smithandwallwork
engineers

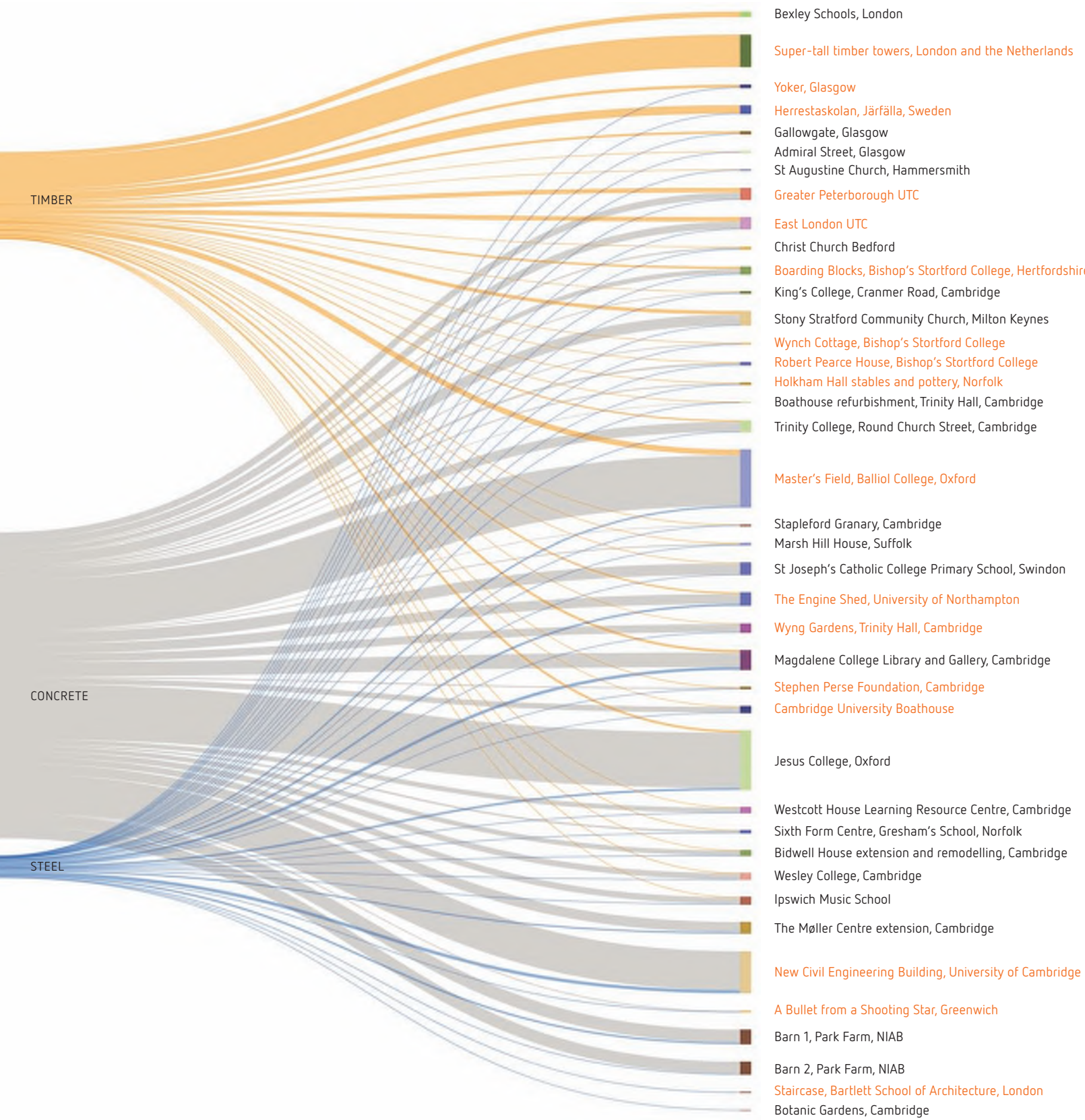
smith and wallwork

Smith and Wallwork is a civil and structural engineering design practice based in Cambridge. We focus on providing bespoke and economic engineering designs that are informed by a thorough understanding of the client brief and the build process. We like to be involved from the very start: embedding the engineering thinking at the early stages of a project and working with the whole team to produce a coordinated design strategy. We know this leads to successful outcomes.

Our directors work on projects from the start through to completion. We believe that this level of experience applied throughout provides significant benefits. The benefits start with early parametric studies that are aimed at creating the optimum engineering solution for a building. Our solutions focus on the small details as well as the bigger concept — it is often the small details that bring success to the build process.

Getting the design right is just one of our aims at Smith and Wallwork. Meticulous planning is also in our blood; delivery on time is paramount; and design programmes, delivery schedules and resource planning are common to all our projects.

This practice profile provides a snapshot of a selection of projects, completed and in design.


TIMBER
CONCRETE
STEEL
Bexley Schools, London
Super-tall timber towers, London and the Netherlands
Yoker, Glasgow
Herrestaskolan, Järfälla, Sweden
Gallowgate, Glasgow
Admiral Street, Glasgow
St Augustine Church, Hammersmith
Greater Peterborough UTC
East London UTC
Christ Church Bedford
Boarding Blocks, Bishop's Stortford College, Hertfordshire
King's College, Cranmer Road, Cambridge
Stony Stratford Community Church, Milton Keynes
Wynch Cottage, Bishop's Stortford College
Robert Pearce House, Bishop's Stortford College
Holkham Hall stables and pottery, Norfolk
Boathouse refurbishment, Trinity Hall, Cambridge
Trinity College, Round Church Street, Cambridge
Master's Field, Balliol College, Oxford
Stapleford Granary, Cambridge
Marsh Hill House, Suffolk
St Joseph's Catholic College Primary School, Swindon
The Engine Shed, University of Northampton
Wyng Gardens, Trinity Hall, Cambridge
Magdalene College Library and Gallery, Cambridge
Stephen Perse Foundation, Cambridge
Cambridge University Boathouse
Jesus College, Oxford
Westcott House Learning Resource Centre, Cambridge
Sixth Form Centre, Gresham's School, Norfolk
Bidwell House extension and remodelling, Cambridge
Wesley College, Cambridge
Ipswich Music School
The Møller Centre extension, Cambridge
New Civil Engineering Building, University of Cambridge
A Bullet from a Shooting Star, Greenwich
Barn 1, Park Farm, NIAB
Barn 2, Park Farm, NIAB
Staircase, Bartlett School of Architecture, London
Botanic Gardens, Cambridge

cross laminated timber
glulam
steel

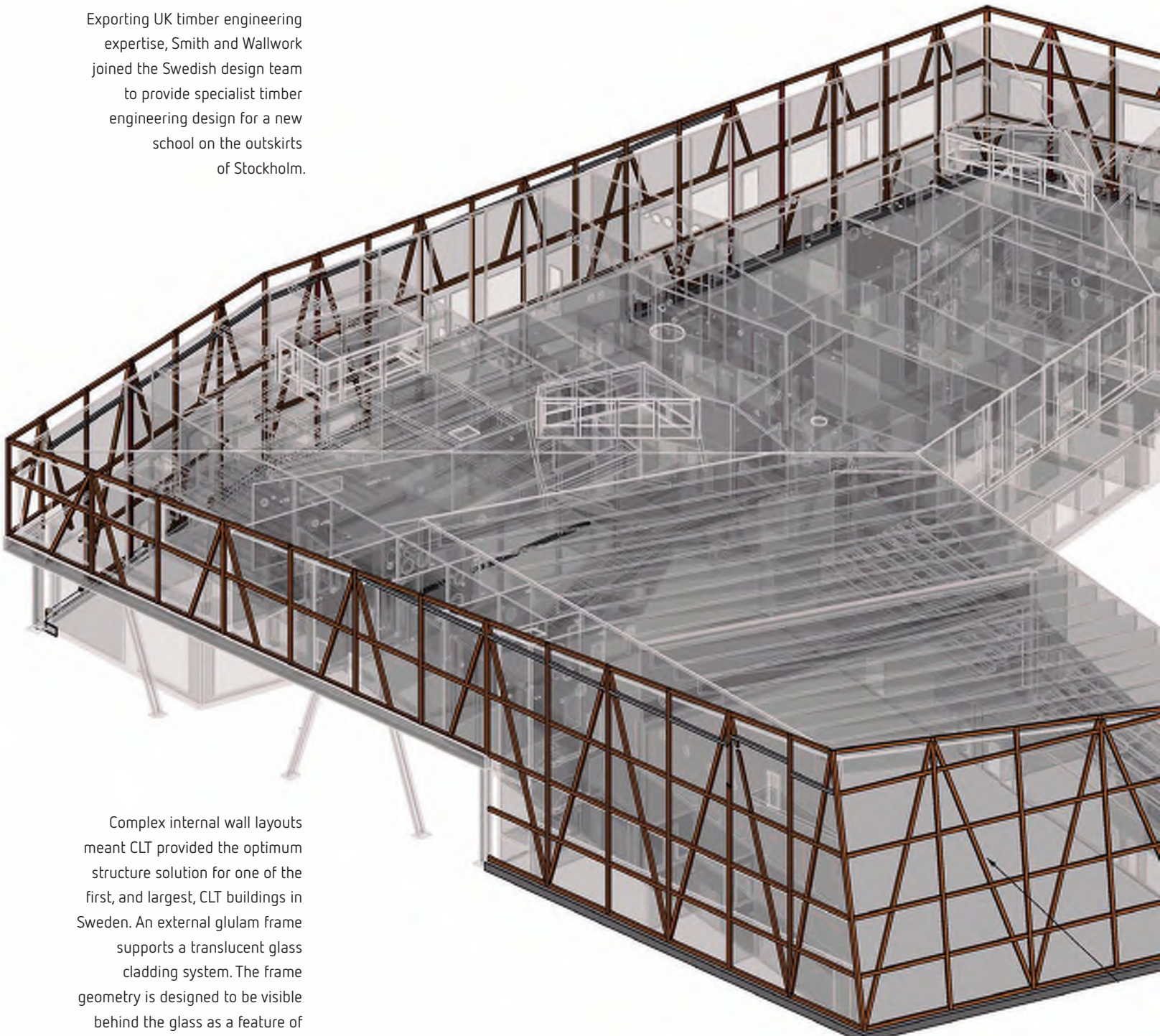
transfer loadbearing wall overlay

gross internal area 7,730m^2 timber 1,358t steel 33t

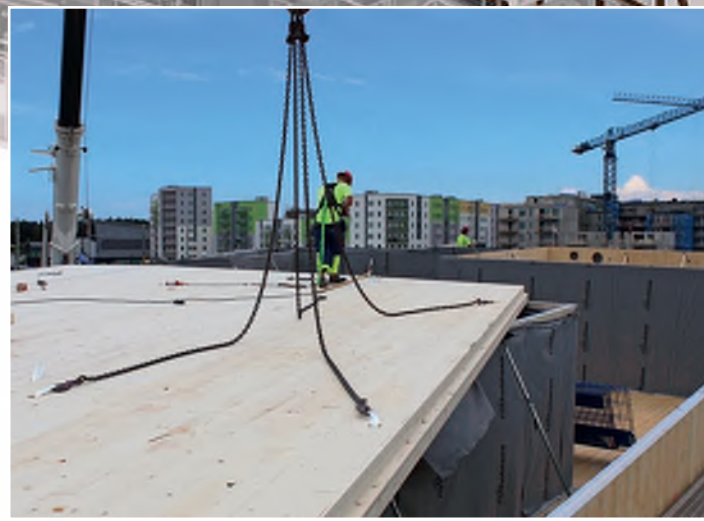
HERRESTASKOLAN

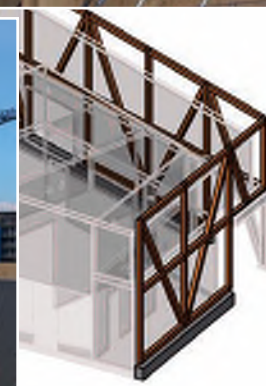
Karlslundsvägen, Järfälla, Sweden

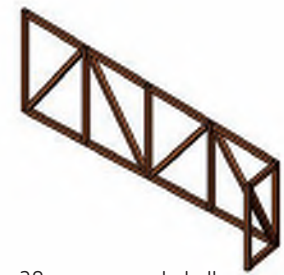
Exporting UK timber engineering expertise, Smith and Wallwork joined the Swedish design team to provide specialist timber engineering design for a new school on the outskirts of Stockholm.



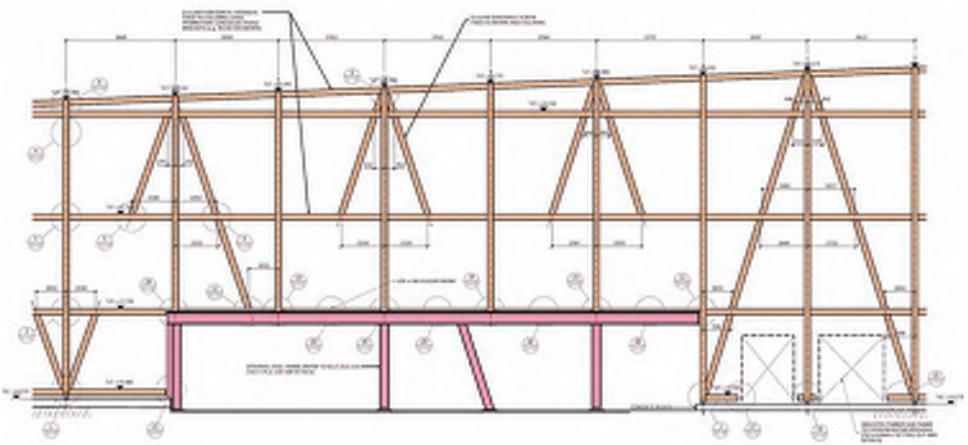
Complex internal wall layouts meant CLT provided the optimum structure solution for one of the first, and largest, CLT buildings in Sweden. An external glulam frame supports a translucent glass cladding system. The frame geometry is designed to be visible behind the glass as a feature of the building's façades.

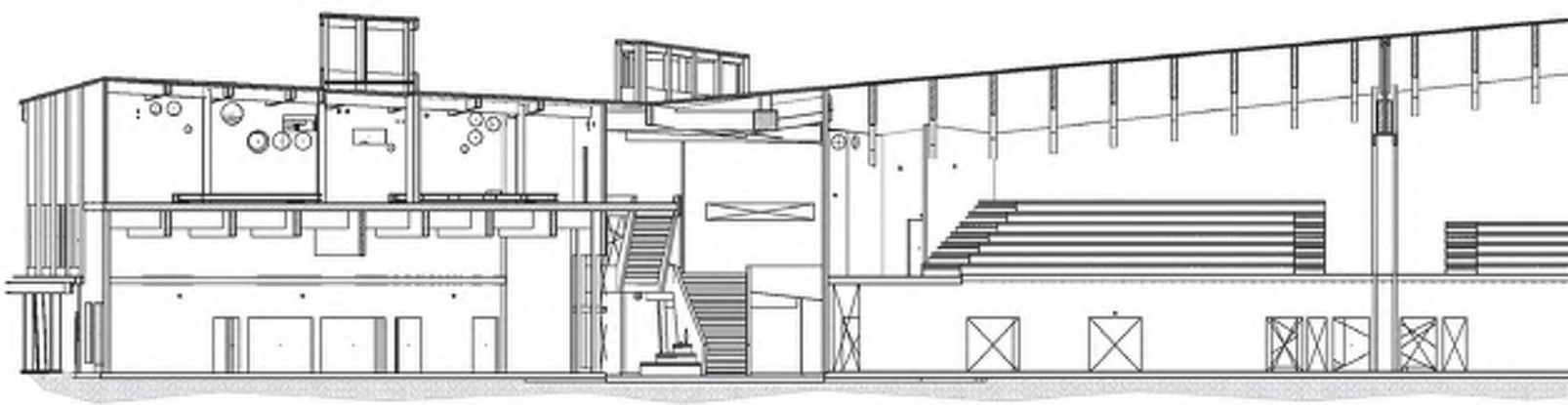


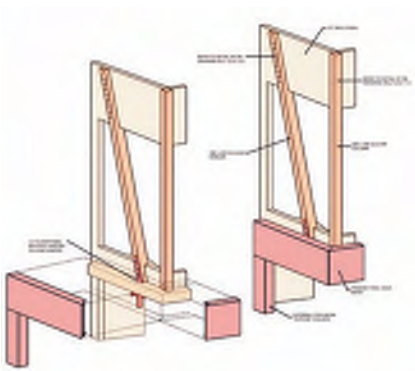


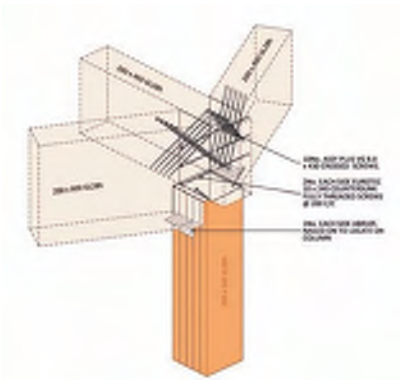


The 30m-span sports hall roof is designed to support Swedish snow loads (which exceed UK floor loading) and consists of 2m deep 'fish belly' profile glulam beams, creating a large multi-use space. Exposed timber finishes are used throughout the building.

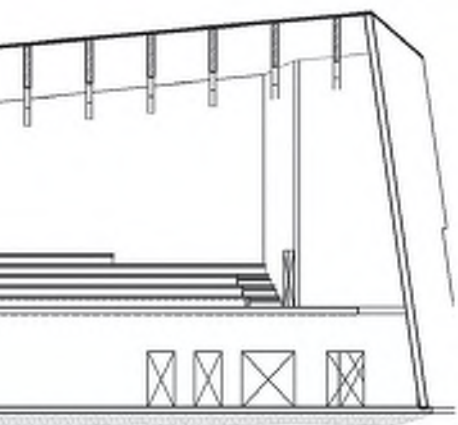








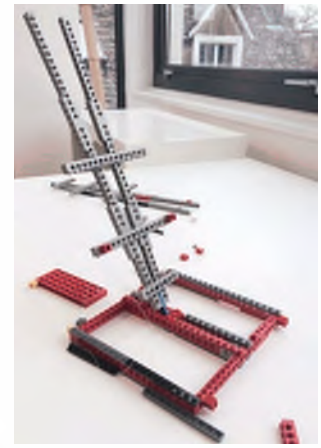
A 3D CAD model was used to solve the complex geometry and coordinate builder's work holes for the building services. The detailing of the timber connections was a key part of this, and of communicating the timber engineering principles.
Steel structure is used in localised areas, predominantly within the façades, and bespoke fabricated sections help deliver the architectural design for the exterior.



CLIENT Järfälla Kommun
ARCHITECT Liljewall arkitekter
CONTRACTOR Skanska
VALUE £27m
COMPLETION January 2016

steel
spiral strand cables
concrete ballast

cable-stayed balanced sculpture

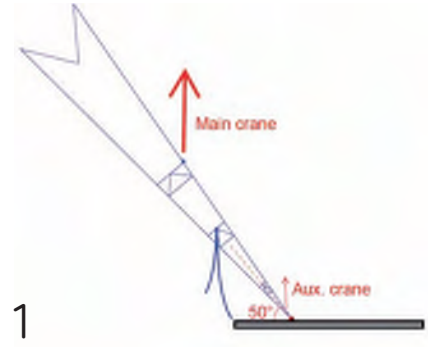


gross internal area 400m^2 concrete 182t steel 20t

A BULLET FROM A SHOOTING STAR

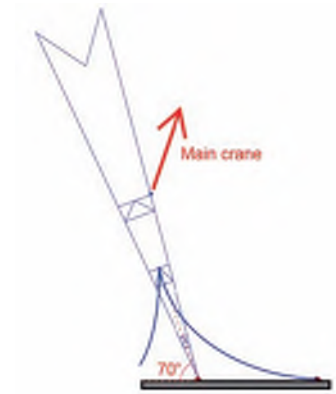
North Greenwich Peninsula, London, UK

Made ground at the Greenwich Peninsula demanded the use of four small-diameter piles locally to support the weight of the pylon. The buried concrete ring beam, which provides ballast to counteract the leaning and wind forces, is ground bearing. The pylon structure was part-prefabricated, bolted together on the ground and temporarily suspended in position by a mobile crane. The pylon's tip was then fixed down and the cables rigged.



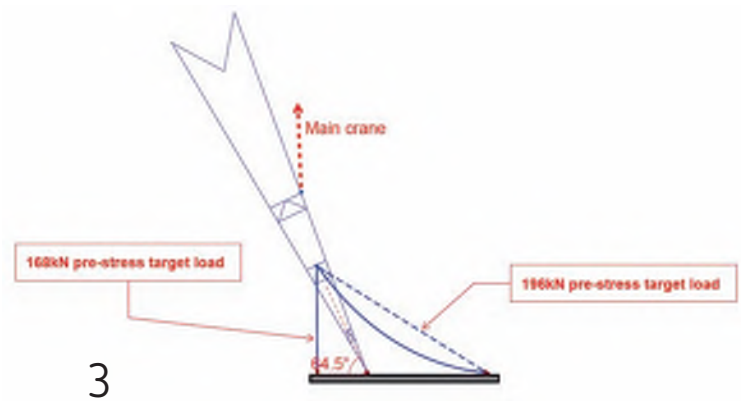
1

Use the main crane to lift the pylon up to 50 degrees. Simultaneously, use the auxiliary crane to keep it off the ground and help position the tip. Pin the tip of the pylon to the anchor plate.



2

Lift the pylon to a 70 degree angle with the main crane. Pull the back cables with a turfer of 1t in order to fix them to their anchor plates. Adjust the turnbuckle/pre-stressing cage to the final specified position



3

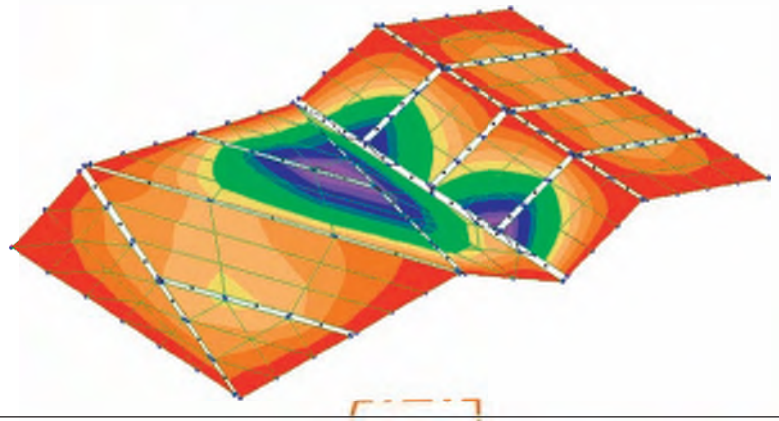
Let the pylon fall down under its own weight. Keep the crane attached for stability and security. Pull the back cables with a turfer of 1t in order to fix them to their anchor plates.

The four cables that stabilise the pylon were pre-stressed to maintain a constant tension under wind load conditions. Cable tensioning was carried out manually with threaded bar blocks. To achieve the 19t pre-stress, a hydraulic wrench was used. Pre-stress levels were then checked using a calibrated statimeter.

CLIENT London Design Festival, Knight Dragon
ARTIST/DESIGNER Alex Chinneck
CONTRACTOR Litestructures
VALUE £330,000
September 2015

piled raft
cross laminated timber
masterplan

resisting gravity through form

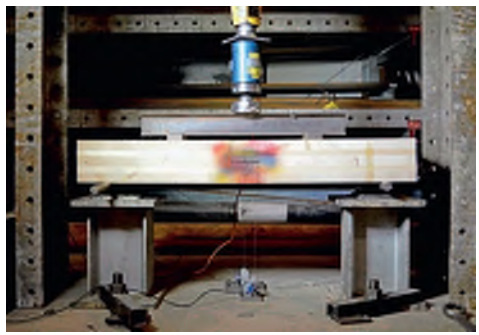


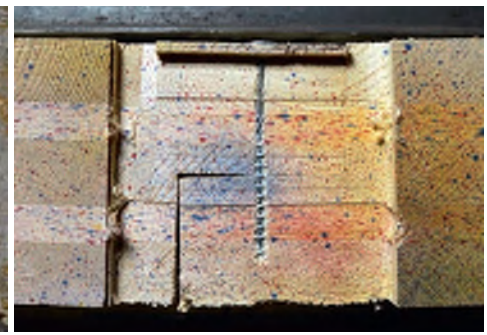
Three new projects for an independent, co-educational college — Wynch Cottage, new boys and girls boarding houses, and the restoration and extension of fire-damaged Robert Pearce House. Work commenced early in 2014 (Wynch Cottage) and completed in December 2017 with the handover of the two boarding blocks and Robert Pearce House.

BISHOP'S STORTFORD COLLEGE

Maze Green Road, Bishop's Stortford, Hertfordshire, UK

We engineered a cross laminated timber (CLT) extension to the existing Wynch Cottage building (c1920) to provide new teaching and study spaces. A key feature of the design is the folded plate roof structure, the geometry of which is used to create a self-supporting clear span roof form.





Exposed CLT finishes are used throughout the building, requiring a high degree of panel joint coordination and attention to the detailing of timber connections. R&D testing at the University of Cambridge was used to determine the bending stiffness of the CLT folded plate roof joints.

