DENDROCHRONOLOGICAL ANALYSIS OF TIMBERS FROM LINCOLN CATHEDRAL

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Introduction

Over the last two years extensive repairs have been carried out on the timber of the roof of St. Hugh's Choir in Lincoln Cathedral. These repairs are necessary because over a period of time, water has penetrated the lead roof, probably through the holes left by rusted nails, and found its way onto the rafters. From here it has seeped downwards along the braces and collected in the mortices. This has resulted in the rotting of the joints and thus the high quality oak timber used in the construction of the roof has decayed. In some places, the softened timber has also become infested with deathwatch beetles. The Nottingham University Tree Ring Group has been extremely fortunate to be allowed to sample timber after it has been removed from the roof. This report of the group is very much an interim one as much more wood is still to be removed and subsequently analysed.

St. Hugh's Choir Roof

The choir roof is believed to be the oldest surviving roof and supposedly dates from St. Hugh's rebuilding of the cathedral after the earthquake of 1185 which severely damaged the whole building. The roof design consists of about 40 trusses, each about 40ft high and 40ft at the base. Most of the trusses have two collar beams, braced at the corners and bat rafters with cross braces below the first collar to provide strength at the base. Approximately every third truss includes a tie beam together with queen posts (see Fig. 1a). Some of the queen posts have subsequently been removed, thus weakening the structure. The remaining trusses rest on short bearers (4 to 5ft long) on the top of the supporting wall (see Fig. 1b). It should be noted that no purlins or wallplates were used in the initial construction and this has resulted in considerable racking of the roof. There are four extra 'half' trusses (Fig. 1c), truncated to the first collar beam height. These have no apparent load bearing purpose and it is supposed that they were used as gantries for hoisting timber to the roof level during construction. The nave roof is the only other roof of the cathedral having similar trusses. Finally there are two trusses adjacent to the tower (see Fig. 1d) that are reputedly of a later period. Certainly there are signs that they were built of reused timber.

Many of the trusses have carpenter's marks. Usually the timber from the same truss have the same mark, but different trusses have different marks. This could possibly indicate that the trusses were built at ground level, dismantled, hoisted to the roof level and then, with the help of the carpenter's marks, reassembled.

Dendrochronological analysis

The damaged timbers are removed by the carpenters and carefully stored until members of the Nottingham University Tree Ring Group are able to visit the Cathedral. Then cross-sections of the timbers are cut using a chainsaw and at the same time details of each timber are recorded. The samples are then taken to the University of Nottingham where they are cut

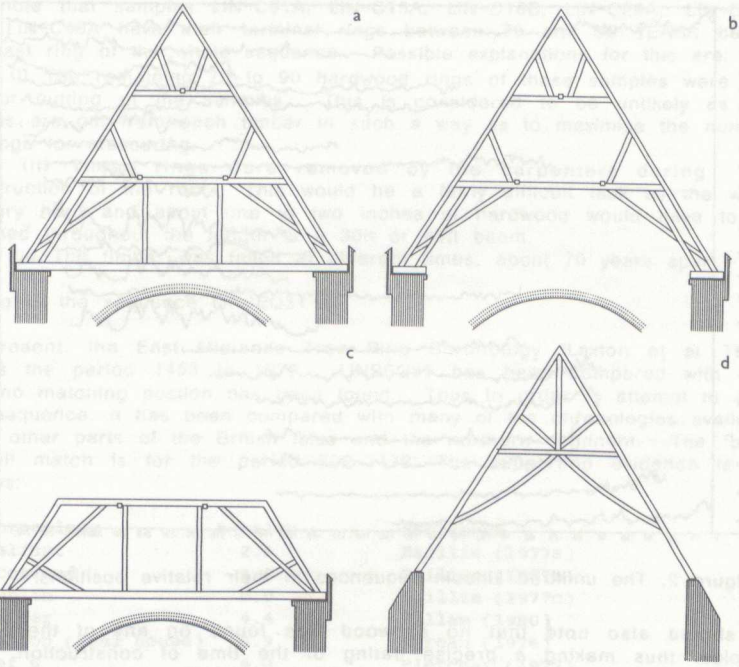

Figure 1: Lincoln Cathedral St. Hugh's Choir roof.
(a) truss with tie beam (b) truss with bearers (c) half truss (d) truss adjacent to tower

and sanded. The tree ring widths are measured using a microscope and then are entered into the tree ring database on the University's computer, together with their documentary details.

