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St Mary's Church, Woodstock, Oxon

11 February 2022

About this church

*St Mary Magdalene. Grade II * listed. Dates from pre 12th century. South door is a fine example of a Norman door. West porch 15th C. West doorway 14th C. Major restoration by Blomfield 1877-8.*

About this report

This report takes the form of a photographic report, with annotations made adjacent to the photographs. The survey and examination of the lead sheet, by invasive methods was undertaken on 21-09-20 Access was by ladder, with Mr Mike Holmes and two contractors from Cotswold Metal Roofing in attendance.

Roofing Report

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Norman door, south elevation

Introduction

I was asked by Mr Mike Holmes of St Mary's Church, Woodstock, Oxon in 2020 to undertake an invasive inspection of the lead roof of the church to ascertain the condition of the lead beneath what could be seen superficially. This is a report of that work, although as a result of that work tenders were invited from two contractors to re-roof the Nave and Side Aisles of the church

The inspection took the form of climbing on the roof, to particularly take apart sections of the South Aisle where access was safely available without fully scaffolding the whole roof, and carefully inspecting an area of lead sheet which was typical of the whole roof. The workmen undertaking the inspection together with me, had been involved in the maintenance of the roof over many years, and many of the soldered patches were their work. Although the roof appears to be in good order, once the lead rolls were lifted, it was clear that the lead was brittle and cracked in multiple locations over the particular area examined. The extensive application of patches over the rolls of the remainder of the roof areas indicated a similar condition. The whole roof is believed to be the same age.

Extract from Building Conservation.Com. Metal Sheet Roofing. Tony Redman. Extracted February 2022

Lead

The Romans are credited with first discovering the weathering properties of lead, which they called plumbum on account of its resistance to rain (pluvia in Latin). This also explains the origin of the name for leadworkers (‘plumbers’) and the chemical symbol in the periodic table, Pb. The Romans were using small lead sheets or tiles for roofing as early as 27 BC.

Lead is a naturally occurring mineral gained by smelting galena ore. It was sometimes mixed with small quantities of silver and tin, and some authorities suggest that small quantities of such ‘impurities’ add to its malleability and weather resistance.

Lead is highly durable, which is why it has been used on important buildings for so long. It is also very easily recycled, which is why it has been prone to theft.

Properly installed and maintained in an environment which does not involve acidic conditions, lead is probably the longest lasting roofing material available. It is UV stable, resists corrosion from normal weather, and is easily repairable by traditional lead workers. In its natural state lead is a whitish silver colour but it tarnishes rapidly to a dull grey in air, although patination oil can retard this as well as preventing staining due to run-off. Lead has a low cost in use compared to other forms of roof covering, largely due to its weather resistance. **But it does have its drawbacks.**

Firstly, lead has a high **coefficient of thermal** expansion and needs to be given the capacity to move without tearing its fixings. The standard thicknesses of lead sheet are defined by ‘codes’ that are based on weight in imperial pounds per square foot, so Code 4 lead sheet’s approximate weight is 4lbs/sq ft, while Code 5’s is 5lbs/sq ft. The Victorians, proud of being able to calculate stresses in materials and design buildings to use materials to their maximum tolerances, often exceeded modern lead tolerances, not always successfully.

Secondly, lead can be subject to **underside corrosion**, especially in contact with green oak, and associated with the use of unvented gas heating systems. An acidic atmosphere condensing in an unvented environment leads to oxidisation and the formation of white lead oxide, a highly toxic powder. Thirdly, lead itself is toxic and builds up slowly in the body requiring care on the part of those who work with it.

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Analysis of the roof in relation to the text above.

There are major problems with the lead sheet roofing at St Marys Church Woodstock. There are leaks in numerous places, which cannot be identified by examining the surface of the roof. This has been done, and the roof sheeting appears to be in fair condition. The roof structure is even, without deflections, and can be assessed as being sound. The invasive examination shows a different story.

