EnergyThe Hanson EcoHouse™ and Hanson QuickBuild™ walling system

The development of prefabricated masonry walls using traditional materials and incorporating vacuum insulated panels.

Paul Rogatzki BSc.Eng; CEng; MIStructE; FIMS,
Head of Design and Engineering, Hanson Building Systems
paul.rogatzki@hanson.biz

Theme 3: Industry needs and case studies

Abstract
The Hanson EcoHouse™ constructed for the BRE Offsite 2007 exhibition demonstrates the latest developments in off-site masonry construction, thermal mass and natural ventilation. The objective was to construct a domestic dwelling using prefabricated components including pre cast concrete flooring systems and prefabricated masonry cavity walls constructed using traditional brickwork / blockwork.

The project proved to be a success achieving a high quality finish, rapid construction, energy efficiency, structural integrity and an attainment of Code for Sustainable Homes Level 4. .The prefabricated walling system is known as Hanson QuickBuild™. Walls using the QuickBuild™ system may be single or cavity construction – including partial or full fill insulation - and may incorporate clay brick, stone, aggregate or aircrete blocks.

Further development work is currently addressing alternative insulation systems in order to overcome the trend towards increasing overall wall thickness. It is in this situation that there is potentially an excellent opportunity for vacuum insulated panels to be included in prefabricated walls.

Key words : prefabrication, masonry, thin joint, cavity wall, Code for Sustainable Homes

1. THE HANSON ECOHOUSE™

Fig 1 Hanson EcoHouse™

Designed as a three-bed detached dwelling, the Hanson EcoHouse™ shows all the benefits of off-site fabrication, that together with thermal mass and natural ventilation assist in the development of a building system targeting the zero carbon houses of the future. In addition, it shows how quickly and easily a liveable and saleable property can be constructed.

Constructed using masonry panels manufactured off site in a controlled factory environment, it brings together the benefits of high quality and speed of construction with virtually no site wastage. The process is also less susceptible to weather delays compared to on-site construction.

Designed to meet the combined challenges of off-site construction and the impact of climate change, this concept house has been constructed using the unique Hanson QuickBuild^{TM} walling system.

1.1 Hanson QuickBuild^{TM} System - Development of prefabricated masonry walls

Walls constructed using thin joint adhesive technology have been an established building technique in Europe for several decades. However the system has seen virtually no use in the UK with the exception of a number of important projects which have been developed by Hanson Building Systems in conjunction with evaluation and testing programmes both within the company, and externally with Oxford Brookes (Dti funded project), Kingston and Surrey Universities.

Completed projects include two university buildings (UWE in Bristol and University of Hertfordshire, Hatfield),

Fig 2 – Dept of Architecture and planning, University of West Of England

Fig 3 – New Digital Laboratory University of Hertfordshire

two private house developments, one of which was a Brick Development Association (BDA) award wining project for it's innovative spine wall construction and an Arts Centre in Luton. However, all projects involved single skin clay brickwork and have been constructed by in-situ techniques where bricklayers have used a pump and gun system to apply the special proprietary adhesive – generally known as "glue mortar"

Fig 4 – private development in Thaxted, Essex –structural spine wall in thin joint brick masonry

Fig 5 – private development in Thaxted, Essex

Following a period of further trials and testing of prefabricated panels built in both clay brickwork and aggregate blockwork Hanson built prefabricated dense concrete blockwork cavity walls for the ground floor construction of a two storey house – known as the Hanson House - for BRE Offsite 2005. Previous development and testing work had demonstrated that glued aggregate blockwork is particularly strong and robust achieving up to twice the standard flexural strength of traditional masonry. The method of construction employed involved traditional bricklayers working with thin joint mortars using trowel and scoop techniques the likes of which are already well established on site. However all of the walls were built in a factory environment.

In terms of structural design, the main consideration is not the integrity of panels once in place, rather the handling, lifting, transportation and further craning into position. In the event this proved most successful and paved the way for a full brick / block cavity construction.