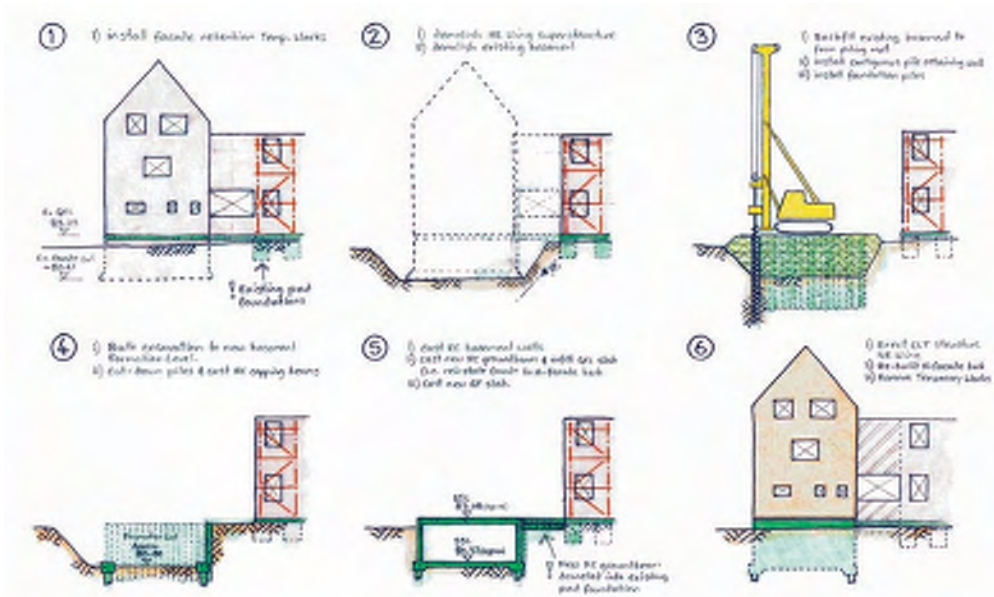
gross internal area 322m^2 timber 51t concrete 195t steel 6t

Wynch Cottage

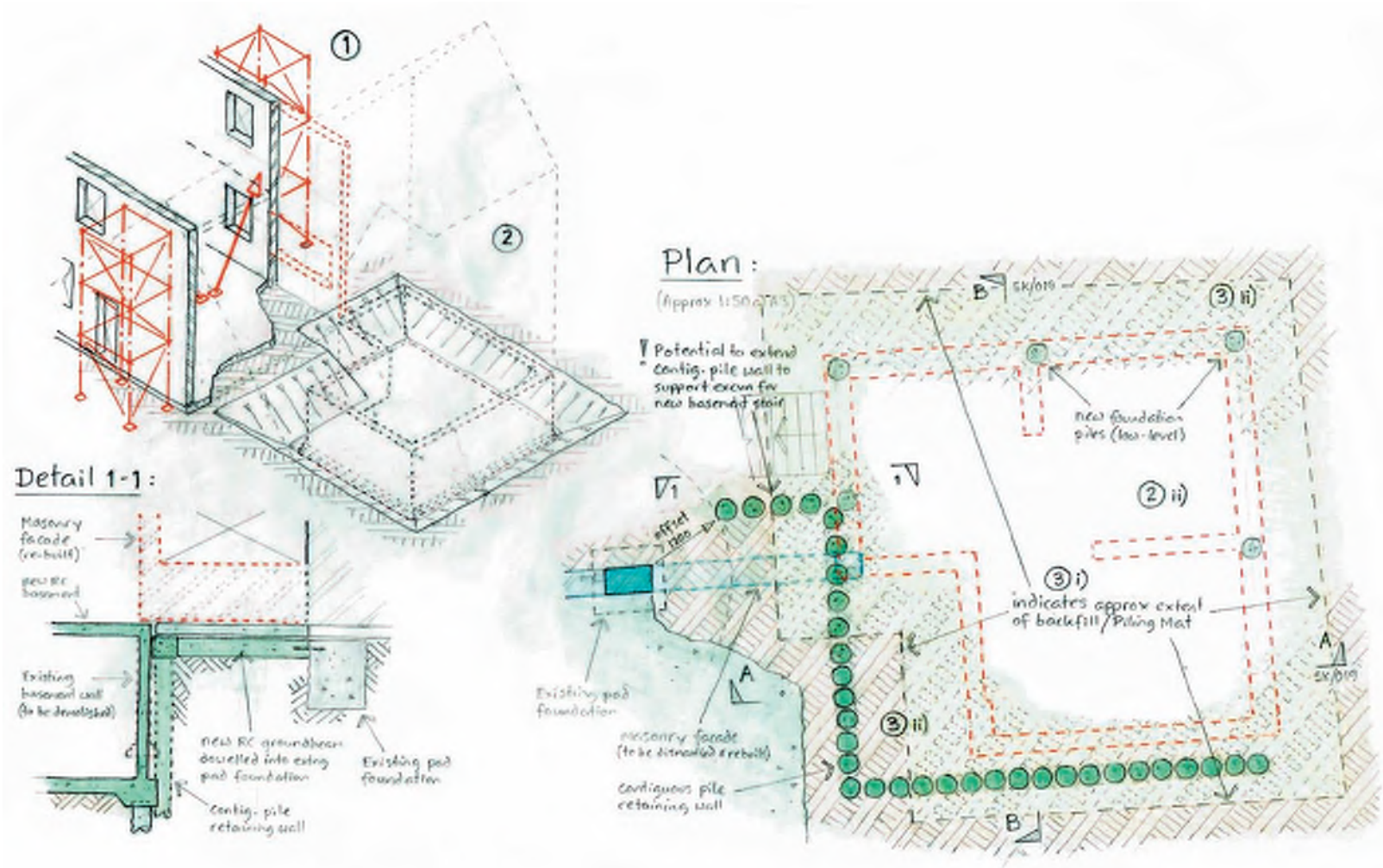
The remodelling, refurbishment and extention of the much-loved Robert Pearce House — an Arts & Crafts period boarding house. It suffered a catastrophic fire on 29 September 2015.

The construction of a new basement and retention of existing brick façades led to the need for detailed consideration of the construction sequence and the temporary works to maintain building stability.

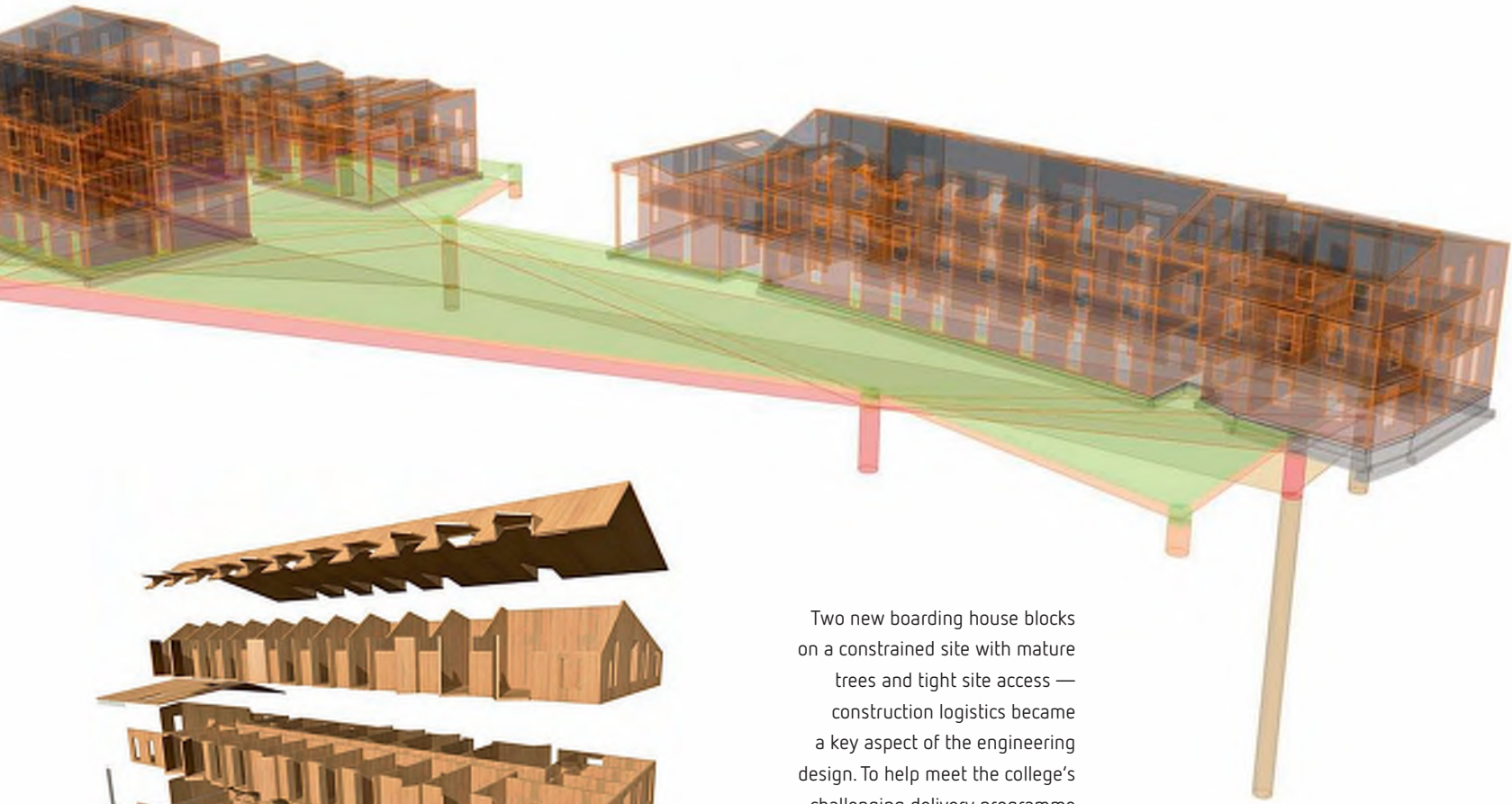
A mix of traditional craftsmanship and modern methods of construction has been used, preserving the design of the original building. The East Wing extension is a cross laminated timber structure, and the civil engineering design uses a surface water drainage system that eliminated the need for buried attenuation tanks and is integrated into the layout of a new courtyard.



gross internal area 975m^2 timber 131t concrete 365t steel 40t

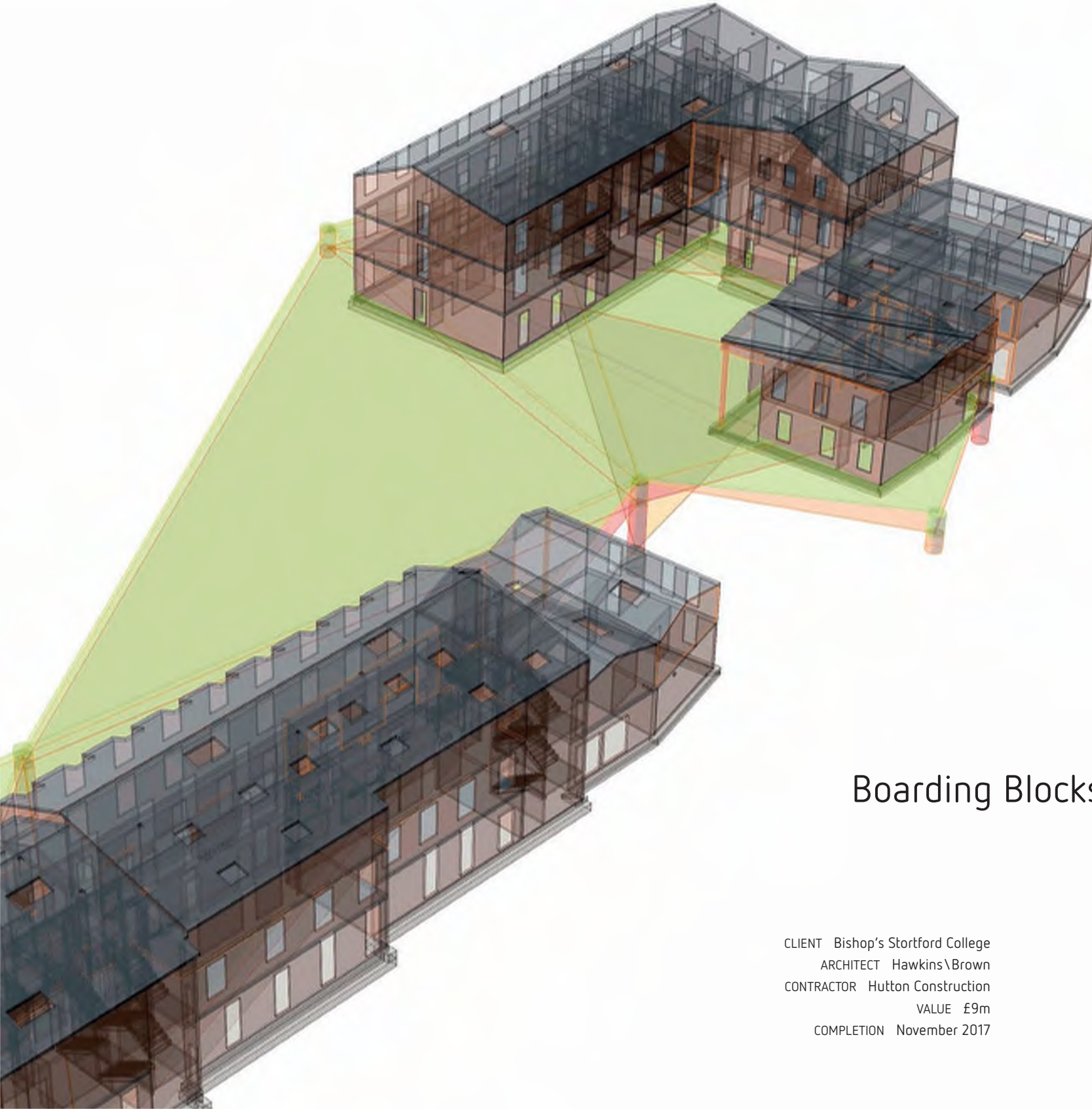


Robert Pearce House



Two new boarding house blocks on a constrained site with mature trees and tight site access — construction logistics became a key aspect of the engineering design. To help meet the college's challenging delivery programme, we used a cross laminated timber structural solution on a piled raft foundation. The CLT folded plate roof forms of the Dayhouses were inspired by the success of the Wynch Cottage design.

gross internal area 3,952m^2 timber 596t concrete 1,718t steel 28t



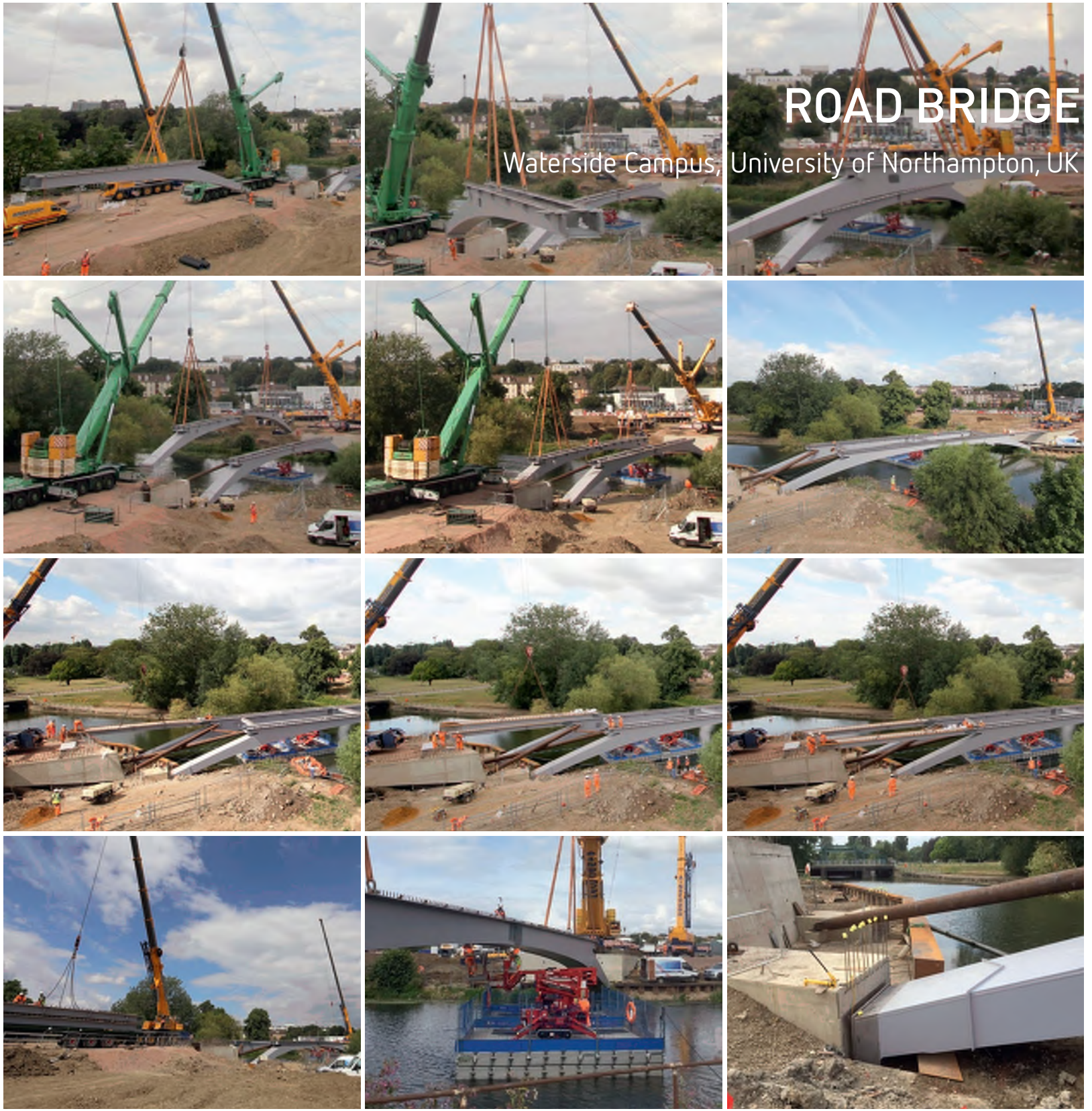
Boarding Blocks

CLIENT Bishop's Stortford College
ARCHITECT Hawkins\Brown
CONTRACTOR Hutton Construction
VALUE £9m
COMPLETION November 2017

steel
concrete
three-pin arch
design led by lift strategy
bridge length 75m arch span 55m steel 200t

ROAD BRIDGE

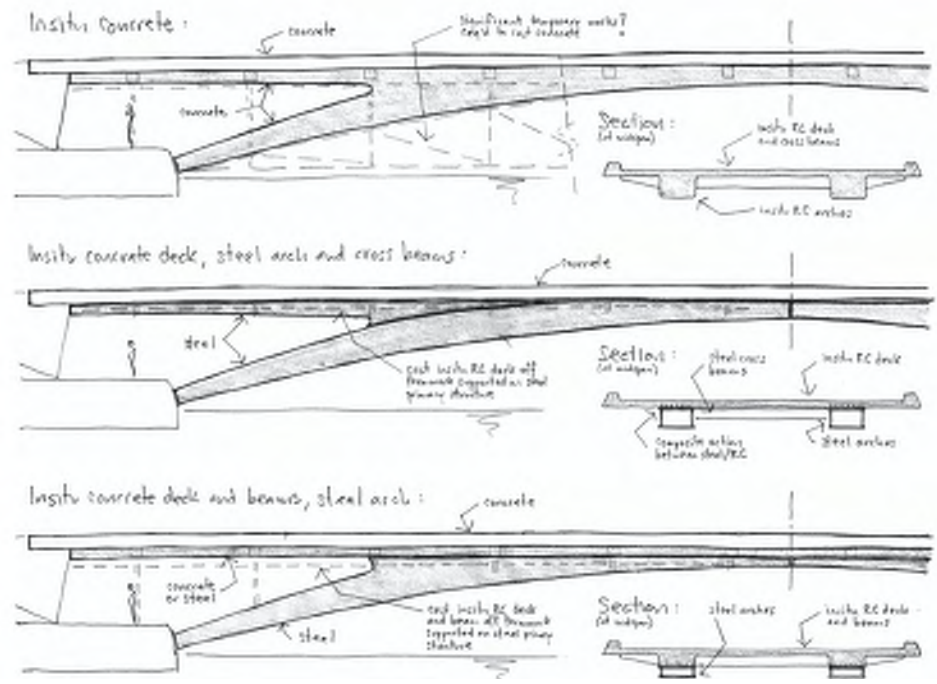
Waterside Campus, University of Northampton, UK

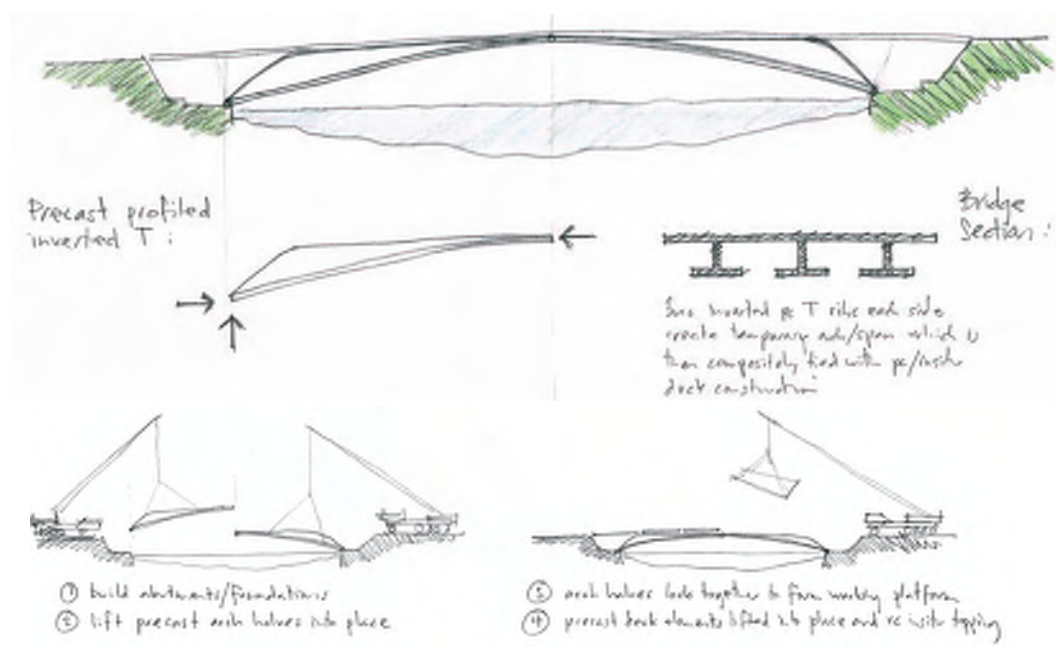


The new road bridge is a vital link to Northampton University's new campus, which is due to open in 2018. We were asked to assist in the development of the engineering concept for the bridge. The architect was keen to see a modest but elegant structure, and we took our inspiration from Maillart as well as from the build logistics.

Our research on cranes and our preliminary structural design highlighted that a 3-pin arch in steel was possible to install using a dual lift approach with 500t mobile cranes. The same solution in precast concrete would demand 1,000t mobile cranes, something not readily available in the UK.

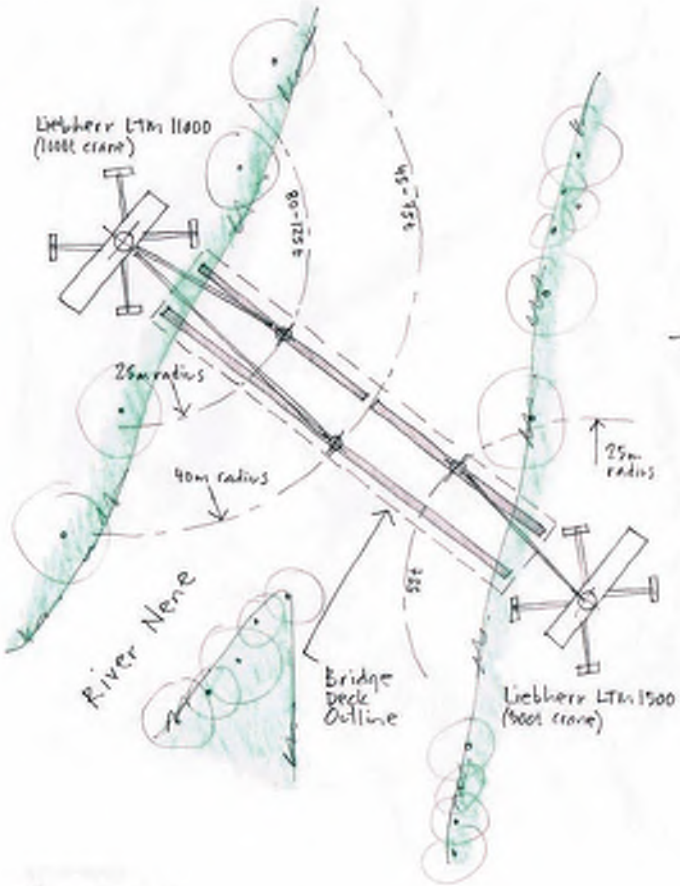
Our concept design was installed in 2017 with CH2M completing the detail design.





