Passivhaus for the many not the few

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Introduction

Cost effectiveness has always been key to the Passivhaus approach. Yet we regularly hear designers say that they would love to design a Passivhaus but ‘have not yet had a client willing to pay the extra’. If an energy standard such as Passivhaus is to have an impact it must become normal practice, it cannot be too expensive, too difficult or too esoteric.

There is an assumption that simplification and cost reduction will lead to reduced performance, inferior quality and an ugly building. Raising the topic of cost early in the design process is often seen as squashing creativity but in fact the opposite is true.

How much extra does Passivhaus cost?

Typical figures quoted are in the range 3-8% extra in Germany and 0-30% (sic) in the UK [Barnes 2015]. Some argue that additional capital cost is offset by energy savings over the life of the building. The least life-cost argument was used to mandate the Passivhaus standard for new public buildings in Frankfurt [Bretzke]. However, the build budget is often fixed and operational costs may be paid by a different party. Others have been keen to show that Passivhaus homes can demand a premium when sold or rented and this justifies additional investment. This is acceptable if we see Passivhaus as a premium lifestyle choice.

In practice the cost of housing has more to do with land prices than building standards. The shortage of building land in the UK means that plots prices are set by the difference between market house prices and the cheapest construction that developers can get away with. Luck in obtaining planning permission on an agricultural field or large garden means a lottery win for the owner who will naturally aim to maximise the sale price. This has pushed land prices up and so construction budgets down.

If a higher standard were to be enforced for all new buildings then land prices could be expected to drop to keep new house prices in line with existing stock. This in part explains the difference in over-cost reported for Passivhaus in the UK compared with Germany where building standards are higher and land is priced differently. Mark Brinkley makes the case very clearly in his writing on self-build [Brinkley 2013].

Passivhaus for no extra cost – really?

Passivhaus buildings have an extra layer of glass, heat recovery ventilation, thicker insulation and are built to a high standard of airtightness, all things that cost extra compared with standard buildings. Simplified heating systems [Clarke 2016] may provide a small saving but this is not enough to *tunnel through the cost barrier* [Lovins 1999] even when we hit the magic $10W/m^2$ heat load (services will not be covered further in this paper).

In fact, the budget for an Architect designed house is typically sufficient to build a Passivhaus so long as this is part of the brief from the start. This is achieved by prioritising Passivhaus over the endless potential demands on the budget.

Conversely where a building has already been designed without properly considering energy performance, bolting on the requirement for Passivhaus will result in a significant increase in cost – the design equivalent of a Passivhaus retrofit. In addition, the aesthetic is likely to suffer. There is discussion about the emergence of a Passivhaus vernacular that embraces the constraints of energy efficiency. Thick insulated walls with deep splayed reveals and wide window seats next to warm glazing might be one example. However if we start with a pre-conceived aesthetic inspired by, say, thin cantilevered concrete, steel window frames and glass to glass corner windows (which, incidentally, the authors really like) then the compromise is unlikely to be a happy one. Trying to impose function on a pre-conceived form, that emerged from a different set of historical constraints, is at best expensive.

Returning to our title, the real challenge is to deliver basic social Passivhaus homes for the same price as basic social housing where there are no expensive finishes or complexities of form to trade. This means we need to achieve more with less and there is a way.

Value Engineering, VE

Value engineering is based on a methodology developed out of necessity during the Second World War by Lawrence Miles who worked for the General Electric Company in the USA.

The aim of VE is to improve function for no extra cost or to reduce cost without any loss of function, i.e. to maximise value. Function can include anything we can define although ‘good design’ and ‘delight’ are harder to measure than heating demand or useable floor area.

Value = (function + quality + performance) / (cost + time)

There are techniques to facilitate VE but like any creative process there is much work and no guarantee of success with inspiration and chance also playing a role.

