Ramboll CPD.
Large Span Timber Structures

Andrew Holloway
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Designing with timber. Know the material.

- Which timber species are available in large baulks. What are the maximum lengths available and at what sections.
- Can the material be procured easily: cost; lead in times; transportation, etc.
- There can be wide variation in durability and strength within a single species dependant on where it is grown. For example Scotts Pine (pinus sylvestris) is more dense and resinous grown above 60 degrees of latitude and can be remarkably strong and durable. Grown in the UK Scotts Pine is considered inferior in strength and durability.
- Structural testing of a small batch of timber from the chosen supplier may do much to inform the engineering process and is not expensive.
- Dry versus 'green' (fresh sawn). One of the big issue with timber but not well understood. The vast majority of timber structures built pre 1850 utilised fresh sawn timber, the structure seasoning in situ.
- Kiln drying large sections of timber above 75mm is very difficult, Oak especially so. Don't specify dry unless you understand whether it is practicable or necessary to do so.
- Large section of timber (say 200mm square) must be air dried over at least 5 years before the moisture content falls below 20%. Larger sections will take much longer. Once dry the timber is more difficult to work, will have developed splits, distorted and bowed and will probably require re-sawing to true up. Very limited stock of this sort of material exist and is almost exclusively Oak.
- Grading timber. Most sawyers wont grade timber as they don't want to incur the potential losses of having to reject timber once 'opened up'.
- Grading is best done in the carpenters yard.
- Don't specify high grade indiscriminately. Identify those components that require the better grades and select accordingly.
- Develop your pallet of timber connection details, truss types, and so on. Don't automatically default to steel to assist joint strength, it is likely to cost more and may not be necessary.
- If designing for green timber consider shrinkage issues. It is surprising how often problems associated with use of green timber can be designed out.
- Above all talk to the carpenters, they are enthusiastic and keen to share their knowledge.
Pre 1800. The ‘Golden Age’ of timber construction.

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Prior to the present day lies an 800 + year old tradition of Carpentry that forms the “structural scaffold” of many of our most beautiful and spectacular historic buildings, many of which are recorded in Cecil Hewitt’s book - Historic English Carpentry.
Forms of post-head and tie beam joints

Fig. 277. An example from Southchurch Hall in Essex. This has the same type of short and straight-swollen jowls, two unrefined tenons, and a full lap dovetail with over-squinted shoulders. This form was designed to show no cavity when normal shrinkage had taken place. The period of its use was close to c. 1300.

Fig. 278

Fig. 279. The form of lap dovetail used for Lampett’s Farmhouse in Essex, which was probably built by Thomas Lampett who possessed the holding from before 1558 until 1411. Similarly acute dovetails were used throughout the 14th and 15th centuries, but the large peg driven through them is peculiarly 14th-century and was an unnecessary practice.

Fig. 280. The tying joint used for the hammerbeam above the oriel window of the hall of Staple Inn, London, built between 1560-1. This is a double lap dovetail. Very few other examples are known, and any merits it may have in replacement with alternative dovetail forms would have to be proved by industrial testing; but it is a masterly joint. An example of a similarly doubled but barefaced lap dovetail exists in the Gresting Granary.

Fig. 281

Fig. 282. The assembly used for the barn at Walker’s Manor House at Farnham in Essex. This was better than the previous example and used a pair of single tenons, one placed on either side of the tail. Dates between c. 1380 and c. 1500 are likely for buildings with this assembly method, the braces of which (as in this barn) conform to the Tudor style of accretion.

Fig. 283. A reversed-assembly from the barn at Prior’s Hall, Widdington, in Essex. As illustrated, this eaves assembly postulated the rotation of the jowls of the wall post through 90 degrees, an ingenious device which was not in use in Essex after the early 15th century and which was most commonly used during the 14th century.
The Barley Barn, Cressing Temple, Essex, c. 1200. Clever use of lap joints give ‘withdrawing strength’ to the passing braces, collars, cross braces and brace struts, making the structure very strong.

