ENERGY EFFICIENCY IN HOUSING: AN EVALUATION OF THE IMPORTANCE OF INCREASED WALL THICKNESS ON HOUSING DEVELOPMENTS

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ENERGY EFFICIENCY IN HOUSING: AN EVALUATION OF THE IMPORTANCE OF INCREASED WALL THICKNESS ON HOUSING DEVELOPMENTS

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ABSTRACT

In April 2002 revisions to Part L of the Building Regulations were introduced, to improve the energy efficiency of UK buildings. For many housing schemes using traditional masonry cavity walls this may result in an increased cavity width and a consequent increase in the dwelling footprint. The potential impact that this may have on site utilisation, particularly in the light of planning guidance aimed at increasing site densities, has raised concern within the development community. Developers argue that even minor increases in wall thickness may reduce the number of dwellings on sites, thereby reducing overall profitability. This paper analyses these concerns by investigating the impact of increased wall thickness in the context of two developments constructed in the late 1990s. The existing site layouts were analysed under different footprint assumptions and an assessment made of the capacity of the layout to accommodate footprint increases. The theoretical analysis demonstrates that dwelling numbers are unlikely to be reduced as a result of the standards introduced in 2002. It is only when anticipated future improved standards are applied that dwelling numbers may be affected. However, the paper demonstrates also that dwelling loss is not inevitable and that it is perfectly possible to produce very low energy housing, while still achieving densities in line with planning requirements and with no reduction in the overall quality of a scheme. In the end it is not a matter of wall thickness but of good site layout and good house type design.

INTRODUCTION

In April 2002, Part L (Conservation of Fuel and Power) of the Building Regulations for England and Wales was revised and (among other things) significant improvements were made to the required standard of insulation (DTLR 2001). Partly in response to the European directive on the energy performance of buildings (EU 2002), the UK government committed itself to another review of Part L aimed at making further improvements by the end of 2005 (DTI 2003). This burst of regulatory activity is almost unprecedented in UK practice and will have important implications for the building industry in general and the house building industry in particular.

Given that housing in the UK accounts for just under 30% of national carbon dioxide (CO_2) emissions, reducing emissions from this sector will continue to be an important area for energy policy as the Government seeks to achieve its target of a 60% reduction in greenhouse gas emissions by 2050 (DTI 2003[1]). However, making dwellings more energy efficient will require ever lower envelope U values[2] until a point is reached where the marginal benefit becomes zero. Developers have long argued that lowering U values imposes development costs on many house builders as a result of the need to increase wall thickness as U values fall. The nub of the argument is that increasing wall thickness increases dwelling footprint (assuming that a reduction in internal space is not acceptable) and in many cases is likely to result in a reduction in the number of dwellings that can be placed on a site. Inevitably this reduces the viability of a scheme. The picture is complicated further by the demands made by recent UK planning guidance (Planning Policy Guidance Note 3 – PPG3, DETR 2000), which seeks to make better use of existing land by increasing site density requirements. Developers are concerned, therefore, that the demands of increased density are in conflict with the tendency towards lower U values and increased dwelling footprints.

The 2002 revision of Part L reduced wall U value requirements from 0.45 to 0.35 W/m^2K and are likely to fall even further in 2005 and beyond. This paper seeks to investigate some of these concerns by investigating the likely impact of an increase in dwelling footprint on the layout of housing developments.

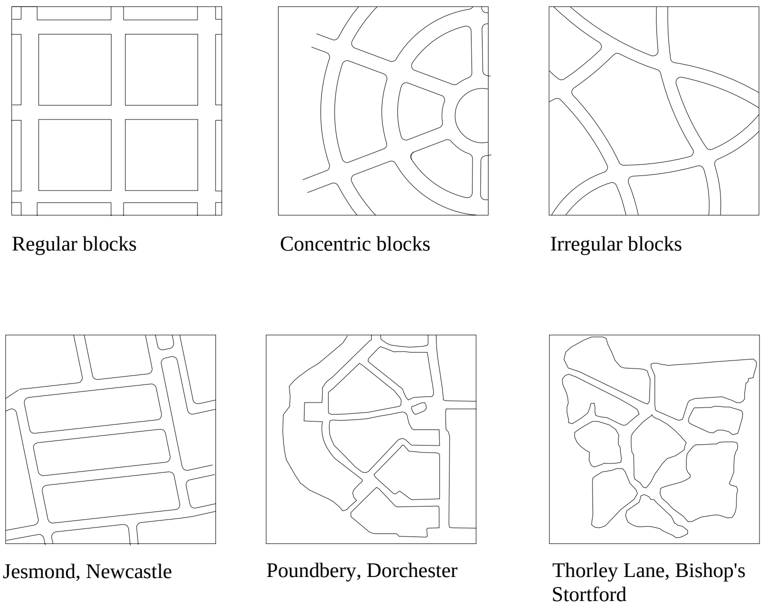

Figure 1 Layout typology with examples (source DTLR & CABE, 2001)

