Designing with AAC to achieve sustainable houses

Cliff Fudge

Technical Director H+H UK Limited, cliff.fudge@hhcelcon.co.uk

Abstract: The definition of sustainable construction can have many meanings and definitions. In 2006, the UK Government published a "Code for Sustainable Homes", intended as a single national standard to guide industry in the design and construction of sustainable homes. The Code measures the sustainability of a home against design categories, rating the whole home as a complete package. There are a number of categories within the Code that are directly linked to the fabric of the home in terms of energy use and reduction in CO_2 emissions. However, a number of other important areas appear and 'credits' can be obtained which make up the final rating for the dwelling. The Code has 6 levels of achievement, from the base level of 1, which is generally just above the minimum requirements of building regulations, to Code level 6 which takes on the definition of a 'zero carbon' house amongst other aspects of design. This paper shows the basis of design for a sustainable home, and gives case studies of homes achieving the higher levels of the Code using Autoclaved Aerated Concrete (AAC) construction.

Keywords: Autoclaved Aerated Concrete

1. INTRODUCTION

A 'Code for Sustainable Homes' [1] (referred to as the 'Code' from now on) has been developed to enable a step change in sustainable building practice and to provide a sustainability rating system for new homes. The Code was prepared by the Government of England and Wales in close working consultation with the Building Research Establishment (BRE) and others, by building upon an existing scheme for sustainable construction.

Published in December 2006, the Code became the single national standard for sustainable homes, used by home designers and builders as a guide to development, and by home-buyers to assist in their choice of house purchase. The Code measures the sustainability of a home against design categories, rating the 'whole home' as a complete package. It is closely linked to Building Regulations for England and Wales [2] and minimum standards for Code compliance were set above the requirements of Building Regulations.

For the Code to be workable there was a need for a 'Technical Guidance Manual' [3], which sets out how to obtain the various credits and points that make up the overall rating.

2. ADDRESSING SUSTAINABILITY IN THE CODE

2.1. The sustainability rating system

The Code measures the sustainability of a home against nine design categories, rating the whole home as a complete package using a 1 to 6 star rating system to calculate the overall sustainability performance, with 6 stars being the highest level. The nine categories and minimum standards for five of these are shown in Table 1. Two of these, energy efficiency and water efficiency, have minimum standards that must be achieved at every level of the Code (See Table 2). Apart from these minimum requirements, the Code is flexible and designers can choose which areas to focus on to achieve the code points.

Table 1. Minimum Standards for Design Categories

Categories	Flexibility
Energy Efficiency	Minimum standards at each level of the Code
Water Efficiency	
Materials	Minimum standards at Code entry level
Surface Water Run-off	
Waste	
Pollution	No minimum standards
Health & Wellbeing	
Management	
Ecology	

Table 2. Minimum Standards for energy and water & points required for each level

Code Level	Energy	Water	Total Points Required from the 100 available
	Improvement in achieved CO_2 emissions over 2010 regulations	Max water consumption in litres/person/day	
1	0%	120	36
2	0%	120	48
3	0%	105	57
4	25%	105	68
5	100%	80	84
6	Net zero carbon	80	90

Table 3 gives the maximum number of credits available for each 'Environmental Issue' within each of the nine categories and the detailed requirements for achieving the relevant credits are given in the Technical Guide to the Code.

Table 3. Total number of Credits available and the Weighting Factor (as a %age of total possible Points Score Available)

Environment Impact Categories	No. of Credits in each category	Environmental Weighting Factor (%)	Points Score for each credit in Category
Energy and CO_2 emissions	31	36.4	1.17
Water	6	9	1.50
Materials	24	7.2	0.30
Surface Water run-off	4	2.2	0.55
Waste	8	6.4	0.80
Pollution	4	2.8	0.70
Health & Wellbeing	12	14	1.17
Management	9	10	1.11
Ecology	9	12	1.33
TOTAL		100	-

There is a different Environment Weighting Factor for each of the nine categories; thus a credit obtained in one section does not have an equal rating in another. It is generally recognised that that the higher levels of the Code are seen as aspirational, but nevertheless achievable. Early case-studies have also shown that there is a significant cost associated with the building of the higher levels of the Code. To place the energy requirements into context, 'Passiv Haus' [4] design is roughly equivalent to Code level 4. It is not intended for this paper to explain how each and every one of the points and credits are achieved as not all of the points are associated with the design or build of the house; many are site specific.

2.2. How a rating is obtained

From Table 3 it is clear to see that some parts of the Code are weighted with a higher importance than others. For example, the energy section carries some 36% of the total points available, with Health & Well-being ranking second. To achieve a rating, the designer must first obtain the minimum standards for each design category. If a specific Code rating has been asked for, the minimum standards for energy and water at that level must also be achieved. The Technical Guide contains all of the information necessary to show how to obtain credits in each section. All of the credits and points are summed and have to meet the total required in Table 2. However, once built it is also necessary to prove that the construction was carried out in accordance with the designer's wishes. Some of the categories have conflicting requirements. It might, for example, be desirable to have larger window areas to increase daylight factors, but larger windows allow more heat to escape and increase losses of CO_2.

