4.Zero waste

An introduction to refurbishment.
Part 1: Identifying opportunities at the feasibility stage

Stephen Fernandez discusses ways in which engineers can explore the potential to refurbish existing buildings instead of demolishing and building anew.

FIGURE 1: Disused buildings at Coal Drops Yard in rundown area of central London

Introduction

The built environment is a major contributor to the environmental emergency that the world now faces. Structural engineers can, however, play an important role in tackling this problem.

Demolishing existing buildings and replacing them with new ones will continue to stress the finite natural resources on our planet, as highlighted by the Construction Declares[1] initiative. Since May 2019, thousands of practices have acknowledged the extreme seriousness of the situation by making a public commitment towards positive change.

The declaration recognises that, if we are to reduce and eventually reverse the environmental damage, we need to take positive steps today. The measures outlined include to 'upgrade existing buildings for extended use as a more carbon-efficient alternative to demolition and new-build whenever there is a viable choice'[2].

Many who work predominantly on new buildings believe that reusing existing buildings is a compromise. As engineers, we can challenge that perception, as there are countless examples where existing buildings have been transformed into some of the most exciting and dynamic places in the built environment.

This article discusses ways in which engineers can identify potential opportunities for refurbishment at the early feasibility stages. Part 2 will then look at how to maximise the opportunities for refurbishment in the design stage.

Benefits of refurbishment

In the UK, 87% of today's buildings are likely to still be occupied by 2050[3] (with a similar percentage worldwide), and therefore it is essential to improve their performance towards zero carbon. Reusing existing buildings can cut embodied carbon by up to 70% compared with demolishing and reconstructing[4].

In addition to the environmental benefits, reusing existing buildings often delivers greater commercial and social returns than demolishing and reconstructing, with evidence suggesting they can yield 10–75% lower costs and tend to be 15–70% quicker to bring back, depending on the level of intervention[3].

Transforming and reusing existing buildings can also bring social benefits, e.g. reuse of vacant industrial premises can stimulate positive changes in attitudes within communities[5].

Coal Drops Yard in London is a fantastic example where largely derelict heritage buildings **(Figure 1)** have been transformed into a popular shopping and dining district. It is now the centrepiece of the regeneration of the wider King's Cross area and the transformation of the existing buildings has created a vibrant city quarter with boutiques, restaurants, bars, cafes and public space **(Figure 2)**.

Despite the dramatic architectural statement made, the structural

JOHN STURROCK

↑FIGURE 2: Transformation of Coal Drops Yard into thriving destination

embodied carbon footprint of this project was only 240kg/m^2 (substructure + superstructure) due to the extensive reuse opportunities found in the scheme.

Imagination is needed at early feasibility stages to identify the potential within an existing building, as is it easy to miss opportunities. In a recent design competition, the client's brief was to design a new office building adjacent to an existing one (the brief did not include any works to the existing). However, rather than just designing a new building, Arup's approach was to provide a new extension but also enhance and transform the existing building as part of the development. Arup won the competition and the client explained that the 'outside the box' solution both met its brief but also ingeniously adapted and enhanced the existing building.

So, transforming and reusing existing buildings can offer many advantages over new-build, including being more cost-effective for clients, creating characterful places and preserving heritage value for communities. As structural engineers, we should be aware of these benefits and confidently discuss them with our clients, as it may be possible to justify the case for reuse over new-build.

Maximising opportunities

As engineers, we have a vital role to play in influencing clients and architects to reuse and transform existing buildings. Often, the decision to retain an existing structure will require some input from the engineer. However, it can be easy to simply focus on the risks and problems associated with keeping it, rather than the potential rewards.

Reusing an existing building is not the answer in every case, but carrying out an early informed assessment can reveal exciting opportunities that would otherwise be missed.

If your client wants to know what they can do with their existing building, the first step it to understand what they want. The types of questions worth asking are:

- What are the client's key drivers?
- Are they unhappy with their existing building?
- If aspects of the existing building are inadequate, can they be adapted rather than immediately concluding to rebuild?
- Are there any problems associated with the existing fabric or structure and can they be repaired to fully address the problems?
- Does the building layout work? (Common challenges include inadequate circulation, insufficient natural light or limited floor-to-ceiling heights. Such issues can be addressed through a multitude of interventions.)

