Renovation not demolition: a case study of saving carbon on a private residence

SYNOPSIS

This article describes a residential project to create a spacious, contemporary family home on the site of a 1960s building, following an early decision to renovate the existing structure, retaining as much of the fabric as possible.

The design approach aimed to simplify the form of the building while also improving its thermal performance and airtightness. Existing masonry walls were retained on the front and side elevations, while internal walls were removed to create open-plan living spaces, requiring a steel sway frame to be installed. A new, almost fully glazed rear elevation was created, with the first-floor wall rebuilt in timber frame.

Existing foundations, concrete strip footings and the concrete ground-bearing slab were largely retained. A new insulated concrete slab was installed where the ground floor was extended, and concrete was broken out locally to allow the installation of new pads where load concentrations exceeded the capacity of the existing foundations.

A carbon assessment indicates that the renovation scheme saved around 45% of the embodied carbon of a hypothetical rebuild scheme, with a footprint of 111kg CO_2e/m^2 compared with 199kg CO_2e/m^2 for the rebuild scheme.

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Project team

Client	Private
Structural engineer	Giraffe Engineering
Architect	CaSA Architects
Contractor	MAKE

Introduction

In the market for high-end bespoke residential developments, client aspirations for a perfect finish, spectacular visuals and high-performing spaces make working within the limitations of an existing building, and all the compromises that entails, particularly challenging.

This project for a large family home on Church Lane in the village of Limpley Stoke, near Bath, started with the assumption by the client that the existing 1960s dwelling would be demolished and entirely replaced. However, led by the architect, we developed a scheme to renovate the existing building, reusing as much of the existing fabric as possible, while achieving the transformational finish demanded by the project brief.

Renovation is a decision which needs to be taken at an early stage, typically before the planning application is submitted, as it will define the shape and size of the property (being constrained by reusing the existing foundations). Therefore, it requires an early commitment from the architect and client, and early engagement with the structural engineer.

In completing this project, we were interested to explore how it performed relative to an equivalent new-build design. Is the embodied carbon saving

> **“LED BY THE ARCHITECT, WE DEVELOPED A SCHEME TO RENOVATE THE EXISTING BUILDING, USING AS MUCH OF THE EXISTING FABRIC AS POSSIBLE**

↑FIGURE 1: Existing house – front elevation

significant, and does it make up for the constraints experienced by having to work within the limitations of the existing building?

Existing house

The original house **(Figure 1)** was well built and had some interesting features which would have undoubtedly appeared fashionable and futuristic in the 1960s, but now gave an overall impression of being dated.

It suffered from awkward proportions, with a low-pitched roof appearing out of proportion to the large masonry elevations and uncomfortably sized square window openings. The main cladding material of reconstituted stone with thick grey mortar joints had stronger connotations of concrete blockwork than the Georgian Bath stone it was trying to imitate.

The eaves were finished in white PVC panelling, drawing attention to the thickness and projection. A 'heavy' featured carport dominated the front elevation. A green copper-coloured membrane with fake seams to mimic a metal roof now appeared dated.

Inside, one futuristic feature was a mechanical ventilation system, complete with a control panel that would be at home in a Bond film **(Figure 2)**. This blew hot air through various voids in the masonry, which would exit through large grilles in the walls of each room. This needed modernising, as did the windowless Jack and Jill shower cubicles squeezed between two bedrooms, and accessed from both by separate doors at each end.

↓FIGURE 2: Original mechanical ventilation system

Design principles

The ambition of the project was to address the uncomfortable aspects of the original house while also upgrading the envelope performance and aesthetic. The exterior would be overclad in new materials, to improve thermal performance and airtightness.

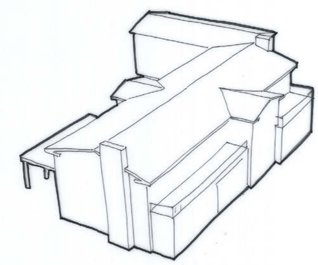
To achieve this ambition, the overall form of the building would be simplified, decluttering the elevations by removing the multitude of projections and embellishments **(Figure 3)**. A new free-standing external wall unifies and extends the front elevation. A new projecting slim-edge roof canopy gathers the spaces together on the rear elevation, and the existing rear projection is removed to simplify the first-floor form.

