The Project

The Weston Tower is the first major intervention to the Abbey fabric since 1745 when the West Towers were added by Nicolas Hawksmo. 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 Transept which has been newly refurbished as the Queen's Diamond Jubilee Galleries in parallel with our work.

Wind Tunnel Testing

Full-scale wind tunnel modeling was put forward at an early stage to be sure that the introduction of a new building would not create certain that might affect the surrounding delicate stone or glassing. 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 drainages 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 discoveries were burials contained within finely decorated antelope lead coffins, thought to be the most opulent of their type found in the country to date. Intervened 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 drew light into the crypt, in which we found an early Barnet 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, both of which had visible 'true-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 gravel of Thorney Island 2.7m down. In agreement with the 13th century masonry 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 conditions out to pick up the periphery. An area of floor has been left open so that visitors can peer down to the medieval foundations. Soft-brick railway engineering bricks are used to support the slab edges around the hole to be divided from Scott's red walls.
Material
The form of the tower is a rotated square based on the geometry of a regular octagon, on plan to an 8 pointed star about 6m across, and 33m tall. Underlying the architecture is the necessity for minimum intervention, to disclose the historic fabric without being substantial its own right.

The walls are stone and timber. The architect to both Triffon projects, Pomeroy 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 maximize light coming in. The steel envelope is not breech so the square centrally located Mitchell provides the lateral stability. 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 wood warping on an incredibly tight site. It was also attractive to have the external walls integrated with the master structure and contained within a single steel package.

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

Reinforced concrete for the shell needed to be thicker, 175mm, eventually, which induces a 225m zone for cast in channels and a service riser. Precast would have been possible and may have been left exposed, but was discounted to avoid manage over George Gilbert Scott’s flying buttresses to the Chapter House. Instead concrete for the shaft itself 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 plates. 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 steel flights connected hand-ladders. These may have been precast concrete, stone or wood. Stone could have been built into the shaft with the tactics designed to work like cantilevered stone slabs, but the small and the warmth of oak and stone left right to go with the building detail. Oak landing and flights are supported on small oak beams which tie the 6 oak 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.

Wood
The flights are traditionally built of solid oak boards with strings on both sides, spanning between half-ladders. The laminations 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 walls and cantilever over the beams. The maximum cantilever span of the triangular bays is 1.2m, which leads the board to a thickness of 70mm (planed down from a standard stock size of 50mm) 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 filled with oak that the boards so that they would tighten into their holes.

Full-scale laboratory testing was carried out on various timber dowel 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, end of free. The position of the heart was also considered for each member so that the long-term distortion could be allowed for.

Main Roof
A conventional pitched timber roof with eight 6m long oak hipped rafters with oak sawing boards housed in a companion the surrounding party walls 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 lies in the roof and cantilevers out to hang the glazing.

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

Steel
Once the concrete had been taken all the way up and the scaffold enclosures wrenched, the steel could follow. Eight 100UC lead clad pier columns with cuplocks at third points mark the points of the octagon. These are restrained by radial 125mm deep, 130mm wide fabricated steel tie-beams that support, and are held in place by, the landings and flights.

Projecting out to the corners of the star between the pairs are 4x1 tall steel frames for backlit lights. As only half of the glazed walls reach ground they are all hung from wires with 50mm thick galvanised bar and small corner angles hidden behind bronze covers. Flame-sprayed zinc protection and control over the welding process were needed to minimize distortion of the frames.
**COASTAL HOUSE, DEVON**

**WOOD AWARDS 2017 ARNOLD LAVER GOLD AWARD WINNER**

**DANIEL DOWEK**

**PROJECT ENGINEER**

**Architect**
- 6a Architects
- J E Stacey

**Contractor**
- Timmer, Masonry, RC
- Conservning existing fabric
- Sequencing
- Traditional carpentry

**Features**
- Traditional carpentry
- Reinforcement detailing
- Management of CAD technician and drainage engineer
- Inspection of timber yard
- Monitoring works on site
- Attendances at all design and site meetings

**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
- Attendances at all design and site meetings

**Materials**
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 tapered balusters dovetailed into the top face of the stringers. By bending them slightly in towards the handrail the tasters have been pre-cut, 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 patterned panelled ceiling. The ceiling spans on to a scraft jointed beam held up by a tall post in the heart of the room.

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 bandurion concrete and then built up in softwood. The existing southern and boundary walls of roof has been extended and extended to cover the new north extension. A consequence of this is that the shape of the roof in the north of the house no longer match with the internal walls resulting in asymmetric houses with large oak tie beams.

**Walls & Stability**
Wind loads are significant due to the exposed coastal location so the panned 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 roofs 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 backed 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 this dry inner face. The solution was to attach these walls back together with 1m long Cintec anchors, and also tie the walls to the new timber floors with patterned plates. A new cladding to the house will also prevent the walls from driving rain in the future.

**Verandas**
An external green oak veranda wraps around the south of the house. The 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 dovetailed into their foundations and into the base above with stainless steel rods.

**Basement**
Usually most of the existing basement has been filled in with layers of compacted fill material down to the natural mudstone so that the stairs 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 inserted from the inside in an underpinning sequence as they are deeper than the foundations of the central walls.