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The Reuse Hierarchy

Introduction

As structural engineers, we have a pivotal role in reducing embodied carbon in the built environment[1][2]. The Reuse Hierarchy presented here provides a clear, evidence-based framework for decision-making, prioritising retention, repair, and refurbishment of existing structures over more invasive and disruptive interventions.

Towards the top of the hierarchy, reduced levels of waste, and reduced external inputs of energy and materials leads to lower embodied carbon. As interventions move further down the hierarchy, waste, material use, and carbon intensity increase. By applying this hierarchy, engineers can maximise the value of existing assets, minimise environmental impact, and align our projects to whole-life carbon and circular economy principles.

Background

Structural engineers play a decisive role in shaping the material and carbon outcomes of the built environment. The primary structure is typically the single largest contributor to a building's embodied carbon, yet it is also the element with the greatest capacity for longevity, adaptation, and continued use. Decisions taken by structural engineers therefore have significant influence on whether value is conserved or discarded.

As structural engineers we must prioritise reuse because the construction sector is a major contributor to embodied carbon and material waste. In the UK, over 60% of waste generated comes from the construction, demolition and excavation sector[4]. Every asset and component reused reduces the need for new materials, cutting both energy consumption and greenhouse gas emissions. Beyond environmental benefits, reuse also preserves the value of existing assets, minimises landfill, and encourages innovation in design for adaptability. With growing regulatory and societal pressure to decarbonise infrastructure, engineers have a professional and ethical responsibility to embed reuse into their practice, moving away from a default 'demolish and rebuild' approach.

We should resist demolition wherever practicable and embed retention and reuse, in some form, as a fundamental consideration in every design, while confirming through whole-life carbon assessment that it genuinely represents the lower-carbon option[5].

The Reuse Hierarchy provides a clear and logical framework for these decisions. Applied as a priority order, it seeks to maintain structural assets and components at their highest possible value, while minimising waste and the need for additional external inputs of energy and materials. Crucially, as one moves down the hierarchy, both waste generation and embodied carbon emissions increase.

The hierarchy can be applied at both an overall asset level, as well as to the various structural items which make up the asset (e.g. foundations, superstructure, secondary steelwork etc.). In each case, preference should be given to the highest level of the hierarchy.

The Reuse Hierarchy

The Reuse Hierarchy (see Figure 1) is defined as follows:

1. Retain
2. Repair
3. Refurbish
4. Retrofit
5. Remodel
6. Repurpose

Each step down represents a reduction in retained structural value and a corresponding increase in intervention, material demand, and carbon impact.

Retain: the structural default

Retention sits at the top of the hierarchy because it preserves almost all embodied value. Retaining existing frames, slabs, foundations, and loadbearing elements avoids demolition waste, new material production, and energy-intensive construction processes.

Multiple industry studies show that the substructure and superstructure typically account for 50–70% of a building's upfront embodied carbon (A1–A5), depending on typology and material choice[6][7]. As a result, retaining the primary structure is consistently identified as the most effective strategy for reducing embodied carbon.

Retention is not passive. It requires investigation, testing, and reassessment, often using modern analysis methods that were unavailable at the time of original design. However, the carbon cost of these activities is negligible compared with the emissions associated with concrete production, steel fabrication, demolition, and waste processing.

