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Designing for Deconstruction in the Context of the Passivhaus Standard.

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Abstract

This research aims to examine Designing for Deconstruction (Dfd) in the context of Passivhaus construction, to highlight potential conflicts in achieving the 'half waste to landfill' and '80% reduction in building energy consumptions by 2050' targets that have been set by the UK government. The study will aim to find solutions to this by identifying environmental impacts of waste materials in landfill, researching existing materials reuse trends, examining Dfd principles and strategies and the Passivhaus standard criteria. The Denby Dale house will be used as a case study to identify conflicts between Dfd and passivhaus. An attempt will be made to make conflicting passivhaus construction details 'Dfd friendly'. Any aspects of the construction that cannot be changed without compromising the achievement of the Passivhaus standard will be identified. The carbon footprint of the materials that cannot be reused completely will be analysed and alternate, less carbon intensive, materials will be proposed.

Keywords: Design for deconstruction (Dfd), Passivhaus, carbon footprint, landfill waste

Introduction to research.

More than 30% of waste in the UK is generated by the construction industry (WRAP) resulting in legislative agenda such as 'Half Waste to Landfill' which aims to reduce construction waste by 50% by 2012 (HM Government, 2008) and has led to the introduction of the Landfill Tax, Aggregate Levy and the inclusion of Smart Waste Management Plan's, for projects above the value of £300,000 in England only (DEFRA, 2008). As the reuse of materials has been identified as a priority in the European Waste Framework Directive, designing for deconstruction (Dfd) is becoming an important aspect of controlling waste produced due to construction processes.

The UK government aims to reduce green-house gas (GHG) emissions by 80% in the year 2050 which has encouraged the popularity of low energy construction standards such as Passivhaus. Thus, Dfd and Passivhaus must be compatible in order to meet both these goals. This has formed the basis of this research, which aims to identify areas of Passivhaus construction that are not compatible with Dfd and find alternative detailing solutions, or alternative less carbon intensive materials, using the Denby Dale house as a case study.

Research Methodology.

The research has been carried out in three stages. First the impacts of C&D waste in landfill in England and Wales has been evaluated by mass (kg) and Carbon footprint, offering a perspective of wider material impacts. The existing materials reuse trends have

been researched to ascertain the current reuse potential of building materials. Next the principles of Dfd are discussed, organized according to the RIBA Plan of Works 2013. In the second stage the Passivhaus standard and the construction specifics of the Denby Dale house have been researched to determine any Dfd incompatible aspects of its construction. The third stage consists of analysing these incompatibilities and determining the type of intervention is required, such as the change of a carbon intensive material (via carbon footprinting analysis using the ICE database, 2011). Finally, the proposed alterations and an analysis of their carbon footprints are compared to that of the existing construction for discussion.

Construction Waste Materials and Material Reuse.

Research was carried out for construction waste materials remaining in landfill for England and Wales and their impacts were analysed in terms of their mass (kg) and carbon footprint (kg CO₂e). as shown in figure 1. Structural concrete has a high impact in terms of mass while plastic in Wales has the highest impact in terms of carbon footprint. Landfill material categories of wood, iron and steel, tiles and ceramics and bricks also have notable effects and should be avoided from landfill.

The most commonly traded building materials for reuse are, bricks, roof tiles and slates, walling stone and timber floorboards. Materials that are most cost effective in terms of procurement for reuse are concrete paving, doors, timber joists and stud-work, structural steel, portal frames and cladding, carpet and reconditioned M&E machinery such as boilers (WRAP, 2008). However, it should be noted that these would alter if deconstruction was accepted as a key component of building design and construction, as a larger variety of reclaimed materials would become commercially attractive.