As a design engineer who studied VE in the 1980s it was a shock to discover that genuine VE is rarely practiced in building. Instead the term is used in a derogatory way to describe cost cutting once the completed design has been found to be over budget. Cost cutting is the antithesis of VE and usually results in reduced value. Thus, most Architects despise the term with passion.

Most costs are incurred at a very early stage in design, before planning has been obtained and this is where the largest savings can be made for least effort as illustrated by figure 1.

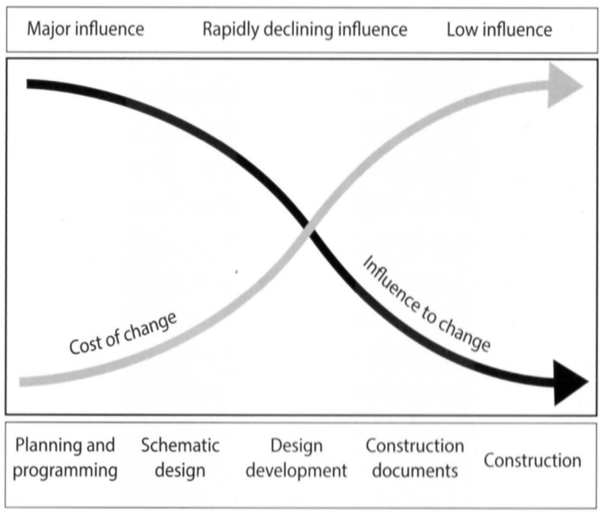

Fig 1. Cost and influence of change over time. [Lewis 2017].

Barriers to VE in Construction

Excellent examples of Value Engineered Passivhaus components are regularly presented at this conference. Innovations in windows & ventilation particularly come to mind.

If VE really can deliver more for less, why is there such resistance applying it to buildings? In manufacturing, the implementer of VE reaps the benefits and gains a commercial edge but in construction there is often a conflict of interest between the designer and the builder. The design team want to maximise function including *wow factor*, perhaps win an award, but have little incentive to reduce cost. Budget considerations are usually limited to a target floor area and an assumed build cost per square metre.

The builder usually comes along later to bid for the work, largely on price, so is very concerned about not losing money, and ideally making a profit. Because of this an experienced contractor will spot costs such as additional steel work but will also recognise patterns from previous projects as 'tricky details' where unexpected costs were incurred. Typically this results in a sucking of breath and the phrase 'not cheap', but unless the builder is part of the design team from the start, her input will be limited to suggesting cheaper, and probably inferior, materials and components.

One way out of this bind is for designers and builders to work as a team, ideally on repeat projects so that lessons from the build (and occupancy) feed back into the design. The examples here were developed by an integrated team of client, Architect, energy consultant, structural engineer, services engineer and builder working on repeat projects, with additional value adding input from the window and ventilation supplier. Unfortunately Design and Build (D&B) has an even worse image than VE!

The Value Engineered Passivhaus, simplicity of form – embrace the box

Any deviation from a rectangular plan will increase costs per m^2 of useful floor area, this is arithmetic. We can do the sums, but m^2 build rates do not include factors for additional corners beyond the standard 4. The extra building fabric costs more but also increase heat loss which means thicker insulation and so even more wall, floor and roof to pay for. Crudely, if the heat loss area divided by the TFA is less than 3 we will have an easier time hitting the heating demand. Double height spaces can be nice but they more than double the cost of that floor area. Passivhaus advocates are keen to point out that Passivhaus does not need to be a box but if we are serious about delivering Passivhaus for all, we need to *think inside the box* [Herring 2007] and stop apologising about houses that look like houses.

Fenestration

Windows and doors cost perhaps 5-10 times as much as the wall area they replace but they add considerable value in terms of daylight, views, means of escape, ventilation and solar gains. However too much glazing or glazing in the wrong place reduces value; overheating in summer, heat loss in winter, reduced privacy, less space for storage and furniture and more glass to clean.

