Northumbria University Architecture Portfolios

THE HUMBLEDON HILL HOUSES
SUNDERLAND

Paul Jones
Professor

https://www.northumbriaarchitecture.com/research

Northumbria University
NEWCASTLE

Front cover

Visualisation of the Humbledon Hill House

1.Project Details

Principal Researcher	**Paul Jones**
Title	**Humbledon Hill Houses**
Output type	**Building and Landscape**
Accommodation	**15 four-bed detached houses with individual gardens all set within magnesian limestone meadows.**
Curator	**Paul Jones | BDN North Ltd**
Function	**Dwellings**
Location	**Sunderland**
Client	**Marikal Developments**
Practical completion	**2021 -**
Area of Houses	**Various ranging from 180-230m2**
Structural Engineers	**Building Design North Ltd**
Environmental Engineers	**Dr Zaid Alwan Northumbria University**
Budget	**£3.5 million**
Developer/ Contractor	**Marikal Developments**
Principal Manufacturer/ installation	**Kingspan *TEK Systems*,Nudura**
Frame contractor	**Potterton timber frame**
URL	**Xxxx**

1. Summary

The Humbledon Hill Houses is an experimental and innovative eco-housing scheme in Sunderland that is located on the slopes of the hill from which the development takes its name. The hill is classified as a Scheduled Ancient Monument as a result of Bronze and Iron Age earth works discovered in the Victorian Period, and later through a number of excavations in the modern era. The geology of the hill is magnesian limestone; in a UK context this is a rare rock type and for this reason- and the specific fauna and wildlife it supports- the site was classified as a Site of Special Scientific Interest in 2003.

A novel collaboration was formed between academia, professional practice and industry to undertake the project. This team has gone on to developed a working relationship with the Local Authority, English Heritage (now Historic England) and Natural England to help deliver a commercial ultra-low energy (both operational and embodied) high quality solution that respects the sensitivity of the site. The development achieved planning permission in June 2016, in what must be considered as amongst the most challenging of planning contexts.

Fig. 01 _ Overview of the site and its surrounding landscape

2. Introduction

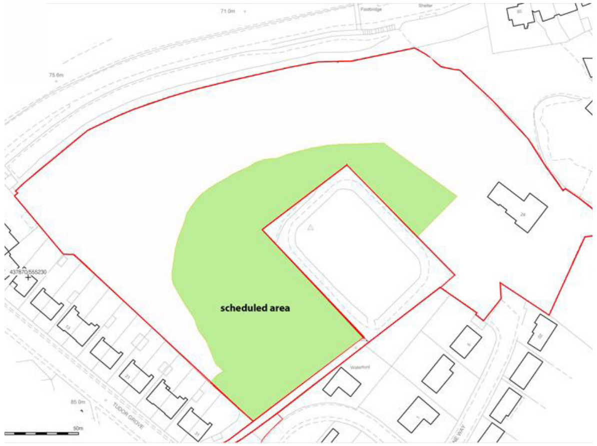

Fig. 02 _ Aerial view of Humbledon Hill

Fig. 03 _ Scheduled area in green

The Humbledon Hill Houses are located approximately one mile to the south west of Sunderland city centre on a rounded eminence, which is approximately two hectares in area. The hill was developed in the 1930s on the lower portion of the south-west and east faces with semi-detached housing. The undeveloped land shown to the north (see fig 2) was classified as greenbelt by Sunderland Planning Department, despite its city centre location, due to its SSSI classification and its agricultural use.

A developer (Marikal Ltd) acquired this land for a peppercorn sum in 2013, recognising its potential; at the time it was deemed to have no commercial value because of being scheduled and environmentally protected (see fig 3). Prior to purchase they sought advice from English Heritage (EH). Initially, they were unsupportive of any type of development on this site, as several poor quality, high density schemes had been submitted by major house builders in the recent past- all of which proposed encroaching on the scheduled area. Marikal stated that their design intention was to construct a low-density development of bespoke eco-houses. English Heritage indicated that they were more receptive to this approach; especially as the developer was committed to enhancing and protecting the scheduled area as well as clearly defining its boundaries.

The local Planning Authority were also initially unsupportive of an application, but as there was at least some support from EH they gave the developer an opportunity to present a case. With recent relaxation of national planning policy- and with the site not being classified within the City's extant planning strategy- both the council and EH were concerned that inappropriate schemes would ultimately gain permission through a legal challenge. The developer was also proposing an executive housing scheme; there was- and continues to be- a shortage of this type of housing provision within Sunderland. Over the next 18 months, through gaining their confidence, both agencies moved to a position of support in principle; but this was after an exhaustive process, including a number of redesigns and extensive historical and environmental surveys.

The Design Team

The developers invited a number of local consultants to a professional interview. The principal investigator was interviewed and proposed that the the project be used as a collaborative research inquiry between academia (Northumbria University) and Building Design North (BDN), working in collaboration with the developer. BDN at the time were principally structural engineers and architectural technologists with expertise in BIM. It was proposed that the design and environmental strategy would be undertaken by the Northumbria University. At interview, Building Information Modelling (BIM) was proposed as a technical and communication platform; the P.I argued that it would be novel to use it for a small-scale residential scheme, as up to this point BIM had only been used on larger buildings. The developer was receptive as this was a departure from the *normative* approach that the other invited consultants had proposed at interview. The design director of Marikal was architecturally trained with expertise in BIM-enabled software. He had an interest in how it could be utilised between the design team and the supply chain to harness what has more recently been termed Pre-Manufactured Value.

Fig. 04_ Views of development showing diversity in form

The Design Phase

From the outset of the project, both Sunderland Planning Department and English Heritage sought a contemporary sustainable development for the site. The brief from the developer was challenging: the design had to be outstanding in terms of quality; an exemplar in sustainability and environmental efficiency; encouraging of biodiversity; rich in place-making characteristics; an integration between built and natural form; and perhaps most important was that it could be built to commercial budget constraints of £1200-1500m2. Seven house-types were developed specifically for the context; these were distributed between the 14 plots to ensure design diversity.

The design team expanded to include key manufacturers who were chosen because of their experience with BIM when manufacturing their building products. The most significant of which were Kingspan TEK (wall components), Velux and the subsiduaries (windows, doors and rooflights) and Nudura Insulated Formwork (lower wall and groundwork components). These companies were keen to showcase their products on an exemplar scheme and utilise their nascent and developing digital capability. Each company is international and very influential within the industry. They were keen to be involved due to the ambition and innovation. They were also very enthusiastic about the project being a research collaboration between academia, practice and industry and for the use of BIM in delivering a sustainable project.

3. Statement of Significance

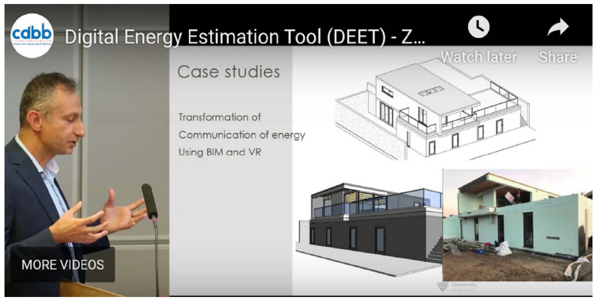

Fig. 05_ CI- Zaid Alwan presenting at Cambridge University on project

The following section summarises the significance of the project, the rigour of the research and its originality. These aspects will be expressed in more length within the expanded text in the report.

Significance

The significance in terms of awards is yet to be demonstrated; the project has only recently been completed, delayed through COVID. The following are significant achievements to date.

1. An outstanding collaboration between Historic England and a Local Authority (Sunderland Council) in the delivery of a sensitive construction project within a Site of Special Scientific Interest and a Scheduled Ancient Monument.

2. Achieving a 12 to 0 in favour cross-party vote at Planning Committee for the project, originally considered undevelopable due to planning, scientific and heritage constraints.

3. The development of a new site-specific green roof system for use in replacing diversity within magnesian limestone landscapes.

4. The project was a research case study by Centre for Digital Build Britain (CDBB) due to its outstanding credentials in operational and embodied energy.

5. It received a £70K grant from CDBB to be a case study to develop a Digital Energy Estimation Tool

6. It was the focus of a Cleaner Production Paper (H Index 150) written by the PI (Jones) and Alwan, on the use of BIM to minimise waste in construction by establishing a Framework for Strategic Sustainable. 120 citations

8. It is showcased internationally by Velux due to the quality of the design and successful integration of the company's products.

9. The project is an early adopter of BIM for small -scale bespoke developments -utilising 50% pre-manufacture value. This process has since been adopted for the design and construction of 250 new houses using MMC by the same developer.

10. Reduction of building waste to less than 5% due to adoption of Modular Coordination through digital model.

11. Winner Residential Project of 2020 in the North East Property Award. First award entered due to COVID. 25 schemes were submitted

4. Statement of Rigour

Fig. 06_Physical models of houses

Rigour

This project has involved extensive practice and praxis-based activities, as well as more traditional methods to realise the development and answer the six research questions.

This has included undertaking different types of surveys and site analysis (both digital and analogue) to establish boundaries and important thresholds, site conditions, views in and out of the site and levels to establish the best location for the individual dwellings.

There has also been extensive modelling (physical and digital) and prototyping in the design process, but more specifically to liaise with the supply chain/manufacturers to cut and form building components. The digital model has enabled us to accurately ensure modular coordination to minimise waste to less than 5%. We have use the digital model to weigh the houses to establish the embodied carbon/energy and predict the operational energy.

The accompanying paper required an extensive literature review and undertaking mixed methods to explore the housing scheme as a case study, including secondary data analysis of papers and trade literature.

5. Statement of Originality

Fig. 07_Green Roof designed for Magnesian Limestone

Originality

This project showed originality in the design and procurement method using BIM to remove the need for a main contractor, instead there was an assembly technician to oversee the erection of components brought to site and the technicians from the supply chain. This approach led to 30% financial savings with the project (source: Marikal).

Originality is also demonstrated in developing a multi-stakeholder collaboration team (academia, developer, professional practice, Historic England and development control) to deliver a project on a highly sensitive important local site was seen as a blueprint in how to develop future sites of this nature (see main text for further information).

The new green roof specifically for Magnesian Limestone Landscapes was a research project in its own right and has resulted in grass roofs which are now flourishing. The developer has used this innovation on two other developments.

This is the first housing project to adopt the Framework for Strategy Sustainable Development utilised in environmental manufacturing (see associated Paper).

6. Research Context

Fig. 08 _ Placelessness- modern uk housing estate

Design Ambition

The UK has had a long tradition for producing high quality residential settlements; although in the modern era this has not been the case, with many estates produced by the major house builders being universally regarded as poor in terms design-quality, innovation and sustainability. Indeed, new British housing is considered to be the worst in Europe (Carrington 2013). Uninspired, inefficient developments are currently being replicated around the UK; they are blighting the rich and diverse British landscape and are leading to a condition of *placelessness, sic*. (Proud, 2016). The principal aim of this design research was to explore contemporary architecture and construction methods, as well as innovative technologies, to produce a high quality, truly sustainable, residential scheme, to counter the normative UK housing model. The challenging location (with the site containing a Scheduled Ancient Monument and located within a SSSI) required a non-standard approach, underpinned by research to better understand the site to inform the design. Rarely are new projects given permission by English Heritage that are in proximity to Ancient Monuments; building within a SSSI is also problematic. This project demonstrated how to navigate the process of achieving planning and *Scheduled Ancient Monument* consent within statutory constraints and how best to find a solution through collaboration with statutory bodies towards a sensitive and appropriate solution.

Buildings that have been designed using BIM-enabled software have been criticised for standardising design; it was not conceived for creative outputs, but for logistic efficiency. Indeed, a number of commentators have argued that it discourages creativity (Kocaturk and Kiviniemi, 2014; Berwald, 2006). The design team recognised the failings of BIM-enabled software for creative design; therefore, the research inquiry was also concerned with how traditional (drawing and physical model-making) and digital modelling could be used together towards creative, rather than, standardised output. The design team also extensively used internal panoramic virtual models to help the design collaboratively.

