

How Structural Engineers can influence sustainability



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Oct '23	P01	Initial issue for external comment
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CUNDALL



There is a lot of information available to structural engineers on their ability to influence sustainable design. However, there is limited guidance on how and when to consider this within their day-to-day delivery of projects, following the standard stages of design as defined by RIBA. This document will look at each RIBA stage in turn and identify the specific activities that can be undertaken to help drive low embodied carbon solutions and contribute to the achievement of net zero on projects, working in collaboration with other disciplines, clients and contractors.

It is recommended that this document is read alongside the graphic on the next page.

This document contains a mixture of original content and information produced by others, all aligned to the RIBA-mapped format. This includes the IStructE [SPoW Sustainability Checklist](#), which has formed the basis for parts of this document, with sections of the text either taken directly or expanded upon and then applied to the RIBA stages. Reference should also be made to the IStructE [Design for Zero Book](#) and the IStructE [Sustainability Resources Map](#), both of which have helped to inform this document alongside the other references





DESIGN TEAM
ENGAGEMENT



EMBODIED
CARBON FOCUSED
OPTIONEERING



ZERO CARBON
DESIGN PATHWAY
DEVELOPMENT



EFFICIENT DESIGN



MATERIAL SELECTION
AND SPECIFICATION

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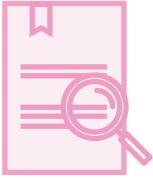
[Implement material specification](#)

POST

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Stage 1 - Preparation & brief



Design team engagement

Establish project aspirations: Work with the client to understand their aspirations and to what extent their governance requires consideration of sustainability. Help the design team to understand the carbon impact of early-stage decisions by asking pertinent questions, which may not be exclusively structural in nature. For example: Is a basement really required? Can the building's orientation or massing be adjusted to reduce operational energy demand? Can "typical" spans, heights and loading allowances for a sector be challenged to allow smaller sections to be used?

Design brief: Linked to the above, work with the client to agree and fix the design brief early on, particularly aspects such as loading allowances and any limitations on headroom and column/wall positions, such that these can be considered when undertaking early design. Aim to avoid changes to the brief beyond this point, as the carbon impact for incorporating will typically increase the later into the project these are introduced.

Information gathering: Aim to remove areas of uncertainty as early as possible to help minimise conservatism. For example ask the client to undertake early ground investigations to understand ground conditions, seek out available record information and identify structural surveys that might help enable reuse of existing assets.

Embodied carbon focused optioneering

Reuse and refurbishment: Advocate for reuse, refurbishment and/or extension (both vertically and horizontally) and demonstrate the potential value of this approach to the client. This could include reviewing other buildings in the vicinity or the client's wider portfolio which could be more suitable for retrofit/refurbishment. If full or partial retention is not feasible, explore opportunities for component reuse (e.g. foundations or steel framing, on-site recycling of concrete and masonry). This may require a pre-demolition audit and/or materials testing. Additional time and cost may be required as a result but could produce savings overall and this should be clearly explained and quantified where possible. Consideration should be given to approaching specialists who could inform on degree of potential reuse (e.g. for steel sections).

Relevant Guides

(Refer to references section for more information)

[Introduction to refurbishment](#)

[Circular design](#)

[Reuse of components](#)

[Reuse of foundations](#)

[Reusing steel](#)

[IStructE Sustainability Resource Map – Section 4.2](#)





Zero carbon design pathway development

Set ambitions and limits: Complete a project pathway/ make use of the [IStructE sustainability report](#) template (report [overview](#)). Agree on appropriate embodied carbon limits for the building type, using benchmarks from LETI, SCORS, or develop project-specific limits for sectors without published benchmarking. Assist with the establishment of a method of embodied carbon tracking/calculation that is compatible across the whole design team and is to an agreed standard and level of detail. Identify whether to target specific accreditations (BREEAM, LEED) and which credits will be targeted so early-stage design can be developed with these in mind.