Source previous 8 slides: Cecil Hewitt - Historic English Carpentry.
Ely cathedral octagon and lantern, completed 1342. According to Hewitt “This huge and spectacular structure has no direct parentage and no immediate progeny.” and is “…without question the supreme achievement of the English medieval period…”

Internal diameter of the lantern is 30’, its central boss stands 152’.6” from the floor.
Lincoln Cathedral north west transept 1762 – 65. Hewitt debates whether this is a bad piece of carpentry since it’s structural integrity is ‘wholly dependant upon their ironwork’. Note the ‘gib and cotter’ tensioning system.
Canterbury cathedral south-east transept roof. 1771. The combination of both queen posts and king post with judicious use of steel makes a very strong truss. Note the raised tie form.
Salisbury cathedral choir transept. 1787 – 1793. The trusses span over 40ft and again utilise a combination of the king post and queen post truss elements to make strong trusses capable of carrying the enormous loads imposed upon them.
Rochester cathedral north transept. 1825. Built of Pine the truss utilises a belt and braces approach with the incorporation of what Hewitt calls a ‘sagging truss’ beneath the collar to stiffen the tie beam. Given the weakness of home grown Pine this seems a wise precaution although perhaps overly elaborate.
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Post 1855. The continuation in the decline of the pre-eminence of timber in Construction. The Bessemer Process - the era of steel begins.

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Part of George Ellis’ joint classification from his seminal work Modern Practical Carpentry. First impression 1906.

Extending joints.
• 1 and 2 fish plate scarfs.
• 3 – 14 carpentry scarf joints.

Transverse joints.
• 15 – 18 lapped joints
• 19 – 25 cogaed joints.
Joint classification. Tenon and birds-mouth joints.
The use of steel to strengthen joints was more common post 1800.
Some examples of chamber joisting. NB. The solid timber is strictly not for show!
Developing the pallet. Some truss types and historic examples

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Extract from Jacob Leupold’s treatise on “Why timber bends, breaks and remains stiff, and how it can be made rigid,” 1726.
Extract from George Ellis’ Modern Practical Carpentry showing bow string trusses and variations of framed girder trusses.
The roof of the third Covent Garden Theatre. Completed 1858. The trusses span 82’.0” and the bays span 13’.2”
The ‘Cubbitt’s’ truss and Belfast truss. Many truss connection components such as the apex detail and ‘truss brace shoe’ were available off the shelf in cast-iron.
Composite trusses. These types of truss were very common in the early 19th C.
Emy and Orme’s forms of mechanical lamination. Emy’s “Description d’un nouveau system d’arcs” was published in 1828. His system involved bending planks of timber and pinning them together with additional clamps, Orme’s of forming shaped flat planks on edge and nailing them together.
St Michael’s church, Tenterden, c. 1900. An example of mechanically laminated timber or ‘mechlam’ construction.
Blackfriars Bridge Centering. Note the use of sophisticated folding wedges to facilitate release of the temporary centering, and the doubled up lapped ‘cleats’ clasping the radial beams.
Early forms of laminated structures before the advent of bonded timber laminations. Timber Bridge in Wetingen. Switzerland. Illustrated in an early treatise on timber. Built by master carpenter Hans Ulrich Grubenmann 1764 – 66. Two large parallel laminated arches were formed using pinned interlocking planks spanning 61 metres.
Carpentry joints (without the use of steel to strengthen) are not generally known for their capacity in tension, although there are some notable exceptions. The anchor beam joint, or wedged and pegged through tenon is one example.

Source: Jack Sobon – Historic American Joinery.
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Contemporary examples.

Andrew Holloway
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The Quince Tree

Architect
Barrett Lloyd Davis

Engineer
Andrew Waring Associates

Timber Structure
The Green Oak Carpentry Company Ltd
Minstead Study Centre

**Architect**
Hampshire County Architects

**Engineer**
Andrew Waring Associates

**Timber Structure**
The Green Oak Carpentry Company Ltd
Bedales Theatre

**Architect**
Fielden Clegg
Bradley Studios

**Engineer**
Ian Duncan
Structure One

**Timber Structure**
Carpenter Oak
and Woodland Co Ltd
The main auditorium
Internal view of auditorium showing trusses and tendons supporting the seating areas.
Auditorium Trusses

Span of Truss 12M. This and other drawings courtesy of Structure One
Truss details.