Site Plan:

1:500 @ A3



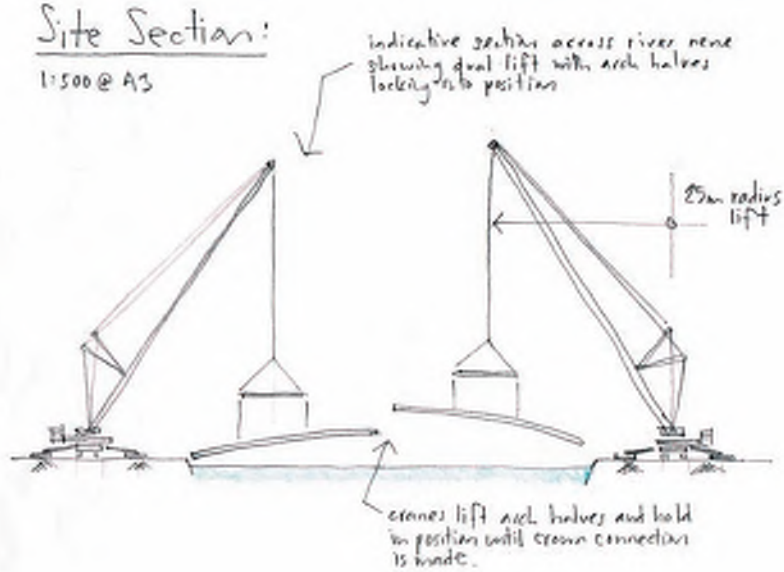
Other cranes:

400t @ 25m radius capacity is 40t

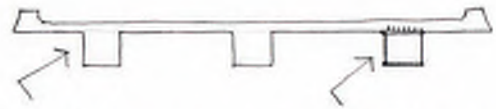
800t @ 40m radius capacity is 40t

Site Section:

1:500 @ A3



Typical Arch Section Elements:



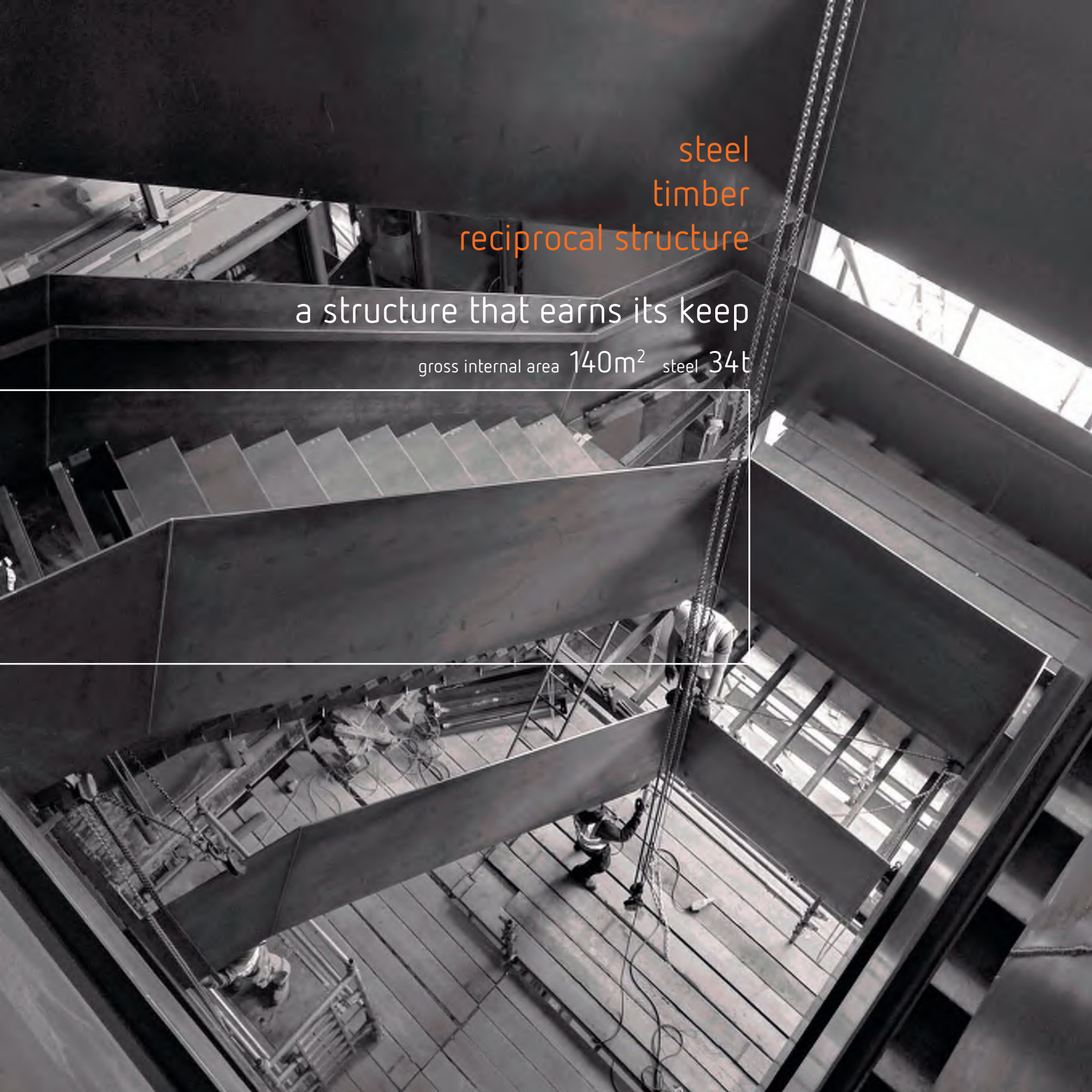
Concrete 1100x1000x30m = 75t ✓ (half arch)

Steel 900x900x30m = 45t ✓ (half arch)

Concrete 1000x1000x60m = 150t ✗ (full arch)

Steel 900x900x60m = 90t ✗ (full arch)

CLIENT University of Northampton
ARCHITECT Moses Cameron Williams
CONTRACTOR Volker Fitzpatrick
COMPLETION December 2016



steel
timber
reciprocal structure

a structure that earns its keep

gross internal area 140m^2 steel 34t

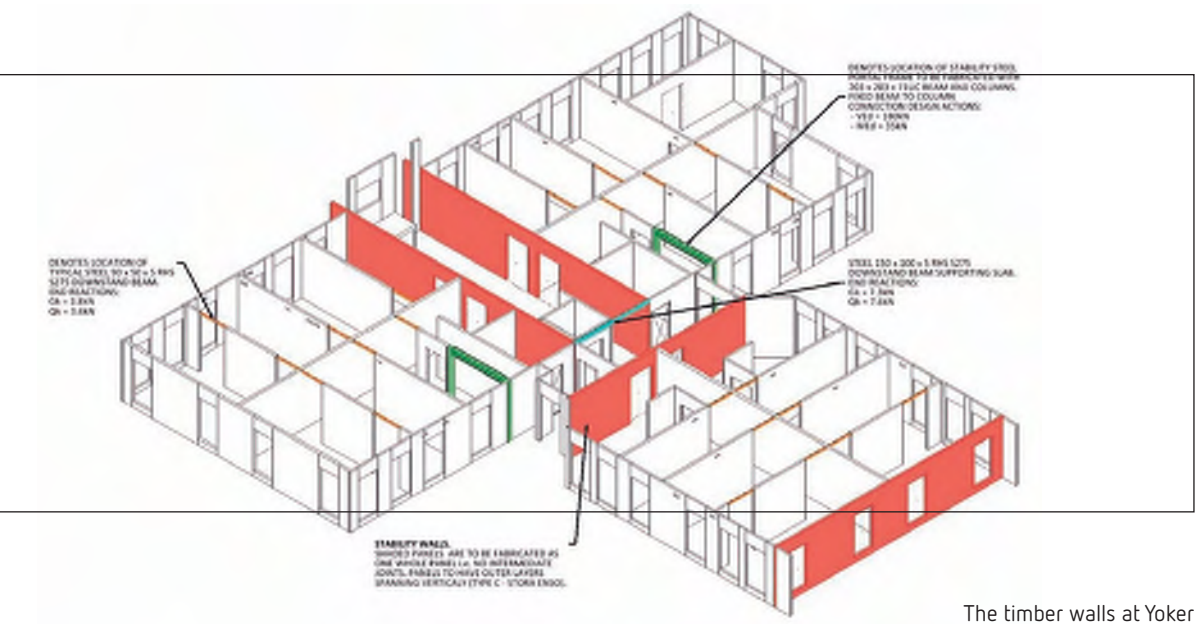
STAIRCASE

Bartlett School of Architecture, UCL, London, UK

CLIENT Bartlett School of Architecture
ARCHITECT Hawkins\Brown
CONTRACTOR Gilbert-Ash / CSI Ltd
COMPLETION December 2016

cross laminated timber
glulam
ultra fast-track

how to stop timber squashing

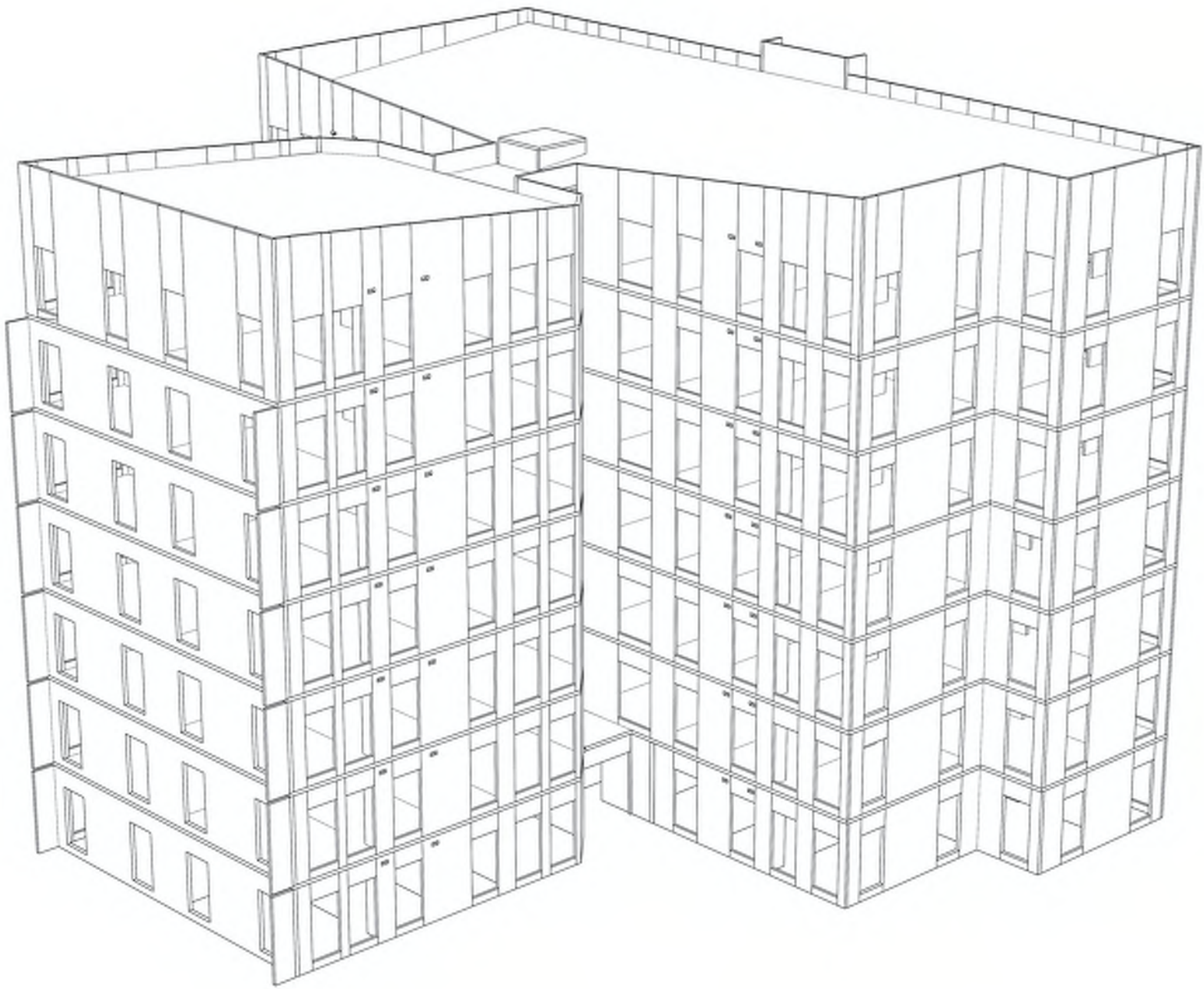


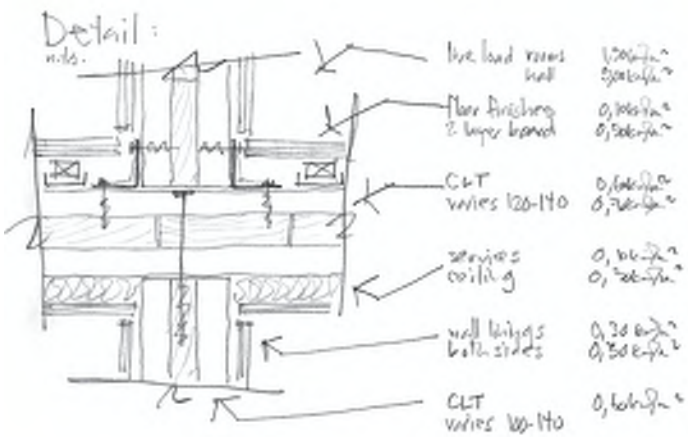
The timber walls at Yoker are designed to resist loads of up to 17t/m (a combination of gravity and wind load). At wall and floor junctions this 17t stresses the timber in its weak direction. As we go taller with timber, these junctions will need special reinforcement techniques to be developed.

gross internal area 3,745m^2 timber 484t steel 4t

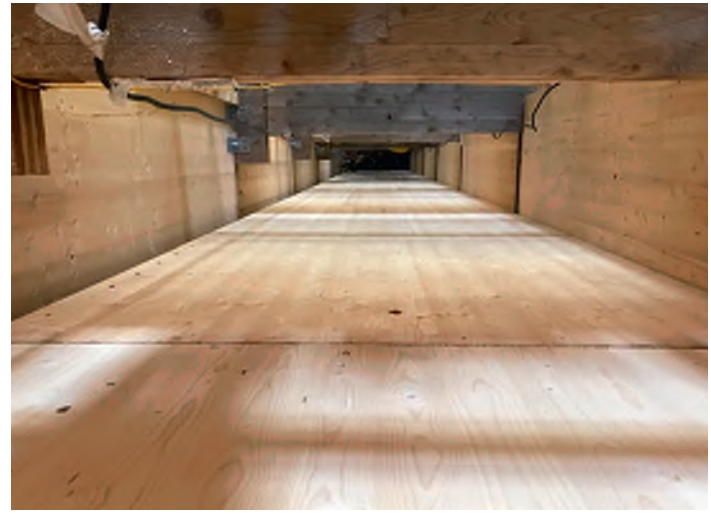
YOKER RESIDENTIAL

Ellerslie Road, Yoker, Glasgow, UK

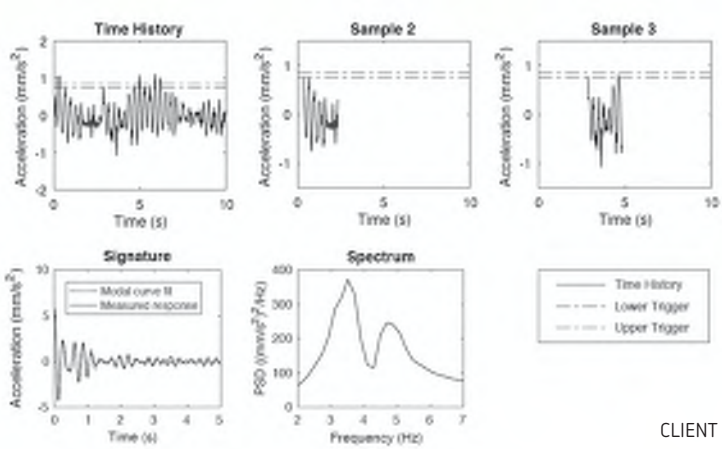




Yoker uses traditional platform construction techniques with industry standard fixings. No platform reinforcement is required. At ground floor, where the forces are greatest, connections to the concrete foundations are required to resist the uplift forces generated from wind over-turning. Up to 3t/m is resisted through steel angle brackets, fixed down to the concrete with resin anchors and nailed to the timber wall panels.



Tall buildings move in the wind and design checks are undertaken to make sure occupants don't perceive these movements. Lightweight timber buildings are particularly susceptible to moving in the wind. At Yoker we worked with Edinburgh University to measure the natural frequency and accelerations on the top floor of the completed building.



CLIENT CCG (Scotland) Ltd
ARCHITECT MAST Architects
CONTRACTOR CCG and Eurban
VALUE £4.7m
COMPLETION February 2018

glulam
cross laminated timber
economical and ultra fast-track

cut-back ribbed slab

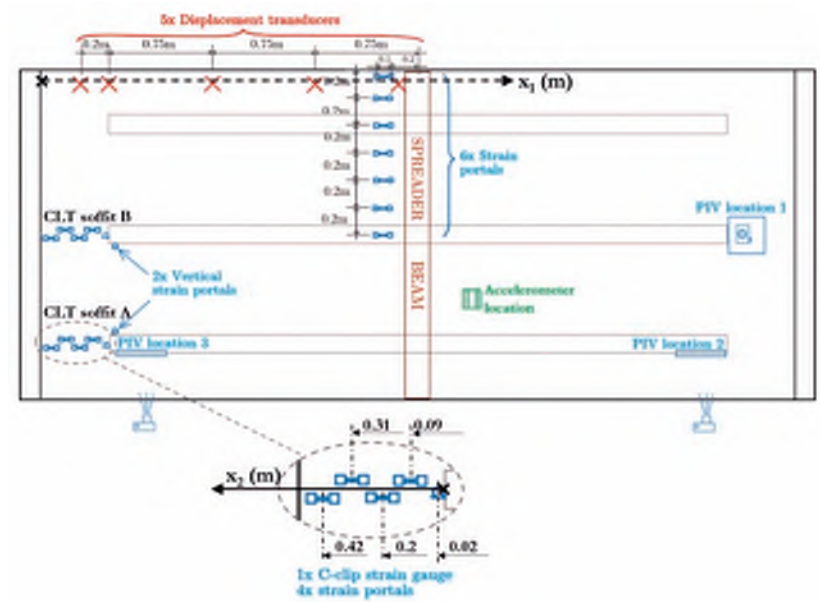
gross internal area 4,550m^2 timber 746t concrete 1,080t steel 55t

GREATER PETERBOROUGH UNIVERSITY TECHNICAL COLLEGE

Park Crescent, Peterborough, UK

Innovations delivered within tight cost and programme constraints for this project include an 11m span CLT / glulam timber ribbed transfer deck. The glulam ribs are cut-back 0.5m from the face of the supports to provide space for horizontal distribution of building services within the depth of the floor.

Complex interaction of forces at the ends of the cut-back ribs led to research and testing at the University of Cambridge Engineering labs, with the results presented in a paper at the World Conference of Timber Engineering 2016.



We used a scale model to interrogate the assembly sequence of the 15m span glulam timber truss — confirming that offsite prefabrication and special road transportation was required.

The storey-height glulam truss was craned into position as a single prefabricated element. Steel downstand beams frame into the bottom chord to reduce the spans of the first-floor cross laminated timber floor panels. The steel beams reduce overall floor depth and are notched at their ends for distribution of the building services.

The truss is left as exposed timber finish so required careful detailing of the connections, which are visible. Full-height glazing (behind the truss) separates first floor office and circulation spaces from the double-height events space.

Full-scale testing combined with finite element modelling of the ribbed slab in the University of Cambridge Engineering labs showed that the penetration depth of the screw connections between the cross laminated timber slab and the ends of the glulam ribs is critical to the ultimate load capacity. A suggested design approach for cut-back ribbed slabs was developed, and presented by Smith and Wallwork at the World Conference of Timber Engineering 2016.

WCTE 2016
World Conference on Timber Engineering

THE DESIGN OF CROSS-LAMINATED TIMBER SLABS WITH CUT-BACK GLULAM RIB DOWNSTANDS – FROM RESEARCH TO LIVE PROJECT

Panayiotis Papanicolaou[1], Simon Smith[2], Tristan Wallwork[3], Allan McRobbie[4], Nicholas Niem[5]

ABSTRACT: A research project was undertaken to investigate the behaviour of composite CLT slabs with glulam downstands cut back from the supports. A desk study and Finite Element Modelling (FEM) were used and evaluated on their ability to model and design such a structure, focusing on the cut back location and utilising reinforcement screws. The project included full-scale laboratory testing of a composite slab to failure with innovative data collection techniques such as Particle Image Velocimetry. A similar structural element was also used in a real construction project and the investigation gave insight towards its design. It was concluded that the embedment depth of reinforcement screws in the glulam downstand is key to the performance of the composite slab with full depth penetration advisable. FEM can give useful results for stress concentrations in the timber and a simplified design method was proposed.

KEYWORDS: Cross-Laminated Timber, Composite Slabs, Particle Image Velocimetry, Finite Element Modelling

1 INTRODUCTION

A research project was undertaken at the University of Cambridge to investigate the behaviour of composite slabs with a CLT deck and glulam downstands. Particular focus was given on the design scenario of stopping the downstand beam short of the support and its effect on localised stresses in the area.

The project included finite element modelling and full scale full-testing as well as being implemented on a live construction project that is now complete.

2 CLT RIBBED SLABS

2.1 MOTIVATION

Cross-Laminated Timber floor panels are typically used for spans up to 7.5m under relatively lightweight floor buildup in office/classroom usage class. For these spans, the floor thickness required is approximately 200-300mm and the governing factors are serviceability limit states (SLS) in Eurocode design with the most common limiting criteria being vibration characteristics.

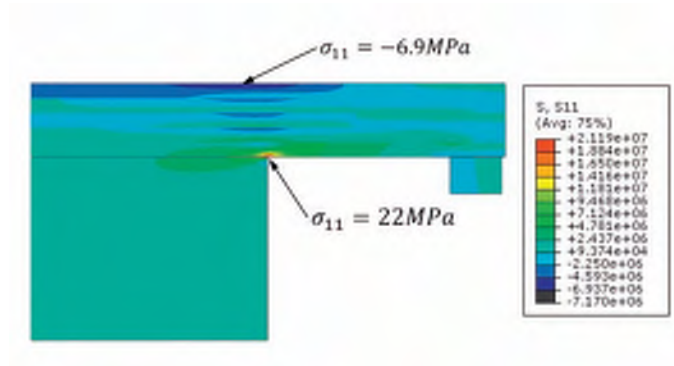
A buckspan could be utilized to enhance the deflection performance and this being unequal to the main span would slightly enhance the vibration performance as well. However, this means that single floor panels need to be increased in length to beyond 8m which might start to introduce other issues in terms of transport costs and access restrictions. It should be noted that, normally, CLT floor panels are limited by manufacturers to 15.5m lengths.

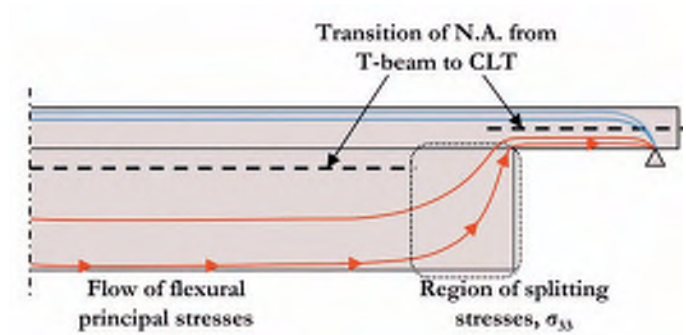
An alternative way to provide the additional stiffness required to meet the SLS criteria is to install Glulam downstand ribs to the underside of the floor panel. The structural element is then a "CLT Ribbed Slab". Gluing technology during fabrication allows the ribbed slab to be manufactured with a fully-composite connection between slab and ribs which can be utilized in the design.

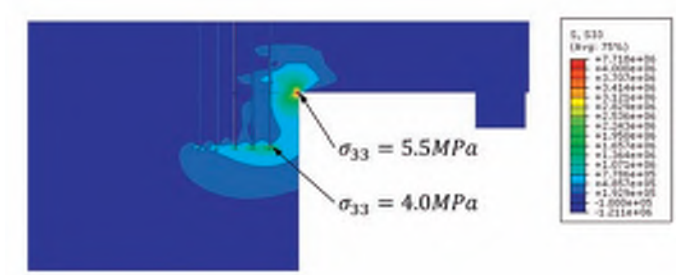
2.2 STRUCTURAL DESIGN

The design of fully-composite CLT ribbed slabs has been the subject of some publications to date and references are included here for completeness.

As per the design of T-beams in other more conventional materials e.g. reinforced concrete, the concept of the effective slab width, b_{eff}, needs to be considered as a result of shear lag. This is introduced for CLT ribbed slabs in [1] and provides an approximate reduced slab width to be used when calculating the design stresses and deflections due to the non-uniform normal stresses in the slab. See Figure 1 and Figure 2 below.





