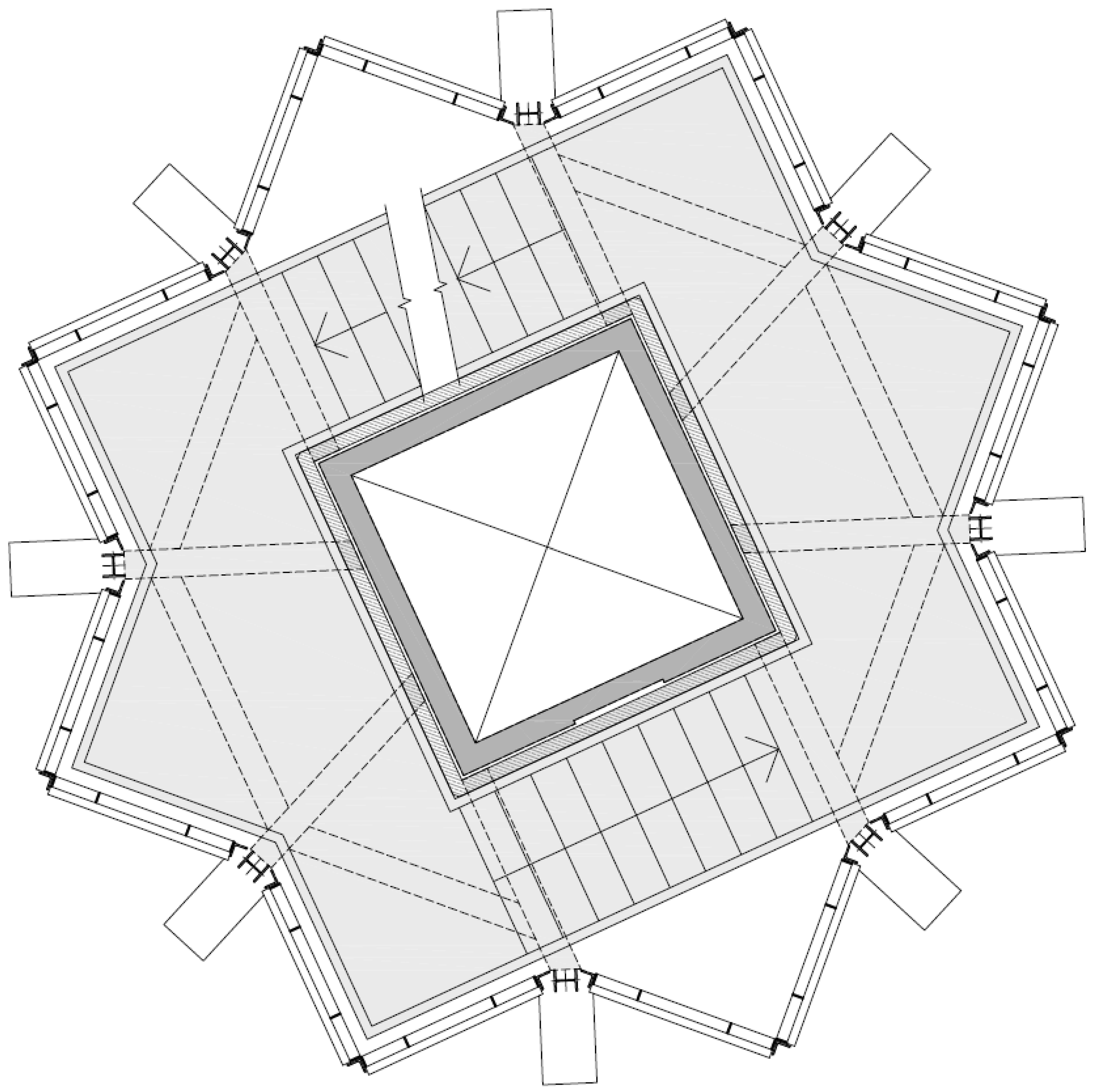
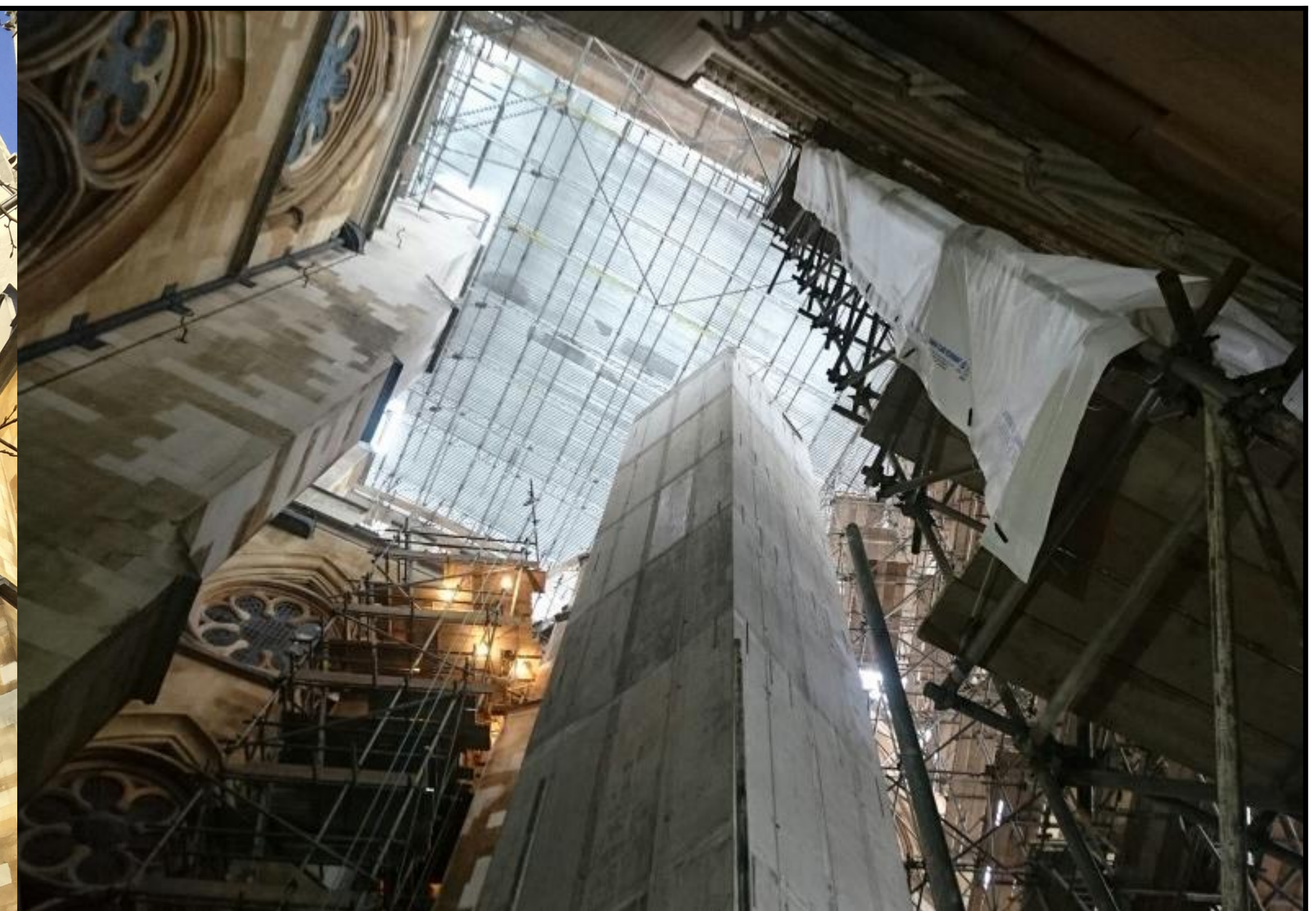
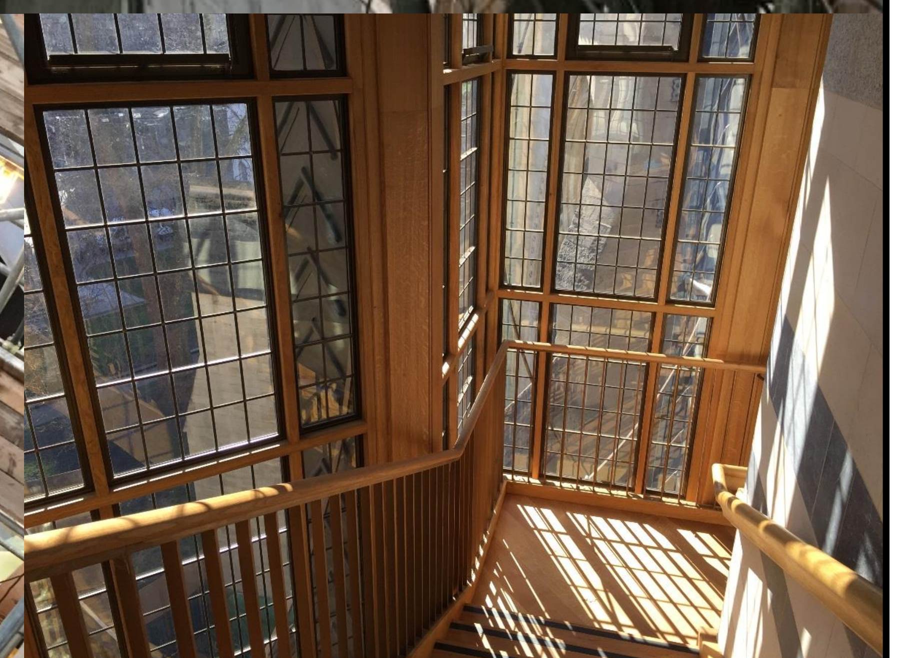
WESTMINSTER ABBEY WESTON TOWER

