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Briefing: Design for deconstruction

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1. INTRODUCTION

The UK government's draft strategy for sustainable construction (at the time of writing out for consultation) proposes a number of targets and milestones in respect of waste

(*a*) by 2012, a 50% reduction (over 2005 levels) of construction, demolition and excavation (CDE) waste to landfill
(*b*) by 2015, zero net waste at construction site level
(*c*) by 2020 zero waste to landfill.

As with other environmental issues, consideration of waste has progressively moved from 'end-of-pipe' waste management to one of resource management throughout the construction process. One such approach receiving increasing attention is designing for deconstruction.

This article draws on the Ciria report *Design for Deconstruction*[1] and introduces the following four principles

(*a*) consider the whole life of a product or material
(*b*) consider the potential of components for reuse
(*c*) consider the processes of deconstruction when designing components and buildings
(*d*) consider the ownership of buildings and their components.

Recent developments in this area are summarised in the conclusion.

2. THE LIFE CYCLE OF PRODUCTS AND MATERIALS

Many initiatives are being developed by manufacturing industries for the long-term aim of attaining a zero-waste economy. By considering the whole life of a product, or of a material used in a product, it is possible to identify where 'waste' is generated or, rather, where a material turns from being useful to being 'waste', then becoming an unwanted problem.

In the UK, this approach has made use of the so-called 'waste hierarchy'. In the Netherlands, the rather more sophisticated 'Delft ladder' is considered (Table 1). The ten stages of the Delft ladder are stages in the life cycle of materials and components at which a designer can take action to ensure they are used at the highest possible level in their life cycle, for as long as possible. By this means, the degradation of materials towards landfill is prevented or slowed down. When making design choices, a designer should consider, in sequence, each stage of the life cycle, as follows.

(*a*) *Prevention*. How can waste be avoided by design (e.g. reducing waste by minimising material use or eliminating components)?
(*b*) *Object renovation*. How can waste be avoided by prolonging an element's life in use (e.g. through maintenance)?
(*c*) *Element reuse*. How can an element be reused after removal (e.g. refurbishment of a kitchen sink)?
(*d*) *Material reuse*. How can materials be reused after removal (e.g. reconditioning bricks for reuse)?
(*e*) *Useful application*. How can materials or elements be recycled or reused in new applications (e.g. using crushed bricks as hardcore or using a structural steel beam in a temporary works structure)?

The 'waste hierarchy' is, effectively, a reduced and simplified version of the Delft ladder.

3. ASSESSING THE POTENTIAL FOR REUSE AND RECYCLING

Designers and specifiers are constantly faced with choices between alternatives. For deconstruction and subsequent reuse and recycling to be brought into the process of choosing (alongside cost, performance, durability, etc.), suitable selection criteria need to be established.

Decisions about how and why to reuse or recycle, and how best to minimise the quantities of materials sent to landfill, will be influenced by the criteria used to evaluate the environmental impact of the alternatives. It is important to ensure that the criteria for assessment and evaluation are agreed among members of the project team and the client early in the project.

To undertake a thorough analysis of alternatives at the design stage calls for a very sophisticated methodology. In practice, busy designers will need to rely on tools that address the complex issues and present them in a form that can be digested by the decision makers. The potential for recycling or down-cycling can be addressed at the level of materials and building elements or construction systems.

3.1. Materials

Materials vary in the ease with which they can be separated from the general mass of a dismantled or demolished building. Iron and steel, for instance, can be separated magnetically,

1. Prevention
2. Object renovation
3. Element reuse
4. Material reuse
5. Useful application
6. Immobilisation with useful application
7. Immobilisation
8. Incineration with energy recovery
9. Incineration
10. Landfill

Table 1. The ten stages of the Delft ladder

Fig. 1. Hand separation of metal from other materials at a waste transfer station (photo: Bovis Lend Lease)

while copper and tin cannot; glass and plasterboard are very likely to be damaged when removed from a building but timber is more robust (Fig. 1). Understanding the processes of deconstructing and demolishing buildings is vitally important in assessing the opportunities for reusing components and recycling materials.

WHY ARE YOU DESIGNING FOR REUSE OR RECYCLING?

The answer to this question will depend fundamentally on whether you are

- a client (and what type of client)
- a designer (engineering, architect)
- another member of the project team
- a manufacturer of a product or material.