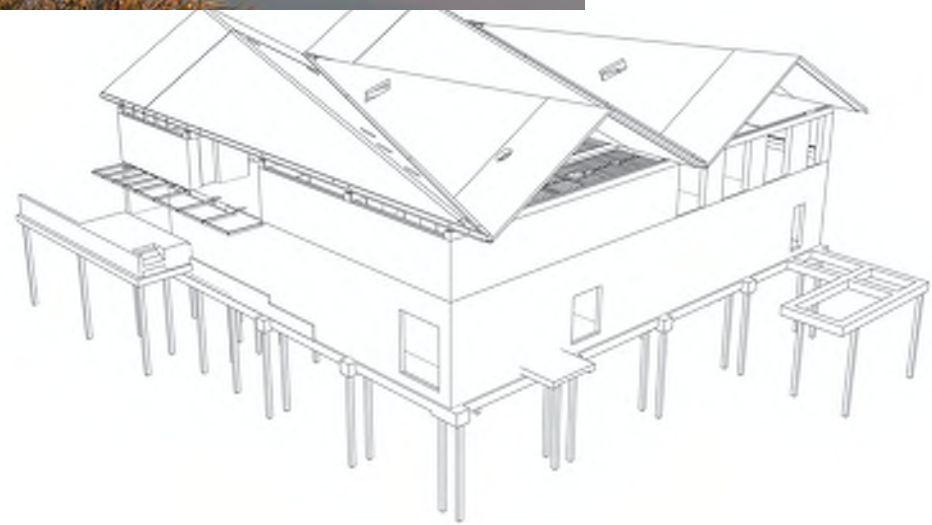


The fast track, contractor-led project was completed inside less than 18 months, a period that included the complete building design and planning approval processes.

CLIENT Greater Peterborough University Technical College
ARCHITECT LSI Architects
CONTRACTOR Kier Construction (Eastern)
VALUE £8m
COMPLETION September 2015

brick
cross laminated timber
water

a floodable building



gross internal area 1,250m^2 timber 63t concrete 920t steel 48t

CAMBRIDGE UNIVERSITY BOATHOUSE

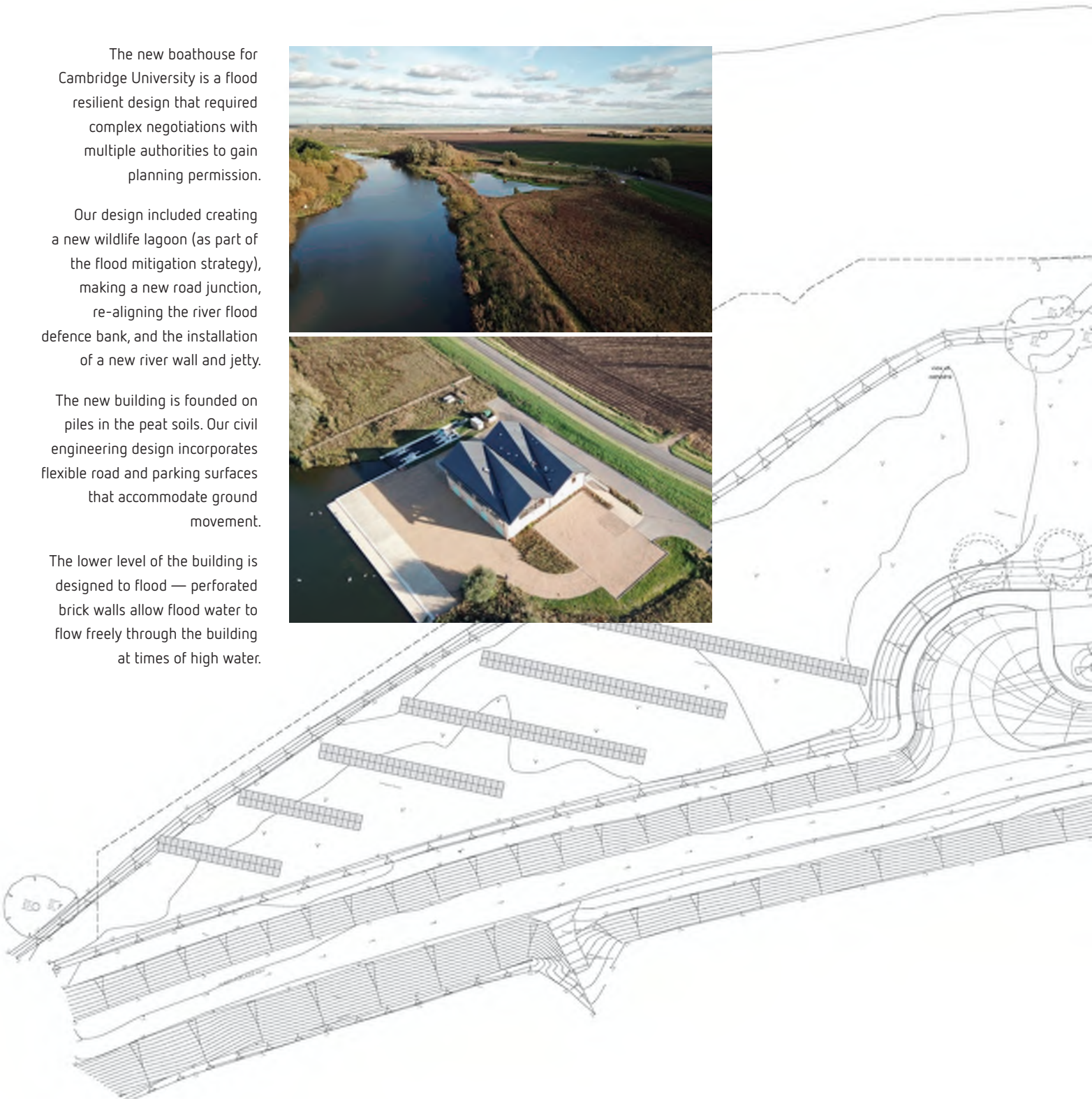
Fore Mill Wash, Queen Adelaide Way, Ely, Cambridgeshire, UK

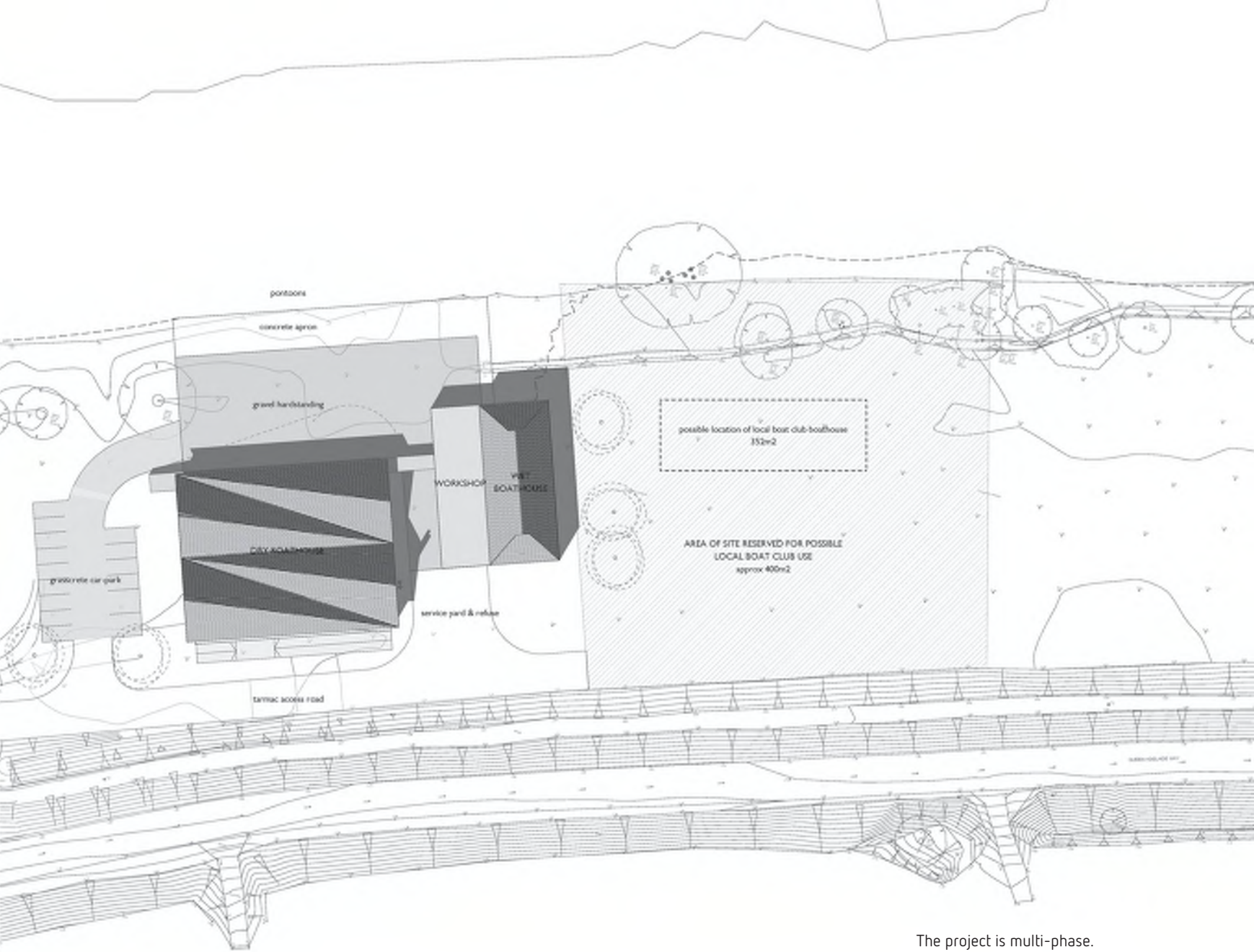
The new boathouse for Cambridge University is a flood resilient design that required complex negotiations with multiple authorities to gain planning permission.

Our design included creating a new wildlife lagoon (as part of the flood mitigation strategy), making a new road junction, re-aligning the river flood defence bank, and the installation of a new river wall and jetty.

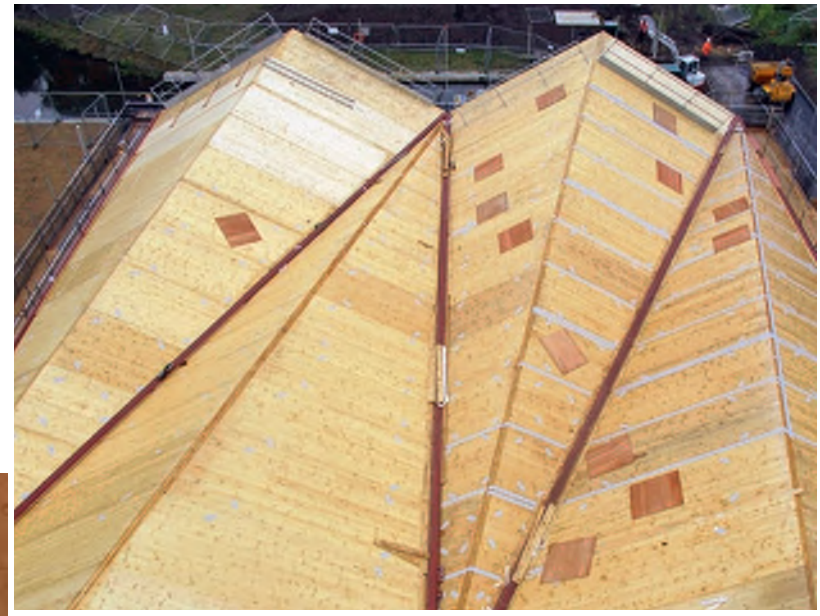
The new building is founded on piles in the peat soils. Our civil engineering design incorporates flexible road and parking surfaces that accommodate ground movement.

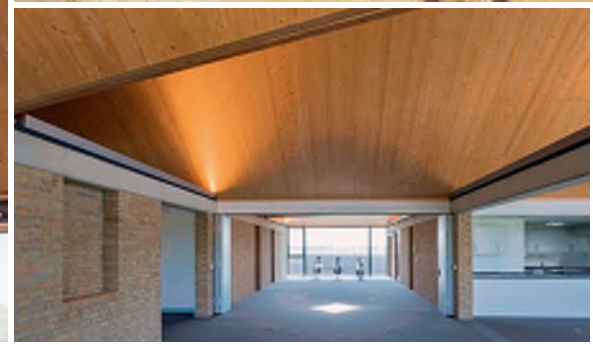
The lower level of the building is designed to flood — perforated brick walls allow flood water to flow freely through the building at times of high water.





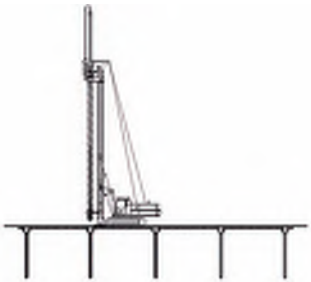
The project is multi-phase. Initial enabling works that formed the site access, river wall, jetty and flood mitigation lagoon were completed in 2015. The new building was completed in 2016 as phase 2. A future phase 3 building is planned.





The folded plate roof of the boathouse is constructed in cross laminated timber, exposed internally to create an all-wood soffit. The structure relies on its completed form to achieve stability, and the roof installation process defined many of the structural details, as did the fabrication and installation tolerances. Concealed steel valley beams span between the reinforced brick cross walls to stiffen the roof.

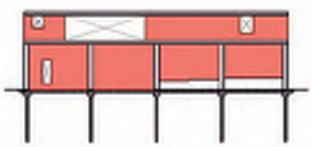
PHASE 1
SITE PREPARATION INCLUDING PILING MAT



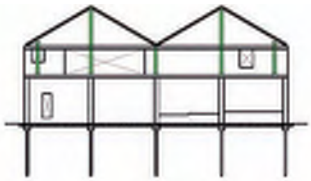
PHASE 2
INSTALL PILES, GROUND BEAMS AND GROUND SLABS

PHASE 3
INSTALL RC COLUMNS, RC RETAINING WALL AND REINFORCED MASONRY COLUMNS

PHASE 4
CAST FIRST FLOOR RC SLAB, SLAB TO BE BACK PROPPED UNTIL FULL STRENGTH ACHIEVED TO CONTROL CREEP DEFLECTION



PHASE 5
BUILD UP PERIMETER BRICK WALLS AT GROUND LEVEL, BUILD UP FIRST FLOOR REINFORCED MASONRY WALL, CAST RC CAPPING BEAM ONTO REINFORCED BRICK WALLS



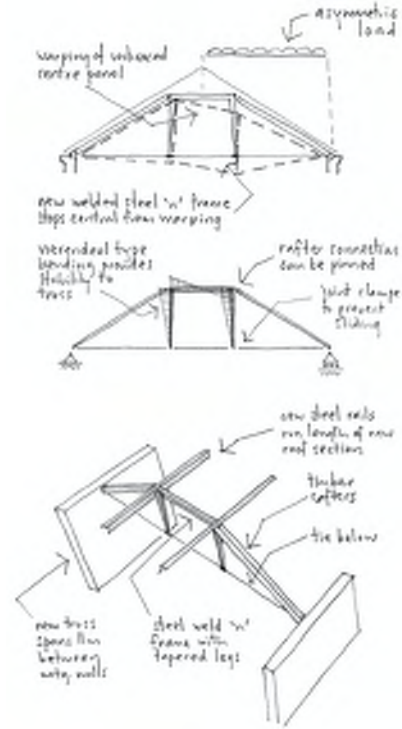
PHASE 6
INSTALL CLT ROOF OFF TEMPORARY PROPPING ENSURING LATERAL STABILITY

PHASE 7
DROP IN STEEL EAVES AND VALLEY BEAMS FROM ABOVE

CLIENT Cambridge University Boat Club
ARCHITECT Jeremy Bailey Architects with Baynes and Mitchell Architects
CONTRACTOR Morgan Sindall plc
VALUE £4m
COMPLETION January 2017

iron
brick
timber

maintaining instability



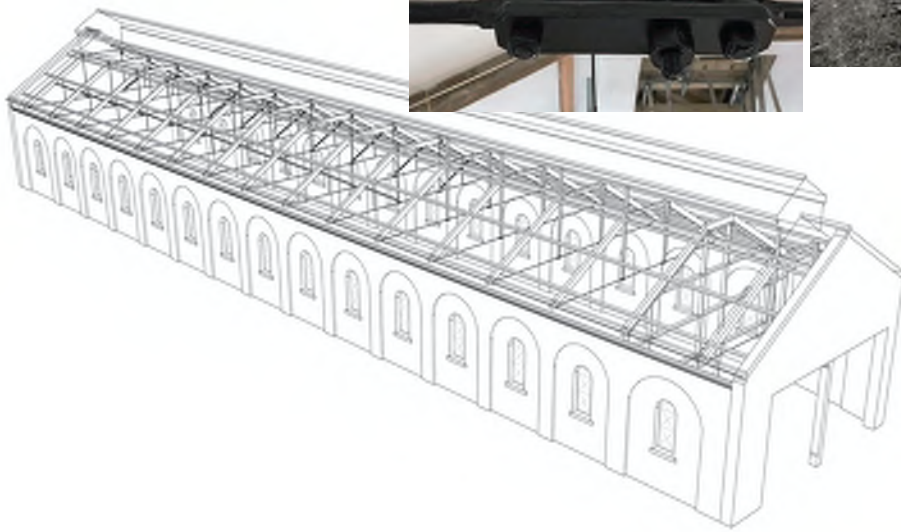
The building's Victorian timber and iron trusses are inherently unstable — a mechanism is created under asymmetric load. The historic trusses gain their stability through pre-compression delivered by the heavy slate roof, The cast iron nodes simply butt-up against the timber with no bolts present.

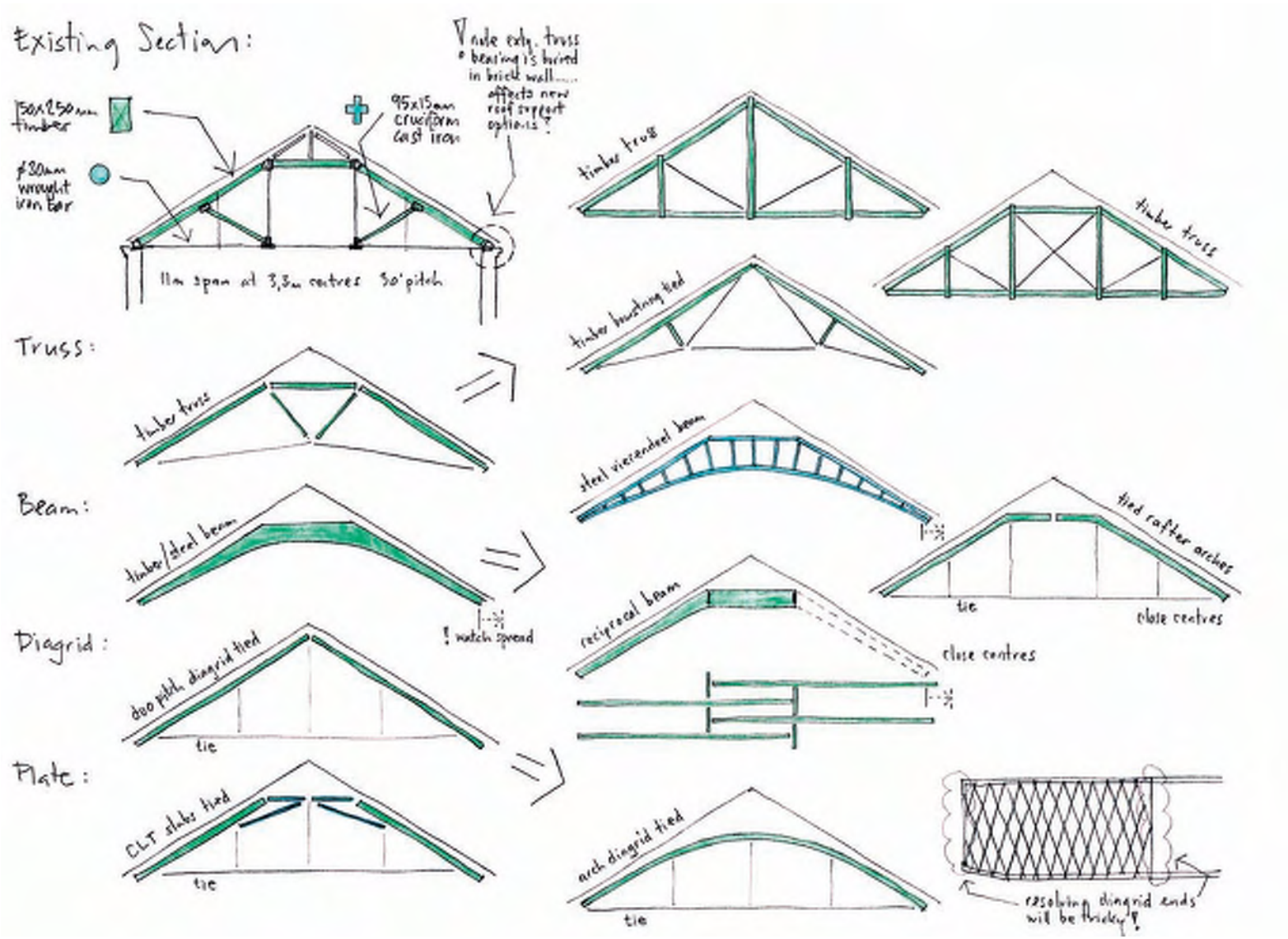
gross internal area 700m^2 timber 14t concrete 233t steel 2t

THE ENGINE SHED

Waterside Campus, University of Northampton, UK

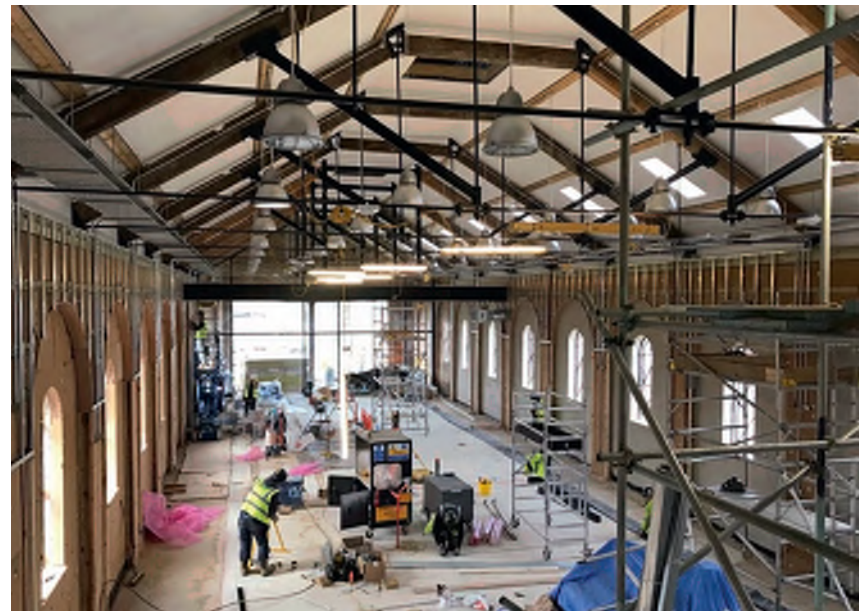
The 1873 Grade II listed Engine Shed originally served the London & North Western Railway, remaining in service until 1965 when it was converted into a welding school for British Railways and in use until 1998. A fire in 2000 destroyed six of the 16 timber and iron trusses. In 2012, Northampton University started negotiations to build their new campus nearby, with the Engine Shed serving as a home for the Students' Union.

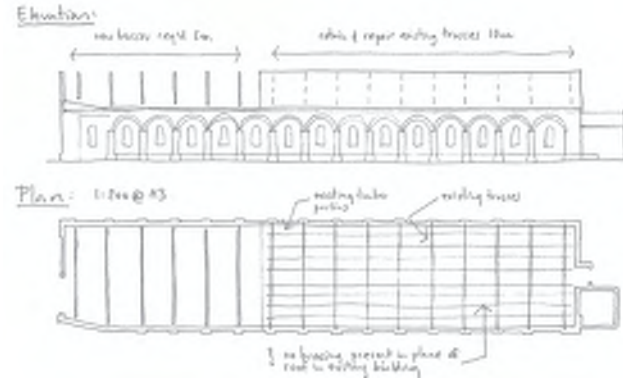



Existing Section:
50x250mm timber
ø30mm wrought iron bar
95x15mm cruciform cast iron
! note only truss bearing is buried in brick wall..... affects new roof support options?
11m span at 3,3m centres 30° pitch
Truss:
timber truss
timber bracing tied
timber truss
timber truss
Beam:
timber/steel beam
! match spread
steel vierendeel beam
tied rafter arches
tie
close centres
Diagrid:
duo pitch diagrid tied
tie
reciprocal beam
close centres
Plate:
CLT slabs tied
tie
arch diagrid tied
tie
resolving diagrid ends will be tricky!