METHODOLOGY:

The investigation adopted a case study approach. This was done in order to get as close as possible to real housing schemes and to be able to evaluate the practical implications of an increase in dwelling footprints. To this end 2 completed housing

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[1] This target is based on the conclusions of the Royal Commission on Environmental Pollution report on energy and climate change – RCEP, 2000.

[2] U value, is the Unit of thermal transmittance through building fabric, measured in W/m^2K.

schemes, built in the late 1990s, to the 1995 edition of Part L (DoE. & Welsh Office, 1994), were investigated and a range of different insulation standards were applied with no change in construction method. Data was collected from two national house builders on a total of four housing developments. The sites were classified according to the typology given in DTLR & CABE (2001), which defines layouts as either regular, concentric or irregular. The types, together with examples are illustrated in figure 1. Of the 4 site layouts obtained, only concentric and regular layouts were represented and an example of each was chosen for detailed analysis. Figures 2 and 3 show the site layouts of the chosen sites with case 1 (figure 2) demonstrating similarities with the concentric form and case 2 (figure 3) being largely regular. The details of each case are set out in table 1

	Case 1 (figure 2)	**Case 2** (figure 3)
Site type	Concentric	Regular
Construction	Masonry cavity	Masonry cavity
Dwelling type	Detached	Detached
Building Regulation Standard; as built	1995	1995
Site area (Hectares)	2.669	2.887
No of units	69	59
Average footprint area; as built (m^2)	76.61	62.79
Average footprint area @ maximum wall thickness (m^2)	88.31	72.73
Maximum footprint increase - m^2 (%)	11.7 (15%)	9.94 (16%)
Dwellings per Hectare	25.8	20

Table 1 characteristics of case studies

In terms of development density the sites are relatively typical of the time they were built. With case 1 having a density around the national average (25 dwellings per hectare) and case 2 below this figure. This compares with the targets set out in PPG3 (DETR 2000) of between 30 and 50 dwellings per hectare.

Having selected the case sites, an analysis of the impact of U values on wall thickness was carried out based on an assessment of the likely range of wall U values that would need to be accommodated. In order to do this the 1995 standard of 0.45 W/m^2K was used as a base point, representing the standard to which schemes were built and the upper limit was set by the Passive House standard, pioneered in Germany (Feist 1995 and Vourvoutsiotis, 2000) with a wall U value[3] of 0.1 W/m^{2}K. At this level of insulation in combination with other efficiency measures, dwellings would have a space heating load that was almost zero in most northern European climates. Figure 4 illustrates the insulation thicknesses that would be required in masonry cavity walls (medium density block inner skin) to achieve the likely U values (including the 2002 value of 0.35 W/m^{2}K) for different types of insulant. As figure 4 demonstrates, the maximum increase in wall thickness could be anywhere between 195mm and 310 mm depending on the conductivity of the insulant used. For the purposes of analysis wall thickness increases were assessed in 50mm increments up to 300mm. At the extremes this could mean that, for fully filled walls, total wall thicknesses could increase from around 270mm (just about possible at a U value of 0.45 W/m^{2}K) to over 500mm. At the extreme the increase in footprint area is large with an increase of some 10 or 11 m^2 (15% or 16%) depending on house type.