Structural renovation

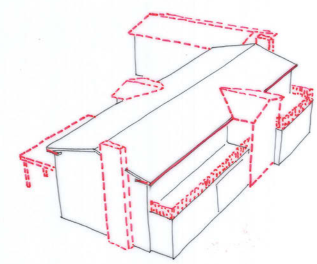
We were fortunate to have access to a set of drawings from the original construction which was still held at the property, showing not only the layout and architectural finishes but also the structural components of the existing house **(Figure 4)**, including the foundations.

Record drawings are so rarely available, yet when present they provide a wealth of information, enabling the existing structure to be fully understood and therefore utilised. Every home should contain its own

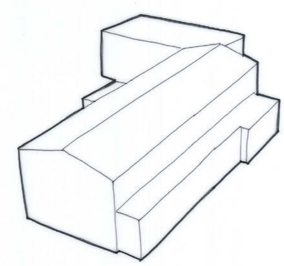
↓FIGURE 3: Overview of design approach



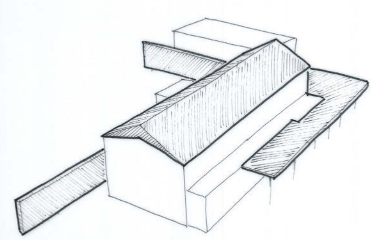
a) Existing house



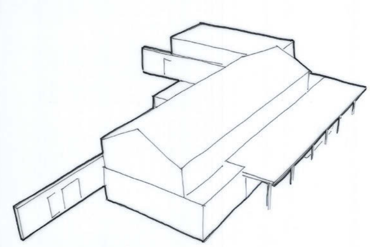
b) Remove excessive articulation



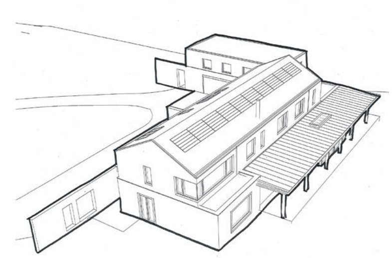
c) Simplified forms



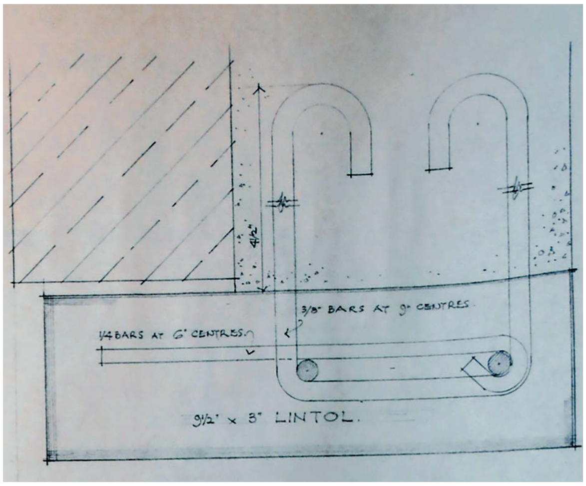
d) Improve proportions



e) Overclad materials.

