4.Zero waste

An introduction to refurbishment. Part 2: Maximising the opportunities at the design stage

Stephen Fernandez guides readers through the key design areas that offer refurbishment opportunities when working on an existing building.

Introduction

Part one of this article considered how to explore opportunities for refurbishment over new-build before any design work begins. The second part now describes how to maximise the potential opportunities for refurbishment during the design stage.

There are many structural considerations which will be specific to each existing building, and the engineer needs to be familiar with a number of topics. Although this article gives a brief introduction, the reader should familiarise themselves further with each area before starting the design (see 'References' and 'Further reading').

Structural considerations

Loading

If there is no proposed change of use, a building is often initially assumed to have been designed adequately to the relevant codes of practice at the time, but this must be validated through structural inspections and surveys. If no visible signs of distress or decay are observed, it may be possible to conclude that the structure is adequately carrying the loads and that strengthening works are not necessary.

Change of use can give a building a new lease of life, and ensuring it is occupied often helps guarantee that it will be maintained, although this can result in a load increase, possibly through new services or additional imposed loading. Unlike for interventions, the implications of change of use can be quickly determined.

A challenge for change of use of historic buildings is justifying floor loadings to current codes of practice, often due to the low values of material strength and stiffness, as older structures can still work to higher capacities.

Many historic buildings were constructed based on experience, sometimes known as 'empirical design' without any structural design. This is still a reasonable structural approach and could be called 'full-scale prototype testing' today.

It is worth highlighting that structures often have multiple load paths, so the challenge is simply to find one plausible route, although this is highly unlikely to be the actual load path.

Taking a blanket approach towards floor loading often results in the conclusion that strengthening is necessary[1], but by carrying out rigorous engineering, considering possible load paths and understanding the actual loading, it is possible to avoid strengthening in the majority of cases.

The 1960s Newton Building at Nottingham Trent University was originally designed as a technical school and was to be adapted without change of use. Floor live loading from the original codes of practice was compared against current codes of practice. The finishes, services, ceilings and non-loadbearing walls were all to be removed. Prior to removal, detailed surveys helped determine the weight of each element and estimate the allowable new superimposed dead loading. Comparing total existing loading with total new avoided strengthening, as there was no net increase and it was not necessary to carry out extensive 'back-justification' calculations to try to establish theoretical capacities.

Office floor loading in historic buildings[2] describes the problems associated with accommodating office floor loadings in older buildings and suggests that actual loading is usually significantly lower. A practical approach could be to develop a better understanding of the original design loads and ensure that the new use respects these, which may require limiting occupancy levels or setting specific uses for certain areas.

When considering loading, it is important to assess realistic loadings and ask: are higher floor loadings (to give flexibility of use) actually necessary? Or can a lower value be used without compromising the flexibility or structural safety?

The use of the building should not overly restrict the loading on the floors, but equally they should not be upgraded to support loads they will never experience. Perhaps now is the time to challenge the loading stipulated in codes of practice generally?

Calculations and analysis

As a starting point, structural validation checks can typically be assessed using current codes of practice. It is possible to use material strengths obtained from historic codes of practice and other referenced sources or obtained from off-site testing of materials obtained from site.

However, it is important to understand how buildings were designed. Many

"ARE HIGHER FLOOR LOADINGS (TO GIVE FLEXIBILITY OF USE) ACTUALLY NECESSARY?

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↑FIGURE 1: 1–2 Stephen Street in London – underground parking and loading bay converted into flexible office space with maximised floor-to-ceiling heights

historic codes of practice used a permissible stress design approach[3], limiting material stresses under varying loading conditions to an allowable or 'permissible stress'. This is different to the typical modern codified approach of 'limit state design', and so understanding the differences can be useful. Note that although many old codes have been superseded, they can be a useful tool when trying to work with existing structures.

Accurately determining the movement of a structure can also be difficult, as it is impossible to accurately understand all aspects of the structural behaviour (e.g. support conditions or connection movement). It is therefore generally beneficial to carry out comparative studies between the existing and proposed conditions, with sensitivity analyses as required.

Where structural modelling is not helpful or meaningful, it may be possible to carry out *in situ* testing and prototyping, although appropriate caution should be taken to gain a reasonable amount of certainty that the loading will be achieved.

Finally, it is also important to consider the entire building holistically and not focus solely on specific interventions. For example, forming large penetrations in concrete slab bays originally designed to act as continuous over multiple bays, or removing areas of floor, or major interventions for building services which can significantly alter the existing building system and affect the overall building stability.

