The Institution of
StructuralEngineers

March 2025
Volume 103 | Issue 3

TheStructuralEngineer

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Retaining value

How a staged approach to investigations and targeted strengthening helped a client realise its ambition for reuse and extension

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Mary Ward Centre, London: Risk management of a heavy retrofit and vertical extension of a 1970s concrete-framed building

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SYNOPSIS

This article outlines how a motivated client and design team collaborated to repurpose a derelict concrete-framed building in Stratford, east London. The case study highlights the importance of early conversations for reuse projects and the need to appoint professionals experienced in retrofit to allow clients to understand the primary risks and enable them to make informed decisions. It demonstrates common risks associated with heavy retrofit projects and how an oversimplistic and conservative approach can be detrimental when assessing the viability of reusing an existing building.

The case study also highlights the current commercial challenges that can inhibit the wider uptake of circular economy principles and building reuse. An approach of retention and heavy structural modification is perceived to be a greater risk than a demolition and new-build solution, with numerous areas which could cause uncertainty and, potentially, commercial issues.

In this instance, a financial incentive in the form of a grant was offered by the Greater London Authority for projects adopting a retro-first approach. This grant helped the client, Mary Ward, to commit to the significant upfront investment required for the investigations needed to understand the full cost and complexity of retention, and minimise the project risks to acceptable levels.

Introduction

Mary Ward is an adult education charity based in London which required premises to relocate and grow its services. The charity identified Queensway House – a derelict 1970s concrete-framed building – in Stratford, in the east of the city, as a potential new home.

The charity was able to secure a grant from the Skills for Londoners Capital Fund for the building's refurbishment. As environmental benefits are important when applying, the funding was dependent upon the reuse of the existing concrete frame. There were also potential cost and programme benefits to the client depending on the extent of structure that could be reused. The existing building offered only approx. 60% of the space required to cater for Mary Ward's growing needs, so it was clear that extending would be necessary.

The building was subsequently extended by two storeys on top and 1.5m to the front to occupy a portion of the wide pavement space which the client owned **(Figure 1)**.

A preliminary scheme was put forward by an engineer for a steel-framed airspace extension on top of

↘**FIGURE 1:** Finished building for Mary Ward Adult Education Centre

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the existing frame. Upon completion of their investigations and analysis, they concluded that a complete refurbishment and extension of the existing structure would be commercially unviable and a demolition and new-build approach should be adopted. Given the funding structure and cost estimate for a new-build solution, this put the viability of the project at significant risk.

As SD Engineers have experience in similarly complex refurbishment projects, we were approached to complete an independent review to better understand whether retention could be achieved commercially. A robust and systematic approach was needed to verify the capacity and suitability of the existing frame, reviewed against the design proposals.

Existing building

The building, designed for office use, occupied a split-level site, with the front portion three storeys and the rear four storeys **(Figure 2)**. It had been unoccupied for several years.

The structure, which is a typical 1970s reinforced concrete (RC) frame, has a 220–255mm deep beam-and-pot slab, cast into supporting perimeter and internal beams. Mass concrete pads support the columns, with ground-bearing slabs at ground and lower ground-floor levels, and a retaining wall along the centre of the building, forming the steps in level to the rear. The building had a blockwork central lift and stair core which had been retrofitted during

Project credits

Client:	Mary Ward Adult Education Centre
Architect:	AWW
Structural engineer:	SD Engineers
Project manager:	Featherstone
Geotechnical:	Soils Limited
Quantity surveyor:	Beadmans
Contractor:	Curo Construction
M&E consultant:	Promode
Principal designer:	MLM
CDM coordinator:	MLM
Acoustic consultant:	RBA Acoustics

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↗**FIGURE 2:** Queensway House (front elevation), pre-intervention a previous intervention, and two corner stair cores framed in brickwork.

Justifying the case for reuse

Not all existing buildings will be suitable for retention and reuse. The client was informed that a further detailed study would be required to identify whether the building could be reused or whether an efficient new-build structure would indeed be a better solution overall. Clear communication with the client on the risks is vital and they must be prepared to invest in these investigations as a sunk cost. This is a particular commercial challenge for building reuse.

Having previously worked on a project with a highly ambitious brief, where we added 120 residential units split across three storeys on top of an existing three-storey 'live' superstore on Peterborough High Street, we have learned that the best way to tackle such challenges is to use a systematic approach and split the investigation works into stages, addressing the highest-risk areas first. If the initial investigations are promising, this can give the client the confidence to invest further in more exploratory works, tackling the next highest residual risks, and so on.