The tree ring sequences are then matched using the technique described in Baillie & Pilcher (1973). Basically this method uses a high-pass filter to remove any long term trends in the sequences and then calculates the cross correlation between two filtered sequences in all the possible positions of one sequence against the other. As an indicator of the 'goodness' of a match, a t-value is computed. A t-value of 5 or more indicates a good correlation between two sequences, one between 3.5 and 5 a reasonable match, one between 2 and 3.5 a possible match and a t-value below 2 a poor match. With the many sequences from the Cathedral, the samples have to be matched in the best overall manner to produce average tree ring sequences, each composed of several samples. For further of the method used, the reader is referred to Laxton et al (1979).

So far, about 80 timbers have been sampled and of these 35 have been measured. From these 35, one major tree ring sequence, coded LINSEQ31, has been constructed. It consists of twenty different samples spanning a total of 297 years (see Fig. 2).

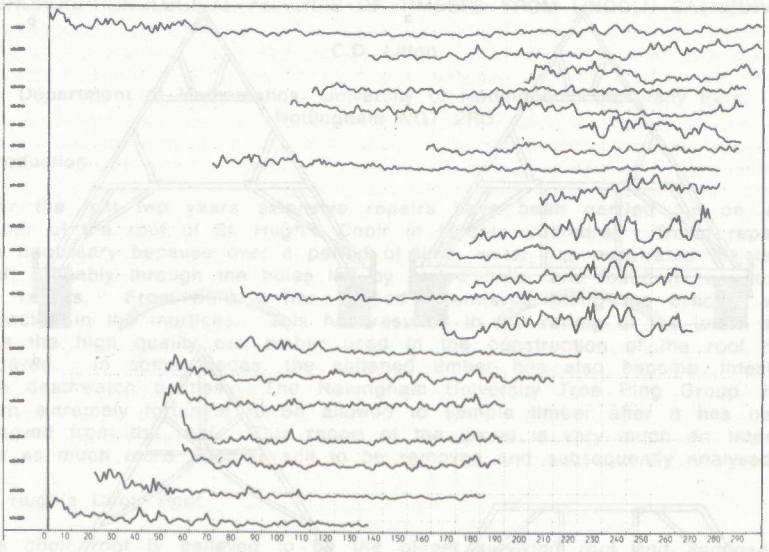

Figure 2: The unfiltred Lincoln sequences in their relative positions.

We should also note that no sapwood was found on any of these 20 samples, thus making a precise dating of the time of construction very difficult. From the remaining 15 samples, two small sequences may be constructed, (see Table 1).

Table 1: Composition of LINSEQ31

Sample Code	Description	Number of rings	Position of first ring	last ring
LIN-C01A	Brace	133	58	190
LIN-C03A	Brace	75	205	279
LIN-C06A	Brace	121	158	278
LIN-C09A	Rafter	164	134	297
LIN-C13A	Collar beam	180	111	290
LIN-C14A	Collar beam	188	102	289
LIN-C15A	Collar beam	163	21	183
LIN-C16B	Collar beam	132	58	189
LIN-C18A	Rafter	143	80	222
LIN-C19A	Collar beam	105	164	268
LIN-C20A	Collar beam	94	177	270
LIN-C23A	Brace	68	221	288
LIN-C26A	Collar beam	100	176	275
LIN-C29A	Additional collar beam support	161	51	211
LIN-C33A	Rafter	105	167	271
LIN-C34A	Collar beam	98	198	295
LIN-C35A	Bearer	188	82	269
LIN-C37A	Collar beam	210	70	279
LIN-C38A	Rafter	135(+40/50)	1	135(+40/50)
LIN-C40A	Unknown	142	50	191

We note that samples LIN-C01A, LIN-C15A, LIN-C16B, LIN-C29A, LIN-C38A and LIN-C40A have their terminal rings between 70 and 90 YEARS before the last ring of the whole sequence. Possible explanations for this are:

(i) The remaining 70 to 90 hardwood rings of these samples were lost in our cutting of the samples. This is considered to be unlikely as two pieces are cut from each timber in such a way as to maximise the number of rings for measuring.

(ii) These rings were removed by the carpenters during the construction of the roof. This would be a fairly difficult task as the wood is very hard and about one to two inches of hardwood would have to be trimmed throughout the length of a 30ft or 40ft beam.

(iii) The timber was felled at different times, about 70 years apart.

