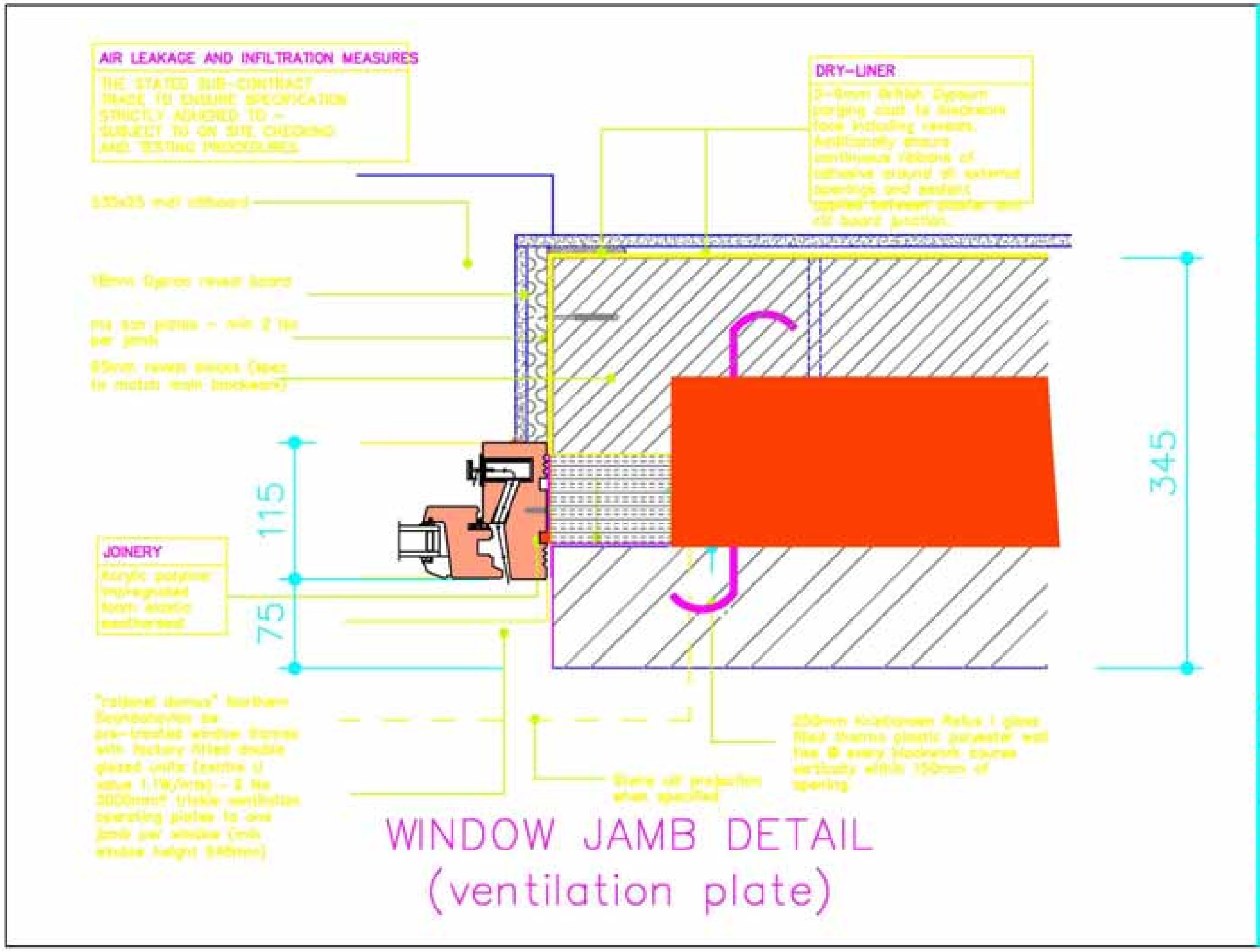
title DEVELOPMENT AT STAMFORD BROOK
EXTERNAL OPENINGS
SPECIFICATION CLAUSES 10/14/15/32 HOUSES

date 05/03/04 | scale 1 : 4 | drawn DMP
dwg.no/rev CD/HTB 6032

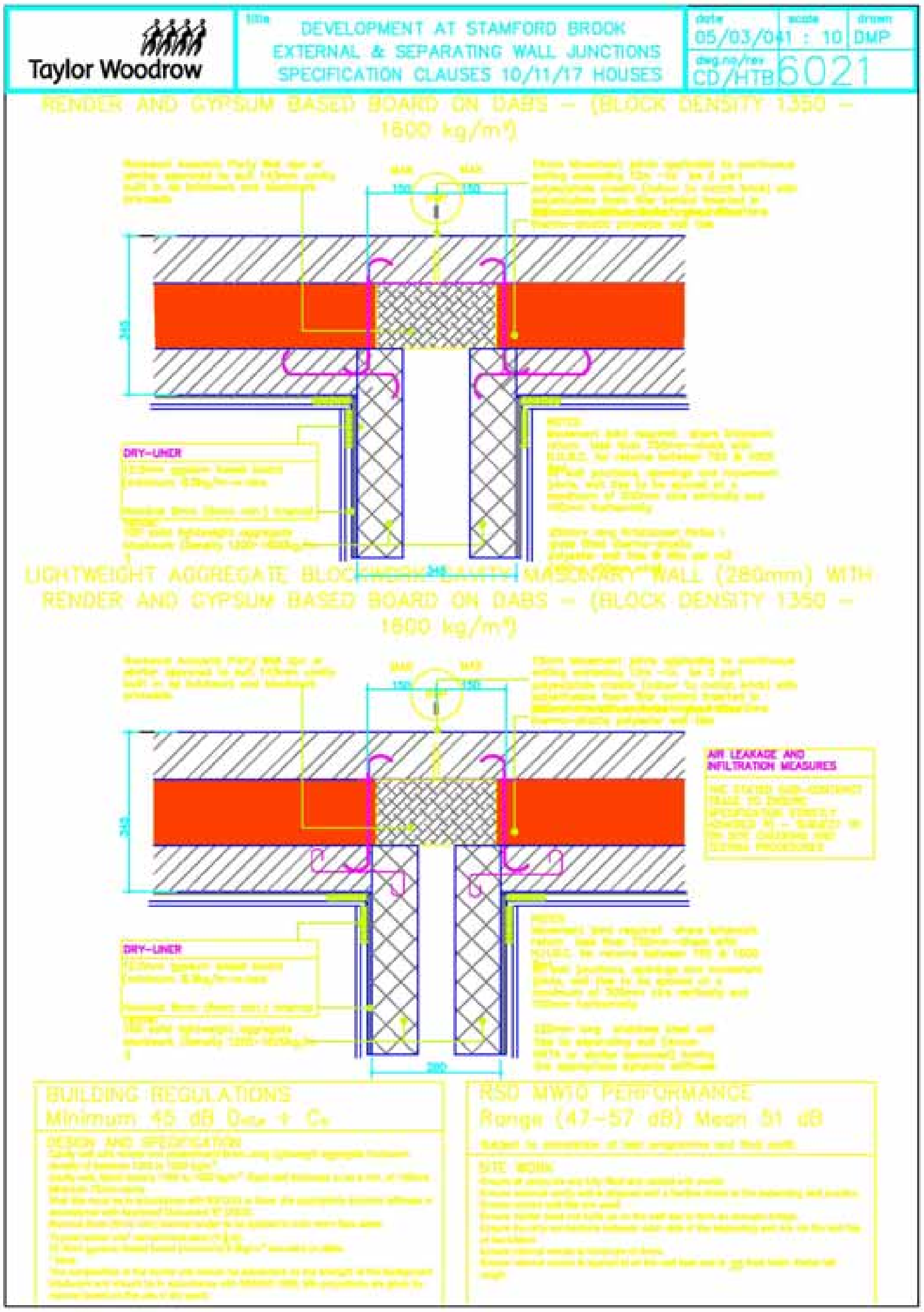
Taylor Woodrow

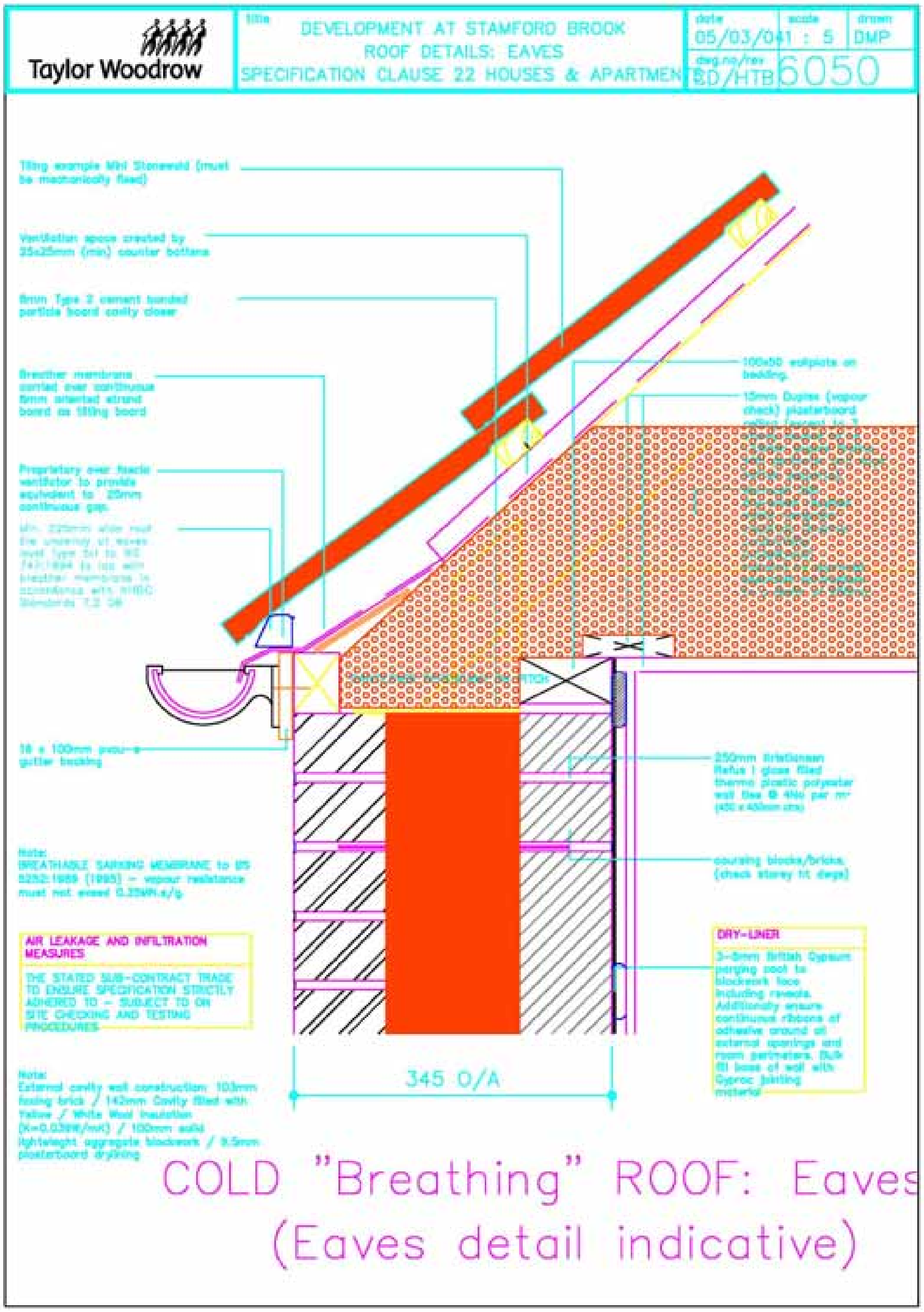
title
DEVELOPMENT AT STAMFORD BROOK
EXTERNAL OPENINGS
SPEC CLAUSES 10/14/15/32 HOUSES & APARTMENTS

date	scale	drawn
05/03/04	1 : 4	dmp
dwg no/rev SB/HTB	6030	



WINDOW JAMB DETAIL
(ventilation plate)


Taylor Woodrow
title
DEVELOPMENT AT STAMFORD BROOK
EXTERNAL & SEPARATING WALL JUNCTIONS
SPECIFICATION CLAUSES 10/11/17 HOUSES
date
05/03/04
scale
1 : 10
drawn
DMP
dwg.no/rev
CD/HTB
6021
RENDER AND GYPSUM BASED BOARD ON DABS – (BLOCK DENSITY 1350 – 1600 kg/m³)
MAX
150
MAX
150
DRY-LINER
NOTES:
LIGHTWEIGHT AGGREGATE BLOCKWORK CAVITY MASONRY WALL (280mm) WITH RENDER AND GYPSUM BASED BOARD ON DABS – (BLOCK DENSITY 1350 – 1600 kg/m³)
AIR LEAKAGE AND INFILTRATION MEASURES
280
BUILDING REGULATIONS
Minimum 45 dB $D_{nT,w}$ + C_{tr}
DESIGN AND SPECIFICATION
RSD MW10 PERFORMANCE
Range (47–57 dB) Mean 51 dB
SITE WORK



Note:
BREATHABLE SARKING MEMBRANE to BS 5250:1989 (1995) – vapour resistance must not exceed 0.25MN.s/g

AIR LEAKAGE AND INFILTRATION MEASURES

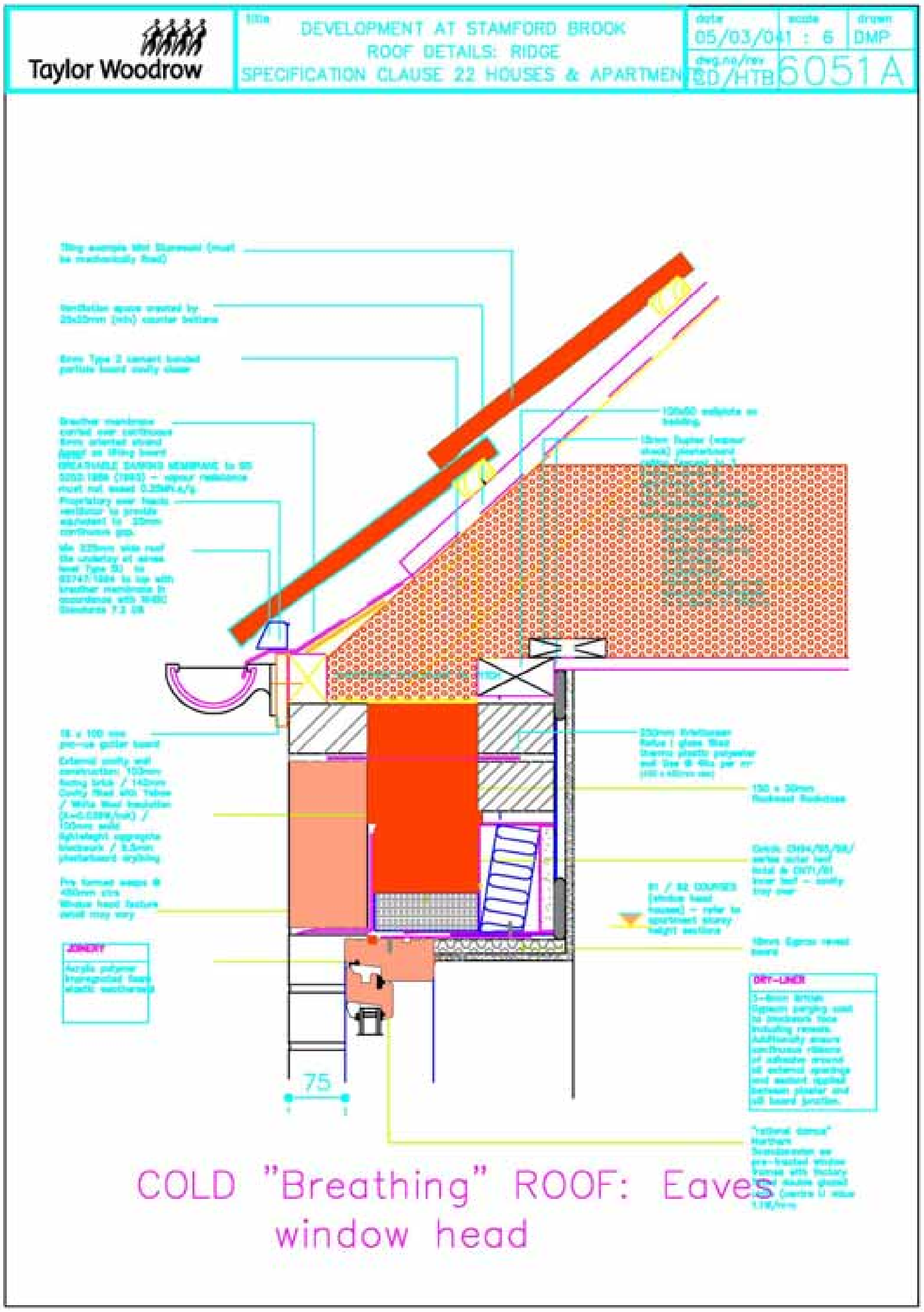
THE STATED SUB-CONTRACT TRADE TO ENSURE SPECIFICATION STRICTLY ADHERED TO – SUBJECT TO ON SITE CHECKING AND TESTING PROCEDURES

DRY-LINER

3-5mm British Gypsum parging coat to blockwork face including reveals. Additionally ensure continuous ribbons of adhesive around all external openings and room perimeters. Bulk fill base of wall with Gyproc jointing material