Some possible answers to the question are

- to help get planning permission
- to satisfy the client's brief (if so, what aim lies behind the brief?)
- to reduce certain types and quantities of materials going to landfill
- to reduce a future liability to pay landfill tax
- to promote your firm as being concerned for the environment
- to promote a product that is well suited to reuse or recycling.

Key stakeholders in a building project can undertake a cost/benet analysis of

- the benefits of designing to facilitate deconstruction
- to whom the benefits accrue
- the value and costs of these benefits to each beneficiary.

WHEN DESIGNING FOR REUSE OR RECYCLING, WHAT TYPE OF REUSE OR RECYCLING ARE YOU DESIGNING FOR?

Are you designing it for reuse or for recycling?

If you are designing for reuse, what type of reuse?

- removal of part of a building (e.g. during refurbishment or adaptation)
- removal of a component or element for reconditioning (e.g. a stone panel from a faade)
- salvaging and storing elements for subsequent reconditioning.

If you are designing for recycling, what type of recycling?

- 'downcycling', e.g. reusing high-performance steel cladding for a purpose that requires lower performance such as industrial/agricultural use
- on-site reprocessing and reuse, e.g. crushing brickwork for use as fill or in landscaping.

HOW WILL YOU INCREASE THE LIKELIHOOD OF THE DESIRED TYPE OF REUSE OR RECYCLING BEING ACHIEVED?

Reuse: make it easier to ascertain at deconstruction the useful life of the product remaining.
Recycling: make it easier to ascertain at deconstruction the materials available for recycling; design the product in a way that makes separation for recycling easy and safe.

WHAT INFORMATION NEEDS TO BE PROVIDED TO FACILITATE REUSE AND RECYCLING?

Careful deconstruction of a building to facilitate reuse and recycling will be easier, cheaper and more likely to be undertaken if the following information is available to those assessing whether deconstruction is feasible

- a full set of as-built drawings and specifications
- details of the design life, service life or warrantees of components, plant and equipment
- methods for establishing the remaining functional performance or life of a product or component
- for items where guidance will be useful (e.g. façade and main structure), a method statement for deconstruction indicating all the key deconstruction activities and their sequence.

As well as appropriate information being available, it will be equally important to provide those undertaking the deconstruction clear identication of components and materials. This can be done, for example, by means of

- annotated diagrams that can be understood by those undertaking the work (i.e. not engineers' or architects' plans and sections)
- colour coding of materials (e.g. plastics) according to their chemical composition
- bar-coded identification or electronic identification 'chip' (e.g. grade of structural steel or timber); however, these pre-suppose the future existence of equipment to read such tags.

Fig. 2. Considerations in designing for deconstruction

3.2. Building elements and construction systems

Building elements are usually installed using a series of assembly and fixing processes that strongly affect how reversible the process is and the degree of damage that is likely to be caused in the deconstruction process. As a simple example, a bolted connection is easier to deconstruct without damage than a welded or glued one.

The criteria for assessment can be grouped to enable each element to be independently assessed for its suitability for

(*a*) general dismantling
(*b*) reuse as a second-hand item
(*c*) reuse as new
(*d*) down-cycling or recycling.

In practice, decisions about dismantling and deconstruction are very similar to decisions that are made regarding design for industrial manufacturing processes ('production engineering' as it is called in the car industry, for example). Many design decisions taken to improve assembly processes can result also in products that are easy to disassemble. For this reason, the use of off-site manufacturing in the construction industry will sometimes lead to easier deconstruction at the end of life. It would be useful, therefore, for demolition (or deconstruction) contractors and specialists in the use of reclaimed goods in new construction to become involved in developing off-site manufacturing processes.

4. HOW TO APPROACH DESIGN FOR DECONSTRUCTION

The decision will need to be taken in the design phase as to whether a building component should be designed with reuse or recycling in mind. It will often be impractical to design an entire building with easy deconstruction in mind. In practice, it will be preferable to adopt this approach for as much of the building as practicable, and certainly preferable to ignoring the issue.

The processes involved in reusing a component when it has come to the end of its first life are fundamentally different from the processes involved in recycling the materials from which something is made. Therefore, for each component of the building being designed, a decision (perhaps an educated guess), will need to be taken as to whether it will be destined for likely reuse or for recycling. Fig. 2 sets out a number of questions that will need to be considered. Figs 3 and 4 illustrate some projects that have addressed deconstruction at the design stage.