Drilling down into the detail of a client's specific issues can often inform a solution that doesn't necessarily involve demolishing and building anew. The works may not be straightforward for the engineer, but it is important that we can articulate and explain the potential options and solutions to our clients. The potential for reuse can be illustrated using examples or case studies clearly demonstrating the transformation, particularly with images and a narrative of 'before' and 'after'.

An important consideration is how the works could be carried out. This doesn't need to be planned in detail but can be a major factor. For example, can the building remain occupied with phased construction? This can offer significant

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benefits, as temporary accommodation will be limited and temporary relocation potentially avoided.

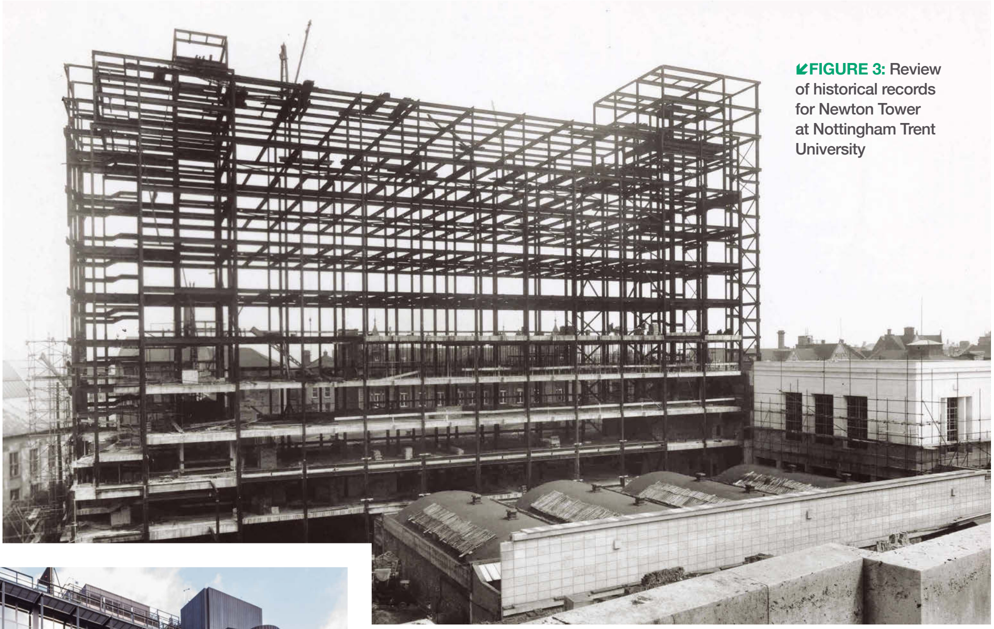
Arup won a design competition where one of the client's key drivers was to ensure that the existing facility remained operational while providing them with a state-of-the-art building. The phasing and decant strategy avoided the need for temporary accommodation and was key to winning this commission.

In addition to understanding your client's specific issues, it is also important to discuss the 'bigger picture' with them. For example, if the client owns several buildings in an area, reusing an existing building could unlock future potential for the surrounding area. Reusing an existing building can also help celebrate their existing assets. There are an increasing number of clients today who want to embrace and showcase sustainability. Can reusing the existing building provide them with green credentials to bring them more business?

What do you need to know?

Carrying out a thorough early assessment can reveal exciting opportunities which can add significant value and might have been missed if reuse was not considered. In order to have early conversations with the client or architect, the engineer needs to have technical knowledge, confidence that the approach can work and believe that it is the right thing to do.

Understanding the variety of approaches and interventions is important, but so is appreciating that all existing buildings are unique and must be considered on a case-by-case basis. The starting point should always be to understand the existing building.



↙**FIGURE 3:** Review of historical records for Newton Tower at Nottingham Trent University

Structural desk study

Before carrying out any works, a structural desk study is vital to develop a better understanding of the existing building. For example, the date of construction may indicate potential inherent defects, knowing the architect or engineer can inform the detailing, materials or structural systems, and the timeline or history may help understand any load path modifications.

↑**FIGURE 4:** 1 Finsbury Avenue, London

Existing information for this desk study may be retrieved from building owner records, local authority records, drawings, calculations and historical mapping (indicating macro changes in plan form or surrounding features); for older buildings, historical papers, articles and photographs can also be useful. The desk study helps to understand a building's history to improve confidence in the structure and its load paths and establish whether it is suitable for reuse.