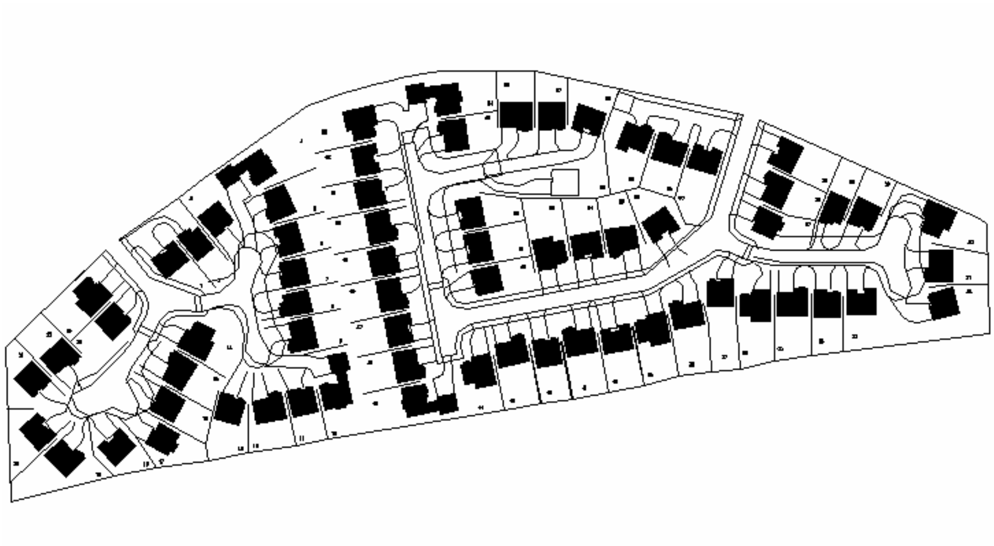

Figure 2 Case study 1: Site layout plan

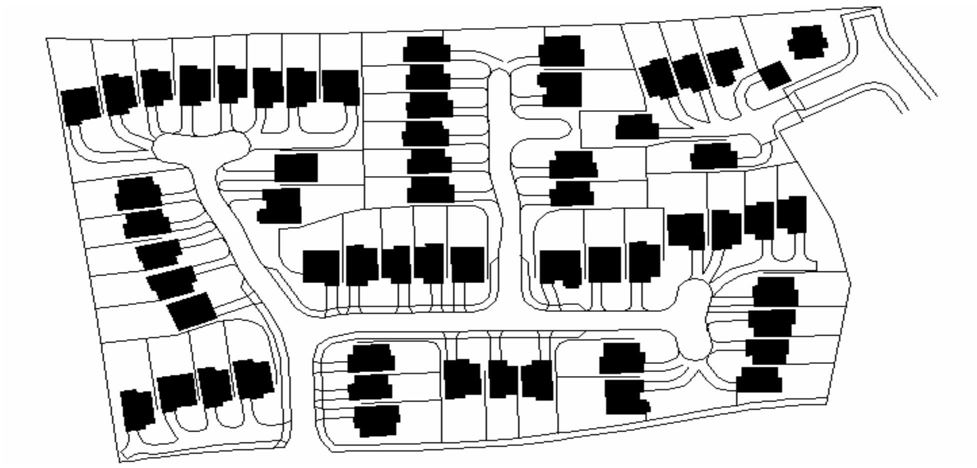

Figure 3 Case study 2; Site layout plan

[3] The passive house institute suggest a general standard of 0.15 W/m^{2}K for opaque envelope elements with a desired standard of 0.1 W/m^{2}K . This project adopted the desired standard as a worst case. Further details of passive house standards an be found at http://www.passivehouse.com

In carrying out the analysis the layouts were tested to see if any key design parameter such as access down the side of dwellings was contravened and, where this was the case, to assess the extent to which modifications could be carried out to accommodate the increase in footprint without compromising overall layout, internal floor area, generic house type mix (such as substituting semi detached or terraced forms for detached) or any other important layout design requirement. In making design adjustments the space standards given in Adler (2002) were used as a benchmark. Drawings were available in AutoCAD format and all design analysis was undertaken by using AutoCAD to overlay increased dwelling footprints. The results of this design analysis are set out below.

