Closing material loops

MAXIMISING CIRCULARITY IN THE BUILT ENVIRONMENT

A joint case study by: mace | ARUP

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This report follows on from Mace's insights report: Closing the circle: Making London the circular construction capital of the world.

Using data from a recently completed new build office development by Mace, this joint report measures the circularity potential of carbon intensive construction materials, such as structural steel, concrete, plasterboard, glazing and building services.

To achieve 100% circularity, building operations must also be considered, including how water, energy, and waste are produced and managed in a circular way. This falls outside the scope of this report, but these aspects will be part of future studies by Mace and Arup.

FOREWORD

Ged Simmond, Mace
Managing Director, Private Sector

The construction industry is at a tipping point, consuming 62% of materials globally and generating 60% of all waste.

Construction has made great strides to become greener and less resource intensive, but if we want to meet our carbon targets – as an industry and as a country – we must develop a new approach to resource use. This means retaining materials in use as long as possible, and avoiding waste creation and the need to extract raw materials in the first place. Ultimately, construction waste will no longer need to be disposed of – it will become a resource for future buildings.

The transition to a circular model requires industry-wide collaboration. Contractors, supply chain, investors, developers, and policymakers must all work together, sharing knowledge and allocating risk fairly. The earlier contractors and their supply chain partners can be engaged on a project, the greater the impact that can be made, and Mace has a major role to play to take this forward.

Mel Allwood, Arup
Director, Sustainable Buildings

Against the backdrop of an increasing global population, the demand for new buildings and infrastructure is growing. With the built environment being one of the biggest contributors to global waste, we must find new ways to design and construct our cities. The circular economy provides a compelling and effective solution to these challenges.

As a sustainability leader for Arup in London, I focus on the delivery of design interventions that optimise the environmental performance of buildings. Along with sustainability benefits, optimising building and material reuse in the construction sector can deliver greater commercial and social returns than demolition and reconstruction.

It requires collaboration across the industry to create transformation. I invite you to explore this report, to learn more about the opportunities posed by material and building reuse and encourage you to join us in striving for the goal of a more circular built environment.

EXECUTIVE SUMMARY

Globally, we are consuming raw materials at a rate far greater than the earth can naturally replenish and the Organisation for Economic Co-operation and Development (OECD) predicts that the global demand for primary materials will double from 79Gt in 2011 to 167Gt by 2060.

The linear economic model of 'take-make-use-dispose' is unsustainable and carbon intensive. Only by adopting a more circular approach can we decouple economic development and growth from material extraction and transition to a more sustainable built environment.

Avoiding the creation of waste is the principal objective of circularity. A 100% circular building would, therefore, achieve zero waste to landfill (as a minimum) throughout its lifespan. However, this metric alone is not sufficient as an indication of a building's circularity – a whole life cycle approach is needed.

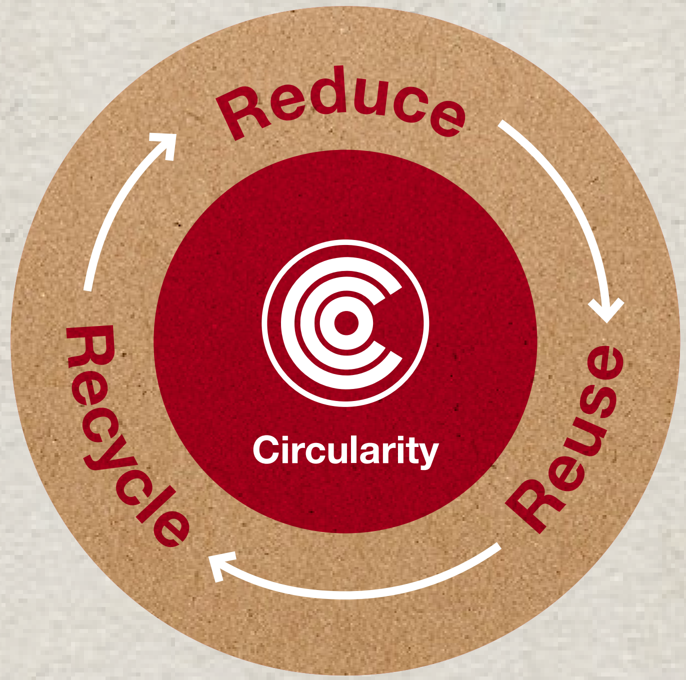
Adopting a circular approach in the construction industry means changing the way materials are used and buildings are designed, with a focus on maximising the retention of existing materials for direct reuse. The materials within a building should, therefore, maintain their quality and remain in good condition throughout the building's lifespan.

Any new build strategy should also minimise the demand for raw materials by either reusing what is available onsite or sourcing reusable materials from other schemes. Where the sourcing of secondary materials is not possible, specified materials should have a high recycled content, or ideally be renewable and/or 'regenerative,' which means they contribute positively to the natural environment, such as through enhancing local biodiversity.

If we are to meet our climate targets we must develop a sustainable model that ensures all building materials are either reusable or recyclable at the end of their intended life.

Circularity

The circular economy in the built environment relies on three core principles:



Reduce

Reduce virgin material consumption in the construction of new buildings by prioritising retention and utilising innovative design and construction strategies.

Examples: Modern Methods of Construction (MMC), retrofit of existing buildings, lean design principles, exposed servicing to reduce finishing layers.

Reuse

Directly re-using construction products and materials so they don't become waste.

Examples: Retrofit, materials passports, urban mining, re-using steel frames

Recycle

Taking construction waste materials and recycling them back into the industry, reducing the use of virgin materials.

Examples: Redirecting flooring materials or concrete waste into new products

Measuring circularity

MEASURING CIRCULARITY

At present, there is no industry defined metric for a 100% circular building. This reflects the fact that circular strategies vary by building type and between components within the same building.

Adding to this complexity, there may be trade-offs whereby improvement in one area of circularity comes at the expense of another. For example, reusing existing structures may restrict the adaptability and flexibility of the project in the future, or reclaimed materials could have a shorter life span than a new product. Warranties on existing products also restrict the current approach towards circularity.

Four key principles of circularity

1 The most circular building already exists

- Maximise retention of existing buildings onsite
- Focus on retention of structure and substructure (carbon hot spots)

2 Where retention is not feasible, ensure there is no non-hazardous waste to landfill of existing components

- Prioritise direct reuse
- Determine actions to enable maximum recycling (closed loop ideally)

3 Design the building to be circular in operation

- Utilise rainwater harvesting and greywater recycling
- Generate renewable energy onsite

4 Where new materials are sourced, consider their end of useful life scenarios

- Do not specify materials that cannot be reused or recycled at end-of-life
- Minimise raw resource extraction (focus on rapidly renewable biomaterials)

MEASURING CIRCULARITY

The UK Green Building Council (UKGBC) released a thought piece entitled "What does it mean to be 100% circular? Metrics, Benchmarks and Indicators for the Circular Economy." The authors considered the polar extremes, listing what might be considered a non-circular approach, compared against what a 100% circular alternative would be:

0% Circular

Material waste
All waste sent to landfill

Material retained
All materials from an existing building are sent to landfill

Adaptability and disassembly
Chemically bonded, composite systems with no ability to change elements to fit a new purpose

Flexibility
Specific, one-use space

Access to services
No access, materials to be removed to access

Material passports
No record of materials

Building in layers
All layers are designed to the same design life

Pre-redevelopment audit (deconstruction)
No audit before

Demolition vs. deconstruction
Demolition of an existing building

Dematerialisation
Low materials optimisation, low optimisation of spaces, high material mass input

100% Circular

Material waste
No waste, all materials reused or retained

Material retained
All materials retained in situ or deconstructed and sent to second-hand market

Adaptability and disassembly
Mechanical connection, no chemically bonded materials, and the ability to remove materials as a whole and replace them to allow for new use

Flexibility
Open spaces, potential to have multiple uses

Access to services
Clear access, no need to remove materials

Material passports
Full, comprehensive material passports for all materials

Building in layers
All layers are designed to their appropriate design life

Pre-redevelopment audit (deconstruction)
Audit of all materials in the building

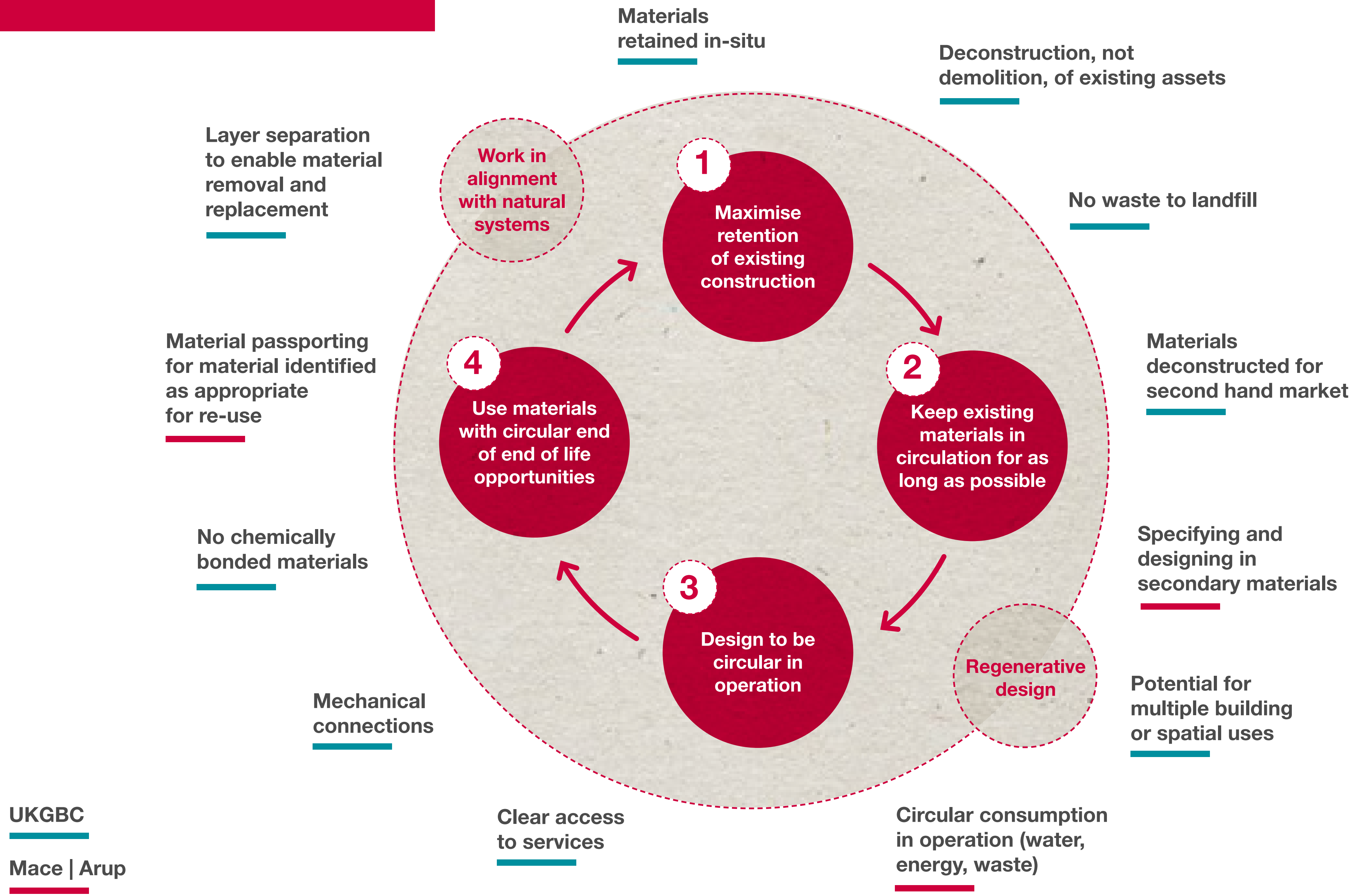
Demolition vs. deconstruction
Deconstruction of an existing building