Note:
External cavity wall construction: 103mm facing brick / 142mm Cavity filled with Yellow / White Wool Insulation (K=0.039W/mK) / 100mm solid lightweight aggregate blockwork / 9.5mm plasterboard drylining

COLD "Breathing" ROOF: Eaves
(Eaves detail indicative)

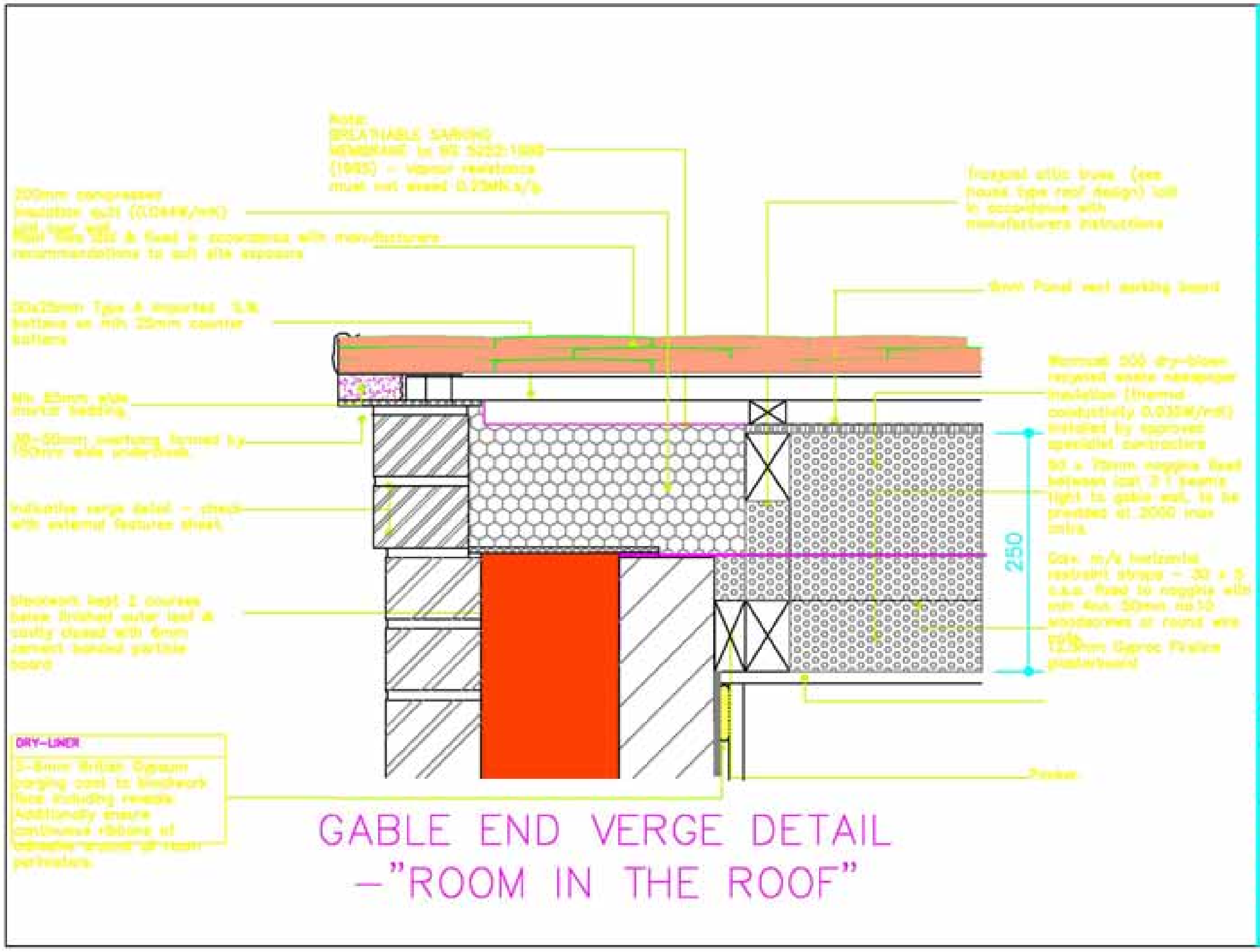

Taylor Woodrow
title
DEVELOPMENT AT STAMFORD BROOK
ROOF DETAILS: RIDGE
SPECIFICATION CLAUSE 22 HOUSES & APARTMENTS
date
05/03/04
scale
1 : 6
drawn
DMP
dwg.no/rev
SD/HTB
6051A
JOINERY
DRY-LINER
75
COLD "Breathing" ROOF: Eaves
window head

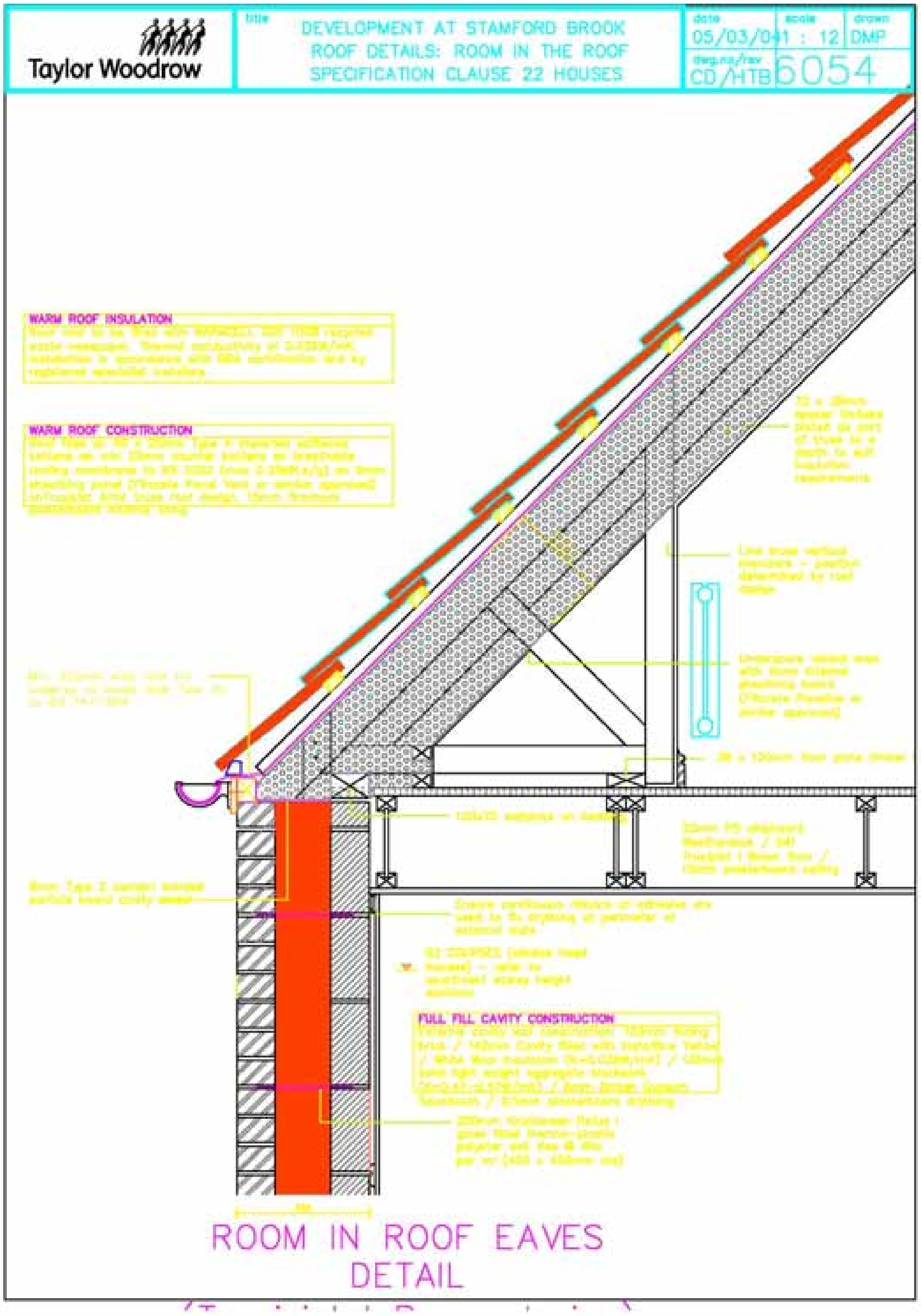
Taylor Woodrow

title DEVELOPMENT AT STAMFORD BROOK
ROOF DETAILS: ATTIC TRUSS VERGE
SPECIFICATION CLAUSE 22 HOUSES & APARTMENTS

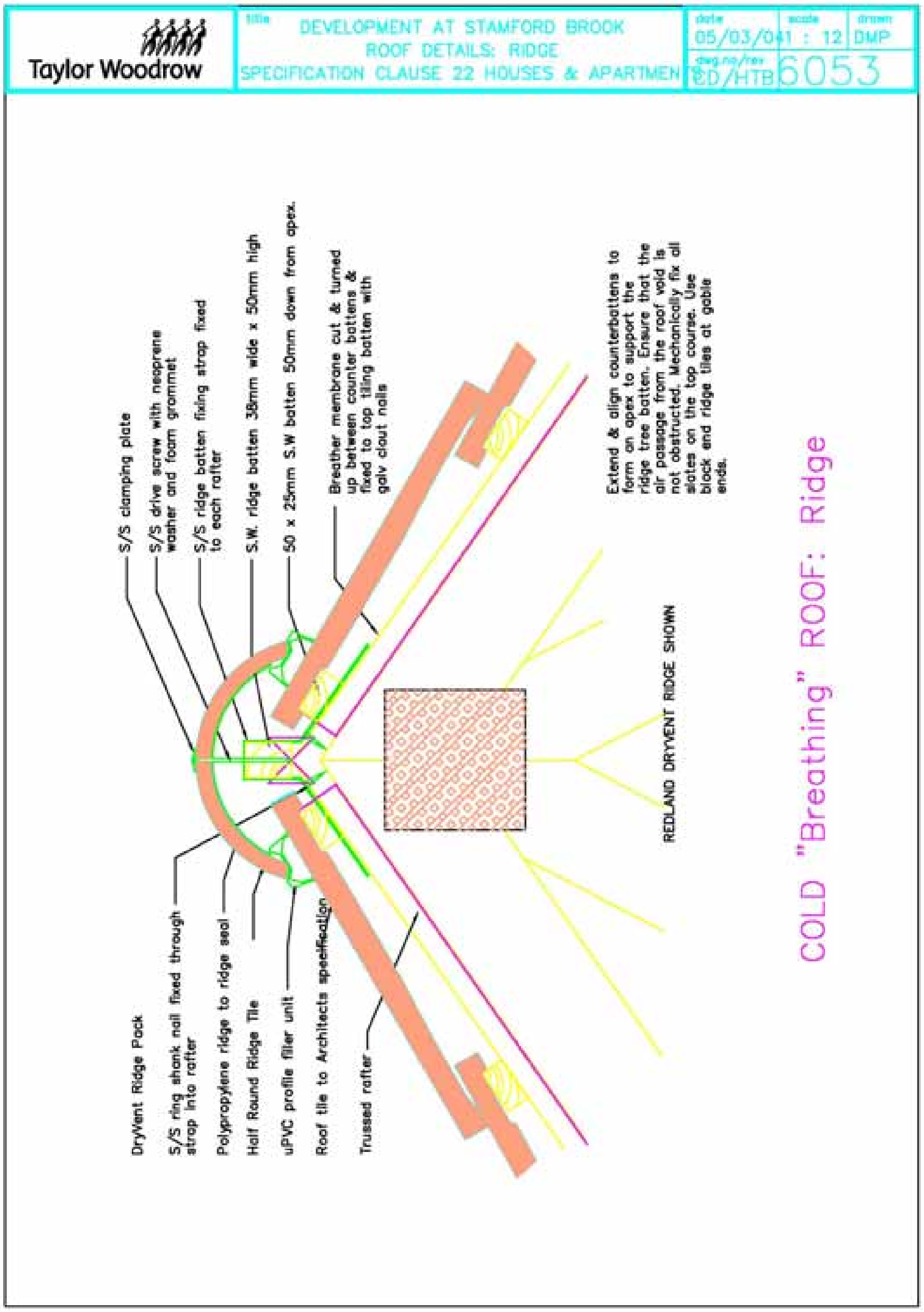
date	scale	drawn
05/03/04	1 : 5	DMP

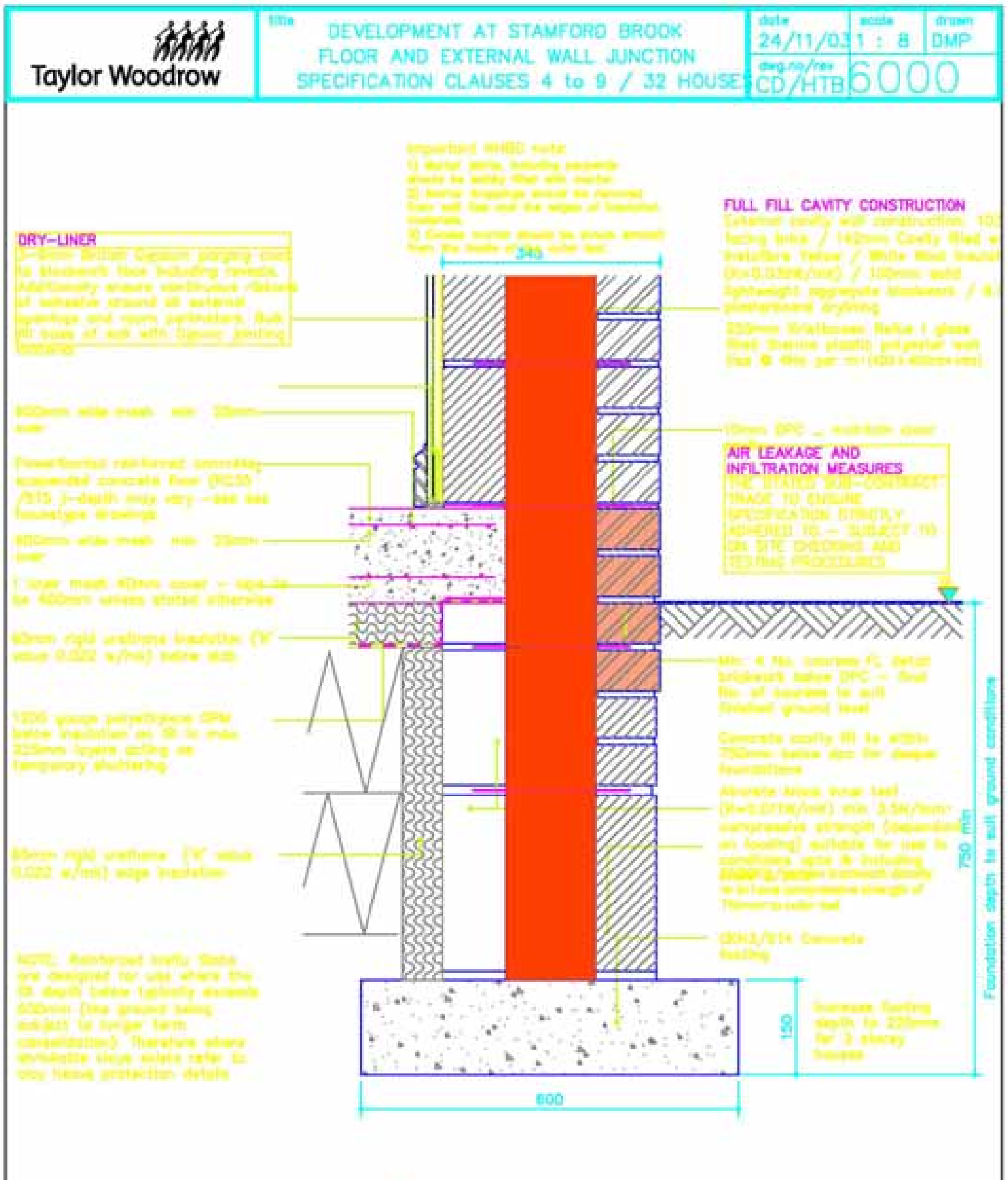
dwg.no/rev SD/HTB 6052





ROOM IN ROOF EAVES DETAIL


Taylor Woodrow
title
DEVELOPMENT AT STAMFORD BROOK
ROOF DETAILS: RIDGE
SPECIFICATION CLAUSE 22 HOUSES & APARTMENTS
date
05/03/04
scale
1 : 12
drawn
DMP
dwg.no/rev
ED/HTB
6053
S/S clamping plate
S/S drive screw with neoprene washer and foam grommet
S/S ridge batten fixing strap fixed to each rafter
S.W. ridge batten 38mm wide x 50mm high
50 x 25mm S.W batten 50mm down from apex.
Breather membrane cut & turned up between counter battens & fixed to top tiling batten with galv clout nails
Extend & align counterbattens to form an apex to support the ridge tree batten. Ensure that the air passage from the roof void is not obstructed. Mechanically fix all slates on the top course. Use block and ridge tiles at gable ends.
DryVent Ridge Pack
S/S ring shank nail fixed through strap into rafter
Polypropylene ridge to ridge seal
Half Round Ridge Tile
uPVC profile filler unit
Roof tile to Architects specification
Trussed rafter
REDLAND DRYVENT RIDGE SHOWN
COLD "Breathing" ROOF: Ridge



round floor / external wall juncti
Reinforced insitu slab
(under floor insulation)

Appendix 4: Effect of lintel choice on thermal performance of head

Effect of internal lintel choice on thermal performance of head

David Roberts 25 March 2003

Following on from the study into optimal offset of window frame from face of outer leaf, revised drawings were made. An offset of 75mm was chosen as a compromise between thermal performance and buildability. Other modifications included the addition of Rockclose cavity closer. However, the latest head detail, shown in Figure 1, did not perform as well as expected.