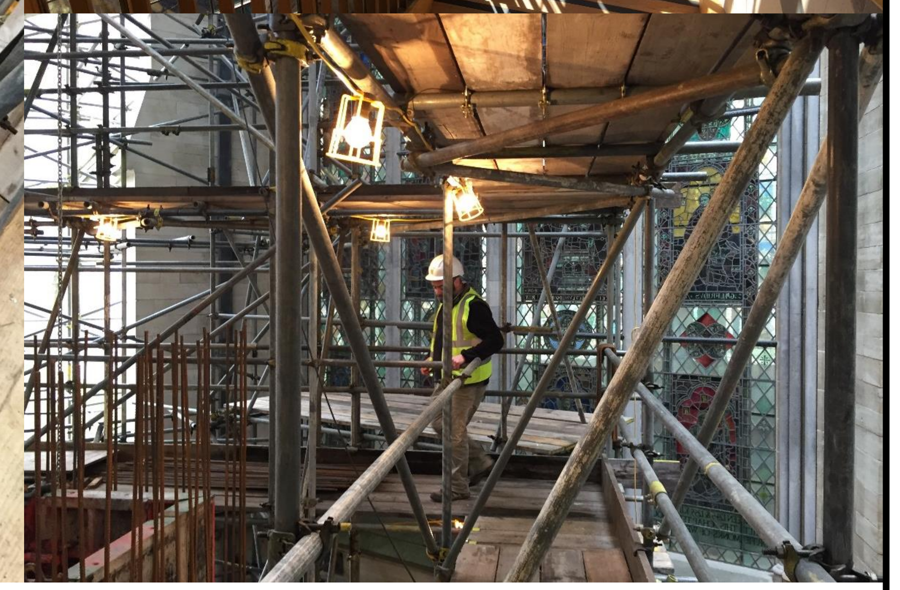
DANIEL DOWEK

PROJECT ENGINEER









Architect - Ptolemy Dean Architects
Contractor - Daedalus Conservation
Structural Materials - Steel, RC, Timber, Stone
Features - Construction sequence
- Sensitive archaeology
- Conceptual design
- Material tests

Role

- Project Engineer from concept to completion
- 2014 - 2018
- Conceptual design and exploration of material options.
- Ongoing development of outline construction sequence
- Detailed design of all structural elements
- Production of structural calculations, drawings and specifications.
- Management of CAD technician and drainage engineer
- Specifications for laboratory, geotechnical and wind tests
- Visits to timber yard & steel fabrication shop
- Monitoring works on site
- Attendance at all design workshops and site meetings

The Project

The Weston Tower is the first major intervention to the Abbey fabric since 1745 when the West Towers were added by Nicolas Hawksmoor. Since its consecration as a monastery in C11 there have been many significant alterations, including transformation from Romanesque to Gothic in C13 under Henry III, rebuilding of the Lady Chapel in C16 under Henry VII, and remodelling the Triforium in 17C by Christopher Wren.

So the Abbey has a long tradition of modifications. This time to provide public access through Poets Yard to the Abbey's Eastern Triforium which has been newly refurbished as the Queen's Diamond Jubilee Galleries in parallel with our work.

Wind Tunnel Testing

Full-scale wind tunnel modelling was put forward at an early stage to be sure that the introduction of a new building would not create vortices that might affect the surrounding delicate stone or glazing. The wind model test also provided an accurate assessment of the wind pressure on the tower that could be used in the design of all of the structural elements.

Archaeology

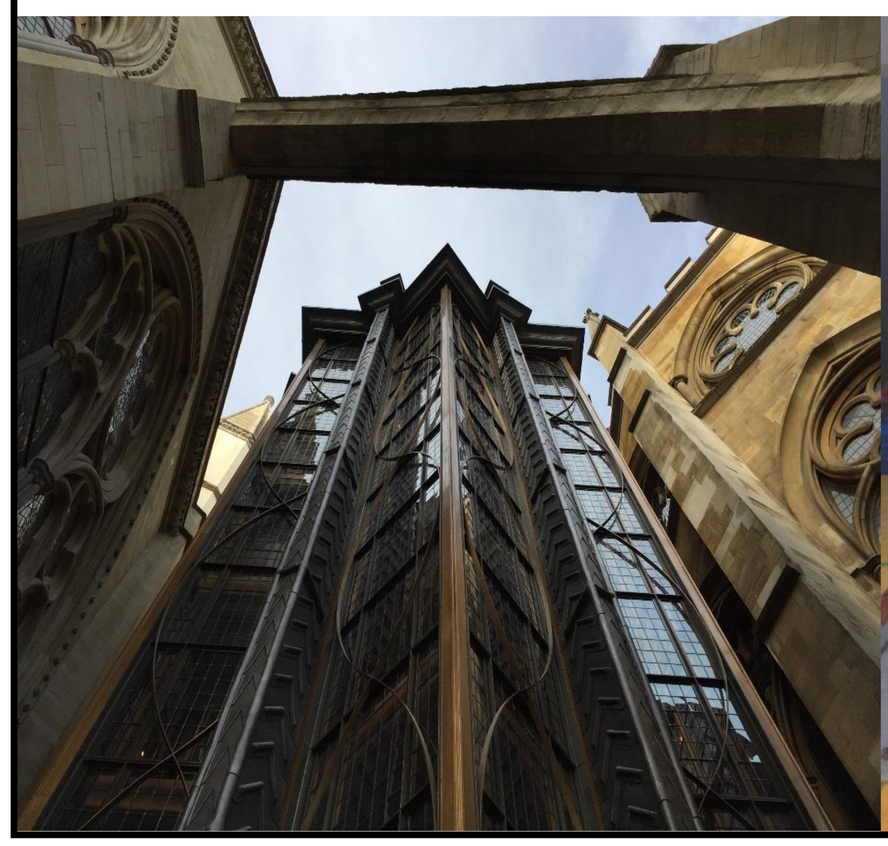
Following demolition of the 1970s toilet block and extensive temporary rainwater diversions for a large portion of the Abbey Roof archaeologists were able to excavate Poets' Yard over a period of about 5 months. The site was found to have been a monastic burial ground and later a stone yard for Abbey construction. The most noteworthy of discoveries were burials contained within finely decorated anthropoid lead coffins, thought to be the most ornate of their type found in the country to date. Interwoven with older archaeology were brick structures from Scott's tenure as surveyor, including drainage runs in the yard and retaining walls for the Chapter House lightwells that draw light into the crypt, in which we found an early Barnak stone coffin built into the bricks.