The previous engineering assessment had identified some key risk areas which suggested a refurbishment approach was unlikely to be feasible. These included:

- low concrete strength to the frame (25N/mm^2)
- unsuitability to support a dance studio with high imposed/dynamic loading at proposed fourth-floor level
- need for expensive foundation strengthening throughout due to the load increase and presence of compressible silt below existing foundations
- proposed demolition of the weak roof slab as this could not support the proposed floor loading.

Additionally, an ambitious cantilevered staircase supported from the core had been proposed but would have required significant strengthening to the existing frame.

With the information available at the time, we concluded that the level of risk to the project cost and programme was indeed too high for the client to commit to a planning application based on reuse. However, we classed these as 'medium' risk items with potential to become 'low' risk. Following discussion with the client, we agreed that investment in further investigation works was worthwhile, particularly given their commitment to retention.

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↗FIGURE 3: Concrete repairs and new steelwork to support additional upper storeys

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↗FIGURE 4: New steel framing at roof level

When undertaking a heavy refurbishment of an existing building, one of the first actions should be to thoroughly review archive information. We reviewed the building control and planning archives, but none of the original structural information was available, and only a few architectural drawings existed. However, we had access to the investigations carried out by the previous engineers and undertook a site inspection to enable us to plan the intrusive survey investigations required.

We then commissioned a series of material-testing procedures and intrusive opening-up works to further validate the existing building's fabric capabilities and address the key risk areas directly.

Superstructure investigations

Concrete samples were taken and localised breakouts carried out on elements at each level, including columns, slabs, down-stand beams and walls. Given the low sample strength found previously, further concrete samples were taken to test the compressive strength and for carbonation.

The existing RC elements were extensively scanned with a Ferroscan survey as a cost-efficient non-destructive method to gain further information. This was combined with a series of targeted local breakouts to expose and validate the bar diameter and spacing from the Ferroscan, while also showing the condition of the bars.

A sample of reinforcing steel was extracted for tensile testing to establish its material properties. The existing building design loadings and stresses were taken as per the historic 1970s concrete design code of practice, CP

114[1]. Two types of reinforcing bars were commonly used at the time: high yield and mild steel. Proof stress testing was undertaken to confirm which bars had been used in which location.

The compressive strength of the concrete was found to be variable and ranged from C20/25 for beams, to C30/37 for columns, to C25/30 for slabs. Carbonation of the concrete was found to only be at surface level, so the risk of reinforcement corrosion was low, as confirmed by the breakouts. With careful detailing of the new waterproofing and cladding systems, the design life of the building could reasonably be extended for another 30–50 years.

The capacity of the existing beams and columns could be directly calculated from the results of the intrusive investigations and dimensional surveys. A column load design check was performed in line with both the old CP 114 and current Eurocode 2[2] in practice.

Based on the findings of the intrusive investigations, the existing roof RC ribbed slab was found to be insufficient in bending to support the proposed floor build-ups and imposed load. It therefore required strengthening **(Figure 3)**.

The other floors used a load comparison of proposed versus existing to justify the educational use, backed up by checks on the ribbed beams. As such, the ground, first and second floors did not require strengthening.

The rear elevation required strengthening as several columns were found to have inadequate biaxial bending capacity with the additional load of the proposed development. The front and central rows of columns were all found to be able to support the proposed loadings without any additional strengthening works.

Foundations

A commonly cited rule of thumb among engineers is that a 10% increase in load on shallow foundations can be accommodated without experiencing unacceptable settlement or ultimate performance. Any load increase beyond this typically requires detailed justification or, all too commonly, the automatic specification of underpinning/strengthening as a conservative and easier solution for the engineer.

Even with the additional two upper floors built using lightweight construction, the total load increase calculated on some of the foundations was found to be over 35%. Due to the split-level basement at the front of the site, underpinning or extending the pad foundations in this location would have been extremely difficult and expensive as the tops of the pads were over 4m below the pavement level. Foundations located on party wall lines would also have been complex to strengthen.

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FIGURE 5: New composite floor for one of additional storeys, and view of central lift core

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FIGURE 6: Existing concrete frame with steel strengthening

We commissioned new boreholes and trial pits to better understand foundation geometry and bearing strata. Excavations revealed that some of the foundation pads were founded within a thin layer of very weak Langley silt member, while others were situated within the Kempton Park gravel member. The Lambeth group (clays) were found 5–10.0m below ground level.