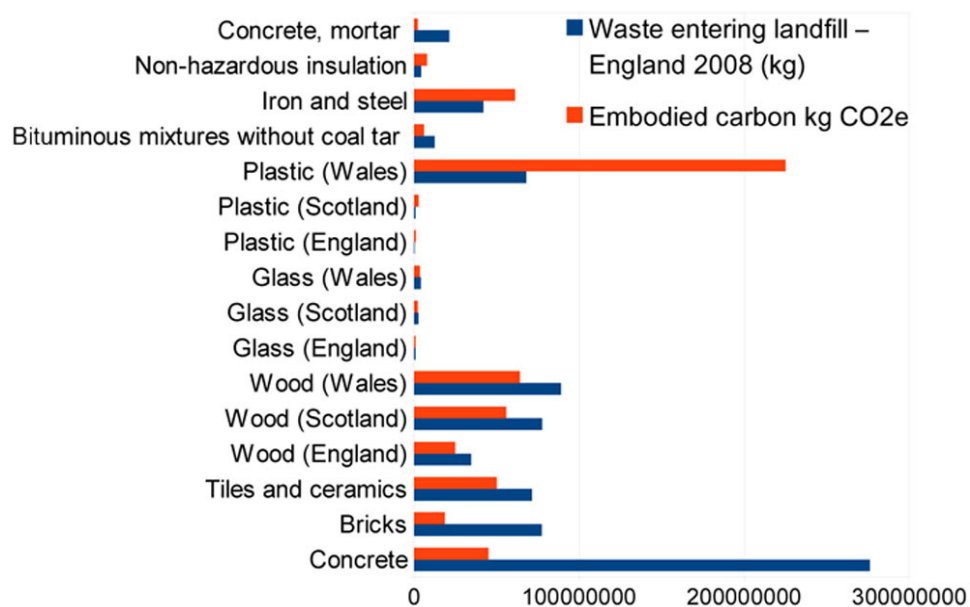


Figure 1. Analysis of Construction Materials in Landfill for England (2010) and Wales (2005-06), in terms of mass (kg) and carbon footprint.

Designing for Deconstruction : Literature Review.

In order to view the process of Dfd in practice its main principles have been considered in terms of their applicability in a construction project and they have been organized according to the RIBA design stages (2013). At 'Stage 0' the client brief and core project requirements are identified and the natural hierarchy of waste minimisation is considered, initially looking at the adaptive reuse of existing buildings and designing new building for adaptability. The recycling of materials and reclamation of energy from building elements are secondary preferences.

At 'Stage 1' the project objectives and brief is considered which includes creating a 'building life pattern scenario', tailored to the requirements and potential future plans of the client. A decision must be made regarding the quality of materials to be used, whether sourcing from reclamation stores or using high quality virgin materials that will retain commercial value during their lifespans.

The 'Stage 2' concept development stage considers outline design proposals and project strategies. At this stage it is important to consider the following so that future repairs and renovations can be carried out with minimal damage to the building materials : adaptable, modular building and space design, the selection of structural elements that are simple to construct and deconstruct, and designing according to Stewart Brand's building 'layers' and their associated lifespans (1995, p.32) .

'Stage 3' is the design development stage. Building components and their fixtures should be designed so that they can be handled by a standard construction team, their tools and machinery. The deconstructable elements should also be easy to access and should be clearly marked and noted in any drawings. Differential weathering should be considered so entire 'layers' will not be taken apart if a small part requires repair. Layers that are 'hidden' such as the insulation, should be accessible without interrupting the building structure.

Selecting mechanical fixtures where possible, minimising chemical adhesive fixtures, and the separation of mechanical, plumbing and electrical services should be considered in 'Stage 4', the Technical design stage. A set of detailed deconstruction drawings and notes must be kept here to include in the owner manual.

While the 'Stage 5' construction stage principles include mainly overseeing the implementation of the Dfd principles in practice, a set of 'as built' drawings and technical notes regarding the construction and deconstruction should be presented to the owner at 'Stage 6', the handover stage. This manual should also include options for renovations and refurbishments to avoid the negation of Dfd strategies in future construction processes, which is to be a part of the new 'Stage 7', which concerns the building 'in use' and would involve aspects such as post occupancy evaluations.

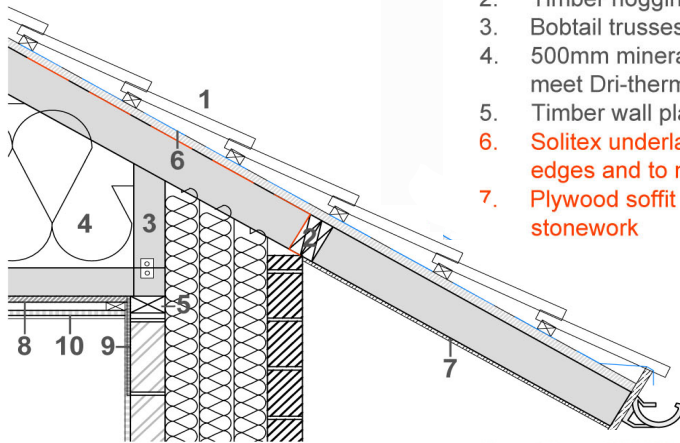
The Passivhaus Standard.