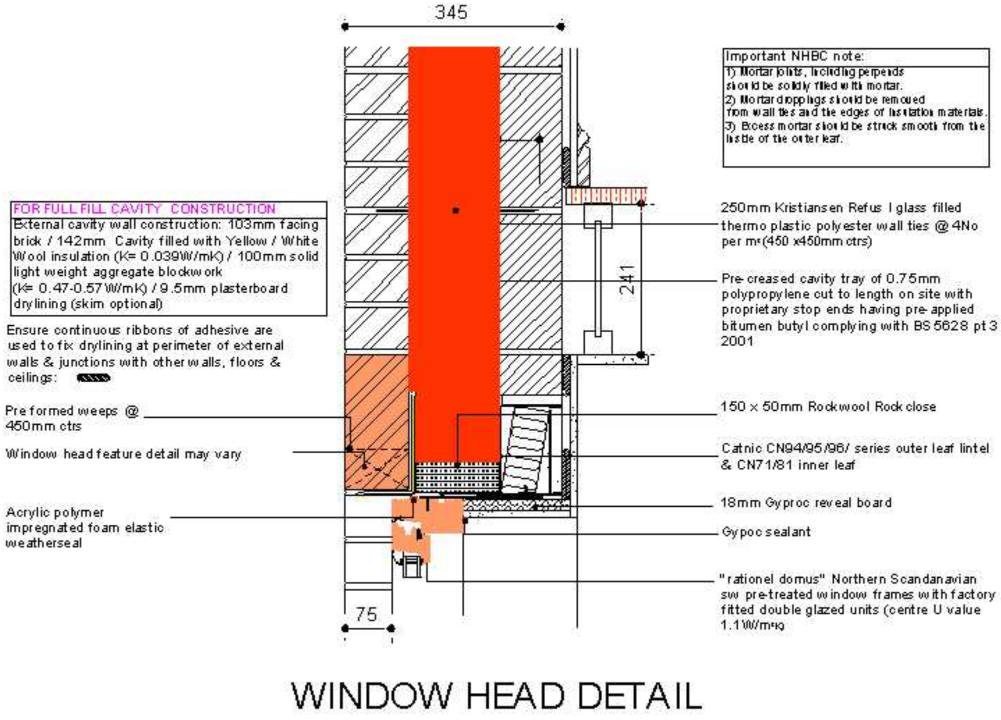
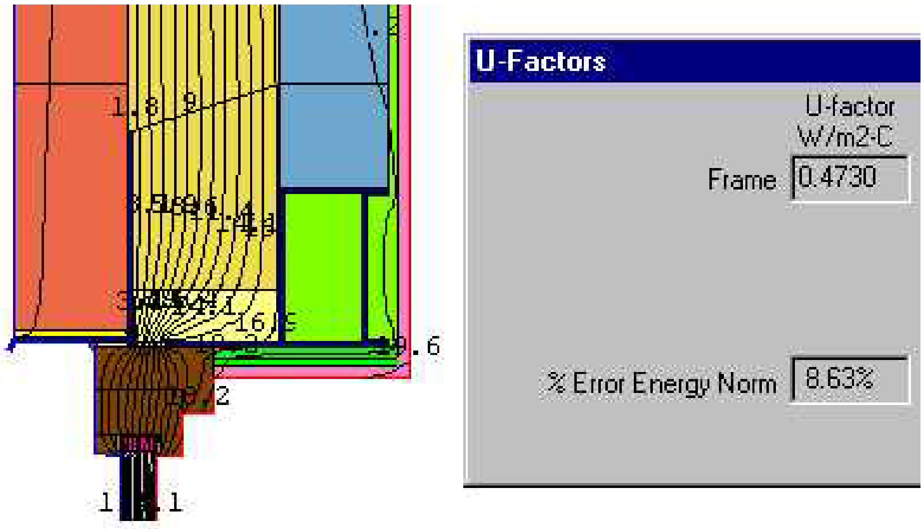


Figure 1: Window head detail (from Dave Poole).

Inspection of the Therm model shows close isoline spacing directly above the frame, see Figure 2. The internal lintel chosen was the Catnic CN71 which is designed to be used in a two-brick thick solid wall, with one leaf supported on the box profile and one leaf supported on the toe. The toe is non-load bearing in this particular application but, unfortunately provides a thermal bridge past the frame and the closer.



U-Factors

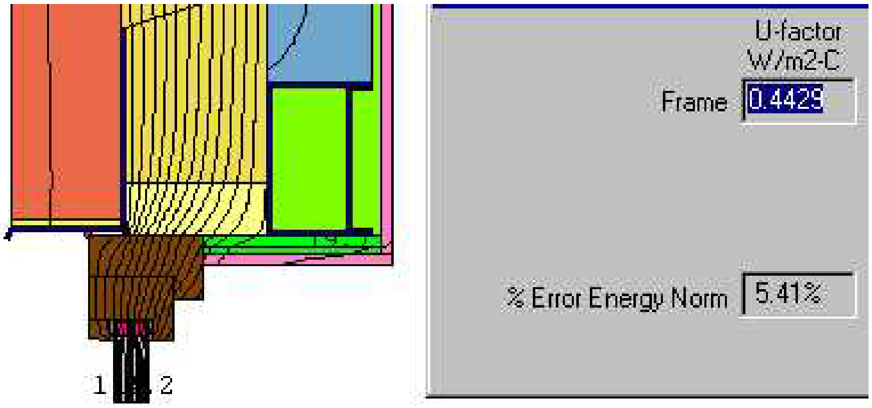
U-factor W/m2-C

Frame 0.4730

% Error Energy Norm 8.63%

Figure 2: Head constructed using Catnic CN71 lintel with toe.

A further Therm model was then made, this time with a different profile lintel, a CN5X, which has no toe, see Figure 3. The isoline spacing is greatly improved in the area above the frame. The U value through the detail with the toe (CN71) is 0.4730 W/m^{2}K. When the lintel without the toe is used (CN5X), the U value through the detail is lower at 0.4429 W/m^{2}K. When these data are input to the Parametric Domestic Energy Calculator using the Doniford house type, the whole wall U value is 2% higher when the lintel with the toe (CN71) is used.



U-factor W/m2-C

Frame 0.4429

% Error Energy Norm 5.41%

Figure 3: Head constructed with Catnic CN5X lintel without toe.

Conclusion

The whole wall U value was 0.2624 when using the suggested CN71 lintel. The whole wall U dropped to 0.2585 when the CN5X lintel was substituted, giving a two percent improvement in whole wall U value.

Appendix 5: Setback of window frame

Effect of window frame position in reveal

David Roberts 27th February 2003

Introduction

An initial investigation was made on the Doniford mid-terrace house-type using the Parametric Domestic Energy Model in order to calculate energy performance and assess compliance with EPS08. Construction details supplied by Dave Poole were modelled in Therm 5.1 to obtain psi values for major junctions. However, as Rockwool Blown Energy Saver is now the preferred method of cavity insulation, the proposed cavity width was widened from 142mm to 150mm. This lowered the one-dimensional wall U value from 0.23 to 0.22 W/m2K (with a corresponding change in whole wall U value). The study first of all looked at elemental U values and the effect that thermal bridging had on whole U values. Then, performance of the three terracing configurations (mid, semi and detached) was considered. Finally, performance was assessed on the basis of target U value and carbon index routes of compliance.

Elemental

The results of the study showed that, in the mid-terraced Doniford, the ground floor and roof elemental U value requirements of EPS08 were met (using a 150mm cavity). However, even though the one-dimensional wall U value was 0.2195 W/m2K, the whole wall U value was 0.3020 W/m2K when the thermal bridging additions were added, exceeding the elemental requirement of 0.25 W/m2K. On closer inspection, the majority of the thermal bridging appeared to be due to the reveal junctions: head, sill and jamb. It was suspected that the position of the frame in the reveal could affect thermal performance of the details and so a comparison was made of different frame positions.

Comparison of frame positions

One of these junctions, the head (Figure 1 - based on drawing no. 031), was chosen for this comparison study. Here, the offset of frame from the outside surface was 35mm.

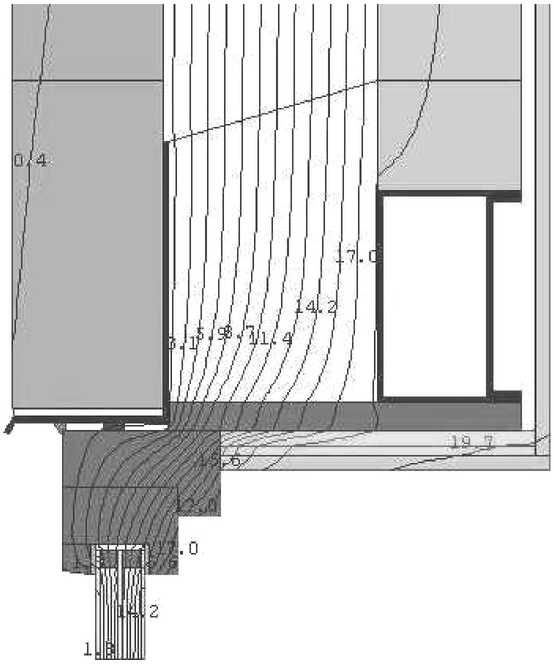


Figure 1: Head detail with a frame offset of 35mm from the outside surface of the outer leaf (as drawing no. 031).

Other frame positions chosen were:

0mm (in-line with the outer leaf);

35mm (the default offset as given in drawing 031;

72mm;

107mm;

127mm (in-line with the cavity insulation);

145mm;

200mm;

250mm (in-line with the inner leaf).

Although lining up the frame with the inner or outer leaves is not common practice, these positions were examined as they represented the extreme conditions. At offsets of over 100mm, it was acknowledged that additional material would be needed to trim the gap between the frame and outer leaf, again, not usual practice.

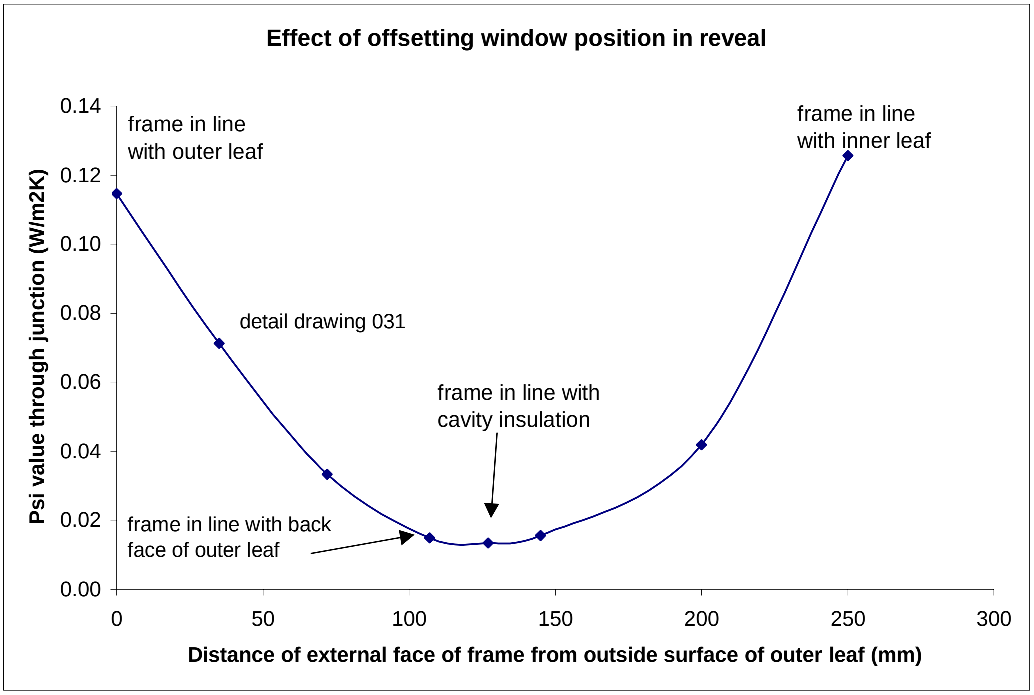


Figure 2: Effect of offsetting window position in reveal on psi value of head junction.

The psi values calculated for each frame offset are shown in Figure 2. The cavity was wider than the frame and so offsets of 107, 127 and 145mm were cases where all the frame was within the cavity. Psi values at these positions were almost identical so an optimum position for the frame, considering thermal and practical viewpoints, could be at 107mm offset as this gives a low psi value and no trim is needed. Isolines for this frame offset are shown in Figure 3.

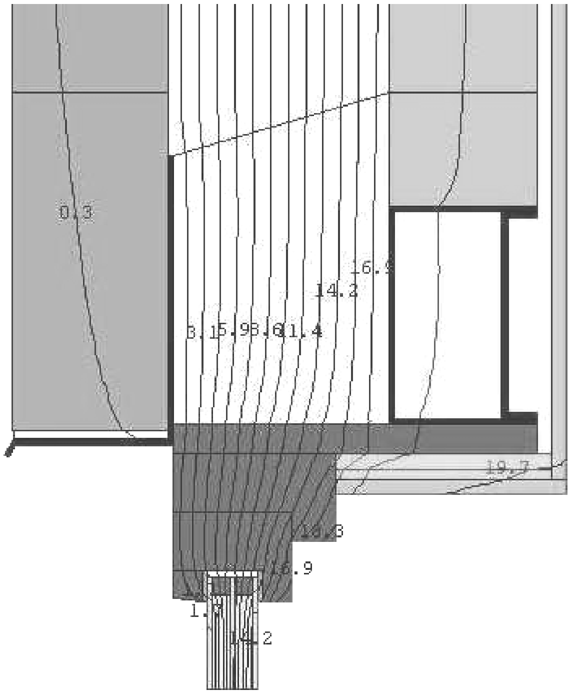


Figure 3: Head detail with a frame offset of 107mm from the outside surface of the outer leaf.

The sill and jamb junctions were also modelled with an offset of 107mm and the thermal performance input into the Parametric Domestic Energy Model. The whole wall U value was 0.3 W/m2K using the offset of 35mm and 0.259 W/m2K when using an offset of 107mm. While this still does not quite meet the whole wall U value requirement of 0.25 W/m2K, it is a substantial improvement over the proposed 35mm frame offset.

Comparative performance of Doniford in mid-terrace, semi-detached and detached house-types – elemental method

The Parametric Domestic Energy Model was then used to compare energy performance of the different terracing configurations of the Doniford. The whole U value results are shown in Table 1.

Table 1: Whole U values for Doniford house-type

	mid-terrace	semi-detached	Detached
roof	0.1509	0.1528	0.1548
wall	0.2593	0.2581	0.2575
ground floor	0.2208	0.2311	0.2414

Table 1 shows that the whole U value for the roof is well within the requirement for all terracing configurations. The eaves bridging at the front and rear of the Doniford is the same for all configurations and the additional gable junction bridging with the semi and the detached account for a very slight increase in whole roof U value.

Interestingly, the whole wall U value reduces slightly as the terrace configuration moves from mid to semi to detached, even though there is increasingly more wall–wall junction. Additional bridging due to this effect is counteracted by the fact that there is proportionately less bridging around windows and doors in the semi-detached and detached versions of the house .

The elemental ground floor U value requirement is met in the mid-terrace but not in the semi and the detached versions, due to the extra lengths of external wall-floor junction.

Comparative performance of Doniford in mid-terrace, semi-detached and detached house-types – target U value method

Target U value and mean U value were calculated and the results shown in Table 2. In each case, the mean U value meets the target U value requirement with between 6 and 8% leeway.

Table 2: Target and mean U values for mid, semi and detached configurations.

	mid-terrace	Semi	detached
Target U (W/m2K)	0.35	0.34	0.33
Mean U (W/m2K)	0.32	0.32	0.31

Comparative performance of Doniford in mid-terrace, semi-detached and detached house-types – carbon index method

Carbon index was calculated for the mid, semi and detached configurations. A boiler efficiency of 85% and ‘medium’ performance MEV was assumed. Table 3 shows that the mid and semi configurations meet the carbon index requirement of 8.7 while the detached does not. An increase in the boiler efficiency to 91% would enable the detached house to comply by this route.

Table 3: carbon index for mid, semi and detached configurations.

	mid-terrace	semi	detached
Carbon index	8.9	8.7	8.5

Appendix 6: Parging paper

A novel approach to achieving airtightness in dry-lined load-bearing masonry dwellings

D Roberts[1] BSc PhD, D Johnston[1] BEng MSc PhD, J A Isle[2] BEng MSc

[1]Centre for the Built Environment, Leeds Metropolitan University, Leeds LS1 3HE

[2]Taylor Woodrow Developments Ltd, Princes Way, Solihull, West Midlands, B91 3ES

Summary

This paper describes a novel approach that can be used to construct airtight dry-lined load-bearing masonry dwellings. This involves the application of a thin layer of 'parging' to the internal blockwork leaf of all external walls.