EXISTING TRUSS

NEW TRUSS



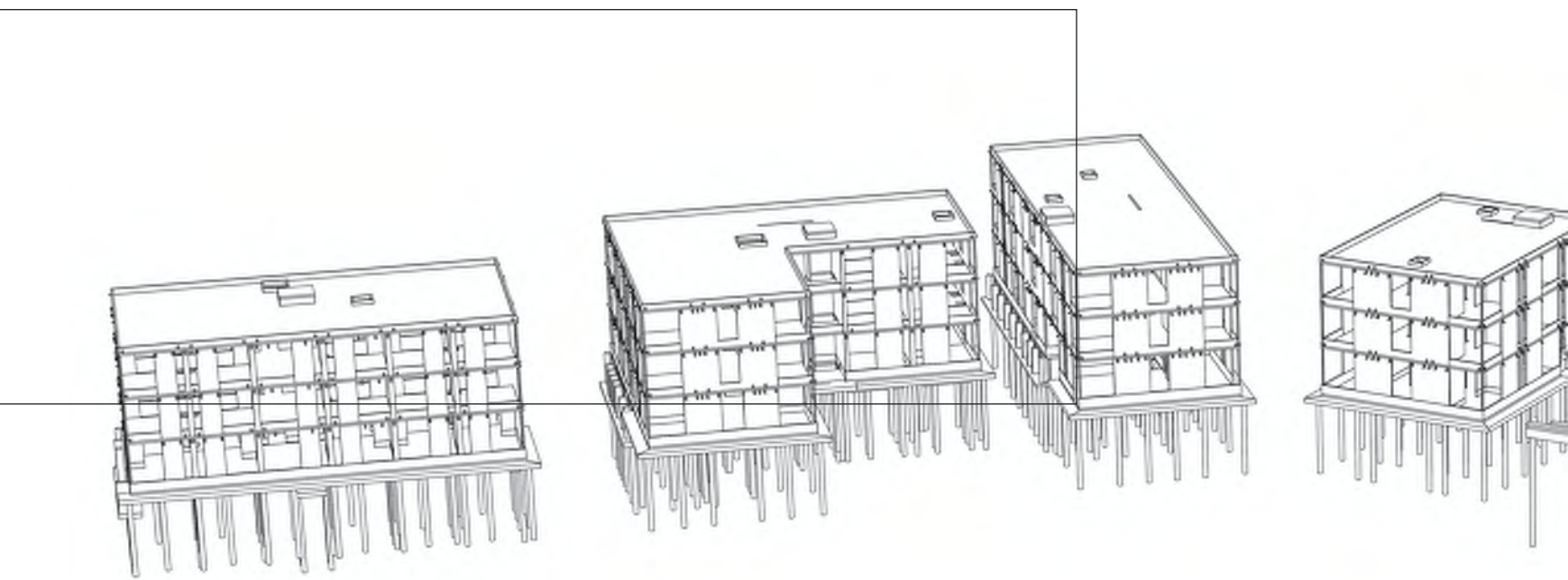


The original trusses that were fire damaged were beyond repair. Smith and Wallwork explored a number of new roof structure options in dialogue with the conservation authorities, and a modern take on the Victorian truss design was agreed — with a slight nod to the unstable nature of the original truss arrangement. For the new trusses, a welded steel frame eliminates the mechanism of the old.

CLIENT University of Northampton
ARCHITECT Moses Cameron Williams, and Purcell
CONTRACTOR Bowmer & Kirkland
VALUE £3.5m
COMPLETION January 2018

cross laminated timber
precast concrete
secant piling

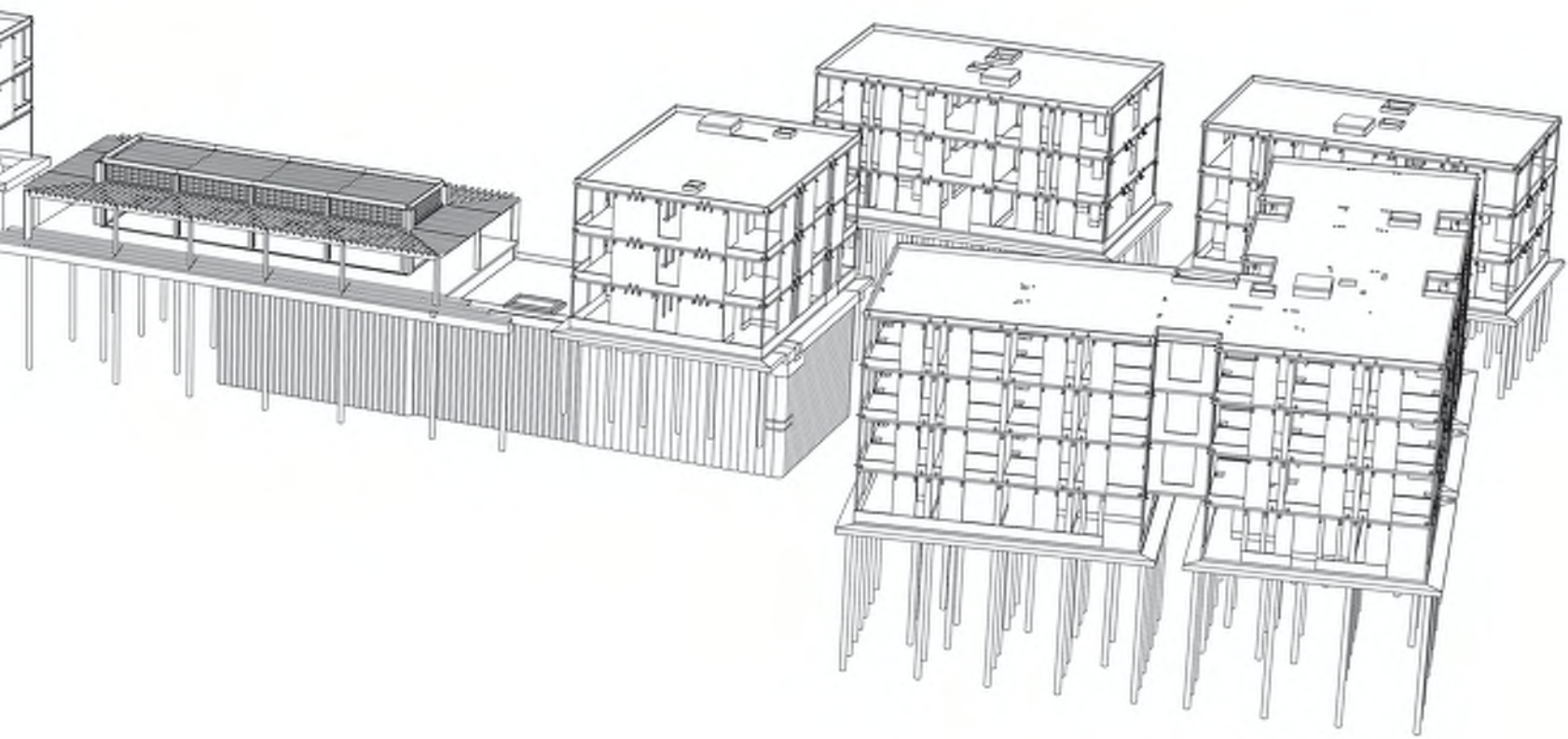
material difference and longevity



gross internal area 7,551m^2 timber 902t concrete 8,227t steel 250t

MASTER'S FIELD, BALLIOL

Master's Field campus, Balliol College, Oxford, UK



The Master's Field development consists of nine new buildings — providing over 200 new student accommodation rooms, a new sports pavilion and an underground squash court.

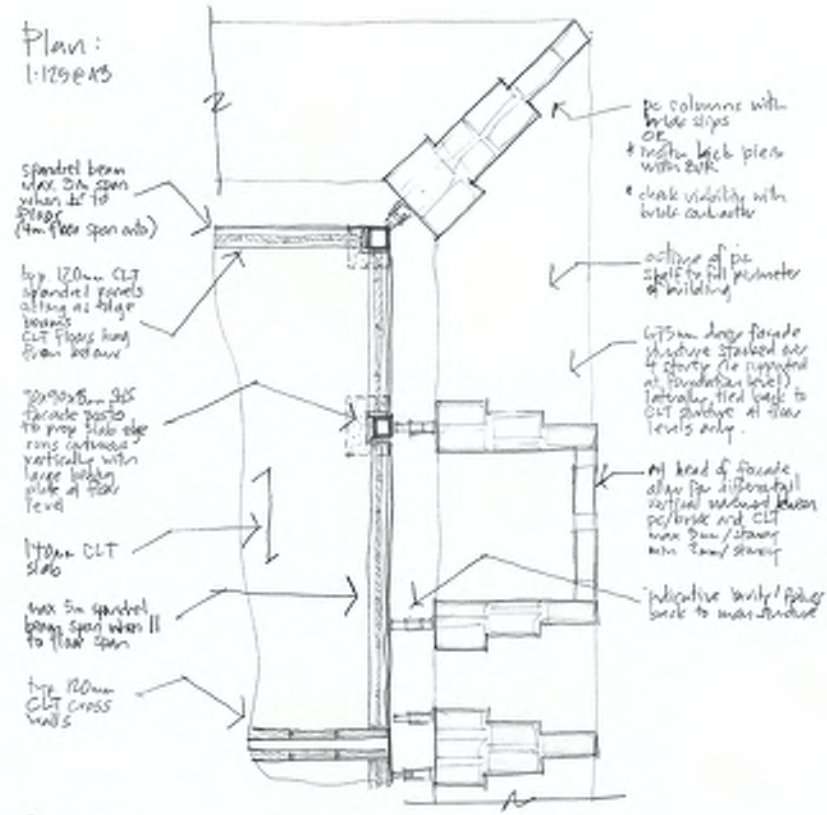
The arrangement of the buildings hugs the existing cricket boundary, negotiates a majestic beech tree and creates new street frontages along Jowett Walk and St Cross Road.

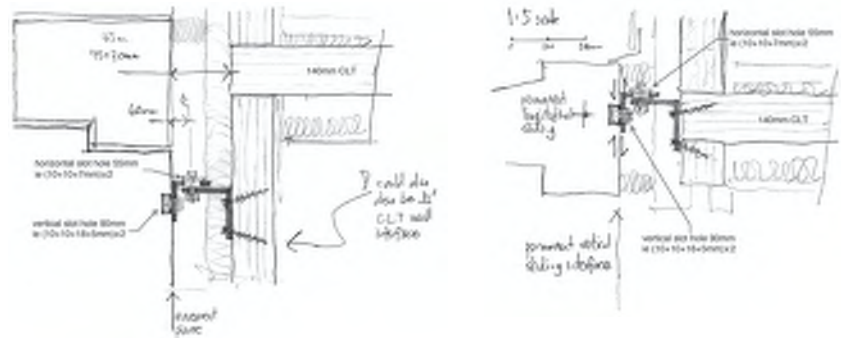
The site came with some challenges, including archaeology (the Civil War ditch) and a strategic water main located just 1m from the new buildings on Jowett Walk.

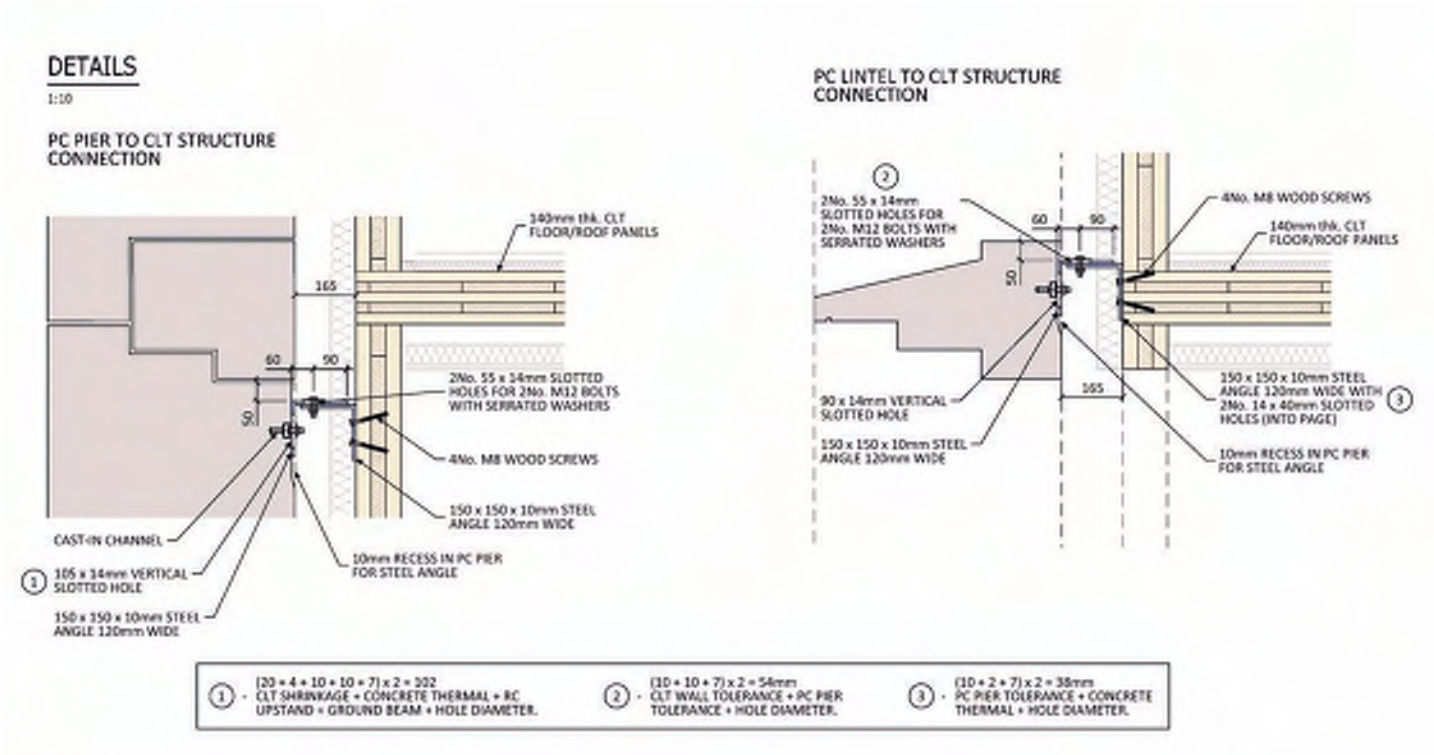
The buildings are founded on economic mini-piled rafts.

Design for manufacture and assembly are at the heart of the project, which includes brick clad precast façades, a cross laminated timber frame and bathroom pods. The deep reveal façades necessitated the use of self-compacting concrete to create the slender mullion and transom elements.

The precast brick façade is restrained back to the main structure, where fabrication and construction tolerances meet potential building movement, placing demands on the design of the detailing.



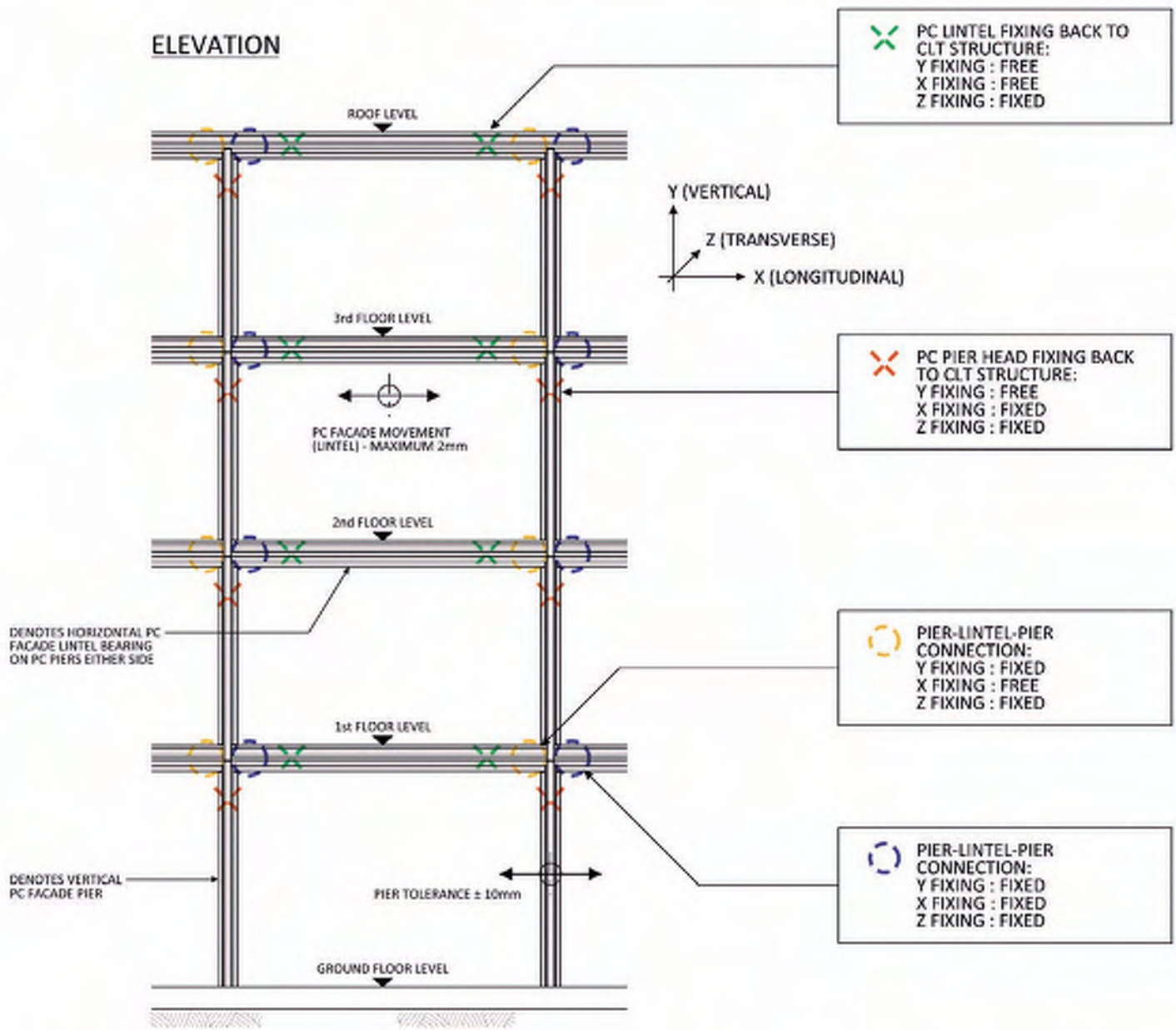




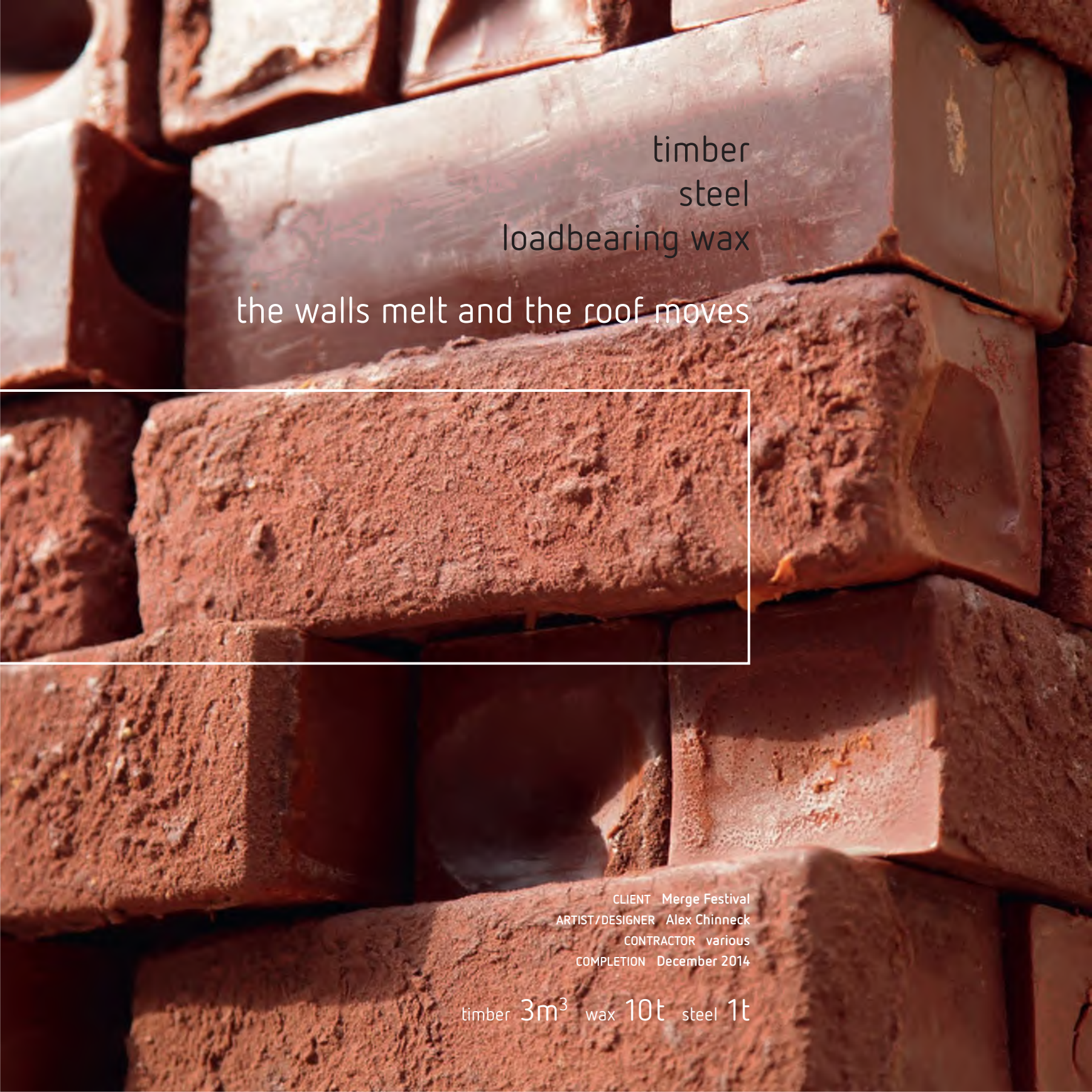
Precast concrete façade design 7th April 2017			
Activity	**50yr**	**100yr/120yr**	**Notes**
Structural design			
wind load	q_p=0.71kN/m^2	q_p=0.81kN/m^2	ref: SaW document '120 year design life'
snow load	s_k=0.35kN/m^2	s_k=0.40kN/m^2	
thermal	-16Δ_{avg}C←12Δ_{avg}C→42Δ_{avg}C	as 50yr	ref: SaW document 'Thermal strains'
impact load	25kN	25kN	ref: SaW document 'Impact load'
Materials			
concrete	Concrete: C40/50 0,45 340 (BS 8500-1 table A.4)	Concrete: C40/50 0,45 340 (BS 8500-1 table A.5)	ref: SaW document '120 year design life concrete elements'
rebar	High yield steel rebar cover: 20mm + Δc	High yield steel rebar cover: 30mm + Δc	ref: SaW document '120 year design life concrete elements'
fixing brackets (angles)	galv	stainless	Hot-dip galvanize to BS EN ISO 1461 85µm
fixing brackets (halfen)	galv	stainless	Hot-dip galvanize to BS EN ISO 1461 85µm
fixing brackets (bolts)	galv	stainless	Hot-dip galvanize to BS EN ISO 1461 85µm
Detailing			
movement and tolerances	✓	✓	ref: SaW document 'Movement and tolerances report' and SaW email 14.02.17

Smith and Wallwork developed connection details and restraint strategies that would accommodate long term timber and concrete movements between the various elements.

The design of the structural elements and the materials specifications were explored in order to assess the implications of doubling their design life in line with Balliol College's long term thinking.



