4.Zero waste

Applying circular principles to the design process

Eva MacNamara explains how structural engineers can incorporate circular economy thinking at each stage of a building's design.

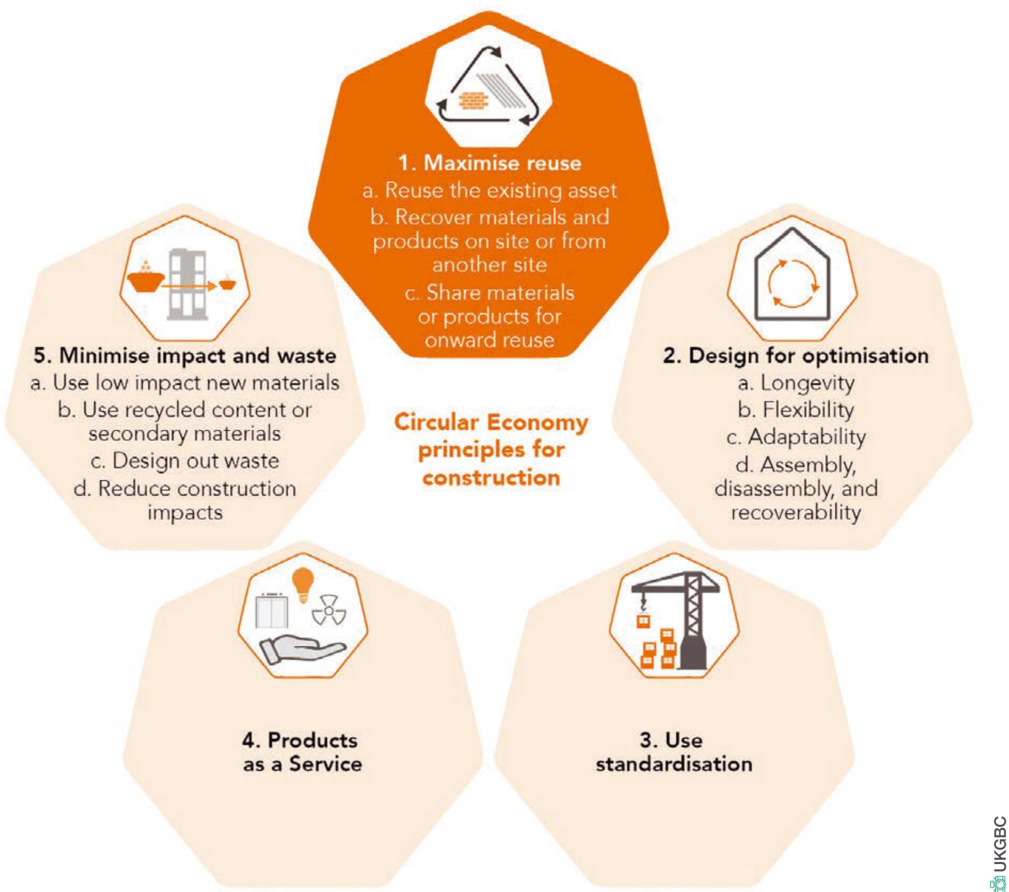
Introduction

In June 2020, *Practical applications of circular economy principles*[1] outlined what these principles mean in the context of the building industry, giving examples around the three main aspects of circular economy thinking that apply to structural engineers:

- →| creatively seeking opportunities for reuse
- →| optimising for whole-life scenarios
- →| designing for deconstruction.

This article builds on the introductory blog post (reproduced in **Box 1**) by discussing actions that structural engineers should take at each stage of the design and construction process to maximise the circular economy potential of their design.

These actions are partly adapted from the UK Green Building Council's *Circular Economy How-To Guide*[2] (which also contains actions for the client, contractor, project manager, etc.), to maximise reuse and create material inventories for the future in line with **(Figure 1).** Although based on RIBA stages, the principles are universal.



↗FIGURE 1: Circular economy principles for construction[2]

Actions

RIBA Stage 0: Strategic Definition and Stage 1: Preparation and Briefing

Often, structural engineers are not appointed until after RIBA Stages 0–1. However, our knowledge and skills are vital if circular design principles are to be applied effectively from the outset. Structural engineers are uniquely placed to assess whole-life, cost-effective solutions for an existing development's likely biggest carbon asset: the structure and foundations.