Dematerialisation
Optimised materials and space, minimum material mass achieved

* What does it mean to be 100% circular? Metrics, Benchmarks and Indicators for the Circular Economy, UKGBC online article Sep 2023

MEASURING CIRCULARITY

These high-level measures in the 100% circular column outline how to approach a project in a circular way. These measures must be factored into a project from the start, with buy-in from all stakeholders, to be successful. This study combines the UKGBC's 100% circular metrics with the four key principles of circularity identified to graphically represent the key considerations and actions that should be incorporated into a project to maximise circularity:



MEASURING CIRCULARITY

These key principles have been used as a basis for developing a red-amber-green (RAG) scorecard to evaluate the potential circularity of materials, with a weighting assigned to each of the criteria. The total number of points achieved across all the criteria is converted into a percentage score reflecting the circularity potential of the material. By taking the average score across all eight categories, a high-level estimate of material circularity is calculated.

By calculating the circularity potential for each material individually, this case study moves away from a 'whole building' assessment and embraces the analysis of the building according to its 'shearing layers,' which refers to the different parts of a building according to their lifespans. These layers include site, structure, facade, building services, interior walls and finishes, and furniture.

Several steps to increase circularity relate to extending the useful life of materials and/or creating opportunities for reuse in the future. While this is important, there is inherent uncertainty as to exactly what actions will be taken in the future. Therefore, the scoring criteria gives a higher weighting to actions that have a near-term benefit and increase reuse, since the benefits are both realised and certain. For example, specifying recycled content is weighted higher as this can be achieved at construction stage, whilst deconstructability is beneficial but not guaranteed at the building's end of life, which may be 60 years in the future. The scoring heavily penalises waste to landfill, since this is the least circular option.

The overall circularity rating is based on the total score calculated as a percentage of the 26 total points available:

>50% low circularity

51-79% moderate level of circularity

80-100% highly circular

Category		Rating	Points
1	Recycled content (volume)	high = above 80%	5
		medium = 30 – 79%	3
		low = below 30%	1
2	Reusability	high = easily reusable with minimal processing	5
		medium = reusable with above 'typical' intervention	3
		low = unlikely to be reused	1
3	Typical wastage rate (% mass)	high = above 10%	0
		medium = 3–9%	2
		low = below 2%	3
4	Recyclability	high = well established recycling routes	2
		medium = downcycling is typical	1
		low = unlikely to be recycled	0
5	Waste to landfill	highly unlikely/none	3
		likely	-3
6	Longevity	high = robust material unlikely to degrade, such as concrete	3
		medium = subject to deterioration, likely to be replaced at least once in building life	2
		low = likely to need replacing less than every ten years	0
7	Adaptability	high = easily moved/reconfigured	2
		medium = can be designed to be adaptable	1
		low = unlikely that it can be reconfigured	0
8	Deconstructability	high = easily taken apart to enable reuse	3
		medium = can be deconstructed, however might not be the norm	2
		low = typically broken apart using high impact means	0

Case study

Material roadmaps to circularity

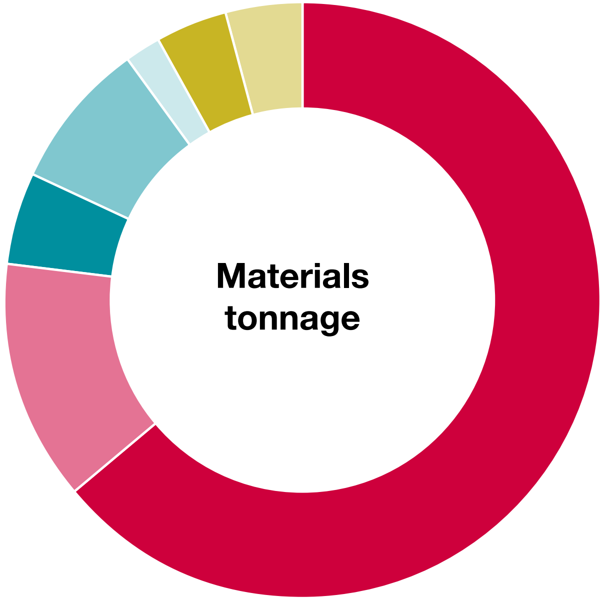
MATERIAL ROADMAPS TO CIRCULARITY

The case study in this report is a recently completed new build Cat A commercial office development in London. Using the case study, this report assesses the level of circularity in a business-as-usual situation and identifies strategies for each major material type to optimise circularity. Circular strategies are explored per building shearing layer, focusing on the substructure, superstructure, façade, and some elements of the interior fit-out such as building services.

A breakdown of the base build materials in terms of tonnage is shown in the chart below:

Analysis of the materials used in the base build of the case study building show that concrete and steel are the most significant material types in terms of tonnage. Other significant materials identified are blockwork, aluminium, plasterboard, and glass.

Building services and raised access floors were not modelled as part of the base build analysis due to a lack of detailed information. However, they are identified in this study as key interest areas. Building services consist of large volumes of metal and for the case study the entire install was new.



	Concrete	64%	12,796t
	Structural steel	13%	2,580t
	Steel (rebar)	5%	1,018t
	Plasterboard	8%	1,547t
	Glass	2%	441t
	Other metals	4%	718t
	Brick/Blockwork	4%	806t

For each of the major material types the following has been considered in terms of circularity:

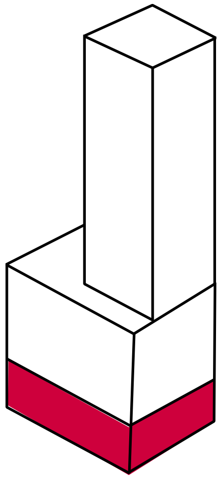
- **The status quo and current limitations**
- **Opportunities**
- **Recommendations**

1. Reinforced concrete

REINFORCED CONCRETE

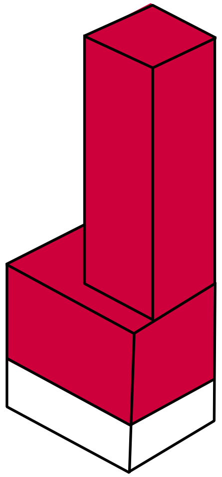
Reinforced concrete was used in the substructure, including the piles and slabs, and the superstructure for the structural cores and floor slabs.

A total of seven different concrete mixes were identified within the project, each containing varying proportions of ground granulated blast slag (GGBS), a waste product from steelmaking that can be used as a replacement for Portland cement. The concrete did not contain any recycled aggregate content. Rebar produced in the UK can have varying proportions of recycled content, up to 98%. This makes it a good candidate for circularity, although the process of melting and reforming the metal is energy intensive.



Substructure

- Piling
- Foundations
- Lowest ground floor



Superstructure

- Columns
- Walls
- Beams
- Floor slabs
- Roof structure

Status quo

Existing concrete structures may have undesirable features. Common challenges include low floor to ceiling heights, insufficient openings in the core and/or floor plate, insufficient structural integrity to accommodate upward expansion, and lack of flexibility (to move or accommodate utilities, for example).

Recycling

Crushed concrete can be recycled and incorporated as part of a new structural concrete mix, but higher proportions of cement are required to accommodate the larger sizes of aggregate. This can result in a higher upfront carbon cost, so retention is the recommended approach.

- At its end of useful life, reinforced concrete is typically separated into crushed concrete aggregate and rebar. The rebar is melted as scrap metal and recycled. This has a positive recyclability rate and is a mainstream practice.
- The crushed concrete aggregate is typically downcycled to be used as sub-base. The product value is significantly reduced during downcycling.

Reuse/retention

- Reinforced concrete has excellent structural qualities but is difficult to reuse directly, unless left in situ.
- Retention of reinforced concrete cores, slabs, and columns from existing buildings has been achieved in many case studies. This approach is not without challenges, but is an established practice, particularly in foundation elements.
- Removal of reinforced concrete for reuse as a structural component is being investigated in the industry but is not currently a refined practice.