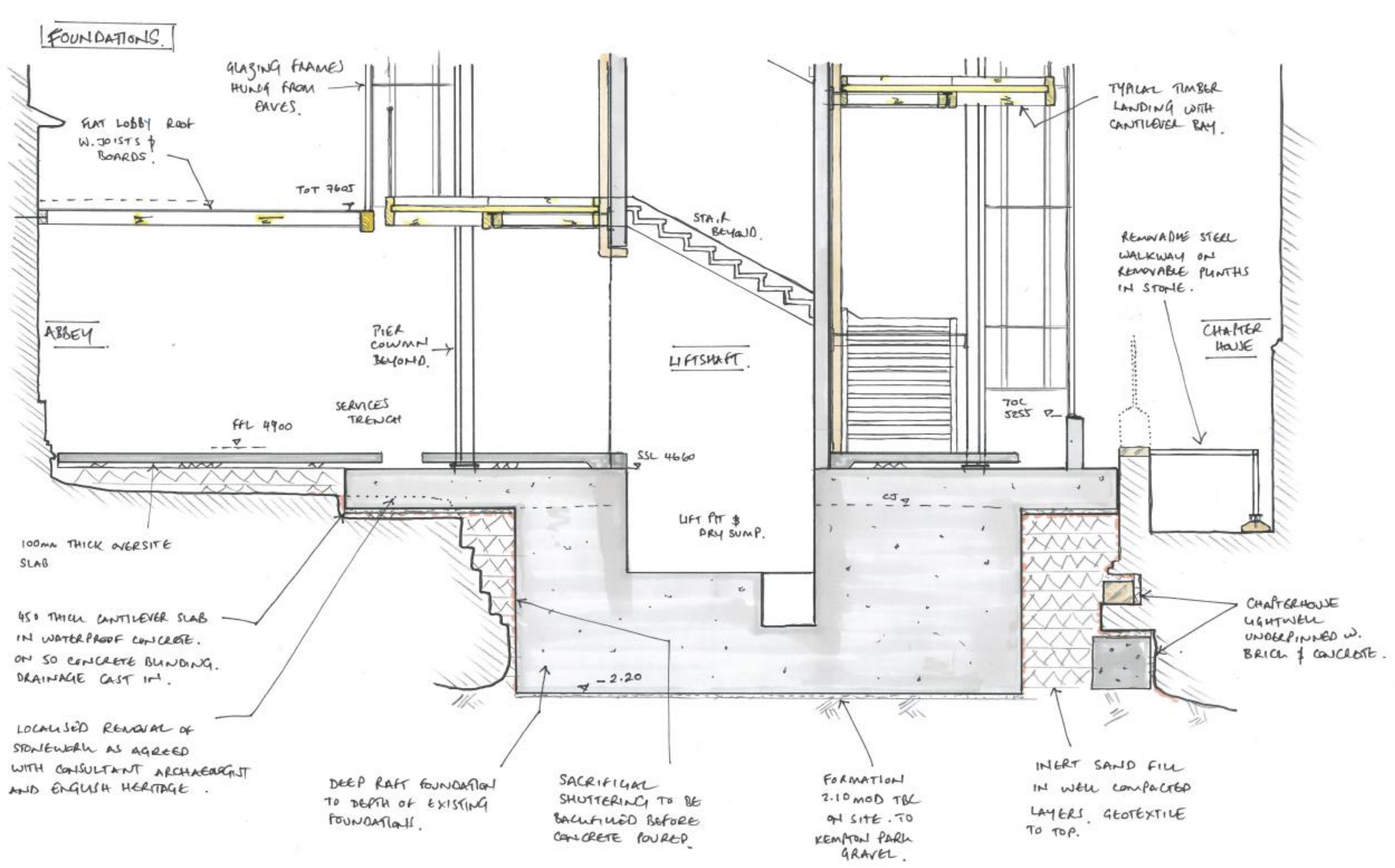
Of particular engineering interest were the steep Caen stone footings to the Ambulatory and the stepped Reigate footings to the South Transept, behind which a rubble "lime-concrete" raft for the Abbey walls extends down to a depth of 2.7m. These existing foundations project a long way further than would be needed to spread the load, so perhaps the final form of the church was unknown at the time the foundations went in.

Foundations

The result of the archaeological and geotechnical investigations was a very tight space to squeeze in new foundations with the good gravels of Thorney Island 2.7m down. In agreement with the 13th century masons a raft seemed to be most suitable, so the tower is founded at the same depth as the Abbey, with the concrete for the new tower well separated from the 13th century stone.

The footprint of the tower over-sails the available space for the raft, so a slab in the ground cantilevers out to pick up the periphery. An area of floor has been left open so that visitors can peer down to the medieval foundations. Staffordshire blue engineering bricks are used to support the slab edges around this hole to be distinct from Scott's red stocks.





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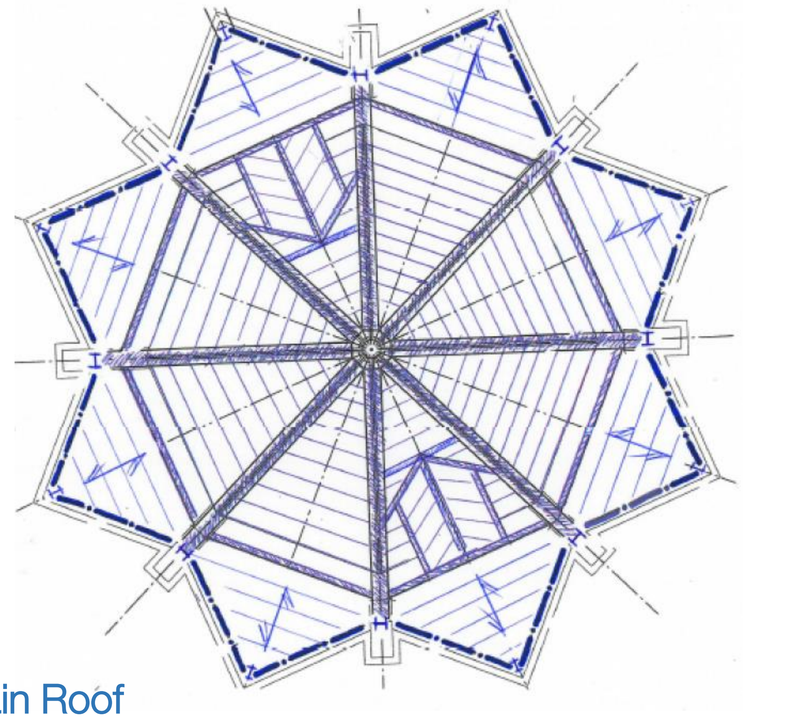
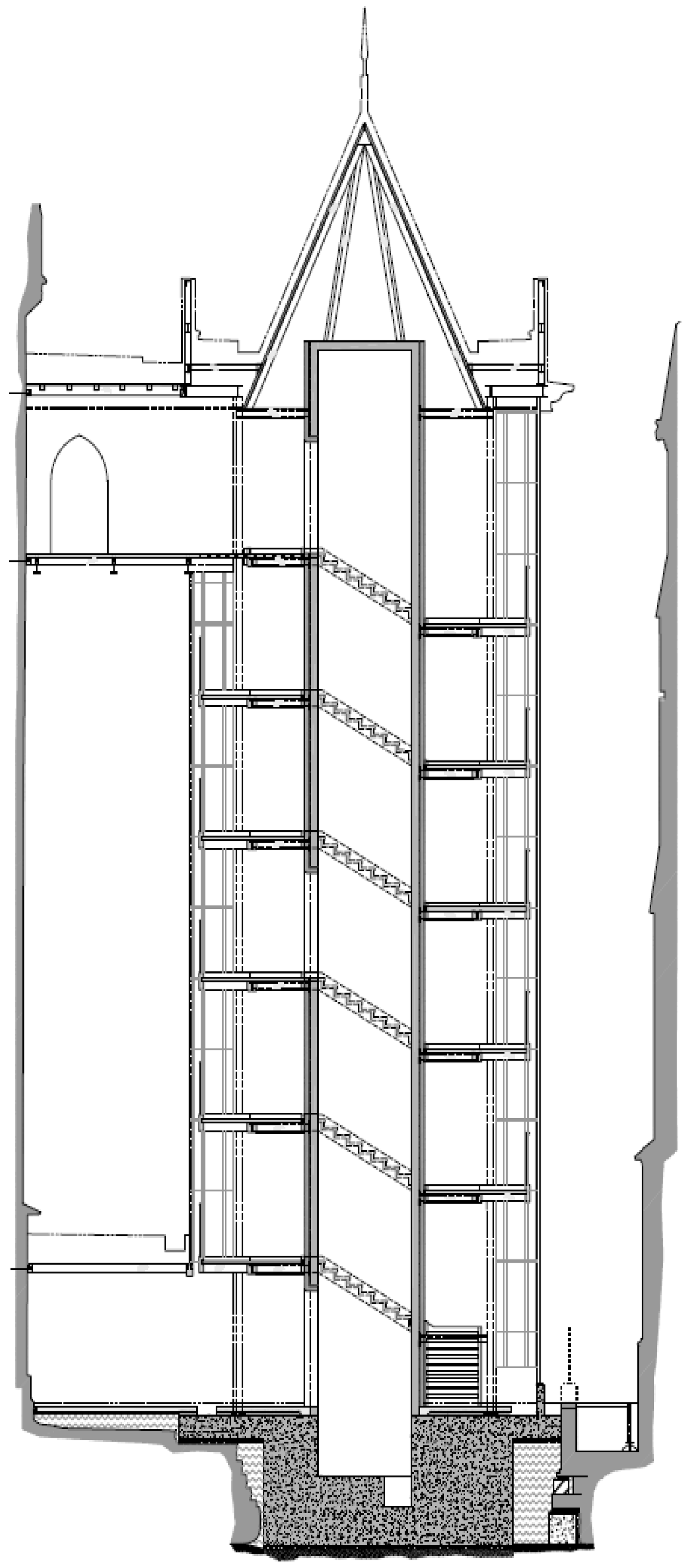