3. HOW TO ACHIEVE A HIGH RATING WITH AAC

3.1. Energy & CO_2 emissions

There are two major sections in the energy category that need to be addressed. One deals with the improvement in CO_2 emissions compared to the current Building Regulations standard. The aim of this credit category is to minimise emissions of CO_2 to the atmosphere arising from the operation of a home and its services, and it does this by assessing the amount of CO_2 emitted from the dwelling as a result of space heating, hot water, and lighting. Lower emissions gain more credits, with a minimum number of credits for this category required for each Code level. The second section of credits is aimed at future proofing the energy efficiency of dwellings over their whole life by limiting heat losses across the building envelope.

Improving the basic thermal performance of the fabric of a house is a major step towards meeting the higher Code levels, which will also need increasing reliance on the use of renewable energy to meet the requirements. The thermal performance of AAC can contribute significantly in this respect and help achieve higher Code credits. Cost effective AAC external walls can be built to achieve a wide range of U-values in both cavity and solid wall construction. Examples of AAC masonry construction around Europe and the rest of the Globe vary considerably. In the UK the most common form of wall construction is the use of cavity construction with an outer brick leaf and an inner AAC masonry leaf, typically of 100mm thickness. The cavity is then partially or fully filled with thermal insulation and with a typical cavity width of 100mm, wall U values in the range of 0.20 to 0.25W/m^{2}K can be achieved, which are generally sufficient to achieve a decent score for Code levels 3. At Code level 4 and above, renewable energy technologies are generally introduced to obtain the reduction in carbon emissions. However, a change to the Code level 6 guidance in 2010 placed an absolute maximum value on the carbon emissions owing to heating and hot water in terms of kg CO_2/m^2/year. This generally results in a requirement for wall U values of less than 0.18 W/m^{2}K, meaning that the cavity in the construction is typically 150mm wide.

In addition there are three key performance attributes of AAC that enhance thermal performance beyond the simple indicator of thermal insulation. The first of these is the need to provide a high level of airtightness as this has become an important aspect of design and construction. Heat that escapes due to a leaky building forms a significant part of overall energy loss. AAC can defeat this with its inherently excellent air-tightness characteristics. The air permeability of AAC from test work is approximately 0.12m^3 /hr/m^2 measured at a pressure 50 Pascals. The corresponding value is 1m^3 /hr/m^2 for AAC masonry in general-purpose mortar. Using thin layer mortar or elements, the value is significantly improved. As a result and with careful attention to detail, AAC constructions can provide highly airtight solutions. Internal surfaces are generally usually plastered or dry-lined with gypsum boards, which can give additional protection. As always, the detailing of junctions and openings is critical to achieving an optimum airtightness value for the construction.

Thermal bridging at junctions also now plays a significant part in energy losses through the construction. Using simple construction details, it has been shown that AAC significantly reduces these losses and plays a major part in the reduction of carbon emissions from buildings. Heat losses at floor and roof junctions are reduced with AAC construction, since the pathway for heat loss is via the material, which typically has a thermal conductivity of 0.10 to 0.19 W/mK.

With higher average seasonal temperatures in the UK now expected due to climate change, summer overheating is a real concern. Structures built using AAC have the ability to effectively regulate the changes in temperature of the internal environment by storing heat during the day, which can then be released back into the property as the temperature drops at night. This in turn creates a comfortable living environment as temperature variations are reduced. The need for supplementary heating and cooling systems is also reduced.

3.2. Environmental impact of materials

The intention of this section of the Code is to encourage the use of materials and constructions with low environmental impact when assessed over the full life cycle of the house. The Code uses the Building Research Establishment's 'Green Guide' [5] ratings as the basis for its assessment. Five elements of the construction need to be assessed, being external walls, internal walls, floors, roofs and windows. There is a minimum requirement for three of the five elements to obtain an 'A+' to 'D' rating in the 'Green Guide': The lowest rating available is an 'E'. Further 'credits' are then available for higher rated constructions: 'A+' rated constructions attract 3 credits, 'A' rated constructions attract 2 credits and 'B' rated constructions attract 1 credit.

The internal and external wall sections of the Green Guide contain a full list of AAC masonry constructions, along with a large selection of other forms of construction. All external masonry wall constructions are rated as 'A+' and thus attract the highest credits that go towards the overall rating to the Code, since the longevity and durability of AAC plays an important part.