The location of the leaks into the church below do not appear to correspond with any identifiable fault or damage in the lead sheet covering above the leaks. This is common, because leaks tend to run down inside the roof structure to a place when they can exit in the form of drips.

There are two main problems with lead sheet roofing. Firstly, its coefficient of thermal expansion, and secondly its tendency to corrode under attack from acids.

The chief suspect at St Marys, is **expansion and contraction**, primarily because the sheets of lead are longer than recommended, and therefore the probable cause is the sheet breaking, or cracking in places due to the thermal movement unable to be accommodated satisfactorily.

From the invasive investigation of a section of the roof, in almost every location where the lead rolls were lifted to examine the lower sheet as it was dressed over the roll, it was evident that there were either linear cracks as the flat sheet lead was formed up to go over the roll, or there were cracks transverse to the rolls. Cotswold Metal Roofing, (the firm from where the roofers came who were assisting with the investigation, and who have had years of experience with this roof), said that the findings were typical of the whole roof.

The lead sheeting has not been lifted to examine if there is corrosion to the underside of the roof sheeting, caused by acid attack from embodied acids in the timber substrate, if it oak, or marine ply. Both are known to cause acid attack. However. the boards a believed to be square edged softwood boards laid with a small gap between them. This can be seen in the planking patterns showing through the lead sheet.

Corrosion is not the suspected reason for the poor state of the lead sheeting. The construction of the roof and the evidence of the cracking strongly points towards excessive expansion and contraction.

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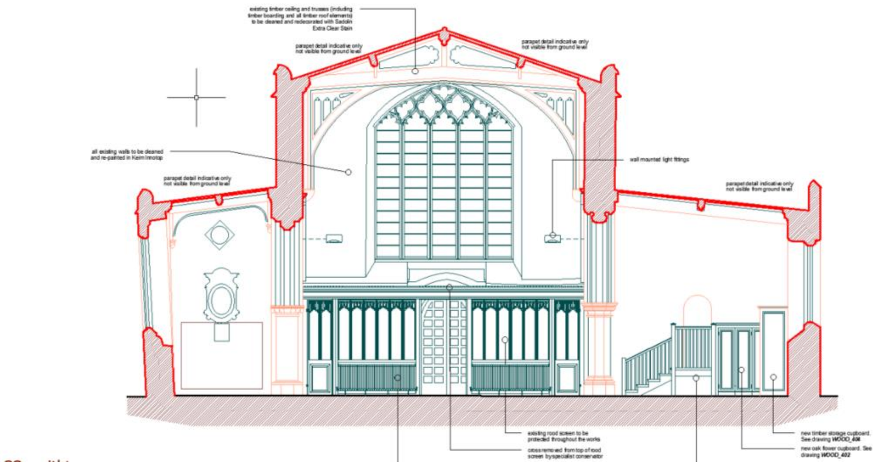
Cross Section NTS



The structure of the roof

The adjacent cross section indicates the roof configuration. The slope of the roof is 18 degrees, which is sufficient for a lead roof. The problem is that lead sheeting should not be laid in a continuous length without a "drip", that is a step to break the length of the lead sheet and allow it to expand and contract with temperature.

The maximum lengths of lead sheet, for 18 degrees pitch are:

Code 5 lead 2000mm
Code 6 lead 2250mm

Only on the South Aisle face would the sheet length come close to Code 6 lead sheet maximum length. On the North Aisle and the Nave the single sheets of lead exceed permitted length considerably.

The roofing sheeting is taken as being Code 6 lead.

The length of the single sheets of lead, not counting valley gutters or fixing laps. .