Material

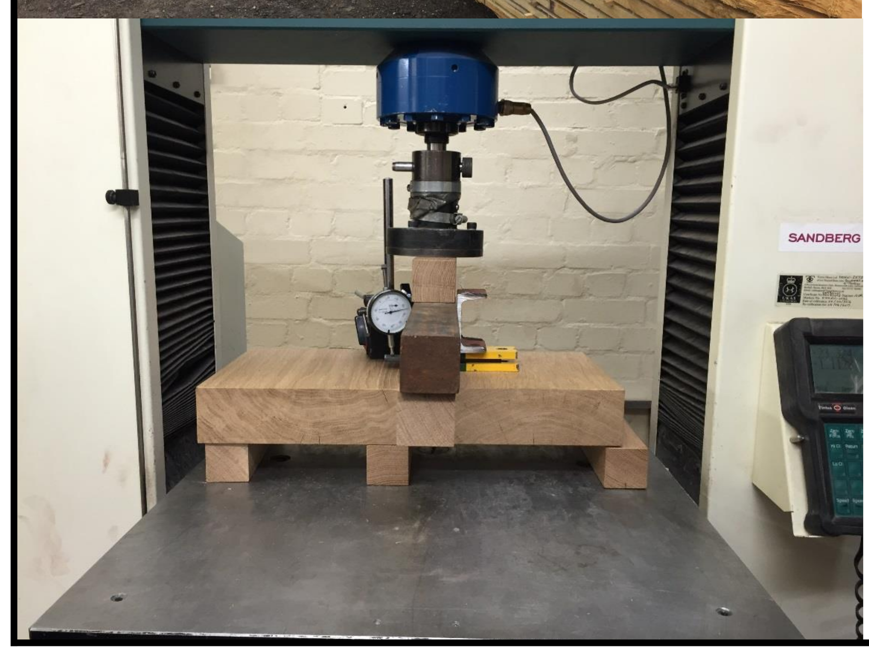
The form of the tower is a rotated square based on the geometry of a regular octagon, on plan it is an 8 pointed star about 6m across, and 30m tall. Underlying the architecture is the necessity for minimum intervention, to discreetly link historic fabric without being substantial its own right. The materials of the Abbey are stone and timber. The architect to both Triforium projects, Ptolemy Dean Architects, felt that the new addition should be decorative and gothic in character, in keeping with previous additions, but detailed in materials of its own time.

The glazed walls lend themselves to a lightweight steel structure to enhance views out over Westminster as one climbs the stairs, and to maximise light coming in. The steel envelope is not braced so the square centrally located liftshaft provides the lateral stiffness. It could have been in concrete or in steel. A steel shaft would have been possible with thinner walls, and steel has the advantage of avoiding wet works on an incredibly tight site. It was also attractive to have the external walls integral with the main structure and contained within a single steel package.

However the dead weight of a steel shaft would not be enough to avoid tension piles at the base as there is no space in the ground to expand the mass of foundations. Steel would have also been too flexible to clad with stone and caused difficulty with detailing of the high level bridge link back to the Triforium.

Reinforced concrete for the shaft needed to be thicker, 175mm eventually, which includes a 25mm zone for cast in channels and a services riser. Precast would have been possible and may have been left exposed, but was discounted to avoid cranage over George Gilbert Scott's flying buttress to the Chapter House. Insitu concrete for the liftshaft therefore appeared to offer the best solution for a stone clad shaft, while keeping lateral movement to a minimum and with enough dead weight to avoid the complication of tension piles. A self-compacting mix would also avoid vibrations disrupting the ongoing Abbey services or shaking the Abbey's monuments.

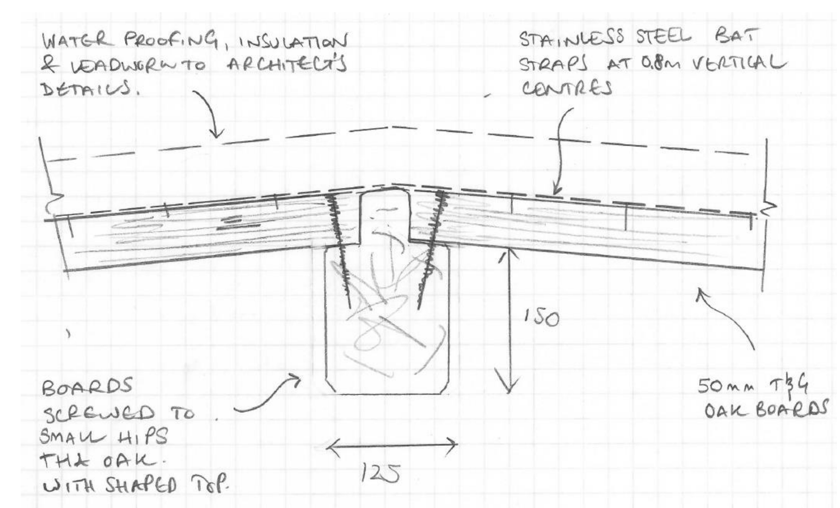
Spiralling round the shaft are 12 identical stair flights connected half-landings. These may have been precast concrete, stone or wood. Stone could have been built into the shaft with the treads designed to work like cantilevered stone stairs, but the smell and the warmth of oak and stone felt right to go with the existing building. Oak landing and flights are supported on small steel beams which tie the 8 steel pier columns back stiff shaft. These piers and the roof are clad in dark lead sheets to distinguish the tower from the stone of the adjacent walls.

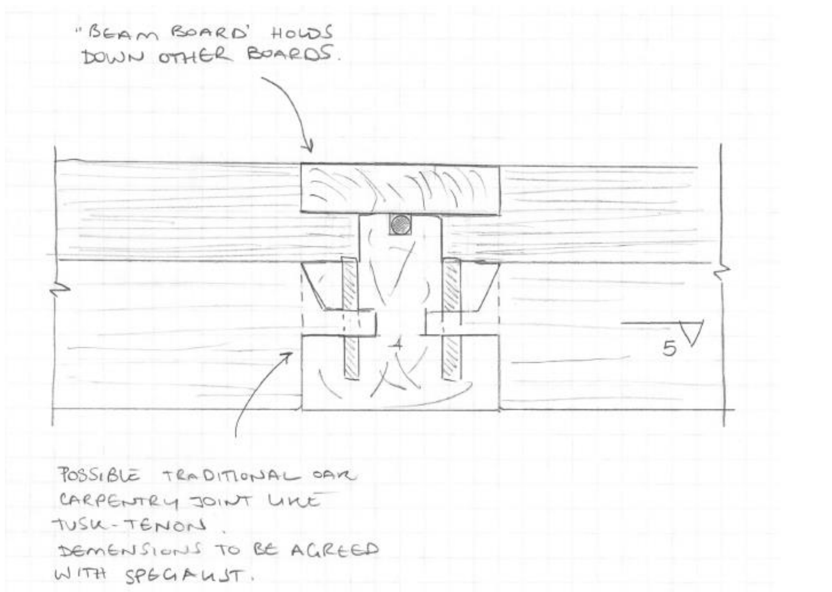


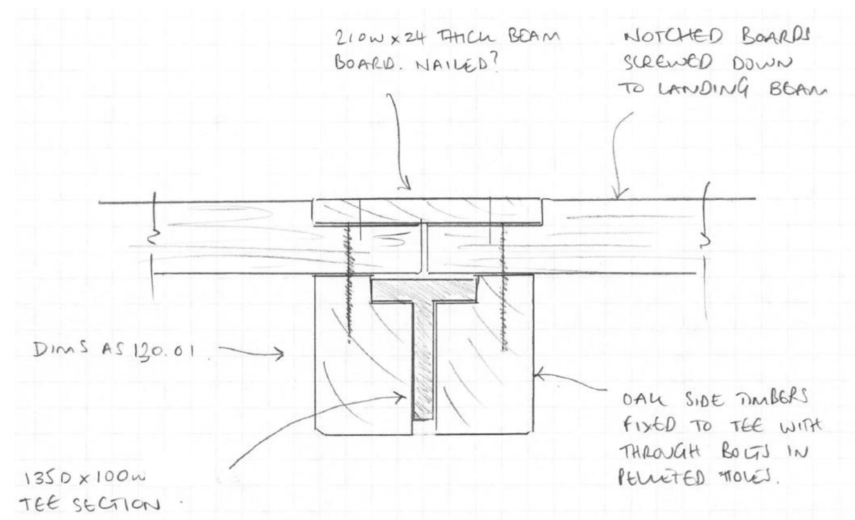
Main Roof

A conventional pitched timber roof with eight 6m long oak hip rafters with oak sarking boards housed in accompany the surrounding pointy roofs and turrets. The boards can develop hoop stresses to prevent the shallow hips from sagging. The top of the piers meet the hips at the eaves behind a heavy lead cornice. At this point a star-shaped steel ring beam ties in the roof and cantilevers out to hang the glazing.