Procurement and BIM

Construction continues to be one of the most profligate industries as a result of outdated methods of communication and logistics, leading to construction and environmental inefficiencies (Egan 1998, Latham 1994, Lepatner 2008). Housing is one of the worst sectors; typically 30% of virgin material delivered to sites ends up in skips (BRE 2010). We argue that by combining BIM and Modern Method of Construction (MMC) there is the capacity to significantly reduce waste and emissions. BIM is rarely recognised for the value that it could bring to sustainable practice. Indeed, in the Government BIM Task Group report (2011) (where the BIM protocols were established), neither environmental efficiency, nor sustainability, were discussed in their protocols. As part of the research we explored alternative procurement routes that were best aligned with BIM bringing together the design team with manufacturers and the supply chain. We argue that residential developments of this size would benefit from dispensing with the traditional contractor-led procurement route. We instead used a variation of *prime contracting* in order to benefit from supply chain and manufacturing expertise; an assembly technician was appointed to coordinate the installations of principal components and organise the finishes.

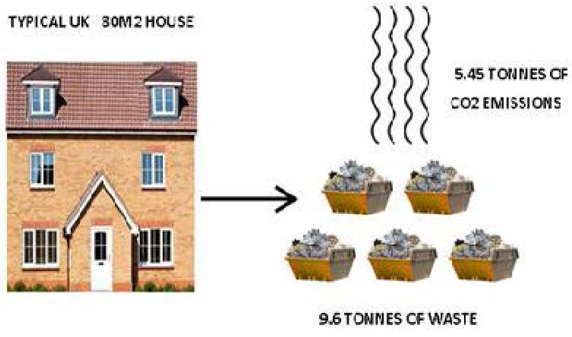

Fig. 09 _ Waste from a typical UK mass produced house

Fig. 10 _ Framework of Strategic Sustainable Development

Environmental Philosophy

As part of the research we also looked beyond normative profligate construction practices and instead utilised a sustainable process and philosophy, developed by the environmental theorist Karl-Henrik Robèrt in 2002- referred to as the Framework of Strategic Sustainable Development (FSSD). This process has been used by a number of international companies, such as IKEA and BMW, to conserve resources and reduce pollution through their manufacturing process. As yet it has not been applied to a construction project. We argued that BIM was a perfect platform to use in combination with FSSD. Its life-cycle model is far more effective than current environmental benchmarking tools, such as BREEAM and LEED, which have been promoted within the industry but tend to be retrospective, tick-box exercises . ◘

7. Research Questions

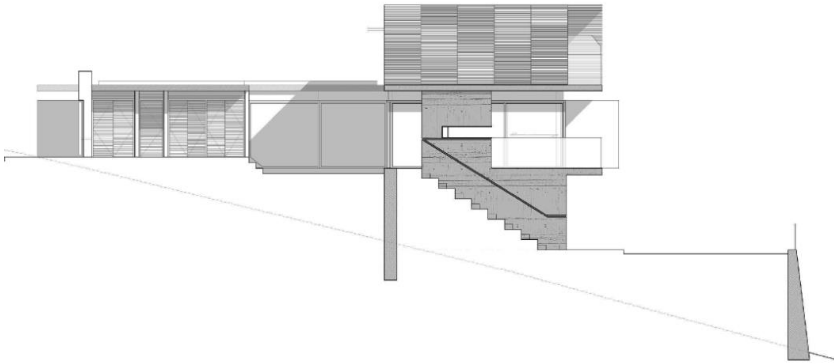

Fig. 11 _ Design Section through house 4

Fig. 12 _ Perspective through to courtyard house 6.

1.
How can a new development co-exist and enhance a Scheduled Ancient Monument and a Site of Special Scientific Interest?

2.
How can site biodiversity be retained when building a new development?

3.
How can we promote rich place-making characteristics and design diversity whilst creating a sense of architectural uniformity across the development?

4.
How can the design qualities of the houses (space, light and view etc.) be maximised, despite the extensive use of computer (through BIM) in the design, manufacture and construction of the houses?

5.
How can operational and embodied energy and waste be minimised through the use of Building information Modelling (BIM) and Modern Methods of Construction (MMC)?

6.
Can bottom up strategies to sustainable development, using BIM and MMC, be more successful than top down policies and initiatives as set by national and local government.

8. Research Methods

The research project is a case study that utilises the mixed methods. Each method was chosen to be able to answer the question; they have been used in combination. They are all specific to design-based research. The way that the method was used is referred to in the narrative on each section.

1. Inscriptive methods including: site analysis and surveys (both digital and analogue) to establish boundaries and important thresholds, site conditions, views in and out of the site and levels to establish the best location for the individual dwellings; as well as drawing and modelling to establish massing and form.

2. Computer and physical modelling, as well as drawing, to test the design of the houses to maximise the qualities of space, light, and view.

3. BIM with MMC used effectively to improve sustainable practices and construction efficiency.

4. A review primary and secondary data as part of an extensive literature review (principally for the accompanying paper). Reference to housing precedent and visiting interesting innovative housing schemes in the UK and abroad. ◘

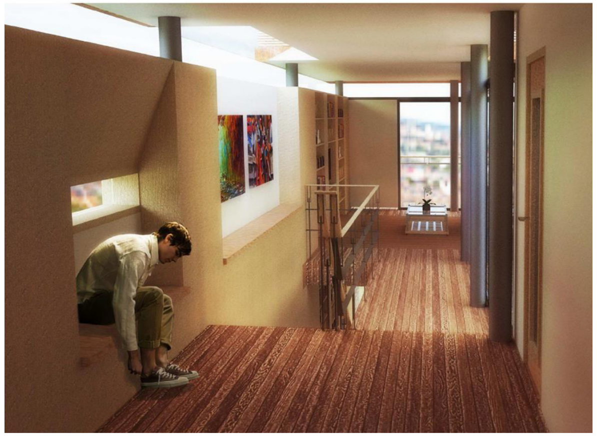

Fig. 13 _ Sketch section through house 4

Fig. 14 _Perspective down corridor towards view

Taxonomy

Conceptual design iterations
Drawing
Model-making
Construction methods
Spatial analysis
Participatory activities
Text-based research
Phenomenology
Theoretical research
Fieldwork
Photography
Topographic survey
Design research
Trial and error experimental design processes
Design-led research
Historical research
Typology research
User experience
Diagramming
Interviews/user consultation
Scale modelling
Digital fabrication methods
Site analysis/study
Visiting similar building types

9. Question 1

How can a new development co-exist and enhance a Scheduled Ancient Monument and a Site of Special Scientific Interest?

Method

Inscriptive methods, including: site analysis and surveys (both digital and analogue) to establish boundaries and important thresholds, site conditions, views in and out of the site and levels, as well as drawing and modelling to establish massing and form.

Fig. 15 _ Cowslip typically flowering March to May

Fig. 16 _ Butterwort- typically flowering June to July

The design team argued that the relationship of the houses to the scheduled monument was fundamental to the success of the project. Previously it was not clear to the general public- who often visited the site to take in the views of the sea and the Wear Valley- what part of the hill was archaeologically significant and what was agricultural land. This is an issue for EH for archaeological sites across the country. Their anxiety is partly due to archaeology being disturbed or damaged as a result of scheduled areas not being demarcated; as well as the general public are not being educated regarding the significance of archaeological sites. EH were keen for us to develop a strategy to enhance and define the setting of the schedule area. Initially, a desk-top study was carried out mapping our own site drawings of existing boundaries onto existing archaeologist's and EH's drawings to establish the Scheduled Area. This exercise demonstrated inaccuracies between EH's drawings and archaeological drawings, from the original digs back in the Victorian period, (for its position- see fig 17). The design team worked with an archaeological consultant employed by EH to establish the exact position of the scheduled area. The developer also commissioned his services to undertake further digs requested by EH at the boundaries of the scheduled area. This exercise was to ensure that there was no additional archaeology. Several proposed schemes were presented to EH to enhance and articulate the Scheduled area. The scheme that was favoured by EH, used the access road to define its southern edge. The road protected any potential archaeology (the archaeological layer was 1200mm below the surface) and clearly defined what was historically significant. The enhancement of it was achieved by planting the scheduled area with magnesian meadows, which would also improve the biodiversity of the site. This intervention could become a sensorial garden of sight, smell and touch that would change through the course of the year as seasonal plants came into bloom see fig 15, 16. English Heritage thought this strategy was pragmatic and imaginative solution that could be used elsewhere.

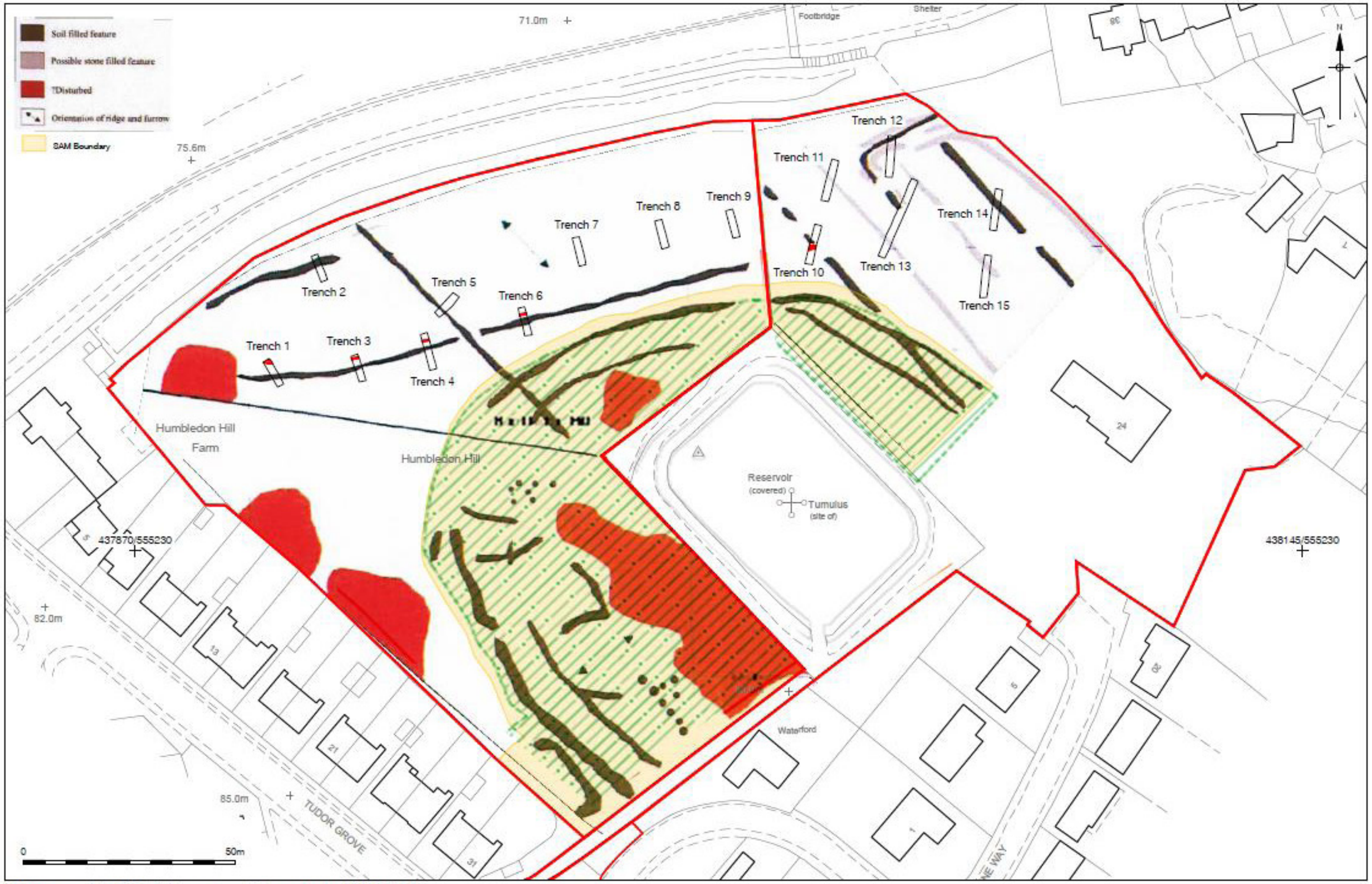

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Figure 5
Trench Locations showing excavated features and geophysical survey anomalies
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Fig. 17_ Combined EH and design team drawing of archaeological surveys and establishment of the scheduled area difference seen in green hatch vs yellow area

Historically, the connection to the wider landscape was fundamental to the people inhabiting the hill (particularly in the Bronze and Iron Age) in terms of defense; their status in the wider community; and the spiritual connection to other physical features within the wider landscape. Therefore, maintaining views out from the site, and views into the site, was considered to be very important for EH. A topographical survey was carried out by the design team to show the terrain. The design team, using this survey and other site analysis (both analogue and digital), set a datum level low down on the slopes of the hill to establish the roofline for all the houses so that these views were undisturbed. By doing this, the development was more visually consistent across the site, as can be seen by fig 18. This exercise also helped establish the best location of the houses to minimize unnecessary excavation.