CLIENT Balliol College
ARCHITECT Niall McLaughlin Architects
CONTRACTOR BAM Construction
VALUE £38m
COMPLETION November 2019



timber
steel
loadbearing wax

the walls melt and the roof moves

CLIENT Merge Festival
ARTIST/DESIGNER Alex Chinneck
CONTRACTOR various
COMPLETION December 2014

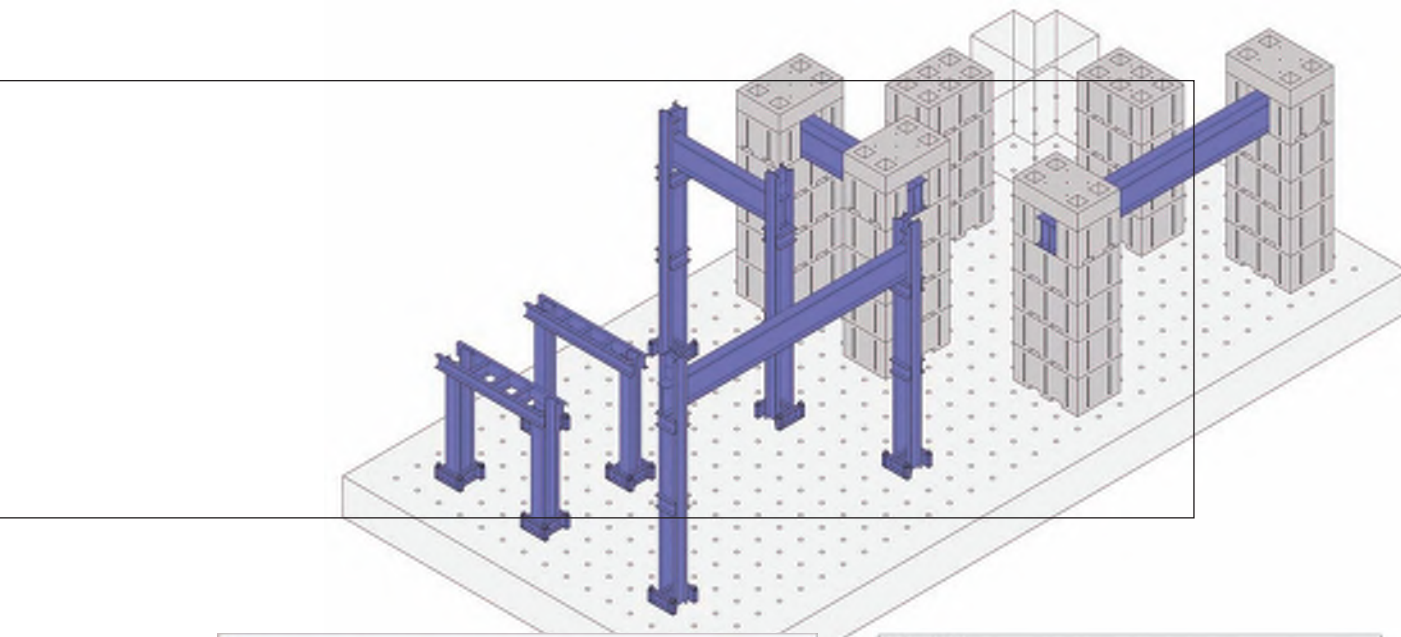
timber $3m^3$ wax 10t steel 1t

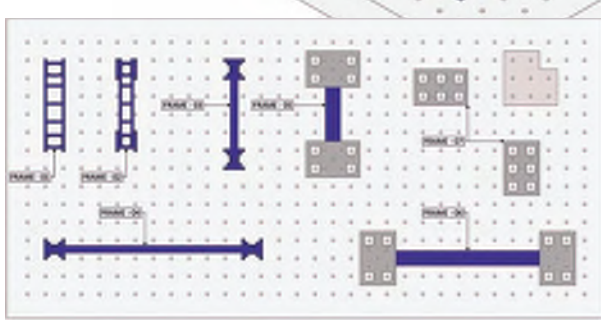
A POUND OF FLESH FOR 50p

Southbank, London, UK

steel
concrete
vibration modelling

an engineer's playground





FRAME LEGEND

FRAME	BEAM	CLEAR HEIGHT	CLEAR SPAN	APPROX FAILURE LOAD
01	2No. 300 x 100 PFC46	2.7m	2.1m	550kN
02	2No. 300 x 100 PFC46	2.7m	2.1m	550kN
03	686 x 254 UB170	4.7m	2.5m	2500kN
04	686 x 254 UB170	4.7m	5.5m	800kN
05	2No. 686 x 254 UB170	3.6m	1.8m	5000kN
06	2No. 686 x 254 UB170	3.6m	4.8m	2000kN
07	N/A	3m	N/A	600kN

NOTES - CONCRETE

1. ALL CONCRETE TO BE C40/50
2. Min. REINFORCEMENT INCLUDING SHEAR LINKS
3. SHEAR CHECK BASED ON LIMIT OF 5N/mm2
4. FOR STEEL BEAM BEARING ON CONCRETE BLOCKS: ASSUME A STEEL BEARING PLATE TO BE PROVIDED (Min. 255 x 220mm PER BEAM, ~100mm HEIGHT).
5. CONCRETE LEGO BLOCKS ARE 1.2 x 1.8 x 0.9 AND WEIGHS 3.5t
6. CONCRETE LEGO BLOCK CAPPING ELEMENTS IS 1.2 x 1.8 x 0.45 AND WEIGHS 2.0t

NOTES - STEEL

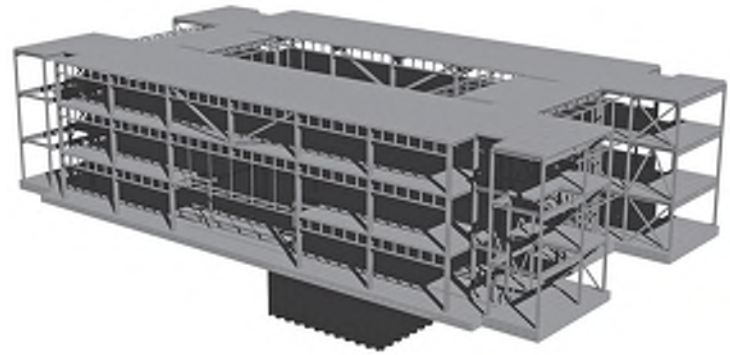
1. ALL STEEL TO BE S355
2. ALL BOLTS M24 Gr. 8.8 IN Ø26mm HOLES

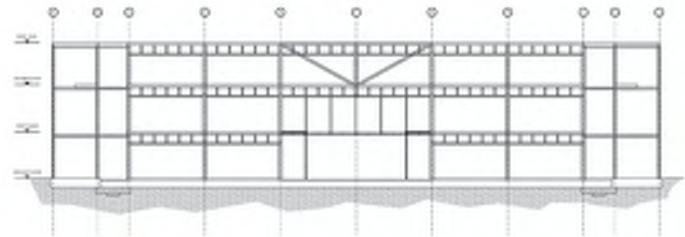
gross internal area 4,356m^2 concrete 6,314t steel 501t

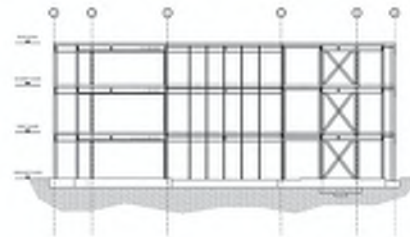
NEW CIVIL ENGINEERING BUILDING

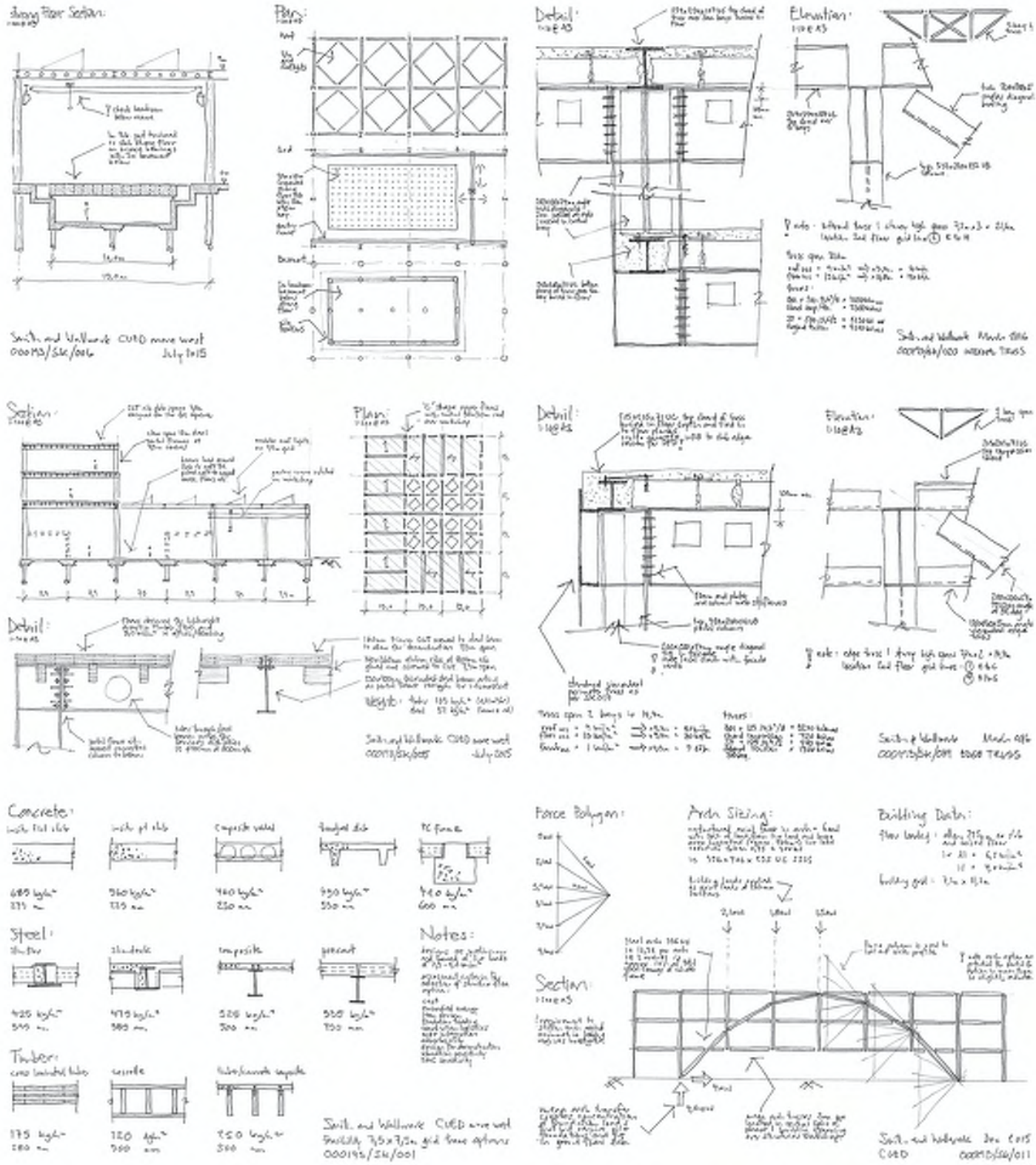
University of Cambridge, UK

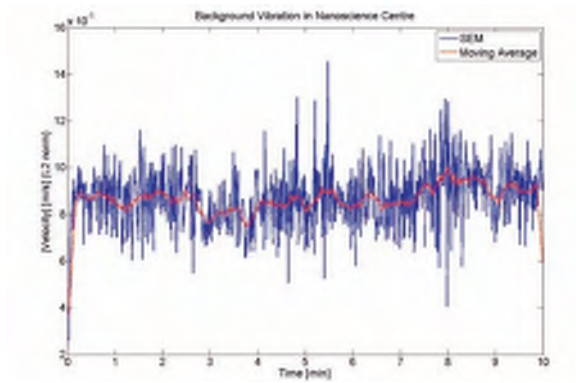
The choice of structural frame was influenced by life cycle energy analysis we carried out using Professor David McKay's unique Energy Cost Metric. Steel, concrete and timber frame options were assessed for embodied, transport and re-use energy scenarios. A steel frame with planks developed for ease of deconstruction and re-use was selected. The building has embedded fibre optics to measure strains, vibrations and run-off from the blue-green roof.








Strong Floor Section:
Plan:
Detail:
Elevation:
Section:
Plan:
Detail:
Elevation:
Concrete:
Steel:
Timber:
Notes:
Force Polygon:
Arch Sizing:
Building Data:
Section:

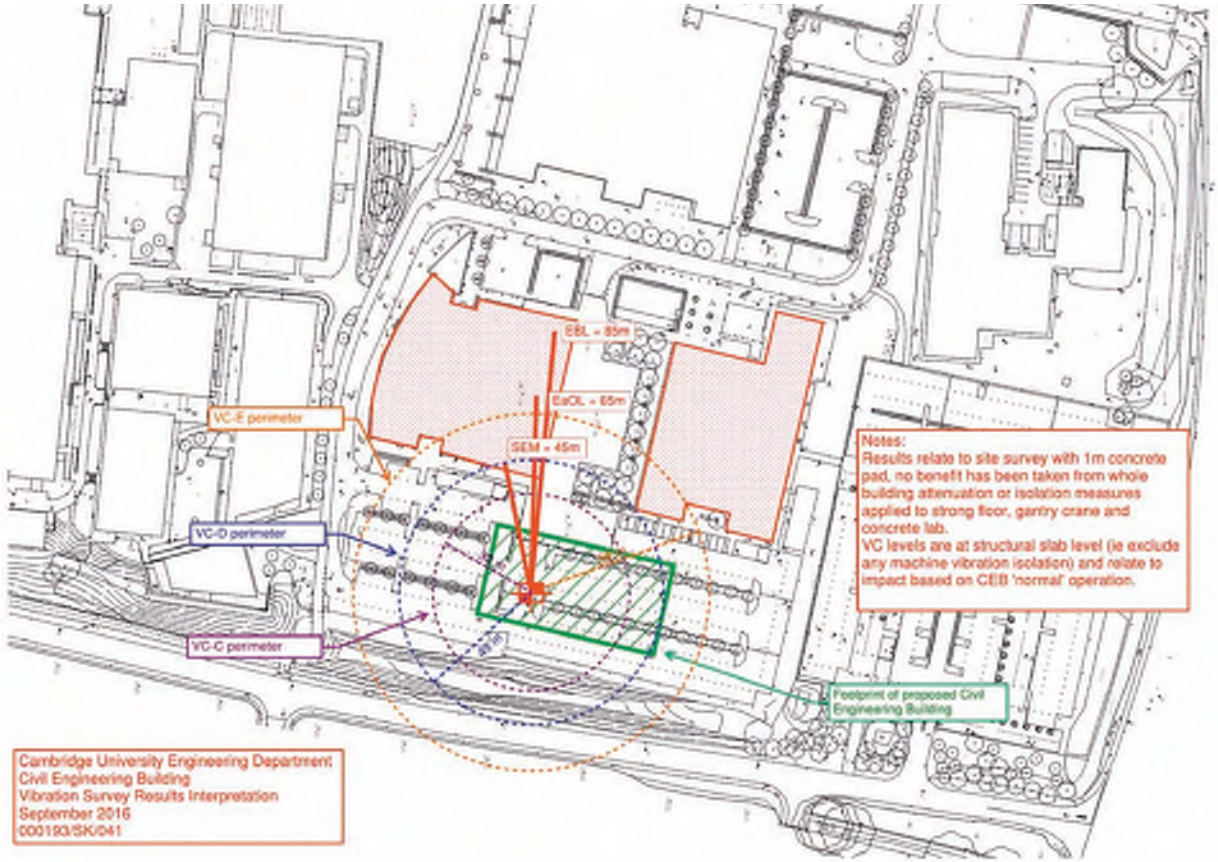


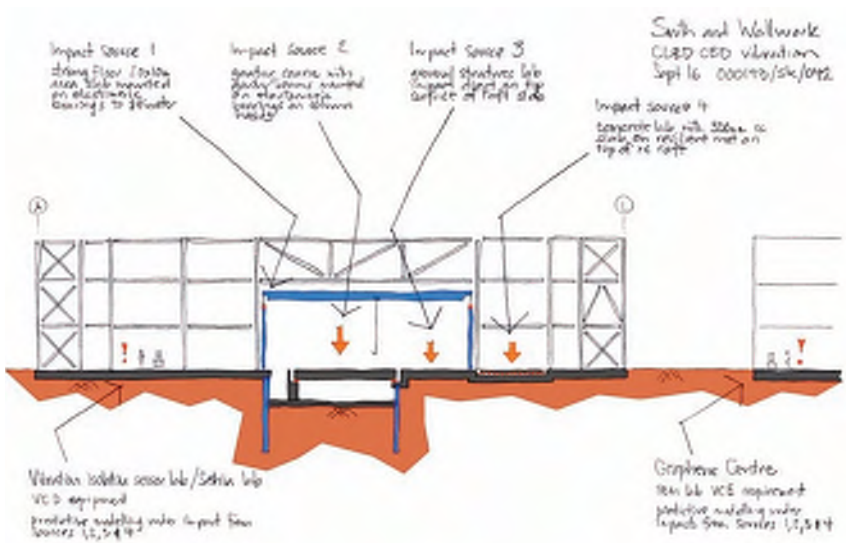
The new engineering campus at West Cambridge is unique. It hosts research and teaching at all scales: nano, micro, macro and mega. Ultra-low vibration environments work alongside vibration generating activities, and the new civil engineering building sits just 20m from the Graphene Centre and its scanning electron microscope.

During the early design stages, a number of vibration surveys were carried out in the existing civil engineering workshops and labs, and on site. We developed an impact test rig to mimic various heavy engineering experiments as well as everyday use scenarios.

Before construction began, site impact tests were conducted on site and vibration levels measured in the Graphene Centre and Nanoscience. The results informed the performance criteria for the design, construction and use of the new building.

Further vibration impact testing carried out on completion of the structure's foundation and frame verified the performance criteria developed by Smith and Wallwork and will be invaluable in developing modern research space for compact sites.

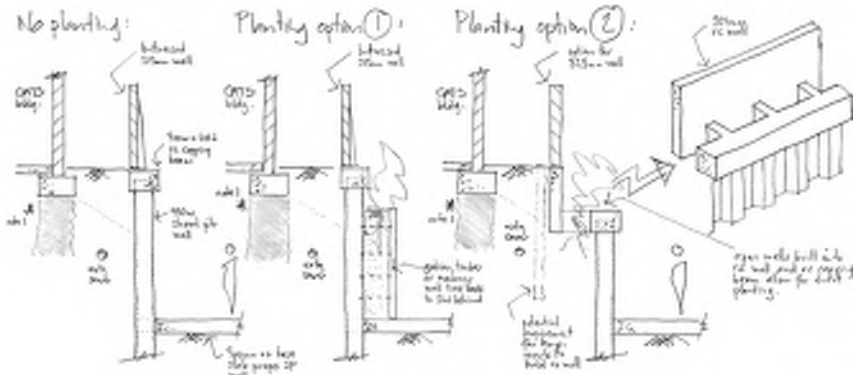




CLIENT University of Cambridge
ARCHITECT Grimshaw
CONTRACTOR SDC
VALUE £20m
COMPLETION March 2019

steel basement
cross laminated timber
concrete

squeezing into place



gross internal area 2,850m^2 timber 271t concrete 1,600t steel 307t

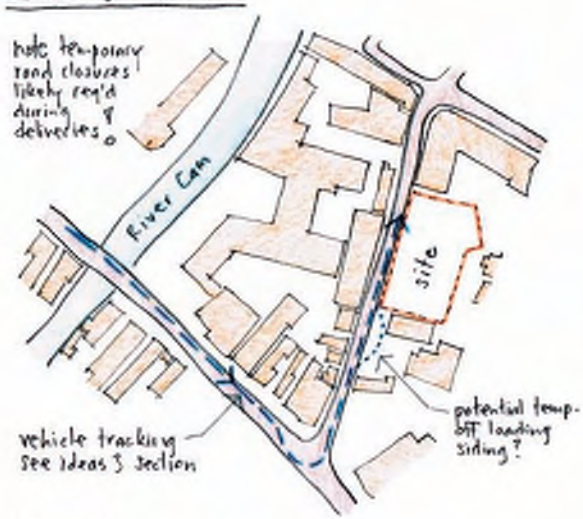
WYNG GARDENS

Trinity Hall, Thompson's Lane, Cambridge, UK

A steel intensive basement solution utilising steel sheet piles was adopted for a new student accommodation building on a highly constrained site. The sheet piles act as permanent retaining walls and support the entire weight of the building. All clutches (interlocks) of the sheet piles are fully welded and a 500mm thick reinforced concrete raft is tied to the face of the sheet piles using welded shear studs to form a watertight 'box'.

The highly constrained site is set in a residential area in the historic city centre of Cambridge. This meant construction logistics were a key project challenge. The sheet piles were installed using a specialist 'silent piling' technique that uses a hydraulic press to push the piles up to 10m into the ground — helping overcome site access issues and minimising noise and vibration disruption to local residents.

Location Plan:



Construction Traffic:

(sub & super-structure)

basement excavation	175no.
insitu RC raft & gnd floor slab/transfer	100no.
option ① cross laminated timber	15no.
option ② masonry and pc slab hybrid + steel roof	100no.
option ③ insitu rc frame + steel roof	125no.

Construction Traffic:

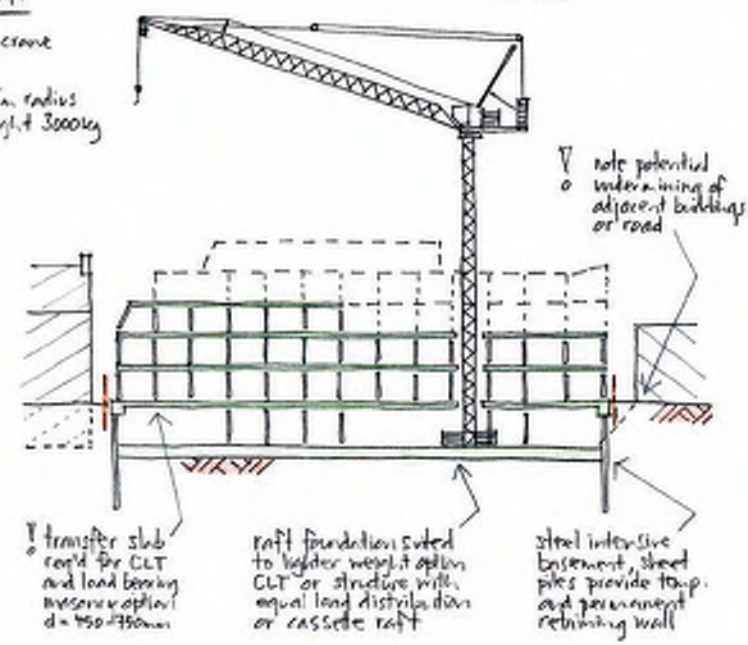
option ① basement + CLT, CLT roof	290
option ② basement + masonry, steel roof	375
option ③ basement + rc frame, steel roof	400

Site Section:

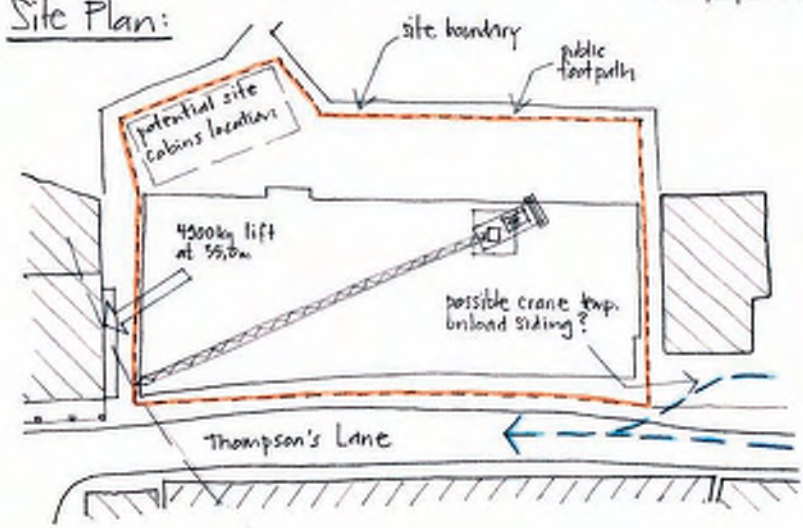
Liebherr luffing crane LTS HC-L 6/12

4500kg lift at 55m radius

max. pc plank weight 3000kg



Site Plan:



The four-storey cross laminated timber (CLT) structure, which houses 73 student bedrooms, sits on top of a reinforced concrete ground floor slab. Offsite prefabrication was used to reduce the number of lorry deliveries and reduce foundation loads. It is also a quick and quiet form of construction, making CLT the right choice for the building structure.

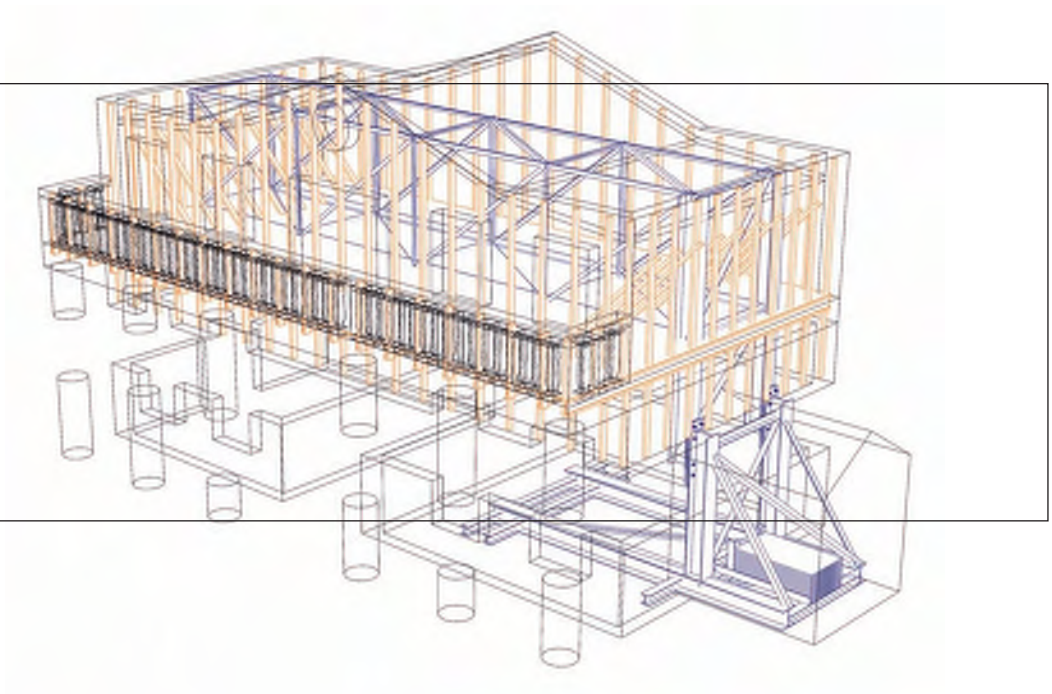
A 'punched panel' CLT solution was adopted to optimise the erection process. The deep beam action of the CLT crosswalls is used in some locations to transfer loads from three floors above.

Tight site constraints meant CLT connections were specifically designed to be installed from inside the building to avoid the need for scaffolding.

