Assessing levels of Deconstruction and Recyclability

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Abstract

Designing for deconstruction and recycling enables resources to be reused in the most efficient and productive way. This is particularly important looking into the future as we move away from traditional construction methods and materials to more composite structures. There is no standard, test or guidance in place that designers or clients can use to assess the ease of deconstruction and subsequent recyclability. Lack of measurement or assessment methods makes it very difficult to measure success until the building is demolished. A recently started project, to develop design for deconstruction criteria to initially evaluate ease of deconstruction and recovery, is the focus of this paper.

Keywords:
Design for deconstruction, Design for recycling, Design for reuse, demolition, Pre-demolition audit

1 INTRODUCTION

Designing for deconstruction (DfD) and recycling enables resources to be reused in the most efficient and productive way when the building is eventually demolished. This is very different from maximising recycling and recovery of existing buildings using the latest demolition or recycling technologies which has tended to be the focus when considering resource efficiency and demolition. There are a number of ways to potentially promote DfD, including the provision of credits in green building standards such as BREEAM (BRE Environmental Assessment Methodology). However, until it is possible to assess the design of a building, in terms of ease of deconstruction, reuse and recycling, it will be impossible to compare the future deconstructability of these designs and award credits on that basis.

BRE have recently started a project, funded by the BRE Trust and Zero Waste Scotland, to develop design for deconstruction criteria that could be used to evaluate ease of deconstruction, reuse and recycling, focussing on housing in the first instance. The first task of the project is nearing completion and relates to reviewing existing work in this area. Some of the findings of this task are presented in this paper.

2 BACKGROUND

A recently completed BRE Trust project called *Dealing with Difficult Demolition Wastes* revealed that the high recycling rates currently achieved by the demolition sector would decline unless the buildings being designed today were easier to take apart. Waste from construction, demolition and excavation represents the largest waste stream in the UK at an estimated 87 million tonnes in 2008. Of this, at least 21 million tonnes is inert waste from demolition [1], such as concrete, bricks and soils. Virtually all of this material is currently reused or recycled either on the same site in the follow on construction, or taken off site for reuse and recycling elsewhere. Similarly, other demolition waste types, such as solid timber, tend to be reused or recycled. All of this leads to high diversion from landfill rates for demolition waste, typically over 90%. However, there is growing concern in the demolition sector that it may not be possible to improve, or maintain, these high recycling rates into the future due to the increasing prevalence of difficult demolition waste.

These wastes are termed ‘difficult’ as they may be problematic to recover, which could be due to their material composition, techniques of demolition/strip-out, contamination, or their low value, and as a result they are likely to end up in landfill. Some may also have relatively high environmental impact, due to their hazardous qualities, high embodied energy or global warming potential, so the inability to recover these products at the end of their life increases their overall effect on the environment.

Many of these issues arise from the decisions made in the design and construction of buildings. Since we cannot guarantee that new technologies will be developed to revolutionise demolition into the future, there should be a focus today on trying to avoid waste related legacies into the future and on actively considering ways in which building components and materials can be put together to facilitate future reuse and recycling. These objectives are the basis of DfD.

3 DRIVERS AND BARRIERS TO DFD

3.1 Drivers for DfD

- *Environmental driver:* Reducing extraction of new materials, reducing materials sent to landfill.
- *Socio-economic driver*: Employment: jobs may be lost in primary manufacturing, but some will be created in the refurbishment of equipment and in the processing of reclaimed materials; social benefits: benefits from reduced loss of land due to materials extraction and landfill sites.
- *Commercial driver*: Landfill tax introduced on 1st October 1996 in the UK is an incentive to deconstruct (annual rise of £8/tonne; currently at £64/tonne for non-inert waste); Aggregate Levy: £2.50/tonne which provides an incentive to use recycled goods and materials.
- *Political drivers:* Government policy on sustainability (minimisation of wastes, maximisation of recycled and reclaimed materials); Key policies include the joint English industry/Government target to halve Construction, Demolition and Excavation (C,D&E) waste landfilled by 2012 based on a 2008 baseline (equating to an extra 6.3 million tonnes of waste being diverted from landfill each year) and CEN TC350 Sustainability of Construction Works – this standard relates to construction products and may include end-of-life recyclability indicators; however there are many other political drivers.
- *Risk management:* Legislation, health and safety, fiscal measures encouraging minimisation of primary materials extraction and waste generation; reclassification of materials and wastes: potential