Initially it was feared that foundations bearing on the weak Langley silt member would need to be underpinned or widened, with a significant impact on cost, programme and embodied carbon. However, by working collaboratively with the geotechnical engineering consultants, the design team agreed on a strategy to explore whether strengthening could be avoided. We supplied detailed time-loading information split out between dead and imposed loads and those impacting brittle sensitive finishes, i.e. glazing. The geotechnical engineering consultants then adopted an analysis method assuming the foundations were underlain by a thin layer of weak cohesive soil (mimicking that found) over a cohesive soil of varying stiffness. The same exercise was carried out with the same weak cohesive soil, this time over a granular soil.

The analysis demonstrated the overall ultimate bearing capacity was highly influenced by changes in the soil mass beneath it and was not primarily determined by the thin clay layer directly underlying the existing foundation. Pore water pressure had dissipated

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FIGURE 7: New steel cross-bracing installed at either end of building to provide additional stability

and ultimate bearing failure was found to be a governing factor. Analysis estimated that, following installation of the glass facade, the increase in foundation load would result in less than 3mm of settlement. As a result of the analysis, only two of the existing shallow foundations at the rear of the building needed to be strengthened. New foundations were designed to bear into the Kempton Park gravels with the same settlement criteria.

Proposed structure

The additional storeys were designed to be constructed using steelwork and a metal deck slab **(Figures 4 and 5)**, with an exposed structural aesthetic to clearly showcase the interface between the new and existing sections and the structural modifications. This exposed structure suited the budget of the client and the ambition to achieve a low-carbon design. Alternative options reviewed for the additional storeys included precast concrete planks and a mass-timber frame. The mass-timber solution was found to be the lowest carbon but was cost-prohibitive for the client.

To address the vibration concern from the proposed dance studio, a series of options were considered by the client and the design team. These included lowering the ground-floor slab to create the required floor-to-ceiling heights at the base of the building, retaining the position but structurally isolating the new steel columns and beams from the existing RC structure, or isolating the new structure from the source vibration using an acoustic floating floor. The acoustic floating-floor solution was selected as the most economical and low-carbon approach.

FIGURE 8: Revit model of steel-framed comparator

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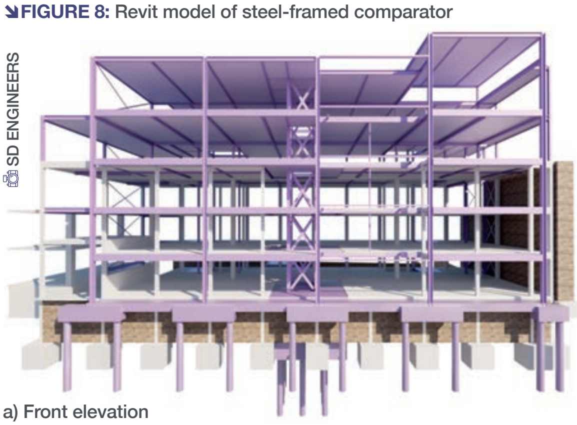
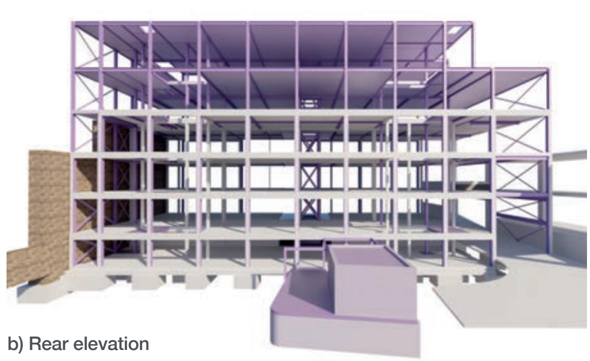


a) Front elevation



b) Rear elevation

The ambitious cantilevered feature staircase design was reviewed and alternative options explored to reduce the loads on the existing frame through the introduction of cables to suspend the landings from the new roof. This largely retained the architect's and client's vision while significantly reducing forces onto the structure and therefore reducing the complexity, cost and carbon of the design. The stairs were later reconfigured further to provide additional internal usable space but still utilised hangers to minimise the structural requirements of the frame and load onto the existing structure.