A direct swap to Passivhaus windows might add a couple of percent to the whole build cost but it is the form of fenestration that has a far bigger impact on costs. Excess glazing will incur costs for additional shading devices. Large and corner

Fig 2. No transoms or mullions. South canopy to be added for shelter & shade.

windows will introduce the need for extra structural support which may include beams, steel cantilevers, wind posts and stronger foundations to accommodate higher point loads or bending moments in structural slabs. This may in turn add program delays, thermal bridges and more complicated airtightness. Figure 2 shows a cost effective Passivhaus where transoms and mullions were avoided completely. The fixed windows cost 30% less than opening ones so the larger windows are fixed. Every room has at least one opening window. Size and position are dictated by views and daylight. This gives clean framed views and more glazing than the client thought they could afford. A canopy will provide shelter and shading for the door and largest south window. The roof is cheap agricultural ‘crinkly tin’ and the cladding is raw, local, rough-sawn Douglas fir. The clients are completing the fit-out, saving money and adding their personal touch.

Structural simplicity

Faced with a gravity defying design, most structural engineers assume they cannot question the designer and will embrace the challenge of solving the problem through ingenious (and expensive) structures and components. An experienced builder will have a deep learned intuition for where hidden structural costs or savings lie but this experience is rarely present in the design team until it is too late to design out the problem. Figure 3 shows the wall slab junction we use on most of our timber frame houses. The balloon frame I stud walls are supported on the slab edge. With no manufacturer data available, simple testing was required to prove that the web was more than capable of carrying the weight of cladding. Earlier iterations were much less elegant with a separate structural frame and custom made Larsen trusses. They cost more, took more time and were less thermally efficient. Whilst difficult to see what could be removed we are already considering simplification.

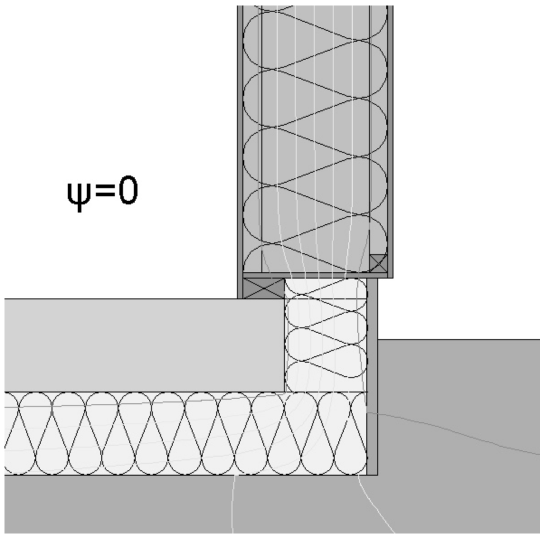

Fig 3. Innovative I stud wall.

Airtightness, fear it and add cost, embrace it and reduce insulation thickness!

The main concern for a first time Passivhaus builder will be meeting a contractually binding airtightness target 10 times more onerous than they already struggle to meet. Conversely experienced teams realise that with simple details and a bit of care, they can consistently achieve air leakage less than 0.2m/h at no extra cost, the definition of value. These teams see airtightness as a saving, with less insulation if they can guarantee an n50 under $0.3h^{-1}$.

There is a cost to achieve an airtight building rather than a leaky one, but using twice as much tape does not halve the leakage. However, a poorly detailed building may require twice as much tape and much more time to only just achieve the target. If we can design out tricky details and convince even a first time Passivhaus builder that there is nothing difficult about achieving the target then costs will come down. If one building achieves an n50 of 0.18 h^{-1} and another achieves 0.64 h^{-1}then we would guess that a lot more time and money, including additional materials and tests, was spent achieving the 0.64 h^{-1}.