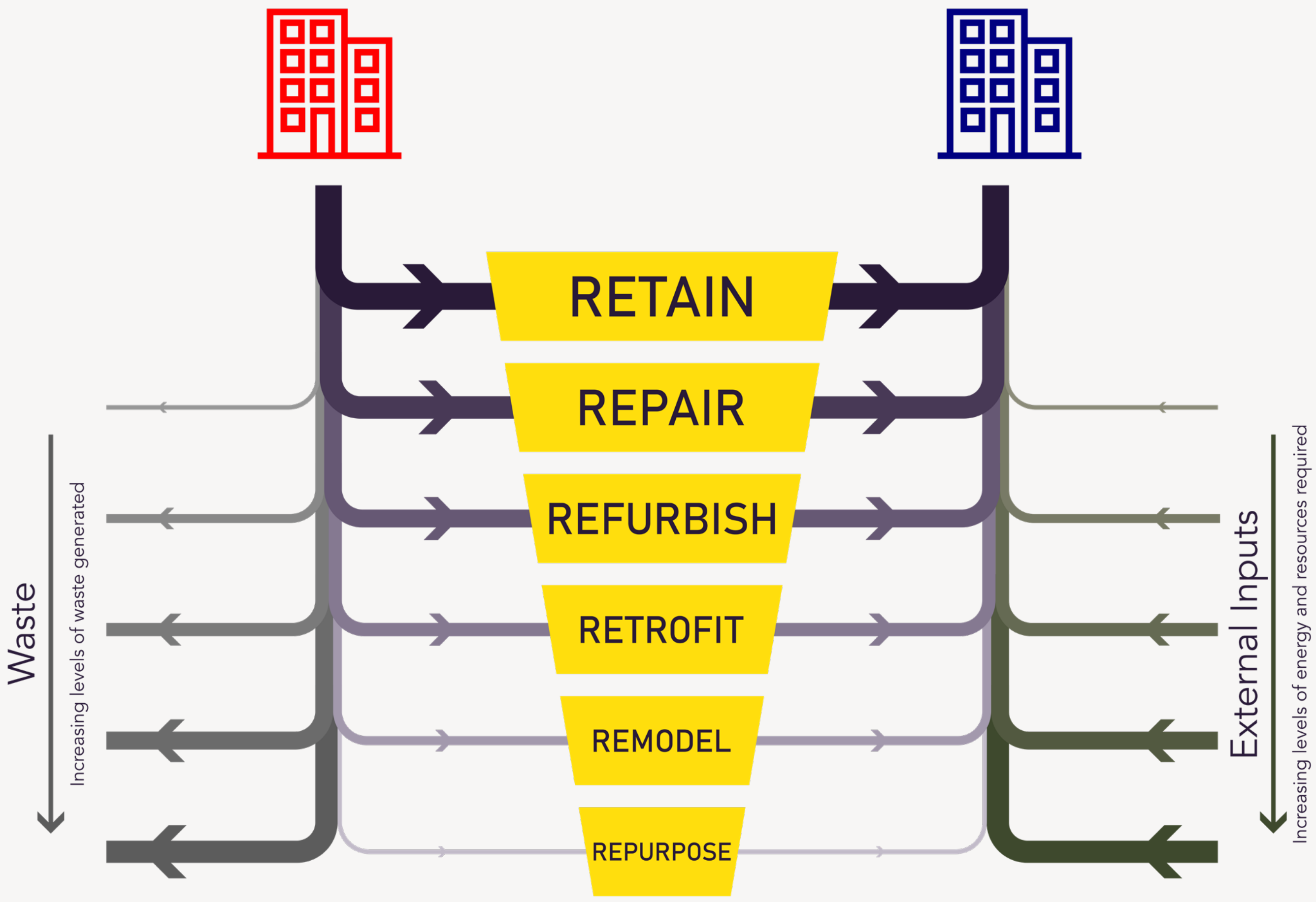

Figure 1: The Reuse Hierarchy

Repair: low-carbon life extension

Repair addresses localised deterioration while retaining the vast majority of the original structure. Typical interventions include concrete repair, corrosion mitigation, strengthening of isolated elements, and protective treatments.

Repair interventions generally carry an order of magnitude lower embodied carbon than replacement of equivalent structural elements and are a key mechanism for extending service life with minimal environmental impact.

For structural engineers, repair demands rigorous diagnosis and durability design, but from a whole-life carbon perspective it remains one of the most efficient interventions available.

Refurbish: retaining the carbon-intensive frame

Refurbishment typically involves retention of the primary structural frame while upgrading secondary elements. This approach preserves the most carbon-intensive components of the building, particularly reinforced concrete and steel frames.

Whole-life carbon studies show that frame retention can significantly reduce upfront embodied carbon when compared with full demolition and rebuild, even where significant non-structural replacement is undertaken[3].

However, these savings are highly sensitive to structural decisions. Conservative assumptions leading to unnecessary strengthening or replacement can rapidly erode the carbon benefits of refurbishment.

Retrofit: carbon trade-offs must be explicit

Retrofit involves performance-driven interventions directed at improving operational energy, resilience, or regulatory compliance, rather than changes driven by structural necessity. Interventions may range from light upgrades, to deeper measures that introduce new services or environmental performance enhancements. For structural engineers, retrofit can include localised structural modifications or strengthening while retaining the majority of the primary structural elements.

While retrofit can deliver substantial operational carbon savings, it often introduces higher upfront embodied carbon due to additional materials and construction processes.

Both PAS 2080: 2023[8] and the UK Net Zero Carbon Buildings Standard[9] emphasise the importance of whole-life carbon assessment, warning against interventions that reduce operational emissions at the expense of upfront carbon impacts. Structural engineers have a responsibility to quantify and communicate these trade-offs clearly.