CLIENT Trinity Hall
ARCHITECT Freeland Rees Roberts, and LSI Architects
CONTRACTOR Balfour Beatty
VALUE £9m
COMPLETION September 2016

lightweight structure
steel
polystyrene

a building without foundations



CLIENT Capital & Counties Properties plc
ARTIST/DESIGNER Alex Chinneck
CONTRACTOR Severfield (steel)
COMPLETION December 2014

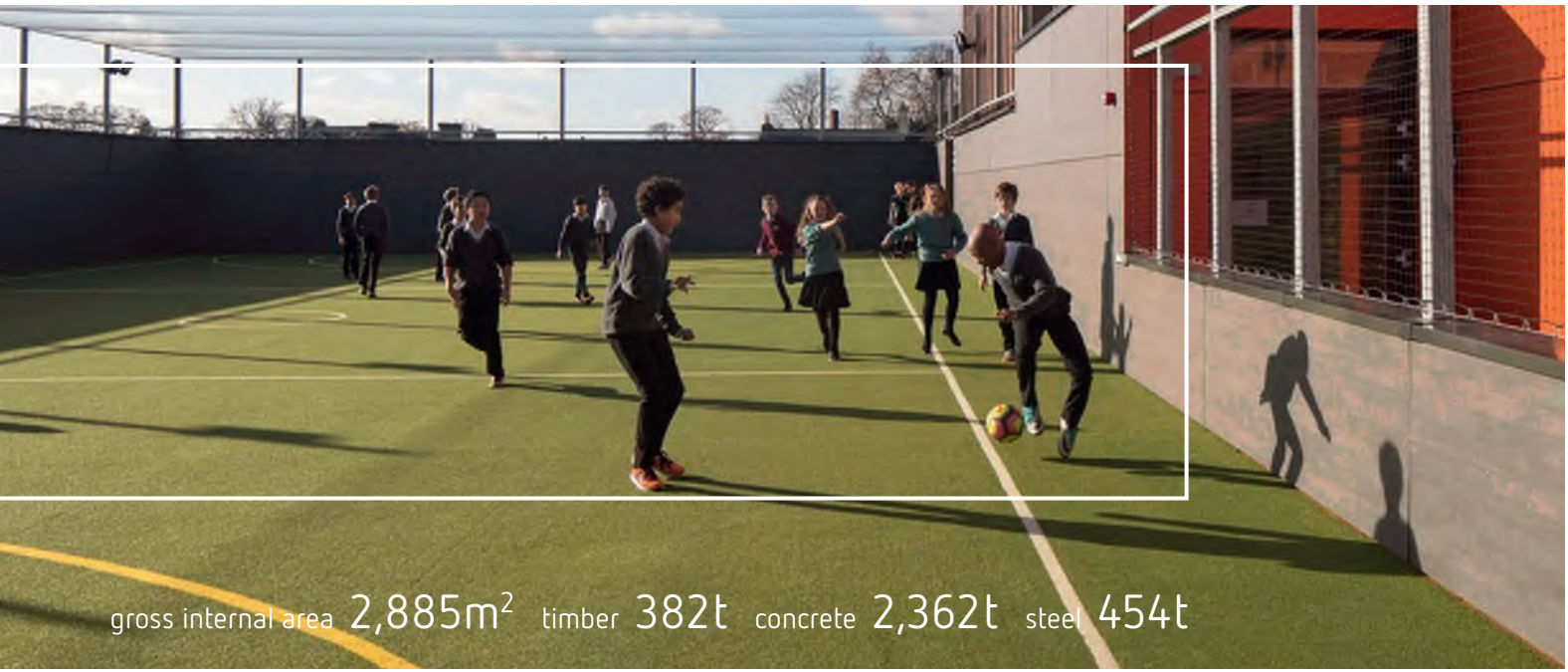
polystyrene and other finishes 5t steel 5t

TAKE MY LIGHTENING BUT DON'T STEAL MY THUNDER

Covent Garden, London, UK

steel
concrete
timber

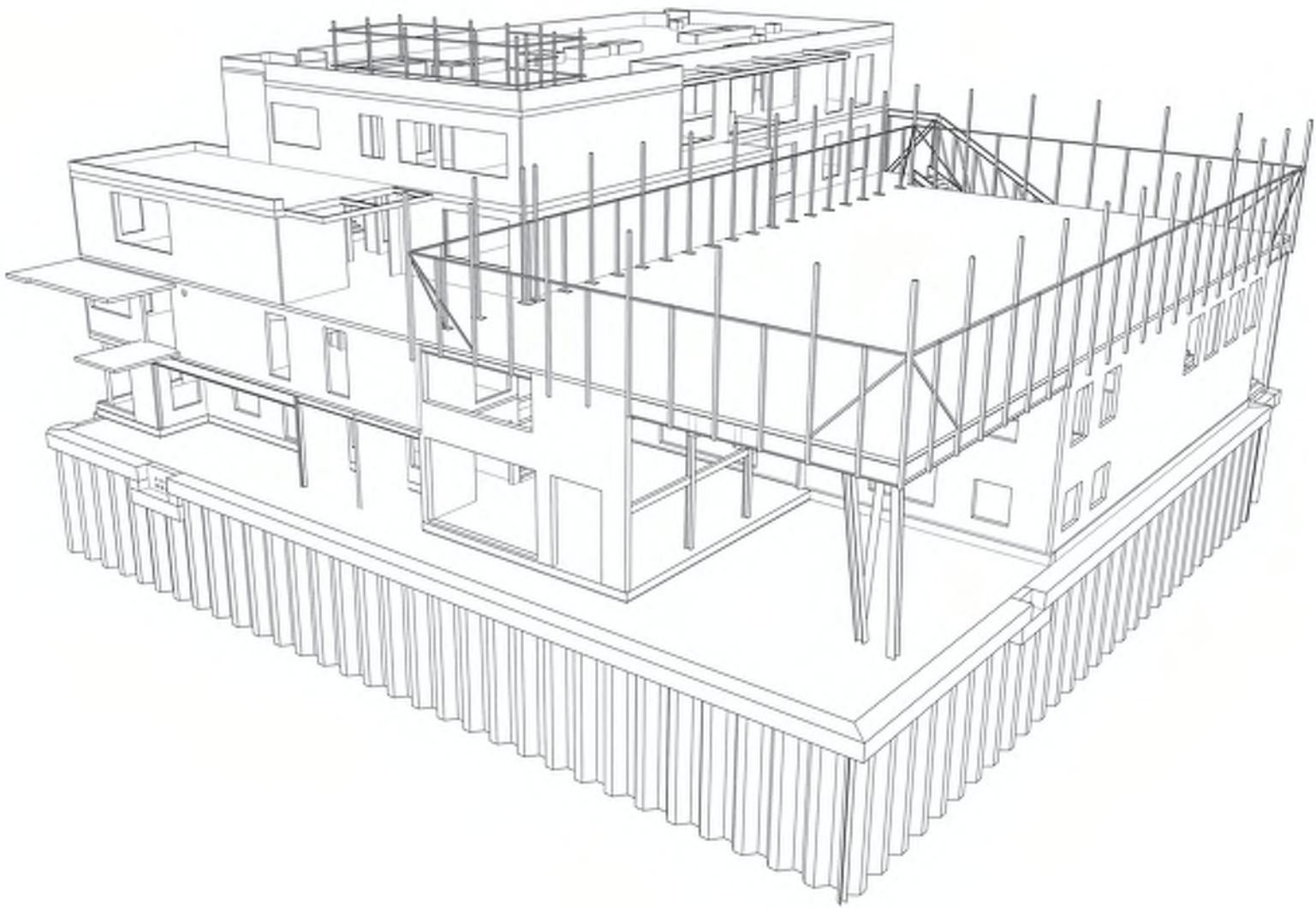
fun and games on the roof



The development at Stephen Perse Foundation represents a milestone for Cambridge and its urban planning in providing an elevated sports pitch, two storeys up. The new multi-use games area sits over an indoor three-storey sports hall that doubles up as events space with bleacher seating.

LEARNING AND SPORTS BUILDING

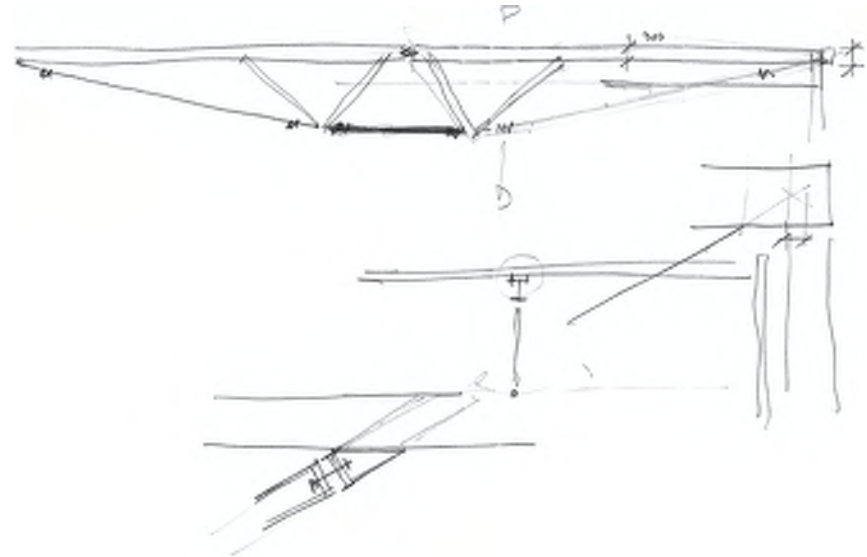
Stephen Perse Foundation, Union Road, Cambridge, UK

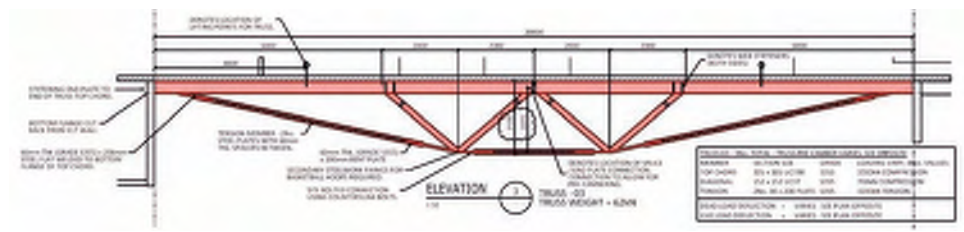


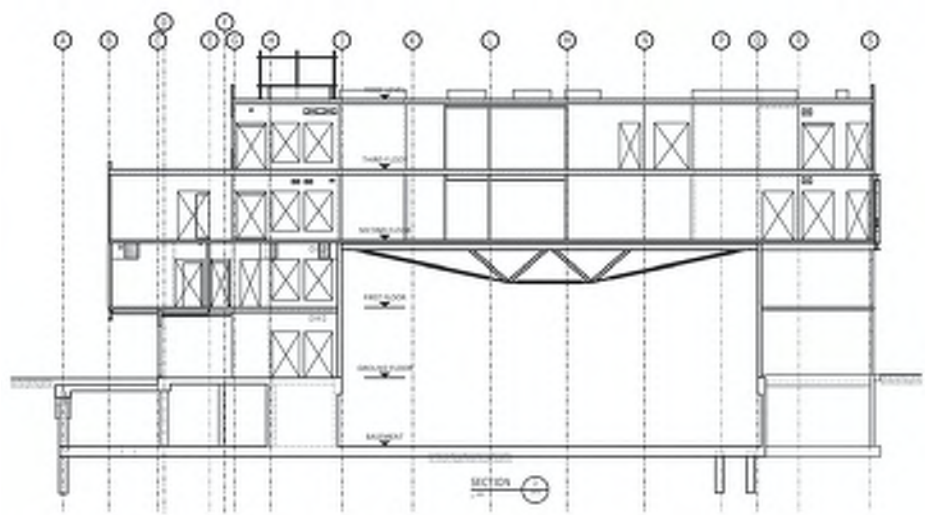
The indoor sports hall sits within a sheet-piled raft foundation basement. The 20m free-span space is topped with steel bowstring trusses that support the roof-top multi-use games area and transfer loads from the two-storey classroom block that bridges the sports hall. Each truss was designed with a specific pre-camber — when installed, a positive camber is maintained in the trusses to aid roof drainage.

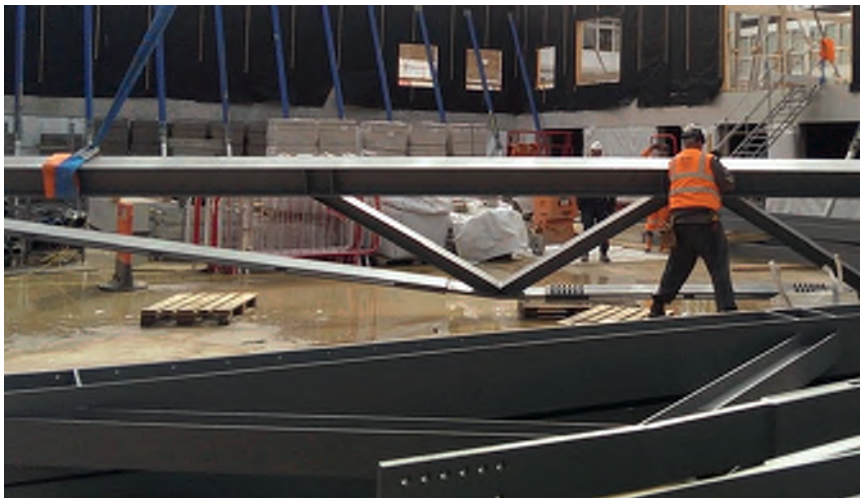
The trusses are located inside a pre-manufactured glulam and cross laminated timber (CLT) frame. This hybrid form of construction reduced construction deliveries to just 35 lorries.

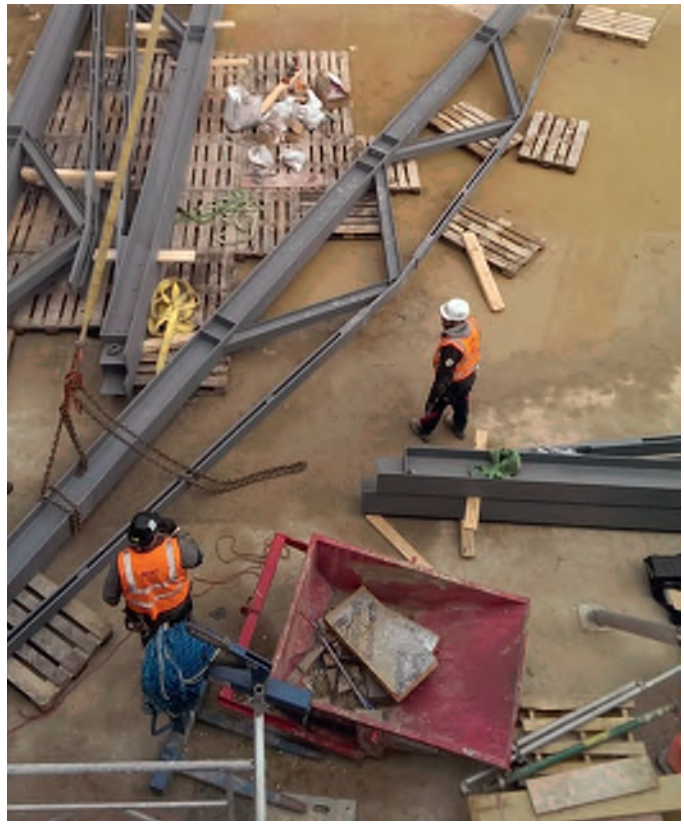
A world first is included at Stephen Perse: a CLT wall flitch truss is installed over the bleacher seating recesses, transferring loads from three storeys above.





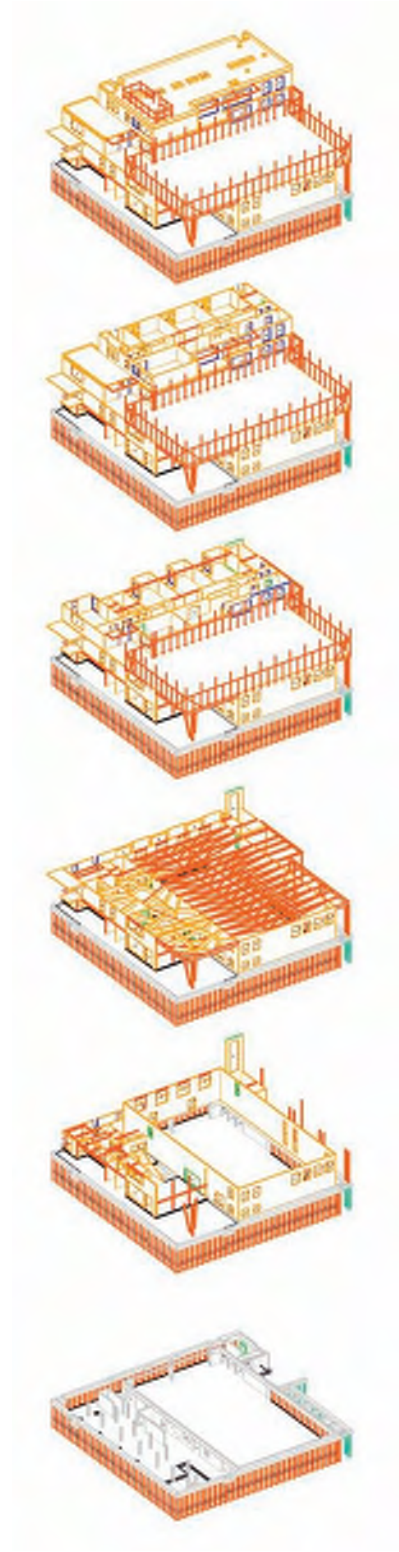






The steel bowstring truss design was influenced by site access logistics. Deliveries were limited to 13m in length, so the truss was conceived as two elements connected on site through simple compression and tension joints.

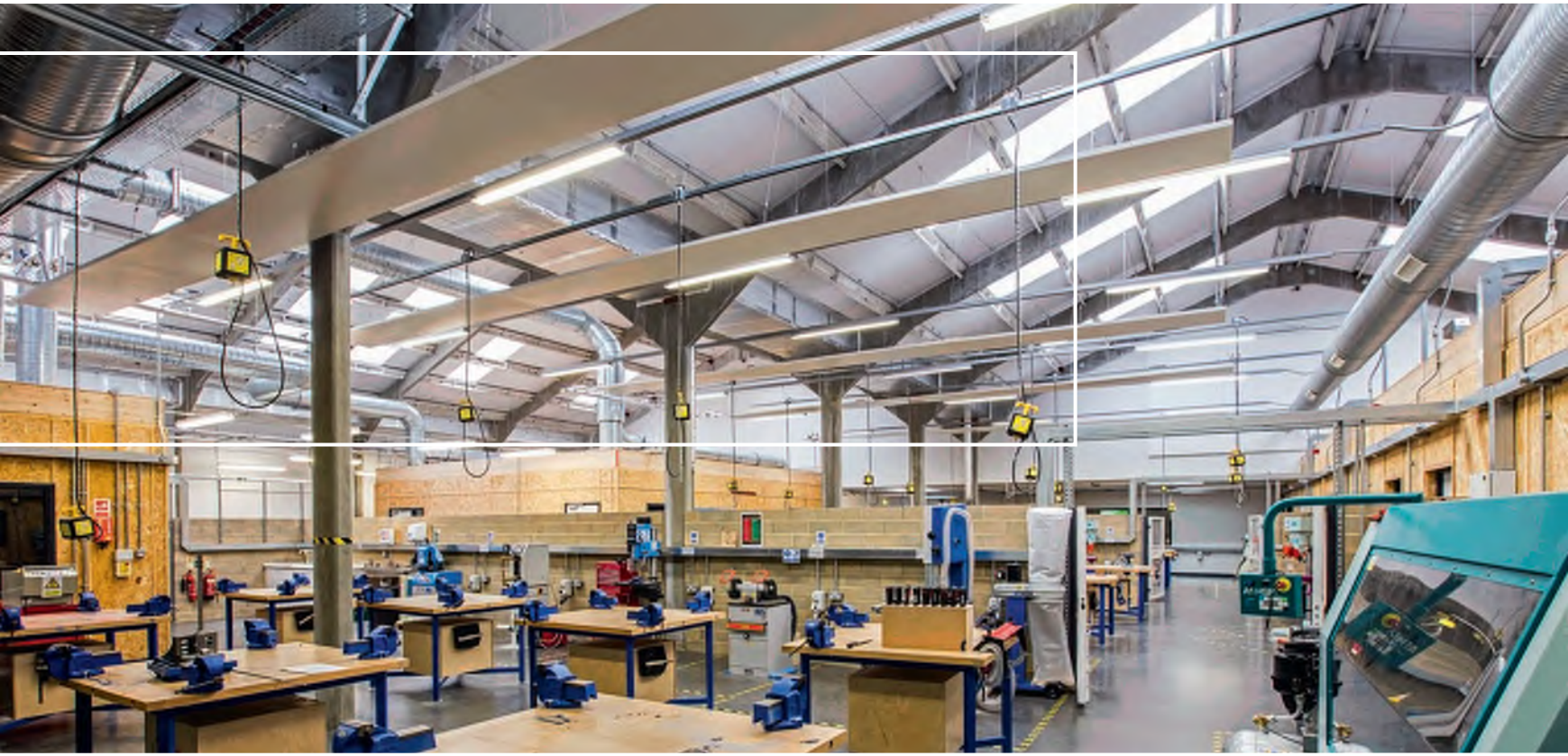
The roof-top games area was enabled through acoustic modelling and architectural visualisations, assuring planners and local residents of viability. Noise also influenced the structural design: using hybrid steel and CLT for the five-storey structure reduced construction noise, as did the silent piling methods used for basement construction.



CLIENT Stephen Perse Foundation
ARCHITECT chadwickdryerclarke studio and LSI Architects
CONTRACTOR Kier
VALUE £10m
COMPLETION October 2017

ground improvement
cross laminated timber
concrete

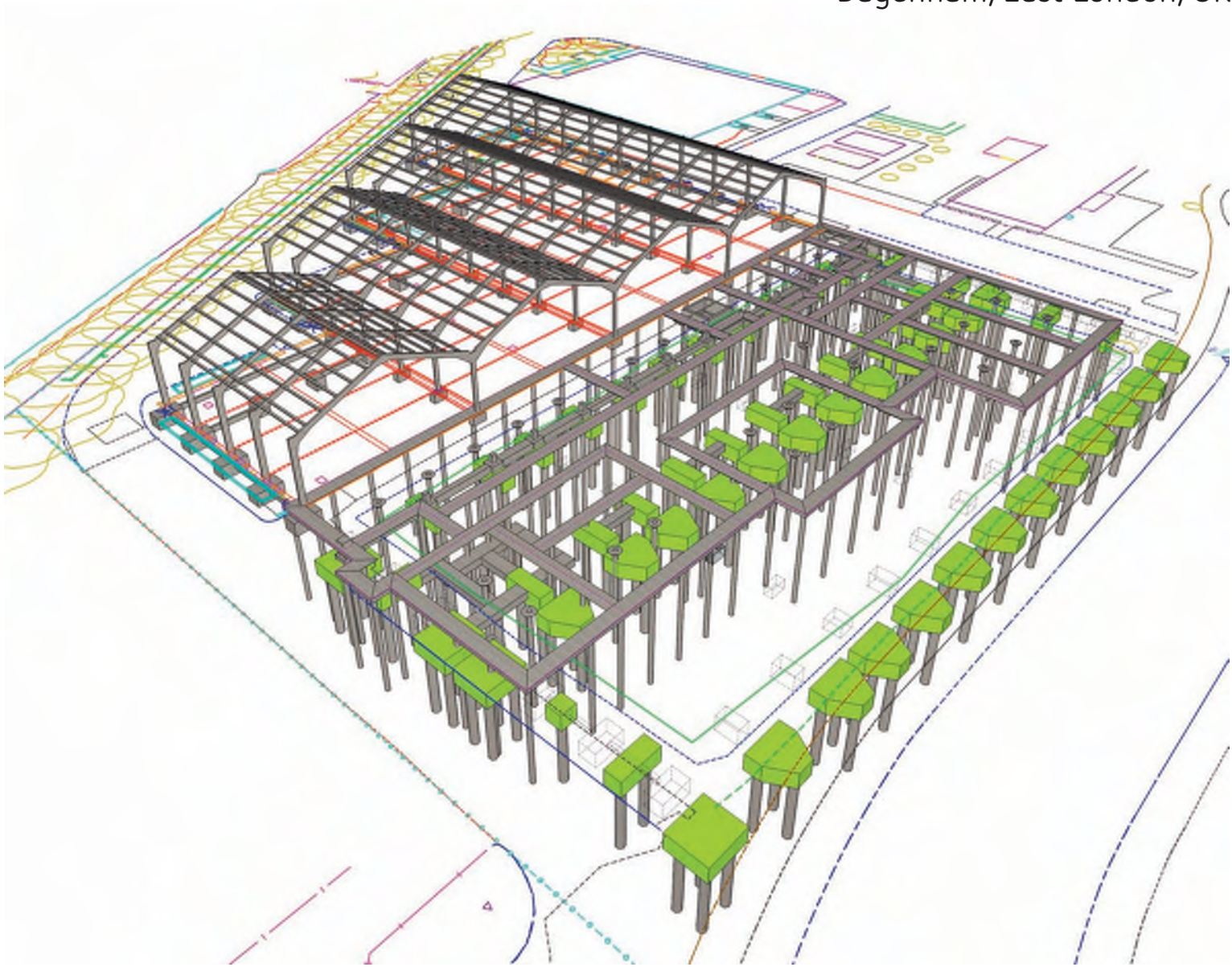
re-using a prefab concrete frame

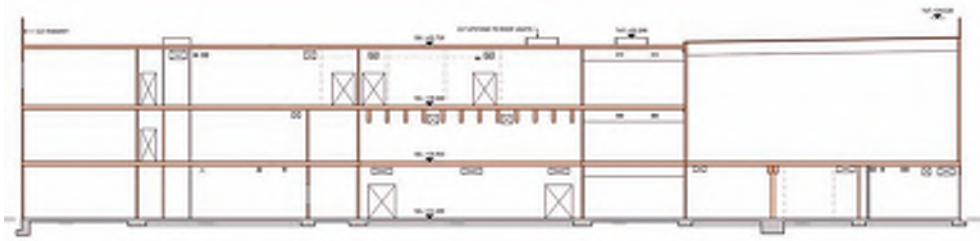


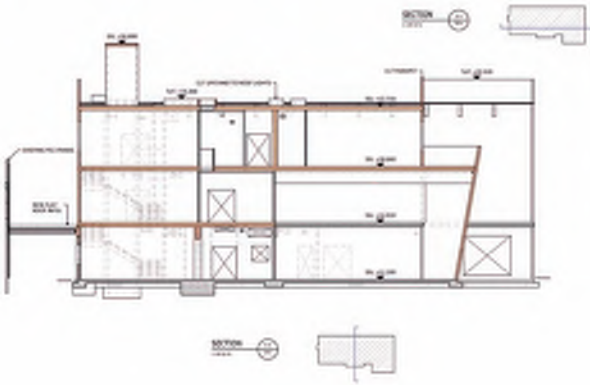
gross internal area 4,270m^2 timber 744t concrete 1,186t steel 38t

EAST LONDON UNIVERSITY TECHNICAL COLLEGE

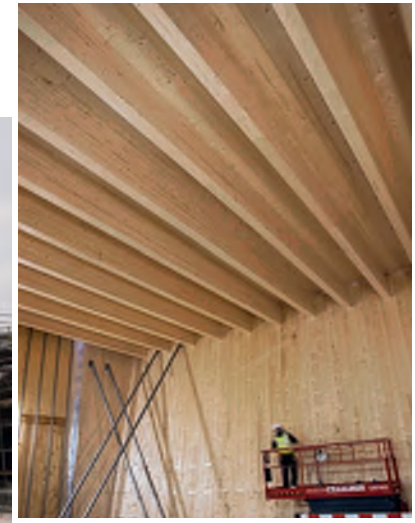
Dagenham, East London, UK







A fast track project on a brownfield site. Adoption of a lightweight cross laminated timber structure in conjunction with ground improvement (vibro stone columns) allowed the shallow foundations to be designed to bridge existing piled foundations.