REINFORCED CONCRETE

Opportunities

Reuse / Retention

Cast in situ concrete slabs

There are opportunities to maximise the retention of built structures by cutting segments from the existing concrete slabs to open floor plates and improve the usability of the existing structure. This approach is most successful where there are limitations, such as low floor to ceiling heights, or insufficient openings in the existing structure. Existing buildings can also be extended to incorporate additional stories through reinforcement of the existing structure, which enables greater utilisation of existing structure.

To deliver the HYLO building in the City of London, Mace extended the existing 16-storey building upwards by 13 storeys and outwards from the existing footprint by 24%, which doubled the net lettable space. This was achieved by strengthening the existing sub and superstructure, building two new cores, and using a lightweight steel frame for the additional storeys. The existing concrete slabs were carved out to create a new atrium opening, which overcame floor-ceiling restrictions.

Pre-cast concrete frame (or decks)

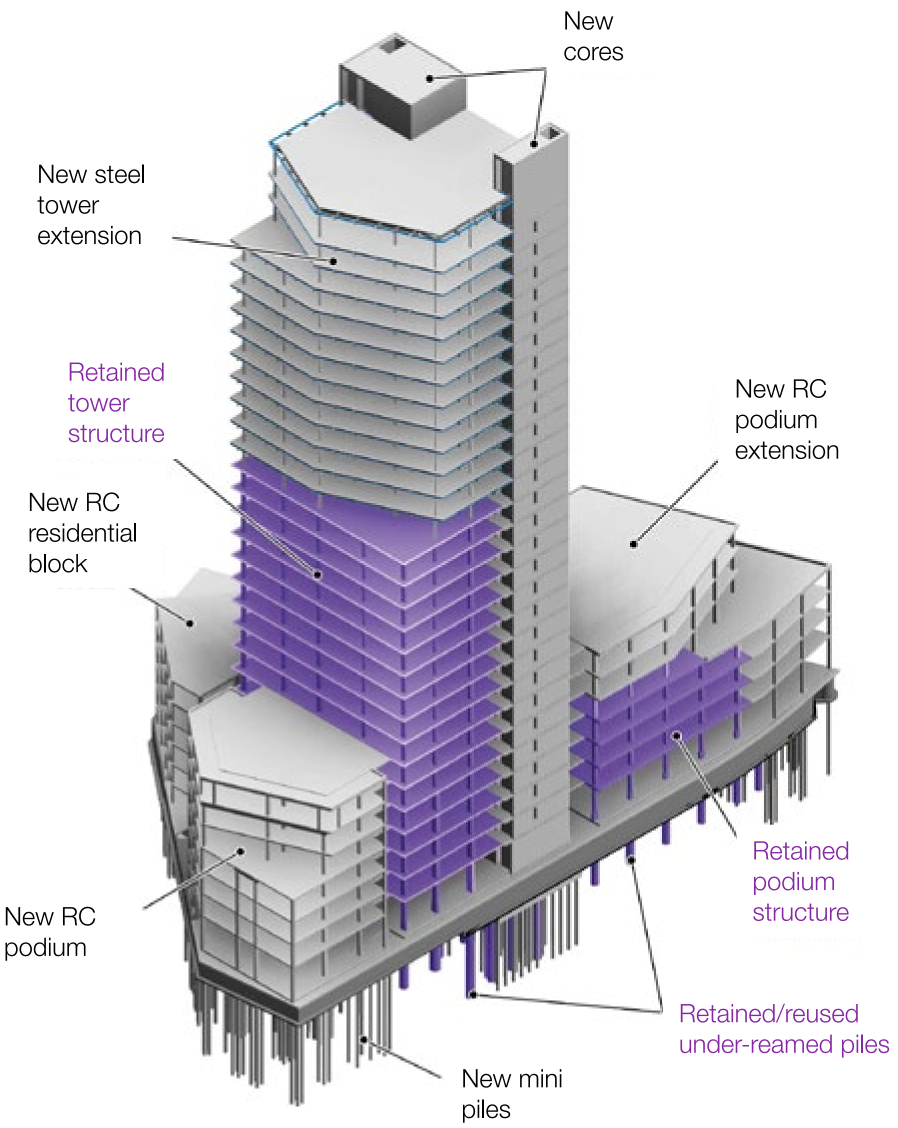
In Finland, Peikko* carried out a pilot study whereby a load bearing precast concrete frame was built, disassembled, and put back together again to prove that it was possible. In Norway, Skanska** reused hollow-core planks from the demolition of a government building in the construction of a new accident and emergency centre.

Piles and foundations

On many sites there are opportunities to incorporate the existing substructure into the new design. At Mace's Stonecutter Court project, 159 existing bearing piles from a previously demolished building were used, with new piles added to construct a taller building than the one which previously occupied the site. Incorporating the existing piles into the design saved over 2,500m^3 of concrete, which equates to 474 tonnes of carbon.

* https://www.peikko.com/blog/pilot-project-proves-that-the-dismount-and-reuse-of-concrete-elements-is-realistic-and-economical

** https://group.skanska.com/media/articles/taking-a-pioneering-approach-to-re-using-concrete-decks/



Source: https://www.akt-uk.com/projects/hylo/

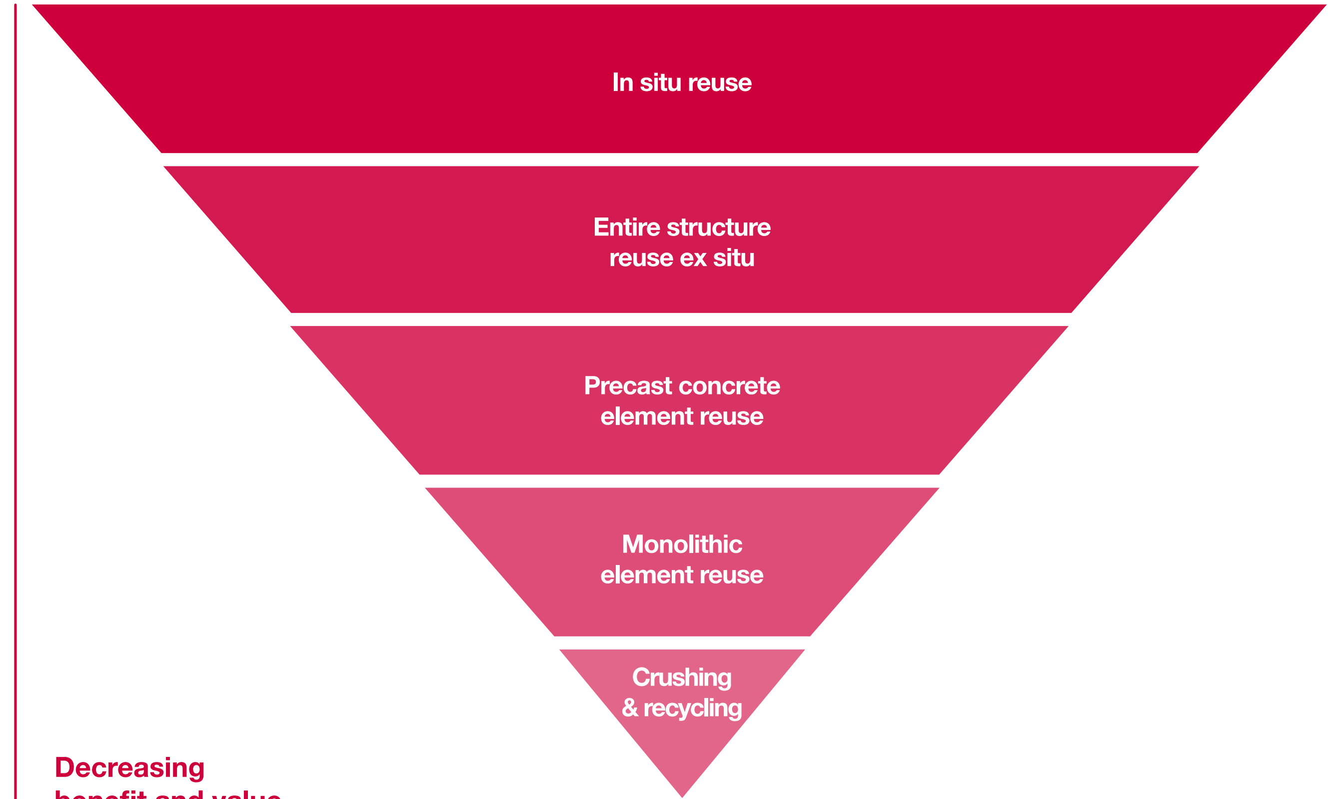
REINFORCED CONCRETE

Recommendations

Reuse and retention

Prioritise the reuse of existing structures. If demolition of above ground structures is unavoidable then consider whether reuse of some elements is possible within the project.

Hierarchy for reuse of concrete



Source: Circular Economy Guidance for Designers, IStructE

Designing for longevity

There can be an increased upfront carbon cost to enabling the deconstructability of structural reinforced concrete elements in high-rise buildings. It is recommended that reinforced concrete structure be designed for longevity instead. For example, designing the structure for a 120-year lifespan with consideration of potential future climatic conditions.

It may not be optimal to design a reinforced concrete structure for deconstruction over a significant life span due to the potential increased embodied carbon. Carbon calculations should be undertaken on a project-by-project basis to understand the implications of building a deconstructable concrete building. Deconstruction is recommended for shorter life span elements that require more frequent replacement and/or maintenance.

Designing for adaptability / flexibility

The reinforced concrete structure in a building should include design features to create space and flexibility in floor plates and enable adaptability should a building change function in the future. Recommendations include:

- Building in additional floor to ceiling heights. For example, 3.2m to allow for future changes in use.
- Designing cores to enable future reconfiguration. For example, form openings within the permanent structure that can be filled as ‘soft spots’ to allow future re-configuration of the cores to match new floor layouts.
- Building in floor ‘soft spots’ for future flexibility to allow connections to be introduced between floor plates.