Remodel: increasing intervention, increasing impact

Remodelling involves significant structural alteration, including removal of loadbearing elements and introduction of new structural systems. At this level, demolition arisings increase substantially, as do temporary works, construction energy, and new material inputs.

Embodied carbon assessments show that once major structural components are removed or replaced, the upfront carbon profile begins to approach that of new construction, even where parts of the original structure are retained.

While remodelling may still offer carbon benefits relative to full demolition, it represents a clear step down the reuse hierarchy and should be justified accordingly.

Repurpose: the highest carbon reuse option

Repurposing involves adapting a structure or components for a fundamentally different use, often requiring extensive modification or reworking. To repurpose structures and structural components typically requires a significant amount of external inputs and generates higher levels of waste than other forms of reuse higher up the hierarchy.

This reinforces the positioning of repurposing at the bottom of the reuse hierarchy. Although still preferable to demolition, it should only be explored once higher-value options – retention, repair, and refurbishment – have been fully explored and discounted.

At present, there is limited repurposing of structural components being implemented in practice. Issues around supply chains, commercial viability, testing, certification and warranties, amongst others, are hampering the take up of this form of reuse.

However, there are an increasing number of research projects, prototypes and demonstrator projects being undertaken which will hopefully improve the viability of repurposing.

Case Studies

The six short case studies that follow illustrate each of the reuse typologies on the hierarchy (Retain > Repair > Refurbish > Retrofit > Remodel > Repurpose). As is often the case in real world projects there is overlap between the differing typologies of reuse, but these examples clearly demonstrate how reuse has been successfully incorporated.

Conclusion

The Reuse Hierarchy reinforces a fundamental principle for structural engineers: as we move down the hierarchy, waste increases, external inputs increase, and embodied carbon rises. No amount of optimisation in new construction can match the carbon savings achieved by retaining existing structures.

In a carbon-constrained future, structural engineering excellence must include stewardship of existing assets as a core competency. The reuse hierarchy provides a clear, evidence-based framework for delivering that responsibility.

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Case study: Retain - Hay Castle

Hay Castle is an example of large-scale, retention-led structural engineering applied to a scheduled ancient monument with nearly a millennium of layered history. Originating in the early 11th century as part of the Norman invasion of Wales, the castle comprises a medieval keep and portcullis alongside a later Jacobean mansion. Repeated fires and periods of abandonment left parts of the structure critically at risk, with significant loss of fabric and long-standing structural deterioration.

engineersHRW's role focused on understanding, retaining and repairing as much of the existing structure as possible, allowing the castle to be adapted for contemporary public use while safeguarding its heritage value. A detailed structural condition survey was undertaken in collaboration with timber and stone specialists, enabling a forensic understanding of the surviving fabric. This research informed a carefully defined schedule of repairs, prioritising stabilisation, repair and reuse over replacement, and providing a clear basis for construction pricing and delivery.

The project involved a comprehensive overhaul of the existing west wing and the reconstruction of the east wing, reusing historic masonry and structural elements wherever feasible. New interventions were designed to work with the existing structure, accommodating modern requirements such as exhibition spaces, education rooms, improved circulation and lift access, while respecting the constraints of the historic fabric. Within the Norman keep, a new viewing platform was inserted with minimal impact, allowing visitors to experience the structure without compromising its integrity.

Throughout the scheme, conservation principles guided structural decisions. Repairs to stonework, timber floors and roofs were undertaken using compatible materials and traditional techniques, ensuring structural continuity and long-term durability. Externally, reinstated elements and repaired openings were handled with restraint, preserving the castle's established character within the townscape of Hay-on-Wye.

The completed project has transformed a fragile, partially derelict monument into a resilient public building, extending its life and relevance.

Structural engineer: [engineersHRW]
Photos: Andy Stagg

Case study: Repair - Bradford Live

Bradford Live is a compelling example of repair-led structural engineering, demonstrating how careful investigation and targeted intervention can revive a highly degraded historic structure. Originally constructed in 1930 as the Bradford Odeon, the building had suffered extensive alteration, prolonged water ingress and structural uncertainty following decades of neglect and a prolonged period of dereliction. When Price & Myers was appointed, the priority was not replacement, but understanding what viable structure remained and how it could be repaired and adapted.

A detailed programme of investigation underpinned the approach. A comprehensive 3D point cloud survey was used to map inaccessible voids and establish a clear understanding of the original structural fabric, the impact of 1960s insertions, and areas of deterioration. This forensic understanding enabled later interventions to be precise and proportionate.