For example, before works were carried out on the 1960s Newton Building at Nottingham Trent University, an extensive search for historical drawings and records informed the subsequent non-intrusive and intrusive surveys. Construction photographs obtained from the British Library were extremely useful, as they indicated locations of stability bracing and the support for the facade system **(Figure 3)**.

In another example, Arup originally designed the office building at 1 Finsbury Avenue in London in the 1980s. It was subsequently transformed into a flexible workspace, with retail space, restaurants and a boutique cinema **(Figure 4)**. Detailed records were retrieved from archives and, by interrogating the original calculations, columns and foundations with spare capacity were identified, allowing new loads to be introduced with minimal physical intervention. Reviewing the existing information also informed the structural strategy to remove floor areas in the basement to create the necessary double-height space for a cinema, while maintaining the stability of the building.

So, gathering existing data helps to develop a clear understanding of the existing structure and will inform any works to transform and reuse it. However, records should not be relied upon solely. If critical assumptions are being based on elements being constructed as drawn, then some corroborative evidence (e.g. physical confirmation of the construction of the element) will be needed.

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Structural form

It is important to identify and document the existing structure and structural elements. This is likely to be informed by the desk study and may require some inspections and local opening-up. However, it can be an iterative process, as the opening-up may reveal aspects not identified in the desk study.

For example, it may be necessary to understand the existing stability system, but if vertical bracing is not found, further local opening-up may be required to confirm that the beam-to-column connections can act as a sway frame.

This process may need to go through several iterations to test initial hypotheses against site observations, with retesting to confirm.

Understanding historical forms of construction is a key skill that engineers need in order to play a decisive role in the refurbishment of existing stock. How could doctors cure patients if they had not studied anatomy?

Condition

It is essential to understand an existing building's condition if it is to be retained. Inspections, opening-up and surveys can help to develop a better understanding of the building, establish the accuracy of the desk study, identify any defects and inform the need for action. With defects, it is important to fully understand the reasons why they occurred to ensure that any rectification is effective.

The engineer needs to be satisfied that the building does not show signs of structural distress and that an identifiable load path and stability system are present. It is not always necessary

↗FIGURE 5: Grade II* listed Arkwright Building at Nottingham Trent University, with significant historical movement due to settlement

to carry out extensive calculations and back-justification for an existing structure. If it does not show any signs of distress, it is possible that the historical performance can justify its future performance.

An approach often taken for old buildings is the '100-year rule'[6]. This relies on a building being at least 100 years old with no structural distress, an identifiable stability system, and no change of loading.

However, the 100-year rule must also be carefully considered on a case-by-case basis, as there is often a natural process of material change throughout a building's life, which may not be immediately obvious.

Settlement movement against time generally follows a logarithmic curve, so after 100 years, foundation settlement is unlikely to be occurring to any discernible degree. Therefore, any cracking to walls or ceilings that is relatively recent is more likely to be due to another cause, such as subsidence (e.g. trees acting on a clay subsoil or drain leakage) or material degradation (e.g. timber decay or corrosion). Such causes must be identified and eliminated.

The Grade II* listed Arkwright Building at Nottingham Trent University, built in 1877, had suffered significant historical movement due to settlement **(Figure 5)**. Rather than instantly condemning the existing structure or attempting excessive repair works, detailed investigations helped understand why the building had moved, where this had occurred and whether it was continuing.

As evidenced by the cracking and distortions, the building had clearly experienced movements and settlements historically, and further movement would be expected if it was to be subjected to significant alterations to loads on its foundations. Therefore, the design approach was to minimise load changes and, where change was unavoidable, to only locally enhance and strengthen.

Although the building will continue to move, it was not considered cost-effective to try to stop it moving altogether. This would have involved attempting to underpin most of the walls, which would have been very expensive, time-consuming and disruptive, and may not have been successful anyway.

Often, if it is known that a building will continue to move, but not to a degree that will result in anything worse than aesthetic damage, it is possible to incorporate detailing in the finishes that will make the effects of any movement aesthetically palatable, e.g. slip planes and joints in the finishes that eliminate irregular cracking, instead focusing it at locations with straight movement joints.

The engineer also needs to be aware that structures from certain periods are prone to particular forms of degradation or construction problems, such as the presence of asbestos or high-alumina-cement concrete.