Dating of the sequence LINSEQ31

At present, the East Midlands Tree Ring Chronology (Laxton et al 1979) spans the period 1453 to 1976. LINSEQ31 has been compared with this and no matching postion has been found. Thus in order to attempt to date the sequence, it has been compared with many of the chronologies available from other parts of the British Isles and the northern continent. The 'best' overall match is for the period 882-1178. The supporting evidence is as follows:

Chronology	t-value	Reference
Belfast	2.3	Baillie (1977a)
Scotland	4.2	Baillie (1977b)
Dublin	5.0	Baillie (1977c)
Exeter	4.4	Hillam (1980)
London (Seal House)	3.9	Morgan (1976)
Ref 6	4.0	Fletcher (1977)
Ref 7 Mk 2	2.9	Fletcher (1977)

Visual comparison of some of the above chronologies with LINSEQ31 is given in Fig. 3.

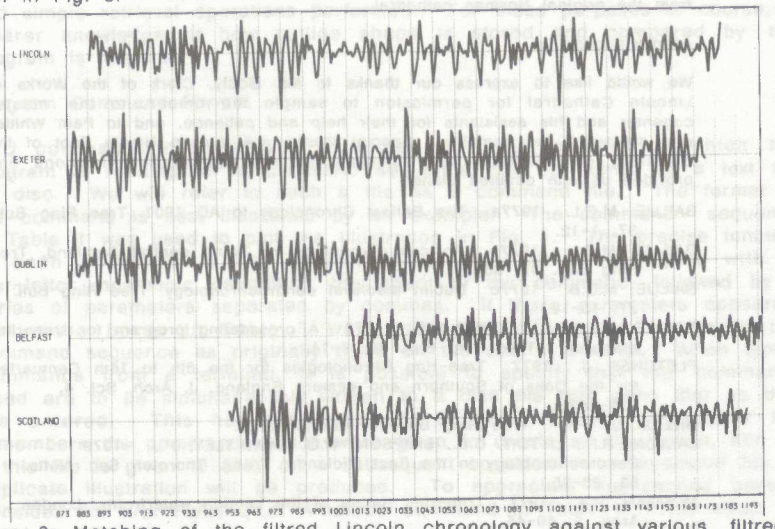

Figure 3: Matching of the filtred Lincoln chronology against various filtred master chronologies.

It should be noted that some of the above chronologies are not strictly independent of each other. The Exeter chronology has been dated via the Dublin sequence, which in turn has been dated via the Belfast and Scotland chronologies.

Of course one must be extremely careful about matching sequences from different parts of the country and therefore from slightly different climatic zones, especially as the width of a ring is a result, partially at least, of the weather for the corresponding year. However, in the east Midlands we have two modern chronologies composed of slow grown oaks, similar to those used in Lincoln Cathedral. These come from Bradgate Park, near Leicester, and Thoresby, near Nottingham, and have known felling dates. The t-values from the Bradgate sequence (length 381 years) against the Belfast and Scotland chronologies at its correct position are 5.2 and 4.9 respectively. The corresponding values for the Thoresby sequence (length 167 years) are 2.8 and 3.6 respectively. This provides some evidence that it is possible to use both the Belfast and Scotland chronologies in the east Midlands.

The interpretation of the date for LINSEQ31 is that the samples are from the roof built by St. Hugh just after the earthquake of 1185. Because of the absence of sapwood it is difficult to give any precise estimate of the felling data, but assuming that the last ring of the sequence is the last hardwood ring and assuming a minimum of 20 sapwood rings, then the felling date would be not earlier than 1198 and would most likely be in the period 1200-1230.

The six earlier samples (LIN-C01, LIN-C15, LIN-C16, LIN-C29, LIN-C38, LIN-C40) remain a puzzle. Again without any sapwood, it is impossible to say definitely that they are from an earlier period of construction although this must remain a possibility. It is interesting to note that the dates of the final rings of the above samples (omitting LIN-C38 as the last 40 to 50 rings were uncountable) are 1071, 1064, 1070, 1092 and 1072 respectively. As it is believed that construction of the original cathedral commenced about 1072 and was completed about 20 years later, could these early samples be from the original building and perhaps reused in the later reconstruction? Certainly this is a possibility, but one must remember that not only would the timber have had to survive the earthquake of 1185 but also the fire of 1141 which destroyed part of the early roof. Without further evidence it is impossible to say that the early samples are definitely from the original Norman cathedral.

Acknowledgements

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