The removal of later intrusive alterations revealed the original auditorium structure for the first time in half a century. With much of the decorative fabric lost, the retained structure became a defining architectural feature, with exposed brickwork, riveted steelwork and new structural elements clearly expressed rather than concealed.

The most significant structural challenge lay in upgrading the roof. Substantial acoustic and thermal enhancements were required, adding considerable load to the existing riveted steel trusses. Rather than wholesale strengthening or replacement, Price & Myers undertook detailed back-calculation of forces through the entire load path, assessing capacity down to individual rivets to verify what could safely be retained.

Elsewhere, repair and sensitive replacement were key. A severely deteriorated hollow precast and timber plank floor was replaced with a lightweight concrete solution carefully designed to replicate the original dead load. A missing balcony section was reinstated and strengthened to meet modern vibration criteria, while historic iron beams spanning the Bradford Beck were locally repaired where corrosion had occurred.

Throughout, the project followed a light-touch philosophy of "doing no more than necessary," resulting in a robust, characterful venue that preserves the embodied value and cultural significance of the original structure.

Structural engineer: Price & Myers
Photos: Philip Vile and Nigel Jarvis

Case study: Refurbish - Kinning Park Complex

The Kinning Park Complex project is a clear example of how sensitive structural refurbishment can extend the life and usefulness of an existing community building while retaining its architectural and social value. Originally constructed in 1916 as an extension to Lambhill Street Primary School, the red sandstone building had evolved incrementally over the decades, accommodating a wide range of community, cultural and educational uses. Narro Associates was appointed to support a major redevelopment that would transform the building into a flexible, accessible, multi-use community hub while working with, rather than against, its historic structure.

Central to the project was a commitment to adaptive reuse and the retention of existing structural elements wherever possible. Structural interventions were carefully targeted to enable new uses across all three storeys without unnecessary replacement. A new passenger lift shaft was introduced to provide level access throughout the building, requiring selective alteration of internal floors and walls while preserving the primary structural fabric. Within a double-height space, a new mezzanine floor was inserted to create additional office accommodation, designed to integrate with the existing structure and load paths.

The refurbishment also involved opening up previously compromised spaces by removing intrusive post-1950s interventions. This revealed the original double-helix stair and restored the clarity of the central atrium, allowing natural light from the existing rooflight to once again animate the heart of the building. These changes improved legibility, safety and accessibility while celebrating the original structural intent.

Where historic structural elements had deteriorated, Narro Associates prioritised repair and restoration over replacement. Existing members were strengthened or repaired using compatible techniques, minimising the introduction of new materials and preserving the character of the building. Improvements to the external fabric, including repairs to stonework and upgraded windows and doors, further enhanced durability and performance.

Completed in 2022, the refurbished Kinning Park Complex has become a vibrant and inclusive community resource. Its recognition by the Royal Incorporation of Architects in Scotland in 2024 reflects the success of a structural refurbishment strategy rooted in reuse, restraint and long-term stewardship.

Structural Engineer: Narro Associates
Photos: Will Scott Photography

Case study: Retrofit - Neighbourhood North

Neighbourhood North is a clear demonstration of how structural retrofit can unlock the value of existing commercial buildings while delivering substantial carbon and performance benefits. Integral Engineering Design supported the transformation of North Quay House, a four-storey 1980s quayside office building in central Bristol, retaining and remodelling the existing steel-framed structure rather than pursuing demolition and rebuild.

The structural strategy focused on maximising reuse of the existing frame while accommodating new architectural and environmental aspirations. A new four-storey steel-framed corner extension with CLT floor decks was introduced to form a double-height atrium entrance and provide additional office space. This intervention was carefully integrated with the retained structure to avoid unnecessary strengthening and to maintain continuity of load paths.

A key element of the retrofit was the upgrading of the building envelope. The existing masonry façade was retained but new larger windows were created to improve the thermal performance and daylighting. These needed some steel strengthening to avoid overloading the remaining masonry, however this approach still reduced overall material use.

Internally, the extension incorporated low-carbon materials, most notably cross laminated timber (CLT) floor slabs, reducing embodied carbon while working within the constraints of the existing steel frame. The embodied and operational carbon of options were considered with lifecycle analyses. In some cases, the monetary cost of an option, e.g. CLT floors versus PMF composite, was calculated as higher, but this was outweighed by the carbon saving and marketing potential.