1.2 Development of the Hanson EcoHouse™ – BRE Offsite 2007

Architects for the the EcoHouse™ built for BRE Offsite 2007 were TP Bennetts. Their design concept was based on the shape and format of a traditional kiln with consideration given to three key areas, namely :-

Thermal mass.
Masonry construction has high thermal mass. This inherent feature enables the dwelling to store heat and remain cooler for longer than lightweight structures meeting the needs of climate change and keeping buildings cool in an energy efficient environment.

Natural ventilation
The design of the EcoHouse™ was based on a brick kiln (appropriate to one of the largest clay facing brick manufacturers). A ventilating roof lantern is used to give light and to enhance the natural air currents, so maximising the energy conservation potential.

Flexible design
Masonry panels manufactured off site in a controlled factory environment provide total flexibility in the design of dwellings. The system has been designed to meet the needs of houdsbuilders and is applicable across a wide range of housing options.

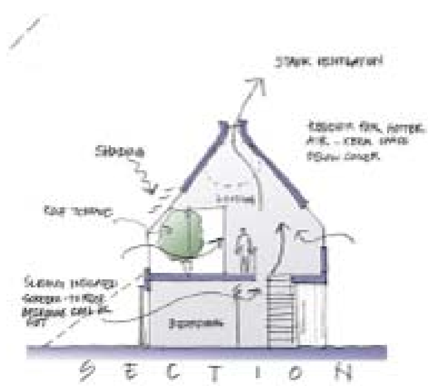


Fig 6 Design concept for the Hanson EcoHouse™

The project is particularly important as it provides the first example of prefabricated cavity walls comprising 102mm clay Hanson facing brickwork outer leaf, 100mm aircrete Thermalite blockwork inner leaf and a partial fill cavity comprising 100mm Kingspan rigid insulation and a 50mm air space.

The two storey dwelling comprises walls that are 2.4m in height by up to 9m in length. Panels were both plain and with openings (both doors and windows) and on site construction time approximated to one storey per day. The ground floor also included a number of internal walls which were constructed in aggregate concrete blockwork.

Clay brickwork was constructed using the polyjet pump and gun system. The blockwork inner leaves and the internal dense blockwork leaves were built by use of a scoop. All three masonry types incorporated an appropriate glue mortar.

This is the first time that prefabricated masonry cavity walls have been constructed using the brick / aircrete materials. Prefabricated aircrete walls have been trialled by Hanson Thermalite but there were some concerns relating to their use in cavity wall panels of the dimensions used for the EcoHouse. Stack bonded brickwork, although desirable as an architectural requirement, also demonstrates the strength properties of the wall particularly showing off the residual strength during transportation and handling by crane.

Fig 7 Lifting of panels Hanson EcoHouse™

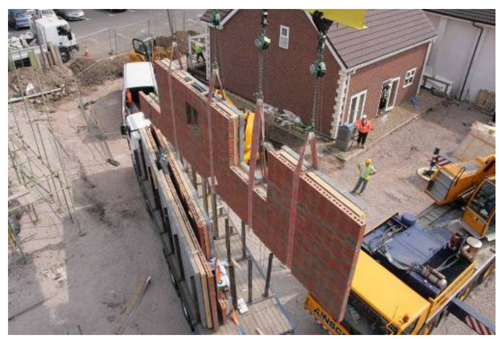


Fig 8 Placement of panel including openings

The key properties of the finished walls include higher flexural strength for both brick and block (up to twice the strength of traditional masonry), increased vertical strength and an increase in resistance to rain penetration of the outer leaf due to the continuous consistent mortar jointing.

The thin fully adhered joints also contributed to an air tightness which is superior to that achieved with traditional masonry (4.9m3/m2/hr).

In addition, the wall construction quality is very high, waste is minimal and restricted to the factory environment and the system does allow for any combination of bricks / blocks and for any brickwork bond without a loss of strength.