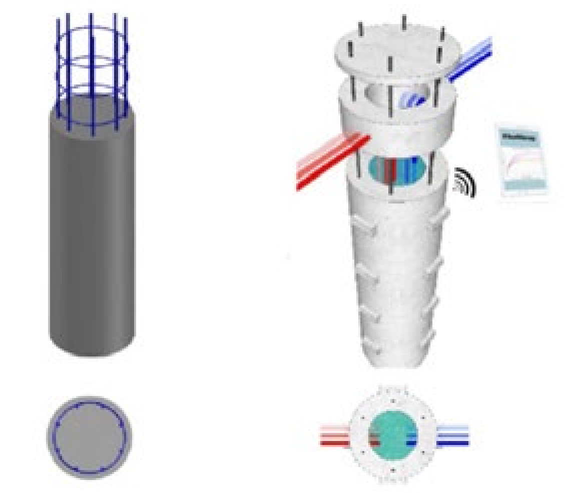
Mace deployed an innovative precast hollow pile (HIPER) solution at a temporary building at Euston.

It used significantly less (50–70%) concrete than a traditional pile solution, resulting in...

80%

less embodied carbon and making it more suitable for reuse.

From this... To this...



REINFORCED CONCRETE CIRCULARITY SCORE

		Status quo		Enhanced circularity best practice	
1	Recycled content (volume)	3	**Medium** – low overall % of concrete, offset by high % of rebar.	3	**Medium** – recycled/reused content of concrete is unlikely to increase significantly in the near-term.
2	Reusability	1	**Low** – reuse not typical.	3	**Medium** – the substructure could be retained in situ. Precast panels/sections could be designed to be deconstructed.
3	Typical wastage rate (% mass)	2	**Medium** ~8% – 15% typical for in situ concrete.	3	**Low** – precast generates much less waste.
4	Recyclability	1	**Medium** – downcycling of concrete is typical, while rebar can easily be recycled.	1	**Medium** – concrete recycling is challenging.
5	Waste to landfill	3	**None** – currently all waste from reinforced concrete is diverted from landfill.	3	**None** – currently all waste from reinforced concrete is diverted from landfill.
6	Longevity	3	**High** – concrete mixes and service life can be designed for longevity. Concrete is historically proven to be a material with longevity.	3	**High** – concrete mixes and service life can be designed for longevity. Concrete is historically proven to be a material with longevity.
7	Adaptability	0	**Low** – typically not very adaptable as structural grids are designed for fit of building use.	1	**Medium** – structural grid can be designed to allow for adaptability.
8	Deconstructability	0	**Low** – typically broken apart using high impact means.	2	**Medium** – precast options can be designed for disassembly.

Status quo: 13 Circularity rating — 50% **Low circularity**

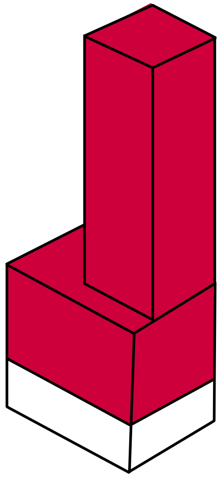
Enhanced circularity best practice: 19 Circularity rating — 73% **Moderate circularity**

2.

Structural steel

STRUCTURAL STEEL

In our case study building, 2,500 tonnes of structural steel were used for the superstructure frame. This was all newly procured steel, with a combination of blast oxygen furnace (BOF) production (which generally uses lower quantities of recycled metal) and some electric arc furnace (EAF) produced steel, which uses higher quantities of recycled metal.



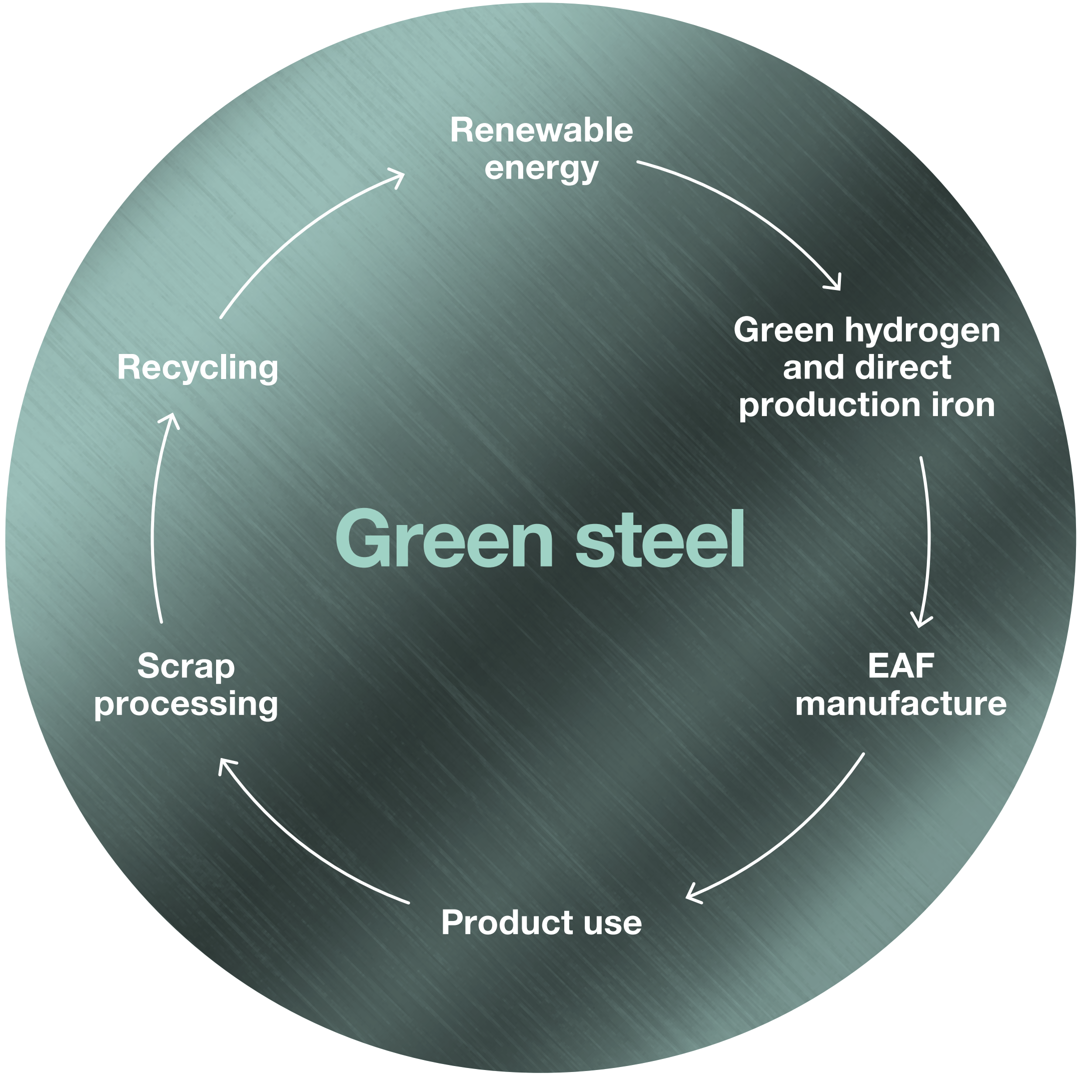
Superstructure

- Columns
- Beams
- Roof structure

Status quo

Reuse
In the UK, only around 6% of structural steel is reused, with the majority melted down and recycled. Reusing steel has the potential to be 50% less energy intensive than recycled steel. Reusing steel does not degrade the product's strength or value.

Recycling
Steel is 100% recyclable and steel from demolition in the UK is typically recycled. The UK produces around 10 million tonnes of scrap steel each year, however currently 80% is exported and therefore not kept within the UK market.



Source: https://libertysteelgroup.com/uk/greensteel/

STRUCTURAL STEEL

Circularity practices for steel

Repair

Such as rust removal epoxy or welding

- prolongs the life of the steel structure
- not always an option (e.g. for load bearing structure)

Reuse

Design steel for reuse or remanufacturing

- maximises the lifetime of the steel structure
- limited due to difficulties in sourcing, costs and recertification

Recycle

High quality steel scrap

- produced steel of good quality that can be used in many applications
- limited availability of high quality scrap

Downcycle

Low-quality steel scrap

- enables the use of many sources of scrap
- impurities are hard to remove and accumulate with each cycle

Reduce emissions

Directly from primary iron and steel production

- necessary even with maximised circularity due to current technical limitations

Source: Structural Steel Reuse, SCI

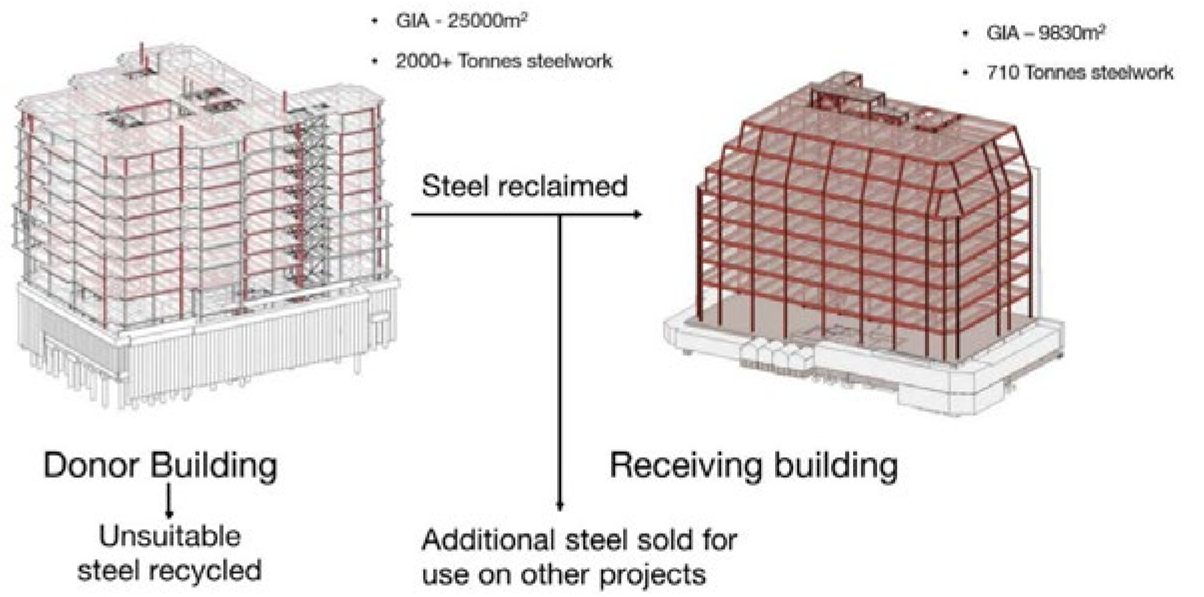
STRUCTURAL STEEL

Opportunities

'Urban mining' of existing steel, for use directly on the same project, or from other sites is the most significant opportunity for a more circular steel industry. There are recent examples of this within the London market. For example the developer GPE has salvaged the structural steel from the demolition of their 2 Aldermanbury Square project and designed another of their London projects to use it.