Given that the structure would remain exposed, meetings were held with the client and design team to discuss the aesthetic of the strengthening works. It was agreed that steelwork would be used to strengthen slabs and columns, providing an economical and honest story of the relationship between the new and existing structures.

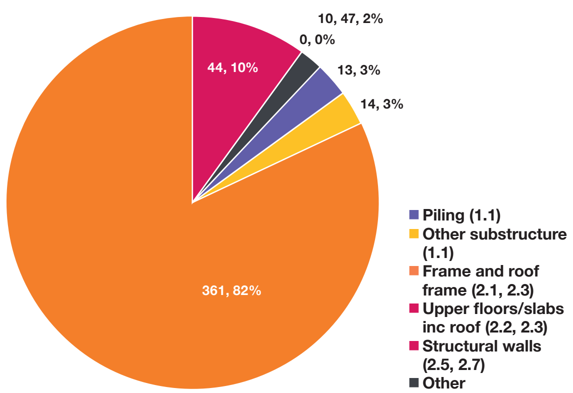
Rather than demolish the existing 'weak' roof slab, we proposed to introduce a steel grillage below the slab. This grillage split the existing slab span, allowing the slab to support the increased floor loadings. The grillage also acts as a transfer structure to support the new columns above. Retaining the slab reduced the need for temporary works and for a new floor to be installed.

Existing columns were strengthened with parallel-flange channel sections bolted either side and packed tight to the floor and soffit to take the additional loading **(Figure 6)**.

A new braced lift core and steel cross-bracing at either end of the building enhanced the stability to account for the increased wind load from the taller structure with the addition of two storeys. The end-bay cross-bracing was a hybrid of new steelwork and existing concrete columns and beams **(Figure 7)**. Investigative works confirmed the existing elements, including rebar in the columns through to the foundation, had capacity for the additional shear and axial loads and could withstand the design forces without further strengthening being required.

The new central lift core required piles due to the restricted footprint and overturning forces to be resisted. The settlement criteria of the piles did not vary greatly from those of the new and existing foundations.

An iterative sensitivity analysis was conducted between the stiffness of the new end-elevation cross-bracing, and the stiffness of the new braced core. This was in order to achieve acceptable building wind drift, while not exceeding pile capacity tension limits in the



This project scheme releases carbon equivalent to:

522 one-way flights from London to New York

261 people's consumption of meat, dairy and beer for 1 year

144 average family cars runnings for 1 year

Scheme performance against targets:

SCORS:	**137 kgco$_2$e/m^2**	**Scheme does not meet target**
RIBA:	**156 kgco$_2$e/m^2**	**Scheme meets target**
LETI:	**228 kgco$_2$e/m^2**	**Scheme meets target**

↗FIGURE 9: Carbon emission breakdown by element, storey addition and strengthening design option (tCO_2e)

proposed core and preventing uplift from occurring in the existing pad foundations below the new braced bays.

Slabs and fire protection

The investigations revealed that the concrete cover to the existing reinforced rib beams was highly variable, from as much as 35mm in some areas to as little as 8mm in others. This level of cover did not meet current code requirements for inherent structural fire performance or structural performance for reinforcement bond.

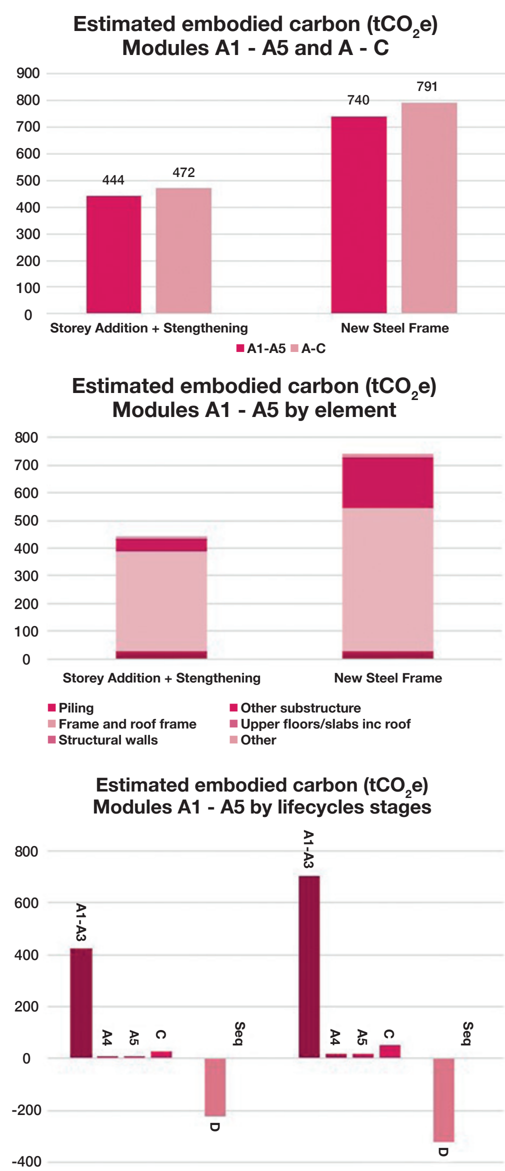
Structurally, the slab had performed adequately over its life, and the applied load to the slab was not being increased. On this basis, a performance-based approach could be satisfied without unnecessary strengthening being introduced.