3.3. Responsible sourcing of materials

This section of the Code aims to recognise and encourage the specification of responsibly sourced materials for key building elements. The majority of materials used in a number of the basic building elements must be responsibly sourced. These elements include both external walls (including external cladding) and internal walls (including internal partitions). In the original section of the Technical Guide to the Code, the credits were generally based around schemes that provide a sourcing mechanism for timber. Up until mid 2009, only timber solutions could obtain the maximum rating for this section. However, the publication of a new Standard, BES 6001 [6], allowed for all products to be assessed against a list of criteria associated with the corporate and social responsibilities of the supplying company. As a result, Companies and products can now obtain the full number of credits available on the basis of the level of compliance that can be shown by the manufacturer; all AAC manufacturers in the UK have obtained this highest rating level.

3.4. Health & wellbeing – sound insulation

The aim of this section is to ensure the provision of improved sound insulation to reduce the likelihood of noise complaints from neighbours. No additional credits are obtained if the minimum level of the current Building Regulations is met for either sound insulation between adjoining walls or floors. To obtain the extra credits this is achieved by either:

(a) The provision of sound insulation through a programme of pre-completion testing, or:
(b) Use of building elements that have been assessed and approved by Robust Details Limited [7], a Company that has set up a scheme whereby builders can register common forms of construction that have proven to be reliable in achieving enhanced levels of performance.

Credits are available where there is a commitment to achieve sound insulation values that are better than the minimum performance standards of the Building Regulations by set amounts. For example, 3 dB above current levels achieves 1 credit, 5 dB achieves 3 credits and 8 dB achieves 4 credits. Detached houses obtain the maximum credits, since they have no adjoining neighbours.

The designer effectively has a choice in how to achieve this. One route is to predict the sound insulation based on experience and knowledge of the workmanship that can be relied upon. The more common approach is via the 'Robust Details' route. This is a well tried and tested approach for acoustic design. The construction details produced are regularly updated and amended as new versions of walls and floors are developed. AAC and other masonry constructions in separating and flanking walls to houses and flats are included in the Robust Details 'Pattern Book' and these can attract credits in the Code. The current highest rating for AAC walls between houses is a construction of 2 leaves of 100 mm AAC masonry constructed in thin layer mortar, with an untied minimum cavity width of 75 mm.

4. EXAMPLES OF AAC HOUSES

4.1. Miller zero

Miller Homes Limited [8], a major house developer in the UK, decided to take real customers, as well as its supply chain on a journey towards the zero-carbon level 6 of the Code for Sustainable Homes. The journey takes place on a 3.65-acre site, where five identical Miller Zero houses meet different levels of the Code for Sustainable Homes. These homes, which are the same in layout to others on the site of 79 units, have been completed to Code levels 1, 3, 4, 5 and zero-carbon 6. The development is an R&D project aimed at showcasing how these various code levels dwellings can be produced and the implications for the supply chain. The Code level 4 house is a good example to examine in more detail and is a two-storey 4-bedroom house with a floor area of 105m^2. It used products that were available on the market and aimed to put them into a functional use while demonstrating that low carbon housing can be achieved today. The design involves improving building fabric performance and shows how, with power and heating micro-generation equipment, a reduction in CO_2 emissions of at least 25% can be achieved compared to the 2010 Building Regulations.

The walls are fabricated from cavity construction with an inner leaf of AAC masonry units in thin-layer mortar, a system that minimises air leakage across the mortar joints and creates a more airtight envelope. Another advantage is their high thermal mass, which provides passive heating and cooling throughout the seasons. Cavity insulation minimises heat losses through the building envelope. The cavity wall achieved a U value of 0.30 W/m^{2}K, with a 90mm cavity fully filled with water repellent blown glass wool insulation. A mono-pitch roof was used with a U value of 0.18 W/m^{2}K, incorporating 160mm of rigid polyurethane insulation. Windows are double glazed with uPVC frame, providing a U value of 1.7 W/m^{2}K. Linear thermal bridging was kept to a minumum with well thought out junction details. The design airtightness of 6.0 m^3/m^2/h (at 50 Pa) was achieved by using internal wall plaster and AAC masonry with thin-layer mortar to minimise air leakage.