Recovery of steelwork from existing buildings
In theory, steelwork can be cut with a grinder near the support or unbolted to recover the full section lengths. In practice, however, contractors generally burn out sections using diagonal cut lines close to the connections. This retains similar working practices to business as usual, reduces the risk associated with not being able to unbolt connections, and lowers the risk of 'catching' the section as it is removed. The section loss resulting from the diagonal cuts is minimal, assuming that all existing connection plates would typically be removed at the end of a beam prior to reuse.

One of the biggest challenges facing clients and developers is procuring second-hand materials with the desired specifications and sizes in sufficient quantity. Manufacturing techniques, such as ribbon-cutting and expansion to form a new cellular beam with enhanced section properties, may be employed to increase the range of available sections that are efficiently reused.



Source: Circular Economy Guidance for Designers, IStructE (pg 234)

Designing for disassembly

Deconstruction/disassembly is the practice of dismantling a built asset to preserve or maintain the material value of each component. A typical demolition approach knocks down materials and breaks them apart, which means they cannot be reused without processing (recycling, or – more often – downcycling). Designing to allow for disassembly or deconstruction can enable materials to be removed with minimal or no damage.

Recommendations

- Review opportunities to reuse existing steel, either in situ or elsewhere in the building design.
- Engage with reused/reclaimed steel stock suppliers. EMR and Cleveland Steel both have storage for steel from demolition, which can be supplied back to the market. Designers can request stock lists to identify potential opportunities for incorporation into projects.
- Where new steel is required, ensure the design is as efficient as possible. Higher grade strength columns (for example) may require less material to achieve the same result.
- Specify high recycled content rolled steel sections.
- Design for disassembly where possible, such as through bolted connections.

STRUCTURAL STEEL CIRCULARITY SCORE

	Criterion	Status quo score	Status quo	Enhanced circularity best practice score	Enhanced circularity best practice
1	Recycled content (volume)	1	**Low** – up to 23% in blast oxygen furnace produced steel.	5	**High** – potential to source the majority of rolled steel from electric arc furnace sources and utilise existing/reclaimed steel.
2	Reusability	3	**Medium** – steel reuse is becoming more prevalent in the industry, however this is the exception rather than the norm	5	**High** – steel reuse is becoming more prevalent in the industry.
3	Typical wastage rate (% mass)	3	**Low** – minimal wastage.	3	**Low** – minimal wastage.
4	Recyclability	2	**High** – recycling is typical.	2	**High** – recycling is typical.
5	Waste to landfill	3	**None.**	3	**None.**
6	Longevity	3	**High** – structural steel should suffer minimal degradation.	3	**High** – structural steel should suffer minimal degradation.
7	Adaptability	1	**Medium** – often designed without future reconfiguration in mind.	2	**High** – Designed for adaptability, so can be easily reconfigured.
8	Deconstructability	2	**Medium** – often welded together, meaning it must be cut apart.	3	**High** – Designed for deconstruction with bolted connection.

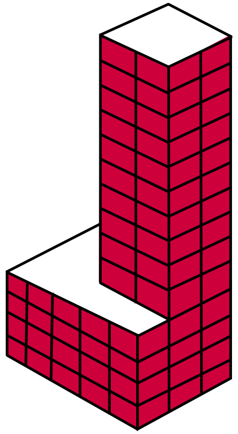
Status quo: 18 Circularity rating — 69% **Moderate circularity**

Enhanced circularity best practice: 26 Circularity rating — 100% **High circularity**

3. Glass

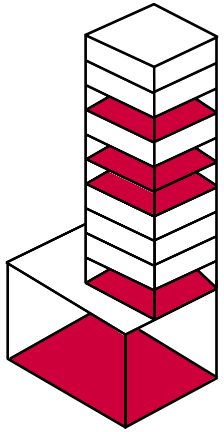
GLASS

A substantial amount of architectural glass has been used in the façade of the case study building, in a lightwell and internally for a mezzanine. Glass is also often used in office fit-outs, typically to create meeting room partitions, although this was not part of Mace's scope for this project.



Facade

- External windows
- Curtain wall
- External glazed doors



Interior fit-out

- Internal glazed partitions
- Glass balustrades
- Internal glazed doors

Status quo

Reuse
Direct reuse of glass is very rare in the construction industry today.

Recycling
Of the 199,000 tonnes of post-consumer waste glass generated in the UK, it is estimated that the majority is not recycled back to glass. Most of it is downcycled into aggregate or deposited to landfill.*

Opportunities

- Research shows that glass, as a 100% recyclable material, can be remelted an infinite number of times and that the construction glass industry has the potential to be a perfect example of a scalable circular economy in action.
- The opportunity for direct reuse of external glazing is very limited. Internal glazing does have the potential for reuse.
- Some UK-based manufacturers offer flat-glass recycling/take-back schemes and have targets to increase the amount of post-consumer glass in the production of new glazing. These take-back schemes require the glass cullet to be segregated and free from contamination.

Limitations
As identified in Arup's 'Re-thinking the life-cycle of architectural glass', there are several barriers to implementing glass reuse and glass recycling back into the float line.

- Changes to the construction process are required to enable effective removal of existing glass, safe storage, and re-integration into a new building design.
- Flat glass collected for recycling must be free from any contaminants. This must be carefully managed on construction sites.
- The industry needs to work together to gain an understanding of the current recycling logistical structure and the typical refurbishment construction process.
- Designers need a robust specification for the recycling of construction flat glass in refurbishment projects.
- Designs and specifications for new façades should follow guidance to maximise the potential of glass to be recycled at the start of the design process.

* Re-thinking the life-cycle of architectural glass – Arup. Publication date 2019

GLASS

Recommendations

The following actions are recommended to improve circularity in construction glass:

- Direct reuse of architectural glass used in interiors, ideally on the same site or on other sites.
- Material passporting via QR codes is recommended to give elements a digital identity and help to enable their future use
- Upskilling of demolition contractors.
- Producing and disseminating clear guidance on storage and transportation.

Closed-loop recycling

Information on closed-loop recycling has been sourced from Arup's 'Re-thinking the life-cycle of architectural glass.'

- If handled correctly, appropriate glass types can be put directly back into the float line to achieve closed-loop recycling. Note: Not all existing glass removed from buildings will be suitable for moving directly back to the float line.
- Closed-loop recycling requires a new network to develop and new processes to be put in place to ensure the quality of recovered glass.
- There are demolition or refurbishment contractor costs in removal, and significant transportation costs in moving materials around, processing, storage, and transportation to the float line. This is required to maintain the very high quality of the cullet that the glass manufacturers will demand.

Glass processing contains a wide range of possible procedures that can influence recyclability potential. Further information on these options is detailed in the specification section.

The glass recycling industry has developed three primary qualities of glass cullet:

- **Class A:** Clean clear cullet suitable for transportation directly to the float line for remelt to new flat glass product.
- **Class B:** Mixed cullet that may include some contamination.
- **Class C:** Contaminated glass product not suitable for remelting.

Specification

The aspiration is for specifications to optimise opportunities for glass to enter the recycled float glass economy at end-of-life. Limitations for recycling occur on some occasions due to glass processing methods and quality.

The quantity of post-consumer glass (that has seen service in buildings) included in the cullet flow is currently very low. Not all glass is suitable for moving directly back to the float line. The table below from 'Re-thinking the life-cycle of architectural glass' (Arup) shows glass processing and the effect on recyclability, which can be used to guide future specifications. This demonstrates that laminated, insulated, and low iron glass all limit circularity potential:

Glass process	Recyclable to float line?	Notes
Annealed glass	Yes	Readily recyclable
Cutting and edge processing	Yes	No effect on recyclability
Laminating	Limited	Current methodology for delaminating reduces quality. Requires improved delamination process to ensure laminating can be reused.
Heat strengthened	Yes	No effect on recyclability
Toughened (or tempered)	Yes	No effect on recyclability
Heat soak tested	Yes	No effect on recyclability
Glass coating (hard and soft)	Yes	No effect on recyclability
Ceramic printing and fritting	No	Current methodology does not allow for recycling of ceramic printed glass
Insulated glass units	Yes	Requires removal of spacer bars and edge seals, limits on processing of individual panes as noted above.
Low iron glass	Yes	Specifying low iron glass may require flat manufacturers to reduce the recycled glass content to ensure a clear product is achieved. Further discussion with glass supplier on a project basis is recommended.

EXTERIOR GLASS CIRCULARITY SCORE

	Criterion	Status quo score	Status quo	Enhanced circularity best practice score	Enhanced circularity best practice
1	Recycled content (volume)	1	**Low** – post consumer waste glass is not widely used in production of new glazing for buildings.	3	**Medium** – pre consumer recycling available in the market (e.g. SaintGobain ORAE glazing) and manufacturers are targeting increased usage of post-consumer glass cullet.
2	Reusability	1	**Low** – exterior glazing is not typically reused.	1	**Low** – direct reuse will be challenging due to the fragility of the material.
3	Typical wastage rate (% mass)	3	**Low** – unless there is breakage.	3	**Low** – unless there is breakage.
4	Recyclability	1	**Medium** – although glass is recyclable in theory, downcycling is more typical.	2	**High** – utilising glass cullet recycling schemes through manufacturers will increase the recycled content of new glazing.
5	Waste to landfill	3	**Unlikely.**	3	**Unlikely.**
6	Longevity	2	**Medium** – glass can have a long service life of 60 years, however insulated panels are likely to have a shorter life span in the region of 25 years.	2	**Medium** – glass can have a long service life of 60 years, however insulated panels are likely to have a shorter life span in the region of 25 years.
7	Adaptability	0	**Low** – difficult to change it without causing damage.	0	**Low** – difficult to change it without causing damage.
8	Deconstructability	0	**Low** – difficult to remove it without causing damage.	0	**Low** – difficult to remove it without causing damage.