One particular benefit which came out only during the transportation and erection process was the flexibility of the panels. Normally masonry is regarded as being very brittle and it is somewhat unforgiving of even minor deformation which is manifested as cracking. In the EcoHouse™ walls vertical deflections of up to 40mm were recorded without signs of cracking. This was due in part to the inclusion of bed joint reinforcement (flat bar profile equivalent to 4mm diameter) which was used to minimise transportation damage.

Although both leaves of the cavity wall were connected by Helifix stainless steel spiral wall ties (5mm diameter, 250mm length), there was notable movement of one leaf relative to the other which was actually beneficial during the location and placement on site.

Accuracy in construction was also a significant plus point with dimensional tolerances not exceeding + / – 5mm on the diagonal of a 9m x 2.4m long panel. Typical deviations in length and height were 2-3mm. This was in part to be expected since all masonry was set out with metal profiles ensuring that, as with any standard masonry, all key dimensions were adhered to even if some variation within joints occurred.

The strength, versatility and ease of buildability of the thin joint adhesive masonry system will certainly allow for the continued use of traditional materials in a variety of building types, albeit with radical departure from traditional methods of construction.

1.3 Structural design concept for the Hanson EcoHouse™

The house is constructed as an "upside down" house ie. three bedrooms and a bathroom down stairs with a large open plan space on the first floor which provides kitchen, dining and living areas. The roof provides a lofty space for natural ventilation through an opening light at the top.

The ground floor is constructed using the Jetfloor beam and insulation block system whilst the first floor incorporates prestressed hollowcore units.

In terms of structural design of the masonry, procedures as outlined in BS5628 Parts 1 and 2 were followed wherever possible. Masonry characteristic strength values used in calculations were based upon tests carried out in accordance with the relevant appendices for that Code. Ground floor walls presented no problem due to the arrangement of internal masonry. However at first floor level, since there are no internal walls all panels had to span vertically between the steel framed roof structure and the first floor. To work successfully as a masonry solution as far as wind loading is concerned this requires the increased strength properties of the thin joint adhesive system, self weight of the roof structure and appropriate restraint at the eaves and floor level.

All materials were manufactured to an approved quality system, regular materials testing was carried out throughout the construction process and workmanship was carried out under regular supervision. Consequently a partial safety factor γ_m = 2.5 was employed in design calculations which gives an improvement on a "standard" or normal construction which uses a γ_m of 3.5.

The wide cavity (150mm) coupled with thin bed joints presented a challenge when ensuring an appropriate strength of wall tie which would be accommodated in the construction format. Joints in brickwork were 6mm and in blockwork approximately 2mm

The superior strength facilitated by the use of thin joint mortars enabled the wall tie spacing to be limited to 900mm c/c both vertically and horizontally even with the use of a stack bonded brickwork.

The ground floor / first floor detail was dealt with by the introduction of a steel channel (edge beam) which although desired by the architect for visual purposes, did allow for a break in continuity of the external masonry and again ensured that any manufacturing inaccuracies could be dealt with by the detail.

The stack bonded brickwork enabled corner details to be dealt with aesthetically by use of a standard vertical movement joint comprising readily compressible filler and a mastic finish. Joint thicknesses were detailed as 20mm to allow for dimensional variation of panels but these were shown to be more than adequate for the construction accuracy that was achieved.

Fig 9 CompletedHanson EcoHouse™ – Code level 4

2. DESIGNING TO THE CODE FOR SUSTAINABLE HOMES (CSH)

At the time when the original Hanson House concept was being put together, the Code For Sustainable Homes had only just been proposed and this proved to be somewhat challenging when carrying out a code assessment which would give an acceptable evaluation for the building.

The CSH is an environmental assessment method for rating and certifying the performance of new homes. It is split into 9 categories, each category being weighted in order of its environmental impact importance.

Energy and CO2 Emisisons
Water
Materials
Surface Water Run-off
Waste
Pollution
Health & Well-being
Management
Ecology

The code highlights 6 categories (ratings) which classify energy saving / efficiency of a building in it's particular environment. Most current construction types would attain Code Level 3 whilst a zero carbon building is required to be at Code Level 6.