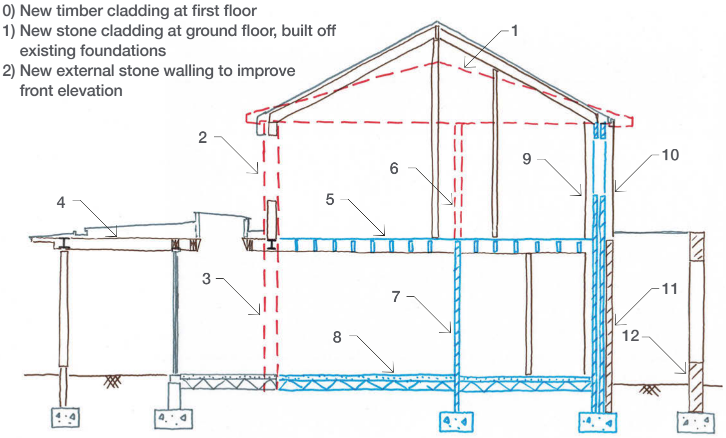


f) Complete proposal



↑FIGURE 4: Extract from record drawings showing level of detail provided

Key
1) Existing trussed roof replaced with new steeper-pitched, vaulted ceiling
2) First-floor rear elevation demolished to simplify temporary works
3) Ground-floor rear elevation demolished to accommodate glazing and rear extension
4) New external roof canopy
5) Existing first floor retained
6) Existing internal walls removed, relocated
7) Some internal ground-floor walls retained
8) Existing ground-floor slab retained
9) Existing walls retained, insulated internally
10) New timber cladding at first floor
11) New stone cladding at ground floor, built off existing foundations
12) New external stone walling to improve front elevation



↑FIGURE 5: Indicative section showing principles of project

Operation and Maintenance Manual, including a set of original drawings for future reference, and details of any alterations.

The record drawings highlighted a specific issue which was also visible on the existing property: the custom-made reinforced concrete lintels over large openings had no bearing onto the outer leaf, and therefore no way to resist the torsional forces caused by supporting the outer leaf of masonry above. This had expressed itself through rotation of the lintels and cracking of the masonry above. With the help of the record drawings, we were able to identify all locations where this detail occurred and rectify by replacing or relieving the existing lintels.

This pitch of the existing roof was increased to improve the external proportions of the building **(Figure 5)**. This was achieved by replacing the existing roof trusses with new, steeper prefabricated trusses over flat ceiling areas, and in other areas, to create a vaulted ceiling. New steel ridge beams were installed spanning between internal walls, with cut timber rafters and plywood sheathing.

On the front and side elevations, the existing external masonry cavity walls were retained, with only minor alterations undertaken to adapt and reposition window openings. Elsewhere, internal masonry walls at ground-floor level were removed to create modern open-plan living spaces. To the rear, large new openings were formed to create an almost fully glazed rear elevation, with sliding doors opening out into the garden.

We explored the possibility of retaining the first-floor masonry wall above the new openings, but this was found to be impractical due to the complexity of the required temporary works, especially since the entire roof structure was to be removed at the same time. Therefore, the entire rear elevation was removed, with propping installed to support the first-floor joists **(Figure 6)**.

This presented the opportunity to rebuild the rear wall at first-floor level in timber frame rather than cavity masonry, which had the benefit of achieving a greater level of insulation and reducing the dead load on the supporting steel beams installed below.

The existing concrete ground-bearing slab was retained. Where the ground floor was extended, a new insulated concrete slab was installed and tied into the existing.

The existing mass concrete strip footings were retained throughout. Where the wall above was removed, there was no need to remove the existing footing, so these were left in the ground except where new foundations were to be installed.

The new brick cladding installed around the building at ground-floor

←FIGURE 6: What remained of existing house after demolition

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ON THE FRONT AND SIDE ELEVATIONS, THE EXISTING EXTERNAL MASONRY CAVITY WALLS WERE RETAINED

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↙FIGURE 7: Completed building

level needed supporting below ground. Trial pits were dug to determine the local ground conditions and to verify the information provided by the record drawings.

It was found that in most cases the existing foundation had a sufficiently large toe to build the brick cladding directly off the existing concrete, and the ground conditions provided sufficient capacity for the existing footings to support the additional weight.

In certain areas where the new cladding needed to project further in front of the existing wall for aesthetic reasons, a new concrete footing was installed beside and wrapping over the top of the existing, to share the load between the two and ensure no differential settlement. Wall ties were face-fixed to the existing stone cladding.