Status quo: 11 Circularity rating — 42% **Low circularity**

Enhanced circularity best practice: 14 Circularity rating — 54% **Moderate circularity**

4. Blockwork

BLOCKWORK

Concrete blockwork is widely used for partition walls, particularly in basements, ground floor levels and party walls. They have excellent compressive strength, are durable, fire resistant, and have strong acoustic performance.

Status quo

The average recycled content of concrete blocks is 24% (Concrete Block Association, Data Sheet 16, 2017), which includes cement replacements and/or recycled aggregate, although there are products available with a much higher recycled percentage. These include Lignacite and blocks and mortar made with zero cement content, which reduces their carbon intensity.

Mortar is typically cement-based, which makes it difficult to separate blocks for direct reuse without causing damage. The typical end-of-life scenario for blockwork is therefore for it to be crushed and turned into aggregate.

Reuse
Not currently an option.

Recycling
Typically, blockwork is downcycled into a concrete aggregate product. With the right processing, this could be used for the manufacture of new blocks.

Opportunities

There are innovative new products coming to market, such as OSTO – a carbon negative aggregate made from waste product that can be used as a substitute for lightweight aggregate in blockwork production.
This can help increase overall recycled content and reduce carbon emissions.

Unfired clay bricks using excavated subsoil combined with straw have successfully been used for basement perimeter walls at the Camden Apex building.* The bricks can be reused or (as they are composed of natural materials) returned to the environment at end-of-life. A limitation of these bricks is that they do not have the same structural strength as concrete blocks and are not therefore a straight substitute. They can, however, be used in the right situation.

Recommendations

- To enhance the circularity of blockwork, the focus should be on material optimisation, efficient production processes, and design that facilitates reuse and recycling where possible.
- Unfired clay bricks could be used in the right circumstances, and mortar can be specified with qualities that enables better block separation at end-of-life. Overall, however, further research and innovation is needed to develop more circular options for this product.

* https://www.bennettsassociates.com/news-and-insights/earth-blocks-tribeca/

BLOCKWORK CIRCULARITY SCORE

		Status quo		Enhanced circularity best practice	
1	Recycled content (volume)	1	**Low** – average is 24%.	5	**High** – up to 75% is currently possible and innovative products may improve upon this.
2	Reusability	1	**Low** – cement bonds make it difficult to deconstruct without causing damage.	1	**Low** – without innovation it is difficult to see how reusability can be improved.
3	Typical wastage rate (% mass)	2	**Medium** – off-cuts are typical.	2	**Medium** – off-cuts are likely to still be typical.
4	Recyclability	1	**Medium** – downcycling is typical.	1	**Medium** – downcycling is typical.
5	Waste to landfill	3	**Low** – can be crushed and used as aggregate.	3	**Low** – can be crushed and used as aggregate.
6	Longevity	3	**High** – minimal degradation.	3	**High** – minimal degradation.
7	Adaptability	0	**Low** – due to cement bonding it is difficult to deconstruct, so a change in configuration is difficult without generating waste and degrading materials.	0	**Low** – due to cement bonding it is difficult to deconstruct, so a change in configuration is difficult without generating waste and degrading materials.
8	Deconstructability	0	**Low** – due to cement bonding it is difficult to deconstruct.	0	**Low** – due to cement bonding it is difficult to deconstruct.

Status quo: 11 Circularity rating — 42% **Low circularity**

Enhanced circularity best practice: 15 Circularity rating — 58% **Moderate circularity**

5. Plasterboard

PLASTERBOARD

Plasterboard is widely used as part of metal studwork partition wall systems and in ceilings.

Status quo

Plasterboard is made using gypsum, which is a form of calcium sulphate typically produced in the UK from a combination of mined naturally occurring minerals and synthetic sources (from desulphurisation of coal power flue gas). Gypsum plasterboard can currently be produced with up to 30% recycled gypsum content, which is sourced from both production and construction/demolition waste. However, according to the Gypsum Products Development Association, the average post-consumer material used in the production of plasterboard in 2021 was only 9.45%.

At the end of its use, gypsum is typically separated from other waste streams and is sent for recycling and/or to landfill. It is difficult to pinpoint the current overall rate of recycling of gypsum plasterboard in the UK, but rates quoted in Environmental Product Declarations vary between 4% (Knauf Core board) and 17% (British Gypsum Gyproc). When plasterboard is contaminated or chemically bonded to other materials its recycling potential is significantly decreased. The supporting metal studwork is typically sent for metal recycling as a higher valued item.

Opportunities

Plasterboard can be made-to-measure and/or pre-assembled in controlled factory conditions to minimise wastage associated with plasterboard offcuts. This service attracts a cost premium, but this can be (at least partially) offset by the reduction in waste disposal costs.

Provided plasterboard is not contaminated or chemically bonded to other materials, it can be used in the production of new plasterboard. Circular design strategies, such as the removal of adhesives from material build-ups to enable better material separation, should be prioritised to maximise the potential of this product for recycling.

Recycling

- Returning off-cuts to the manufacturer for recycling through take-back schemes.
- Sending waste to independent plasterboard recyclers to make into new plasterboard and cement.
- Some gypsum can be used as a soil conditioner.
- Some gypsum can be repurposed to make bathroom furniture mouldings.

Limitations

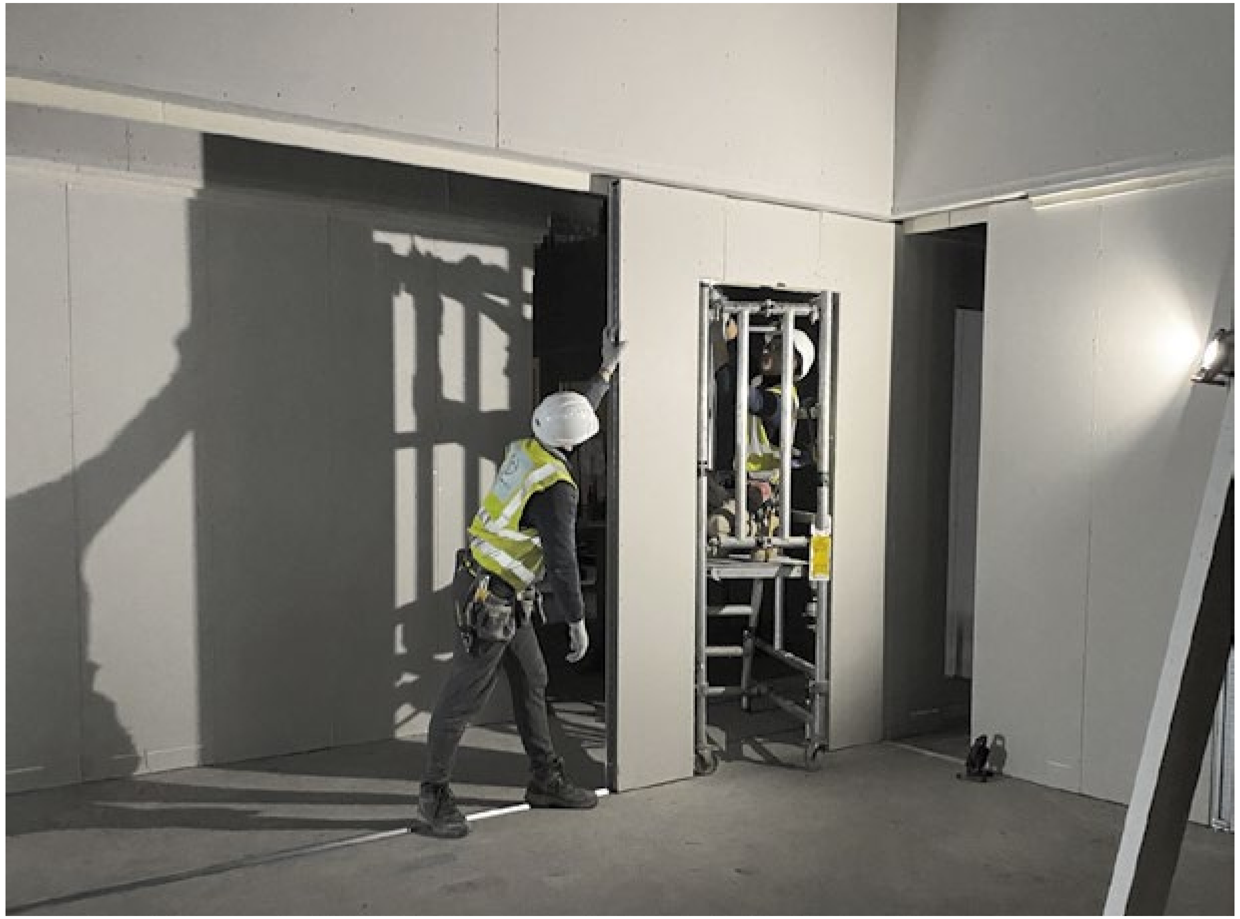
Recycling

- Old plasterboard removed in demolition and refurbishment projects can be contaminated with other materials and is therefore harder to separate.
- Current technology does not support the recycling of specialised plasterboard types, such as those with foil backing.
- Plasterboard itself is sometimes composed of composite materials, such as plasterboard bonded with insulation, which poses challenges when it comes to separation.

Recommendations

- To ensure plasterboard/gypsum is recycled at end-of-life, avoid specifying composite/bonded boards where possible.
- Use manufacturer take-back schemes for plasterboard waste.
- Take advantage of made-to measure services to avoid onsite wastage.
- Consider the use of bio-based boards where possible as an alternative to gypsum.