Whilst this approach has so far only been undertaken on a field trial using one dwelling, the results suggest that the application of the parging layer improves the airtightness of the dwelling substantially and air leakage rates of less than 5 $m^3/h/m^2$ @ 50Pa can be achieved. The paper also identifies a number of additional measures which, if undertaken, could reduce the air leakage of this dwelling even further.

1 Introduction

There is a commonly held perception that new masonry dwellings are more airtight than older dwellings. This is not generally found to be the case. Comprehensive data published by the Building Research Establishment (BRE) on the air leakage of some 471 dwellings of different age, type and construction, suggests that dwellings built between 1980 and 1994 are, on average, as airtight as those built at the beginning of the 20th century(1). Air leakage data on dwellings built from 1995 onwards are limited. Recent measurements undertaken by the BRE on 32 post-1995 dwellings suggests that these dwellings may be marginally more airtight than the stock as a whole(1). However, the range of air leakage encountered in the post-1995 dwellings is still very wide and the size and non-random nature of this sample preclude certainty. This variance in the air leakage from one property to another reduces the ability of the housebuilder to deliver a consistent product in terms of ventilation and heating performance.

Part of the reason for the poor performance of new dwellings is likely to be attributable to the method that is used to finish the external walls. Traditionally, UK dwellings were wet plastered. This process had the advantage of sealing any badly pointed joints or shrinkage cracks in the inner leaf thereby closing air pathways between the wall cavity and the interior of the house. However, due to perceived skill shortages, the speed of construction and economic reasons, wet plastering has almost entirely been replaced by plasterboard dry-lining in new dwellings. In dwellings constructed using plasterboard dry-lining, the air gap between the plasterboard sheet and the masonry wall acts as a plenum. Air can move freely within this plenum, effectively interconnecting all of the leakage paths in the dwelling. The result is that dry-lined dwellings tend to be significantly leakier than wet-plastered dwellings(2).

A novel approach to constructing airtight plasterboard dry-lined dwellings has been proposed and field trialed on a new dwelling at Pewterspear, near Warrington. This approach involves the application of a thin (2-4mm) plaster-based parging coat to the interior surfaces of the dwellings external walls, prior to the installation of the plasterboard dry-lining (see Figure 1). The function of the parging* coat is to act as an air barrier and reduce air leakage through the blockwork. Although this represents a novel method of its use, parging was traditionally used as a lining material for chimneys to ensure that gases could not escape through mortar joints and cracks in the structure. Nowadays, parging is being used to improve the acoustic performance of masonry aggregate block separating walls, by sealing the blockwork and covering up any deficiencies in workmanship, prior to the application of the dry-lining(3).

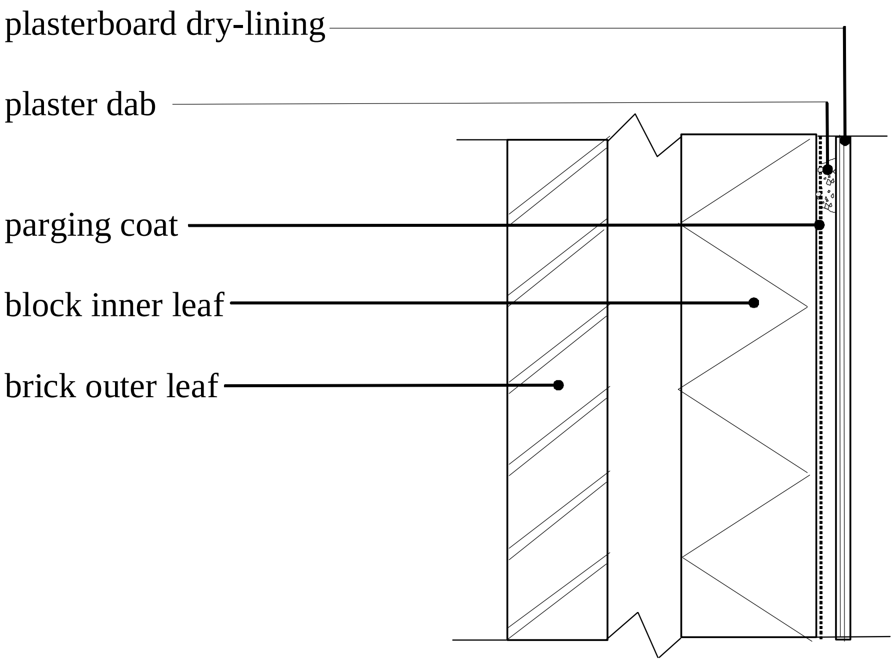


Figure 1 Section through external wall showing location of parging coat.

The results published here form part of a much larger field trial that is being set up to support a future review of Part L of the Building Regulations, by evaluating the impact on the masonry house building industry of an enhanced energy performance standard(4). The project is being supported under the Government's Partners in Innovation programme in Construction adminstered by the Department of Trade and Industry and the Office of the Deputy Prime Minister. The construction project is being carried out in partnership with the National Trust. In all, approximately 700 houses will be built to the enhanced standard and parging will be adopted, along with other measures, to help achieve the proposed maximum airtightness target of 5m^3/h/m^2 @ 50Pa for all dwellings. This target will be verified by fan pressurisation. Initial pressurisation tests were undertaken on three two-storey detached dwellings at the Stone and Trentham sites to determine the airtightness of new dry-lined load-bearing masonry construction, using a Minneapolis blower door. These tests indicated air leakage rates of between 7-9 m^3/h/m^2 @ 50Pa, which,

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* Parging is a material that has some of the properties of a browning and bonding coat.

although better than the UK mean value of 11.5 $m^3/h/m^2$ @ 50Pa(1), are almost a factor of two greater than the airtightness target contained within the enhanced standard. This suggests that the 5 $m^3/h/m^2$ @ 50Pa target may prove difficult to achieve using existing dry-lined load-bearing masonry construction techniques. Following these results, a field trial was set up to investigate the effect that parging could have on the airtightness of dry-lined load-bearing masonry construction.

The dwelling selected for the parging trial is located on the St Georges Place site, Pewterspear, near Warrington, Cheshire. It consists of a 196 m^2 three-storey detached dwelling, of brick-block cavity construction, which has a solid concrete ground floor and is lined internally with plasterboard on dabs. The dwelling was constructed to conform to the then current Building Regulations (1995 Edition(5)) and contains no cavity wall insulation. No additional attention was paid to airtightness during the dwellings construction, apart from at the junction between the first floor joists and the external wall, which were joist-wrapped using a method patented by the builder. Unfortunately, it was not possible to measure the effect of the joist-wrapping on airtightness within this trial, but other studies have found joists to be an area where significant leaks can occur (1, 6).

2 Results of the parging trial

Pressure tests were undertaken at seven stages throughout the parging trial, giving an indication of the relative importance of each step. The first pressure test was undertaken in December 2002, just prior to the application of the parging coat. The test resulted in an air leakage rate of 12.1 $m^3/h/m^2$ @ 50Pa (see Figure 2), which is comparable to the UK mean of 11.5 $m^3/h/m^2$ @ 50Pa. A plasterer was then employed to apply a thin coat of parging to all of the internal surfaces of the external walls. The plasterer was not informed of the purpose of the parging. The total time required to parge the house was of the order of 2 man days. Material costs for the parging were minimal (approx. £0.65/m^2).

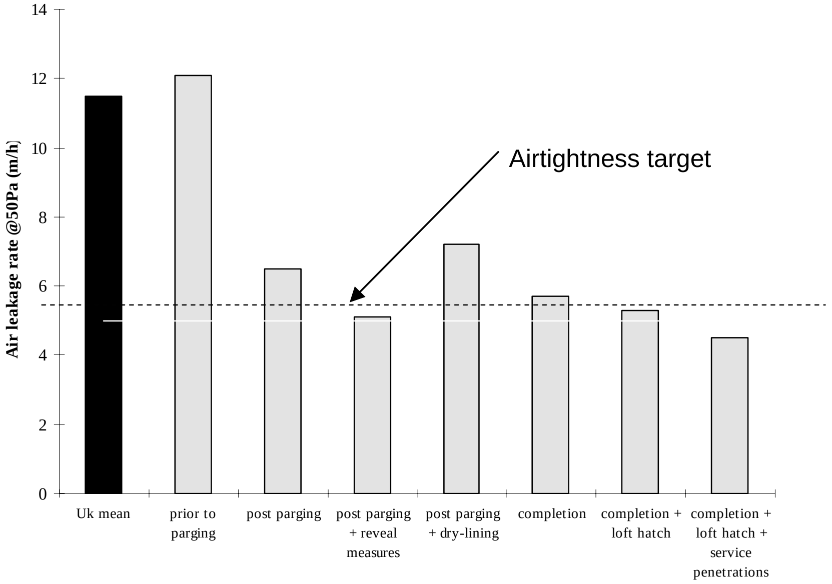

Figure 2 Results of the parging trial.

The dwelling was pressure tested the day after the parging coat had been applied, highlighting the quick-drying nature of the parging (it dries in approximately 2 hours). This suggests that it is possible for the plasterer to parge and then dry-line the dwelling in one continuous operation. However, the speed of the operation also highlights that the timing of any inspection of the parging coat is critical, since any omissions in the parging layer would be difficult to identify or rectify once the plasterboard dry-lining has been applied.

The pressure test resulted in an air leakage rate of 6.5 $m^3/h/m^2$ @ 50Pa (see Figure 2), representing a reduction of almost 50%. The plasterer was heard to comment that the standard of construction of the house was particularly good. Most of the blockwork was pointed and all the perpends appeared to be full of mortar[*]. This suggests that an even greater improvement in air leakage may be achieved by applying a parging coat to a poorly constructed house, as the parging would fill any areas where the pointing was deficient. However, if too much reliance is placed on parging, workmanship in other vital areas that contribute to airtightness may not be as meticulous. A visual inspection of the parging coat was then undertaken which revealed that the parging coat was incomplete in a number of areas, most notably at window reveals and at the underside of some of the lintels (see Figure 3). The occurrence of air leakage at these areas was verified by depressurising the dwelling, and identifying the leaks by hand and using hand held smoke generators.

Figure 3 Gaps in parging at window reveals and underside of lintel

An attempt was made to seal some of the leaks around the reveals and the lintels using duct tape. Although this was not ideal, an improved air leakage rate of 5.1 $m^3/h/m^2$ @ 50 Pa was recorded when the dwelling was subsequently re-tested (see Figure 2). This suggests that if a complete coat of parging had been applied to this dwelling by a plasterer who had been informed about the importance of the parging coat, then it may have been possible to achieve an air leakage rate of less than 5 $m^3/h/m^2$ @ 50 Pa within this dwelling.

The dwelling was then re-tested in May 2003, following completion of the dry-lining and internal decoration of the dwelling. It was anticipated that the addition of the dry-lining would not make a significant difference to the airtightness of the dwelling, since the parging coat would be acting as the airtight layer, rather than the plasterboard dry-lining. However, the air leakage rate unexpectedly rose by just over 10%, from 6.5 $m^3/h/m^2$ to 7.2 $m^3/h/m^2$ @ 50 Pa (see Figure 2). The reason for this increase in air leakage was probably attributable to the addition, and relocation, of a number service penetrations that had not been properly sealed. For instance, the installation of the burglar alarm system and the relocation

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[*] Open perpend joints have been identified as a significant air leakage route(1).

of the soil pipe are shown in Figures 4 and 5. Measurements undertaken by the BRE have identified service entries as a significant area of air leakage(1).

Prior to the occupants moving into the dwelling, the dwelling was tested in June 2003. This time, the dwelling had been snagged and the carpets had been fitted. An air leakage rate of 5.7 $m^3/h/m^2$ @ 50 Pa was recorded, representing a reduction in the air leakage rate of 1.5 $m^3/h/m^2$ @ 50 Pa, but still in excess of the enhanced standard air leakage target of 5 $m^3/h/m^2$ @ 50 Pa (see Figure 2). Further inspection of the dwelling revealed a number of areas where workmanship and detailing could improve airtightness. The loft hatch was of poor quality and did not fit correctly, resulting in it whistling loudly during the pressure test. In addition, a number of gaps were observed in the bathrooms and toilets, between the waste and water pipes and the chipboard tongue and grooved flooring. These sorts of gaps are not uncommon in new house construction. They also tend not to be sealed, as they will not be visible when the floor covering is laid and the bath panel fitted. Interestingly, these areas of air leakage could easily have been reduced or avoided at the outset, by specifying an airtight loft hatch and ensuring that those responsible for installing the waste and water pipes were contractually obliged to ensure that any penetrations through walls, floors and ceilings are sealed.

In order to establish the effect that the loft hatch and the gaps around the waste and water pipes had on the dwellings air leakage, two further pressure tests were undertaken: one with the loft hatch sealed; and one with the gaps around the pipework and the loft hatch sealed. Due to the short time-scale that was available to pressure test the dwelling, both the loft hatch and the gaps between the pipework and the flooring were sealed using duct tape. However, in practice, expanding polyurethane foam, silicone mastic or decorators caulk would be used to provide a more satisfactory and permanent seal. The most important measure undertaken was sealing the gaps between the pipework and the flooring. This resulted in a reduction in the air leakage rate of 0.8 $m^3/h/m^2$ @ 50 Pa. Sealing the loft hatch resulted in an improvement in the air leakage rate of 0.4 $m^3/h/m^2$ @ 50 Pa. The net effect of undertaking both of these measures was a reduction in the dwellings air leakage rate to 4.5 $m^3/h/m^2$ @ 50 Pa. This figure falls within the 5 $m^3/h/m^2$ @ 50 Pa target contained within the enhanced standard.

3 Conclusions

The tentative conclusions from this work are:

The air leakage of dry-lined load-bearing masonry dwellings can be significantly improved with minimal cost by applying a parging coat to the internal surfaces of all of the internal walls. However, consideration should still be given to other areas of significant air leakage, such as loft hatches and service penetrations.

Measurements undertaken at Pewterspear suggest that parging can reduce the air leakage rate of dry-lined load-bearing masonry dwellings by a factor of 2. In addition, if the application of the parging coat is coupled with an airtight loft hatch, good standards of workmanship and the sealing of service penetrations, an air leakage rate of less than 5 $m^3/h/m^2$ @ 50 Pa can be achieved.

The application of the parging coat can be undertaken within a day and unlike wet plaster, there is no drying out period. The dry-lining process can begin after a period of approximately 2 hours.

No specific skills are need over and above that of a plasterer. A short briefing is required to inform the operative of the objectives. Other trades who are likely to puncture the walls or apply fixings require instructions to be included in their Works Specification.

The process not only reduces the maximum rate of air leakage but is likely to provide a much narrower band of variation, enabling the housebuilder to produce dwellings of an improved and more consistent standard.

Parging should be viewed as a method that does not reduce leakage entirely but merely contributes to airtightness, as do other methods and good workmanship.

It should be noted that these conclusions are based upon the results of applying a parging coat to a single dwelling only. Further work needs to be undertaken on a representative sample of dwelling types to be able to quantify the effect that parging can have on the airtightness of dry-lined load-bearing masonry dwellings.

Acknowledgments

We gratefully acknowledge the assistance given by David Poole, Technical Manager and site staff of Taylor Woodrow Developments Ltd; staff of the National Trust.

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Appendix 7: Window paper

Thermal performance of double-glazed timber windows

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April 2002

Abstract

This paper presents a short exploration of the actual and potential performance of double-glazed timber windows. This work has been carried out in support of the St Nicholas Court Project and the forthcoming Brookside Farm Project*. The main reason for undertaking this work was to discover whether double glazed timber windows were capable of meeting an energy performance standard (Lowe & Bell 2001) that has been devised by Leeds Metropolitan University for these housing projects. This performance standard requires windows to have a U value no higher than 1.3 W/m^{2}K or a domestic window energy rating (DWER) of 70 or better.

The starting point for the work was a high performance timber-framed window marketed by Environmental Construction Products. This window incorporates an intermediate low emissivity coating, an argon-filled gas space and a standard aluminium spacer to achieve a whole window U value of 1.66 W/m^{2}K and a domestic window energy rating of 68.1. The exercise shows that it is possible to achieve the DWER target, defined above, by adopting warm edge technology (in this case, Superspacer), an intermediate emissivity coating (ε=0.083) and replacing argon with krypton in the gas space of the insulating glazing unit. However, meeting the U value target appears more difficult, even with a very low emissivity coating (ε=0.026).

The substantive conclusion from this study is that the proposed window standard is near the limit of what can be achieved with double glazed timber-framed windows using existing frame and glazing technologies. However, this paper represents a first foray into this territory. It is based on only one frame type and a small number of glazing systems - all North American. Considerably more work would be needed to provide a comprehensive overview of the likely impact of window energy rating and the proposed performance standard on windows in the UK market.

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* The St Nicholas Court field trial is being supported by DTI under Partners in Innovation (39/3/604), by the Joseph Rowntree Foundation and by the Housing Corporation. The project web site is at http://www.lmu.ac.uk/hen/benv/cebe/st_nicks.htm. Support for the Brookside Farm project has been secured from DTI under PII, from the National Trust and from industry.

1. Introduction

The central objective of the study reported here was to begin to examine the implications for window design, of an enhanced energy performance standard for dwellings. The latter has been developed at Leeds Metropolitan University in the context of two current Partners in Innovation Projects (Lowe & Bell 2001). It is based on the structure and compliance modes – elemental, target U value and carbon rating method - of the current Part L (DTLR 2001), and is intended for possible incorporation into the Building Regulations at the next major revision.