Fig. 1. Miller Zero Carbon Project

Heat and hot water is provided by a ground source heat pump (GSHP), which utilises the latent heat from the ground to power an underfloor heating system. Due to the relatively high airtightness of the building envelope this necessitates the use of a mechanical ventilation heat recovery system with summer by-pass option to provide fresh, clean air to the house. As with all low carbon construction, there is a balance to be achieved between the fabric and the use of renewable energy. However, it will be recognized from the construction details given here that the boundaries of fabric construction are not being pushed. Thus Miller Homes were able to demonstrate that by using conventional techniques, with a conventional workforce, masonry can survive at relatively high Code levels. The Code 6 house did provide more of a challenge. Whilst solid AAC masonry was an option, it was decided to construct the structural walls with storey height 200 mm thick, 600mm wide AAC panels, as there are fewer smaller joints through which air can leak, thus creating a more airtight envelope. Another advantage is the high thermal mass, which provides passive heating and cooling throughout the seasons. Exterior insulation minimised heat losses through the building envelope and through reduced thermal bridging. With 200 mm of rigid phenolic external insulation a wall U value of 0.09 W/m^{2}K was achieved. The Roof consisted of a mono-pitch incorporating 190mm polyurethane insulation between rafters, underclad with thermalboard, providing a U value of 0.12 W/m^{2}K. Triple glazed low e glass, Krypton gas filled, insulated edge technology and uPVC frame windows were used with a U value of 0.68 W/m^{2}K. An Airtightness 1.5 m^3/m^2/h at 50 Pa was obtained by using internal wall plaster.

All heat and power generation comes from renewable resources. These include a biomass boiler **(**15 kW wood pellet) connected to under floor heating and a hot water cylinder for maximum efficiency. A large photovoltaic array (4.8 kW p – 38 m^2) on the roof provides power.

The house uses a mechanical ventilation system with an in-built heat recovery unit and summer by-pass option. Further details of this and others can be found on the website of the Zero Carbon Hub [9].

4.2. Barratt Green House

The Barratt Green House is a family home designed to provide a solution to the need for low energy, high-density volume housing of the future. It was the first home to be built by a mainstream house builder to achieve Level 6 of the Code. The house was a prototype constructed at the BRE Innovation Park to the North London. Designed as part of a national competition, the award-winning home comprises a blend of modern technology and well-proven design principles with the aim of resolving some of the issues of living in a more sustainable way, but without compromising quality of life. The design is a three-storey, 3-bedroom family home and is conventional in appearance.

The main structure of the house is 200 mm thick storey height AAC elements, 600 mm thick. The reason for the choice was the opportunity to achieve a high airtightness specification of 1.0 m^3/m^{2}h. The single skin of AAC is enveloped in approximately 180 mm of high performance (phenolic) insulation, achieving a U-value for the walls of 0.1 W/m^2/K. This is combined with thin-layer mortar joints, which reduces thermal bridging, and internally the walls are dry-lined to allow services to run in the void between the wall and the plasterboard. Internal walls mainly consisted of AAC masonry and owing to high loads for floors and steel support beams, block strengths in excess of 8 N/mm^2 were required.

Fig. 2. Barratt Green House Project

A positive decision was made to use AAC walls with concrete floor slabs within the thermal envelope to provide high thermal mass that mitigates the peaks and troughs of temperature change within the home and prevent overheating. Automatic window shutters were added to help prevent over-heating of the house in summer. To achieve a zero carbon target, photovoltaic panels were used on the south-facing roof and the adjacent building simulate a district power supply. Heating and ventilating is via a background forced air ventilation system that extracts heat from the kitchen and bathrooms and pumps it into other areas. All ventilation is run through a heat exchanger to minimise losses. By using AAC walls, the contractor was able to easily chase out the walls to accommodate the vents and pipes needed for the ducting for the ventilation system. At various stages of the construction, the airtightness was checked to ensure that the design value was being achieved. The house also has an air-source heat pump, which is powered by PV-generated electricity.

All of the materials used were carefully selected such that maximum points could be achieved in the design. AAC was an ideal choice and although the 'Green Guide' did not contain AAC element constructions, the BRE assessed the external wall independently. Windows were selected to provide a balance of low heat loss, whilst positioned to provide maximum daylight.

5. CONCLUSIONS

AAC construction can be used to achieve the highest ratings within the Code for Sustainable Homes, with AAC constructions performing particularly well in the heavily loaded energy section of the Code. AAC has a lot to offer in terms of its durability and longevity and fire performance, which are not currently aspects covered by the Code, but may in future. Cost effective solutions have been achieved by a number of major house builders in the UK.

BIBLIOGRAPHY

[1] Department for Communities and Local Government, 2006. Code for Sustainable Homes-A step-change in sustainable home building practice, www.communities.gov.uk, London.
[2] Department for Communities and Local Government. Building Regulations, www.planningportal.gov.uk, London.
[3] Department for Communities and Local Government, 2010. Code for Sustainable Homes-Technical Guide, www.communities.gov.uk, London.
[4] www.passivhaus.org.uk, website of the BRE, Watford.
[5] www.bre.co.uk/greenguide website of the BRE, Watford.
[6] BRE Environmental & Sustainability Standard 6001- Framework Standard for the Responsible Sourcing of Construction Products. BRE, 2008 Watford.
[7] www.robustdetails.com, website of Robust Details Limited, Milton Keynes.
[8] www.millerhomes.co.uk, website of Miller Homes Limited, Edinburgh.
[9] www.zerocarbonhomes.org website of the Zero Carbon Hub, Milton Keynes.