Ryder

Design for Disassembly
Minimising Value Loss at End of Life

Ryder Architecture Limited
Newcastle
London
Glasgow
Liverpool
Manchester
Hong Kong
Vancouver
Amsterdam

www.ryderarchitecture.com

Contents

Project number
2010:07

Document reference
BDEV-RYD-00-XX-RP-A-0000-S2

Revision
P1

Date
4 May 2023

Author
Fergus Sweeney

Checked by
Peter Barker

This document has been designed to be viewed / printed A4 double sided.

Introduction

To Design for Disassembly (DfD) is to create products with the intention of minimising value loss at the end of life.[1] In construction, this involves designing a building with consideration for how it will be dismantled and the recovery of materials at the end of its useful life.

In theory, there is the potential for a large proportion of a building structure and materials to be recovered and reused upon demolition. However, the extent to which this can occur depends on which materials have been used and the way they have been installed.

For example, composite materials or elements containing multiple components bound together by irreversible fixing methods can be expensive and energy intensive to break down. This makes it difficult to reuse or recycle these elements, creating waste and generating further emissions during demolition and disposal.

DfD seeks to address this by designing with disassembly in mind and with a clear plan for deconstruction to maximise the recovery and reuse of materials at the end of life.

Stow-Away Hotel, London

Despite growing traction in recent years, DfD is not a new concept, and has been used by different cultures throughout history. For example, indigenous people designed their tipis to be easily erected and disassembled to suit their nomadic lifestyles.[2]

DfD has also been utilised in Japan for centuries due to the prevalence of timber in its construction methods. The Ise Grand Shrine is part disassembled and replaced every 20 years as part of the 'Shikinen Sengu' rebuilding practice. Continuously replacing the central wooden structure has enabled the original design to be preserved for the last 1,300 years.[3]

Despite this long history, DfD is significantly underutilised in modern construction, often due to a short termist approach to cost and building life cycles.

Destructive demolition through the use of excavators, bulldozers and explosives tends to be the typical approach for most buildings, with an estimated 35 percent of waste being sent to landfill without any further treatment.[4] DfD can play an important role in reducing this waste and maximising the quantity of material that is recovered, reused and recycled.

Indigenous tipi

Ise Grand Shrine, Japan

Closing the Loop

From Linear to Circular

The circular economy is an evolution of the way in which we produce and consume goods and services. It involves reshaping the traditional linear model by minimising waste and pollution, circulating materials and products and regenerating natural systems.

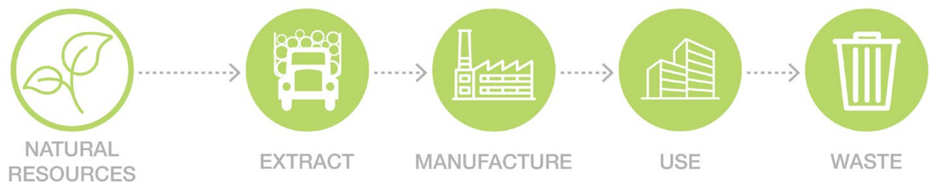
The circular economy aims to reshape the traditional linear model by making the outputs of one process become the building blocks of another.

The circular model is intentionally restorative and regenerative by design, and is based upon three key aims:

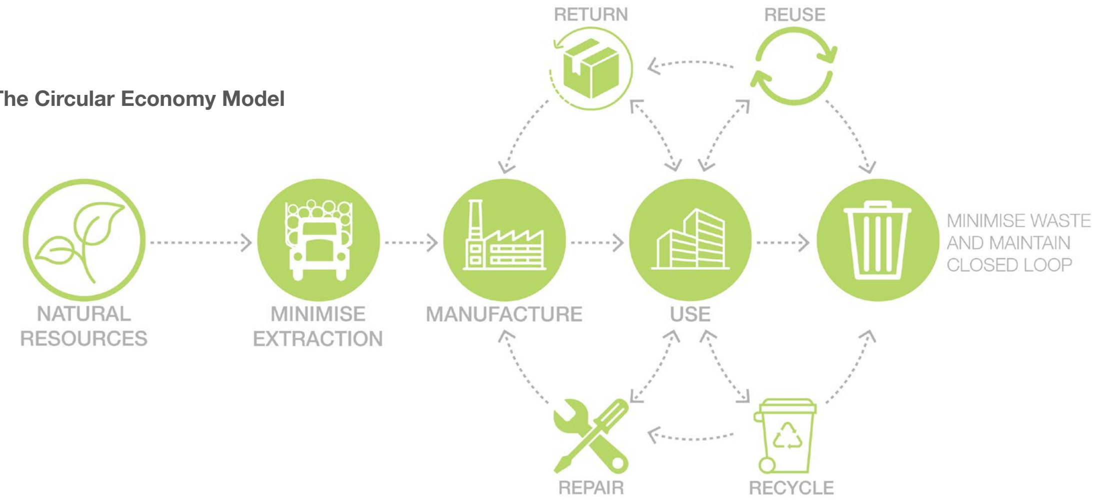
- Minimising waste and pollution
- Circulating materials and products
- Regenerating natural systems

A circular economy aims to keep resources in use for as long as possible, extract the maximum value from those resources whilst in use, and then to recover as many products and materials as possible at the end of each service life.

The Linear Economy Model



The Circular Economy Model



For the circular economy to function as efficiently as possible, it must follow an effective waste hierarchy. This prioritises waste reduction efforts that use as little energy as possible in the order of repair, reuse, remanufacturing and recycling.

Over recent years there has been a significant focus on recycling. However, it is important to recognise that recycling is an energy consuming process, doing so during waste collection, transportation, sorting, processing and remanufacturing.

It is therefore often more efficient and economical to repair and reuse building components instead. Recycling does however still play a vital role in both waste and emissions reductions and therefore continues to form a key component of our strategy to tackle the climate emergency.

DfD is paramount to achieving the circular economy and maximising the use of the waste hierarchy. Designing with deconstruction in mind makes it easier and cheaper to recover, reuse and recycle the various components that make up our buildings. Not only will this save scarce resources, but it also reduces emissions across the building life cycle, aiding in the transition to net zero.


Stow-Away Hotel, London

Our definition of net zero follows a whole life approach and aligns with BS EN15978 Sustainability of Construction Works. This approach recognises that emissions are generated at all stages of the building life cycle including construction (A1-A5), occupation (B1-B7) and end of life (C1-C4).

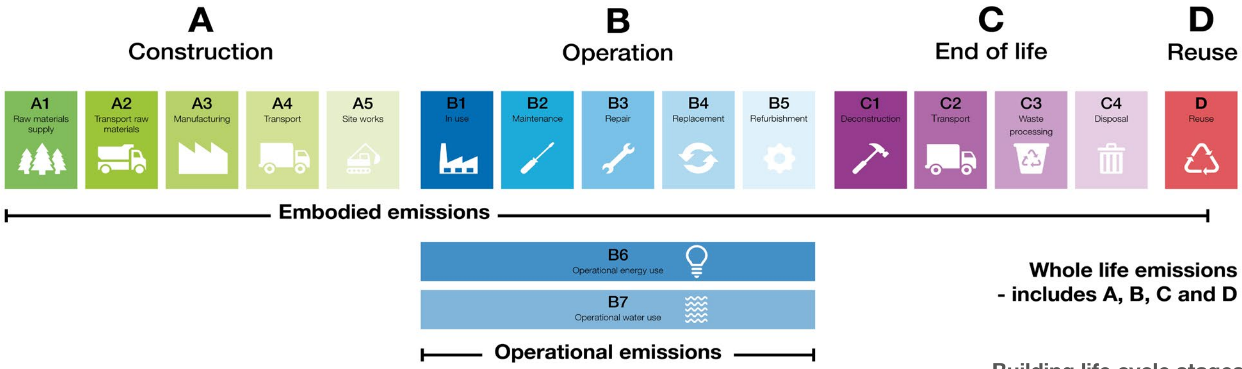
Emissions during stages C1-C4 can be reduced by employing waste reduction strategies and DfD. The need for energy intensive demolition is reduced, and the process of sorting and disposing of waste is made more efficient.