For the fire issue, we explored commissioning a finite-element analysis to assess the fire performance of the slab as a whole, as a way to avoid the need for additional protection measures. However, the very low cover in numerous areas meant this approach was deemed to be unviable.

The solution adopted was the inclusion of a thin cementitious render to all the existing soffits to provide sufficient cover. This posed a setback for the architectural team as they had envisioned showcasing the painted soffit of the beam-and-pot floor. It also added both cost and carbon to an otherwise stripped-down interior.

Disproportionate collapse

The proposed height and new use meant the building was reclassified as a consequence class 2b structure according to the Eurocodes. It was required to be tied vertically and horizontally to satisfy current



↗FIGURE 10: Carbon emission comparison – refurbishment and steel-frame extension vs new-build steel frame

disproportionate collapse requirements. Although the building has an RC frame, there are no tie beams between the perimeter and internal columns; the columns are tied by the beam-and-pot floor. An intrusive investigation and calculations were therefore performed to confirm that the reinforcement detailing between the existing slab and edge beams satisfied the tie force specified in the code. This approach omitted the need to introduce new tie members, which would have added cost, carbon, and complexity to the services distribution.

Carbon assessment

To inform their progress on reducing embodied carbon in designs, designers should collect data and evidence, and benchmark projects. This information also allows clients to make informed decisions about their schemes, particularly with regards to reducing carbon emissions and the impact of construction on the environment.

To calculate the saving in CO_2 by opting for the refurbishment approach, a new steel-framed building was developed for comparison. The new steel frame was analysed in Tekla[3] and imported into Revit[4] **(Figure 8)**, assuming the same foundations as provided in the proposed option and metal deck slab to allow a like-for-like comparison.

As both the existing and new frames were fully modelled in Revit, technicians used the plug-in for Revit (using EOC ECO2[5]) to calculate the embodied carbon of the two options. Subsequently, the Structural Carbon Tool[6] was used to calculate how much CO_2 would be produced by the single elements.

The carbon assessment for the structural refurbishment calculated there was a reduction of over 40% in embodied carbon compared with the construction of a new building (not including the demolition of the existing frame), with the scheme meeting RIBA and LETI targets **(Figures 9 and 10)**.

Conclusion

The process of reusing the 1970s concrete-framed office building came with extensive challenges, at both design and construction stages. With a project of this type, the key to success is communication and systematic risk management to fully understand the commercial viability.

The upfront investment required for sufficiently detailed investigative works to determine the key risks for refurbishment viability can be significant, with no guarantee they will yield a positive outcome. Additionally, even with extensive investigations, there will always be further challenges uncovered throughout construction, so a suitable contingency is needed with refurbishment projects.

Without the Skills for Londoners Capital Fund, this project might have never come to fruition. The upfront cost for sufficient investigations can be difficult to justify for most clients, but especially difficult for a charity. While VAT is still charged on refurbishment projects in the UK, and planning reform and a carbon tax are still in development, a grant such as this is another tool the government can use to enable reuse possibilities that would otherwise not be financially viable for most clients.

This case study highlights that, when assessing whether it is commercially viable to retain and extend an existing building, an oversimplistic or conservative approach will not only limit new innovations in construction, but will be detrimental in the fight against climate change. Reusing existing building stock and reclaimed materials will be one of the greatest contributions structural engineers can make in reducing the embodied carbon emissions associated with construction projects.

Mary Ward Adult Education Centre opened its doors to students and clients in September 2023, marking a significant milestone in its transformation and its ability to provide additional services for a worthy cause.

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