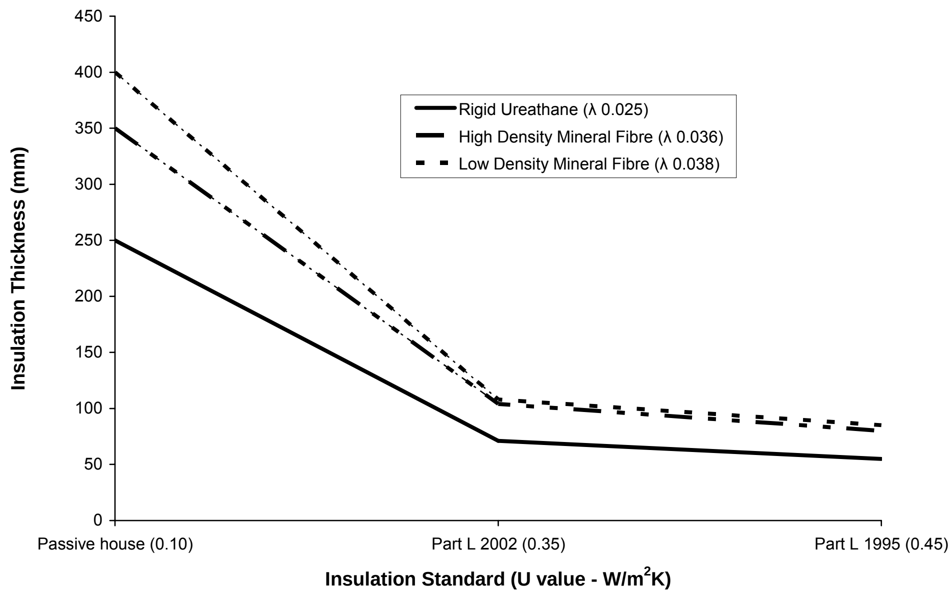

Figure 4 Insulation thickness against U value for different insulants

SITE DESIGN ANALYSIS

The application of footprint increase to the site layouts identified the need to tackle the following design issues:

- **Flank access**; this refers to the need to maintain adequate access down the side of the dwellings. Any modifications involving this design aspect sought to maintain the original design intent. For example removing access from one flank of a detached dwelling where previously there had been access down both flanks was not accepted as a minor modification.
- **Dwellings over-sailing boundaries**; this refers to the tendency for a dwelling footprint to extend over an existing plot or site boundary or other boundaries such as site roads.
- **Dwelling plan form**; this aspect impacts on the dwelling plan and on the potential for problems with the location of windows and doors as the wall length between projections (for example between a bay window and porch projection) is reduced by an increase in wall thickness.
- **Dwelling loss**; this aspect is a function of the ability of the layout to accommodate footprint increases. In each of the cases study developments an

assessment of likely dwelling loss was made following layout adjustments as indicated above.

Flank access

In dealing with the problem of flank access Adler (2002) suggests that a minimum of 760mm is required to allow forward movement for a self propelled wheelchair and 800mm for a pushed wheelchair. However, it is widely accepted that for internal layouts 900mm is a more comfortable width for travel along an enclosed space. Accordingly a 900mm width was selected as a minimum standard for flank access. This compares with existing access widths of 955mm in case 1 and 1000mm in case 2. The flank access design issues are assessed below for each case in turn.

Case study 1; flank access

Given a 900mm minimum access width, footprint increases of 50mm could be accommodated with no adjustment. With some redesign of the wall construction, possibly involving thinner insulants, this would be sufficient to enable the Part L (2002) U value standards to be accommodated but further increases would require layout modifications. Since all dwellings have dual flank access and are broadly similar this would apply throughout the site.

In making layout modifications the simplest approach would be to modify the footprint shape so that the additional area required would be taken from those areas that are less critical than the flank access areas. For most dwellings in this case study, front and back walls would have to be shifted out by around 230mm and the impact of this is illustrated in figure 5. Shifting walls in this way has very little impact on site design, but it would impact on internal layouts and although in practice this would remain an option, for the purposes of this study it was discounted.