By greening the roofs of the houses (discussed in the following section see fig 23-28) the design team felt that the development would better integrate into the landscape; and their visual impact would lessen to enable visitors to benefit from the wider views of the sea and the Wear Valley.

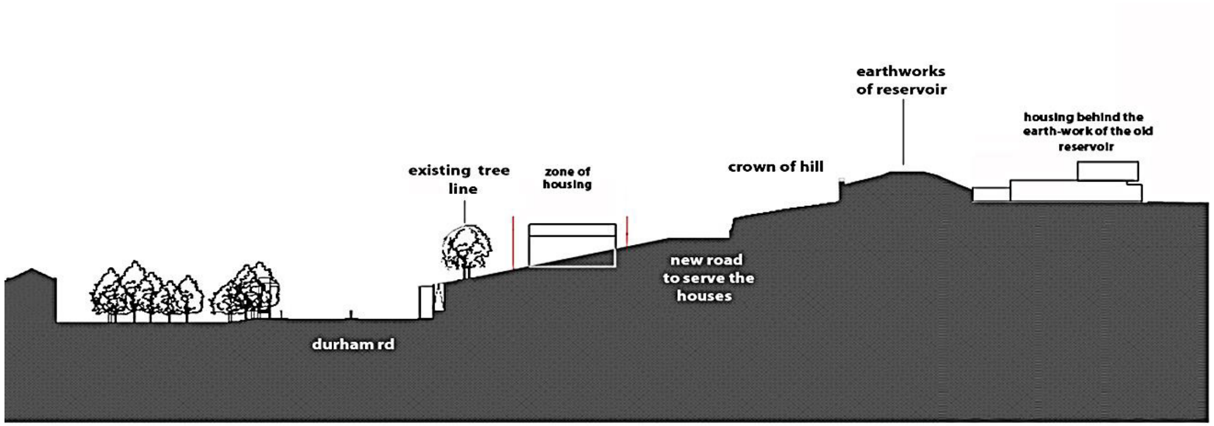

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Fig. 18 _ Notice boards around the site showing historical information regarding the hill

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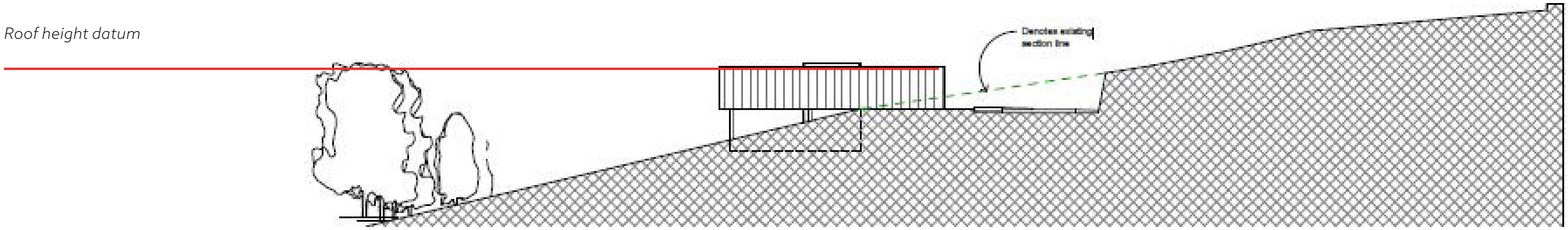
Fig. 19 _ Showing section through site



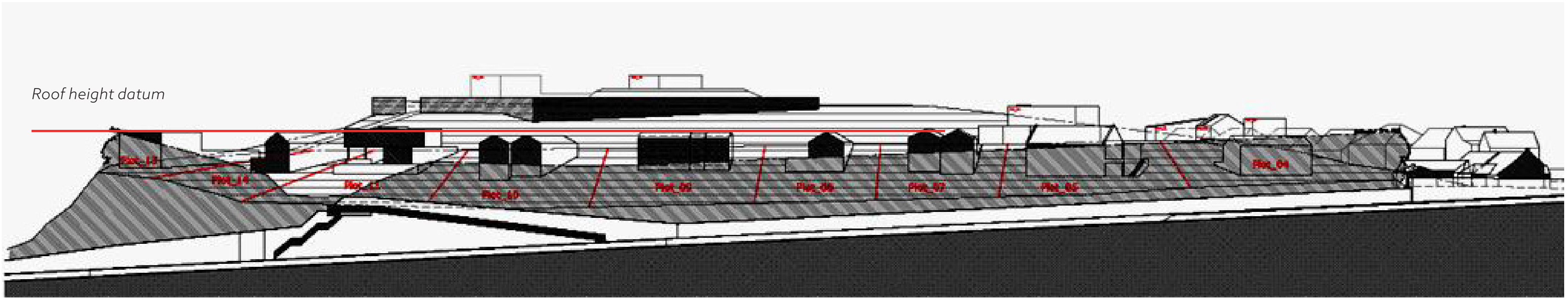


Fig. 20_ Diagrams showing continuity of roof height irrespective of roof profile and topography of land

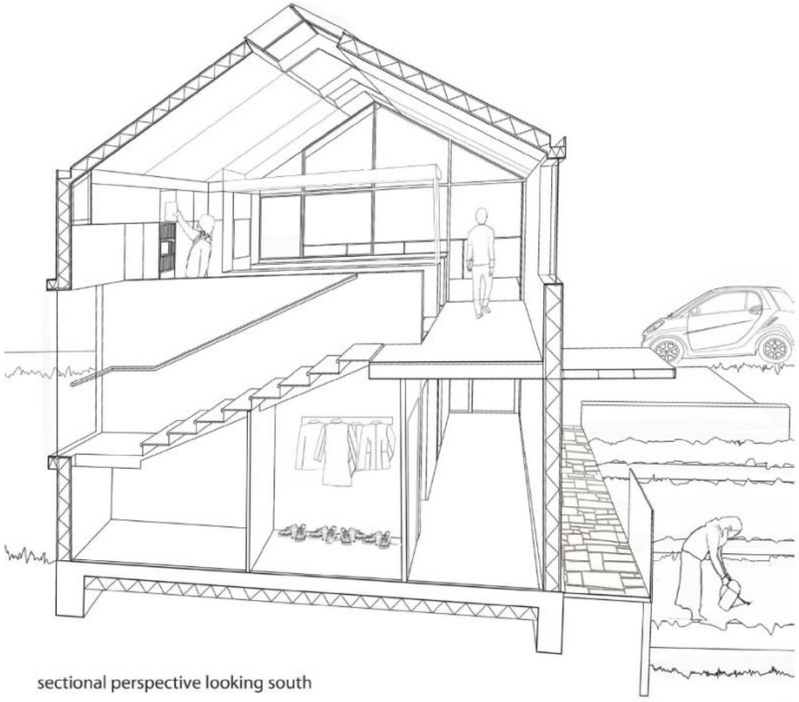


Fig. 21_ Design section through house 10

Fig. 22 _ Notice board showing geological information regarding the hill

There was appreciation by HE of our approach (informed by research); this is demonstrated through the scheme receiving *Scheduled Monument Consent* and Planning Permission- in perhaps the most challenging of historic contexts. The inspector's comments support this in feedback to the design team in favour of development.

'The developer and his associated team have demonstrated a commitment to the enhancement of the ancient monument. Their work, including site, desktop, historic and archaeological surveys has given us a much better appreciation of the hill's historic context. The scheme as proposed makes a positive contribution to the potential setting of the monument; we therefore are very supportive in principle of this innovative, sustainable, well-designed housing scheme'...'In years to come it could itself be viewed as heritage'.

Rob Young, Inspector of Ancient Monuments Historic England

10. Question 2

How can site biodiversity be retained when building a new development?

Method

Inscriptive methods including: site analysis and surveys (both digital and analogue) to establish boundaries and important thresholds, site conditions, views in and out of the site and levels; as well as drawing and modelling to establish massing and form.

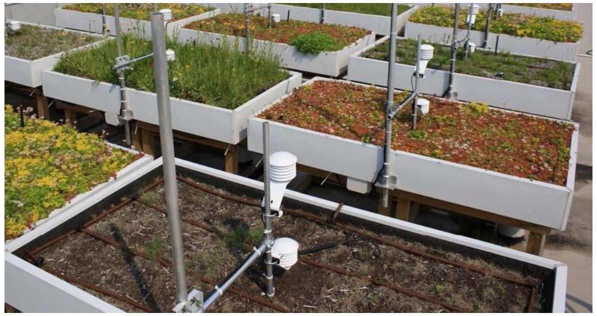


Fig. 23 _Test samples of magnesian limestone extensive green roof

Humbledon Hill is constructed of magnesian limestone; this rare rock type supports specific plants that can grow in alkali soil. Currently, the site is predominantly grassland as a consequence of its agricultural use; there is potential, as part of the landscaping scheme, to introduce other plant species that will, in time, increase the biodiversity of the site by attracting new animals and fauna. The grass layer was stripped back to re-introduce meadows species, especially over the area that is scheduled.

A Magnesian Limestone Extensive Green Roof Project

A significant percentage of green space on the site would be lost through the building of the houses; we therefore looked to replace this lost biodiversity by proposing green roofs for the houses that are context specific. The roof system that we developed included the usual liners and insulation; however, to be able to emulate conditions on the ground, the supporting soil has to remain alkali. The optimum pH for normal soil is 6.5-7.0; however magnesian limestone soil on the hill ranges between 7.5-8.0. Green roofs need to be drained, but at an appropriate rate to maintain the correct pH. The soil layer (substrate) within most green roofs tends to be acidic as a consequence of acid rain, particular if they do not drain quickly enough, due to the density of the liners and the composition of the soil and the pitch of the roof. This can stunt the growth of the vegetation. By adding ground-magnesian limestone (dolomite) at different grades and quantities to the soil, this results in an alkali soil; however, if it is too alkali this will restrict the growth, or kill the vegetation. The biological testing of the roof was carried out through collaboration with the design team and Lindum, the green roof specialists and Limestone Landscapes; the former experimented with the composition of the soil, especially how much limestone to include and its granular size, to best maintain the optimum Ph.

The substrate includes a mix of soil from the hill (approx 25%), dolomite (approx 15%) and a neutral low-nutrient material base (approx 60%) comprising crushed brick, expanded clay shale and composted material. The research considers the proportion of these three materials. If substrate is acidic it is usually recommended that a nominal amount of 30kg of dolomite is added to 10m2 (assuming depth of 150mm and >200Kg/m2). Samples were grown introducing dolomite at increments of 3Kg to the substrate from 24 to 39 kg and at a range of: fines to 3mm and 3mm to 6mm granularity. There was 12 samples tested see fig 23.

The design team used Bauder filter fleeces, mineral drains and drainage boards, and collaborated with the company as to what products should be used considering the porosity required for the filter layers, and the most appropriate drainage for the depth of roof etc. The main function of the filter layer is to prevent small media particles, such as plant debris and fines, from entering and clogging t he drainage layer. This project is an ongoing until the houses have been through two seasons of complete growth before feeling confident that the roof composition is correct for the context. Typical testing samples can be seen by the photo (fig 23),

There is evidence of some species (with appropriate conditions) flourishing and new insights are already available through the work to date. There are some samples that did not work so well, which is equally important to the findings of the research. If the grass roofs eventually proves to be successful, the developer and green roof specialists intend to promote the use of the new green roof in other projects built within magnesian limestone landscapes.

Fig. 25_ Showing first house under construction with Bauder epdm waterproof layer

Fig. 24 _ Magnesian species growing on roof of one of the houses (i.e. common bent, upright brome, betony), oxeye daisy...