However, to achieve full circularity, DfD must go further than just aiding disassembly. Designs should plan for the recovery, reuse and recycling of materials once this disassembly has taken place.

The subsequent reuse of building elements and materials reduces the requirement for raw materials on future projects and thus the emissions associated with new construction (A1-A5).

DfD can also impact the operational stage (B1-B5). Building components designed to be disassembled often utilise more durable materials from the outset to enhance lifespan. These higher quality materials reduce the frequency of maintenance, repair and refurbishment.

A holistic approach to DfD therefore reduces emissions, minimises waste and saves resources. Designing with deconstruction in mind, and placing the emphasis on reuse, restoration and regeneration can help to replace the traditional linear model with the circular approach to construction that is so vital for achieving net zero.



Building life cycle stages

Barriers

Developing a circular economy is not without its challenges. A wide range of materials are used across the industry, all with varying life cycle properties. This makes it difficult to track a product throughout its life, which is often a barrier to the widespread uptake of recovery, reuse and recycling.

Another issue is the fragmented nature of the industry. Construction projects are often huge undertakings involving several stakeholders and a complex supply chain. Poor coordination throughout the supply chain can therefore contribute towards a high level of waste and missed opportunities for reuse.

The way in which we design buildings is also rapidly evolving. Composite materials and the use of chemical adhesives are becoming increasingly common due to the prioritisation of assembly speed and their greater durability over traditional natural materials. However, eventually these materials will deteriorate, and current practice does not always involve their recovery, reuse or recycling.

Stow-Away Hotel, London

Benefits

As well as the environmental benefits, there are additional economic and social advantages to DfD and supporting circularity in construction. Findings from developers like Clarion are beginning to evidence the financial benefits of adopting circular economy principles, showing that millions of pounds can be saved in waste disposal and material savings.[5]

DfD will play a role in protecting the industry against increasing material costs, material shortages and a rising landfill tax rate. Reducing the amount of waste sent to landfill also reduces vehicle movements, congestion, noise and air pollution, along with the associated health implications that can result.

A key requirement of achieving a circular economy is the adoption of new innovative business models. Roland Berger estimates that these new business models have the potential to add an additional 600 billion Euros to the global economy by 2025, with an annual growth rate of 12 percent.[6]

This includes advanced software, eco focused engineering and consulting services, and new and efficient construction methods such as 3D printing, prefabrication and advanced materials.

One example is the concept of ‘products as a service’. This involves changing the traditional ownership model to one in which the manufacturer of a product, say, a carpet, owns the carpet and the occupier simply pays a rent for its use. This incentivises the manufacturer to ensure that the product lasts as long as possible before being easily reused or recycled, enabling it to retain value even at end of life.[7]

DfD also contributes to social value. For example, the Vancouver Affordable Housing Agency (VAHA) is using modular structures to provide a rapid solution to the affordable housing problem in Vancouver.[8] As the structures can be easily disassembled and relocated, the City of Vancouver provides VAHA with land for the scheme for at least three years.

Once the land is needed for a different use, the buildings can simply be disassembled and relocated to another site.

The lightweight nature of the structures also enables them to be located on contaminated brownfield sites that would require extensive remediation work before constructing something more permanent. This helps to maximise the efficient use of land across the city.

Design Principles

Despite challenges, we are beginning to design with a focus on deconstruction to promote functional flexibility and the reuse and recycling of components and materials. Five key design principles have been outlined for the effective use of DfD.

Material choice

It is important to avoid composite materials where possible, as well as those that are cast in situ, welded or bonded together using chemical adhesives. These can be cost and energy intensive to break down, often requiring destructive demolition. Specifying lightweight materials and minimising different material types can also ease recovery and transportation.

Increasing the quantity of previously recycled materials that are specified on new projects can play a significant role in the progression of DfD across the industry. Doing so will incrementally improve the maturity and readiness of the supply chain with regards to circularity and will help to develop new business models and economies around waste management and materials supply.

