MC 2025
PEOPLE & BUILDINGS
Proceedings of 14th Masters Conference:
London, 15th September 2025

Network for Comfort &
Energy Use in Buildings
http://www.nceub.org.uk

Circular Design in Vertical Extensions: Reclaimed Steel in Structure

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Abstract: Based on the Global Status of Buildings and Construction report, approximately 37% of global CO2 emissions are from materials in building construction. Additionally, with the Government's requirements to achieve Net Zero emissions in the UK by 2050, rapid solutions are required to decrease carbon and CO2 emissions. Moreover, 80% of today's buildings are expected to be in use by 2050, which shows retrofit strategies are a more sustainable solution.

This paper explores the potential of circular design strategies with a focus on reclaimed steel in structural systems by using the Crowndale Centre in London as a live case study. The research explores how parts of the existing structure can be retained for rooftop extension.

Preliminary findings suggest that reclaimed materials can substantially reduce embodied emissions, but wider adoption requires overcoming technical barriers and concludes with practical recommendations for integrating reclaimed elements into structural systems, contributing to more circular design strategies.

Keywords: circular economy, reclaimed material, embodied carbon, steel structure

1. Introduction

The built environment is one of the most significant contributors to climate change, with approximately 37% of global CO_2 emissions linked to construction activities. In the United Kingdom, commercial buildings alone account for 20% of national emissions. The UK is obligated to cut down on carbon from the building sector; therefore, as regulations hold strict positions, a reduction in embodied carbon has become a significant part. Notably, since 80% of the buildings that will exist in 2050 have already been built, the emphasis is shifting from new construction to retrofitting existing structures, a strategy that is both environmentally and economically more sustainable. Therefore, material reuse can contribute to reducing embodied carbon in retrofitted buildings.

This paper aims to investigate the performance of using reclaimed materials, especially steel, in construction projects from the perspective of embodied carbon to align with broader sustainability targets. A few of the central research questions guiding this study are focused on understanding the feasibility, benefits, and challenges of reclaimed steel taken from demolished buildings in new constructions, especially office buildings in London. This paper analyses the use of reclaimed steel in buildings to decrease embodied carbon through the case study of "Crowndale Centre", an office building located in London.

In the part related to the case study analysis, the usage of reclaimed steel in the Crowndale Centre will be examined and investigated based on the literature review to see if this case study is aligned with the mentioned regulations and its impact on carbon emissions. Informing practice with lessons learned regarding strengths and limitations in this approach to reclaimed steel, going forward with a view toward low-carbon construction strategies.

2. Circular economy

The World Economic Forum defines circular economy as 'An industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse and return to the biosphere, and aims for the elimination of waste through the superior design of materials, products, systems, and business models (World Economic Forum, 2022).

The reuse of materials is one of the fundamental aspects of the circular economy, which aims to preserve the value of materials for the longest time possible (World Economic Forum, 2022). Incorporating reclaimed materials into construction projects can significantly lead to lower embodied carbon by reducing reliance on manufactured and newly extracted resources, while also cutting down on waste and related environmental impacts. However, despite its numerous benefits, material reuse remains uncommon and comes with several obstacles in many countries (Arup, 2021).

3. Steel Work

3.1 Assessment and initial data collection

Before the deconstruction and reclamation of the steelwork, collecting data and assessing the existing structure is essential:

- A detailed explanation of the structural system and its performance should be defined.
- The approximate age of the structure should be estimated, which can be obtained from architectural drawings, building records, or local sources.
- A basic listing of the steel members, like beams, columns or braces, should be provided for an easier and faster testing process (Industry CPD, 2021).
- Steel elements should be examined first for any visible damage or repairs or significant corrosion and loss in any part.
- Any evidence of permanent deformation or plasticity, such as warping, yielding or buckling, must be noted because of impact on integrity and reusability (ASBP, 2022).