The removal of existing masonry shear walls necessitated the introduction of a new steel sway frame to resist lateral wind loads. The existing foundations were again reused, in this case through the introduction of a steel ground beam which was able to spread the loads into the existing foundation below. This also stiffened the sway frame by way of moment-resisting connections at both ends.

At first-floor level, the existing floor joists were retained and supported on new steel beams running the length of the rear elevation over new glazed openings. Where possible, the new steel beams were supported on padstones built into the existing ground-floor masonry walls. Where necessary, new steel posts were installed to support the vertical loads and to provide lateral restraint to the masonry, which was reduced in places to short piers between glazed openings.

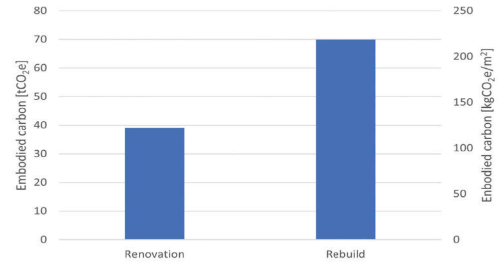
Where concentrated point loads on the foundations occurred, the record drawings allowed us to fully utilise the existing foundation capacity and determine on a case-by-case basis where new foundations were required. Where load concentrations exceeded the capacity of the existing foundation, the concrete was broken out locally to allow the installation of new pads.

The creation of a projecting roof canopy across the rear elevation **(Figure 7)** was a key intervention to modernise the property and enhance the connection between the internal open-plan living spaces and the rear garden. This was formed by perimeter steel beams supported on a series of flitched timber posts with countersunk stainless-steel bolts. Thermal breaks were inserted into the steel connections where these penetrated the thermal envelope.

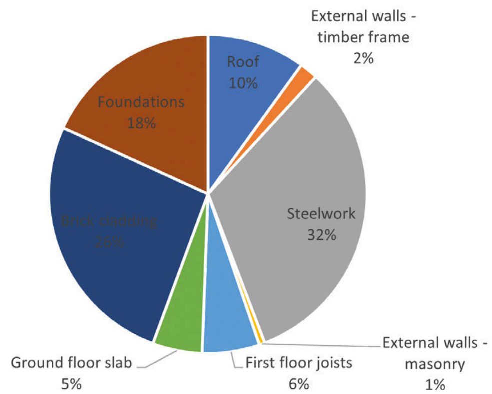
Carbon assessment

A carbon assessment was undertaken using the IStructE Structural Carbon Tool v2.0 (www.istructe.org/the-structural-carbon-tool/). This calculated the embodied carbon in the substructure and superstructure for the renovation scheme and compared it with a hypothetical new-build scheme in which none of the existing structure was retained.

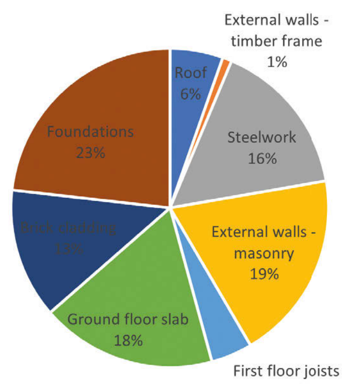
The analysis shows the embodied carbon for the renovation was 39t CO_2e, compared with 70t CO_2e for the rebuild scheme **(Figure 8)** – a saving of 45% of the overall embodied carbon for the



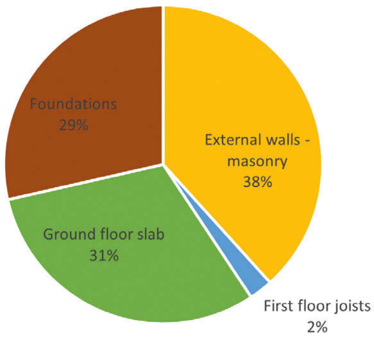
↑FIGURE 8: Comparison of embodied carbon for each scheme



↗FIGURE 9: Renovation: share of embodied carbon by material



↗FIGURE 10: Rebuild: share of embodied carbon by material



↗FIGURE 11: Savings: embodied carbon by material

scheme. This equates to 111kg CO_2e/m^2 for the renovation and 199kg CO_2e/m^2 for the rebuild scheme.