The ‘deconstructable structure’

Designing a simple, open span structure, focused on flexibility with standardised dimensional grids and components not only increases building lifespan but also allows for ease of deconstruction. Providing adequate tolerances minimises the need for destructive demolition and using standard sized components enables them to be recovered and reused more readily. Greater consideration during facade design and detailing can also ensure cladding systems are deconstructable and aid in their removal at the end of life.

Accessible and removable connections

The use of bolted, screwed and nailed connections instead of chemical adhesives, binders or sealants reduces the need for specialist tools and equipment. This eases the process of deconstruction and increases the quantity and quality of material that can be reused and recycled. These connections should remain visible and accessible where possible to ease their removal.

Designing for flexibility and longevity

Creating a flexible design can extend the initial lifespan of a building. Applying open building principles with interchangeable components enables alterations to layout and functionality without the need for significant intervention. Specifying high quality, robust materials can provide additional longevity by creating buildings that are designed to last, delaying the need for repair, replacement or demolition.

Digital tools

Technology allows us to track, trace and map resources more efficiently than ever using digital tools such as Building Information Modelling (BIM) and Material Passports. Material Passports are interoperable datasets that describe defined characteristics of materials, products or systems, attributing them value for recovery and reuse.[9] Some materials such as plastics can be difficult to identify. Material passports embedded within the BIM model can be used to store this information including resource origin, carbon data, date of production and expected lifespan.

Certification and Regulation

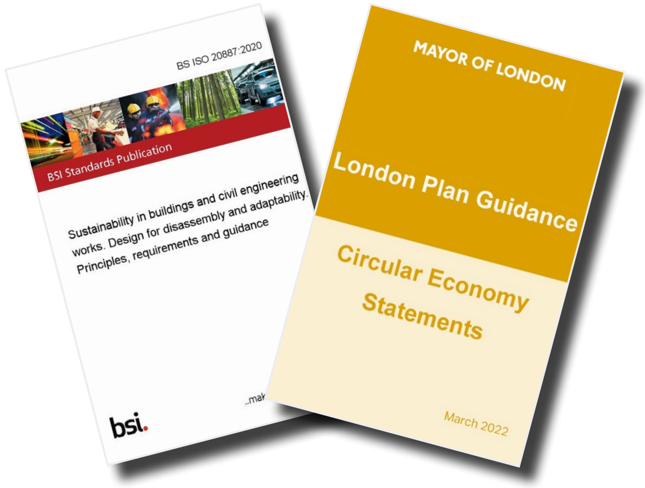
With renewed emphasis on the climate emergency and the benefits of circularity, DfD is gradually beginning to re emerge into mainstream construction. The International Organization for Standardization (ISO) recently published its standard for building disassembly. ISO 2887:2020 provides an overview of Design for Disassembly and Adaptability principles including potential strategies for integrating them into the design process.

Certification systems such as BREEAM also offer accreditation points for the consideration of DfD in projects. BREEAM Wst06 Design for Disassembly and Adaptability aims to avoid unnecessary material use, cost and disruption arising from future adaptation works and to maximise the reclamation and reuse of materials upon demolition. A credit is awarded if a Functional Adaptation Strategy is outlined by the design team and the client at concept design stage. This requires exploring the ease of disassembly and the functional adaptation potential of different design scenarios.

As part of the New London Plan - a statutory Spatial Development Strategy for Greater London - it is now required that new planning applications demonstrate how the components of a building can be recovered and reused at the end of life. This is required in the form of a Circular Economy Statement, to be submitted at each of the following stages:

- Pre application
- Application submission (outline and detailed)
- Post construction, ideally prior to handover

The requirement to assess circularity as part of each application ensures that a DfD approach is embedded into every new design. Doing so will help to scale up its use and to spread knowledge and awareness across the industry. It is expected that a similar approach will be adopted across the rest of the UK and internationally.