The challenging geometry of the castellated parapet is in the language of the piers, with fabricated steel framing, and lead clad boarding.







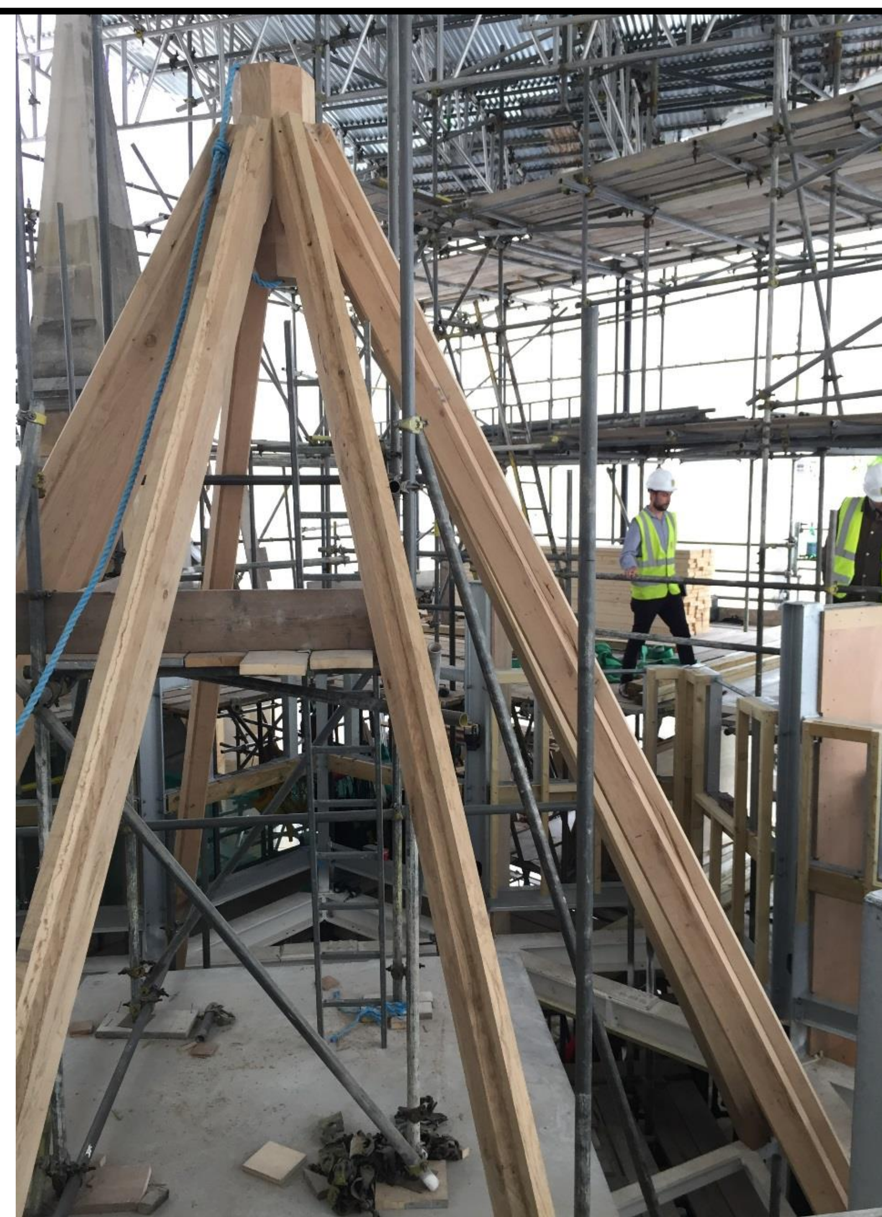
Wood

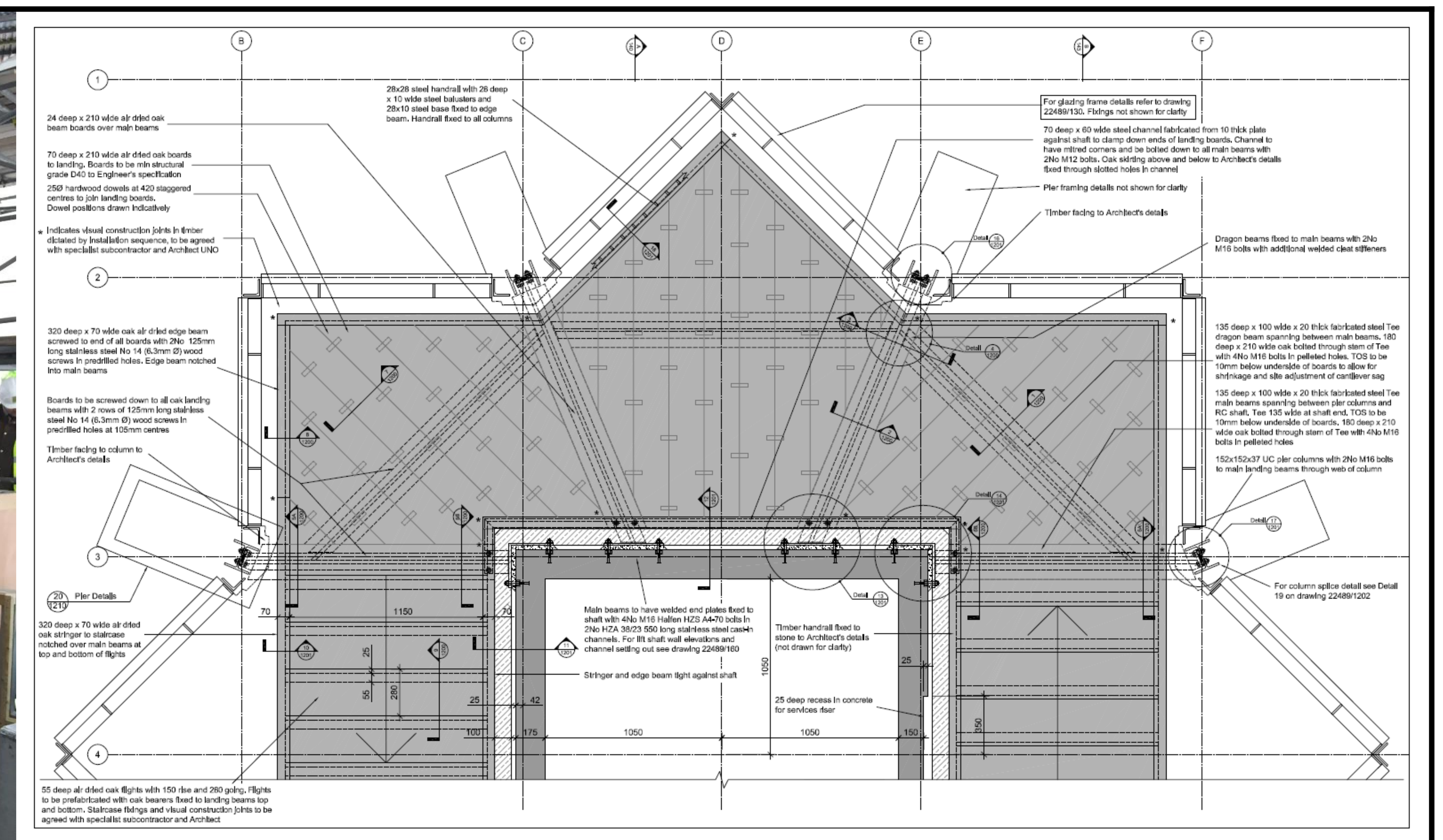
The flights are traditionally built of solid oak boards with stringers on both sides, spanning between half-landings. The landings are also in oak boards radiating from the centre of the tower and sitting on small oak-clad steel landing beams. The boards project out to, but do not touch, the perimeter triangular glazed bays, so are clamped within the stone wall and cantilever over the beams. The maximum cantilever span of the triangular bays is 1.2m, which leads the boards to a thickness of 70mm (planed down from a standard stock size of 80mm) for vertical deflection, which is amplified by rotation of the back span.