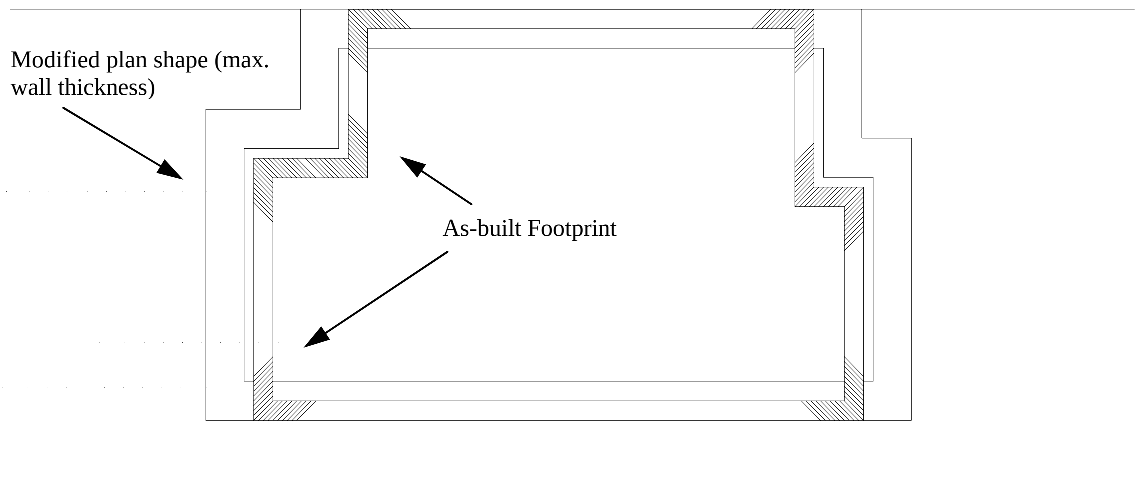

Figure 5 Modification to dwelling plane shape to maintain flank access widths

In order to accommodate thickness increases up to the maximum of 300 mm it would be possible, with some compromise in functionality, to make use of a flank access edging width of 350mm down one side that would be suitable for short distances or occasional use by an able-bodied person (Adler 2002). This would retain access down both sides but would require house type designs to accommodate the asymmetrical arrangement. In case study 1 this would enable wall thickness increases of 330mm[4] to be accommodated. Some 30 mm more than the maximum increase. A more radical approach would be to changing house types to semi-detached, or even short terraces but this would compromise the overall development mix.

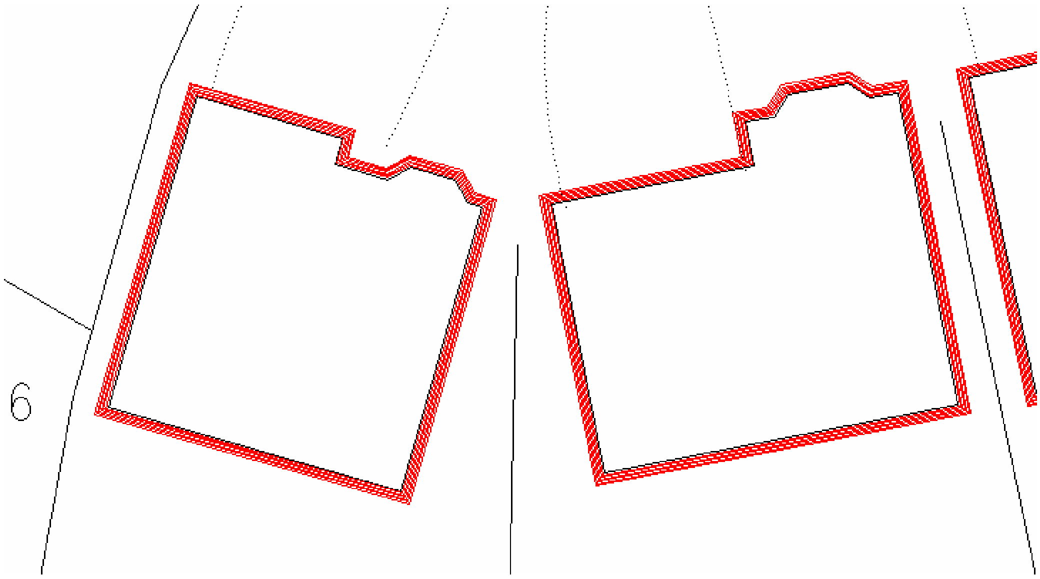

Figure 6 Splayed layout with single flank access "pinch point"

The problems of maintaining flank access are most apparent when flank walls are parallel to boundaries and the walls of adjacent dwellings. However, when flanks are splayed, as illustrated in figure 6, there is much more capacity to manoeuvre dwellings so as to maintain access widths. This type of layout has a single pinch point which in many cases can be adjusted by moving footprints forward or back and adjusting angles with respect to boundaries and adjacent dwellings so as to accommodate the increased area as wall thickness increases. This more concentric approach to layout in a number of the blocks in case study 1 tended to enable adjustments to be made without recourse to reducing flank assess widths at all. As a result, the impact of increased wall thickness was much less severe than in case study 2 where many more dwellings had walls parallel to boundaries and adjacent dwellings

Case Study 2; flank access

Unlike case study 1 the scheme had a mixture of single and dual access dwellings. Where access was provided, a width of 1000mm had been used. This means that in dual access dwellings accommodating increases up to 100mm would be feasible, posing few problems in adjusting to 2002 standards or slightly higher. However in single access dwellings the whole of a footprint increase would have to be accommodated in one flank, therefore reducing the wall thickness increases to 50mm and rendering the problem of 2002 compliance a little more difficult, although, with the use of low conductivity insulants, possible.