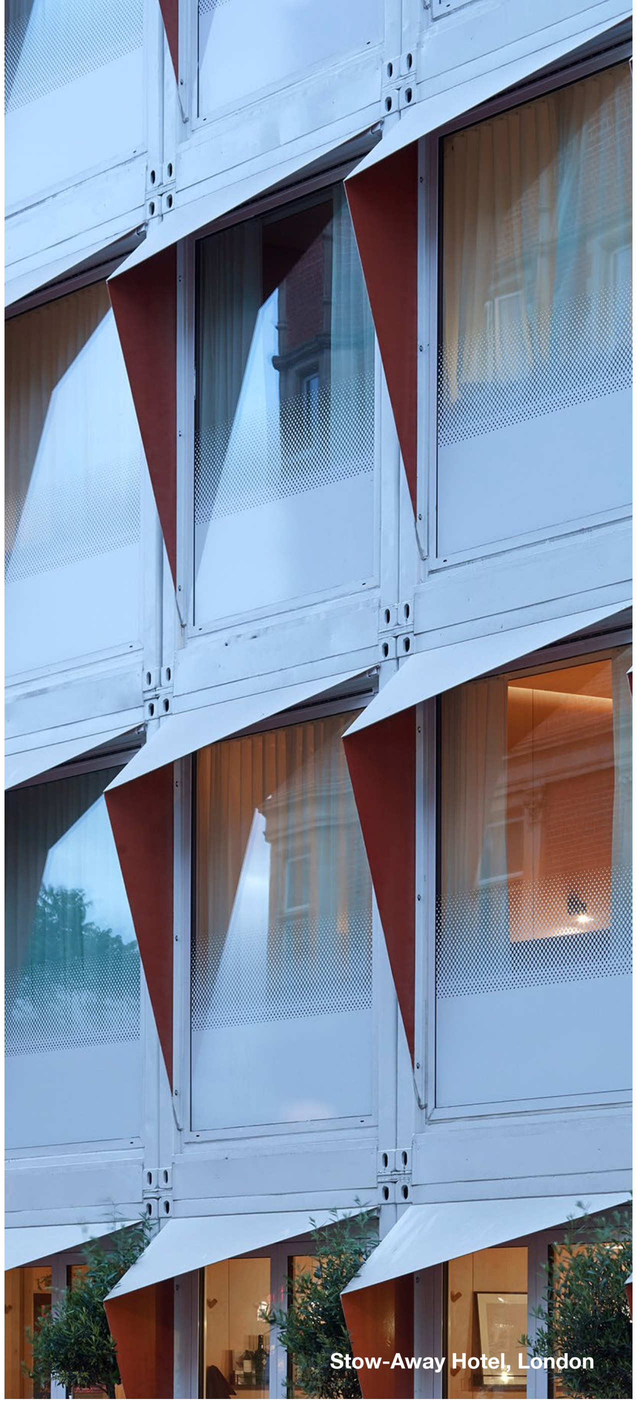
Case Studies

Stow-Away Hotel
London, UK

A pioneering example of a successful DfD project is the Stow-Away Hotel in Waterloo, London. It is a 20 room, five storey, modular development made from 25 High Cube shipping containers. The containers had reached their end of life in the shipping industry and are now stacked five by five to form the popular aparthotel.

Each container forms its own room and is constructed as if it were an individual building. This makes the whole structure reusable, with the opportunity to dismantle the entire building for reconstruction at another location.

To aid this, the services of each unit were designed to be cut at a single location above the door and then reconnected to new supplies once restacked. This innovative design creates a high level of circularity, saving on scarce resources and reducing the whole life embodied carbon of the development.



Stow-Away Hotel, London

The use of recycled containers generates both cost and carbon savings due to a large reduction in raw material requirements and waste generation.

Opening out of the five ground floor containers to form a wine bar in the Stow-Away Hotel, London

The reuse of shipping containers for the Stow-Away Hotel, London

Vallance Road
London, UK

Another DfD scheme was proposed for Vallance Road in Whitechapel, London. Similarly to the Stow-Away Hotel, a modularised system was selected, providing a standardised layout that can be easily disassembled, reconfigured and reused at the end of life.

The modules were designed to replicate standard 40ft shipping containers, but with the traditional steel casing replaced with Cross Laminated Timber (CLT) floor, wall and roof panels. Openings were incorporated into the design of each module to enable occupancy as either single or multiple units without the need for structural modification.