The second stage of the research begins with an analysis of the Passivhaus standard, which is a voluntary, low-energy consuming construction standard. Its main characteristics includes a continuous layer of insulation, the minimisation of thermal bridging in construction, a very airtight building envelope, good quality triple glazed windows and provisions for mechanical ventilation with heat recovery (MVHR). The standard has a performance based assessment system with rigorous criteria such as an annual heating and cooling demand of 15kWh/m² and an airtightness level of 0.6 air changes per hour. It is recommended that high quality materials are used for passivhaus construction and prefabricated elements that are carefully designed for specificity are preferable in this scenario (McLeod.R. et al, 2007).

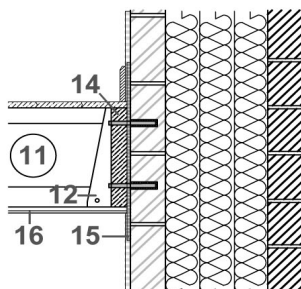
The Denby Dale House case study.

This is a three bed dwelling in West Yorkshire with a project cost of approximately £141,000. It is the first passivhaus building to be built using double blockwork cavity wall construction in the UK. The intention of the project was to create a passivhaus dwelling using a construction method familiar to local builders, using materials that could be readily found at any building merchants. The following page contains a detailed wall construction section of the case study, with its Dfd incompatible construction aspects in red lettering.

ROOF



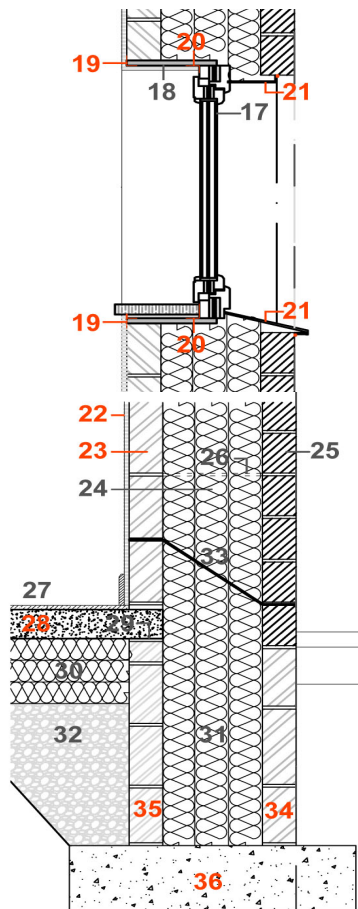
1. Clay roof tiles fixed to timber battens - fixed to timber counter battens - nailed to rafters.
2. Timber noggins and fascia board - nailed to trusses.
3. Bobtail trusses with 500mm upstands.
4. 500mm mineral wool insulation - loose laid and brought out to meet Dri-therm wall insulation.
5. Timber wall plate - nailed to blockwork.
6. Solitex underlay membrane - fixed with airtightness tapes at the edges and to noggins.
7. Plywood soffit board - nailed to trusses and masticed to stonework



8. 18mm OSB boards - butt jointed with Pro Clima airtightness tapes.
9. Sand and cement parging under plaster finish.
10. 25mm thick timber battens with plasterboard and skim finish .

FIRST FLOOR JUNCTION

11. 302mm Boise engineered timber I-beams.
12. Steel beam hanger - screwed into timber plate and I-beams.
13. Engineered chipboard tongue and groove flooring - glued and nailed to I-beams.
14. 45 x 302mm timber plate - bolted to wall (stainless steel threads with washers and epoxy resin).
15. Sand and cement parging to wall.
16. Plasterboard nailed into I-beams with 10mm skim plaster finish.