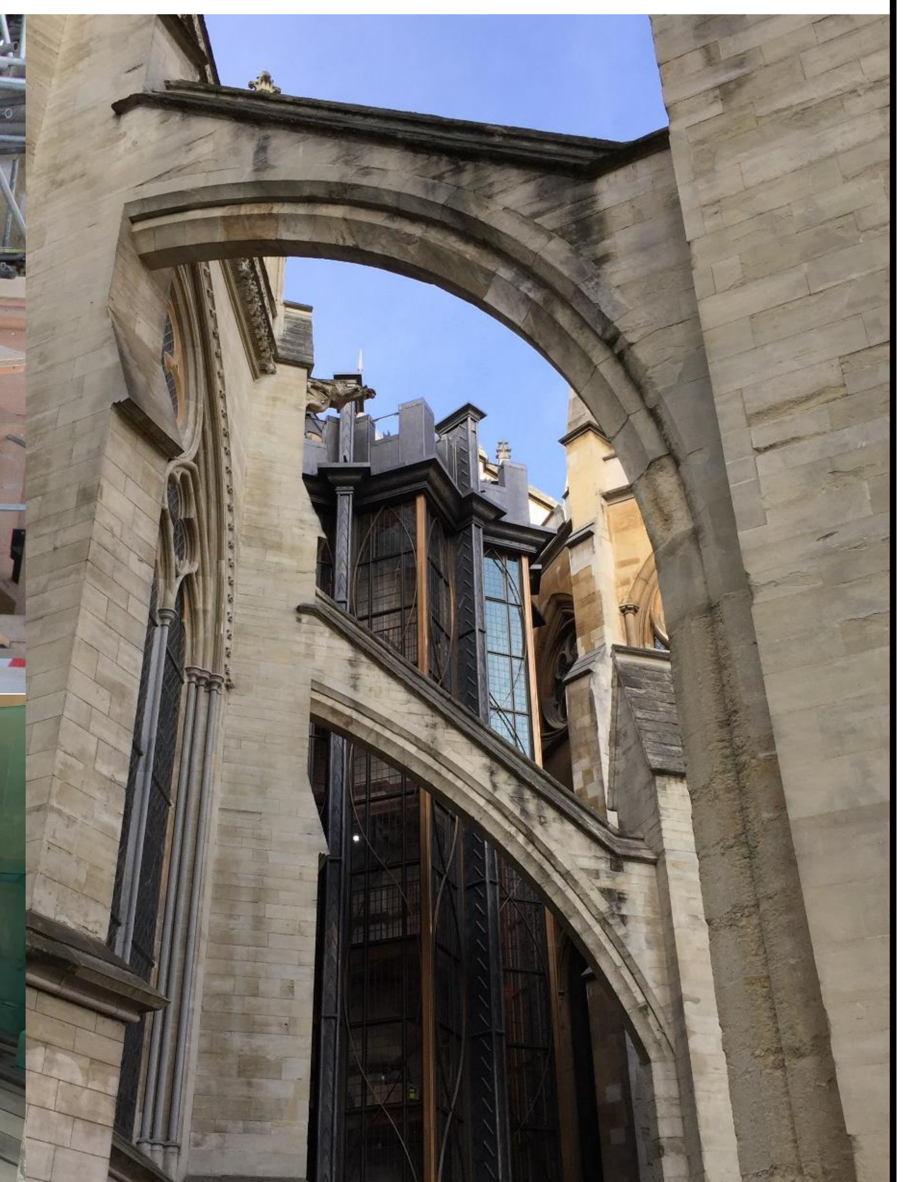
With thick oak boards the landing plates could be used to horizontally brace the external steel frame to prevent rotation, and allow simple connections between steel beams that could be concealed beneath timber cladding. Turned oak dowels are used to transfer both longitudinal shear and vertical loads between adjacent boards. The dowels were fitted drier than the boards so that they would tighten into their holes.

Full-scale laboratory testing was carried out on various timber doweled assemblies to expand upon the ultimate yield theory for metallic fasteners given in the codes of practice. The variables we were interested in were the relationship between dowel grain and load orientation, reduced edge distances commonly used in traditional oak frames, and gaps of varying thickness between boards to simulate long-term shrinkage in oak.

A lot of research went into our specification for both air-dried and green oak. English and French oak was sourced, with limits on the moisture content, angle of grain, bow, sapwood, and age of tree. The position of the heart was also considered for each member so that the long-term distortion could be allowed for.



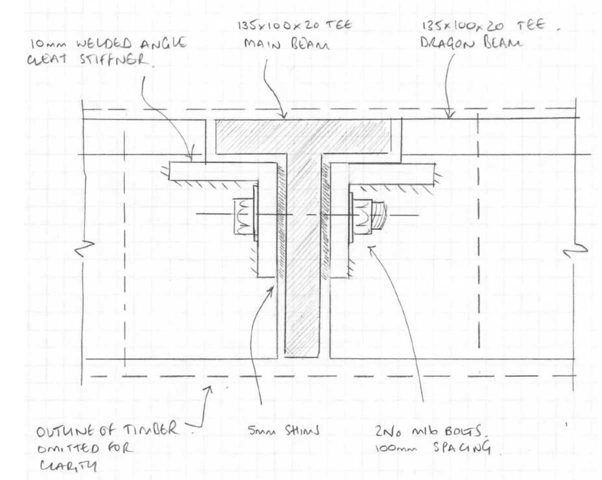




Steel

Once the concrete had been taken all the way up and the scaffold enclosure rearranged, the steel could follow. Eight 152UC lead clad pier columns with splices at third points mark the points of the octagon. These are restrained by radial 135mm deep 100mm wide fabricated steel tee-beams that support, and are held in place by, the landings and flights.

Projecting out to the corners of the star between the piers are 4.1m tall steel frames for leaded lights. As only half of the glazed walls reach ground they are all hung from eaves with 10mm thick mullion hangers and small corner angles hidden behind bronze covers. Flame-sprayed zinc protection and control over the welding process were needed to minimise distortion of the frames.



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COASTAL HOUSE, DEVON

WOOD AWARDS 2017 ARNOLD LAVER GOLD AWARD WINNER

TheWoodAwards

DANIEL DOWEK

PROJECT ENGINEER

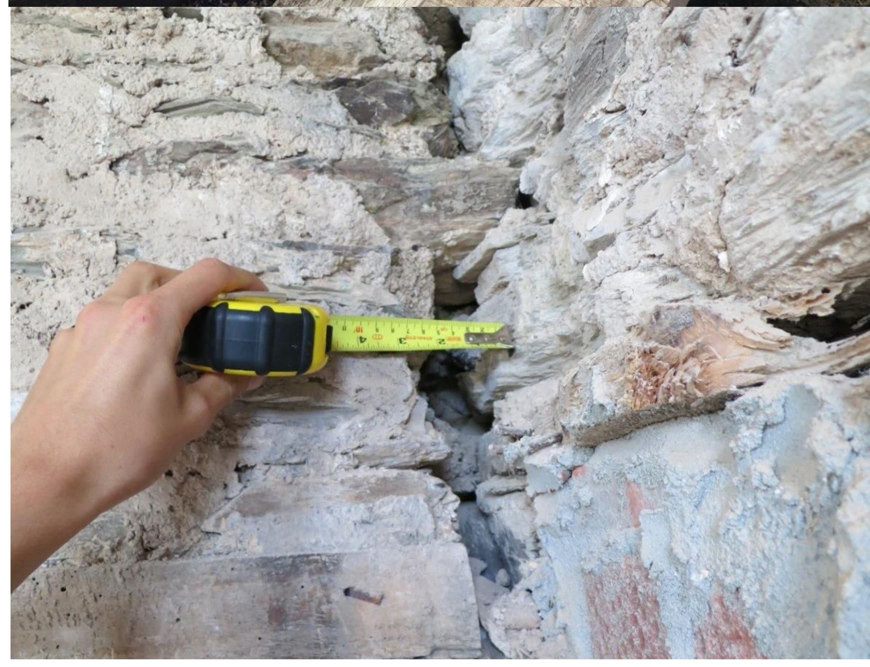
Architect	- 6a Architects
Contractor	- J E Stacey
Structural Materials	- Timber, Masonry, RC
Features	- Conserving existing fabric
	- Sequencing
	- Traditional carpentry