The use of CLT lends itself favourably to DfD with the component panels connected together by mechanical fixings without the need for welding or chemical bonding. This provides the opportunity for the individual panels to be reused or recycled as well as the full modules themselves.

Vallance Road proposal

Connection of the panels can be done via multiple fixing methods, the simplest of which being structural Self Tapping Screws (STS) driven at cross angles to provide a shear connection. Other options include using concealed metal plates with dowels, standard corner brackets or plates depending on requirements.

The CLT also requires no internal finishing. This reduces the amount of composite material present inside the building and ensures that the connections between panels are easily accessible and removable, aiding the deconstruction process.

In terms of the interior fitout, the scheme proposed a modular system developed by DIRTT, whose patented elements allow overheads, displays and other objects to be mounted seamlessly off surfaces. This enables them to be easily adapted with the changing needs of tenants, allowing elements to be disassembled, moved and reconfigured quickly and easily.

Despite the numerous benefits associated with the use of volumetric containers, there can be some drawbacks with regards to logistics and transportation. There is a limit to the number of modules that can fit onto the back of a flat bed lorry which can lead to a number of trips from the factory to site which has an associated environmental impact.

Assembling the individual panels onsite in lieu of premanufactured containers can therefore aid transportation and simplify the logistics process. For each container that can fit onto the back of a lorry, around ten individual panels could be transported instead. This reduces the disruption, costs and the emissions associated with transportation. It also provides a more scalable solution that can be easily applied to larger developments.

Flax Place
Leeds, UK

DfD module designs are not limited to low rise developments, with the same concept being proposed for a 14 storey, mixed use residential scheme in Leeds, known as Flax place.

The proposal involved a volumetric modular construction using steel containers from CIMC Modular Building Systems, a subsidiary of the largest shipping container manufacturer in the world.

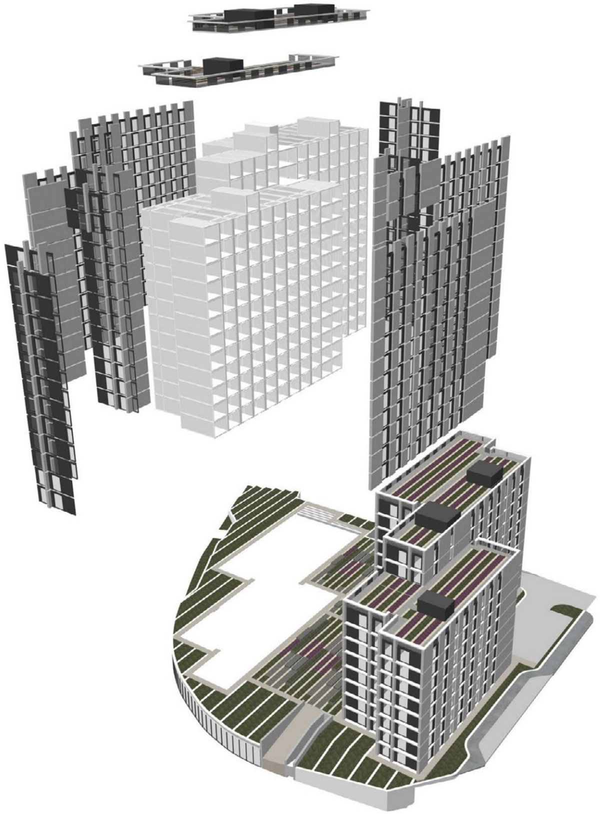
The containers would form a combination of one, two and three bed units to give a total of 300 apartments, as well as retail space and a GP surgery.

The modules were designed to be fixed together via a series of bolted connections at each corner, without the need for welding or adhesives. Square hollow section rails at each vertical edge also enable façade or balcony bolting where necessary.