Foundations

Foundations should be assessed when there is an increase in loading, e.g. due to change of use or if additional storeys are to be introduced – although often old foundations can be justified to take an increase in loading[4].

Reusing existing foundations is becoming a key consideration, particularly in inner-city sites. This can be due to congestion in the ground (which may have resulted from several generations of development) making it difficult to install new foundations without expensive foundation extraction.

Reusing the foundations can yield significant cost savings and provide increased programme certainty due to the reduced risk associated with groundworks.

Holistic design

Floor-to-ceiling heights

The floor-to-ceiling heights should be reviewed in an existing building at an early stage as these can influence how it can be reused. For example, offices typically require greater heights to accommodate service requirements, but developing a truly coordinated solution can maximise the floor-to-ceiling height.

It is possible to work within the constraints of an existing building to maximise the floor-to-ceiling heights. Refurbishment works at 1–2 Stephen Street in London have transformed a previously dark and dingy 1960s building into an efficient and stylish workplace, increasing both asset value and rental income.

The underground parking and loading bay have been converted into flexible office space and floor-to-ceiling heights have been maximised by adopting a semi-exposed services design with floating bespoke metal rafts **(Figure 1)**. This required close coordination and the transformation has increased the lettable area by 10%, which significantly increased the rental value.

Alternatively, more extensive structural modifications are possible. The existing basement in the University of Nottingham's George Green Library would not meet modern building regulations for headroom, daylight and access. The columns were therefore lowered to transform the basement into a useable floor[5], which required major temporary works to support the existing structure.

A pair of deep steel channels were clamped onto the existing columns, transferring their load onto a temporary frame using hydraulic jacks **(Figure 2)**. This process was repeated across the entire basement (while the floors above were occupied) and allowed each column to be lengthened to create a more useable level.

The carbon footprint of such temporary works should also be assessed – at George Green Library, the works were reused several times and the overall carbon savings outweighed the emissions from fabricating the temporary works.

↓FIGURE 2: Lowering existing foundations to increase floor-to-ceiling height at George Green Library, University of Nottingham

Internal layout

When considering the future use of an existing building, the internal layout should be reviewed to understand how reusing the building may meet the client's requirements. The existing structure can be viewed as a constraint, but often provides an opportunity to cost-effectively do something transformative when considered early enough.

Opening up spaces in existing buildings can transform them significantly. If alterations can be limited to removing only non-structural walls, then this can be achieved quickly and simply, but deeper interventions should be considered where the potential impact makes this worthwhile.

The Zeitz Museum of Contemporary Art Africa, in Cape Town, South Africa, is a radical transformation of a historic grain silo, consisting of 42 tightly packed concrete cylinders, which had been disused since 1990 due to containerised shipping.

Rather than demolishing the redundant structure, spaces have been carved out of the cellular concrete cylinders to form galleries and an atrium, allowing natural daylight into the spaces and revealing the original intersecting geometries in an unexpected way **(Figure 3)**. The structural engineering helped give this historic structure new life by reimagining the interior space while retaining the industrial character[6].

The Newton Building at Nottingham Trent University contained redundant engineering workshops and a loading bay, and was subdivided with numerous walls. Opening up the lower levels previously blocked off by a combination of walls, vertical bracing and shear walls stabilising the nine-storey tower has radically transformed the spaces.

The bracing and shear walls have been totally reconfigured, with new bracing and goalpost frames providing lateral stability **(Figure 4)**, to create a new 'communal lung' for the campus. This has secured the long-term future of this Grade II* listed building **(Figure 5)**.