The elemental compliance mode in the enhanced energy performance standard requires windows to have a maximum U value of 1.3 W/m^{2}K or to have a domestic window energy rating (DWER) of 70 or above. Both U values and domestic window energy ratings are to be calculated according to the methods laid down by the British Fenestration Rating Council.

These window performance targets were set with the following objectives in mind:

both U value and window energy rating target should be near the limit of what could be achieved with high performance double glazing in well designed window frames, in order to stimulate the introduction of warm edge technologies and the use of argon or krypton in the gas spaces of such windows;

the maximum window U value should be somewhat harder to achieve than the minimum DWER, to allow for the potentially poor solar transmission properties of un-rated windows and to provide some additional incentive for window manufacturers to energy rate their products.

The starting point for this study was a window marketed by Environmental Construction Products of Huddersfield. This window is based on a top hung reversible softwood frame, and an IGU with a low emissivity coating (ε=0.09) and an argon-filled gas space with a standard aluminium spacer. With this specification, it achieves a whole window U value of 1.66 W/m^{2}K, a window solar factor[*] of 0.48 and a domestic window energy rating of 68.1.

2. Method

Window performance for the base case and for a series of variants incorporating different coatings, gas space widths, krypton gas-fill and warm edge technology, were calculated using two software packages – Therm and Window – that underpin both the US and UK window energy rating systems[†]. Both packages have been written by the Windows and Daylighting group at Lawrence Berkeley National Laboratory (LBNL), The versions used for this study were Window 5.0β and Therm 2.1a. Both may be obtained, with comprehensive documentation, from http://windows.lbl.gov/. -

For readers not familiar with these packages, the calculation steps, for each frame and glazing variant, are:

design the insulating glazing unit in Window 5.0β, then import it into Therm 2.1a;

draw head, jamb and sill components in Therm and, using the imported glazing system, calculate frame and edge U values for each component;

import component frame and edge U values back into Window 5.0β;

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[*] In CEN terminology, “solar factor” (g) is an accepted abbreviation for “total solar energy transmittance” (BS EN 410: 1998). Solar factor is a property of the glazing system, not of the whole window. We have adopted the term “window solar factor” to refer to the analogous property of the whole window. In North America the term “solar heat gain coefficient” is used.

[†] The US window energy rating system is operated by the National Fenestration Rating Council (NFRC). The UK window energy rating system is being developed by the British Fenestration Rating Council (BFRC). Information on the BFRC system may be found at http://www.bfrc.org/.

use the imported values to calculate whole window U values and window solar factors (referred to as solar heat gain coefficients in Window and Therm);

substitute the whole window U value and solar factor for each variant into the BFRC window energy rating equation, to calculate the domestic window energy rating (DWER).

Boundary conditions for all calculations were CEN rather than NFRC. Window sections were taken from Environmental Construction Products' catalogue (see Appendix 1). Thermal conductivities for window frame and glazing components were taken from Annex A of EN 10077-2 (see Appendix 2). Glass data were taken from the Glazing Products Database maintained by LBNL*. With one exception, all glazing variants were assumed to make use of Cardinal glass products (see Appendix 3).

An independent check on the accuracy of LMU's simulation procedure was possible by making a comparison with simulations undertaken earlier in 2001, on LMU's behalf, by an independent consultant, Pat Pinnington. Pinnington used Therm 2.1a and Window 4.1 to calculate component and whole window U values for the H-window. Planitherm glass, used by Pinnington, was not in contained in the version of the glass database used for this study, so for this comparison only, another manufacturer was chosen, Viracon. The database references for the glass used are: 888 (4mm clear glass) and 6159 (4mm glass with ε=0.088 coating). The results of these simulations are presented in Table 1. The discrepancy between the results, thought to be caused by differences between different versions of Window and the use of glass from different manufacturers, is of the order of 3%. In our view, this is an acceptable margin of disagreement.

Table 1: Estimates of whole window U values based on simulations undertaken by the authors and by Pinnington for a 1200 × 1200mm window.

	U value (W/m^2K)	DWER
Pinnington (using Window 4.1 and Planitherm ε=0.09	1.62	67.5
LMU (using Window 5.0β and Viracon ε=0.088)	1.68	67.9

3. Base case window

The BFRC window energy rating system is based on two standard sizes of window - 1230 × 1480 mm and 740 × 1230 mm. The former is based on current CEN standards and the latter has been adopted by BFRC pending development of a European Window Energy Rating System. This paper focuses on whole window U values for the larger of these two sizes. Table 2 shows component and whole window U values and solar factors for this base case window.† The domestic window energy rating for this window was 68.1. This window provided the base case against which subsequent improvements to thermal performance were measured.

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[*] To a good approximation the properties of glass are described by just 3 or 4 numbers - the solar and optical transmission coefficients and the emissivity(ies) of surfaces. The absence of a comprehensive European Glazing Products Database is unfortunate, but it is usually possible to find a good match in the LBNL database to products available in the EU.

[†] The whole window U value for the BFRC/CEN standard size in Table 2 is slightly lower than that shown in Table 1. This is due to the slightly lower frame and edge fractions of the larger window.

Table 2: Thermal performance of base case window (1230 × 1480mm top-hung casement, ε=0.088 surface 3[*], 20 mm argon-filled gas space, aluminium glazing spacer.)

Component	U value (W/m^{2}K)	solar factor g
Whole window	1.655	0.476
Centre pane	1.451	0.636

4. Description of modifications to base case window

The effects of the following changes to the base case window – singly and in various combinations - were then investigated:

changing the emissivity of the coating on surface 3 from 0.088 to: 0.026, 0.037, 0.042, 0.046, 0.056, [0.071], 0.083 and 0.102.

replacing the aluminium glazing spacer with Superspacer;

changing the width of inter-pane gas spaces for argon and krypton filled IGUs;

providing a 2-stage draught seal for the sill section of the casement.

For completeness, the authors compared the performance of the top-hung casement base case with a fixed-light equivalent and also examined the effect of window size by calculating the performance of a half-CEN size top-hung casement window.

4.1 Effect of emissivity

To model the effect of emissivity on U value and DWER, several glass types were required to model IG units. The glass database in Window 5.0β contained 1000 different panes from a variety of manufacturers. From this database, a series of Cardinal products were selected with emissivity values of: 0.026, 0.037, 0.042, 0.046, 0.056, [0.071], 0.083 and 0.102. In conjunction with a 3mm clear glass pane (also made by Cardinal, database ID 2001), these were used to construct a series of IGUs, each with 20mm argon-filled cavity. Finally, whole window U values and solar factors for each IGU in the standard H-window frame were calculated and are shown in Figure 1 and Table 3.

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[*] This follows the convention of numbering glass surfaces in a window from the outside. Placing the coating on surface 3 maximises solar heat gain and is therefore the optimal configuration for a heating-dominated climate.

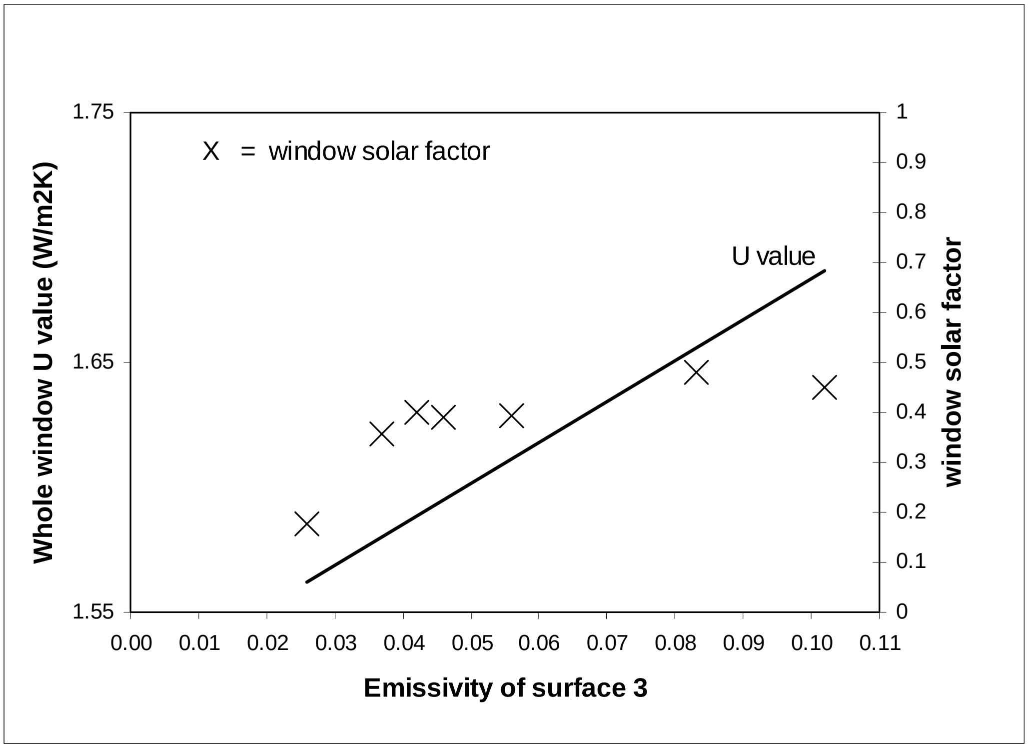

Figure 1: Whole window U value and solar factor for IG units of different surface 3 emissivities.

Figure 1 shows the expected linear relationship between emissivity and U value[*]. Extrapolation of the graph also shows an absolute limit on whole window U value of around 1.52 W/m^{2}K with a 20 mm argon-filled gas space. The relationship with solar factor is more complicated but generally the graph indicates that solar factor tends to increase as emissivity increases.

Although, as expected, the lowest emissivity glass (0.026) gave the lowest U value, the best DWER was found when using an emissivity of 0.083[†]. Following this finding, it was decided to examine two series of models, one with a surface 3 emissivity of 0.026 and one of 0.083.

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[*] The radiative conductance of a gas space is proportional to $\varepsilon = (1/\varepsilon_1 + 1/\varepsilon_2 - 1)^{-1}$ where ε_1 and ε_2 are the emissivities of the surfaces facing the gas space (BS EN 673:1998). Where $\varepsilon_1 \approx 1$ and $\varepsilon_2 \approx 0$, $\varepsilon \approx \varepsilon_2$.

[†] Preparatory work suggested that a DWER of around 69 might be obtained from a unit with surface 3 emissivity of 0.071 (using, e.g., Cardinal glass ID 2033) but confirmation was not possible because Therm was unable to read the incomplete optics file and produce the head, jamb and sill component U values.

Table 3: Whole window U values and DWER for a range of IG units made with Cardinal glass.

Database ID	Surface 3 emissivity	Centre pane U value	Solar factor (g)	Whole window U value	Window solar factor	DWER
2030	0.026	1.296	0.205	1.555	0.176	61.45
2028	0.037	1.321	0.464	1.581	0.356	65.83
2049	0.042	1.333	0.529	1.592	0.401	66.87
2024	0.046	1.343	0.513	1.599	0.390	66.51
2046	0.056	1.372	0.516	1.614	0.392	66.40
2006	0.083	1.445	0.639	1.652	0.479	68.23
2017	0.102	1.488	0.597	1.686	0.449	67.08

4.2 Replacing the aluminium spacer with Superspacer

Component and whole window U values for this step are presented in Table 4. The effect of Superspacer is to reduce whole window U value to 1.42 W/m^2 for the ε=0.026 unit, which translates into U value improvements of over 14%. However, Cardinal's ε=0.026 coating appears to have been optimised for cooling dominated climates and units containing this product have very low solar factors. As a result the DWER for the ε=0.026 unit is almost 8% lower than the base case.

For the ε=0.083 unit, the overall U value was increased by over 8% and the DWER improved by over 2%.

Table 4: Comparison of U values for whole window, centre pane and frame components using metal spacer and Superspacer.

Component U value[*]	Base case (metal spacer) (W/m^{2}K)	Variant ε=0.026 Superspacer (W/m^{2}K)	Improvement (%)	Variant ε=0.083 Superspacer (W/m^{2}K)	Improvement (%)
Whole window	1.655	1.419	14.3	1.520	8.2
Centre pane	1.451	1.296	10.7	1.445	0.4
Window solar factor	0.476	0.171		0.475	
DWER	68.1	62.8	-7.8	69.6	2.1
Head frame	1.598	1.372	14.2	1.379	13.7
Head edge	2.235	1.696	24.1	1.810	19.0
sill frame	2.088	1.876	10.2	1.883	9.8
sill edge	2.392	1.815	24.1	1.927	19.4
Jamb frame	1.611	1.372	14.8	1.379	14.4
Jamb edge	2.229	1.696	23.9	1.810	18.8

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[*] In the US the term U factor rather than U value is used for frame and edge components of windows.

4.3 Optimising gas space width for argon fill

Figure 2 shows the effect of cavity width and emissivity on centre pane U values for argon-filled units. The results show that centre-pane-optimised gas space widths lie between 14 and 16 mm for such units. To a good approximation, the effect of emissivity on centre pane U value is independent of gas space width. But, for cavity widths below the optimum, the U value rises sharply as conduction becomes the dominant mode of heat transfer across the gas space, while for widths above the optimum, the U value rises slowly due to increased convection within the gas space.

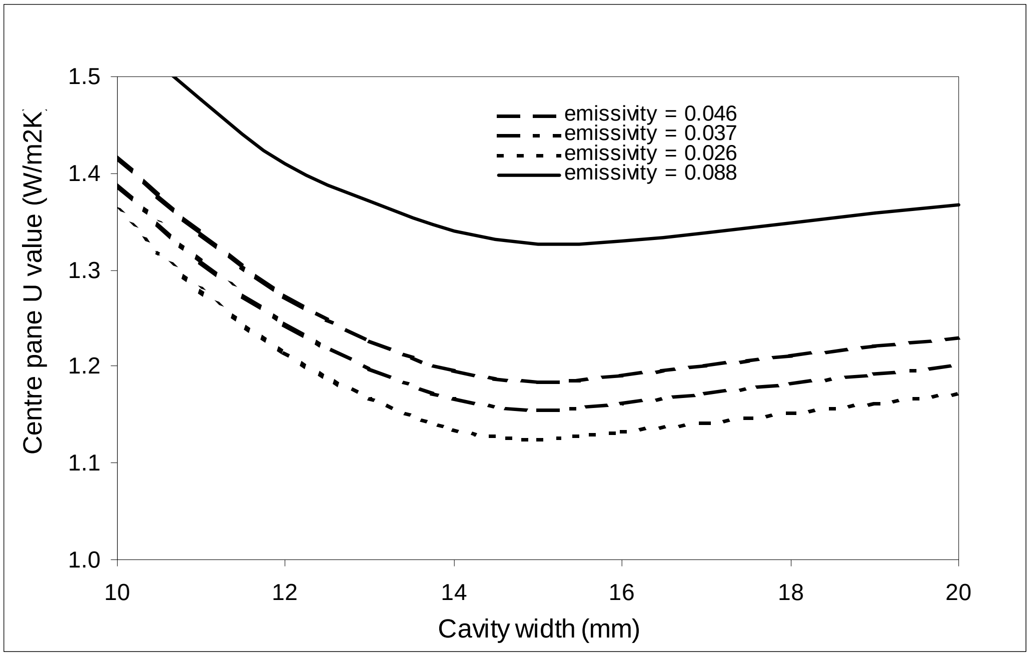

Figure 2: Centre pane U value as function of gas space width and emissivity for argon-filled IGUs.

It should be noted that optimising gas space width for centre pane performance does not lead to optimal whole window performance. The reason for this is frame and edge U values are determined only by conduction - thus greater gas space widths will always result in lower frame and edge U values which will tend to offset the effects of increased convection within the gas space itself. Whole-window-optimal gas space widths will always be greater than centre-pane-optimal gas space widths. The difference between the optima depends on frame and glazing edge performance and, in particular, on the thermal performance of the glazing spacer. The effect of gas space width on whole window performance is explored further in section 4.5.

4.4 Optimising gas space width for krypton fill

Figure 3 shows the effect of cavity width and emissivity on centre pane U values for krypton-filled units. The results show that centre-pane-optimised gas space widths lie between 9.5 and 10.5 mm for such units.