[4] The total space available is; existing access width (955) – edging width (350) + space saving on main access flank (55) = 655. Split between both side walls gives 330mm.

Unlike case study 1 almost all dwellings had flank walls parallel to each other. This meant that, in most dwellings, only adjustments involving a reduction in access widths were available. Although existing access widths were marginally greater than in case 1 the number of single access dwellings (18 out of 59 – 30%), combined with boundary over-sailing problems (see below), made adjustment without dwelling loss almost impossible to achieve.

As with case study 1 the option of reducing a symmetrical dual access dwelling to one with a reduced width of 350mm down one flank and 900mm on the main access flank was possible, giving the capacity to absorb wall increases of up to 375mm, well above the anticipated maximum requirement of 300mm. If such an approach were used, every dual access dwelling would release some 150mm that could be used to contribute towards the space needed for single flank access dwellings, However, given that to achieve a U value of 0.1 this would require between 600 and 400mm per dwelling the space from 3 or 4 dual access dwellings would have to be allocated to each single access dwelling.

Over-sailing at boundaries

This issue is closely related to the problem of flank access. In its most critical manifestation footprint increases can result in dwellings over-sailing the site boundary or a road boundary, with consequent dwelling loss. Where increases would encroach on a plot boundary the boundary can be adjusted but, particularly in case study 2, this eventually results in problems at the site or road boundary. As in the case of flank access, layout design adjustments were easier to make in case study 1 because of the freedom to stagger dwellings and the fact that each dwelling had flank access space on both sides. In this case, the layout adjustment resulted in no over-sailing even up to the maximum footprint increase. In contrast, case study 2 with its regular block layout, straight building lines and single flank access dwellings was much more difficult to redesign without compromising the existing road pattern or dwelling plan shape.

Dwelling plan form

Figure 7 illustrates part of the plan of a dwelling from case study 1. This dwelling has an integral garage and bay window on the front with its entrance adjacent to the bay window. As wall thickness increases the wall length between the garage and the bay window is reduced by up to 600mm. This problem is, primarily one of dwelling design and although there may be some impact on site layout, in the cases studied no significant impact was observed. In only one case, one of the smaller dwelling types in case study 1 (see figure 7), was it necessary to consider minor adjustments to the dwelling plan. In this case the space between the bay window and the projection of the integral garage was reduced to such an extent, when the maximum increase was applied, that there was no longer sufficient space for an adequate entrance door and a redesign of the plan would be necessary.

Dwelling loss

The overall impact of the layout issues discussed above resulted in no dwelling loss in either case where the requirements of the 2002 edition of Pat L were applied but the application of passive house U values would result in the loss of loss of eight dwellings (just over 13%) in case 2. In case 1 no dwelling loss occurred even when the maximum increase in wall thickness was applied. This increase was absorbed by making minor adjustments to dwelling location within its plot and, in some parts of the layout, adjusting flank access widths. As indicated above the difference in the ability of the two schemes to absorb increases was related primarily to the nature of the initial layout. Case study 1 was less regular than case study 2 and blocks of dwellings were much less constrained by site boundaries and the road layout. The fact that there were fewer dwellings with parallel flank walls in case 1 provided considerable flexibility and enabled wall thickness increases to be accommodated by adjusting the location and angle of dwellings with respect to each other and existing plot boundaries.