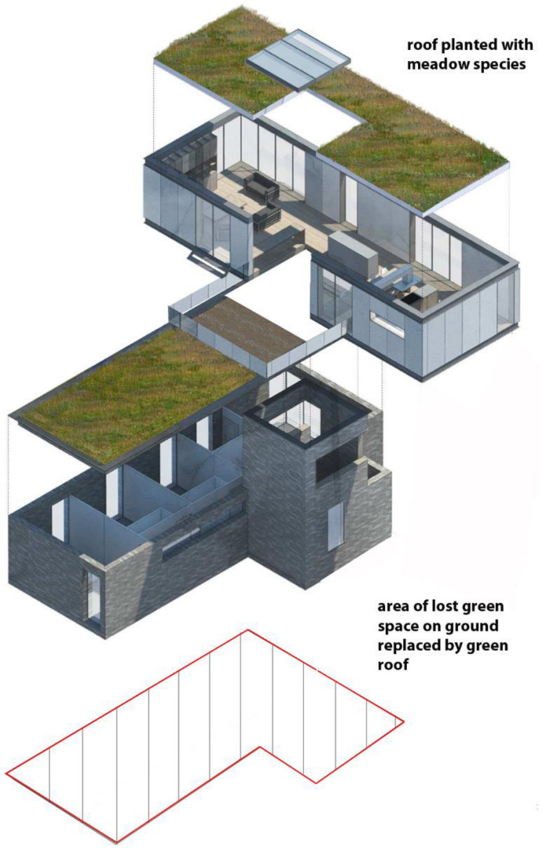
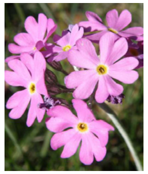


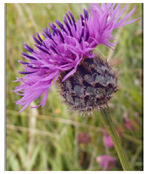
Fig. 26 _ Exploded drawing showing roofs being planted to replace green space lost on the ground through the building the houses

Fig. 27 _ Neo-vernacular houses facing Durham Road



bird's eye primrose

cowslip



greater knapweed

Common spotted orchid

Magnesian limestone meadow

Fig. 28 _ Plant species for magnesian limestone meadow

11. Question 3 & 4

How can we promote rich place-making characteristics and design diversity whilst creating a sense of architectural uniformity across the development?
How can the design qualities of the houses (space, light and view etc.) be maximised, despite the extensive use of computer (through BIM) in the design, manufacture and construction of the houses?

Method

Computer and physical modelling, as well as drawing to test the design of the houses to maximise the qualities of space, light, and view.
A review of typological housing precedent through primary and secondary sources.

Fig. 29 _ Weisenhoff Houses- Stuttgart

Fig. 30 _ Borneo Housing-Amsterdam

The Humbledon Hill Houses development is a rare development in the UK context, due to the dwellings being bespoke- designed specifically for this development in accordance with the context. There are very few housing schemes in Europe that have this as a model. Those that do are internationally renowned. Weissenhoff- built in the 1930s in Stuttgart, Germany- is one such development (see fig 29; each dwelling was designed by a world-renowned architect. Borneo Island- (illustrated as an exemplar in Sunderland Planning Department's residential design guide) is another development that embraced design diversity (see fig 30). Both projects represent the optimism of the age and have been considered as progressive in their time as examples of outstanding collaboration between the designers, the developers; manufacturers/contractors and the statutory agencies. Both schemes have been an important source of inspiration for the development. Each house is different, but the degree of difference was controlled by the planners, who argued that in this instance, a degree of uniformity was more important for the site. (see final drawings)

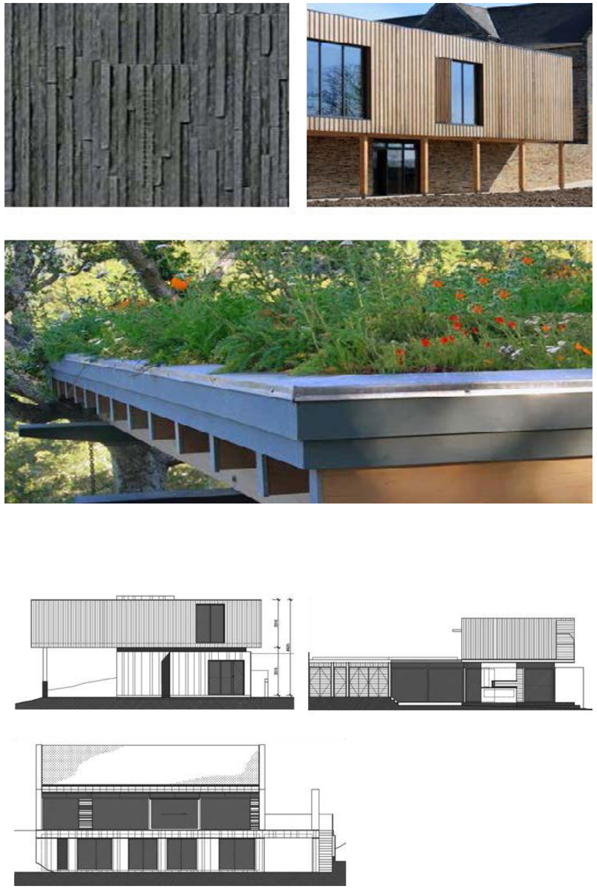


Fig. 31 _ Showing design diversity and material palette

The principal ambition of the design team was to create a sustainable development and an outstanding place to live, whilst also contributing to the protection and enhancement of the natural, built and historic environment. We argue that place-making at this development is encouraged through the sensitive integration of built and natural form, where there is a uniformity of scale and materials, as well as an interplay between the private and public landscape. Design diversity is achieved in the form and spatial language of the buildings and by the use of fenestration. The design team set a number of strict constraints to design to. The principal investigator and the developer established the following guidelines and constraints:

1. The houses could not be more than two-storeys

2. have four bedrooms

3. be no less than 185m2 and no more than 220m2 in total area

4. have a green roof

5. be contemporary in language and form

6. a common material palette i.e. externally: stone slips base, oak boards upper, green roof, aluminium windows and trims, fascias etc. Internally: timber veneer-ply linings, plasterboard, oak flooring, linoleum, micro toppings (micro-cement or resin)

7. be designed to modular sizes utilising modern methods of construction.

We argue that creating a sense of uniformity and achieving design diversity are not dichotomous. The urban designer at the council and the Head of Planning Control were very much in favour of our approach. As the designs developed they argued that the neo-vernacular house designs should be placed along Durham Road (see fig 27) , and the more challenging houses, with projecting upper floors and flat roofs, be built behind the tree cover.

Fig. 32 _ Marcel Breuer- Wolfson Trailer House

Fig. 33 _ Pierre Koenig- Stahl House

To fulfil the design potential of the houses we recognized that reference to precedent was important to help establish the design language. We did this in part by concurrently researching and interrogating a number of important houses from the 20th century- especially those that had been built in similar topographies and settings. The work of Marcel Breuer and Pierre Koenig were chosen particularly because a number of their houses were built into a slope, and both architects were adept at working with this type of terrain. The design team considered the architect's design intention in relation to the following:

1. the use of domestic space;

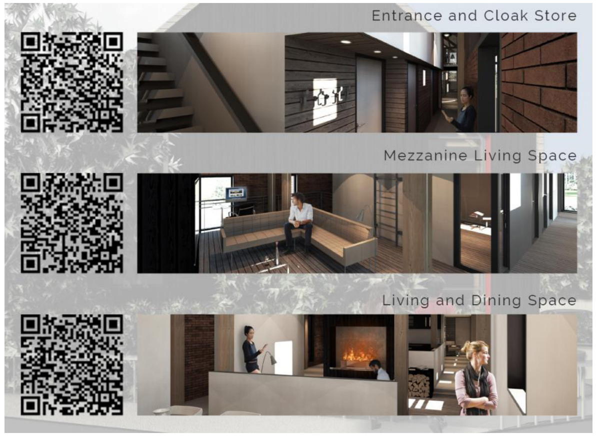
2. work/live relationship;

3. the blurring of inside and outside;

4. the house as a place of entertainment;

5. intelligent storage and servicing solutions.

The design teams also studied the plans and sections of these houses to help solve complex planning problems and to consider the value of the room versus the free plan. We argued that, irrespective of advances in computer technology, the traditional methods of constructing physical models and hand drawings remain important design tools throughout the design process. Sketch models remained the chosen method of investigation. A number of M. Arch students, were involved in the design and modelling the projects operating as members of the design team, they tested design ideas through the making of the physical models; they became virtual only when there was consensus that the form, space and language of the individual houses had been established. The computer software was particularly useful when virtual models were built of individual spaces; parametric lighting levels could be accurately imputed for specific times of the day to assess the quality of light (both natural and artificial). Materials could be inputted and replaced very quickly and the composition of the room could be assessed through 3D panoramas that enabled the design team, the client and the manufacturers/ contractors (later in the process) to understand the design aspirations.



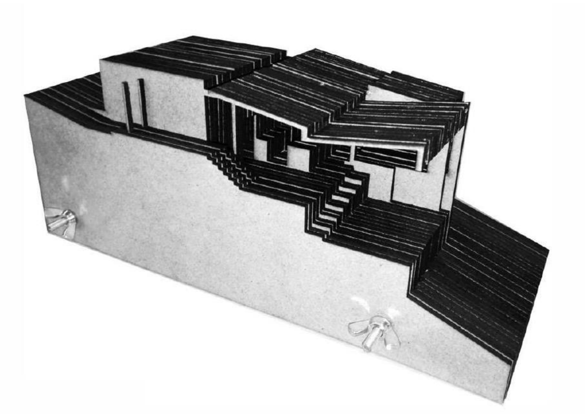


Fig. 34 _ QR codes embedding panos as a design, communication and marketing tool

Fig. 35 _ Examples of sketch and computer models to test design qualities

The use of panoramas gave everyone a much better understanding of the strengths and weaknesses of the individual houses. QR codes embedding virtual models (known as panos) were printed on the drawings so that the design team could access and steer the developing design language and materiality through scanning them onto their phones and ipads. We therefore argue that the quality of space light and view is of an exceptional standard due to exploiting the relative merits of digital and analogue methods used during the design process.

The sense of place and visual quality of the scheme is difficult to assess until the development is built, although on paper and in virtual space there is enough potential to suggest that the development, when complete, will be fulfil the design intentions. A number of eminent practitioners and academics have seen the work through lectures and presentations and believe it to be potentially significant. Roger Stephenson OBE- who is a multi-award winning architect, and was an examiner for Northumbria (with a specialism in housing and a member of the RIBA housing panel) referred to the work in an examiner's report as;

'…stunning and innovative'.

Professor Flora Samuel believes the project,

'… has the potential to be an exemplar and important internationally… and a outstanding example of research-informed pedagogy where staff and students collaborate as co-creators of knowledge'

Due to the quality of the design all the houses have already been sold from plan- in this case virtual model- (please scan the QR codes to the left fig 34) The feedback from the developers, the estate agents and the buyers has been incredibly positive with several stating that they would not have taken the risk of buying off plan, without having had sight of the physical models (example fig 35) and virtual panoramas.

12. Question 5

How can embodied energy, operational energy, and waste, be minimised with the use of Building information Modelling (BIM) and Modern Methods of Construction (MMC)?

Method

To use BIM with MMC in combination, both as a design and communication platform, to improve environmental (energy efficiency, reduce omissions and waste) and construction efficiency.

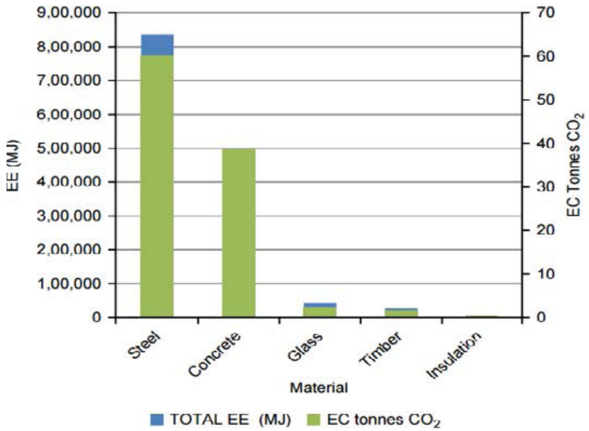


Fig. 36 _ Graph showing embodied energy of materials

There is often a commitment to reducing operational energy in construction projects, but very little account is taken of the role that embodied energy plays in building efficiency and general sustainability. Building Information Modelling (BIM) enables data to be applied to building components that can be used to improve efficiencies, in this case energy efficiency. In the past 2 and 3D drawings were purely geometric and therefore the quantities and specification could only be estimated. BIM-enabled software now facilitates total accuracy. To minimise the amount of embodied energy consumed this software was used to:

- accurately weigh the houses

- calculate the volume of the primary building components and multiply by the density of the material.

The houses were calculated to weigh between 12.8- 16.5 tonnes depending on the design and the volumes ranged from 480m3-585m3. Once these weights and volumes were established the design team carried out a number of additional processes to calculate the embodied energy, through:

- applying values from the *Inventory of Carbon and Energy Coefficients* (ICE) to the primary elements to obtain the embodied energy in MJ/m3.