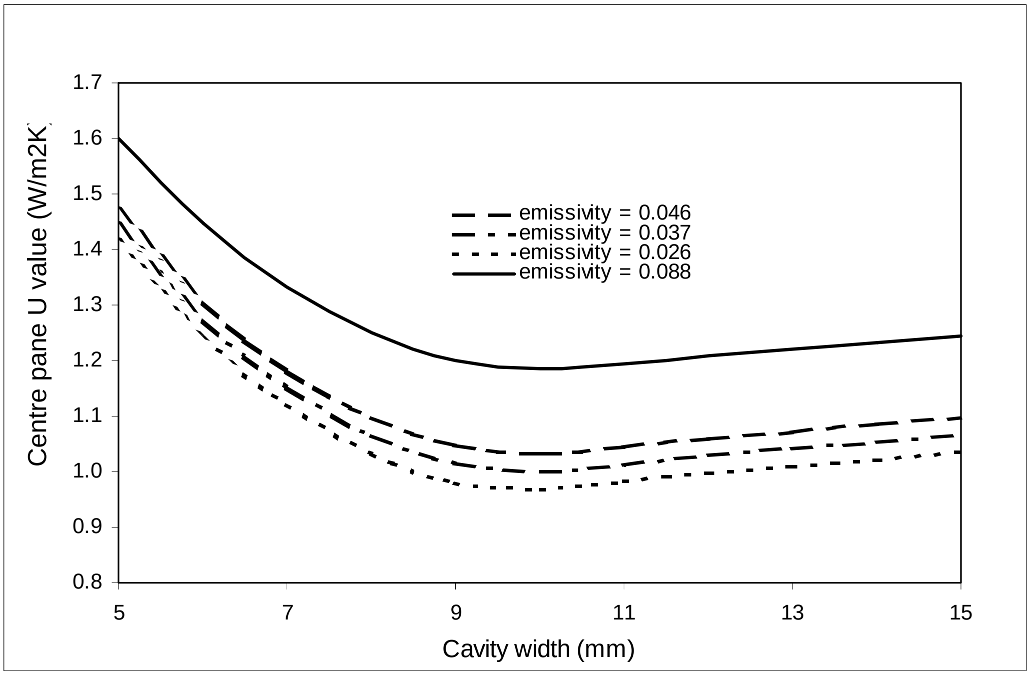

Figure 3: Centre pane U value as function of gas space width and emissivity for krypton-filled IGUs.

The comments made in the preceding section about the relationship between whole-window-optimal gas space widths and centre-pane-optimal gas space widths apply still more strongly to krypton-filled units. This is due to the reduced width of such units. This in turn increases the benefit from warm edge technologies such as Superspacer.

4.5 Effect of gas space (argon) width on whole window performance

The effect of gas space width on the performance of windows with very low emissivity coating (ε=0.026), Superspacer and argon-filled IGU was explored. The results are presented in Table 5 and confirm that gas spaces wider than the centre-pane-optimal can give a marginally better overall performance, measured on U value and DWER, despite a poorer centre pane performance. Windows with aluminium glazing spacers would show larger relative improvements in performance for very wide gas spaces, although from a lower starting point. However, various other factors may need to be taken into consideration when using very wide gas spaces[*].

Table 5: Windows with Superspacer, ε=0.026, and argon-filled IGU.			
Component	20 mm gas space	25 mm gas space	30 mm gas space
Whole window U value	1.419	1.396	1.377
Centre pane U value	1.296	1.343	1.350
Window solar factor	0.171	0.170	0.171
DWER	62.8	63.0	63.3

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[*] The maximum width of Superspacer currently available is 20 mm. The H-window would need to be redesigned to accommodate wider IGUs as the width of the component frame section is only 68mm. There may be stability issues with wide IGUs as well as on-site handling and installation difficulties.

4.6 Providing a 2-stage draught seal for the sill section of the casement

Initial analysis of the sill section showed a thermal weak point between the casement and the sub-sill. This is indicated by the constriction of the isotherms at this point in Figure 4a. The isotherm spacing was improved by adding a second draught seal (a neoprene gasket) towards the front of the casement, thereby replacing the narrow ventilated cavity with a larger unventilated cavity. The effect of adding the second seal on the isotherm spacing is shown in Figure 4b. The effect on U values is shown in Table 6.

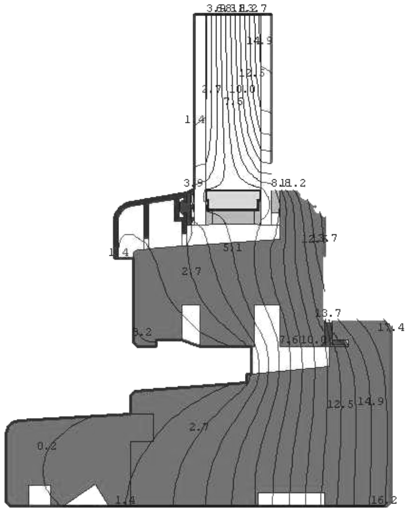

Figure 4a: Base case sill.

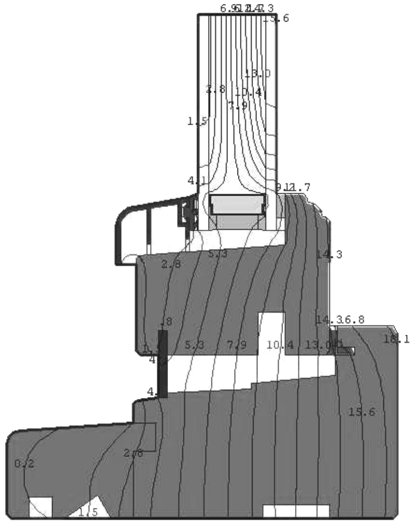

Figure 4b: Sill with two-stage seal.

Table 6: Effect of two-stage seal on whole window and sill U values.

Component	Base case (W/m^{2}K)	Variant (W/m^{2}K)	Improvement (%)
Whole window U value	1.655	1.634	1.3
Frame U value	2.088	1.858	11.0
Edge U value	2.392	2.204	7.8

The second draught seal improves the sill U value by 11% and the whole window U value by a more modest 1.3%. The annual energy saving would be of the order of 1 kWh, suggesting that additional benefits would need to be identified to make it worthwhile re-designing the sill section of this window.

4.7 Combining Superspacer and low ε coatings of 0.026 and 0.083 with krypton-filled gas spaces

The combined effect of very low emissivity coating (0.026 instead of 0.083) and Superspacer on the performance of a window with a krypton-filled IGU was explored for a gas space width of 20 mm. This width was chosen because, as noted in section 4.5 above, an IGU with a gas space optimised for centre-pane U value does not result in a minimum whole window U value - particularly in the case of narrow, krypton-filled units. As with argon, windows with wider gas spaces will achieve still lower whole window U values, though at the cost of slightly lower solar factors.[*],[†]

The results are presented in Table 7.

The overall U value of the combination using ε=0.026 is 1.331 W/m^{2}K, representing an improvement of almost 20% over the base case. Even so, this figure still lies outside the proposed standard of 1.3 W/m^{2}K. The DWER for this window is 63.8 which falls well below the required value of 70.

At 1.44 W/m^{2}K, the ε=0.083 window does not reach the proposed U value standard either but its DWER of 70.5 means that this window would reach the proposed DWER target of 70.

Table 7: Window with Superspacer, ε=0.026 and ε=0.083, and 20 mm krypton-filled IGU.

Component	Base case (W/m^{2}K)	Variant ε=0.026 (W/m^{2}K)	Improvement (%)	Variant ε=0.083 (W/m^{2}K)	Improvement (%)
Whole window	1.655	1.331	19.6	1.44	13.0
Centre pane	1.451	1.168	19.5	1.328	8.5
Window solar factor	0.476	0.172		0.476	
DWER	68.1	63.8	-6.3	70.5	3.5
Head frame U value	1.598	1.366	14.5	1.374	14.0
Head edge U value	2.235	1.595	28.6	1.72	23.0
sill frame U value	2.088	1.872	10.3	1.878	10.1
sill edge U value	2.392	1.709	28.6	1.836	23.2
Jamb frame U value	1.611	1.366	15.2	1.374	14.7
Jamb edge U value	2.229	1.595	28.4	1.72	22.8

4.8 Comparison with a fixed-light equivalent

Fixed light equivalents of head, sill and jamb components were modelled. These are shown in Figure 5. The most important difference between the fixed and opening versions of this window is that the former has a lower frame fraction. In the base case, this raises the window solar factor from 0.476 to 0.535 and the DWER from 68.1 to 69.5, as shown in Table 8 (a). It can be seen that the whole window U value for the fixed light widow was almost the same as the base case. The head and jamb components had higher U values than the base case as shown by the negative values in the final column. The sill component performed considerably better than the base case sill, however. Further analysis of fixed light performance can be found in section 4.9.

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[*] The term “thick window” was coined by Olivier and Lowe (1995) to describe windows in which very thick glazing systems are deliberately used to minimise edge and frame losses.

[†] This effect is caused by the reduction in gas space thermal resistance for IGUs that are wider than centre-pane optimal. This in turn means that a larger proportion of the solar energy that is absorbed by the inner pane and coating will be conducted outwards through the IGU and will not contribute to the WSF. In practice the effect is small.

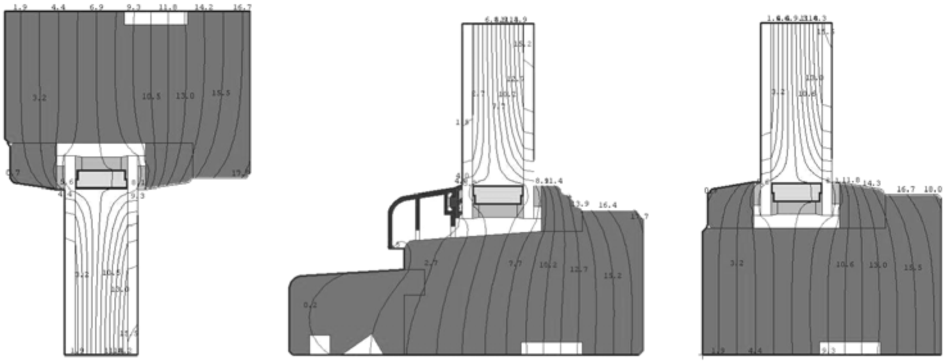

Figure 5: Head, sill and jamb components for a fixed light equivalent of the base case window.

Table 8 (a): Comparison of fixed-light equivalent.

Component	Base case (W/m^{2}K)	Fixed light (W/m^{2}K)	Improvement (%)
Whole window	1.655	1.665	-0.6
Centre pane	1.451	1.451	0.0
Window solar factor	0.476	0.535	
DWER	68.1	69.5	2.1
Head frame U value	1.598	1.665	-4.2
Head edge U value	2.235	2.342	-4.8
Sill frame U value	2.088	1.665	20.3
Sill edge U value	2.392	2.433	-1.7
Jamb frame U value	1.611	1.665	-3.3
Jamb edge U value	2.229	2.341	-5.0

Table 8 (b) shows how fixed lights perform with the additions of superspacer, krypton fill and a surface 3 emissivity of 0.026, respectively, in terms of DWER.

Table 8 (b): Fixed light performance using (CEN standard size 1230x1480)

	U	WSF	DWER
20 mm Ar, ε=0.088, Al spacer	1.665	0.535	69.54
20 mm Ar, ε=0.083, superspacer	1.514	0.534	71.18
20 mm Kr ε=0.083, superspacer	1.422	0.535	72.21
20 mm Kr, ε=0.026, superspacer	1.296	0.183	64.48

4.9 Effect of reduced window size

Because of the fixed dimensions of framing components and the fact that frame and edge U values are higher than centre pane values for high performance glazing, smaller windows generally perform less well than larger windows. As noted above, the BFRC system takes this into account by defining two standard sizes of window – sometimes referred to as CEN and half-CEN. Calculations presented so far have been for the larger of the two sizes. The effects of window size for the combinations of technologies discussed in this paper are summarised in Table 9.

Table 9: Effects of window size on performance

	BFRC full size (1230x1480)			BFRC half size (740x1230)		
	U	WSF	DWER	U	WSF	DWER
20 mm Ar, ε=0.088, Al spacer	1.655	0.476	68.12	1.713	0.410	65.78
20 mm Ar, ε=0.083, superspacer	1.520	0.475	69.58	1.533	0.408	67.70
20 mm Kr ε=0.083, superspacer	1.440	0.476	70.49	1.468	0.409	68.45
20 mm Kr, ε=0.026, superspacer	1.331	0.172	63.81	1.459	0.161	62.12

This information is presented graphically in Figure 6, along with data from Table 8(b).

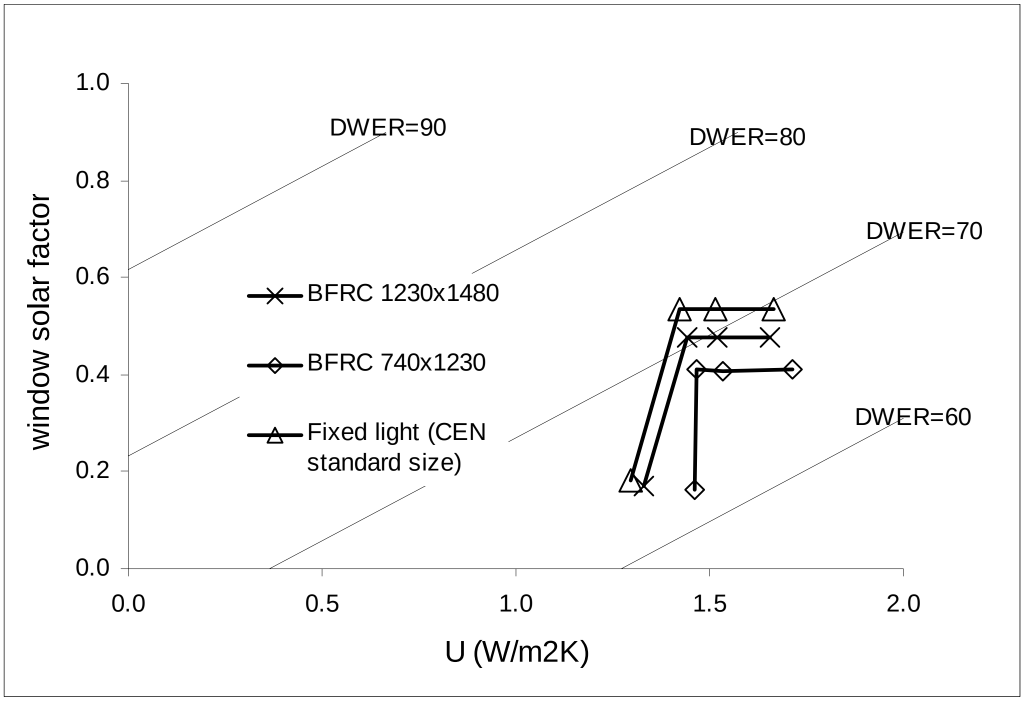

Figure 6: Performance options for double glazed timber windows on a solar factor-U value plot. The diagonal lines show the equivalent values of DWER.

5. Summary and conclusions

This paper has explored the effects on thermal performance of a series of technical changes to the specification of a commercially available, timber, double-glazed window. At the BFRC full size and in its base case configuration, this window has a U value of 1.655 W/m^{2}K and a solar factor of 0.476. The effects of the changes considered above may be summarised as follows:

(1) replacing the base case coating (ε=0.088) with a high performance coating (ε=0.026) gives a whole window U value of 1.555 W/m2K - a 6% reduction compared to the base case;

(2) of the relatively small number of glazing variants in this study, one incorporating a coating with emissivity ε=0.083 gives the highest DWER;

(3) the combination of argon, Superspacer and very low emissivity coating (ε=0.026) gives a whole window U value of 1.419 W/m^{2}K. This is a 14.3% reduction compared to base case - however, the DWER is much lower at 62.8;

(4) the combination of argon, Superspacer and an intermediate low emissivity coating (ε=0.083) gives a whole window U value of 1.52 W/m^{2}K - an 8.2% improvement compared to the base case – and a DWER of 69.6, close to the target of 70;

(5) lowest centre pane U values are achieved with gas space widths of 14mm to 16mm for argon-filled units and 9mm and 11mm for krypton-filled units; but

(6) lowest whole window U values and highest energy ratings appear to require gas spaces up to twice as wide;

(7) combining a very low emissivity coating (ε=0.026) with Superspacer and a 20 mm krypton-filled gas space gives a whole window U value of 1.331 W/m2K - almost a 20% reduction compared to the base case;

(8) combining an intermediate low emissivity coating (ε=0.083) with Superspacer and 20 mm krypton gives a DWER of 70.5 and meets the proposed performance target;

(9) predictably, fixed lights performed better than their opening casement counterparts, while smaller windows performed less well than larger windows.

There are a number of options for increasing the performance of timber double glazed windows further. We have shown that adding a 2-stage seal to the sill section achieves a small improvement (≈1.5%). Future work could explore the practicalities of using very wide glazing cavities which appear to give better overall performance despite poorer centre pane U values. Significant improvements would require the re-design of the timber frame profile to reduce its U value. Such options would be available in the medium-to-long term but have not been explored here.

This exercise has confirmed that the enhanced energy performance standard proposed by LMU can be met with timber windows of both BFRC standard sizes, with a combination of Superspacer, optimised low emissivity coatings and krypton-filled gas spaces. The standard is a demanding one for such windows and designs with higher frame fractions - for example, multi-light windows or windows with decorative glazing bars - may not meet the standard. However, it appears that the glass products used in this analysis may have been optimised by manufacturers for a mixed or cooling dominant climate characteristic of much of continental North America rather than for the heating-dominant climates of northern Europe. Use of glass products optimised for heating-dominant climates might well result in improved solar transmission and energy ratings, and lift more of the window variants examined in this study, above the DWER 70 threshold. The absence of entries from major European manufacturers from the LBL glazing products database is a severe limitation on the work that can currently be carried out.

Despite its limitations, this study represents a first step to a full understanding of the impacts of the BFRC's window energy rating system and LMU's enhanced energy performance standard on the UK window market. The work now needs to be extended to other framing materials (including PVCu, aluminium, steel and pultruded fibreglass) and to include a comprehensive range of frame sections, glazing systems and window configurations for each material.

6. References

BS EN 410: 1998 Glass in building – determination of luminous and solar characteristics of glazing.