3.2 Acceptability of reclaimed steelwork

To make sure that reclaimed steel will be safe and effective, it should meet some prior checklist:

- Considering historic grade of steelwork (after 1970 that is S275 grade);
- Avoid encased steelwork;
- Composite steels that for instance have metal deck on top can be extracted but can lead to waste of material, delays, and cost uplift;
- The additional 15% factor is need to be added to the design in buckling check for mostly columns; (ASBP, 2022).
- No built-up members which are formed from various steel pieces (unless welds are tested and meet the certification);
- No spliced members which are connected by bolts or welded splice (in this case, the individual segments can be disassembled, cut and then reclaimed; otherwise, welds need to be tested for performance);
- No considerable loss of any part due to corrosion (if any loss exceeds 5% of the element thickness, it is recognised as considerable and unsuitable);
- No evidence of surface plastic deformation or decreasing corrosion (SCI, 2020).

• Elements should meet the geometric tolerances which are mentioned in BS EN 1090-2 (if they do not meet tolerances, then straightening can be performed to become acceptable) (Selvaraj & Chan, 2024).

Table 1. properties to be declared for reclaimed steelwork according to BS EN 1090-2 (Author)

Features	To be declared	Process
Strength	yes	Examined by both non-destructive and destructive tests
Elongation	yes	Examined by destructive tests
Tolerance on shaping and dimensions	yes	According to dimension survey
Heat treatment delivery condition	If required	Conservative assumption as default
Stress reduction of area requirements	If required	Do not need to declare in general
Impact toughness and strength	If required	Conservative assumption as default
Thickness requirements	If required	Do not need to declare in general
Limitations on internal cracks to be welded	If required	Do not need to declare in general

3.3 Advantages

• Structural steel is usually disassembled instead of demolished, which makes it easier to recover and reuse.

• Bolted sections can be dismantled or even cut nearest to the joints to keep and use most of the length.

• Beams and columns can be cut and resized according to new design needs.

• The smaller pieces can be cut, cleaned and stored in the existing or new site, which decreases the costs.

• The strength and performance of reclaimed steel remains as the new one if the cleaning and testing performs in good conditions.

• The steelwork can be designed with mechanical fixings so it can be deconstructed at end of life (Selvaraj & Chan, 2024).

3.4 Challenges

Reclaimed steel can become more expensive in projects due to the cost of extraction from the old site and the transportation needed for testing and verifications (ASBP, 2022). As cleaning or easier stages can be done in site but testing or cutting big pieces cannot be done in the site. So, the cost of transportation, testing, painting, and reconstruction will be added (Pamidighantam, 2025). These steps also increase the time and labour. However, the cost of new steel is significantly lower in this process. The comparison between the cost of new and reclaimed steel is shown in the graph below.

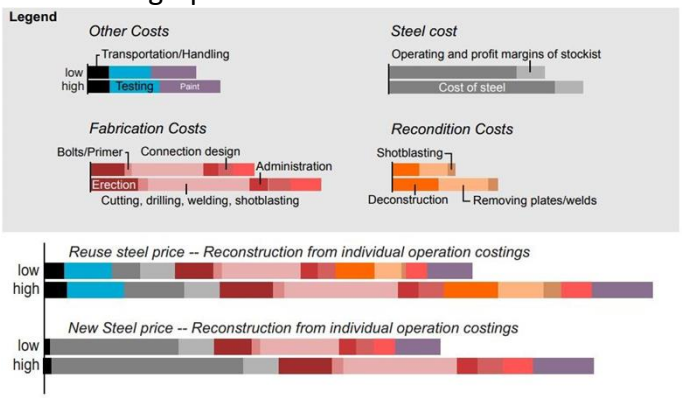

Figure 1. Comparison between reconstructed and new steel prices (Dunant, et al, 2018)

Another challenge of reclaimed steel is finding suitable material at the right time. The timing between sellers and buyers sometimes does not align, or design teams find it challenging to source the proper size or type of steel elements at the required time in the company they have contracted with. This can cause project delays or design changes that would be another challenge (Industry CPD, 2021).