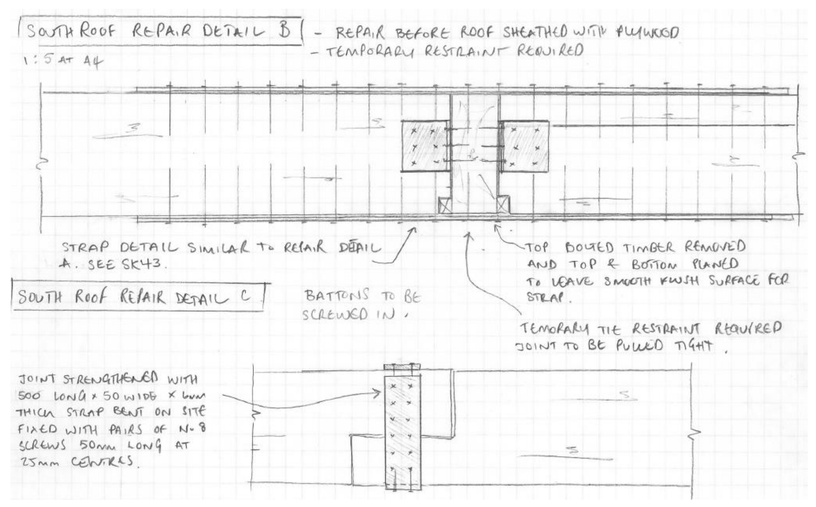
The Project

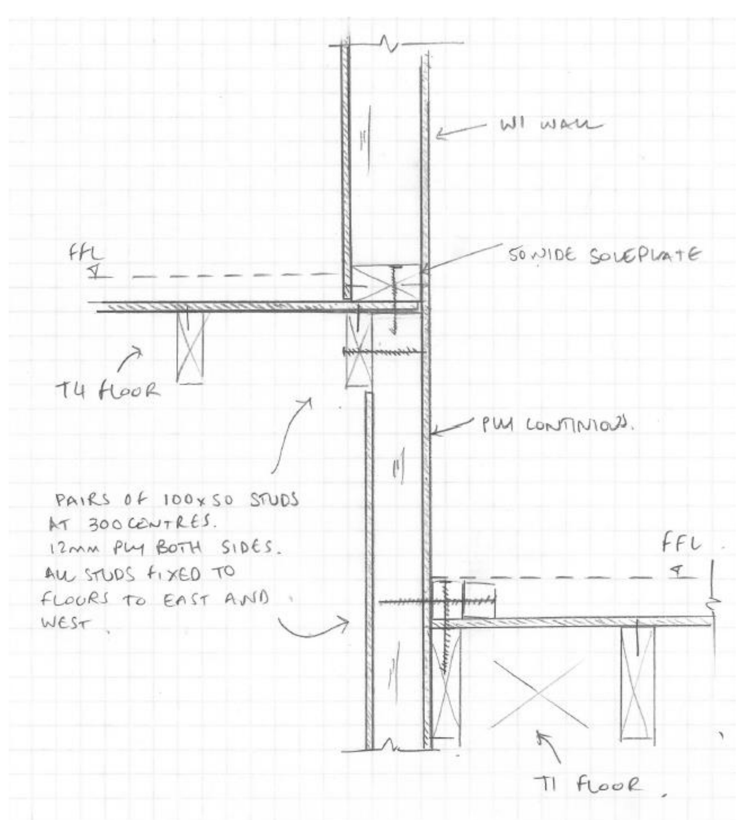
Renovation of a large Georgian house on the Devon coast in Dartmouth with 6a Architects for a family's primary residence. The brief was to retain the character of the house, keeping the existing thick rubble stone walls and stripping out and renewing much of the internal timber structure.

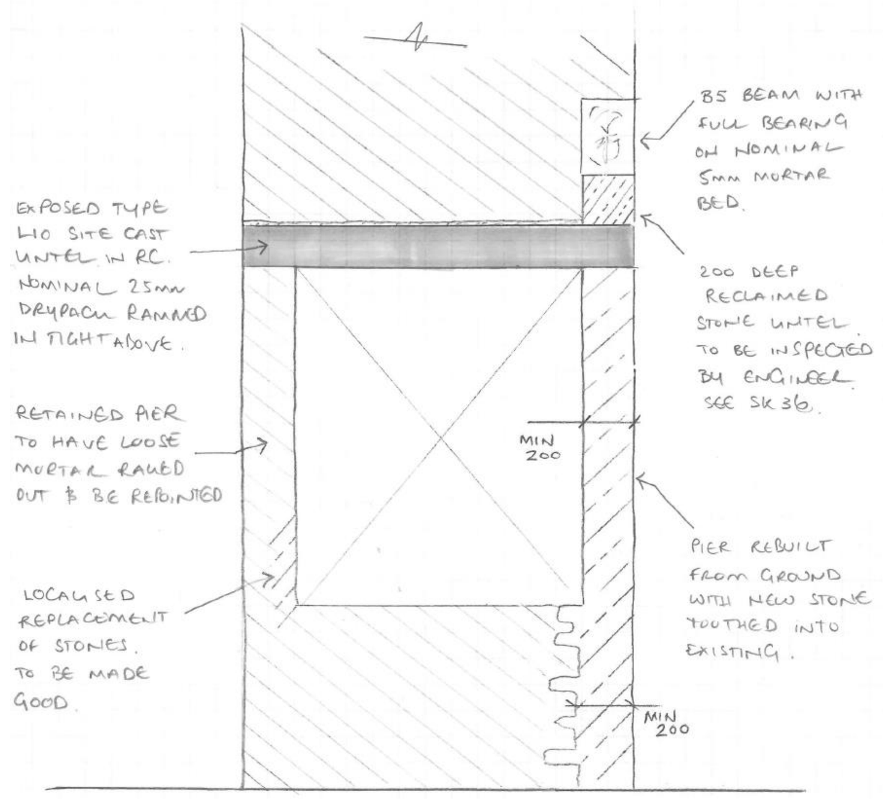
Role

- Project Engineer from concept to completion
- 2014 - 2016
- Conceptual design
- Production of outline construction sequence
- Detailed design of all new structural elements
- Specification of timber and stonework repair details
- Production of structural calculations, drawings and specifications
- Reinforcement detailing
- Management of CAD technician and drainage engineer
- Inspection of timber yard
- Monitoring works on site
- Attendance at all design and site meetings









Material

The new structure is mostly timber with a few visible reinforced concrete elements. Large exposed oak beams and posts with traditional joints are used to support the floors, walls and roofs. The use of long span oak beams has meant that limiting long term creep deflection and moisture movement has been a key design consideration. Specification of well-seasoned oak, together with limits on the strength grade, moisture content and growth ring orientation has been critical.

The central boarded staircase uses oak stringers with elegant splayed balusters dowelled into the top face of the stringers. By bending them slightly in towards the handrail the balusters have been pre-stressed, allowing them to be as slender as possible. A concrete framed opening at the bottom of the staircase leads into the drawing room with an impressive exposed herringbone strutted joisted ceiling. The ceiling spans on to a scarf jointed beam held up by a tall post in the heart of the house.

The north end of the house, probably a later extension to the original building, has been raised with an additional storey, with the external stone walls capped with reinforced concrete and then built up in softwood. The existing southern end trussed purlin roof has been retained and extended to cover the new north extension. A consequence of this is that the slopes of the roof in the north of the house no longer marry up with the internal walls resulting in asymmetric trusses with large oak tie beams.

Walls & Stability

Wind loads are significant due to the exposed coastal location so the joisted floors are tied to the walls, and the floors and roofs are sheathed with boards or plywood to transfer the lateral loads to the masonry walls. The sequence of works for replacement of the existing floors and removal of the roof boards therefore presented an interesting structural challenge in order to safeguard the stability of the existing stonework, which is very loosely bedded in a soft lime mortar.

The external walls are bowing out somewhat, with vertical cracks measuring up to 50mm between the external walls and internal cross walls. The cause of this is likely to be a combination of the eccentric loading on the walls from the roof, and moisture penetrating into the outer face of the walls causing the stone to expand differentially and push away from the dry inner face. The solution was to stich these walls back together with 2m long Cintec anchors, and also fix the walls to the new timber floors with pattress plates. A new cladding to the house will also prevent the walls from driving rain in the future.