Relevant Guides

(Refer to references section for more information)

[SCORS Introduction](#)

[LETI embodied carbon primer](#)



Stage 2 - Concept design



Design team engagement

Design coordination: Work with the wider design team to establish key coordination principles. For example:

- Agree horizontal and vertical services distribution strategy and interface with structural frame
- If a basement is planned, establish appropriate waterproofing strategy as this could drive the basement form and size

Compare upfront and operational carbon of facade system options and discuss the interdependencies of the structural design with the façade design and MEP design (e.g. deflection criteria and impacts of these on structural form). Advocate for the façade engineers and services engineers to conduct sensitivity analyses on the balance of embodied and operational carbon over the whole life of the building. Coordinate with all disciplines to minimise finish requirements (fire, durability, noise, aesthetics), particularly raised access floors and screeds which can be very carbon intensive.

Relevant Guides

(Refer to references section for more information)

[Balancing embodied and operational carbon.](#)

Structural resilience: Identify potential climate change impacts on the design requirements for the project over its intended life span to ensure resilience (eg increased storm/wind intensity, increased depths of snow, increased temperatures, rising flood levels) and factor into the Basis of Design.

Relevant Guides

(Refer to references section for more information)

[Safety when designing lean](#)

Embodied carbon focused optioneering

Carbon calculations: Calculate carbon and present results to inform design decisions and comparison of options. Don't let uncertainty deter from undertaking carbon calculations – do them anyway. Clearly communicate the scope and limitations of assessment, providing a summary against the limits. Use estimations and like-for-like studies at early stages. Communicate opportunities and progress to the design and client teams regularly (eg add to agenda for team and client meetings).

Relevant Guides

(Refer to references section for more information)

[How to calculate embodied carbon](#)

[Brief guide to calculating embodied carbon](#)

[IStructE structural carbon tool](#)

[Built environment carbon database](#)

[RICS Whole Life Carbon Assessment: Second edition](#)

Early manufacturer communication: Speak to a variety of suppliers to gain a better understanding of accurate embodied carbon values specifically related to the job and site location, to help inform the design choice. Feed this data back into embodied carbon assessment. Early engagement may also reassure design team on availability and cost of materials e.g. availability of supplementary cementitious materials, cost differential of electric arc furnace steel, stock of second-hand steel.





Deconstruction/reuse: Develop design principles with the intention that structural elements can be disassembled for reuse in the first instance or recycled where necessary. Ensure plan for responsibly disposing biogenic materials to avoid end of life emissions. For example timber to be recycled into particleboard or wood pellets, or used as biomass ideally with energy recovery, and not going to landfill.

Relevant Guides

(Refer to references section for more information)

[Demountable composite construction systems](#)

and basements, highlighting the carbon impacts of each. Review proposed capacity and serviceability criteria and challenge where appropriate to reduce material use. Ensure ULS governs where possible with appropriate utilisations both in ULS and SLS (note this must be accompanied with efficient sizing and appropriate form). Consider ease of constructability to help lower contractor's efforts/emissions.

Relevant Guides

(Refer to references section for more information)

[Setting carbon targets](#)

[Lean design](#)

[Design for zero book](#)

Zero carbon design pathway development

Communicate best options: Inform client of the best and most innovative options trialled in optioneering. Outline best practice and use a project-appropriate medium (e.g. Stage 2 report) to highlight the key realistic steps to reduce carbon in the next stages of the project.

Review project pathway: Review sustainability ambitions and targets as defined in pathway and ensure the design adheres to them or any reasons for not achieving are recorded. Review the design principles agreed with other disciplines and ensure the design is working to achieve the required whole life carbon performance, including any actions for the next design stage.

Efficient design

Maximise structural efficiency: Review proposed building layouts and massing considering structural efficiency and cross-discipline impacts. Ensure efficient layouts of cores and vertical systems, reducing services distributions and the need for transfers and complex framing. Advocate for maximum structural efficiency: eg avoid long spans, shallow structural zones, transfers,

Review client requirements: Continue to challenge brief requirements that are restrictive to low carbon design. Consider building typology, design life & location to understand levels of certainty around future use of building. Engage with planners to understand the long-term vision for the surrounding area. Agree strategy towards designing for adaptation to avoid increasing upfront carbon as far as reasonably possible (eg through access to structure for strengthening, drop out panels for service distribution, etc). Demonstrate cost benefits of targeted strengthening if this becomes a driving requirement, instead of blanket flexibility through excessive loading and serviceability criteria. Ensure adaptation strategies align across disciplines.