Neighbourhood North achieved BREEAM Outstanding and EPC A ratings, demonstrating the effectiveness of a retrofit-first approach. By retaining and adapting the existing structure, the project has extended the life of a dated building, reduced waste and embodied carbon, and delivered a modern, low-energy workplace that reconnects with its waterfront context.

Structural Engineer: [Integral Engineering Design]
Photos: Integral Engineering Design

Case study: Remodel - Selfridges Duke Street

The Selfridges Duke Street project demonstrates how large-scale structural remodelling of an existing building can be successfully delivered through forensic analysis, careful sequencing and close collaboration, even within a fully operational retail environment. Expedition Engineering was appointed to unlock the potential of Selfridges' flagship London store by enabling a new customer entrance on Duke Street and improving circulation across the wider building, all while maintaining largely uninterrupted trading.

Decades of piecemeal alterations had left the store with a highly complex and inefficient structural arrangement. Before any remodelling could proceed, Expedition undertook detailed structural investigation to confirm their understanding of the existing fabric of one of the UK's oldest steel-framed buildings. This process of unpicking the structure was fundamental to identifying load paths, constraints and opportunities for reuse, allowing ambitious architectural proposals to be realised without unnecessary demolition.

The creation of the new Duke Street entrance required extensive enabling works, including the relocation of existing structural obstructions and the formation of new openings. These interventions were carefully planned and phased so that major structural alterations could take place just metres from customers. Even significant basement and foundation works were executed while the store remained fully operational, demanding exceptional precision in temporary works design and construction management.

A key intervention was the construction of a 50m long truss bridge within the basement to relocate HGV delivery access. This not only resolved complex logistics constraints but also improved the streetscape at Duke Street. Beneath the bridge, a new escalator tunnel was formed to provide a dedicated access route for office staff, further enhancing internal circulation.

As the structure was progressively exposed, unforeseen conditions were inevitable. Expedition maintained a continuous on-site presence, enabling rapid engineering judgement informed by detailed analysis. This approach often reduced or eliminated the need for intrusive strengthening and managed risk pragmatically to mitigate impact on programme.

The £300m redevelopment has increased retail space by 10% and extended the life of a century-old building by an estimated 100 years, demonstrating the value of adaptive structural remodelling over wholesale replacement.

Structural Engineer: Expedition Engineering
Photos: Expedition Engineering

Case study: Repurpose - Rafter Walk

The Rafter Walk project exemplifies how repurposed materials can play a central role in modern structural engineering. This 170m long steel-frame bridge, featuring distinctive timber fins and designed by Asif Khan Studio, spans the historic Canada Dock in London as part of British Land's Canada Water Masterplan. Whitby Wood provided the structural, civil, geotechnical, and geo-environmental engineering for the scheme, delivering a sensitive design that balances aesthetic ambition with sustainability and practical constructability.

A key innovation was the use of repurposed steel tubular piles as foundations for the bridge. The boardwalk is supported on pairs of repurposed 356mm diameter steel tubes, used as piled foundations, supplied by Cleveland Steel and Tube. Originally manufactured for gas distribution, these ex-stock seamless pipes were a cancelled order, offering sufficient material strength (higher than originally specified) and with certified mechanical properties. By repurposing these tubes, the project avoided sourcing new steel, reducing embodied carbon and promoting circular economy principles.

Installation required precise positioning to support the double-curved bridge deck, which spans typically 8m between supports. Tubes were driven using excavator-mounted side grip vibrating hammers and back-driven 5–6m into the stiff clays beneath the dock, ensuring stability for the steel superstructure above. The ladder-frame arrangement of paired piles, coupled by cross elements, provided a robust foundation system capable of accommodating the timber bearer-supported decking and fin plates that anchor the architectural timber fins.

Rafter Walk not only provides a visually striking pedestrian route with environmental enhancements such as new wetlands and the Southern Steps, but it also showcases the potential for circular engineering solutions. By integrating repurposed steel into the primary structural system, Whitby Wood delivered a low-carbon, technically rigorous, and contextually sensitive bridge, highlighting how existing resources can be transformed into durable, high-performance infrastructure.

Structural engineer: [Whitby Wood]
Photos: Luke Hayes

The Engineers Reuse Collective CIC is a not-for-profit group of practising engineers championing, accelerating and delivering reuse in the built environment to support the transition of the UK's built environment to Net Zero Carbon.

Our mission is to dramatically increase reuse within the built environment, with minimal reprocessing, to support the transition to circular economy principles and to urgently reduce the carbon intensity of the built environment.

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