Government timescales dictate that all new build homes attain level 3 by 2010, level 4 by 2013 and level 6 by 2016 for private sector work. Public sector buildings need to attain level 4 and level 5 by 2010 and 2013 respectively.

The Hanson House achieved a realistic Code level 4.

Initial design requirements in terms of environmental comfort were based on the thermal mass concept which exploits the density of the construction materials (ie concrete and brick for both floors and walls) to provide a cool structure on hot days as the building materials absorb the heat. This heat is then slowly released during cooler conditions. In simple terms the peaks and troughs in temperature changes over a day/night cycle are not as severe as for other structures which do not possess high thermal mass.

The walls of the house achieved a U value = 0.18W/m^{2}K, an acceptable figure in terms of the wall performance but this highlights an issue which is of some concern ie the ever increasing width of the cavity in order to maintain such low values.

3. DEVELOPMENT OF CAVITY WALLS – COMPOSITION AND REDUCING U VALUES.

A brick / block cavity wall has proven to be a popular efficient form of construction, versatile in terms of finishes and properties. However the traditional cavity wall comprised no more than a 103mm brick outer leaf, 50mm air space and a 100mm iner leaf plus 12mm plaster finish. This gave an overall thickness of 265. Cavity walls require both leaves to be connected with wall ties at sufficient frequency and of sufficient strength to allow both leaves to act integrally when resisting the loads to which they may be subjected. Generally speaking a cavity should not exceed 150mm in thickness as this not only compromises the integrity, but will increase the size, frequency and cost of stainless steel ties which will have to be of the order of 250mm long. Additionally the plan area of a building is compromised by increasing wall thicknesses – either by reducing the living space or increasing the overall building footprint. This will inevitably mean that fewer houses are constructed in an effort to improve building performance.

The following table illustrates the changes that have occurred from the early 1970's potentially up to 2016 in terms of U values, wall composition and overall thicknesses giving a specific example of mineral wool as the insulation.

It must be noted that improvements in materials ie in insulation types and block masonry materials have helped to keep walls to a minimum thickness but clearly the modern day wall is almost double its original thickness.

Table 1

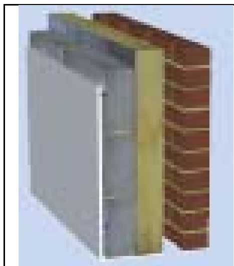
Wall thickness (mm)	Year	U value	construction
			103mm brick, 50mm cavity 100mm block, mineral wool thickness shown below
265	Pre 1976	1.5	None
305	1978	0.6	40
325	1991	0.45	60
349	2002	0.35	85
425	Current design request	0.2	160

Some examples of walling solutions offered by Hanson are illustrated. Note how the overall wall thickness increases as the U value is reduced. A U-value of between 0.15 and 0.27 W/m^{2}K for external walls will be appropriate to meet future requirements through to 2016.

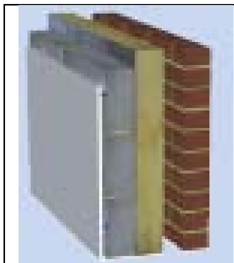
Table 2

<u>Cavity Walls</u>

Brick / Block / Partial Fill

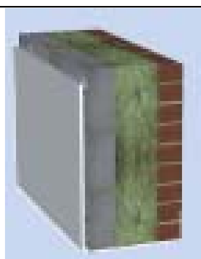


Brick / 50mm air gap / P U board (λ = 0.023) / Inner leaf - 100mm Thermalite Turbo block (aircrete) / dry lining						
U-value (W/m^2K)	0.15	0.18	0.20	0.22	0.25	0.27
Wall thickness	375mm	332mm	320mm	310mm	300mm	292mm
Insulation thickness	125mm	82mm	70mm	60mm	50mm	42mm