Relevant Guides

(Refer to references section for more information)

[Design for zero book](#)





Basis of Design: Capture all agreed principles and approaches within a Basis of Design document, which should be shared with client and design team for agreement at close of Stage 2. This will provide confidence that Stage 3/4 design can be progressed without risk of change.

Material selection and specification

Material choice: Consider which structural materials are most suited to the building's setting, typology and other requirements (e.g. local availability, lightweight vs thermal/acoustic/damping mass, easily transported to site, compatible with off-site manufacture and modularisation, buildable and maintainable by local workforce). Are there insurance or costing issues that could be overcome with early stakeholder engagement e.g. use of structural timber or novel products?

Relevant Guides

(Refer to references section for more information)

[Making low carbon material choices](#)

[Design for zero book](#)

[Short guides to carbon factors for key materials](#)

[IStructE Resources Map: Section 2.0](#)

[Mass timber insurance playbook](#)

Low-carbon designs: Review different superstructure and substructure systems, estimating the carbon footprint of each, and advocate for the lowest carbon combined solution (helpful to compare against a baseline solution to clearly show improvements).

- Consider carbon impacts of using different materials and systems.
- Consider alternative and low-carbon foundation solutions, like using ground improvement techniques to reduce size of foundations needed (working with geotechnical engineers).
- Ways to incorporate local and novel products and solutions and encourage best practice in the industry.
- Advocate for sensible location of heavy (or dynamically sensitive) equipment by positioning them on ground bearing slabs, suspended slabs with short spans and greater structural depth, or isolate heavy loads close to vertical supports.
- Green roofs for biodiversity, blue roofs for SuDS, allowance for PVs.

Relevant Guides

(Refer to references section for more information)

[Lean design](#)

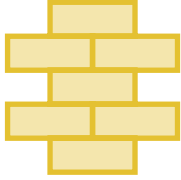
[Design for zero book](#)

[Mass timber insurance playbook](#)

[CONCEPT Tool](#)



Stage 3 - Spatial coordination



Design team engagement

Early coordination: Seek early design freezes with the client and design team, particularly prior to tender, to enable time to carry out final member calculations and reduce sizes where feasible.

Early contractor engagement: Advocate for early contractor engagement to discuss approaches to reduce carbon and improve efficiency at the construction stage, such as use of precast concrete over in-situ. Seek clarity on product specific deflection limits and other serviceability criteria as they might be more lenient than what is specified by brief/typical codified limits.

Embodied carbon focused optioneering

Update carbon calculations: Update carbon calculations to reflect development of design and present results to inform design decisions. Make use of Revit model to assess material quantities more accurately, making use of developed embodied carbon calculation tool where appropriate. Communicate opportunities and progress to the design and client teams regularly (ie add to agenda for team and client meetings). Calculate carbon impact of any proposed changes so this can be factored into decision making progress of whether to adopt alongside other parameters such as cost, buildability and programme impact.

Relevant Guides

(Refer to references section for more information)

[How to calculate embodied carbon](#)

[Brief guide to calculating embodied carbon](#)

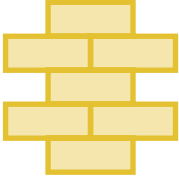
[IStructE structural carbon tool](#)

[Built environment carbon database](#)

Zero carbon design pathway development

Review project pathway: Review sustainability ambitions and targets as defined in pathway and ensure the design continues to adhere to them or any further reasons for not achieving are recorded. Review the design principles agreed with other disciplines and ensure the design is working to achieve the required whole life carbon performance, including any actions for the next design stage.





Efficient design

Optimise ULS design: Look to optimise the ULS design as far as possible. Examples of ways to do this could include

- Permanent & partition loads should ideally be accurately assessed based on specific systems specified.
- Use codified load reduction factors within load combinations (eg multi-storey building factors, ECO eq.6.10a, etc).
- Seek input from fire engineer to undertake detailed calculations, avoiding potentially conservative code tables and potentially allowing omission/reduction of fire protection.
- Explore the possibility of using reduced live loading in areas such as mechanical plant and storage as requirements mature (note any deviation from design standards may require client approval, further justification and additional liability and must be managed carefully).