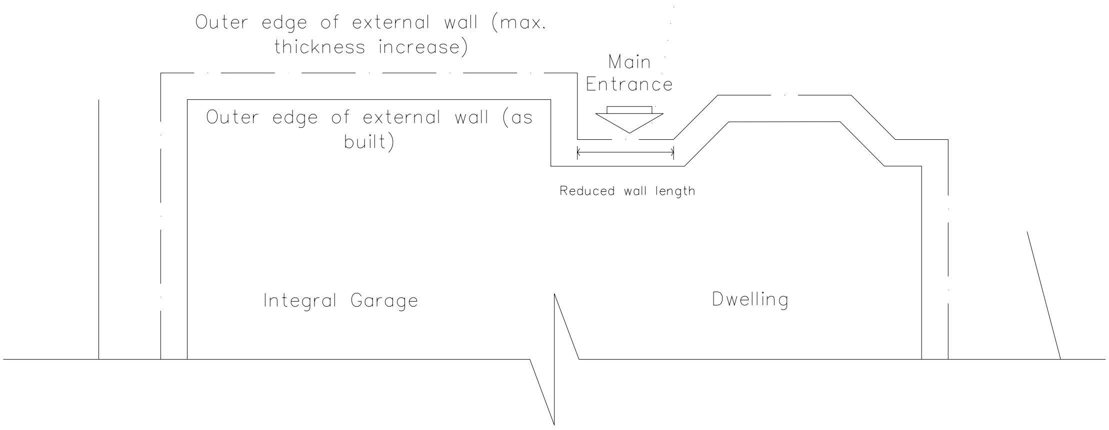

Figure 7 Impact of wall thickness on wall length at internal corners

DISCUSSION

The purpose of this study was to examine the potential effects of improved energy efficiency regulations on housing developments. More specifically the study sought to address the concerns expressed by developers that improved insulation requirements would result in lower site densities thus reducing economic viability and counteracting the prevailing planning guidance. Although limited in its coverage, this study suggests that the relationship between insulation standard and layout density is by no means a simple one. If we compare the two cases we can see that the site in case study 1 has an area some 8% less than that in case study 2, it is filled with 17% more dwellings that are, on average, 22% larger. Moreover, when wall thicknesses are increased to take into account even the most extreme U value standard, site 1 is much more able than site 2 to accommodate the footprint increases involved.

This study took a very constrained view of the problem, this was quite deliberate in that it provided a worst case scenario and one which would tend to favour the position that dwelling loss is likely to occur as dwelling footprints increase in response to improvements in wall U values. Indeed in case study 2 a significant number of dwellings would be lost if the constraints of the existing layout and existing house type designs were retained. However, faced with the requirements of a wall U value of 0.1 (the lowest likely value) a number of design responses are possible which would counteract the tendency towards lower development densities. In the first place the design of walls may change to enable thinner constructions. This could range from the greater use of brick clad framed structures that incorporate insulation within the structural frame (a position advocated by the timber and steel frame industries) to the use of low conductivity insulants such as rigid urethane within traditional cavity construction. Even if no attempt is made to modify the masonry cavity wall, revised house type designs could reduce the impact of thicker walls by a shift towards the greater use of semidetached and terrace forms or modifying plan shapes of detached forms as indicated figure 5. The recent trends towards more compact housing forms following the advent of PPG3 (DETR,2000) reduce the problem since wall thickness increases would be shared between more than one dwelling[5]. As indicated above, whatever the design response at the level of the dwelling, considerable scope remains in site layout design. In the case studies the existing road and plot layouts were taken as given but in practice, a designer, starting with a blank site, has considerable flexibility, within the general constraints of site shape and the location of access points. It is quite likely that with the freedom to redesign the road layout, case study 2 could accommodate passive house standards with no dwelling loss.

CONCLUDING REMARKS

Given the fact that this study was limited to the analysis of only two cases and that it adopted a rather constrained approach to the redesign of the schemes, it cannot be considered to be conclusive and it is inevitable that the debate will continue for some time. However, it is clear that increases in wall thickness within the range looked at in this study are unlikely to have a major impact on dwelling densities in many cases. There may be some sites with a particularly difficult shape and/or access arrangements that would be affected but even then it would be difficult to pin the blame on wall thickness alone. Design has always been a matter of finding the most beneficial route through a series of constraints and conflicting requirements. Responding to the need for significant improvements in the energy efficiency of dwellings is no different. With a positive approach to the design of dwelling types and good site layout design the problems posed by any demand for increased wall thickness are unlikely to result in a significant long term problem for developers.

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[5] Although this is true in general where terrace designs are used in which dwellings are staggered along a terrace the detailing between party wall and external walls becomes problematic and it is often easier to maintain the external wall cavity along the party wall.

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