Input at this early stage may fundamentally change the brief and the outcomes of the project, through decisions such as those shown in **Figure 2**. Talk to your clients so they understand this concept in future. This kind of work could be in the form of a pre-design tender agreement, at Stage 0 and 1, covering:

- →| a pre-refurbishment audit of structural assets to establish early opportunities and constraints
- →| recommendations on how the programme and logistics may be impacted to allow for circularity (e.g. surveys, testing, sourcing reuse materials off site, or finding an onward use for items to be removed from site).

Engagement at this stage includes showing the client the benefits of not limiting the design to a specific usage type, instead highlighting the benefits of loose-fit design to accommodate future changes in use.

RIBA Stage 2: Concept Design

Conceptually explore opportunities for reuse and disassembly in the future and work out how that might alter a more traditional design approach. For example, determine what future flexibility and adaptability means for the building design to avoid it becoming a stranded asset, or resulting in its premature demolition.

Review asset inventory data, or seek further information, and maximise use of those assets in line with the overall philosophy of optimising for whole life. If the data is not available, now is the time to commission it and any further investigations required. Support the process by advising what testing is required to allow reuse of existing assets on the site, or those which might be imported.

Carry out feasibility (including lifecycle carbon) assessments and studies on preliminary design proposals to identify opportunities to incorporate reused or recycled materials into the structure. Scan the horizon for emerging technologies.

Where new-build structure is required, make strategic decisions regarding whole-life sustainability of that structure. Agree what approach will be taken to optimise the longevity and flexibility of the spaces designed. Agree the end-of-life strategy for the structure, and the approach that will need to be taken for deconstruction.

Realistically assess the life expectancy of the design as a whole, but also split into individual materials, components, systems. Ensure these have potential for associated maintenance and replacement strategies to maximise whole life.

RIBA Stage 3: Spatial Coordination

Ensure client and design team confidence in the reuse process is maximised, and risk is minimised. Alongside early engagement with approvals bodies, do this through assessing realistic quantities for reuse and any specific testing that needs to be done relating to their condition for strength, durability and appearance, to meet the requirements of the design team as a whole. This may also include fire testing, emission testing and testing for the presence of hazardous materials, among other things. Mock-ups or samples for integration of old and 'new' could be worthwhile to the process. A back-up plan may also be useful.

Early contractor input can potentially help de-risk the tender documentation and mitigate against contractors pricing in perceived risk of a circular approach.

Incorporate reuse proposals and strategies clearly into stage documentation and tender information where relevant. These should also be clear in planning documentation, where relevant.

Ensure design for deconstruction is covered, typically through reversible connections between the structural elements themselves, and with consideration of how non-structural layers of the building may be removed easily.

RIBA Stage 4: Technical Design

Incorporate reuse requirements into stage documentation, specifications, performance specifications and other tender information. Note this is also likely to include structural elements that are to be disassembled and reused off site. Discuss the proposed procurement method with the client and what this will mean if there is a change of plan in the tender documentation, as reuse opportunities can evolve for better or worse during the construction phase.

Include in the tender and construction documents:

→| any elements that are to be carefully disassembled and stored for reuse within the development or for onward reuse elsewhere, preferably locally

BOX 1. AN INTRODUCTION TO THE CIRCULAR ECONOMY FOR STRUCTURAL ENGINEERS

Given that construction is responsible for well over half of the extraction of virgin resources, and contributes to some 60% of total waste streams, we as engineers have a responsibility to ensure we use materials wisely.

Applying circular economy principles to structural design is one key practical part of moving towards net zero; we need to maximise the value of material and minimise embodied energy to deliver.

In engineering, this means:

→| creatively seeking opportunities for reuse
→| optimising for whole-life scenarios
→| designing for deconstruction.

These targets become part of our brief for good design. With practice, it will become as natural as historically selecting the best material for the job.

Reuse (or partial reuse)

First in the hierarchy of the circular economy for the structural engineer comes reuse. You've probably taken this approach many times before, some of this is not new. Some of it might be.

For structural engineers, on the site of an existing development, the building structure and foundations will be the primary asset.