During the removal of the internal finishes in the 1960s George Green Library at the University of Nottingham, numerous defects were identified around the perimeter. The building was designed with a combination of *in situ* concrete and precast concrete. The defects encountered were concluded to be a result of poor workmanship and detailing, water penetration at windows and condensation behind finishes, which over time had resulted in the reinforcement corroding and concrete spalling **(Figure 6)**.

The defects were considered to affect the structural strength, robustness and stability of the building and therefore repair was deemed essential. Detailed investigations were carried out to understand the extent of the defects and to develop a repair detail, including visual and delamination surveys, chloride profiling, carbonation, compressive strength and cement content analysis, and cover surveys.

Often, contractors prefer new-build to refurbishment if given a choice, due to the perceived additional risk of the unknown in a refurbishment. De-risking refurbishment by undertaking intrusive investigation at an early stage is therefore important.

Listed status

Listed buildings are considered nationally important and therefore have extra legal protection. The 'listing' of a building in England refers to it being on the statutory list of 'buildings of special architectural or historic interest'. The listing recognises that a building is special in a national context and brings with it controls over alteration, extension and demolition. There are similar protections in place in other countries.

Conservation accreditation systems exist in the UK for members of professional bodies such as the RIBA, RICS, ICE and IStructE which are mandatory for working on some types of projects. Conservation Accredited Engineers[7] have the skills and passion to match the demands of listed buildings, but theoretically any structural engineer can work on buildings protected by heritage legislation. However, it is important to understand the conservation philosophy, different forms of construction, historical materials and to be able to sensitively handle historical fabric[6,8].

↗FIGURE 6: Major structural defects were uncovered at George Green Library, University of Nottingham

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↖FIGURE 7:
Minimum interventions at St Pancras Renaissance Hotel, London

A listing can be perceived as a hindrance and some engineers struggle with the 'philosophy of conservation'. Engineering training is often focused on calculating and analysing, and we are expected to deliver a structure that will not fail. Where the philosophy of conservation has not been understood, this has sometimes led to unjustified interventions to the detriment of the historical fabric.

Conservation philosophy involves adopting principles such as minimum intervention, reversibility and honesty[6,8]. Working on historic structures requires the engineer to develop a wide array of skills and knowledge, but the engineer can also play a pivotal role in helping to protect and prolong their lives.

For example, the 19th century Grade I listed St Pancras Renaissance Hotel in London was brought back into use after 20 years of dereliction and is now a five-star hotel with luxury apartments. However, major works were necessary to meet the requirements for a modern 'luxury' building, particularly for servicing.

The project required a balance between preservation and modification, with a general approach to minimise alterations and to retain as much of the historic fabric as possible **(Figure 7)**. Existing load paths were maintained and remained unaltered, but new slabs were also inserted to support heavier loading from plant, kitchen and cold storage areas, and new staircase and lift cores were introduced to improve circulation and satisfy the fire strategy requirements. These modern insertions were designed to be reversible.

In contrast, the works at the Newton and Arkwright Buildings at Nottingham Trent University involved transforming two separate, and very different, Grade II* listed buildings **(Figure 8)** and joining them together to create a modern academic space and 'heart' to the campus **(Figure 9)**. The brief was to transform outdated and underutilised buildings into modern teaching facilities while conserving the original fabric in an elegant and economical way.

The range of interventions does not compromise the original character but has brought new life to the existing buildings. The transformation secures their long-term future, as well as forming a major entrance into the heart of the campus.

Next time…

The second part of this article will describe how the structural engineer can maximise the potential opportunities for refurbishment once in the design stage. This will cover a number of topics that the engineer will need to be familiar with, including specific structural aspects (such as loading, analysis, foundations), holistic multidisciplinary design considerations (such as floor-to-ceiling heights, adapting the internal layout, upgrading for new building services, facade upgrades), and practical considerations (such as phasing, temporary works).

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Stephen is a Conservation Accredited Engineer and Associate Director at Arup in the UK, leading the civil and structural team across Birmingham and Nottingham. He leads multidisciplinary design teams on projects locally and internationally and has extensive experience working on existing buildings of different ages.

↓FIGURE 8:
Existing buildings at Nottingham Trent University

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↓FIGURE 9:
Transformation of existing buildings at Nottingham Trent University

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