Relevant Guides

(Refer to references section for more information)

[Floor loading and the climate emergency](#)

[Safety when designing lean](#)

[Fire safety and the climate emergency](#)

[Lean design](#)

[Design for zero book](#)

Review SLS criteria: Look to optimise the SLS design as far as possible. Examples of ways to do this could include:

- Review SLS criteria and avoid conservatism by accurately defining deflection, sway, cracking, settlement and dynamic criteria based on actual systems and usage where possible (e.g. ensure façade criteria is aligned with supplier requirements). Relax criteria or allow local exceedance where possible to do so without impacting function.
- Accurately assess vibration if governing. Consider actual walking patterns and critical response areas.
- Use pre-cambering and pre-setting where deflection governs.
- Consider whether modelling member end fixity in detailed design stage could improve SLS performance.

Relevant Guides

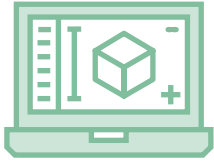
(Refer to references section for more information)

[Lean design](#)

[Design for zero book](#)



Stage 4 -Technical design



Embodied carbon focused optioneering

Update carbon calculations: Update carbon calculations as design approaches completion. Use Revit model to assess material quantities more accurately, including embodied carbon calculation plug-in where appropriate. Ensure calculations are consistent with material specification. Calculate carbon impact of any proposed changes so this can be factored into decision making process alongside other parameters such as cost, buildability and programme impact. Communicate results as part of design to ensure visibility to all parties, including contractor during tender, so these can be considered during procurement and construction.

Relevant Guides

(Refer to references section for more information)

[How to calculate embodied carbon](#)

[Brief guide to calculating embodied carbon](#)

[IStructE structural carbon tool](#)

[Built environment carbon database](#)

Efficient design

Optimise section sizes: As a basic principle, minimise volume of material used. Optimise material strengths to suit design requirements, for example:

- Use lowest strength concrete required for durability and crushing in beams and slabs.
- Use higher strength concrete in compressive members.
- Consider using S460 steel in members that are governed by strength rather than stiffness, such as columns, to reduce section sizes.

Account for full restraint conditions of members governed by buckling. Use software to quickly size all the members then engage with the contractor on where it may be necessary to put material back in, for example to suit buildability. Avoid temptation to add further reserves of capacity “just in case” and design for optimisations close to 100% alongside design reviews and rigorous calculation checking.

Relevant Guides

(Refer to references section for more information)

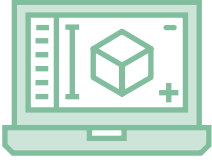
[Rationalisation vs optimisation](#)

[Design for zero book](#)

Zero carbon design pathway development

Review project pathway: Review sustainability ambitions and targets as defined in pathway and ensure the design adheres to them or any reasons for not achieving are recorded. Ensure the strategy is clearly communicated to the Contractor so any requirements can be suitably considered.





Assess modelling assumptions: Consider partially fixing beam ends in structural model to take advantage of real-life connection rigidity (say 10% fixity). Structure becomes stiffer and mid-span bending moments and deflections are reduced, potentially allowing reduction in member size. Similar approach can be adopted for fixity of column bases. The assumptions on fixity must be clearly communicated to the connection designer.

Relevant Guides

(Refer to references section for more information)

[Design for zero book](#)

Relevant Guides

(Refer to references section for more information)

[Sustainable steel specification](#)

[Sustainable concrete specification](#)

[Low carbon concrete routemap](#)

[The efficient use of GGBS in reducing global emissions](#)

Member reuse: Explore the possibility of direct reuse of existing structural elements, particularly steelwork, rather than using new sections. If possible, make use of contractor/fabricator's contacts as to what might be available, or otherwise make use of the IStructE database.