BS EN 673:1998 Glass in building- Determination of thermal transmittance (U value) – Calculation method.

DTLR 2001 *Building Regulations 2000 Approved Document, Part L1: Conservation of fuel and power in dwellings.* London: the Stationery Office.

Lowe R.J. & Bell, M. (2001) *A Trial of Dwelling Energy Performance Standards for 2008: Prototype standards for energy and ventilation performance.* Leeds

Metropolitan University, Centre for the Built Environment. (http://www.lmu.ac.uk/hen/benv/cebe/st_nicks.htm)

Olivier, D. & Lowe, R.J. (1995) Advanced Glazing: An Integrated Approach. *in* Proc. Conf. Window Innovations 95, Toronto, June 1995. pp 516-524.

Appendix 8: Interview questionnaire

Evaluating the Impact of an Enhanced Energy Performance Standard on Load-bearing Masonry Domestic Construction

Design process interview

Name…

A. YOUR BACKGROUND

1. Before we explore areas related directly to the project I would like you to provide a brief overview of your professional background. (a short CV if you like).

I would now like to turn to aspects of your background which relate specifically to the project and the energy and environmental issues it is attempting to address.

2. Could you tell me about any experience you may have had of energy and/or environmental projects prior to the Stamford Brook project.

Is this experience based on work inside your current organisation? - If not where from?

Does any of the experience you describe come from personal experience outside your normal professional sphere of activity?

3. Knowledge about energy efficiency and environmental matters is likely to vary across the range of people and organisations involved in the project. Perhaps you would describe the extent of the energy and environmental knowledge you had before you became involved in the project?

Can you provide any examples of …

How would you describe the depth of your knowledge of …

4. What about the state of knowledge generally within the organisation for whom you work? How would you describe that?

Can you provide any examples of …

How would you describe the depth of the knowledge of …

5. What do you think were the motivating factors insetting up the scheme?

B. THE PROCESS: DESIGN AND DEVELOPMENT

6. Could you, first of all, describe what you see as your role in the project?

7. How does this role differ from that which you would normally take, in a more typical housing project?

8. How does the role you describe relate to the roles of others?

If it would help, you could, perhaps, draw a bubble diagram to explain.

People not mentioned – prompt with “what about the role of {name} the {position} (e.g. Sara Braune, the Land Agent)”?

Formal roles

Informal roles

9. From the point at which you became part of the project could you outline what you have done? Please provide as near a chronological account as you can?

Identify the start of involvement and then keep asking – “What did you do next?”

Reminders about stages may be required - such as design of concept, design of details, involvement in cost assessments etc.

I would now like to ask some questions concerning the design of the scheme.

10. Bearing in mind the energy efficiency and environmental objectives of the scheme, I would be grateful if you would describe, from your point of view, what you see as the key design decisions that have been taken so far?

What has been the extent of your involvement in this decision.

For each area mentioned – ask what do you think were the main factors in making the decision.

In your judgement, how likely are any of these decisions to change?

11. Please would you outline those areas where design decisions are still to be taken?

How involved do you expect to be in … {decision/aspect}

What, do you think, will be the most important factors in reaching a decision on … {particular aspect}

Any other areas?

12. Please comment on how easy or difficult you think it will be to meet the energy standards set for the scheme?

Can you say more about the ease/difficulty of ……{aspect}

What problems do you foresee in meeting the energy standards?

13. Has anyone outside the team intervened in the design in any way?

Nature of intervention

Extent of intervention

Knowledge gained

14. Do you feel there are any outstanding buildability issues that have not been fully addressed by the design process?

15. Do you have any other comments on the way in which the various aspects of design have been or are being addressed?
Can you elaborate?

C. THE PROCESS: MANAGEMENT APPROACH

16. In what ways, if any, has the management of this project differed from other projects that you have been involved in?

Prompts if differences:
Can you tell me more about……..{aspect}
Are there any other differences?

If no differences:
How surprised are you at the lack of difference?
Why do you think there is no difference?

17. How easy would it be for other sites in other regions (within the builder's organisations) to replicate achieving the enhanced standard?
What do design teams need in order to respond effectively to the enhanced standard.

18. How easy do you think it would be for other builders nation-wide to achieve it?

19. Have there been any synergies/drawbacks with two developers working together?
Approach used in selecting subcontractors and managers.
How do you think site designers and detail designers have worked together?

20. Do you have any other general comments about the management process in this project?
Please elaborate.

D. MARKETING

21. What aspects of the houses built to the enhanced environmental standard might increase saleability/profit?

22. What do you think might be the customer perceptions of these houses?

23. What areas of risk/uncertainty are there in marketing a low energy site?

24. Would anything learnt/designed on this project become part of a marketing strategy on other sites?
What experiences will be taken to other projects.

Any other comments?

E. DEVELOPMENT OF KNOWLEDGE, SKILLS AND UNDERSTANDING

25. Would you say that your knowledge of the relevant issues has changed during the time you have been involved?

In what way? Can you elaborate?
How did you learn (more) about *[particular aspect*]/ this?
Can you give any specific instances or examples?
Are there any other aspects?
I would like us to focus mainly on specific things related to the project. [to be used if the answers get very general]

If No:

Can you say why you think that?

26. Do you think that you have been able to contribute to the knowledge of the team?

In what way? Can you elaborate?
How did you get *[particular aspect*]/ this across?
Can you give any specific instances?
Who were the main recipients?
Are there any other areas?
I would like us to focus mainly on specific things related to the project. . [to be used if the answers get very general]

If No:

Can you say why you think that?

27. Do you think, there are any areas where the team needs to learn more in order for the project is to be successful?

Can you say more about the areas where more knowledge in required?
What do you mean by *[particular aspect*]/ this?
Can you give any specific examples?
Who needs to acquire this knowledge?
Are there any other areas?
I would like us to focus mainly on specific things related to the project [if general]

28. Were there any design areas that would have been difficult to do without LMU input?

Assess level of influence of LMU

29. Do you have any other comments you would like to add about the questions of knowledge we have just been discussing?

F. DEVELOPMENT OF ATTITUDE, INTEREST AND MOTIVATION

30. How would you describe your personal views, at the beginning of the project, as to its energy and environmental objectives?

I am thinking of views about such things as: its necessity, how worthwhile you thought it was, or how realistic you thought it was.

Are there any other points you would like to make on this?

31. Do you feel that any of your personal views about the energy and environmental objectives of the project have changed over the course of your involvement?

Can you say something about what has changed?

How would you describe your current view?

Is there anything else you would like to add about your current view?

32. Do you feel that the views within your organisation about the energy and environmental objectives of the project have changed over the course of your involvement?

What was their view before the project?

How would you describe the current views within your organisation?

Can you say something about what has changed?

Is there anything else you would like to add?

33. Before you were introduced to the project, what did you think about the adequacy of the current building regulations?

Is this a personal view?

What was the view of the organisation?

34. During the course of the project, have your views about the adequacy of the current building regulations changed?

Please elaborate on how your views have changed

Do you think the view of your organisation has changed?

35. Are there any other areas in which your views or those of your organisation have changed during your involvement in the project?

Please describe them and the extent of the changes.

36. Are there any other comments you would like to make regarding any part of this interview?

Please elaborate

Thank you for taking part in this interview.

Appendix 9: Construction specification

Taylor Woodrow Developments and Redrow Homes Construction Specification for Load-bearing Masonry Houses at Stamford Brook

1	Dave Poole	12-09-03
2	David Roberts	30-10-03
3	Gary Fox, Nikki Burns, Paul Brickles, Chris Palmer, David Roberts	05-11-03
4	Joe Isle, Dave Poole	18-11-03
5	David Roberts	21-11-03
6	Dave Poole, David Roberts	27-11-03
7	Peter Warm, Sara Braune, Rob Jarman, Steve McGlade Paul Brickles, Maria Andersson, Joe Isle, David Roberts	28-11-03
8	David Roberts (clause 28.3)	08-03-04

1.0 General

All works and materials shall be in accordance with:

1.1 EPS (Environmental Performance Standard, Statement of Interpretation and Intent)*.

1.2 Construction (Design and Management) Regulations 1994.

1.3 British and European Standards where applicable.

1.4 NHBC Standards.

1.5 Requirements of the Town and Country Planning Act.

1.6 Prototype standards for energy and ventilation performance.†

1.7 Approved documents with respect to the requirements of Schedule 1 and to regulation 7 of the Building Regulations 2000 and subsequent amendments for England and Wales (except items specified in 1.1 & 1.6, above).

2.0 Energy efficiency

2.1 Limiting thermal bridging and air leakage: Construction and site works shall reflect the requirements of Draft Proposed Robust Construction Details which were designed specifically for the Stamford Brook project.

2.2 Whole U-values for construction elements shall meet the requirements of the EPS08 document, summarised in column 2, Table 1. Maximum trade offs are shown in column 3, Table 1.

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[*] EPS was written and developed by the National Trust, Environment Conscious Building Services, Leeds Metropolitan University, Redrow and Taylor Woodrow to be used on the Stamford Brook project. This document to be read in conjunction with the latest version of the “Approved Products and material schedule”.

[†] Draft prototype building regulations (Parts L & F) proposed for 2008, written by Malcolm Bell & Robert Lowe, Leeds Metropolitan University.

TABLE 1: WHOLE U VALUES		
ELEMENT	EPS08 WHOLE U VALUE (W/m2K)	EPS08 MAX TRADE OFF (W/m2K)
ROOF VOID	0.16	0.19
ROOM IN THE ROOF	0.16	0.19
CAVITY WALLS	0.25	0.30
STUD WALLS	-	-
WINDOWS	1.3 (or DWER 70)*	1.56
DOORS	1.3	1.56
GROUND FLOOR	0.22	0.26

3.0 Workmanship

3.1 To be carried out in accordance with BS 8000 “Workmanship on building sites” all parts and, additionally, to be carried out in accordance with workmanship items included in this specification.

4.0 Foundations

4.1 All sites to be properly assessed and investigated.

4.2 Foundations and substructure designs shall be suitable for the ground conditions.

4.3 Sites are properly remediated where necessary or appropriate design precautions taken.

4.4 Appropriate documentation and validation to be provided on request.

4.5 Foundation design to follow NHBC guidance.

4.6 Foundations shall be designed by a suitably qualified person where buildings exceed 3 storeys in height or where poor ground conditions occur.

4.7 Refer to supplementary note regarding concrete mixes.

4.8 Recycled aggregate to be used wherever possible.

5.0 Drainage below ground

5.1 Adoptable sewers to Section 104 (of the Water Industry Act) requirements in accordance with Sewers for Adoption.

5.2 Where not adopted to be constructed to ADH of the Building Regulations and NHBC Standards 5.3.

5.3 All drainage schemes require the approval of the Building Control Authority and local sewerage undertakers. Drainage design shall be in accordance with BS 8301.

5.4 Clay pipes and fittings to be produced in accordance with BS EN 295 part 1: 1991 (clay) and BS 4660: 2000 / BS EN 1401 part 1 1998.

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[*] Domestic Window Energy Rating certified by the British Fenestration Rating Council.

5.5 Polypropylene inspection chambers to be used (not PVC).

6.0 Walls below DPC level

6.1 Concrete blocks for use below DPC should comply with BS 6073 and have:

6.1 Density equal to or greater than 1500 kg/m³ or

6.2 Have a compressive strength equal to or greater than 7N/mm².

6.3 Aircrete trenchblocks suitable for soil classification. The manufacturer should be consulted.

6.4 For in-situ ground floor slabs, inner face of blockwork to have ZODP 65mm rigid urethane perimeter insulation (λ=0.022W/mK).

6.5 Where foundation depths exceed 1.5m in soils classified as having medium to high shrinkage potential, the perimeter wall insulation should be substituted for Claymaster protection board in accordance with engineers recommendations.

6.6 The selection of mortar for use above and below DPC should follow the recommendations given in BS 5628: part 3; see table 14, and NHBC guidelines.

6.7 Note: 3 storey house types may require blockwork of 7N/mm² compressive strength. A suitably qualified structural engineer should be consulted.

7.0 Ground floors

7.1 Construct and insulate floor in accordance with Construction Detail Sheets*. Refer to thermal calculations to demonstrate compliance with energy efficiency standards (clause 1.1). Floor types to suit prevailing ground conditions are: (1) Ground bearing concrete in-situ slabs; (2) Suspended reinforced concrete slabs (suitable for “Basic” radon / gas protection).

7.2 Provide a smooth powerfloat finish to each floor type.

7.3 Ground-bearing or suspended concrete ground floor slabs are to incorporate 65mm rigid urethane under-slab insulation (λ=0.022w/mK, Kingspan Thermafloor TF70 or similar approved) with 65mm edge insulation continued from insulation layer down to footings.

7.4 For reinforced suspended in-situ floor slabs where soils are classified as having shrinkage potential, the under floor insulation is to be substituted for Cellcore CP void formers in accordance with engineers recommendations.

7.5 Insulation materials to have zero ozone depletion potential.

7.6 Note: Gas carcassing to be incorporated into floor (pre-plastic coated copper pipework) with min 25mm cover and tested for soundness to IGE requirements.

8.0 Radon

8.1 Geographic areas where measures are required as listed in the BRE Guidance Document ‘Radon: Guidance on protective measures for new dwellings’ 1999 revision (BR 211) is defined as either requiring full or basic protection, the relevant construction detail sheets should be referred to and implemented on site as necessary.

9.0 Damp proof course

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[*] “Construction detail sheets” as designed by Dave Poole and LeedsMet.

9.1 DPC of black polyethylene to BS 6515 to be laid min 150mm above finished ground level. FL quality facing brickwork to extend min 4 courses below DPC extending to suit external ground levels.

10.0 External cavity walls

10.1 Wall ties performance – To conform to BS DD 140: 1986 or BS EN 845-1 for Type 3 masonry-to-masonry walls. They will have adequate durability and will not be impaired by contact with conventional cavity insulation materials, mortar admixtures or timber preservative treatments.

10.2 Wall ties specification – 250mm Kristiansen Refus 1 glass filled thermoplastic polyester ties spaced at 450mm centres vertically and horizontally (4 per m²) and at every blockwork course vertically around openings. These wall ties are not suitable for buildings over 3 storeys (15m max wall height) without further testing in accordance with BS EN 845-1:2001.

10.3 142mm cavity retro-filled with granulated mineral wool fibres (λ=0.039W/mK) manufactured from silica sand and treated with an inert water repellent and installed by a BBA Certified installer (check walls over 12m). Insulation installer to fully fill all drill holes made during injection of insulation.

10.4 100mm inner load-bearing leaf of solid aggregate blockwork (typical density 1200-1600 kg/m³) manufactured to BS 6073 having a compressive strength of 3.5 or 7.0N/mm² (dependant on location). 65mm reveal blocks to match.

10.5 Head, sill and jambs to be closed at reveals with 100 x 75mm (Rockwool Rockclose or similar approved, λ=0.035W/mK) insulating DPC – black polyethylene to BS 6515.

10.6 Parging coat to be applied to internal surface of external blockwork (min 3mm thick over blockwork, regulating to max 6mm at joints) prior to drylining (after windows are fitted and prior to ceilings). The intention is to provide a complete airtight layer on all external walls. Particular attention should be made to window and door reveals. Parging coat is not necessary in the wet plastered houses.

10.7 9.5mm gypsum based plasterboard drylining with joints taped and sealed ready for decoration, alternatively a 3mm plaster skim coat may be specified. Head and jamb reveals to have 18mm Gyproc insulated reveal board.

10.8 External render to be a proprietary one coat decorative coloured scratch render (Blue Circle Rendaplus Colourtex S or similar approved) providing a high degree of waterproofing, hardness and durability to be applied in accordance with manufacturers instructions. Substrate to be lightweight aggregate blockwork.

10.9 See also, section 17 – “separating walls”.

Workmanship note

10.9 It should be noted that misaligned horizontal mortar beds with thick wall ties, the rotation of the ties within the mortar bed is limited by the thickness of the mortar bed and interference between the blocks and bricks and the embedded ends of the tie. Further, the minimum embedment is 50mm. A high degree of workmanship is therefore required to take account of these limitations in build tolerances.

10.10 Brickwork pointing to be bucket handle or weather struck (not recessed).

Wet plaster

10.10 Partners In Innovation requires 50 No dwellings to have a “wet plaster” internal finish – pre-mixed gypsum based Thistle wet plaster system confirming to BS 1191. First coat 11-13mm with 2mm finish coat applied in accordance with manufacturers instructions.

11.0 Movement joints

11.1 Movement joints may be required where straight walling occurs in runs in excess of 12 metres in brickwork and 6 metres in blockwork (i.e. without returns and openings e.g. in straight terraces), where thermal movement may occur due to material properties or where differing strata occur in foundations. Check with Structural Engineer.

12.0 Lintels

12.1 Galvanised steel lintels designed, tested and manufactured fully in accordance with BS 5977. Openings over 1.2m wide may require ‘propping’ until the brickwork over has matured. Minimum bearing of lintels to be 150mm each end. Bearing to be onto complete block. Lintels above internal doors to have minimum 100mm end bearings. All lintels to manufacturers schedules and calculations. Expanded metal reinforcement over meter boxes.

12.2 To limit thermal bridging paths each masonry leaf is to be supported with INDEPENDENT lintels – Catnic CN94/95/96 outer leaf and CN71/81 inner leaf or similar approved. The outer leaf lintel is to have a pre-creased built in cavity tray (Zed led or similar approved) of 0.75mm polypropylene cut to length on site with proprietary stop ends having pre-applied bitumen butyl complying with BS 5628: part 3 2001.