PLASTERBOARD



eekowall – Prefabricated inner wall system

At the Peterborough Court redevelopment in London, Mace has utilised a new prefabricated wall system that has significantly reduced the amount of drywall waste generated on site. The 'eekowall' system uses dry-lined panels preassembled off-site to a specified height, that are brought on site, interlocked, and fixed. The panels can incorporate door and service openings. They also contain integrated conduit channels to direct electrical or data cables to any position within the wall module. Because the modules can be disassembled for modification or repair, the walls can be adapted over time for different uses.

PLASTERBOARD CIRCULARITY SCORE

	Criterion	Status quo		Enhanced circularity best practice	
1	Recycled content (volume)	1	**Low** – low and recycled content to 9.45%	5	**High** – higher recycled content could be achieved with good quality reclaimed material.
2	Reusability	1	**Low** – it is difficult to separate/ deconstruct without causing damage.	3	**Medium** – if designed for disassembly, plasterboard could be reused.
3	Typical wastage rate (% mass)	0	**High** – off-cuts are typical.	3	**Low** – using made to measure/prefabricated content.
4	Recyclability	0	**Low** – although it can be recycled if not contaminated, it is often chemically bonded to other materials.	2	**High** – provided it is not bonded and can be separated easily.
5	Waste to landfill	-3	**Yes** – challenges separating it from other contaminants can lead to it being disposed of in landfill.	3	**Low** – provided it can be easily separated/ segregated.
6	Longevity	0	**Low** – plasterboard has a relatively short in-use lifespan.	0	**Low** – plasterboard has a relatively short in-use lifespan.
7	Adaptability	0	**Low** – it can be difficult to move it once installed without causing damage.	1	**Medium** – if designed for disassembly.
8	Deconstructability	0	**Low** – can be difficult to remove it without causing damage.	2	**Medium** – if designed for disassembly.

Status quo

-1
Circularity rating

4%
Low circularity

Enhanced circularity best practice

19
Circularity rating

74%
Moderate circularity

6. Raised access floors

RAISED ACCESS FLOORS

In the case study building, there were eight floors of commercial office space, all with raised access floors, a common feature across modern offices. These floor tile systems are typically made from a combination of particleboard (i.e. chipboard) wrapped in thin metal to create the floor tiles, supported on a metal pedestal frame.

Status quo

The case study building utilised all new raised access floor tiles, which is a standard approach for new build commercial offices In the UK.

Opportunities

Reuse
Provided the raised access floor is undamaged, the floor tiles have strong potential to be directly reused. Demand has surged for reclaimed floor tiles, which can offer significant cost and carbon savings, and demand is currently outstripping supply. Metal pedestal frames are not typically reused, but (provided they can be removed without damage) there is no reason they could not be.

Recycling
Floor tiles can be separated into their metal and particleboard components, which can then be easily recycled. The metal pedestals can also be recycled. Kingspan, one of the UK's largest manufacturers of raised access floors, operates a product take-back scheme.

Limitations
Reclaimed or reused raised access floor tiles may not have the same airtightness as new tiles.

Recommendations

It is recommended to specify reclaimed raised access floor tiles wherever possible. To secure the materials, it is important to engage with suppliers early in the process. Large developers may be able to reserve supply from deconstruction projects to use on other schemes, or deconstruction contractors could advise on upcoming availability.

At Mace's Hylo project over...

400t

of embodied carbon was saved by using more than...

10,000m²

of recycled raised access floor panels

RAISED ACCESS FLOORS CIRCULARITY SCORE

	Criterion	Status quo score	Status quo	Enhanced circularity best practice score	Enhanced circularity best practice
1	Recycled content (volume)	1	**Low** – metal is likely to contain some recycled content.	5	**High** – increasingly floor tiles are being reused. Products with a high recycled content are also available, such as the RMG 600+ tile from Kingspan.
2	Reusability	3	**Medium** – not common practice yet, although it is possible.	5	**High** – provided tiles are not damaged they could be suitable for reuse. There is a high demand for reused floor tiles within the London market.
3	Typical wastage rate (% mass)	3	**Low** – any surplus can be returned to the supplier.	3	**Low** – any surplus can be returned to the supplier.
4	Recyclability	1	**Medium** – manufacturer take-back schemes are available .	2	**High** – engage with manufacturers to utlise take-back schemes
5	Waste to landfill	3	**None.**	3	**None.**
6	Longevity	3	**High.**	3	**High.**
7	Adaptability	2	**High** – tiles can be removed and reconfigured.	2	**High** – tiles can be removed and reconfigured.
8	Deconstructability	2	**High** for tiles, **medium** for pedestals.	3	**High** – if connections are designed for disassembly.

Status quo: 18 Circularity rating — 69% **Moderate circularity**

Enhanced circularity best practice: 26 Circularity rating — 100% **High circularity**

7. Building services

BUILDING SERVICES

Building services is a broad category and includes complex systems (i.e. heating and cooling systems), lighting, cable, and ducting/conduits.

Complex equipment can be difficult to disassemble and can have a short service life compared to the other building layers considered in this report. Some pipework, ducting and conduit materials, such as metals, are relatively easy to recycle and could be suitable for reuse, although this is not common practice.

Status quo

Reuse

Building services are not commonly reused between fit-outs. There are several issues that make reuse difficult, including the relative cost of strip-out versus dismantling and reconfiguration, equipment sizing selection specific to a project, lack of manufacturer take-back capacity, and issues around procuring warranties for reused items.

Recycling

Some building services elements can be separated into their component materials and recycled through regular waste channels.

The aim of a circular economy is to keep materials at their highest value for as long as possible. Lots of building services components are composed primarily of metal (coils, chassis, ducts, and cable trays, for example) so often the easiest logistical route is to separate for scrap metal rather than reuse. Scrapping metal is a well-established process and therefore has minimal programme impact, does not require any storage, and provides some financial incentive. The downside is that although the material may get recycled, the components have immediately lost value and need to be manufactured again to be repurposed.

Opportunities

The impact of tenant changes to Cat A and Cat B fit-out across the lifespan of the building can be very high and (in the case of Cat A fit-out) often involves the disposal of newly installed materials and equipment because they do not suit the layout and aesthetics required by the tenant.

Examples of potential measures to address this include:

- Use of a limited number of show areas with Cat A fit-out.
- Use of virtual tools (rather than physical fit-out) to help tenants visualise the finished spaces.
- Moving towards ‘Category C’ offices, which are fitted out by landlords with minimal changes between tenants. The use of this model requires consideration of measures to improve flexibility such as soft spots within walls and floors, incorporation of movable partitions, specification of hard wearing, easy-to-clean finishes, and flexible lighting systems. Information can be provided to landlords summarising the environmental savings of implementing this Cat C approach, which the tenant can in turn use to promote their green credentials and provide measurable alignment to their values and targets.
- Cat B designed to utilise Cat A components, aiming to retain as much as possible.

BUILDING SERVICES

There are also opportunities to increase reuse of building services, such as:

- Reuse of distribution elements like cable trays and ductwork.
- Reuse of equipment such as light fittings and fan coil units.
- Procuring products as services, with components owned by a third party who will take them back and reuse when they are no longer needed on the project.

Limitations

There are several barriers to implementation for the reuse and recycling of building services.

Reuse

- Strip out and recycling of distribution elements is generally more expensive than dismantling and reconfiguration.
- Programme issues can arise with reuse onsite. Offsite reuse currently requires project teams to be proactive in finding opportunities for reuse of materials on their own projects.
- Few manufacturers are equipped to offer ‘product-as-a-service’ models.
- Where building services equipment is suitable for reuse, there is often no infrastructure to enable it to be tested and certified.
- Where warranties are not available, clients may not be prepared to accept reused systems and equipment.
- Storage of deconstructed components is a considerable barrier to the reuse of building services equipment.
- Elements may be missing key identifying information, such as technical submittals, compliance certificates, or operation and maintenance manuals. Stringent record keeping or the utilisation of Material Passports will be required to resolve this.

Recycling

- Research and development are required from manufacturers to increase the potential for equipment to be broken down into component parts for recycling.
- Upskilling of demolition or deconstruction contractors is required to ensure stringent segregation of material streams for recycling.

Recommendations

Building services generally have a high whole life-cycle carbon impact. They also account for large quantities of waste across the building’s lifespan.

- A key recommendation for building services is engagement with equipment manufacturers to highlight the importance of reusability and recyclability and promote the development of improved products and processes for reuse. This includes creating modular products that can be scaled up or down as required to meet a building’s sizing needs.
- Engagement with letting agents, tenants, and landlords is required to promote more circular models for the letting of commercial space that is more easily adaptable to the needs of different tenants, highlighting the potential value in re-using equipment rather than buying it new, through programme improvements and reducing costs associated with sourcing new.
- Platforms to assist in the reuse of equipment would be beneficial to promote reuse between projects and address logistical issues with reuse onsite.
- A greater focus should be placed on designing for deconstruction, ensuring the building layers are separated to minimise disruption for operators when the next fit-out takes place. Deconstruction will need to form part of the ‘golden thread’ of information with easily accessible guides on reuse and recycling options.

Guidance on specification

Specifications by the design team should clearly set out materials that have been identified for reuse and the anticipated recovery route for those materials.

Early engagement is key. The project brief must outline what the building could be used for in the future and the design should be developed with those scenarios in mind. This will inform considerations such as floor-to-ceiling allowances, risers, plant space, and distribution strategies.

BUILDING SERVICES CIRCULARITY SCORE

		Status quo		Enhanced circularity best practice	
1	Recycled content (volume)	1	**Low** – metal is likely to contain some recycled content, but it is not generally a high %.	3	**Medium** – with a greater push for reuse and recycled content.
2	Reusability	1	**Low** – not common practice.	3	**Medium** – second hand markets could be fostered.
3	Typical wastage rate (% mass)	0	**High** – large amount of wastage associated with tenant fit-out.	2	**Medium** – avoiding tenant fit-out waste.
4	Recyclability	0	**Low** – difficult and time consuming to disassemble units.	1	**Medium** – if designed for disassembly materials can be separated for recycling.
5	Waste to landfill	-3	**Yes** – due to difficulties separating materials for recycling.	3	**None** – if designed to allow disassembly, however this could be challenging for some equipment.
6	Longevity	2	**Medium** – 15-year service life is considered typical.	3	**High** – if designed for upgradeability, however this would require a significant change in approach.
7	Adaptability	0	**Low.**	1	**Medium** – if designed for upgradeability, however this would require a significant change in approach.
8	Deconstructability	0	**Low.**	2	**Medium** – if designed to allow disassembly, however this could be challenging for some equipment.