Can they be adapted to suit a new scheme? Can a cut-and-carve approach unlock new ways in which the building can work (and will this actually save the client programme time and money)? Can the foundations take an increase in load to suit additional storeys?

Think of these as a design review of the existing structure rather than a set of rules.

Maximising the circular approach also involves interrogating the existing building to advise the client on how the shorter-life components could be disassembled from the main structure for reuse. For example, can it be determined whether components are connected to the structure with reversible mechanical fixings when intrusive surveys are being carried out?

By including these sorts of investigations, it reduces the risk for the client when the contactor prices for disassembly.

New-build and whole-life thinking

Circular guidance advises us to design buildings for the future addressing longevity, flexibility, adaptability and assembly, disassembly and recoverability.

Therefore, for structure and its life range of, say, 30–300 years, lean design with a long life and loose fit will be the best contribution to the circular economy, whole-life carbon and likely whole-life cost.

So, how do you do that? And how does it fit in with the 'shorter life' of other building components (which are designed in the circular world for easy maintenance, disassembly and remanufacture)?

Practically, this means avoiding the interdependency of the structural frame and other components (such as the facade), so that they can be easily separated, and the shorter-life components can be renewed in a straightforward way.

We must also consider material choices. For example, in a scenario where a potential lack of maintenance will lead to degradation, the upfront increases in cost and carbon related to stainless steel may be worth the investment if the painted mild steel alternative is likely to need replacing sooner.

Of course, a whole-life approach requires the industry to consider how the value of investment is captured; there must be evidence that a quality building is able to get better rents and higher sales values. And for the 'new' development, can materials be reused from another project? Probably.

As the built environment moves more firmly this way, material inventories and databases will make this easier. In the UK, WRAP has a helpful guide **(https://bit.ly/WRAP-guide)** which includes a directory of reclaimed materials – other countries may have similar resources.

You'll probably need to also devise a contingency plan, in case those materials are no longer available – perhaps sharing knowledge of assets between firms could be part of the solution?

Facilitating reuse and low carbon

To facilitate reuse for others in the future, ensure that the BIM is adequate to record this. Ensure the handover information at the end of the project always includes a deconstruction and reuse methodology, regardless of what other circular aspects have been incorporated (or not) so far.

Finally, if some elements of the building are truly virgin, they should be lean within the long-life and loose-fit approach. Ensuring low carbon though the supply chain will necessitate modifying specifications to suit (e.g. specifying electric arc furnace steel over basic oxygen furnace steel, halving the embodied carbon of the material).

Conclusion

Taking just a few key approaches can make a big difference. The circular economy is so important because it is really fundamentally about whole life, which is at the top of the hierarchy for sustainability, whichever way you want to look at it.

NB This box was first published as a blog on the IStructE website[1].