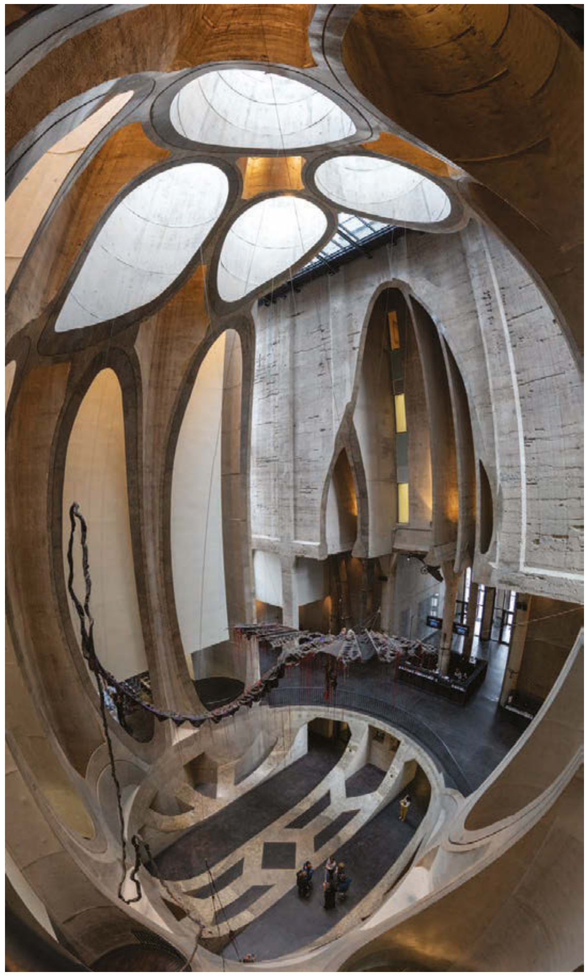

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FIGURE 3: Transformation of grain silo complex at Zeitz Museum of Contemporary Art Africa

Upgrading building services

Although the structure can often be reused in an existing building, existing services frequently need to be replaced with new systems. However, existing buildings should not be treated as a 'blank canvas' with the new service distribution – the starting point should be to coordinate and thread through the existing fabric.

Being proactive as a structural engineer can help guide the services team towards solutions that require minimal intervention for maximum impact. This requires detailed investigation and close coordination between the structural and services team members, but can generate significant cost and programme savings. It is often important that the mechanical and electrical strategy is developed in more detail than for a new-build.

The Newton Building's previous life as a chemistry department yielded unsuspected drainage channels in the laboratory floors and penetrations through beams. These were utilised to distribute the power, data and audio-visual connections and maximised the floor-to-ceiling height. Existing services risers were also reused for vertical distribution, with limited new risers formed through the existing floor. Other features, such as underground service tunnels and basements, were also reused to distribute services.

Facade upgrade

Many old buildings have poor environmental performance, often suffering from summer overheating and significant heat loss in winter. When contemplating reuse of an existing building, an important consideration is the envelope and there are various approaches that can be adopted.

The extreme is to remove the existing cladding entirely, stripping back to the existing structure and replacing with modern cladding. The weight of the new cladding should be considered to either match what the structure was originally designed for or supported, or to determine the extent of strengthening required.

The development of the Arup office in London at 13 Fitzroy Street involved stripping two existing 1950s buildings back to the superstructure, allowing new cladding to be introduced to create a single office complex. Recladding the existing buildings entirely meant that an innovative approach could be adopted, incorporating the ventilation ductwork distribution within the facade, resulting in shallow raised floors for air supplies and maximising the floor-to-ceiling height **(Figure 6)**.

The passive performance of the facade can be improved by incorporating measures such as secondary glazing. The Newton Building has long single-glazed facades between vertical stone

FIGURE 4: Reconfigured stability bracing and shear walls at lower levels of Newton Building, Nottingham Trent University

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FIGURE 5: Opened-up spaces at Newton Building, Nottingham Trent University

fins, but the envelope was vastly improved by retrofitting secondary double glazing with electronically operated blinds within the cavity between the existing and new glazing.

Note that it may be necessary to accept the performance of the existing envelope without altering the fabric in any way – often an approach taken towards listed or heritage buildings to retain the original fabric and character.

Practical considerations

Phasing

Phasing the works can transform existing buildings while still partially occupied. This can be very attractive as it may avoid the need for temporary accommodation. However, it does require careful consideration from the outset and can also influence the structural design and construction methodology.

The implications for building services can also be significant, which in turn can impact the structure. It is therefore essential that phasing of all disciplines is incorporated into the design from the beginning.

At the George Green Library, a key aspect was ensuring continuous operation. A detailed phasing strategy was therefore developed to coordinate construction works with providing an operational facility **(Figure 7)**. This involved first constructing the adjacent extension and lowering the existing basement.

After completion of the extension, the existing library operations were 'decanted' and re-located into the extension, allowing the major refurbishment of the existing building to be completed. This resulted in no temporary accommodation being required and generated considerable savings on potential 'enabling' costs.

Temporary works

Structural works to existing buildings often require temporary works to be considered at an early stage, as they very often will influence the structural design and construction methodology. The temporary works can require significant structural input and may play a major role in establishing the financial viability of a project.