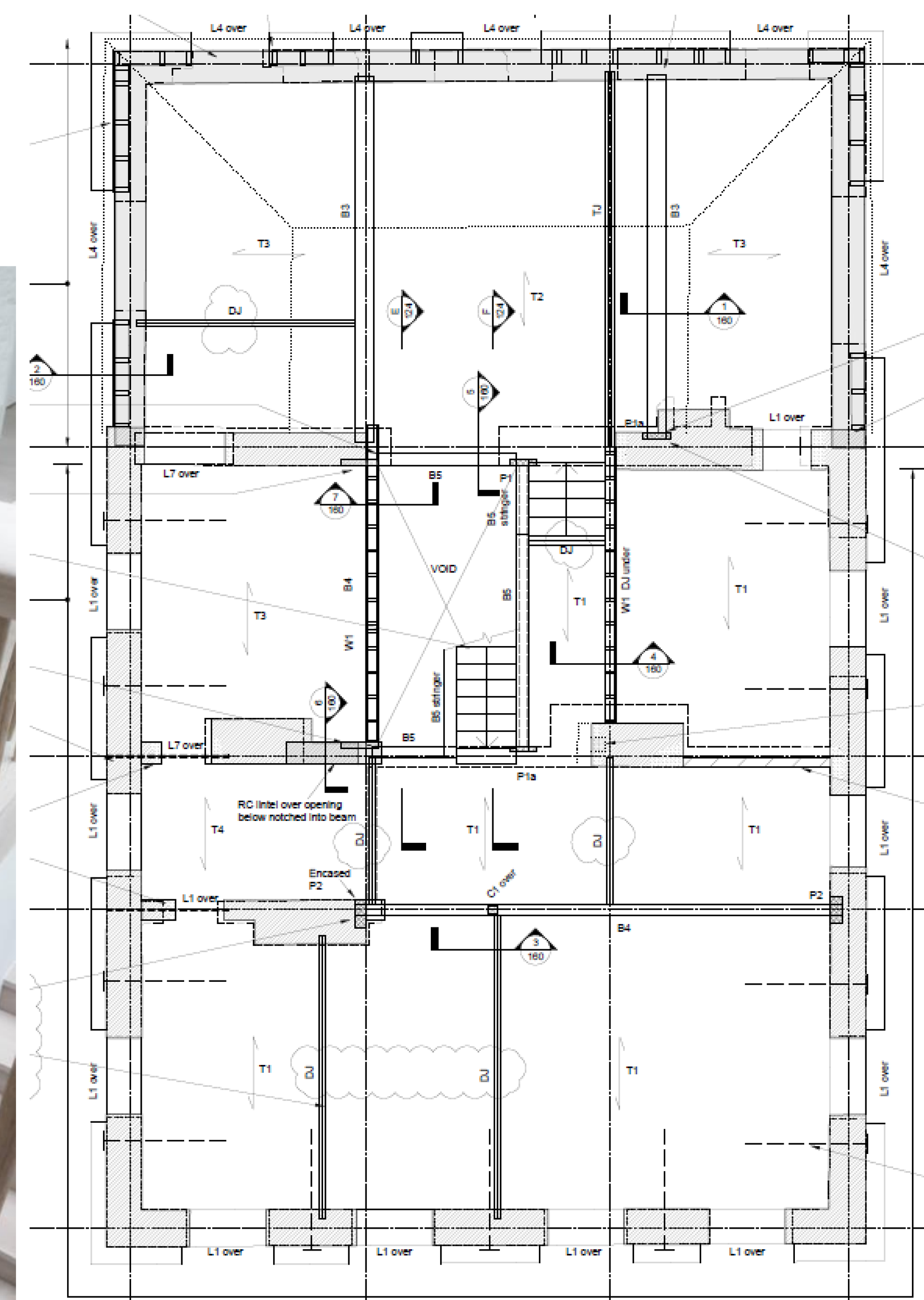
Veranda

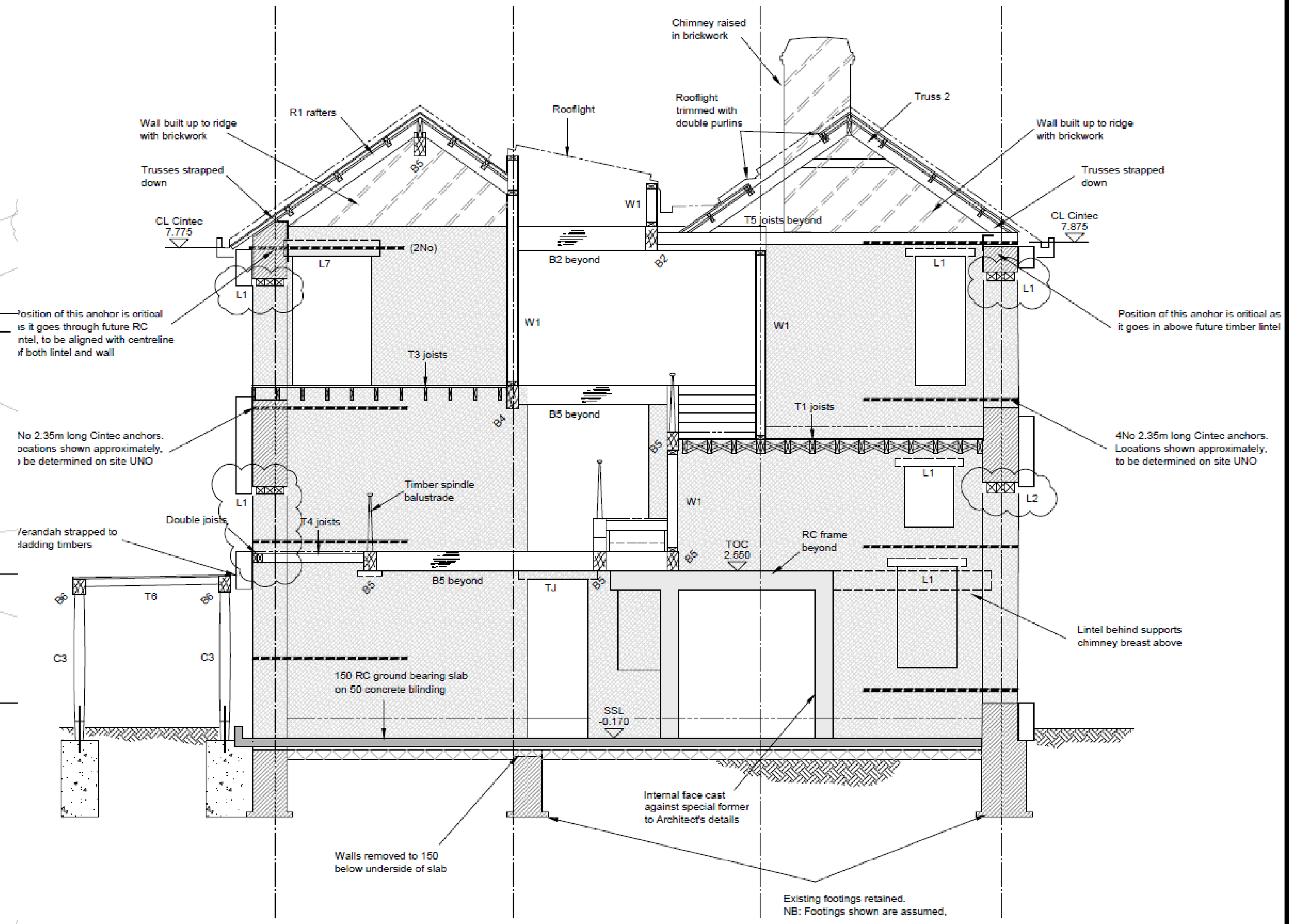
An external green oak veranda wraps around the south of the house. This features tapered oak posts supporting a shallow oak rafter roof. The veranda is pegged together with mortice and tenon joints and strapped back to the walls of the house for stability. To counter uplift forces, the posts have also been dowelled into their foundations and into the beams above with stainless steel rods.

Basement

Unusually most of the existing basement has been filled in with layers of compacted fill material down to the natural mudstone so that the storey heights of the floors above could be more generous. A new basement corridor has been deepened to form a cellar in the centre of the house. To do this U-shaped sections of reinforced concrete were installed from the inside in an underpinning sequence as they are deeper than the foundations of the central walls.

Completed photographs by 6a Architects





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