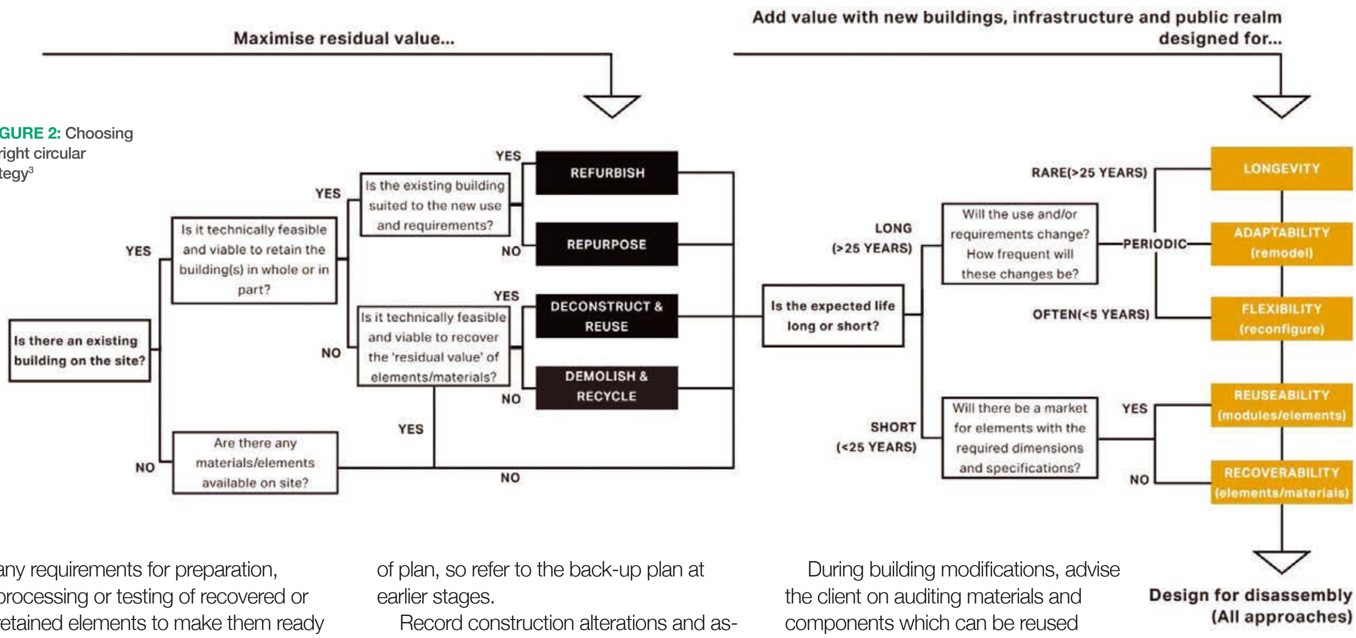


FIGURE 2: Choosing the right circular strategy[3]

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- any requirements for preparation, processing or testing of recovered or retained elements to make them ready for reuse
- detail of the proposed element reuse; note where allowances need to be made for size variations in recovered materials
- information for samples or mock-ups of reuse elements that are required for client approval prior to construction.

Under the Construction (Design and Management) Regulations 2015, the principal designer should include information related to the proposed demolition (think about deconstruction) and requirements for reclaiming materials, as well as addressing health and safety risks[4].

RIBA Stage 5: Construction

Ensure the contractor understands the circular strategy, key assumptions and requirements. Challenge the contractor on how they may contribute to improving the circularity of the project by, for example, avoiding single-use temporary works.

Be prepared for further reuse opportunities arising during the targeted reuse of the existing building as the contractor, as is usual, may uncover the unexpected. This may also mean a change of plan, so refer to the back-up plan at earlier stages.

Record construction alterations and as-tested material data (such as concrete cube results) within the BIM/asset databases to facilitate reuse by others in the future.

RIBA Stage 6: Handover and Stage 7: Use

Handover documentation should include:

- a functional adaptability plan so that the full potential of the building can be easily understood and utilised in the future to prolong its life
- an as-built BIM model (or materials inventory if BIM is not used), and a deconstruction plan for end-of-life disassembly of the structure. Where possible, information around material and products should be fed into a wider materials inventory, to facilitate sharing of assets between projects **(Box 2)**.

While in use, refurbish, reuse and extend lifecycles using operation and maintenance documents, and advise the client on updating the materials inventory and deconstruction plan.

Review extending the life of the building by reusing from elsewhere and incorporating emerging technologies.

During building modifications, advise the client on auditing materials and components which can be reused elsewhere as part of the value chain.

As good practice for the circular economy is currently developing, a workshop on lessons learned may capture important experience for future developments and industry knowledge sharing, where appropriate.

BOX 2. HOW IS LEAN DESIGN COMPATIBLE WITH THE CIRCULAR PRINCIPLES OF LONG LIFE AND LOOSE FIT?

Circular principles should result in lean design for a whole-life brief. Single use with no future proofing might result in the most materially lean design for one usage cycle, but would unlikely be the leanest use of material over a whole-life period. Taking this into consideration, design for societal changes and loose fit becomes part of the brief (change of use, future proofing for changes in service strategy, fitting renewed skins with a different approach, etc.). Overall, this may result in higher embodied carbon and capital costs, but is likely to be lower when whole life is addressed.

So, be clear on the brief (also contribute to it, and challenge it) and then be as lean as possible in the design to meet it. If circularity is not embedded throughout the project, then there is a risk that whole-life carbon will be increased by premature redundancy. The key is that the structure is reused in the future, and can be disassembled and reused elsewhere, so all the principles of circularity need to be committed to.

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