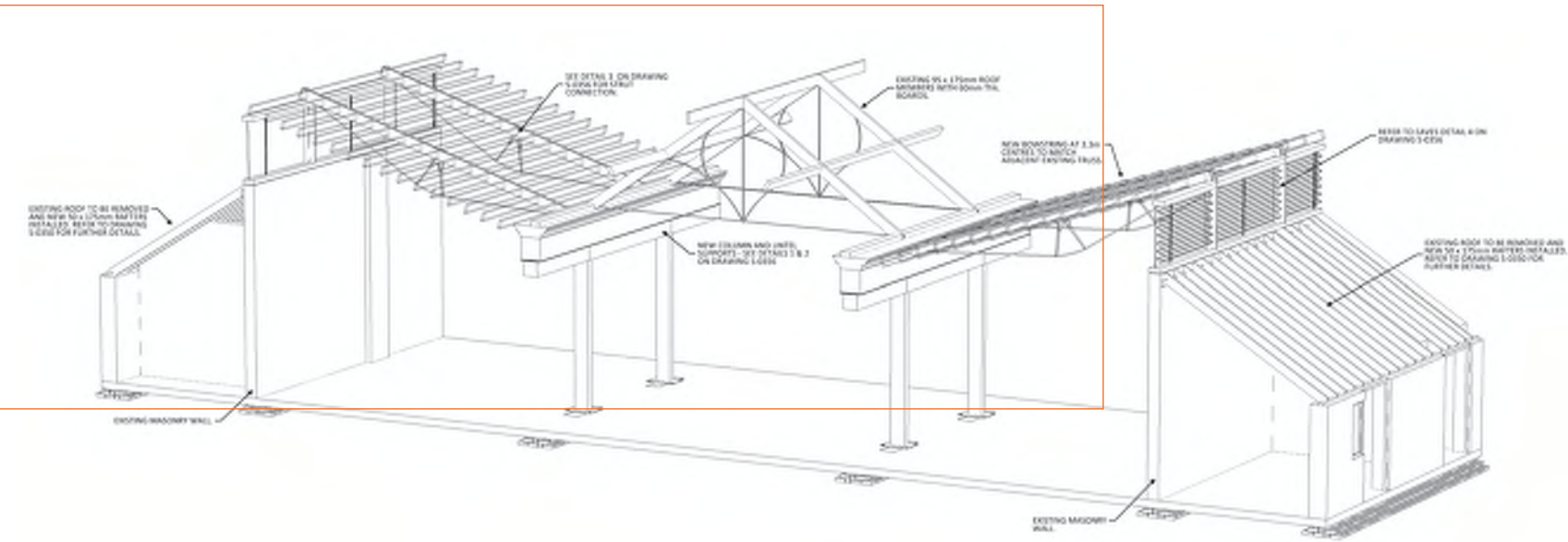
Inspection and back-analysis of extant precast concrete structural frames enabled the existing 1960s industrial building to be retained and remodelled to form new specialist engineering workshops.

New structural steelwork tie beams and stability bracing were installed to allow the whole building to be stripped and re-clad. Part of the retained frame is left exposed externally to form an outdoor games court.

CLIENT Kier
ARCHITECT LSI Architects
CONTRACTOR Kier
VALUE £11m
COMPLETION November 2016

piled raft
cross laminated timber
concrete

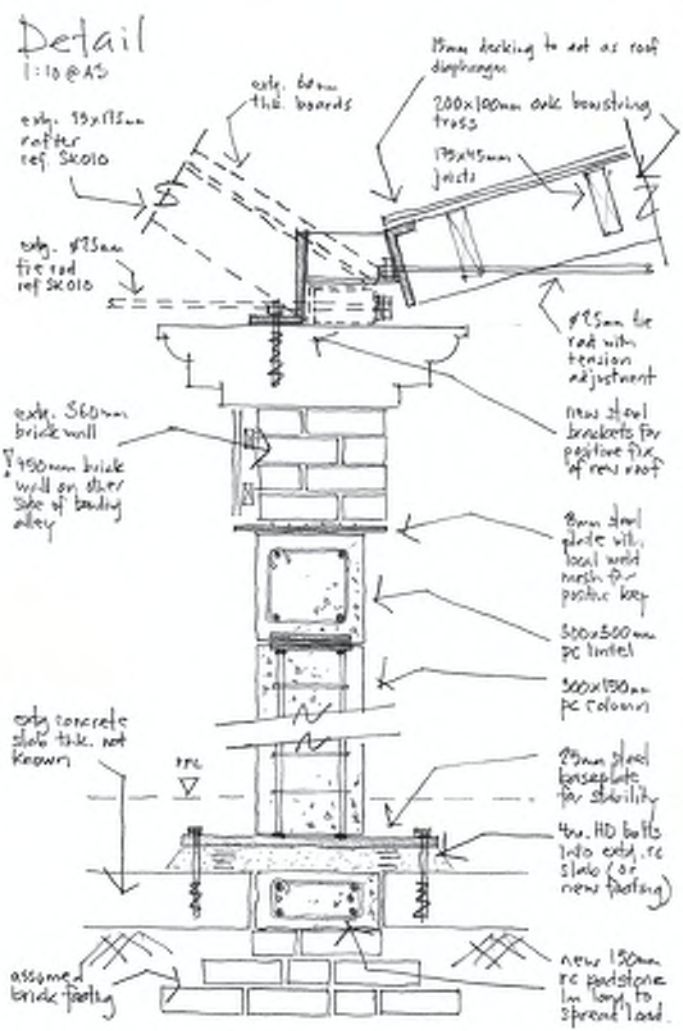
look, no walls!

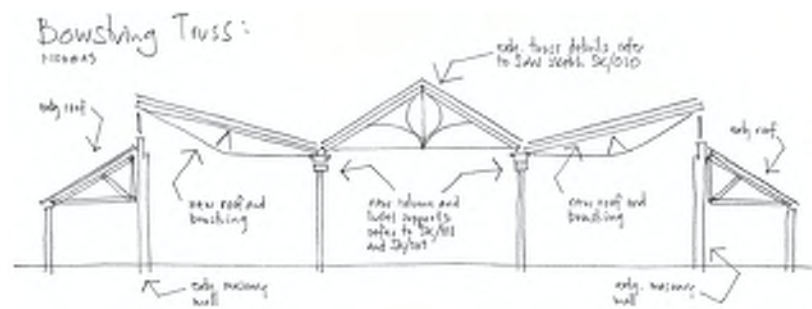


gross internal area 4,575m^2 timber 45t concrete 240t steel 14t

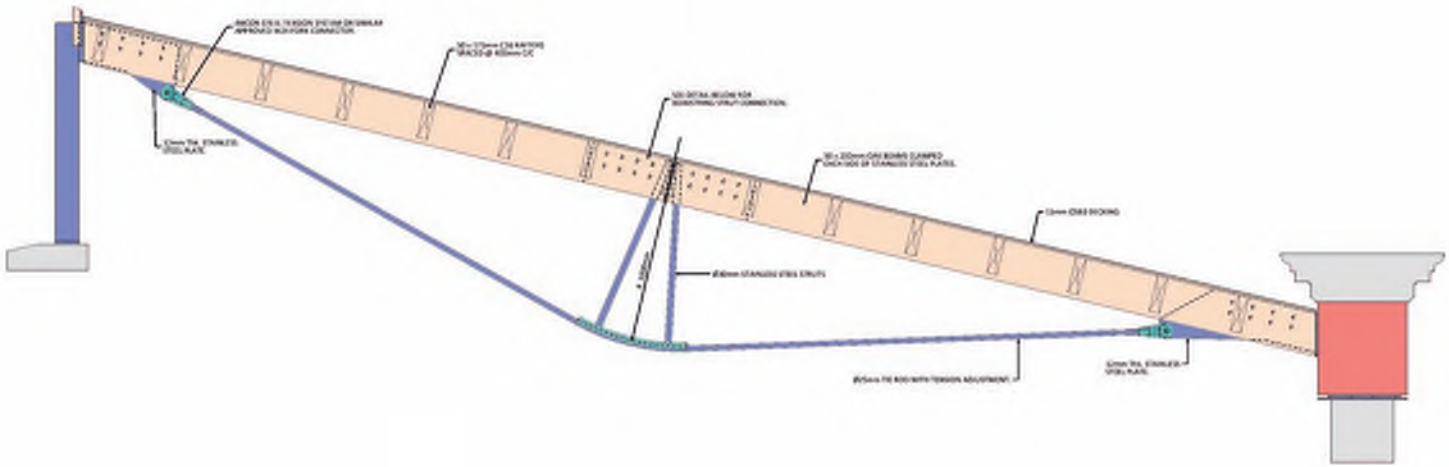
HOLKHAM HALL STABLES AND POTTERY

Wells-next-the-Sea, Norfolk, UK





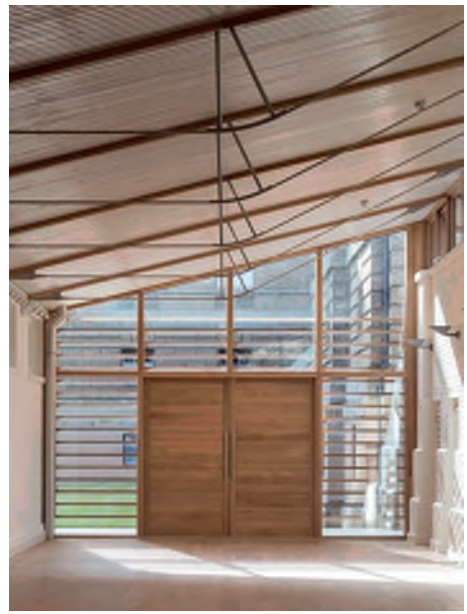
Creating one space from three was the main challenge in converting an 1867 bowling alley and 1960s extensions into a new events space. Slender pre-cast concrete columns and lintels with concealed connections prop the existing wall and roof to the bowling alley, and the extensions get new feature roofs.



The new roofs to the 1960s extensions consist of oak and stainless steel bowstring trusses, rising from the bowling alley to create new clerestory windows that bring light in to the space.

The stainless steel ties are single elements, curved around a bespoke saddle piece at the centre of the span.

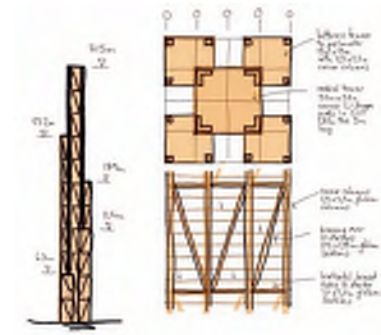
The trusses are propped by slender steel flat plate columns at the clerestory — hidden within the oak mullions of the window frames. The devil really is in the detail in the Holkham Hall project.

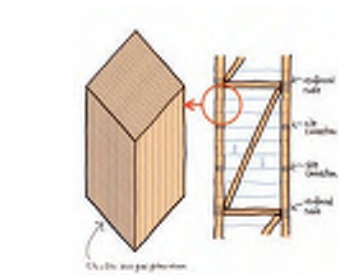


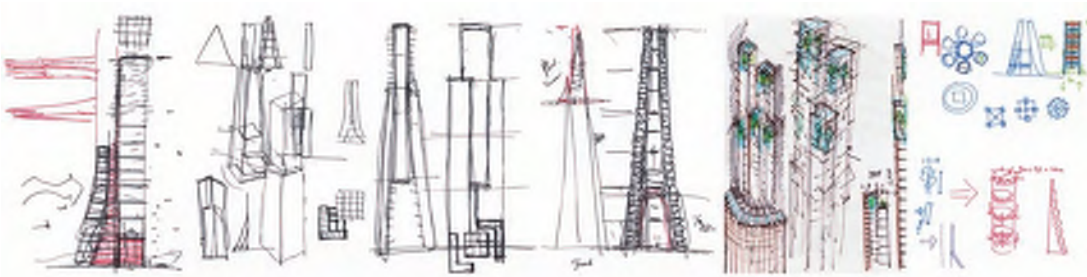
CLIENT Holkham Hall
ARCHITECT Hopkins Architects
CONTRACTOR Robson Construction Ltd
VALUE £3.3m
COMPLETION July 2016

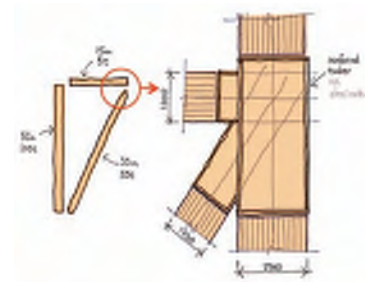
cross laminated timber
glulam

stepped buttressed mega-truss









gross internal area 100,000m^2 timber 30,000t

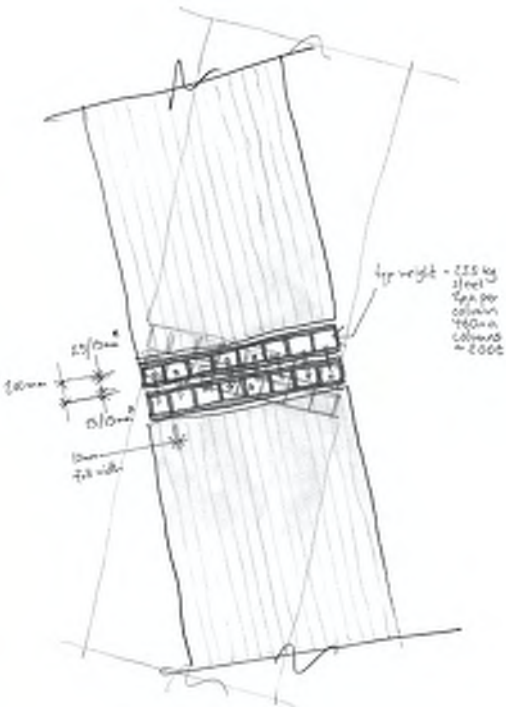
SUPER-TALL TIMBER

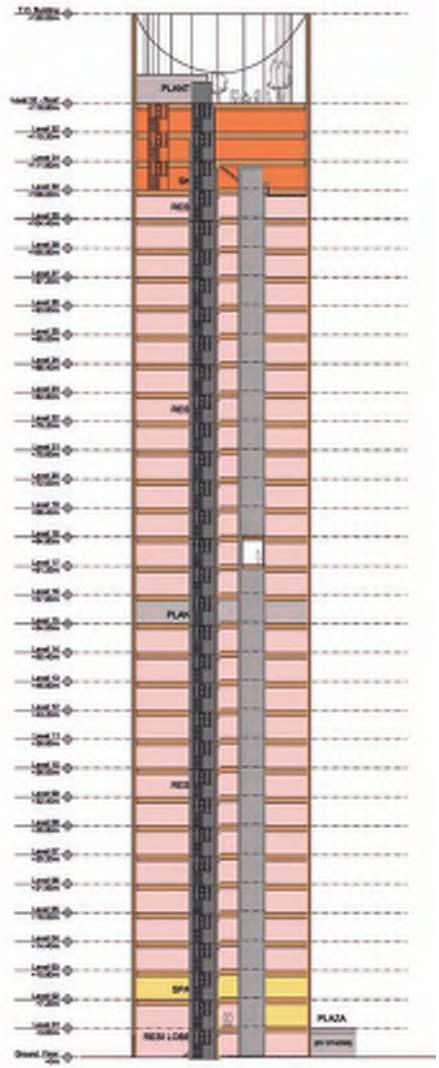
proposal for London

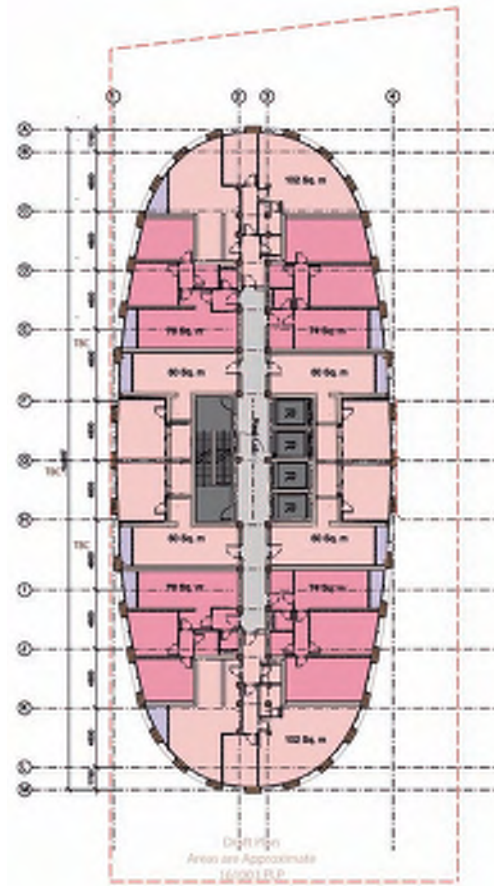
CLIENT University of Cambridge
ARCHITECT PLP Architects

The London tower is a provocative research proposal, led by University of Cambrdge. It challenges the construction industry to re-think what it could do with timber, our only renewable construction resource that can deliver buildings quickly and quietly within our urban environments.

Tall timber buildings will be lightweight compared to their concrete cousins, this helps foundation engineering but generates challenges in connection design (load reversal) and dynamics, which is where our research is focused.

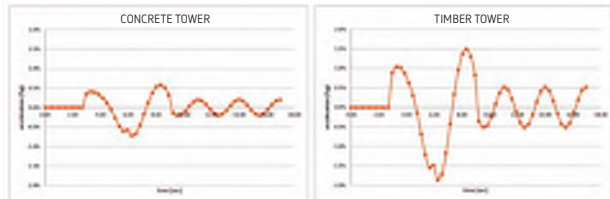






At 32 storeys the Dutch tower represents a huge leap in timber engineering. City planners responded positively to our proposal, waiving height restrictions for ground breaking sustainable design.

Our dynamics engineering predicts accelerations of 10milli-g for the lightweight timber tower. By adding 5million kg of mass to the building (in the form of concrete screed) accelerations are reduced to acceptable levels.



gross internal area 26,016m^2 timber 5,255t

SUPER-TALL TIMBER

proposal for the Netherlands

CLIENT Provast
ARCHITECT PLP Architects

urbanisation

To build just that small piece of the shiny new apartment block in the city that you recently moved into would have taken approximately 100 tonnes of concrete and steel. If you aim higher (literally), and your apartment is in a high rise building, the figure could more than double.

This intensity of material use probably has not changed much over the history of the modern construction industry. However, the good news is that your new apartment has been designed to meet ever-more stringent regulations, aimed at using less and less energy for heat and power.

As our buildings become more energy efficient in their operation, it is only natural that the industry's focus should shift — perhaps towards a better understanding of how we can build more apartments with less, or even different, materials.

Modern buildings are complex machines and there is little or no opportunity for prototyping. Marginal gains made through a reduction in material use can easily be wiped out by another aspect of the project: an over-zealous buildability review, a natural ventilation thermal mass strategy or a competitive design fee. And, bizarrely, sometimes more material costs less — we have all experienced this at some stage in our construction careers.

So what are our options?

Perhaps one of the first things to do is to start recording how much material is used in the construction of each new building. This could be done at an individual, company or national level, possibly utilising open-source platforms mimicking the carbon-buzz initiative. Data collection is key.

Some UK authorities are already paving the way, making embodied carbon calculations a requirement for achieving planning permission. However, a focus on carbon muddies the waters somewhat, causing us to lose sight of the base measurement of resource use and efficiency.

If you look at materials availability, European Union forests have consistently over-produced. Each year millions of tonnes of wood growth is not harvested. Could this renewable resource displace some of our use of non-renewable materials such as concrete and steel?

We are already seeing timber buildings up to twelve storeys high emerging in our cities. If your new apartment is in one of these multi-storey structures, it weighs just 20 tonnes, and if designed properly could have been erected in record time. This is a reduction in weight by a factor of five — great news for structural engineers whose main battle is with gravity.

However, as timber buildings go even higher in the quest to densify our cities, the obsession with gravity will soon be replaced with new challenges, such as how to keep tall timber buildings from moving too much in the wind. We need to further our knowledge through research into detailed technical issues like the dynamic response of timber structures, and how to design suitable timber connections. And we need research into fabrication and construction logistics, as well as in how to achieve financial viability and exploit economies of scale.

Smith & Wallwork's recent work with a Dutch developer has shown us that a 30 storey timber structure (25 tonnes per apartment) is still some way off when it comes to competing with a concrete frame in terms of cost. Despite having the go-ahead to build 50% taller than the existing local planning ceiling — granted because of the proposed use of timber construction — it was still not possible to achieve a viable business case for the project. Perhaps land prices in London would see a different outcome?

For 20-30 storey timber buildings, hybrid structures will probably be the answer in the short term, pairing concrete or steel stability cores with timber gravity frames. This would help allay developers' fears of risks associated with something new.

The march towards urbanisation and denser living is creating opportunities to re-think construction futures. Engineers have a duty to engage ... and to be able to answer Buckminster Fuller's question to Norman Foster: "How much does your building weigh?"[1].

More importantly, we need be able justify the answer.

Simon Smith and Tristan Wallwork

Cambridge, 2018

[1] Quoted by Norman Foster in relation to the Sainsbury Centre of the Visual Arts in 1978, in D. Jenkins, *Norman Foster Works 1*, Munich: Prestel, 2003, p. 550

research and development

Measuring-up in timber: a critical perspective on mid- and high-rise timber building design
by Patrick Fleming, Simon Smith and Michael Ramage, 2014
published in Architecture Review Quarterly

Cross laminated timber in-plane force analysis
by Jeremy Toyn (University of Cambridge) and Smith & Wallwork, 2014

UK forest resource opportunities for higher value use
by Iason Pelekis (University of Cambridge) and Smith & Wallwork, 2014

Cross-laminated timber buckling
by Thomas Place (University of Cambridge) and Smith & Wallwork, 2014

Reducing urban flood risk with SuDS
by Bryn Pickering (University of Cambridge) and Smith & Wallwork, 2014

Viability of cross-laminated timber from UK resources
by David Crawford, Robert Hairstans, Simon Smith, Panayiotis Papastavrou, 2014
published in Proceedings of the Institution of Civil Engineers

British timber in construction
by Simon Smith, 2014
published in Proceedings of the Institution of Civil Engineers

CLT composite rib slabs
by Nicholas Niem and Allan McRobie (University of Cambridge),
and Smith & Wallwork, 2014

3D printed energy absorbing structures
by Adam Sanders and Digby Symons (University of Cambridge), and Smith & Wallwork, 2015

Integrated water management
by Melanie Jans-Singh (University of Cambridge) and Smith & Wallwork, 2015

Connections between CLT elements and future challenges for CLT in practice
by Tristan Wallwork and Fernando Perez, 2016
published in Proceedings of Joint Conference of COST Actions

Life cycle energy in construction
by Mark Allen (University of Cambridge) and Smith & Wallwork, 2016

Urban densification: Are timber structures the solution?
by Eftychia Dichorou (University of Cambridge) and Smith & Wallwork, 2016

Folded plate CLT roof structures
by Ewan Macpherson and Allan McRobie (University of Cambridge), and Smith & Wallwork, 2016

Point supported and two-way spanning CLT slabs
by Solene Fercocq and Allan McRobie (University of Cambridge), and Smith & Wallwork, 2016

Re-cycled glass panel product load testing
by Adam Melvin and Allan McRobie (University of Cambridge), and Smith & Wallwork, 2016

Seismic timber design
by Rory White and Allan McRobie (University of Cambridge), and Smith & Wallwork, 2016

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