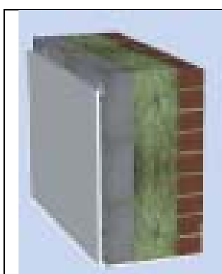


Brick / 50mm air gap / P U board (λ = 0.023) / Inner leaf - 100mm Fenlite block / dry lining						
U-value (W/m^2K)	0.15	0.18	0.20	0.22	0.25	0.27
Wall thickness	385mm	345mm	332mm	322mm	310mm	305mm
Insulation thickness	135mm	95mm	82mm	72mm	60mm	55mm

Brick / Block / Full Fill



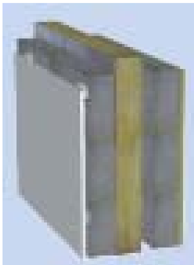
Brick / mineral wool (λ = 0.032) / Inner leaf - 100mm Thermalite Shield block (aircrete) / dry lining						
U-value (W/m^2K)	0.15	0.18	0.20	0.22	0.25	0.27
Wall thickness	400mm	340mm	325mm	315mm	300mm	285mm
Insulation thickness	200mm	140mm	125mm	115mm	100mm	85mm



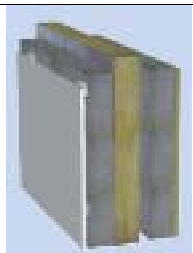
Brick / mineral wool (λ = 0.032) / Inner leaf - 100mm Fenlite block / dry lining						
U-value (W/m^2K)	0.15	0.18	0.20	0.22	0.25	0.27
Wall thickness	400mm	375mm	340mm	325mm	315mm	300mm
Insulation thickness	200mm	175mm	140mm	125mm	115mm	100mm

Table 2 (cont'd)

Block / Block / Partial Fill

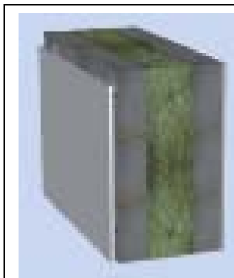


Render / Outer leaf - 100mm Thermalite Hi Strength 7 block (aircrete) / 50mm air gap / P U board (λ = 0.023) / Inner leaf - 100mm Thermalite Turbo block (aircrete) / dry lining						
U-value (W/m^2K)	0.15	0.18	0.20	0.22	0.25	0.27
Wall thickness	350mm	325mm	315mm	305mm	290mm	285mm
Insulation thickness	100mm	75mm	65mm	55mm	40mm	35mm

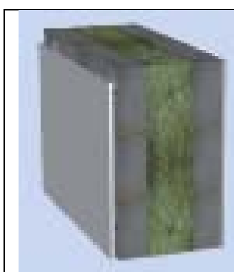


Render / Outer leaf - 100mm Fenlite block / 50mm air gap / P U board (λ = 0.023) / Inner leaf - 100mm Fenlite block / dry lining						
U-value (W/m^2K)	0.15	0.18	0.20	0.22	0.25	0.27
Wall thickness	385mm	345mm	330mm	320mm	307mm	305mm
Insulation thickness	135mm	95mm	80mm	70mm	57mm	55mm

Block / Block / Full Fill



Render / Outer leaf - 100mm Thermalite Hi Strength 7 block (aircrete) / mineral wool (λ = 0.032) / Inner leaf - 100mm Thermalite Shield block (aircrete) / dry lining						
U-value (W/m^2K)	0.15	0.18	0.20	0.22	0.25	0.27
Wall thickness	385mm	330mm	315mm	300mm	285mm	275mm
Insulation thickness	185mm	130mm	115mm	100mm	85mm	75mm



Render / Outer leaf - 100mm Ultralite block / mineral wool (λ = 0.032) / Inner leaf - 100mm Ultralite block / dry lining						
U-value (W/m^2K)	0.15	0.18	0.20	0.22	0.25	0.27
Wall thickness	400mm	350mm	325mm	315mm	300mm	300mm
Insulation thickness	200mm	150mm	125mm	115mm	100mm	100mm

Thermal mass

The benefits of thermal mass are easily demonstrated simply by visiting a selection of demonstration projects which all lay claim to achievement of energy efficiency and attainment of Code levels in excess of 4. Any structure built of a dense material will keep the internal temperature of the building at a more stable level ie the heating up and cooling down time due for example to high external temperatures is less severe due to the temperatures storage capacity of the material. Clearly masonry presents an ideal solution when exploiting the benefit of thermal mass.