Relevant Guides

(Refer to references section for more information)

IStructE [Circular Partnerships Database](#)

Contractor proposals: If contractor is in place, look to update design to take on board any potential sustainability improvements available via the supply chain, such as use of precast concrete, modular design, prefabrication, etc

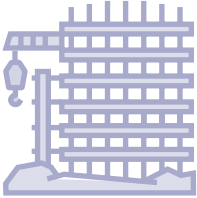
Material selection and specification

Sustainable material specification: Make sure that lower-carbon materials are not seen as a bolt-on that can be value-engineered out post-tender. The materials specification should align with assumptions made in embodied carbon assessments during design, which the client should have bought into. Include key sustainability requirements directly in material Specifications, and require suppliers to demonstrate compliance through embodied carbon calculations.

Cement replacement targets/requirements, or adoption of alternative products (eg Earth Friendly Concrete), should be explicitly noted in specification, while allowing for flexibility in cement combinations to suit local availability. Specify record-keeping requirements of steelwork to allow potential reuse in future. Take care not to over-specify eg avoid highly worked concrete finishes where not required, steelwork protection tailored to specific environments rather than adopting most onerous requirements throughout.



Stage 5 - Manufacturing & construction



Design team engagement

Sustainable construction: Establish a project mechanism for undertaking as-built assessment of embodied carbon, which includes tracking material waste. Share data, carbon calculations and design decisions (including the Pathway Document) to allow the Contractor to understand design intention and optimise CDP (Contractor Design Portion) items (e.g. steel-to-steel connections, RC detailing, piled foundations). Engage with contractor on the potential use of the permanent stability system in the construction case to avoid the need for additional temporary works. Advise on the impact of any proposed design changes from a carbon/sustainability perspective. Aim to avoid any load allowance increases or similar changes to the permanent design needed only for the construction stage through use of appropriate temporary works (e.g. backpropping).

Embodied carbon focused optioneering

Update carbon calculations: Continue to update carbon calculations to take on board any Contractor changes/developments and relevant CDP design.

Zero carbon design pathway development

Achievement of targets: Ensure that project pathway requirements, including the structural embodied carbon targets, are achieved through construction and don't deviate from the proposed design. Collaborate with clients, architects, engineers, and contractors to further reduce construction waste.

Efficient design

Record information: Ensure that key structural principles are clearly communicated to enable future modification and/or refurbishment of buildings. Ensure loading plans and key structural info (eg material grades, foundation capacity, etc.) is captured to assist in the future adaptation of the building or its deconstruction/demolition. One approach to this could be generation of a standard "building information" package with a design philosophy, loading plans, general arrangements, pile schedules, concrete cube results and other relevant information.

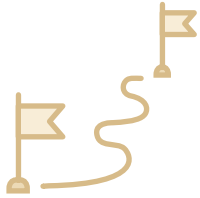
Digital twin: BIM model should be used to store as-built information (including carbon data), acting as a digital twin to be used during operation and at end of life.

Material selection and specification

Implement material specification: Discuss specifications with contractors to understand limitations and possibilities. Safeguard sustainability measures against value engineering or programme pressures where possible eg enforce limits on cement content so concrete strength is not increased for time gains (consider admixtures in this case). Identify elements which may be more suitable for reused steel (eg secondary steel). Aim to get support from client to ensure design and specification is what is constructed on site. Push for suitable evidence of compliance from Contractor, as required by specification and provided through formal technical submittal process.



Post project completion



Design team engagement

Lessons learnt: Capture feedback and report successes and failures to inform future work. What was effective and what hurdles were faced? What sustainability deliverables were achieved and missed? Share findings internally and externally where suitable to do so and use to inform future discussions. Develop innovation plans and/or need for additional investigation to address any barriers that may have been encountered. Investigate opportunities for further collaboration with contractors to develop low carbon construction solutions on future projects. Where appropriate, provide feedback to the client on sustainability performance and remind them that the earlier engineers can get involved in the project, the more they can influence the design and achieve a more efficient structure (e.g. shorter spans).

Knowledge sharing: Prepare case studies and offer thought leadership to share lessons learned more widely (e.g. through The Structural Engineer and conferences). Consider presenting to others in team where proprietary products or novel design/construction approaches have been successfully used, including embodied carbon benefits and how design approach would need to accommodate to allow adoption.

Zero carbon design pathway development

Pathway achievement: Review against initially set out targets in the project pathway document.