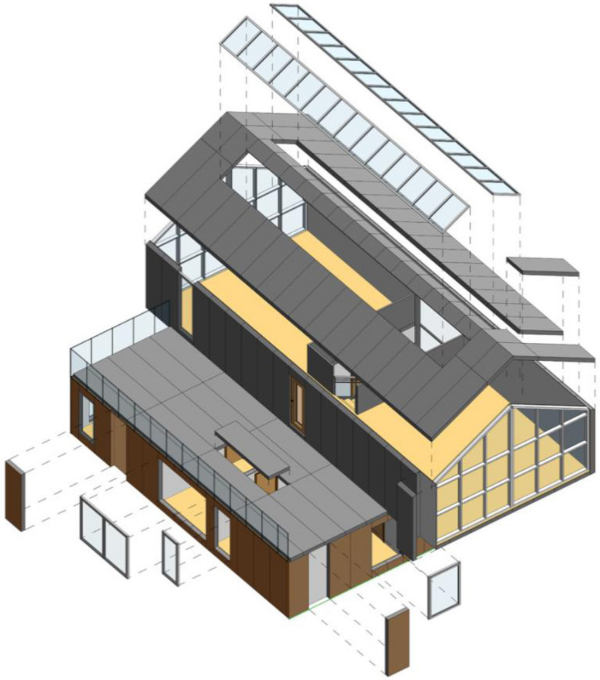
- convert MJ of energy into kW for the building components; and then convert the kWh of energy to tonnes of carbon.

By undertaking this process we derived accurate measures of embodied energy and carbon, which enabled us to assess our initial designs and make changes to the construction, thus reducing the impact of embodied energy.

Figure 36 is presented in the graph (left), for both embodied carbon and also the embodied energy. Material choices can be made to minimise impact, substituting materials with a high embodied energy such as steel and concrete with a combination of timber and composite boards (for strength). In the initial designs, steel and concrete accounted for approximately 50 per cent of all emissions within the project but represented less than 10% of the volume. This was due to the weight and density of the material. The embodied energy in the ICE database is usually measured in mega joules (MJ).

Efficient Construction

Example of one of the house showing construction through modular coordination



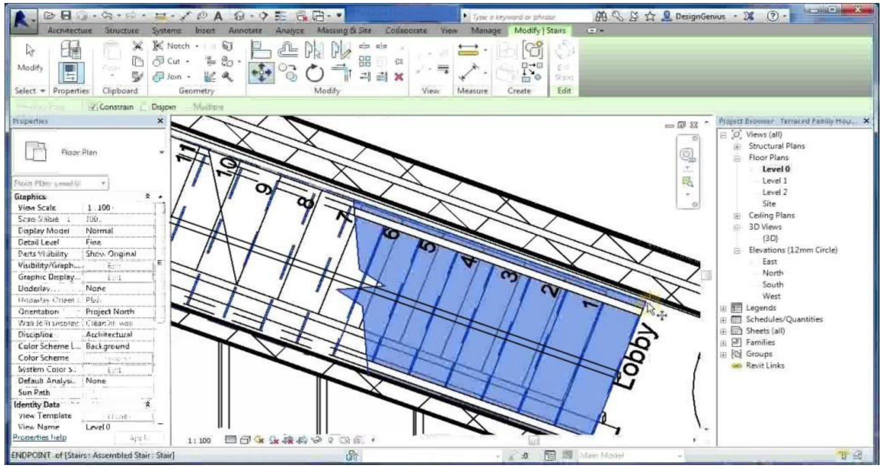
due to modular coordination less than 5% waste, compared 30% in typical new build housing source: BRE

Fig. 37 _ Showing one of the houses broken into structural components through modular coordination

The heavy loadbearing components in the original scheme were reduced, such as the concrete retaining structures, the concrete floors, the steel frame etc and load bearing wall components. The retaining structures had by far the most embodied energy (combining both concrete and steel), so instead of integrating them into the construction the houses, they were built separately as gabions that were filled with the excavated and lose stone from the hill. This meant that there was no new concrete material brought to site. We recognised that heavyweight construction provided thermal mass that would be useful in storing heat so we retained the concrete floor elements, but it was decided due to the nature and form of the houses that lightweight wall construction was more applicable. The steelwork frame was removed and replaced by a timber frame (see example of one of the technical sections).

We used BIM-enabled software to accurately model the buildings to ensure modular coordination, thus reducing the waste generated to an estimated 5% of total volume and 2% in total weight. The waste generated thus far has principally been through imperial vs metric sizes of sheets, and the chamfering of wall and roof sheets within the pitched roofs. Kingspan, who are supplying the wall and roof components, estimate only 5% material waste compared to 30% generated in a typical UK newbuild house (BRE 2012). Of the 5%- the vast majority can be recycled by the manufacturers. As the majority of the housing components were being constructed in the factory, most of the waste was recycled at source. Kingspan, through its obligations to IS0 14001, reuses 95% of its waste material. Its insulation is pulped to be reused; the timber waste is used in chip and strand boards. Saw dust constitutes 20% of the remaining 5%; this is dried for CHP incineration.

Fig.37 and Fig 38 shows one of the houses broken into its constituent panels, theoretically there should be no waste. If the houses are disassembled in the future the panels can also be reused. Because of the improved tolerances in the factory the operational performance of the building skin will also be improved compared to building on the site.



Type: nbl_TmbrSctns_KingspanInsulation_TEKCladdingPanel_Frame_Granite

Type Parameters

Parameter	Value
Cost	
Author	NBS
BIMObjectName	nbl_TmbrSctns_KingspanInsulation_TEKCladdingPanel
Help	www.nationalBIMlibrary.com
IssueDate	2013-02-18
ManufacturerURL	www.kingspaninsulation.co.uk
NBSDescription	Structural insulated wall panels
NBSNote	
NBSReference	45-60-90/415
NBSTypeID	
Uniclass2	45-93-85/484
Version	1.0
Certification	BBA Certificate 02/S029
Framing	
Insulation	Polyurethane (PUR) foam board
InsulationTickness	112 mm
PanelFacings	15 mm OSB/3
Perforations	
GlobalWarmingPotential	Less than 5
GreenGuideRating	A or A+ depending on the full wall construction
MassDensity	33 kg/m³ insulation
OzoneDepletionPotential	Zero
StandardLength	7500 mm maximum
StandardThickness	142 mm
StandardWidth	200 mm - 1220 mm
ThermalResistance	5.100 m²K/W
WaterVapourTransmission	33.6 MNs/g insulation, 7.5 MNs/g OSB/3 facing
ThermalConductivity	0.023 W/mK insulation, 0.13 W/mK OSB/3 facing
IFC Parameters	

above

Fig. 38 _ Shows layout of sips panels on revit model

right

Fig. 39 _ Example of parametric data generated through BIM software shared amongst design team and manufacturers

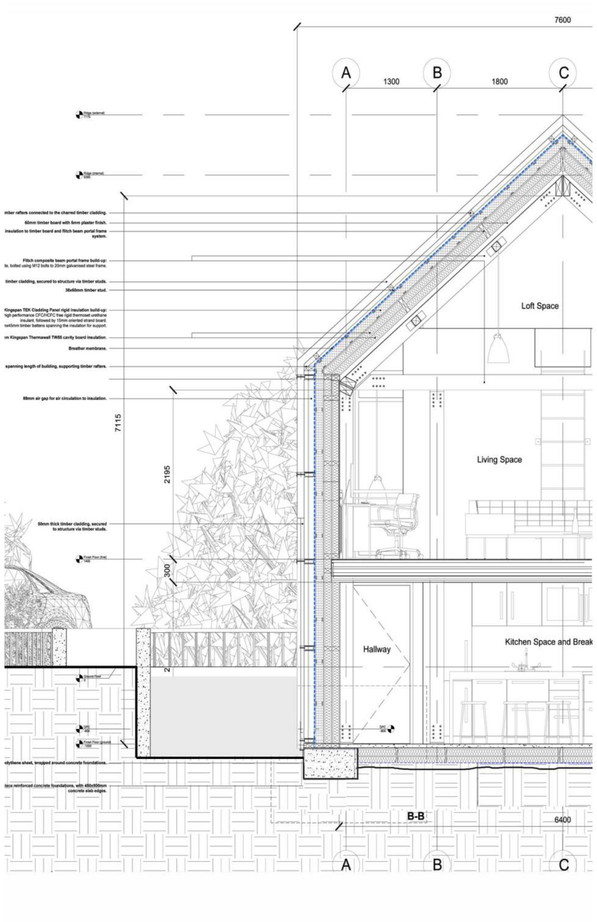


Fig. 40 _ Example of section drawing for house type showing SIPS and CLT panel system

The planning officer was keen on the lower floors being constructed of loadbearing material such as brick or stone, to visually anchor the buildings into the hillside and to also reference the material palette of wider context. This was problematic in terms of the achieving a low embodied energy value. The decision was taken to recycle the excavated stone from the site and cut it into 20 mm slips and incorporate it into the Kingspan proprietary rainscreen frame. Collaborating with Kingspan helped with the technical discussions on this detail; the stone slip will be cradled, as opposed to being mechanically fixed. This facilitates the reduction of embodied energy. By using a modified rainscreen, the embodied energy component is significantly reduced by building from the materials found on the site.

If stone had not been available to us we had intended to use a timber crib retaining wall, which has a very low embodied energy component. The stone cutting will be carried out on site using a mobile circular saw so that transportation is negligible.

Operational Energy

BIM enabled the design team to achieve lower operational energy as a result of designing a super-efficient, thermally continuous, building skin. The design team were able to share the parametric drawings with the manufacturers (particularly Kingspan). They could then assemble the building units in the factory ensuring airtightness and continuity of insulation. The clash detection facility showed where there were issues with junctions for potential heat-loss. The BIM model was also used to assess where the heat loss was most significant. As expected the windows were highlighted as being hotspots for potential inefficiencies, especially around the reveals-even though triple-glazed argon filled windows were specified. Originally, oak frames were proposed; the BIM model, however, demonstrated that replacing oak for aluminium frames with thermal breaks- and ensuring a continuity of the thermal seal both inside and out- significantly reduced the heat loss and air leakage.

The heating and hot water strategy proposed the use of a 12KW air-source heat pumps for the houses. This equipment works best for heating when the differential between the internal and external air temperature is at a minimum of 22 d C (and above -20C externally). Inefficient houses, in terms of the building skin, therefore reduce the effectiveness of this technology. The houses (although yet to be tested) are designed to fulfil the strict energy requirements of the passivhaus standards (airtightness (n50) ≤ 0.6 h-1 @ 50 Pa and u-value 0.15 W/m2.K); the energy consumption is therefore significantly lower than the typical new build UK home. Airtightness is crucial. BIM has enabled us to explore the continuity of seal and insulation as well as the integration of a Heat Recovery unit to avoid condensation internally leading to mould. The developer's contractors will oversee the work on site to ensure airtightness.

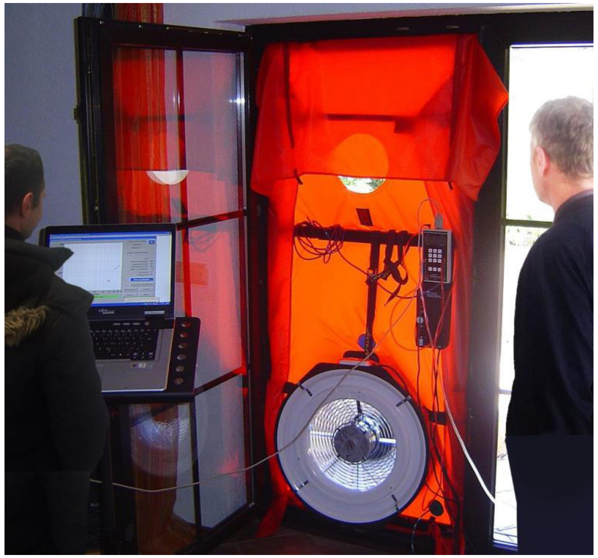


Fig. 41 _ Research team testing pressure pilot house

Fig. 42 _Photo of principal researcher's self-build house which is a pilot for the HH houses

The outcomes of the research are difficult to establish before the project is complete; however, the researcher's own house which is almost finished onsite and is a pilot for the Humbledon Hill houses. The integrated use of BIM and MMC together have significantly reduced the waste generated from the building of this house to two skips, with vast majority of the waste being generated through packaging. The timber off-cuts, of which there are two bulk bags, are being retained for fuel; although these could be pulped for chip or strand board. The vast majority of manufacturing waste has been reused by the manufacturers. The timber frame and sips system was by Swift Timber Frames instead of Kingspan.