4. Analysis of reclaimed steel in Crowndale Centre

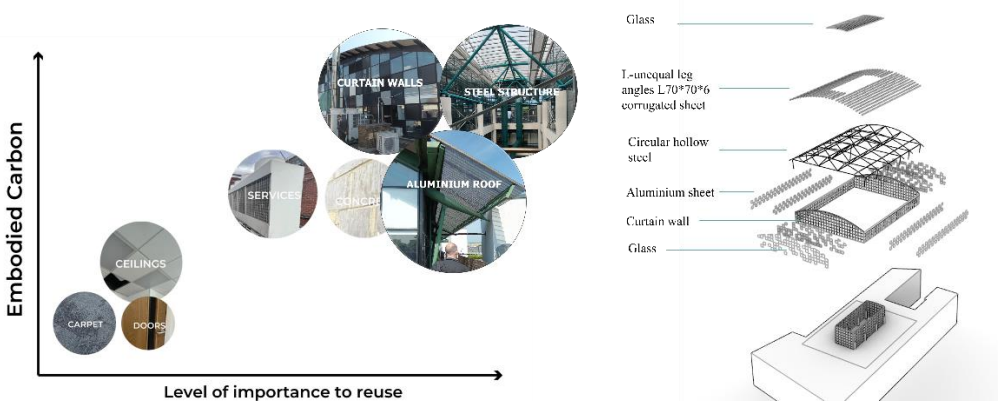

Figure 2. Importance of reusing materials and their availability in Crowndale Centre (Author)

The upward extension that is designed to add 3 floors to the 80s Crowndale Centre office building required about 100 tonnes of steelwork. Through analysis and structural considerations, 21 tonnes of required steel can be reclaimed from 4th floor of the existing site to use as columns.

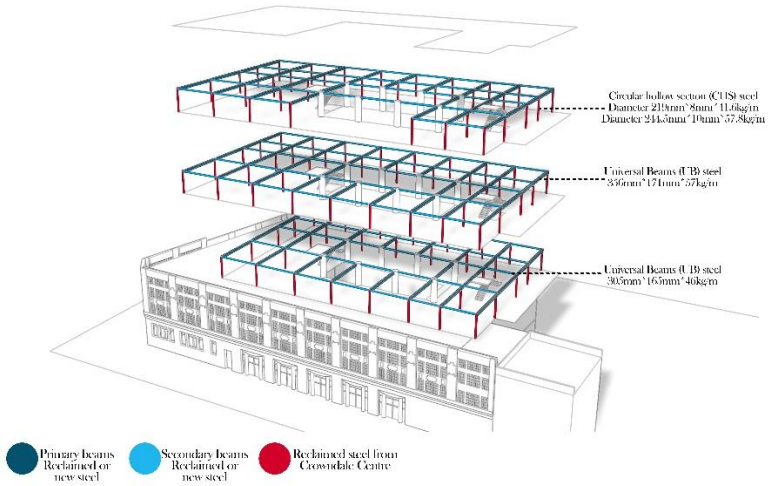

Figure 3. Reclaimed Structural steel design in Crowndale Centre extension (Author)

Cleveland Steel & Tubes is considered a place for the reclaiming process, as no other place in London can recertify the reclaimed steel. As a result, the steel pieces that are identified for reuse must be transported to Cleveland's stockyard in Yorkshire for testing and certification. This process added considerable time and cost compared to doing the testing and transfer locally within London. However, the sustainability features in this project estimate the prices and embodied carbon by figures that indicate it is more beneficial to do it this way compared to buying new steelwork.