5. POTENTIAL BENEFITSOF VACUUM INSULATED PANELS

There is clearly a benefit in using masonry cavity walls although structural integrity and thermal performance need to be addressed

The issues highlighted above provide a clear invitation to VIP manufacturers to address development of a panel system which might be incorporated into the cavity wall. This might enable walls to be constructed in a format that has not been possible for over 30 years ie the 265mm (or less!) system where the vacuum panel may be encased.

Prefabricated masonry walls could certainly benefit from such a system since the wall tie issue would not be so critical. Prefabrication might also suit vacuum panels as construction and handling are carried out in a factory controlled manor.

A wall with a "sensible" cavity width will be better for structural performance, with less demands on the wall ties.

6. THE CHALLENGE TO VACUUM INSULATION PANEL MANUFACTURERS

1. Design a vacuum panel which is sufficiently thin to be accommodated in a 50mm cavity wall. Designers demand ever lower U values which require more insulation and / or insulated dry lining systems. The cavity wall has increased from a traditional width of 275mm (102 brick, 100 block and 75 fill or partial fill) up to in excess of 350mm which includes a 150mm partial fill cavity. Thicker cavity walls use more valuable land space.

2. Provide a vacuum panel with sufficient resilience / robustness that it cannot be punctured. Alternatively place a panel within wall cavity in such a manner as to avoid puncture by external fixings

3. Determine size of panel in order to allow simple cavity wall construction without the need to avoid wall ties. Insulation bats are generally co-ordinated in size to fit in between wall tie spacing.

4. Details of connections between adjacent vacuum panels are critical. How will the panel efficiency be affected by joints?

5. Traditional cavity walls - and the Hanson prefabricated QuickBuild wall - use clay brickwork external cladding with a 60 year guarantee in accordance with the Building Regulations. This refers specifically to durability and structural integrity. A vacuum insulated panel must have a relatively long life / low maintenance if it is to be considered.

6. How long will the vacuum panel last – how often and by what technique will the vacuum panel require servicing.

7. If the panel itself is more expensive than traditional insulation, it will be very important to have cost comparative information against traditional walls, ie not only material but also savings in build area, construction time and long term running costs

Bibliography

Article – LANE T. – *Experimenting with Glue*, Building, April 2002
PhD Thesis – HOGG J – *Integrated Procurement Routes for Prefabricated Brickwork*, Dec 2003
British Standard : BS5628 part 1 and 2 – Use of Masonry
Dti Project, Oxford Brooke – OGDEN R et al, *Thin Joint Glued Brickwork*, 2005
Paper – FRIED A. et al., – *Thin Joint masonry in the UK*, Masonry International, Summer 2005
Paper – BAICHE B. et al., *Thin Joint Glued Brickwork, An alternative Technique for the UK Construction Industry*. – Masonry International, 2006
Book – De SAULLES T, *Thermal Mass for Housing*, The Concrete Centre, 2006
PhD thesis – KANYETO O - Investigation of the Behaviour of Laterally Loaded Thin-Jointed Concrete-Block Masonry Panels - 2007
Booklet - Hanson Eco House 2007
Article - ROGATZKI PP. Building the EcoHouse™ –The Structural Engineer Oct, 2007
Code for Sustainable Homes 2007
HANSONThermalite thin joint
Booklet – HANSON, EcoHouse™ - on Code for sustainable homes 2008
Paper – ABLEY I, Immediate prospects for vacuum insulation in the British site built housing sector.Global Insulation Conference, 2008
Paper – ABLEY I, System thinking for better insulated British Housing, Global Insulation Magazine, October 2008.