Initial test of the pilot house the airtightness was recorded by Zaid Alwan as ≤ 1.0 h-1 @ 50 Pa; (.6 required for Passivhaus) however, this is before the building was decorated and a final sealing.

A post construction and occupancy analysis will be carried out once the houses are built to see if the operational energy and airtightness components were fulfilled. ◘

13. Question 6

Can bottom up strategies to sustainable development, using BIM and MMC, be more successful than top down policies and initiatives as set by national and local government.

Method

To use BIM with MMC in combination both as a design and communication platform to improve (energy efficiency, reduce omissions and waste) and construction efficiency.

This question is discussed at length in the paper:

The paper explains how BIM can be used as a communication and operational tool within the construction industry to facilitate environmental efficiency in accordance with Framework of Sustainable Development.

Strategic sustainable development in the UK construction industry, through the Framework for Strategic Sustainable Development, using Building Information Modelling.

Published in the International Journal of Cleaner Production. Available @

http://www.sciencedirect.com/science/article/pii/S0959652615019101

The Editor made mention of our paper in the comments on the special issue. ◘

14. Research Outcomes

The design team has followed the framework from early on in the design process. The paper has already been well-received and been cited 100 times with 5000 downloads in one month since it was published in Jan 2017. Kingspan are very interested in whether the research on FSSD has applicability for their manufacturing processes. They are interested in Northumbria University collaborating with their research department. The authors have been invited by Goran Broman to Chalmers University to see if there is possibilities for collaboration to improve UK construction using FSSD. Zaid Alwan, one of my co-authors, is currently in discussion as to when to visit.

Excerpt from Editor's paper on special issue about our paper

Leadership in the construction sector Alwan et al. (2016) argue that many sustainability related impacts from the construction sector stem from ineffective leadership, ingrained cultures, outdated technologies and poor logistics. The authors recommend bottom-up approaches and propose the use of the Building Information Modelling tool, integrated with the FSSD, to support such approaches and with that more effective leadership in the construction sector.

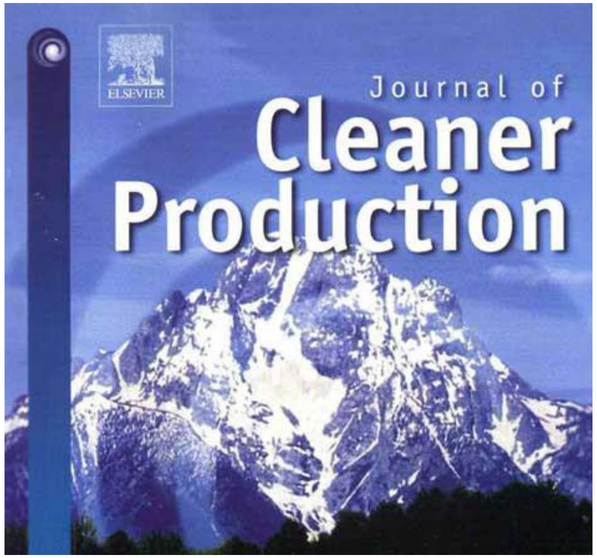
Goran Broman.

15. Dissemination

The project will be extensively published once complete, with several principal architectural magazines interested in the project for inclusion. The intention is for the project to be submitted for awards. The design team lead by Rick Marsden (the developer) has already won a national Constructing Excellence Award for the project; but we are confident that this is just the beginning of commendations.

The RIBA journal and the Architects Journal have been contacted Northumbria University Press Team with the sketch design. They are very interested in covering the project- especially with the nature of the collaboration and the student inputonce it is complete.

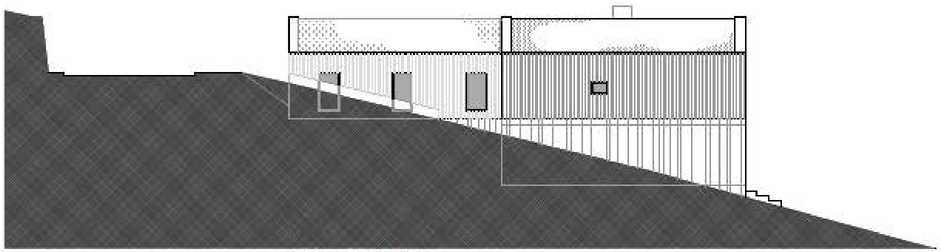
The principal publication to date is in the international environmental journal *Cleaner Production* which has an Impact Factor of 5.84 and an H index of 150- a top 10% journal in environmental science. 120 citations. The project has also been presented at the third international *Oikonet* Conference (Sustainability-Design-Participation) (2016) in Manchester, where I was a panel chair for the conference and a committee member. I have been asked to present the project to the *RIBA Housing Group* in May by Roger Stephenson OBE. This is a think-tank that have influences government, the profession and within the industry.



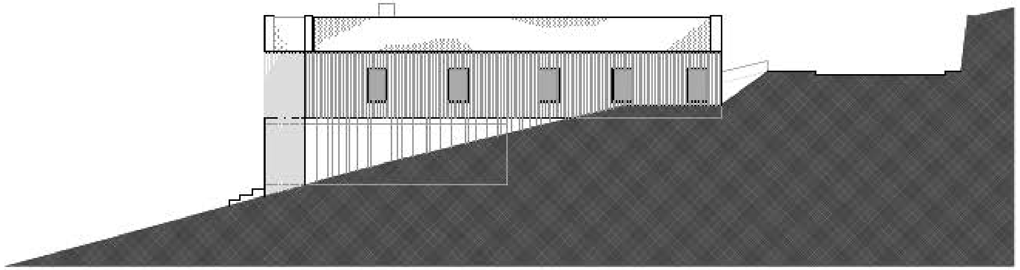
The project has been showcased by the Centre for Digital Build Britain on its website and presented at conferences at Cambridge University and the American University in Cairo.

16. Examples of Production Drawings & Photos

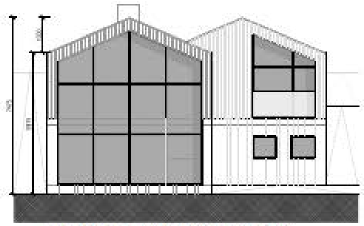
City of Sunderland College (**FE**)



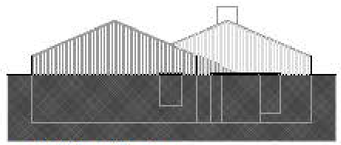
1:100 Side Elevation



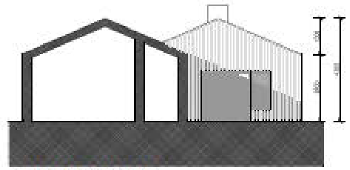
1:100 Side Elevation



1:100 Rear Elevation (Durham Road)



1:100 Front Elevation



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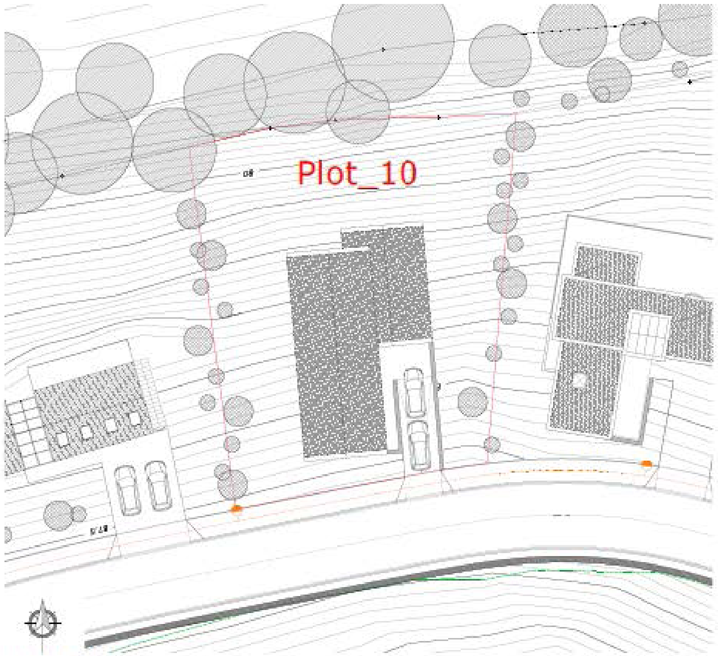
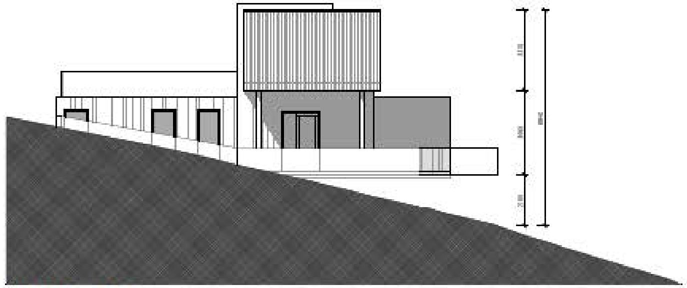


1:200 Site Plan

1:100 Ground Floor Plan

1:100 Lower Ground Floor Plan

1:100 Front Elevation



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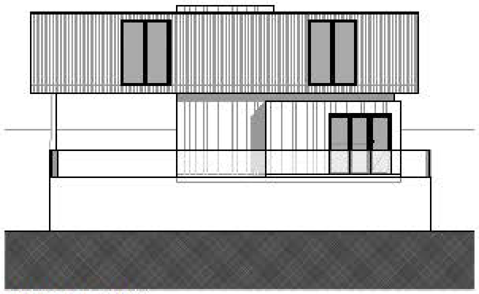
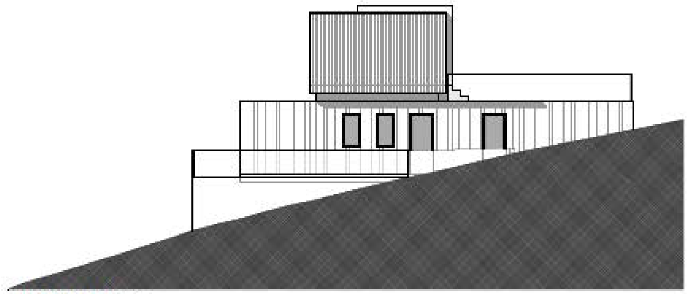


1:100 Rear Elevation



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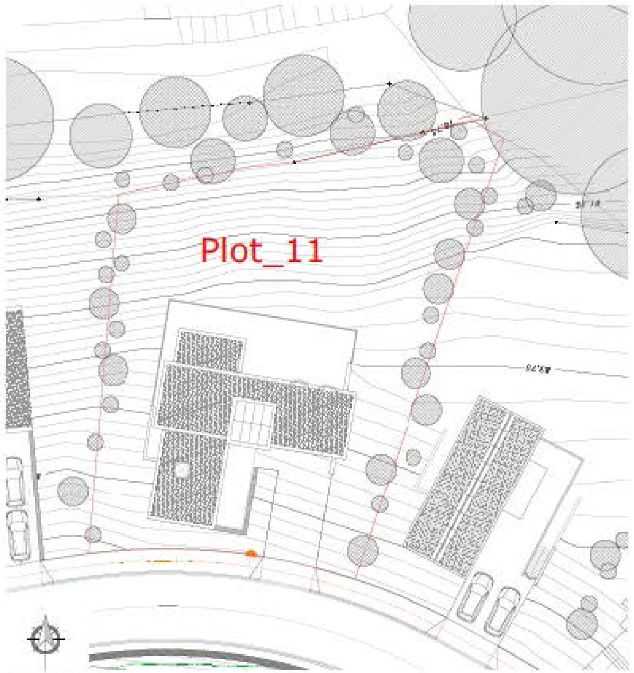
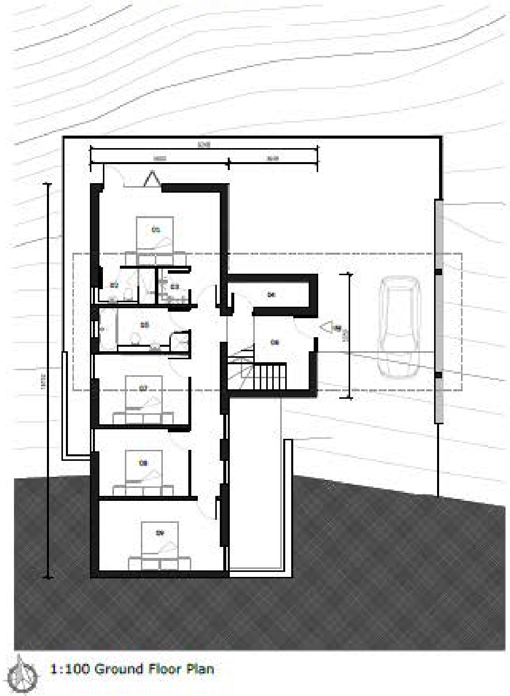
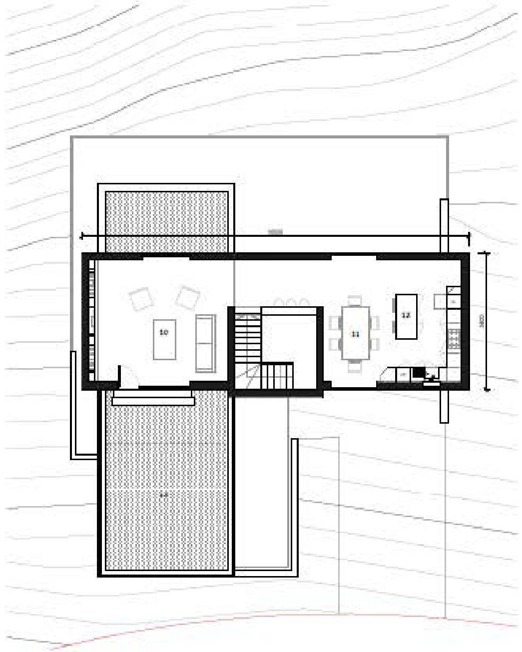