Status quo: 1 Circularity rating — 4% **Low circularity**

Enhanced circularity best practice: 18 Circularity rating — 69% **Moderate circularity**

Conclusion and recommendations

CONCLUSION AND RECOMMENDATIONS

The review of the major construction materials used in the case study building has shown that while there are well-established recycling routes for some construction materials in the UK, downcycling is still prevalent.

This report has identified key steps currently available to improve circularity for the major construction material types associated with a Cat A commercial office development. To realise the full circularity potential for each material, these roadmaps must be factored into a project at the concept and design stage.

To better assess and drive improvement in circularity on construction projects, a set of holistic metrics and KPIs that consider the whole life cycle, rather than just diversion from landfill, is needed.

A breakdown of the scorecard ratings is shown in the table on the right, which includes the quantity (tonnage) of each material type used in the case study building and what percentage this represents of the total. An average overall circularity improvement score has been calculated based on the aggregated percentage improvement in circularity for each material type, weighted according to the percentage of the total tonnage.

This method means the materials that make up most of the building by weight have the greatest influence on the overall score, which in this instance is concrete and steel. The scorecard shows that the total circularity improvement that could be achieved for the case study building is +28%. It also shows that substantial improvements are achieved for plasterboard and building services, but as these materials contribute a relatively small percentage of the overall weight, they do not have a significant impact on the overall average score.

Material	Material quantity		Mace case study building: Circularity rating		Mace case study building: Circularity improvement	
	Tonnage	As proportion of whole building	Case study	Enhancement	Per material	As proportion of whole building
Concrete	13,813	67%	50%	73%	23%	15%
Structural steel	2,580	12%	77%	100%	23%	3%
Glass	441	2%	42%	54%	12%	<1%
Blockwork	804	4%	42%	58%	16%	1%
Plasterboard	1547	7%	4%	73%	69%	5%
Raised access floors	303	1%	69%	100%	31%	0%
Building services	1169	6%	4%	69%	65%	4%

Total circularity improvement **+28%**

CONCLUSION AND RECOMMENDATIONS

This scorecard approach enabled a quick and simple means of assessing circularity and highlighting the materials that present the biggest challenges and opportunities. For future projects, this scorecard approach could be used early in a project life cycle to guide teams towards more circular strategies. Mace is developing this method further, creating a circularity assessment tool to use across its construction projects.

The case study building review has shown that while a 'typical' approach on a prime commercial office building does not prioritise circularity, there are materials that already have excellent circularity potential such as structural steel, rebar, and raised access floor tiles. External glazing, blockwork, building services, and plasterboard have limited circularity potential. Significant embodied carbon reductions could be achieved through a more circular design of building services, which tend to have a relatively short lifespan and are made from carbon intensive materials.

This study has not considered material types associated with full fit-out, such as finishes and furnishings. Prime office tenant spaces undergo frequent refurbishments, leading to significant amounts of waste. It is therefore recommended that circularity should be a key consideration when designing office fit-outs, and landlords should incentivise or mandate circular approaches.

This study has highlighted, through the material roadmaps, several recommendations to improve material circularity and a red-amber-green (RAG) scorecard to help assess and rate circularity.

The table below summarises key findings and recommendations for each material specified.

Material	Current standard approach	Current circularity score	Improved circular approach	Improved circularity score
Structural steel	• Majority of all new steel from blast oxygen furnace production, with minimal recycled content. • Disassembly not a priority in design. • Poor traceability of supply.	69%	• New steel Electric Arc Furnace produced, with high recycled content. • Reused/Reclaimed steel, easy to disassemble and reuse at end-of-life. • Reduce welded connections to assist deconstruction. • Material passport including physical stamp.	100%
Reinforced concrete in sub and superstructure	• All new sub and superstructure. • Relatively small overall recycled content of concrete (typically GGBS as a cement replacement). • Rebar can be made with high recycled content. • Not designed for long service life, neither for disassembly.	50%	• Retain and reuse existing substructure. • Minimise need for new RC through lean design. • Demountable precast panels (core walls and planks). • High recycled content rebar. • Designed for a longer service life.	73%
Glazing	• Minimal recycling of existing glass. • New glazing does not typically include post-consumer recycled material.	42%	• Reused or high recycled (post-consumer) glass. • Non-laminated glass is easier to recycle.	54%

CONCLUSION AND RECOMMENDATIONS

Material	Current standard approach	Current circularity score	Improved circular approach	Improved circularity score
Blockwork	• All new blocks. • Traditional blockwork uses mortar to bond, making it more difficult to reuse without downcycling. • Recycled content around 20%.	42%	• Retain/reuse existing blocks from decommissioned buildings. • Higher recycled content. • Use dry interlocking blocks which can be easily assembled and disassembled. • Explore the use of alternative binders and additives to enhance longevity without compromising future likelihood of reuse.	58%
Plasterboard	• Gypsum based plasterboard, made with some recycled content (Typically only 9.45% but can be up to 30%) and can be recycled at end-of-life provided not contaminated/ bonded. Currently only 17% of plasterboard waste is recycled.*	4%	• Implementation of closed-loop schemes. • Deconstructable/De-mountable for adaptability. • Increased recycled gypsum content. • Use of sustainable bio-based materials (cellulose).	73%
Raised access floors	• All new raised floor tiles and pedestals	69%	• Reclaimed floor tile. • Reused pedestals.	100%
Complex building services	• Reuse of services components is rare. • Complex parts can make reuse and recycling challenging. • Services tend to be replaced after just 15 years.	4%	• Avoiding waste from tenant fit-out. • Modular units, designed for disassembly. • Units designed for disassembly and upgradability. • Products as a service model, whereby manufacturers retain ultimate ownership.	69%

* British Gypsum Gyproc EPD

CONCLUSION AND RECOMMENDATIONS

Closing material loops: Recommendations

There are five key actions that can support a more circular materials approach on a construction project:

1. Ensure that circularity is a key metric for the success of a project in the same way that carbon and green building certifications currently are. There needs to be full commitment on reuse from the inception.
2. At design stage, assess the materials and systems in use and understand what it would look like to close the material loops in each case, following the waste hierarchy to prioritise direct reuse where possible.
3. Engage with material reuse suppliers early in the project to inform them of any suitable materials that might become available from deconstruction, and to understand availability/stock of materials that could be used in the project.
4. Design and construction teams must take responsibility for the end-of-life scenarios of all building inputs, with consideration of how the building comes apart as much as how it goes together.
5. Embed circularity actions in building operations and maintenance documentation for futureproofing, including material passports.

Building/material passports

Material passports are digital documents containing a building's components, characteristics, and materials. They provide a reliable source of information regarding their potential value for current use, future recovery, and reuse. By recording details of the components used these digital 'passports' make it significantly easier to harvest materials for future reuse.

Material exchange platforms

An online marketplace for materials, where developers can buy and sell materials salvaged from previous projects, would help address lack of supply in the circularity material market connecting buyers and sellers.

The construction industry is at a turning point. Fundamentally, moving from a linear to a circular way of thinking in construction will require a change in how we approach projects. Reused and recycled materials must be prioritised from the start of a project if we want to reach net zero.

Supporting policies and regulatory frameworks play a pivotal role in driving circular construction practices. Governments and regulatory bodies must incentivise sustainable procurement practices, mandate minimum recycled content requirements, and offer tax incentives for adopting circular approaches.

Joint supply chain initiatives – such as material recovery programmes and closed-loop systems underpinned by a flexible warranty extending the coverage period for products designed for reuse – all form part of a holistic approach to avoid using raw materials in the first place and accelerate a shift towards a circular construction model.

CONTRIBUTORS

mace

Mace is a global company of consultancy and construction experts. It provides consulting and construction services for many of the world's most inspiring buildings and infrastructure projects and programmes – from Olympic parks and iconic skyscrapers to state-of-the-art data centres, schools, hospitals and homes.

The privately-owned company, headquartered in London, UK, has an annual turnover of £1.9bn. Over 30 years, its growth has been fuelled by an adventurous spirit and the relentless pursuit of a better way. Today, the company employs over 7,000 people across four global hubs in the UK & Europe, the Middle East and Africa, the Americas and Asia Pacific.

In January 2021, Mace became a carbon neutral business and launched Steps Without Footprints, a strategy detailing how it will continue to reduce Scope 1, 2 and 3 emissions. In December 2022, Mace passed the major milestone of saving over one million tonnes of carbon from its clients' operations, and in March 2023 they announced a new target to save over ten million tonnes of carbon globally by 2026 .

ARUP

With over 16,000 experts spanning various fields from engineering and economics to ecology, Arup operates in 30 countries and has engaged in projects across 160 countries.

In 2020, the firm joined the World Green Building Council's (WGBC) Net Zero Carbon Buildings Commitment, aiming to achieve net zero carbon in operation for all assets under its control by 2030.

Renowned for expertise in infrastructure and buildings, Arup's approach to the design and delivery of projects encapsulates the idea of 'Total Architecture', which demonstrates how circularity is manifested in the built environment. Influential relationships with government and key industry stakeholders means that it is well positioned to promote and drive forward the circular economy agenda.

Arup has been a knowledge partner of the Ellen Macarthur Foundation since 2016. Both organisations advocate for cohesive, system-level change as the foundation of shaping a better world.

Research

Salvatore Capotosto
Operations Director, Private Sector – Mace

Matthew Brinklow
Senior Sustainability Manager, Responsible Business Practice – Mace

Amy Smith
Sustainability Consultant – Arup

Margaret Hamilton
Associate, Sustainability – Arup

Kerem Karakose
Graduate Digital Consultant – Arup