13.0 Cavity trays

13.1 Proprietary (Zed led or similar approved) pre-formed self supporting polypropylene stepped cavity trays c/w catchment trays and internal / external corners complying with BS 5628: part 3 1985 to extend beyond the wall tie drip and manufactured to suit a 142mm cavity width.

14.0 External doors and windows - general

14.1 1.3W/m²K whole window U value / 1.56W/m²K max trade off values where windows, outer doors and rooflights are to equate to no more than 25% of the gross floor area or:

14.2 All dwellings to have BFRC certified high performance window systems. They are to have a domestic window energy rating of 70 or better where windows, outer doors and rooflights are to equate to no more than 35% of the gross floor area. Annual energy ratings must be certified by the British Fenestration Rating Council. The BFRC window energy rating system provides a rigorous framework for the calculation of whole window U values and solar heat gain fractions, and for combining these quantities into an annual energy rating that indicates the impact of increasing the window area of a typical dwelling by 1m². A window with an energy rating of 70 will be approximately energy neutral in a typical new dwelling – solar gains from such a window cancel out heat losses.

14.3 The allowable window area must be verified by calculation in accordance with the whole house energy performance evaluation using the “Domestic Performance Calculator[*]” software.

15.0 Window and door specification

15.1 To incorporate the ventilation requirements as described under clause 26.

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[*] Carbon rating-based spreadsheet held by David Roberts at LeedsMet which will be used to assess building regulation compliance with EPS08.

15.2 Glass – 26mm 2-layered low-energy pane (argon filled with warm-edge spacebar technology) (DIN 52619 / EN 673). Alternatively, triple-glazed units achieving the same performance may be used.

15.3 Timber – All timber (excluding hardwood used for door bottom sills) to be FSC or equivalent (such as Northern Scandinavia softwood).

15.4 Timber preservative (not CCA) – Vacuum impregnated according to DS 2122 class B.

15.5 Surface treatment – Gori system 890, water based, gloss 30 is applied after priming treatment,

15.6 Ironmongery – Concealed adjustable side-hung ironmongery with friction 2-3 point espagnolette. Locking (except to escape windows) silver anodised handles.

15.7 Manufacturer to confirm specification meets with NHBC Standards Chapter 6.7.

15.8 Escape windows to comply with ADB requirements.

15.9 Safety glazing to comply with ADM requirements.

15.10 Obscure glazing to bathrooms, WC's and front entrances.

15.11 Easy clean hinges.

15.12 Key-lockable handles with two point ventilation locking system (except to escape windows).

15.13 Doors constructed using Scandinavian faces with an insulated core of rigid polyurethane (ZODP) and timber blocks for hardware fixing. Factory fitted double glazed units (toughened glass to BS 6206) to be fitted and sealed into the door and having either glazing bars or leaded lights and decorative coloured glass dependant on door style and matching the window thermal performance. The doors are pre-hung at works into the softwood frames to give a clear 800mm opening and fitted with a proprietary weather seal threshold system (aluminium with gold effect finish) suitable for mobility access requirements to principle entrance and non-mobility version to secondary entrance.

16.0 Internal walls (to achieve 40dB sound reduction)

16.1 Load-bearing walls to be 100mm aggregate 3.5N/mm² blockwork (7.0N/mm² or greater to ground floor 3 storey) and faced with 9.5mm gypsum based plasterboard dry-lining (except to wet plaster dwellings).

16.2 British Gypsum Soundcoat (parging) applied to the external wall blockwork face and all reveals prior to first fix.

16.3 Partitions to be 75mm Gyproc Gypwall dB plus (Active family) metal stud system.

Workmanship to achieve ADE Robust Details:

16.4 Ensure all gaps are sealed around partition perimeters and junctions – apply Gyproc jointing material between plasterboard base and floor.

16.5 Ensure any gaps are sealed around wall perimeters and junctions with a continuous adhesive dab.

17.0 Separating walls (to achieve minimum value of 45DnTw+Ctr dB)

17.1 Separating walls can EITHER be built with the same cavity width as external walls giving a 345mm wall OR with a smaller cavity giving a 275mm wall. Each leaf comprising:

17.2 100mm 3.5N/mm² lightweight aggregate blockwork of 1200 – 1600 kg/m³ density.

17.3 8mm min render mix of cement:lime:sand (1:½:4) applied to room side (except to floor zone and within roof space).

17.4 12.5mm gypsum based plasterboard (min 8.5 kg/m²) on dabs.

17.5 Wall ties specification – 250mm Kristiansen Refus 1 glass filled thermoplastic polyester ties spaced at 450mm centres vertically and horizontally (4 per m²) for 142mm cavity widths. For other cavity widths, use ties with similar acoustic, thermal and structural performance.

17.6 No flues to be built in separating walls. (See section 33 – “Focal point fires”).

Workmanship (to be inspected on site):

17.7 Ensure all perpends are fully filled and sealed with mortar.

17.8 Ensure cavity wall is stopped with a firestop closer at the separating wall junction.

17.9 Ensure that mortar does not build up on the wall ties to form an acoustic bridge.

17.10 Ensure the only connections between each side of the separating wall are via the wall ties or foundation.

17.11 Ensure internal render is a minimum of 8mm.

17.12 Ensure internal render is applied to all the face and is NOT float finished.

17.13 Ensure continuous gypsum adhesive dab applied to all ceiling, wall and floor junctions with separating wall.

17.14 Ensure cavity wall continued into roof void and fire stopped in accordance with NHBC guidance 7.2 Siteworks.

18.0 Internal doors

18.1 FD20 fire doors applicable (houses with three storeys) at every level opening on to a fire protected escape route (landings / hallway), and fitted with self closer. Provided half hour fire rated construction is maintained in the floor zones, fire doors may be omitted from bathrooms and airing cupboard but must be specified to stores particularly where located under stairs which should be under drawn to give half hour resistance.

18.2 Door between integral garage and house to have one hour fire protection.

19.0 Cavity Barriers and fire stopping

19.1 External wall at eaves and verge levels - cavity to be closed by either continuation of soffit board fully across the cavity or with mineral fibre quilt dressed over wall plate and in to cavity immediately before felting.

19.2 The cavity masonry separating wall should be continuous to the underside of the roof covering and fire stopped.

19.3 150mm thick acoustic party wall insulated DPC (Rockwool or similar approved) positioned in the cavity at the junction of the separating and flanking walls.

20.0 Intermediate floors (to achieve 40dB sound reduction)

20.1 Intermediate floor construction is to comprise:

20.2 22mm moisture resistant flooring grade P5 chipboard – subject to National Trust approval (Weather Dek2 or similar approved) laid and fixed strictly in accordance with manufacturers instructions and supported at all boarded room perimeters.

20.3 241mm engineered timber I-beams at max 600mm centres (floor design by suitably qualified person).

20.4 15mm gypsum based ceiling board, joints taped and filled to receive decoration. Alternatively a 3mm plaster skim finish may be specified. For the application of a textured decorative finish square edge boards should be used with a nominal 3mm gap between boards and applied in accordance with manufacturers instructions.

20.5 I-beams are to be “built-in” to external walls strictly in accordance with NHBC technical guidance note using ‘joist-wrapping’ or equivalent techniques to limit air leakage.

20.6 I-beams to be supported in galvanised steel hangers (Strong-Tie Simpson or similar approved) as specified on the floor design to separating walls.

20.7 Galvanised steel lateral restraint straps (Strong-Tie Simpson or similar approved) as specified on the floor design.

20.8 Note: This specification clause should be read in conjunction with the following documents:

1] TJI Joist Safety Bracing and Site Practice (T28-11-00).

2] TJI technical Bulletin – Installing a Silent Floor System, Safe Working Practice (T28-12-00).

3] Safe Working with Engineered I-beam Floors and Masonry Hangers on Separating Walls (T28-10-00).

21.0 Staircases

21.1 To be manufactured to BS 585 pt 1 and to comply with ADK of the building regulations.

22.0 Roofs: Cold breathable roof

22.1 Main roof construction to comprise:

22.2 Roofs with a slate or tile covering to be designed and fixed in accordance with BS 5534: parts 1 & 2 or laid strictly in accordance with manufacturers installation instructions taking into account wind loads etc to suit the location and height of building.

22.3 25 x 38mm Type A imported timber battens (FSC certified or equivalent, such as Scandinavian) in accordance with BS 5534 part 1 1997 Annex G & H. Ventilation space created by 25 x 25mm (minimum) counter battens over breathable sarking membrane to BS 5252: 1989 (1995), vapour resistance must not exceed 0.25 MN.s/g. Over fascia ventilators to provide equivalent area equal to 25mm continuous gap at eaves.

22.4 All dwellings to have blown recycled cellulose insulation (for example, “Warmcel”) in the cold roof construction. 15mm vapour check plasterboard to ceilings (12.5mm Fireline vapourcheck to 3 storey with fully supported edges).

22.5 Minimum 225mm wide underlay type 5U to BS 747 at eaves level and to overlap with breathable membrane.

22.6 Trussed rafters are to be designed In accordance with BS 5268 structural use of timber and BS 6399 loadings of buildings. Calculation sheets should be made available on request. The roof configuration should be designed by a suitably qualified person and the design shall incorporate all necessary longitudinal binders and diagonal bracing as required by BS 5268 pt 3. (refer to NHBC Standards 7.2).

22.7 Galvanised steel truss shoes and lateral restraint straps (Strong-Tie Simpson or similar approved) as specified on the roof design.

22.8 100 x 50mm bedded wallplates skew nailed with two 4.5 x 100mm long galvanised round wire nails, one each side of truss. For situations where the roof is required to resist wind uplift (check with building inspector!) replace with truss clips and appropriate holding down straps.

22.9 All timber to be FSC certified or equivalent.

22.10 Preservatives must not be CCA.

Room in roof

22.9 Vertical stud walls in “room in the roof” situations and dormer cheeks to be insulated with blown recycled cellulose insulation (for example, “Warmcell”) to achieve the wall U value requirement of 0.25W/m²K.

22.10 Room in the roof (U = 0.19W/m²K) ventilation and insulation as above. 241mm Series TJI Trusjoist engineered and designed I-beam based floor deck with truss rafter based roof design by Trusjoist to suit roof configuration.

23.0 Rainwater goods

23.1 Rainwater gutters and down pipes to be manufactured from galvanised steel or heavy grade uPVC to BS 4576 in black unless stated otherwise. Gutter to be 112mm half round section with 68mm circular drops. Rainwater butts to be provided on downpipe.

24.0 Flashings

24.1 Code 4 milled lead sheet to BS 1178 in lengths not exceeding 1.5m. Step and cover flashing dressed over tiles by at least 150mm and turned up brickwork at least 150mm.

25.0 Plumbing

25.1 All fittings to have 75mm deep seal traps in ABS plastic confirming to BS 3943. Basins and bidets to have 36mm diameter wastes; all other wastes to be 42mm diameter except showers and combined appliance wastes which shall be 50mm diameter and WC's which will be 100mm diameter. uPVC push in type 110mm soil and vent pipe with ground floor rodding access for testing and maintenance above spill over level.

25.2 WCs to be efficient, siphon flush, leak-free WRAS approved and, preferably, low volume flush. Aerated hot and cold taps to all sinks and basins. Flow regulators to be installed on all hot or cold mains pressure taps including outside taps if fitted.

26.0 Space and Water Heating

26.1 Central heating systems shall be designed in accordance with BS 5449 part 1 "Code of Practice for central heating for domestic premises", BS EN 442.

26.2 All pipework except where exposed (copper in airing cupboards for example) to be Barrier Hepworth Hep.2.O with de-mountable or slim-line fittings to BS 5955 pt 8 – Specification for the installation of thermoplastic pipes and associated fittings for use in domestic hot and cold water services and heating systems. Heating designs to indicate “routabout” access of pipe manifolds in floor voids. Feed, return and domestic supply pipework is to be located behind drylining of walls and within partitions.

26.3 Zone control by provision of thermostatic radiator valves to each room, except that containing the thermostat (hall normally).

26.4 Full programmer for space and water heating.

26.5 Roll topped radiators (Potterton Myson or other approved). Output to BS EN 442.

26.6 Performance – Carbon intensity of space and water heating* shall not exceed 70kg of CO_2 per gigajoule of useful heat.

26.7 Specification - Condensing boilers having a minimum SEDBUK rating of 90%, a rated output of 6kw and an auxiliary electrical requirement for boiler fan and circulation pump of 200w. NOx emissions of less than 70mg/kWh.

26.8 Provision to be made for boiler condensate.

27.0 Airing cupboard

27.1 Insulated heating feed and expansion tank. Indirect copper hot water cylinder to BS 1566: 2001 insulated with 70mm min PU foam zero ODP. Capacity dependant on demand. 3 kW immersion heater with engraved switch and neon indicator located outside airing cupboard.

27.2 32 x 22mm softwood pre-made slatted shelving, min $0.5m^2$ to NHBC standards.

28.0 Mechanical Ventilation and Electrical work

28.1 Background performance – Mechanical extract system combined with a means for the direct admission of outside air to the rooms. Total airflow through the dwelling as Part F table and provision to limit over-ventilation under adverse weather conditions.

28.2 Background specification – Mechanical central extract (MEV) serving wet rooms to BRE Digest 398 having DC motor and fan arrangement with close ratio multiple speed options allowing fine tuning to suit room volumes. Controls to have normal / boost controls.

28.3 Air intake provision - Push vent fitted in side frame on hinge side to provide $3000mm^2$ EQUIVALENT area (or 4000mm2 FREE area) of controllable ventilation to non-wet rooms. (Note: 4000mm2 equivalent area = 3000mm2 free area).

28.4 On designated plots† a balanced mechanical ventilation system (MVHR) shall be installed. With air-to-air heat recovery devices, supply and extract air flows must be balanced (no window vents).

28.5 Secondary means of ventilation performance – Additional means shall be provided to ensure adequate background ventilation under conditions when the primary ventilation system is not operational.

28.6 Secondary means of ventilation specification - Windows to have secure opening position corresponding to an equivalent area of $8000mm^2$ to each wet and habitable room.

28.7 In kitchens, a capability to boost the rate of mechanical extraction (during cooking) to 30l/s from a point above the hob, should be provided in addition to ventilation openings.

28.8 On designated plots, MEV and MVHR systems shall be equipped with measuring points for checking operating conditions and energy consumption.

28.9 All 100mm ducting, fittings and internal grilles to be manufactured from PVC-free materials.

28.10 Mains supply for the MEV unit will be provided by the electrical contractor.

28.11 BS 7671 “Requirements for electrical installations” (IEE Regulations 16th edition) requires a completion certificate to be provided to the builder by the electrical contractor. This certificate covers all aspects of the installation, including earth bonding.

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[*] See EPS08.

[†] Plots chosen for the PiI field trial.

28.12 Install smoke alarms in accordance with ADB building regulations.

28.13 Energy efficient lighting is to be provided to each home in accordance with Approved Document L1 approximating to 50% of all rooms in order of most use: Hall / Lounge / Landing / Dining / Kitchen / Bedrooms. Fittings complete with 18w CFL's.

28.14 Pendant light fittings to rooms other than kitchen (fluorescent c/w diffuser) and batten holder to WC, bathroom and loft, all complete with GLS tungsten lamps.

28.15 3-gang grid switching (light, extract fan and isolation) to bathroom. Pull cord to WC. Two way light switch between floors to hall / landings. Neon indicator to loft switch.

28.16 External lighting where provided outside also to comply with BS 7671 (CFL PIR with time control).

28.17 Non PVC cables must be used for ring mains and lighting circuits. All other wiring components to be non-PVC where possible.

29.0 Joinery items

29.1 Joinery items to be FSC certified or equivalent.

29.2 Skirtings to be 94 x 14mm torus MDF (low formaldehyde as agreed with the National Trust). Architraves to be 58 x 18mm torus MDF. 153 / 77 x 25mm MDF internal door linings.

30.0 Tiling

30.1 As indicated on the kitchen and bathroom layouts.

31.0 Access and facilities for the disabled

31.1 The approach, entrance, circulation and mobility facilities – all in accordance with ADM of the building regulations – see relevant National Construction Details.

32.0 Air leakage and infiltration

32.1 Performance – A dwelling shall have an air leakage rate measured by pressurisation test at 50Pa, and expressed as an average over the internal surface areas of the dwelling, of no more than $5m^3/h/m^2$. Every house to meet this leakage rate after a trial / learning period of 20 houses per developer.

32.2 3-6mm British Gypsum Soundcoat applied to the external wall blockwork face and all reveals prior to first fix.

32.3 Apply acrylic polymer impregnated foam elastic weatherseal to rebate around door and window frames

32.4 Strictly apply "Draft Proposed Details 2008".

32.5 Proprietary loft access traps (Glidevale premier or similar approved) with insulation U values equal to the roof insulation and having bolts which when secured will resist a positive (upward) pressure of over 50Pa without air leakage.

33.0 Focal point fires

33.1 Room-sealed gas fires may be offered as an option in detached and in semi-detached dwellings where the fireplace is on an external wall. In these situations a balanced flue will be used. Balanced flues do not require additional room vents. In mid-terrace and semi-detached dwellings where the fireplace is on a separating wall, no gas fire (or gas point) is to be fitted.