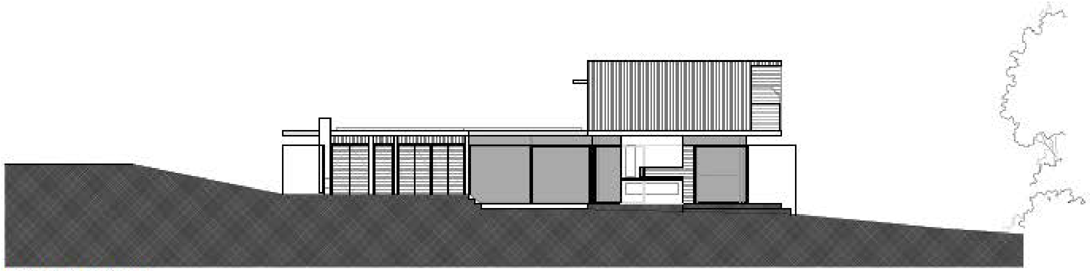
1:200 Site Plan

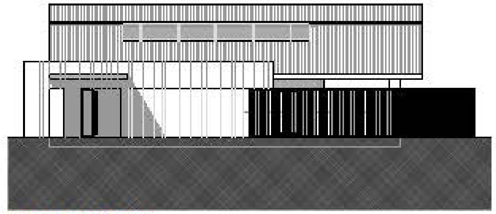


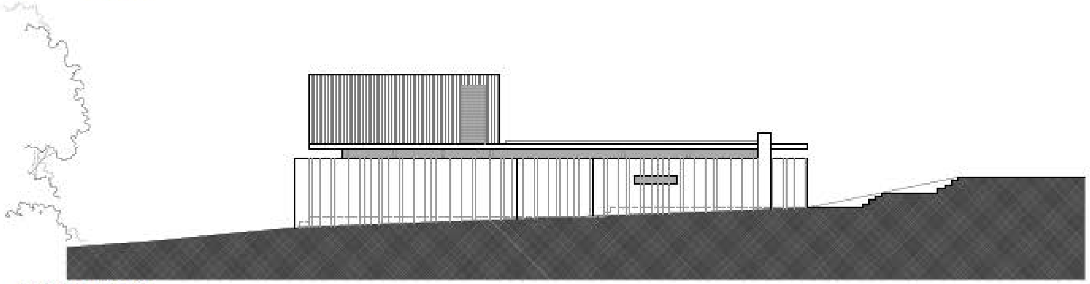
1:100 Ground Floor Plan



1:100 First Floor Plan


1:100 Side Elevation


1:100 Front Elevation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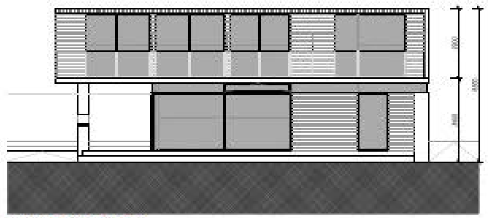
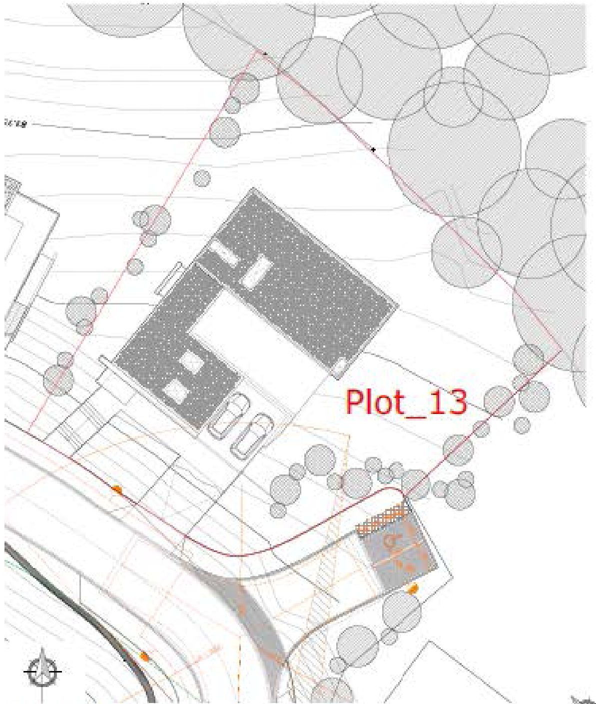
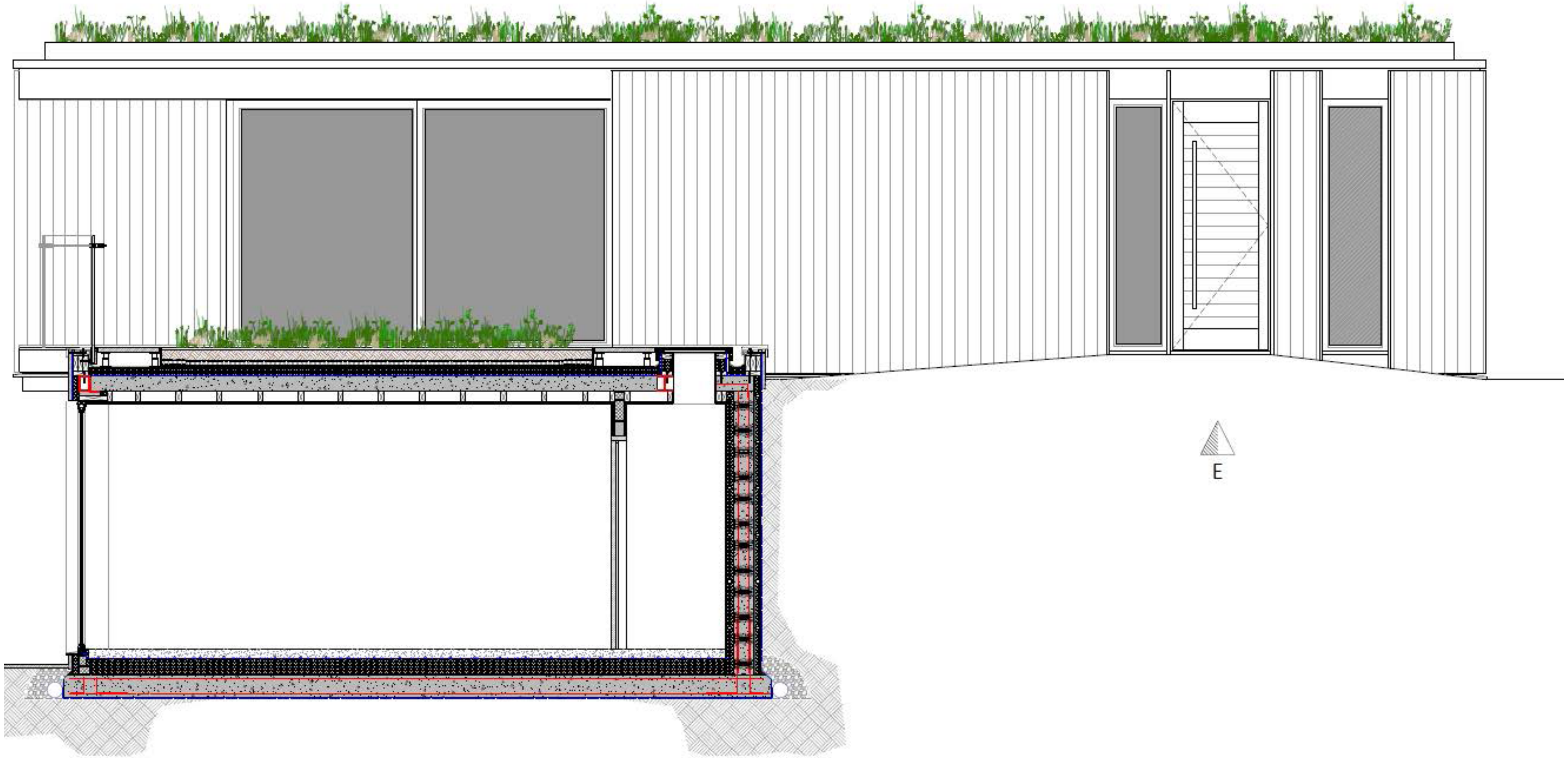