5. OWNERSHIP AND RESPONSIBILITY FOR BUILDINGS

There are clear differences in attitude between owners of buildings (e.g. private houses) and those who rent them—the former are much more likely to look after, maintain and repair the property than the latter. At present this notion has not really addressed the end of such a building's life. For practical

Fig. 3. The Japan Pavilion, Expo 2000, Hanover—the recycling of building materials and components was one of the design criteria (photo: Buro Happold)

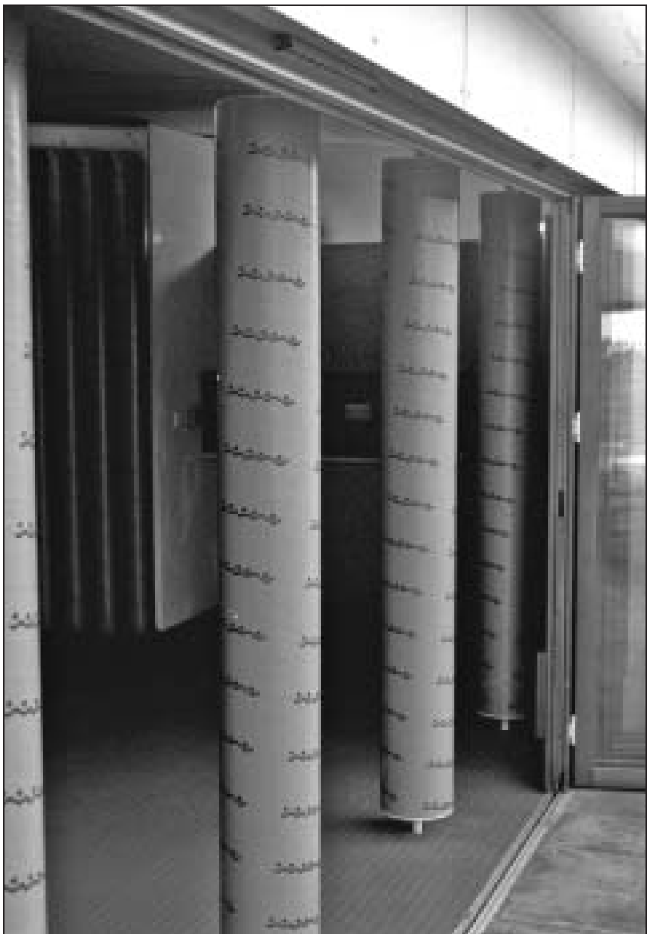

Fig. 4. Made almost entirely of wood and cardboard, this school building (roof, walls, internal structure, air ducts) has been constructed to be fully recyclable at deconstruction

purposes, such buildings are still considered as assets whose value depreciates towards zero. Lasting ownership of a building is likely to have a direct effect on its design and construction not only because of its ultimate disposal but because an owner can be encouraged to consider subsequent use and then ensure it comes about.

Such attitudes to ownership have led some companies to apply the same philosophy to parts of buildings. Just as it has been possible to rent a television and a building, some firms have devised the idea of providing a building element as a service rather than product to be bought.

6. RECENT DEVELOPMENTS

Over the past two years, two important project tools have become available that will significantly help project teams to address the dismantling or demolition of buildings, and the use of reclaimed or recycled materials and goods in new construction.

The Institution of Civil Engineers' (ICE) demolition protocol[2] provides a methodology for tracking the amounts of demolition arisings that are reused or recycled and thus prevented from being sent to landfill. Already, several projects have achieved targets in excess of 85%.

The recycled content toolkit[3] developed by the Waste and Resources Action Programme (Wrap) enables project teams to audit the proportion of reclaimed or recycled materials and goods, calculated by value, that are used in new construction. Many projects are already achieving targets in excess of 20%.

As more historical data from the demolition protocol and recycled content toolkit are collected, so designers and contractors will be able to set and achieve even higher targets. At present, however, the Wrap scheme does not usefully distinguish between using reclaimed goods and recycled materials and so does little to encourage deconstruction and reclamation in preference to demolition and recycling. Wrap is currently undertaking studies that will redress this inherent bias and, hence, do much to encourage deconstruction. The first step is to provide a directory of sources for reclaimed construction goods and materials. The second and bigger challenge will be to devise a simple means of specifying performance targets for design for deconstruction.

7. CONCLUSIONS

The need for future adaptability, renovation by replacement of elements as opposed to wholesale reconstruction, requirements to incorporate reused or recycled materials within buildings and structures, together with increased scrutiny of waste arisings, further escalation of disposal costs are just some of the many drivers that point to the need for increased consideration of design for deconstruction.

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