Document progress: Record and document design decisions to monitor progress towards the zero carbon goal (e.g. projects where it has been possible to utilise recycled steel sections). Share these so everyone can monitor progress.

Benchmarking: Capture embodied carbon data in database to allow for future benchmarking.



References



[Balancing embodied and operational carbon:](#) IStructE publication introducing the idea of a 'carbon payback period' as a metric for assessing the net carbon emissions of design decisions whose scope spans both the embodied and operational carbon

[Brief guide to calculating embodied carbon:](#) IStructE publication briefly outlining embodied carbon calculation principles with an example.

[Built environment carbon database:](#) An industry group working on creating a database of embodied carbon for the built environment.

[Circular design:](#) IStructE publication that explains how structural engineers can incorporate circular economy thinking at each stage of a building's design.

[CONCEPT tool:](#) Concrete Centre-developed spreadsheet tool that compares conceptual designs to Eurocode 2 for 13 forms of RC frame construction, then ranks them in order of cost, programme and embodied carbon

[Demountable composite construction systems:](#) The Steel Construction Institutes publication presenting an approach for designing reusable steel-concrete composite structures.

[Design for zero book:](#) IStructE guide that explains why overdesign is so prevalent, and its impact on material consumption and CO2 emissions. The guidance covers the design process, through to fabrication, assembly, use, and deconstruction. Includes case studies.

[Fire safety and the climate emergency:](#) IStructE publication that urges structural engineers to improve their understanding of 'fire resistance' as the profession looks to innovate rapidly in response to climate change.

[Floor loading and the climate emergency:](#) IStructE publication arguing for designers to challenge overspecification and grasp the opportunity that reduced floor loads offer for low-carbon structural design.

[How to calculate embodied carbon:](#) IStructE publication outlining a set of embodied carbon calculation principles for the structural engineering community to follow.

[Introduction to refurbishment:](#) IStructE introduction to refurbishment.

IStructE [Circular Partnerships Database](#) provides information on vendors who responsibly source building materials.

[IStructE structural carbon tool:](#) IStructE tool to calculate the embodied carbon in a structure.

[IStructE Sustainability Resource Map:](#) IStructE document overview of available sustainability guidance, divided across a number of different areas

[Lean design:](#) IStructE publication that explains how structural engineers can produce designs that make efficient use of materials to reduce their environmental impact.





[LETI embodied carbon primer](#): LETI document providing best practice and toolkits for reducing embodied carbon in buildings

[Making low carbon material choices](#): IStructE publication on choosing the most suitable material for a project and how to use it efficiently.

[Low carbon concrete routemap](#): ICE guide to sustainable use of concrete.

[Mass timber insurance playbook](#): Guide to enable a collaborative approach between construction teams and insurers, opening the door to more.

[Rationalisation vs optimisation](#): IStructE publication that explores ways to improve the utilisation ratio of designs and encourages engineers to challenge assumptions that favour rationalisation over optimisation.

[Reuse of components](#): IStructE publication that briefly describes how materials and components can be reused, along with examples.

[Reuse of foundations](#): IStructE publication covering the key considerations for reusing foundations, including potential benefits, risks and investigations required.

[Reusing steel](#): SCI publication.

[RICS Whole Life Carbon Assessment: Second edition](#): This document sets out an RICS-approved, technical methodology for assessing the carbon emissions arising from buildings and related infrastructure projects throughout their life cycle.

[Safety when designing lean](#): IStructE publication that considers the safety implications when aspiring to a lean design.

[SCORS Introduction](#): IStructE publication providing an overview of the SCORS rating system for embodied carbon assessment

[Setting carbon targets](#): IStructE publication that explains the SCORS rating system and how to adopt targets for projects.

[Short guides to carbon factors for key materials](#): Arup documents setting out the origins of carbon factors for steel, concrete and timber.

[Sustainable concrete specification](#): Concrete centre publication that intends to assist designers in optimising the sustainable credentials of concrete through specification.

[Sustainable steel specification](#): BCSA publication that specifies general requirements and practices for achieving environmentally sustainable steel building construction.

[The efficient use of GGBS in reducing global emissions](#): IStructE paper reviewing the use of GGBS in concrete, providing guidance on how to use it for maximum efficiency in a holistic sense.