1:100 Rear Elevation



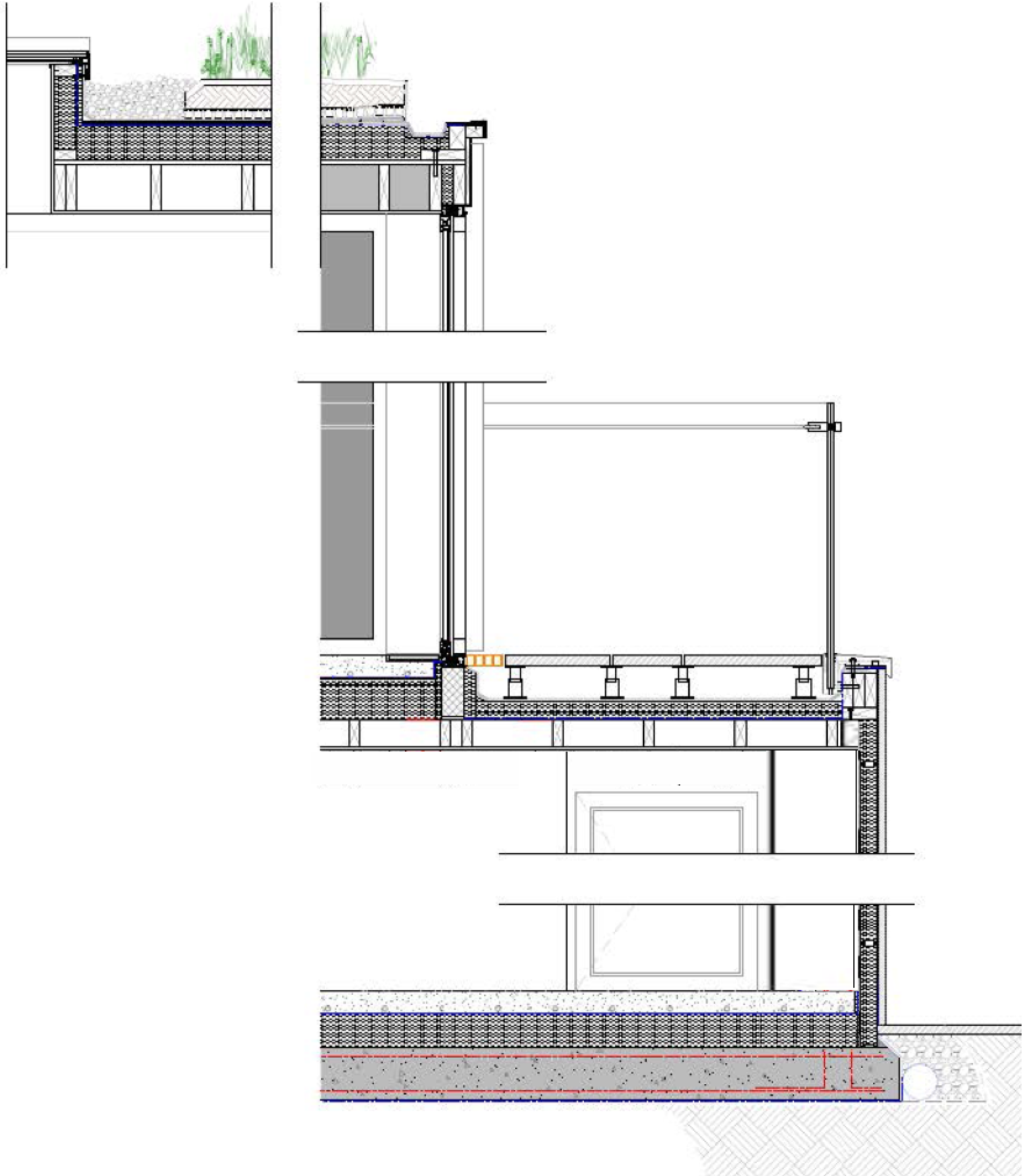
1:200 Site Plan

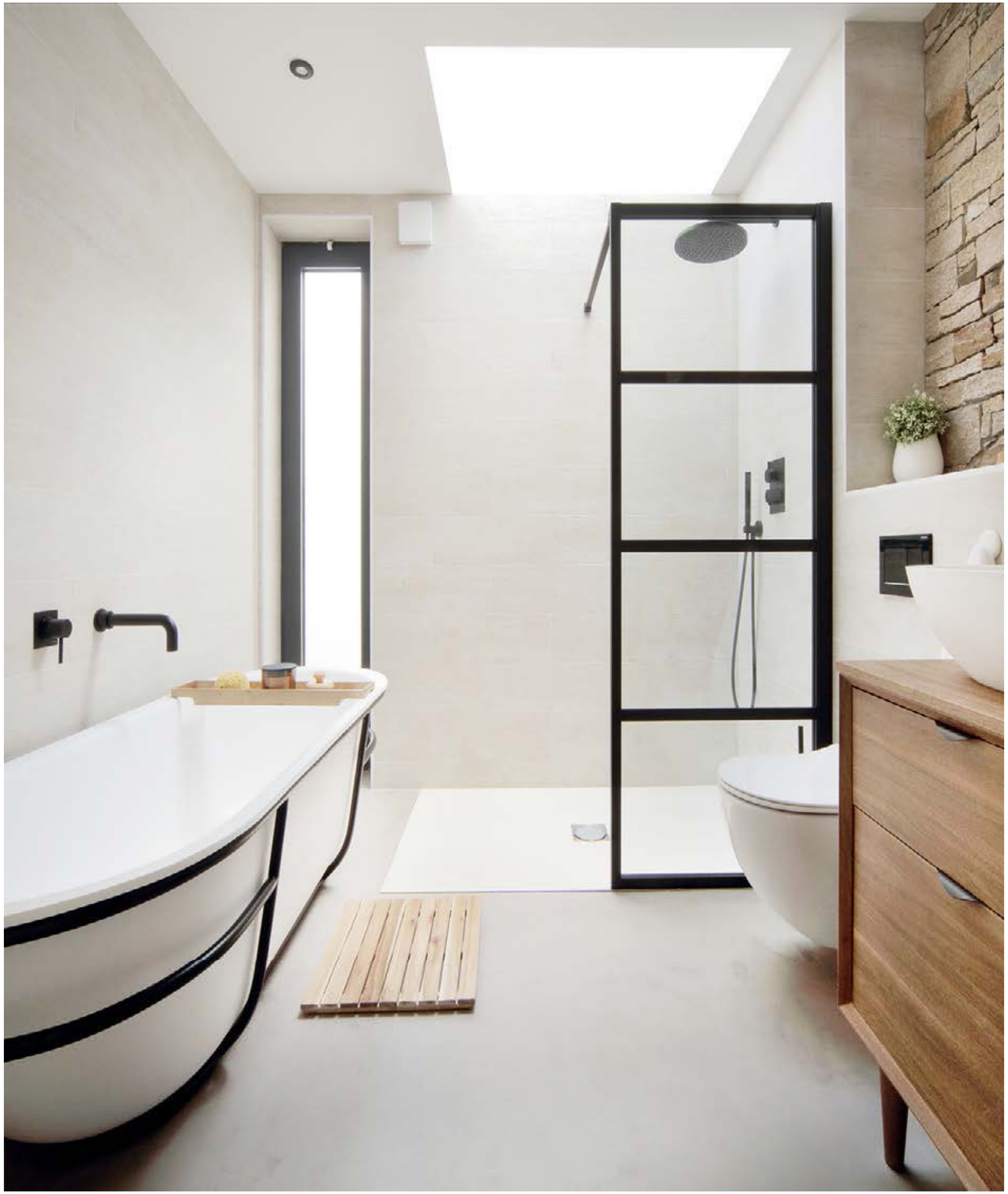

1:100 Ground Floor Plan

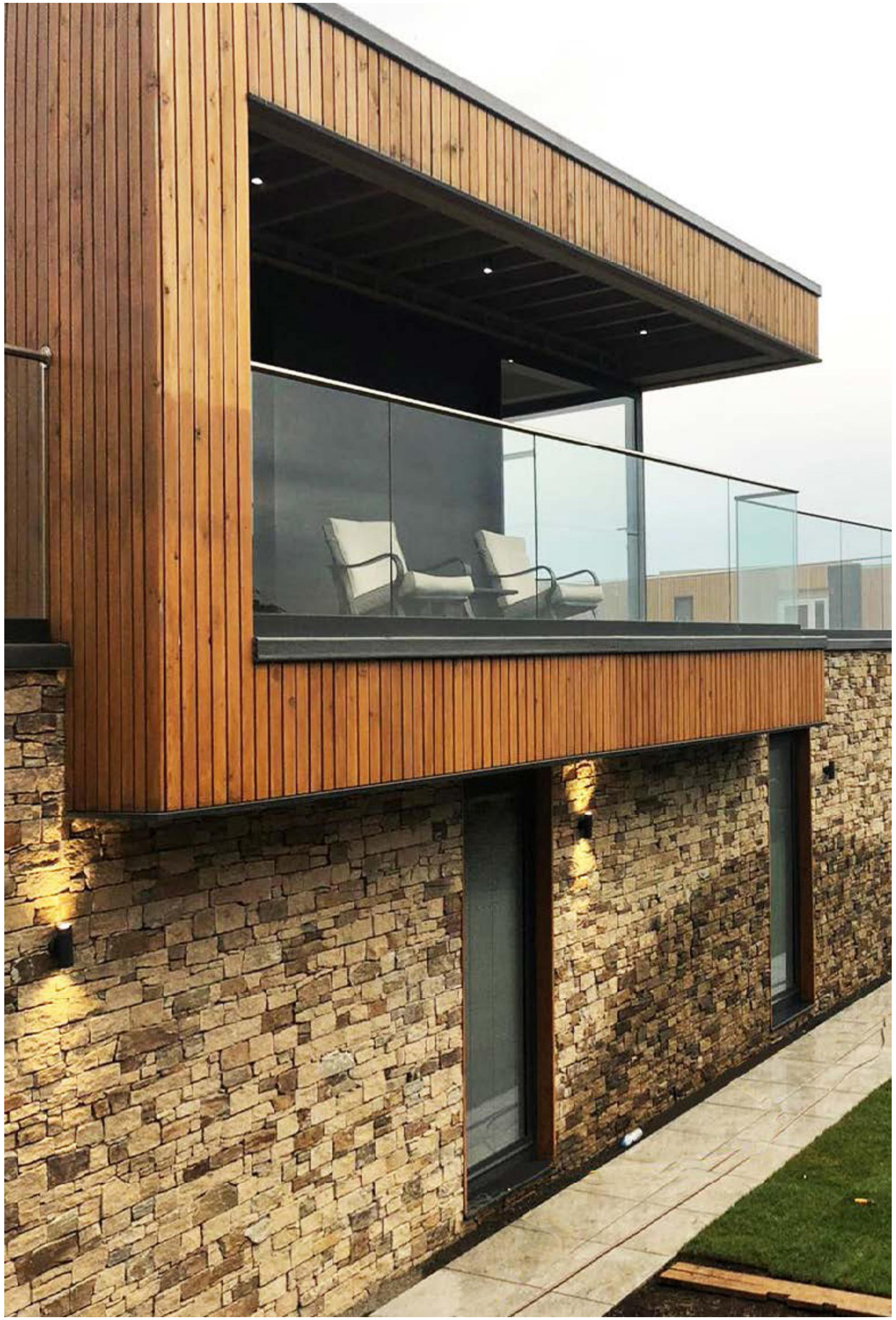

1:100 First Floor Plan

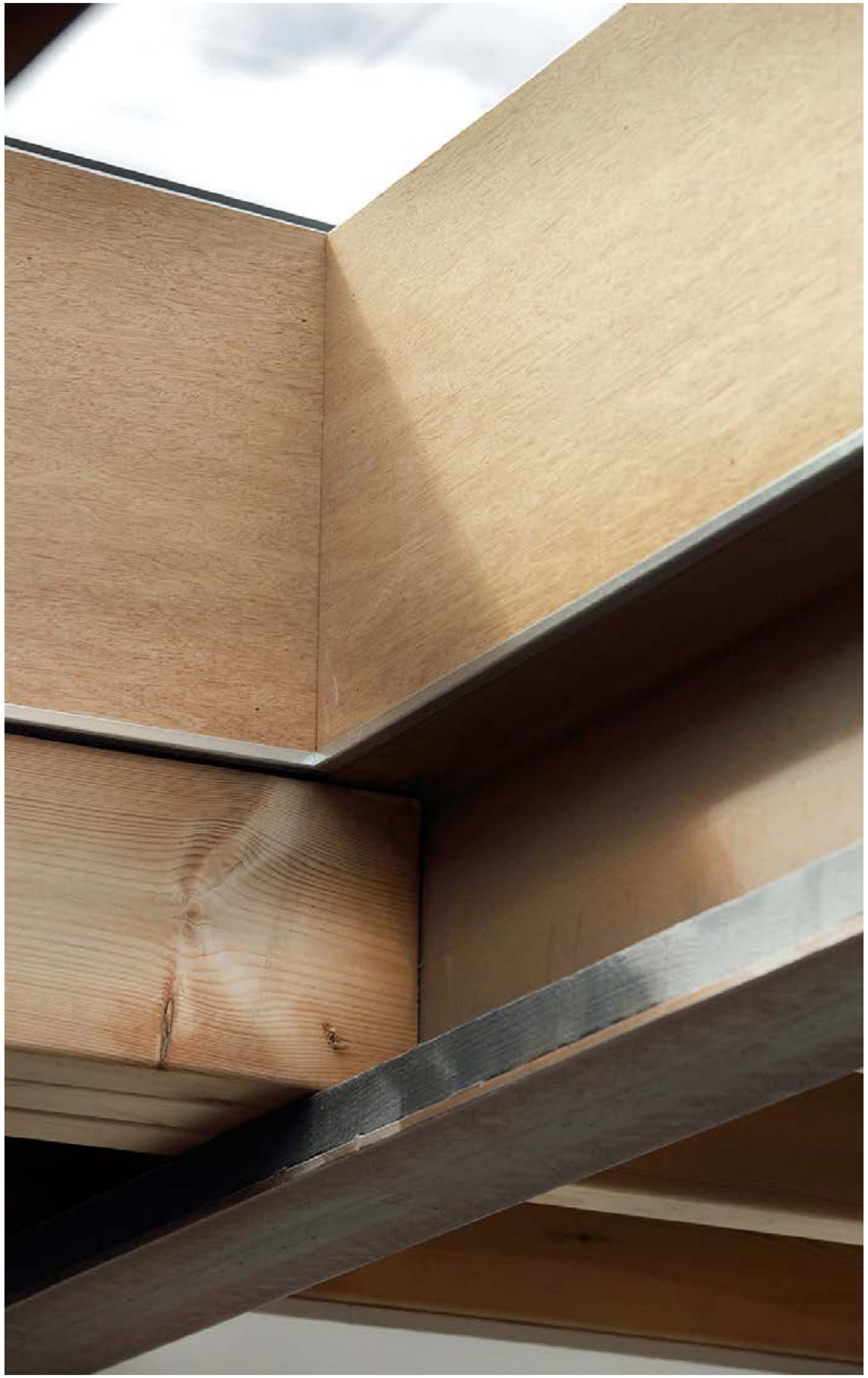


1:50 Proposed Section AA [PLOT 08]









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18. Illustrations