WINDOW OPENING

17. Triple glazed Ecopassive window - FSC certified timber and insulated frame.
18. Plywood boxing.
19. Pro Clima Contega airtightness tapes - applied to plywood box, concrete blockwork and covered with wet plaster finish.
20. Pro Clima Tescon airtightness tapes - applied to plywood box, and window frame.
21. Bespoke aluminium cavity closer and insulated external sill- cut into window frame and masticed to stonework.

EXTERNAL WALL

22. 15mm two coat wet plaster finish.
23. 100mm concrete blockwork with cement mortar.
24. 300mm Dri-Therm fibreglass batt insulation.
25. 100mm Yorkshire stone with lime plaster.
26. Basalt and resin Teplo wall ties - with insulative properties.

GROUND FLOOR

27. Engineered timber flooring and skirting board.
28. 100mm poured concrete.
29. EPDM Radon barrier.
30. 225mm Knauf polyfoam insulation.
31. 300mm closed cell insulation.
32. Compacted hardcore.

FOUNDATIONS

33. Plastic cavity tray - reduce thermal bridging.
34. 100mm concrete blockwork - cement mortar.
35. 100mm aerated blockwork - cement mortar.
36. 225 x 850mm Poured concrete strip foundations.

Figure 2. Detailed construction of Denby Dale house

Dfd Compatible Alternative Solutions : Carbon Footprint Comparison.

Foundations and Ground floor.

The alternative for the ground floor construction includes a precast concrete ground beam system with 300mm polystyrene infill panels. This requires a smaller poured concrete floor screed of 60mm and is Dfd compatible. However, as seen from figure 3, the overall carbon footprint of the alternative exceeds that of the original, as polystyrene has a high carbon footprint compared to concrete.

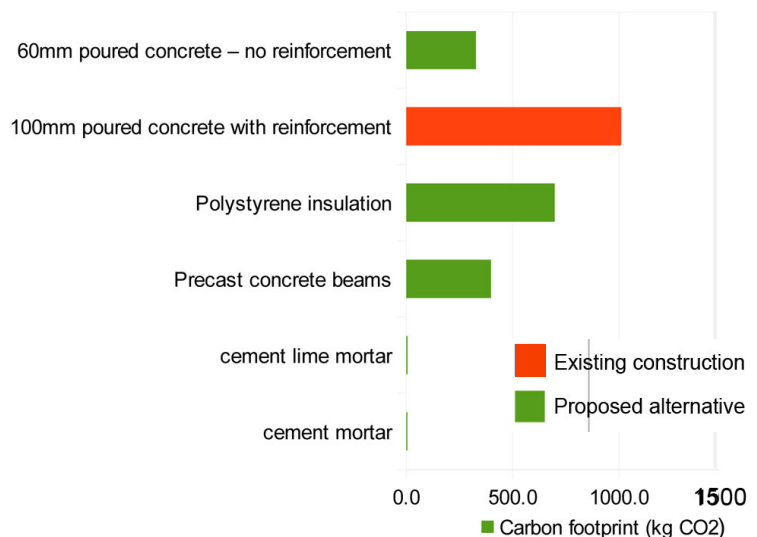


Figure 3. Carbon footprint comparison of original Ground floor and propose ground floor construction.

External Wall.

One alternative uses lime plaster and mortar to replace the cement mortar and gypsum plaster in the original construction.

The second alternative is to dry line clayboard with airtightness tapes applied at all edges, and apply lime plaster to finish. This method would avoid the staining of the concrete blockwork by direct lime application, which would reduce its commercial appeal.

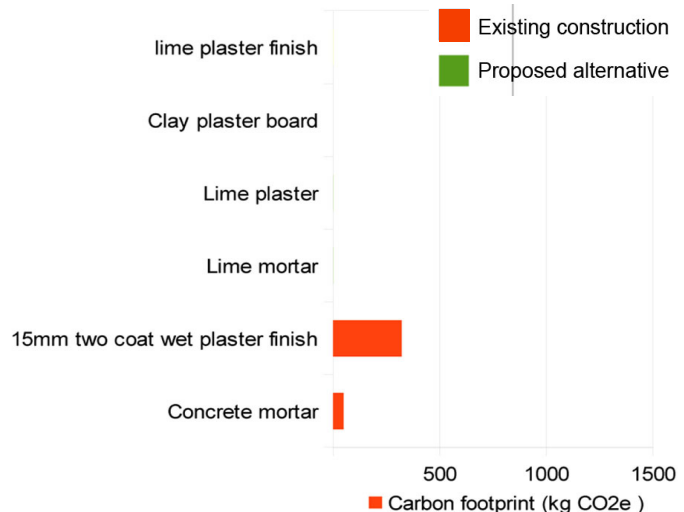


Figure 4. Carbon footprint comparison of original External wall and proposed external wall constructions.