reuse of material after the life of the project needs to be thought through; producer responsibility/liability.

- *Economic reasons for using design for deconstruction:* The economic drivers include increasing the flexible use and adaptation of property at a minimal future cost, reducing the whole-life environmental impact of a project and reducing the quantity of materials going to landfill.

3.2 Barriers to DfD

- *Lack of legislation*: no legislation exists in the UK that requires client or contractors to consider deconstruction at the design stage.
- *Human barrier:* it is easier for people to carry on doing what they have always done and people tend to prefer new materials to second hand ones.
- *Additional design cost*
- *Procurement and contractual responsibilities*
- *Technical barrier*: jointing systems, for example between pre-cast concrete beams, are usually stronger than the actual beam and are very difficult to deconstruct.
- *Economic barrier*: cost of individual units (tiles, paving slabs etc) is usually low, so it is more cost effective to buy new ones.
- *Dimensional barrier*: usually structural units (beams, columns, etc) are for one-off bespoke structures with unique dimensions.
- *Physical barriers*: pre- and post-tensioned beam/ floors, jointing systems, natural ageing of concrete, reinforcement corrosion, presence of coatings.
- *Contamination and aesthetics of components issues*: contamination with pollutants (petrol, grease, grime)
- *Perception and education:* perception that composite and strongly bonded elements are more durable and stronger structurally. In reality, a well designed building that incorporates design for deconstruction elements should pose no increased risk of structural failure.
- *Problem of storage and double-handling of materials:* movement between sites can increase costs of reuse
- Lack of markets for reusable elements or components.

4 DESIGN STAGES

The level of detail in relation to DfD will depend upon the stage of design. Ideally the commitment to embed DfD will be set from the very early stages of a client selecting a designer, to ensure the appointed designers are willing and able to incorporate DfD into the design process. *The Environmental Design Pocketbook* [2] suggests that DfD should be considered at the following (RIBA) stages:

- Work stage C: Outline proposals/concept

Commit to designing for deconstruction

- Work stages E,F: technical design and production information

Detail for deconstruction

- Work stage L: post-practical completion

Undertake a deconstruction drawing and logbook, to include audit of building material standards and reclamation potential

This guide also provides a checklist of issues to consider in terms of DfD, including issues such as undertaking a health and safety assessment of the proposed deconstruction strategies in accordance with Construction Design and Management (CDM) Regulations.

5 DESIGN CONSIDERATIONS FOR DFD

At the simplest level, there tends to be two main considerations, firstly the materials and components used; secondly, the way in which they are put together (and thus able to be taken apart). It then gets a lot more complicated in terms of specific design and material selection decisions that will have a positive or negative effect. In the UK, there are a number of guidance documents that can help the designer and build team identify what could be done to facilitate DfD.

A CIRIA report on *Principles of design for deconstruction to facilitate reuse and recycling* is one such report [3]. This provides advice by building element, along with multiple case studies to illustrate particular points. In terms of developing criteria for the products and materials selected, this report provides an excellent overview for each building element, in terms of:

- Steps to maximise value at deconstruction
- Design for reuse after deconstruction
- Design for recycling after deconstruction

It also combines information from the Sassi 2002 report (see section 6 for more detail on this report) on the ratings developed for different specifications relating to the building element type, where they were available. For example, when considering the building envelope, an evaluation is provided for curtain walling, stone cladding, concrete, GRP cladding, windows, metal sheeting, and roof coverings. Additional rating information from the Sassi 2002 report is also provided for different external wall specifications. If this approach is followed to its logical conclusion, in that the generic design choices for each element are evaluated, followed by a finessing for each specification, a robust assessment process for the overall design could be developed. What is less clear is how much additional data will need to be collected to have a complete dataset and the time that might be needed to carry out a DfD assessment using such a dataset.