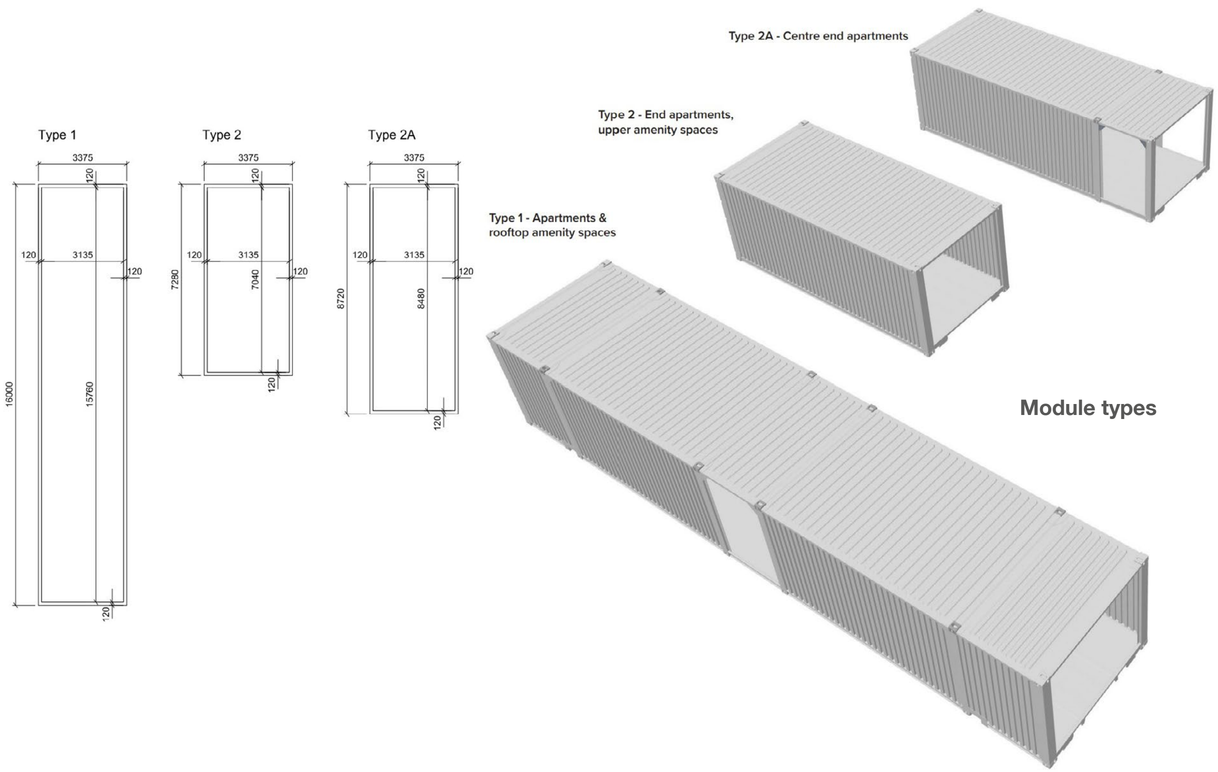
Flax Place proposal

Modular apartment types

Typical floor plan



Exploded axonometric showing container stacking



Module types

Two options were identified for the façade buildup, both with their own advantages with regards to DfD. The first was a system of Brick Faced Glassfibre Reinforced Concrete (GRC) panels. Brick Faced GRC is a composite material in which brick facings are mechanically bonded to a GRC backing to form a completed wall panel.[10]

The composite nature of the panels limits their reuse to similar configurations only, however they can be easily recycled. They can be detached as whole parts in a top down disassembly of the façade once seals are removed, eliminating the need for destructive demolition. The panels can then be crushed and recycled as concrete aggregates.

The alternative façade option involved a Corium system by Wienerberger and Taylor Maxwell. In this design, brick slip tiles are mechanically fixed to a steel backing section.

The profiled steel rails are mounted in horizontal rows via a vertical support system, onto which the brick tiles are simply clipped into place. The joints between the tiles are then pointed with mortar to provide the appearance of brickwork.

The mechanical fixing method enables the Corium tiles to be detached from the façade at the end of life. If retrieved carefully enough, the tiles can be reused on another façade. Alternatively, if damaged upon removal, they can be easily sorted and recycled for use as road hardcore.

The Corium panels are given a design life of 35 years,[11] however if a single tile is damaged it can be removed and replaced with a fresh tile, without the need to remove the whole area.