Window, First Floor and Roof.

A pre-formed recycled PVC and polystyrene insulation cavity closer was suggested for the window openings. However, its carbon footprint was greater than the box in the original construction. The Pro Clima adhesive tapes would still be required to maintain the airtightness required for passivhaus as well, reducing the reusability of the cavity closer.

Gypsum ceiling tiles on timber battens were proposed from the first floor and roof ceilings. The carbon footprint of this is less than the original. Mastic remover may be used to remove small areas of mastic applied to areas such as the roof soffit edges.

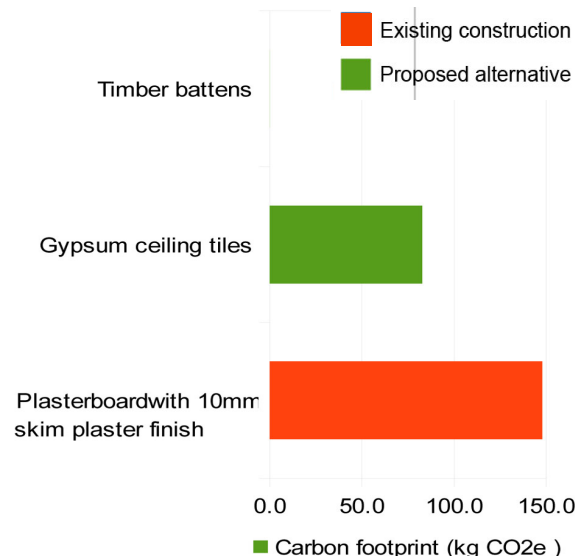


Figure 5. Carbon footprint comparison of original ceiling and proposed ceiling constructions.

Discussion and Conclusion.

The Dfd compatible alteration attempts were focused on materials such as structural concrete which not only affect the deconstructability of the building but have a high impact on landfill waste as well. Simple mechanical fixtures were recommended for the timber flooring which would retain its commercial value and avoid more wood from going into landfill.

The replacement of the adhesive fixtures have not been recommended although it is a significant factor in causing material wastage in deconstruction. The use of mechanical fixtures for airtightness would require more time and skill than applying adhesive tapes, which is reliable and quick and is necessary for achieving the airtightness levels of the Passivhaus standard. The adhesives would be difficult to remove for repairs or renovations. If removed from components such as windows their surfaces would be damaged thus reducing their reuse potential.

Lime plaster can be used to achieve a good level of airtightness. However, it requires more time to dry and a skilled builder for its application thus making it more expensive. It may also stain the surfaces it is applied to, reducing the reusability of those materials. Nonetheless, it is a relatively carbon neutral material since it absorbs carbon dioxide as it dries, making it a feasible alternative for wet plaster application.

Although ceiling tiles which are mechanically fixed to timber battens are more time consuming and labour intensive than plasterboard with skim work, the services pipes of the dwelling are installed within the I-beams of the first floor, thus making it an important suggestion to ensure easy access to services which may be need repair.

In masonry construction the building 'layers' that are ideal for Dfd cannot be adhered to as the insulation is kept within the layers of block and stonework. Therefore, it cannot be accessed for replacement without interrupting the structure of the building. However, the insulation used in this case is rot resistant and would last the lifetime of the building, provided that it has been installed to the manufacturer's specifications.

It is evident that achieving Dfd compatible passivhaus construction can prove challenging in areas such as airtightness. Adhesive tapes are necessary for achieving airtightness in masonry construction as materials such as concrete blockwork are relatively porous. Therefore, it can be concluded that studies regarding deconstructable airtightness measures, such as 'removable' airtightness tapes, are required to ensure the easy dismantling of passivhaus construction building components for repair or deconstruction.

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