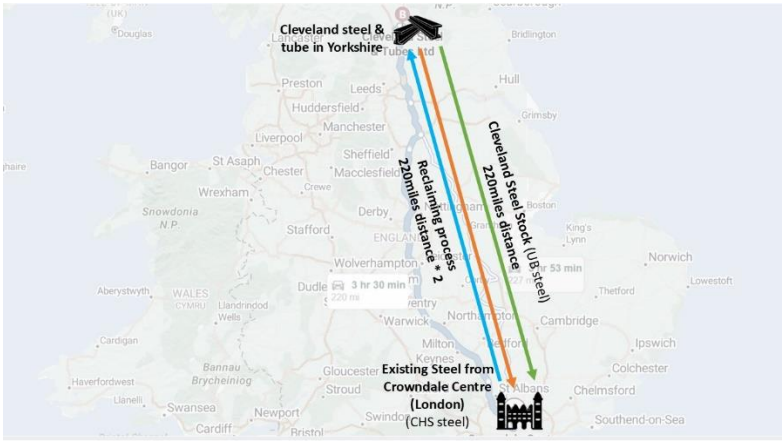

Figure 4. Transferring steel from Crowndale Centre to Cleveland Steel (Yorkshire) for the reclaiming process (Author)

The diagram below illustrates the comparison of embodied carbon between 4 different strategies assuming new steel and then reclaimed steel from stage A1 to A3, and then from stages A1 to A5 that include all transportation and site construction. It shows the challenges of transportation for reclaimed strategy; however, the amount of embodied carbon for new steel is nearly 3.5 times more than all reclaimed. These numbers show how much carbon savings and other benefits can occur in bigger projects.

In many cases, using new steel such as plates and bolts to connect columns and beams is inevitable, so it is suggested to consider many factors such as cost, time and embodied carbon, as using reclaimed materials does not always make sense. So in this project, the connection types are considered as 3d printing pieces.

From my perspective, designing smaller grids (5 to 7 meters) is more beneficial because there will be more flexibility to find the steel, and it can be located more easily in the design rather than larger beams.

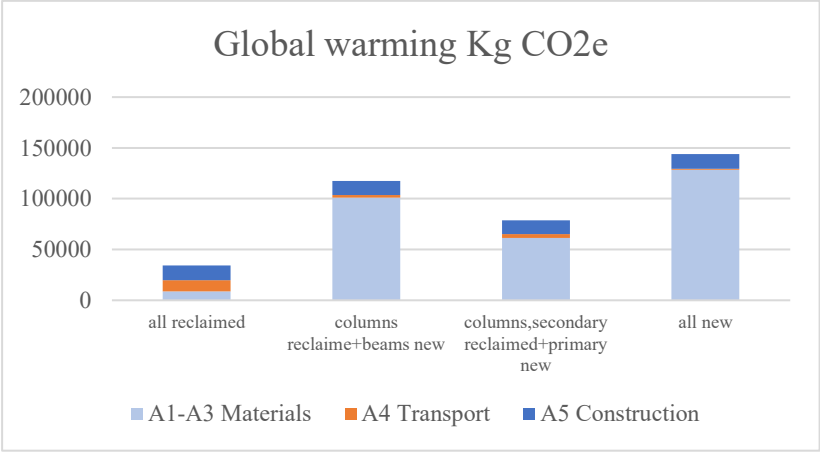

Figure 5. embodied carbon figures for steel at different product stages (author)

5. Conclusion

The Crowndale Centre project clearly shows the potential for transforming old building stock into high-quality, low-carbon workspaces. This building has become a sustainable office by preserving and prioritising reclaimed material and bringing nature to the project.

As the demand for sustainable construction grows, developing better standards and guidelines will be essential in the construction field. Although there have been many

improvements in this process, like increasing the number of stockholders in the UK, there is still a broader gap in industry knowledge and networks for reclaimed materials. So, it is still necessary to introduce it to more clients and designers.

Reclaimed steel sections from old buildings into new structures, if done appropriately, can have a valuable effect on reducing carbon emissions by eliminating energy consumption in the process of re-melting the steel or in the manufacturing of virgin steel. Although there are some undeniable challenges, such as increased transportation and testing costs or finding exact materials according to the design, the environmental benefits and long-term impacts outweigh the obstacles. As a result, reclaimed steel is recommended for use in building developments, mainly if steel can be found on-site or at sites near the building. Also, find a company nearby to test it to decrease the time-consuming and transportation costs.

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