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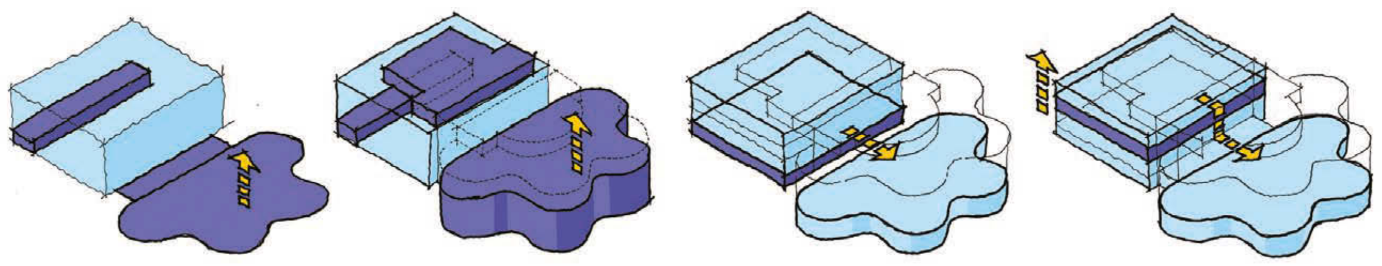
FIGURE 6: Original (left) and refurbished building (right) at 13 Fitzroy Street, London



↑FIGURE 7: Consideration of phasing to keep existing George Green Library occupied throughout works

It may be necessary for the engineer to highlight the temporary works as a critical item, and careful feasibility studies should be carried out so that their viability and likely costs can be assessed. Where significant, the embodied carbon of these works should be assessed as part of understanding the impact of the work.

Opening up the spaces in the Newton Building described previously could only be achieved with early consideration of the temporary works. The sequence of works was carefully planned to ensure that suitable structural support was in place at all stages, that it could physically be installed and that it was suitably priced and programmed **(Figure 8)**.

Conclusions

The two parts of this article provide a brief overview of the primary areas that are necessary to consider when dealing with existing buildings. Part 1 discussed ways in which engineers can identify potential opportunities for refurbishment at the early feasibility stage. Part 2 has considered ways to maximise these opportunities through design.

In order to make best use of our existing building assets, engineers should be able to provide an informed response to the client, which includes thoroughly assessing the technical feasibility of reusing the building. This assessment can help reveal potential opportunities to add significant value, so the engineer can play a pivotal role in unlocking that value.

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

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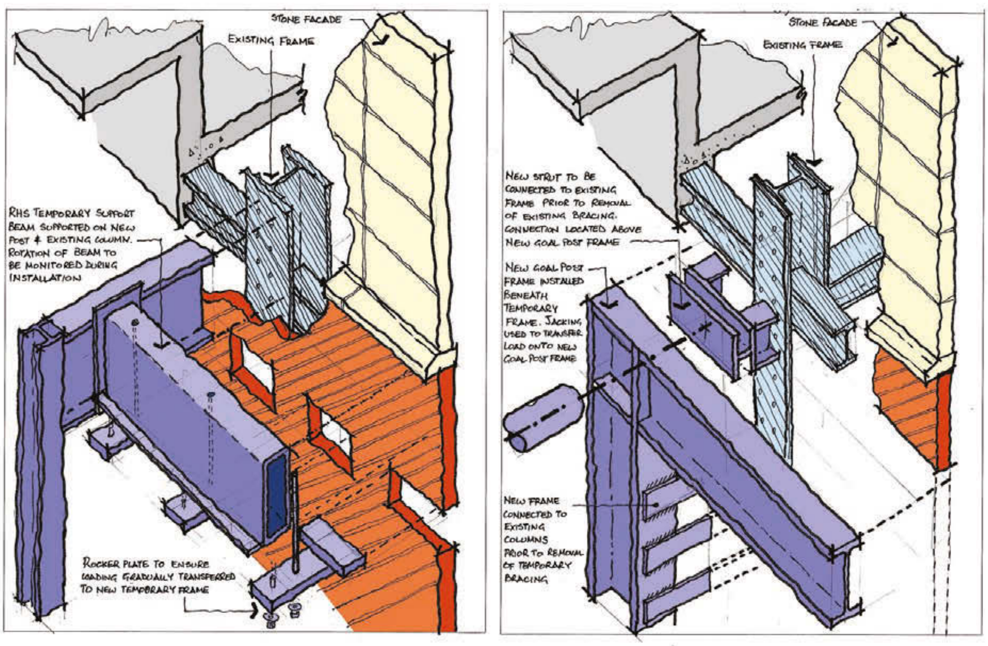

↓FIGURE 8: Sketches illustrating early temporary works considerations at Newton Building, Nottingham Trent University

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