An analysis of the difference between the two schemes reveals where the carbon saving was achieved **(Figures 9–11)**.

The vast majority of the carbon saving came relatively equally from the reuse of the three main concrete-based components of the existing structure: the external masonry walls, the ground-bearing slab and the concrete foundations.

A total of 11.5t CO_2e, or 38% of the overall carbon saving, was avoided by reusing the existing blockwork inner leaf: the original outer-leaf stone cladding was not a saving, since in the hypothetical new-build scenario, the new brick cladding forms the outer leaf and the original stone cladding is not discarded.

Retaining the existing concrete ground-bearing slab over the extensive footprint of the existing house contributed to 31% of the overall carbon saving: a total of 9.26 tCO_2e. This includes an allowance for 150mm of granular fill beneath the concrete slab, which amounts to 20% of this figure.

Reusing the existing concrete strip footings contributed to 29% of the overall carbon saving.

As the existing roof was entirely replaced, there were no carbon savings achieved in this category. The roof structure, being timber and relatively lightweight, comprised only 6% of the overall embodied carbon of the rebuild scheme; therefore, the reuse of the roof structure is less significant in carbon terms than the heavier concrete elements.

The element of the renovation which embodied the highest level of carbon is the structural steelwork, which amounted to 32% of the renovation scheme, equivalent to 9.9t CO_2e. This was required to support the large openings formed in the existing masonry walls, including the new sliding door openings installed on the rear elevation.

The second most carbon intensive element of the renovation scheme was the new brick cladding, which wrapped around the front and sides of the existing property at ground-floor level, including a new free-standing brick wall installed along the front elevation of the house. This new cladding did not serve a structural function, but was instead introduced to update the aesthetic of the building, hiding the dated original reconstituted stone cladding.

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Limitations

Structural embodied carbon is, of course, only one part of the overall picture. Non-structural components and architectural finishes on this project will include timber cladding **(Figure 12)**, the slate roof covering, internal stud walls and plasterboard finishes, as well as floor coverings and insulation. These will all contribute to the overall embodied carbon of the project. However, all these

a) Before

b) After

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↘FIGURE 13: Rear elevation

←FIGURE 12: Front entrance, showing contemporary palette of materials used

components are replaced in both the renovation and rebuild scenarios; therefore, this doesn't affect the total value of embodied carbon saved by the renovation relative to a rebuild scheme.

Although the new brick cladding is arguably providing more of an architectural than a structural function, it is included in the carbon analysis as it makes such a significant contribution to the overall embodied carbon of the renovation scheme and it is important to take this into account when comparing it with a rebuild scenario.

The operational carbon footprint of the building has not been considered in this analysis, but forms another important part of the picture of overall carbon emissions over the full life of the development. One of the primary aims of the renovation was to improve the thermal performance and airtightness of the existing building. In addition to this, an air source heat pump and photovoltaic panels were installed to reduce the operational energy consumption.

Conclusion

There is a limit to the absolute sustainability credentials that can be claimed by a large and luxurious single-family dwelling. However, in relative terms, the decision in this project to retain as much of the existing building's fabric as possible has saved approx. 45% of the embodied carbon in the substructure and superstructure compared with starting from scratch with a new-build home. This amounts to a saving of around 30t CO_2e, equivalent to 36 one-way flights from London to New York (as helpfully revealed by The Structural Carbon Tool).

Furthermore, this project has shown that working within the constraints of an existing building is not a barrier to achieving a high-quality architectural finish **(Figure 13)**. The final result does not feel lessened or restricted by the original building from which it has emerged, but the project was instead strengthened by the challenge brought by the constraints it imposed on the design.

This project provides an argument for design teams, when tasked with transforming or rebuilding an existing development, to retain and reuse as much of the existing structure as possible, in particular those elements which hold the greatest amount of embodied carbon, including concrete/masonry walls, ground-floor slabs and concrete foundations.