SEDA [4] produced a detailed guide to *Designing for Deconstruction* that can be downloaded free of charge. The guide examines the context and principles of designing for deconstruction and then focuses on five typical construction details compared with alternatives which optimise the potential for each detail to exploit deconstruction and waste reduction techniques, along with explanations and costs. Some of the ‘quick wins’ for deconstruction are summarised here:

- Nails and bolts have appropriate uses as per the type of connection and size of the members. A variety of nails in one building causes the requirement for multiple tools for removal. A mix of bolts, screws, nails requires constant shifting from one tool to the next. Fewer connectors and consolidation of the types and sizes of connectors will reduce the need for multiple tools and constant change from one tool to the next.

- Long spans and post and beam construction reduce interior structural elements and allow for structural stability when removing partitions and envelope elements.
- Doubling and tripling the functions that a single component performs will help “dematerialize” the building in general and reduce the problem of layering of materials.
- Separating long-lived components from short-lived components will facilitate adaptation and reduce the complexity of deconstruction, whereby types of materials can be removed one at a time, facilitating the collection process for reuse/recycling.
- Lightweight materials and lightweight structures reduce the stresses on the lower portions of the building and reduce the need for work at height and use of equipment.
- Simple consolidation of plumbing service points within a building not only has the benefit of reducing the length of lines, but it also reduces the points of entanglement and conflict with other elements such as walls and ceilings/roofs.
- Separating the plane of the top and bottom of the wall from the plane of the floor structure facilitates mechanical separation and structural stability during the deconstruction process. Precast concrete floor panels act in this manner.

Building heavily upon the SEDA report, a US publication [5] produced a simplified ‘10 key principles’ for Design for Disassembly. These are summarised as:

1. Document materials and methods for deconstruction
2. Select high quality materials
3. Design connections that are accessible.
4. Minimize or eliminate chemical connections.
5. Use bolted, screwed and nailed connections
6. Separate mechanical, electrical and plumbing (MEP) systems.
7. Design to the worker and labour of separation.
8. Simplicity of structure and form
9. Interchangeability
10. Safe deconstruction

A significant work programme in the Netherlands is also useful to consider in more detail. The Industrial, Flexible and Deconstructable (IFD) building programme [3] was set up by the Dutch government and ran until 2004. There were three calls for designs to be submitted that demonstrated IFD principles. The winning bids were then supported as demonstration projects for IFD. The demonstration projects would be interesting to look at in more detail to see how the design objectives were met in practice, and whether there were any particular barriers to implementation. However, the area that might be more useful to the current BRE project could be to look at the criteria used by the assessment panel to decide which projects should be funded. These are summarised as:

- Is an industrial production and construction method used?
- To what extent are the buildings (or parts of) flexible and deconstructable?
- Are new and innovative IFD building methods implemented?
- What is the scope for wider implementation to similar buildings?
- Is the targeted reduction in demolition and construction waste achieved?
- Does the proposal contribute to a more efficient construction process?

A discussion with some of the panel members may help to draw out the actual process used to measure the likely impact of the submitted proposals from a design perspective.

Going through these reports provides a sense of consistency in the key considerations that relate to designing for deconstruction. However, an assessment method would need to be able to weight the impact of inclusion (or not) of a consideration in terms of the resulting impact on future reuse, recycling and recovery.