Whilst some designers take pride in the large number of details they provide we should be aiming to eliminate the need for any airtightness drawings! A recent self-build with inexperienced builders required only four A3 drawings to detail all the air and weathertight junctions. We made one visit to demonstrate taping and the first blower door result was 0.09 m/h. Simplifying airtightness details tends to simplify construction in general. Someone said that the devil is in the detail so the more details the more devils! Figure 4 is a refinement of an old idea, sprocket rafters. The builder (Mike Whitfield) used the same detail on the un-insulated garage because it was quicker and more robust even though the wind tightness was not required. Purlins and ridge beams are avoided if possible, saving cost and crane hire. If used they do not penetrate the air or wind tight layers.

Fig 4. Avoiding penetrations increases value.

Passivhaus consultancy for no extra cost!

How can we do more for less? This is critical if we are to get the design right before planning is granted. At this point fees are rarely available for specialist consultancy but it is early decisions about form, wall thickness, fenestration and orientation where most value is locked in. This is one reason why many designers fail to design a Passivhaus despite their enthusiasm and CEPH qualification, the client will not pay the extra fee pre planning. A number of professionals do not offer Passivhaus as an extra, like seat belts in cars it is standard.

The smaller the budget the easier it is to achieve this. For a simple rectangular house, the heat demand and summer comfort can be modelled in PHPP in half an hour using simple hacks. Dimensional inputs are limited to number of floors, internal width and length, ceiling heights, floor depths and roof pitch. External dimensions are then derived from standard build-ups in the U values sheet. Our standard detail psi values are already in the area sheet and the lengths are read from the dimensions already calculated.

An estimate of internal wall length and width and stair dimensions allows the TFA to be estimated. For a small house this is the most sensitive variable and uncertainty about stair and internal walls adds an unnecessary level of risk and complication at the design stage even though they don't affect fuel bills or comfort.

Windows and installation psi values are in place from the previous project and can easily be tweaked for site specific views and daylight. Adding a cell in the area sheet allows us to rotate the building and our standard reveals are already in the shading sheet but easily changed. We have immediate feedback and the PHPP can track the design as it progresses.

Certifiers advise allowing plenty of slack in the PHPP at an early stage but this can add considerable cost that is hard to remove later. This topic is worthy of its own paper.

Another potentially costly aspect of the consultancy fee is site visits, especially if the project is some distance away. For early projects we would visit site regularly to solve problems that were often airtightness related. Experience shows that details that 'will be easier to sort on site' are never easy. For a recent self-build project site visits were offered as an extra.

Because the house went up so easily the client did not feel the need to pay for a site visit. Keen to learn from the build we visited anyway on the pretext of demonstrating how to install a window. We arrived in heavy rain so proceeded to install a window behind the weatherproof wrap. The rain continued for weeks so all windows were installed this way. Had it not been raining as we arrived we would have cut a hole in the wrap before installing the window. Having been prepared to write the day off as R&D, the client was happy to pay for our time and we all learnt a lot. Zero site visits are least cost but unlikely to be best value for the client or design team needing to learn. Blower door tests are particularly valuable in terms of providing feedback on what works.

Figure 5. Windows installed in the dry behind the wrap during heavy rain.

Conclusions

Whilst cost cutting is done by haggling and shopping around, VE is a creative process with uncertain outcomes. Often the simplest solution takes the longest to achieve. We do not claim credit for any of the examples shared in this paper, all are the result of input by many people and some are simply adapted from standard details. Many of these innovations happened solving problems on site so the saving was only realised on the next project. Savings only happen if the budget is reduced, otherwise time and costs expand to fit – like the time writing this paper. Building is never under budget!

The only thing Architects hate more than VE is D&B. The marriage of these could be re-branded as Integrated Design if that helps us move on. Something needs to change fast if sustainability is to become normal, which is part of the very definition.

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Abstract

Cost effectiveness is a key part of the Passivhaus approach and yet cost continues to be a barrier to widespread uptake. The authors argue for an apparently controversial approach that is common in manufacturing but almost absent from one-off build projects.