Detail of connection at lower tie to corner brace

Detail of diagonal strut to lower tie.
Truss details.

Detail of Gibb and Cotter connection.
Backstage Truss

All tie rods M-20 mild steel, grade 43.

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These end two tie bars must be anchored on the outside faces of column and chord.

2 No main ties (All M-20)
2 No wind ties
1 No 75x175 splice

2 No 90x175 top chords
1 No 90x200 strut

2 No 90x175 bottom chords

Main load bearing ties shown in the heavier line.

Note: B1 and B2 refer to barrel details.

Is this right???

Door swing
Suggest split door stop.

2 No 34x4 CHS strut/ties

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STLIB

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CROSS PROOLUM

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SITE WALL

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Connection details of backstage truss

102 split ring: Standard end distance = 140; Standard spacing = 229

Shear capacity of 102 split ring for parallel to grain loads in SC4 timber = 20.6 kN
Pool Barns
Some examples of large span pool barns.

Architect
Various

Timber Engineer
Various

Timber Structure
The Green Oak
Carpentry
Company Ltd
Bramfield Hall Pool Barn. Spans over 10 metres and utilises the sling braced truss.
Park House Hotel Pool Barn. Span 12 metres. King post truss with king post bolt tensioning. Note that the tie beam is jointed at the king post.
Marlow Academy

Based on geodesic principles. The structure has a span of 22 metres and is 68 metres long, yet the ribs are only 300 x 75 Kerto LVL.

Architect
Building design
  Partnership – Glasgow

Project Engineer
Building Design
  Partnership – London

Timber Engineer
John Westmucket – Symonds Group Ltd

Timber Structure
Cowley Structural Timberworks Ltd
The Cowley Connector.
The outer sleeve is bonded into the Kerto LVL ribs with a poly urethane type adhesive, the inner threaded section is then screwed into the nodal connector.
The Cowley Connector
Cowley Connector
Photos, drawings etc., courtesy of Gordon Cowley
The Lookout

**Architect**
David Morley Architects

**Structural Engineer**
Price and Myers

**Timber Structure**
The Green Oak Carpentry Company
Column arrangement at external walls

Column arrangement internally
Mitigating the effects of shrinkage on green turned columns
The Downland Gridshell

Architect
Edward Cullinan Architects

Engineer:
Buro Happold

Timber Structure
The Green Oak Carpentry Company
Architectural concept developed in conjunction with Ted Cullinan, Michael Dickson (Buro Happold) and Christopher Zeuner (then director of the Weald and Downland Open Air Museum)
The Archive Store
Laminated whitewood main floor beams
Archive store with 105mm thick T+G whitewood plank ‘lid’ complete, end walls assembled and perimeter partially prepared to receive gridshell.
Lath production.
Scaffold ready for assembly of shell grid
The ‘Node Clamp’. Initially the idea was to slot the laths to allow them to slide over each other as the shell was manipulated from flat into its doubly curved form. The node clamp illustrated here allows this to take place whilst avoiding costly machining of the timber. Layers 2 and 3 are pinned together via the central steel plate and represent the neutral axis.
Lattice complete and on the way
Going . . . .
Going . . . .
Still going . . . .
Gone!
Shell edge fixings.
Basic shell form completed.
Ribbon roof assembly
WRC Cladding boards.
Completed structure.
Windmill Hill Farm

Stressed skin diagrid comprising 300 x 70mm veneered oak glulam with ply skin. The structure has a span of 21.6 metres and is 11.8 metres in breadth.

Client
The Rothschild Foundation

Architect
Stephen Marshall Associates

Project Engineer
Thornton Tomasetti

Main Contractor
Kingerlee Ltd

Timber Structure Specialists
The Green Oak Carpentry Company Ltd
8. The Savill Gridshell

**Architect**  
Glen Howells Architects  

**Gridshell Engineer**  
Buro Happold  

**Timber Structure**  
The Green Oak Carpentry Company
Edge condition and blocking prior to fitting layers 3 and 4.
Photos of the Savill Building courtesy of Warren
Ramboll CPD.
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Thank You

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