6 WEIGHTING OF DESIGN CONSIDERATIONS FOR DFD

Ultimately, the current BRE project wants to produce a set of weighted design criteria that could be used to assess the level of deconstruction, reuse and recycling, and hence compare future performance at demolition stage. A useful starting point could be the work undertaken by Dr Paola Sassi, published in 2002 [6]. Here, the criteria for assessment are applied to each building element in relation to:

- Criteria for suitability for general dismantling, such as installation fixing methods, time and information required to dismantle elements.
- Criteria for suitability for reuse as a second hand item, such as durability, requirements for performance compliance and fixings needed for reinstallation.
- Criteria for suitability for reuse as new, includes an additional requirement to ensure aesthetic standards are met.
- Criteria for suitability for downcycling and recycling, such as reprocessing requirements.

Applying the individual criteria produces a score for ‘top’ rating and ‘bottom’ rating, i.e. best case and worst case scenario. These are then added up and normalised to give a score (between 0 and 1) to allow comparison of different design specifications at an element level. Looking at the output tables for specifications such as a range of floor finish specifications, there are possible synergies with BRE’s Green Guide to Specification [7] where an agreed assessment process could result in ratings for DfD for each specification, alongside the existing categories, such as ‘Climate Change’ and ‘Ecotoxicity’. Given that there are thousands of specifications, such an approach could be very time consuming and resource intensive unless there is a mechanism to automate data collection and subsequent interpretation into a single score or rating.

Another interesting perspective is to make a distinction between design decisions that facilitate reuse from those that facilitate recycling, as discussed in a paper by Philip Crowther [8]. Here, possible DfD principles are assessed as being 'very important' or 'less important' depending on whether the outcome is going to be reuse or recycling. For example, minimising the number of different types of connector is important, where labour is deployed to maximise the amount that can be subsequently reused, as this reduces the time taken to dismantle a building into its component parts. It is less important for recycling as it is likely that machinery will be used to demolish a building where recycling is the objective, rather than reuse.

7 OTHER INDUSTRIES

Having considered the existing knowledge base surrounding DfD in the building sector, a look further afield to other industry sectors may help in the development of an assessment methodology. The most advanced sector in this respect is the automotive sector, driven by the End-of-Life Vehicles Directive that came into force across the EU in 2000. This directive sets out binding targets that must be met by the automotive sector. The next target needs to be achieved by 2015 when a minimum of 95% by weight of scrapped vehicles must be reused, recycled or recovered (of which a minimum of 85% must be reused or recycled).

The important point is that manufacturers are responsible for ensuring these targets are met for their products. In the UK, these responsibilities are set out and regulated by BIS [9], and are summarised as:

- Meet vehicle design and information requirements, which includes a restriction on heavy metals, and any plastic or rubber materials and components, must be given a code so that they can be dismantled and recovered separately.
- Keep technical documents to show compliance with the design requirements for four years from the date the vehicles, materials and components are put on the market.
- Register with the Department for Business, Innovation & Skills (BIS) and declare responsibility for the vehicles produced.
- Implement an ELV take-back system, this has to be BIS-approved, free and reasonably accessible.
- Achieve recovery and recycling targets for the vehicles manufactured and with a declared responsibility for when they are scrapped. Details of the reuse, recovery and recycling rates achieved must be submitted to BIS on an annual basis.

In the absence of an End-of-Life Buildings Directive, it is unlikely that similar levels of resourcing or reporting will be possible in the building sector. However, some of these principles could be amended for use in the DfD of buildings, in terms of demonstrating best practice and providing evidence accordingly.

8 CONCLUSION

A review of existing work has shown that there is a readily available source of information that could be consolidated and built upon to form an assessment methodology for measuring design for deconstruction. The challenge will be to develop the assessment methodology in such a way as to be a robust and reasonably accurate assessment of the future deconstruction potential, easy to apply, able to use the data available at the point of detailed design, and able to be adapted easily in line with design and procurement changes.

9 REFERENCES

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