They also generate significantly less waste than traditional brick slips as they are produced as purpose made products instead of being cut from standard pre fired bricks.


Flax Place facade

A Circular Future

It is unrealistic to expect every new building to be designed like the Ise Grand Shrine, or even to be as fully dismantlable as the Stow-Away Hotel or Vallance Road. However, every new design should involve a greater consideration to how the various materials and components can be recovered and reused at the end of life.

Whether that be a fully dismantlable building, or simply the use of easily recyclable materials, we can reduce the level of waste and emissions that result from every project.

We have the digital tools and the design expertise to achieve this, but a cultural change is still needed. We must move away from the short termism that prioritises fast assembly and cheap construction, instead, moving towards a circular economy that maximises value across the whole life cycle of an asset.

Existing buildings should be viewed as material banks from which we can obtain significant value, and each new design should involve a high level of consideration to the materials used, how they are fitted together and crucially, how they can be taken apart.

This will maximise the potential for recovery and reuse and extend the lifetime of the buildings that we design. Doing so will save emissions and scarce resources, enabling us to close the loop of the linear construction model and finally achieve a fully functioning circular economy.

Further Information

Fergus Sweeney
Research Assistant
FSweeney@ryderarchitecture.com

Sean Bignold
Architectural Director
SBignold@ryderarchitecture.com

References

1 Suffian, S. Dzombak, R. Mehta, K. (2016) Nonconventional and Vernacular Construction Materials. Woodhead Publishing. https://www.sciencedirect.com/topics/materials-science/design-for-disassembly#:~:text=To%20design%20for%20disassembly%20or,at%20the%20end%20of%20life

2 Balodis, T. (2017) Deconstruction and Design for Disassembly: Analyzing Building Material Salvage and Reuse. https://curve.carleton.ca/system/files/etd/75676d84-d07f-41e0-951e-cb93c90a7d5d/etd_pdf/3ba5a49f42fd83942d887562b90314c8/balodis-deconstructionanddesignfordisassemblyanalyzing.pdf

3 Smithsonian Magazine: Rachel Nuwer (2013) This Japanese Shrine has been torn down and rebuilt every 20 years for the past millenium. https://www.smithsonianmag.com/smart-news/this-japanese-shrine-has-been-torn-down-and-rebuilt-every-20-years-for-the-past-millennium-575558/

4 Menegaki, M. Damigos, D. (2018) A review on current situation and challenges of construction and demolition waste management. Current Opinion in Green and Sustainable Chemistry. https://www.sciencedirect.com/science/article/abs/pii/S245222361830018X

5 Clarion Housing (2020) Circular Economy Strategy. https://kb.goodhomes.org.uk/wp-content/uploads/2020/05/Circular-economy-strategy.pdf

6 Roland Berger (2021) It's Time for Construction to Embrace the Circular Economy. https://www.rolandberger.com/en/Insights/Publications/It%E2%80%99s-time-for-construction-to-embrace-the-circular-economy.html

7 Mayor of London (2020) Design for a Circular Economy Primer: Good growth by design https://www.london.gov.uk/sites/default/files/design_for_a_circular_economy_web.pdf

8 VAHA (2021) 220 Terminal Avenue. https://vaha.ca/projects/main-st-modular/

9 BAMB (2020) Materials Passports. https://www.bamb2020.eu/topics/materials-passports/

10 Ibstock Telling (2020) GRC Brick and Tile. https://telling.co.uk/grc-brick-and-tile/

11 Wienerberger (2020) Corium Brick Tile Cladding. https://www.wienerberger.co.uk/products/facades/corium-brick-cladding-systems.html

Images

Page 4 Native American Tipi: Encylopedia of the Great Plains (2019) Tipis http://plainshumanities.unl.edu/encyclopedia/doc/egp.arc.048

Page 4 Ise Grand Shrine: World History Encylopedia (2017) Naiku, Ise Grand Shrine https://www.worldhistory.org/image/6483/naiku-ise-grand-shrine/

Stow-Away Hotel: Edmund Sumner photography ©Edmund Sumner @edmundsumner (instagram)