South Aisle, 2364mm	**Permitted length 2250mm**
Nave per side, 3752mm	**Permitted length 2250mm**
North Aisle, 4353mm	**Permitted length 2250mm**

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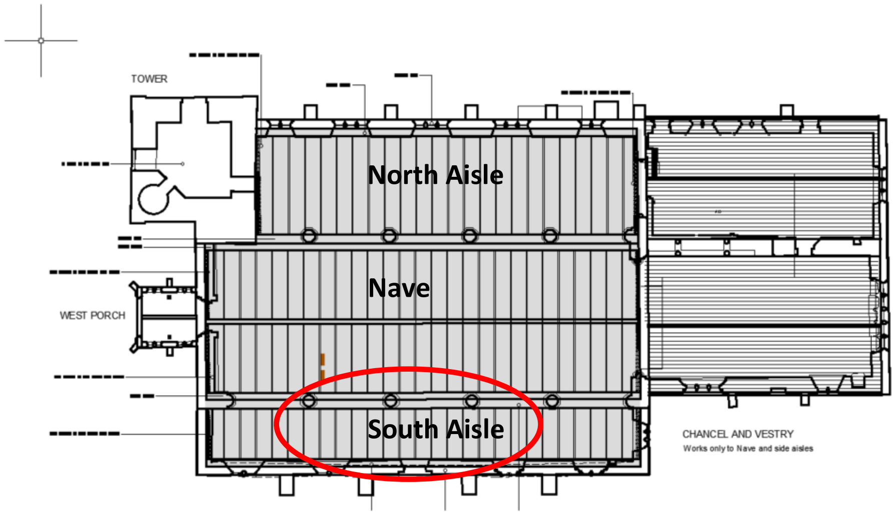
Roof Plan NTS



The adjacent roof plan shows the 4 parts of the church. Tower, Porch, Nave and Side Aisles, and Chancel and Vestry area.

This report is primarily about the leaded part of the roof, the Nave and Side Aisles.

The area accessed is shown in a red outlined ellipse adjacent.

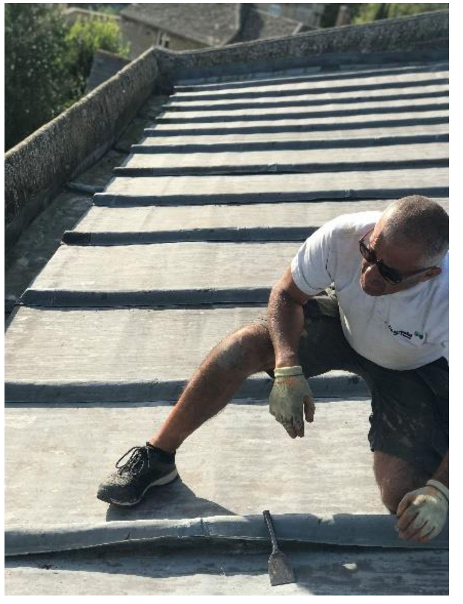


Photo 1

Workmen in the process of lifting one of the lead rolls on the South Aisle.

Photo 2

This photograph shows the damage to lead roll under the cover-roll, and how the cover-roll has been soldered twice in the same region.

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Photo 3

This photograph shows typical problems of in-line cracking in the lower rolls of the lead, beneath the cover-rolls

Photo 4

A furthe photograph showing transverse cracking in the lower lead roll.

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Photo 5

This photo shows two typical problems. First is the ripple in the lead caused by excessive expansion. The second is the cracking caused by the same reason. Attempted repairs are evident.

Photo 6

Here another crack can be seen transverse to the line of the roof sheets, caused by expansion and contraction stresses.

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Photo 7

Thi photograph shows a typical in line crack in the cover-roll indicating the weakness of the lead along the fold line, and that it is fixed from movement by the roll

Photos 8 and 9

Typical illustration of a lead roll that looks in good condition. However after lifting it up, there is a crack about mid way along the lead sheet.

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Photo 10

The reason for the cracks in the roof.

This photograph shows the lead cover strip at the top of the slope covering the hanging fixings at the head of the slope. The single sheet length has been measured excluding 300mm at the head of the pitch, below the lap of the cover strip. Also 300mm has been deducted from the overall dimension of the total length from parapet to south wall, for the width of the valley gutter. Even so, the single sheet length is 2364mm whereas the permitted length is 2250mm

Even though this is close to the recommended length, the roof slope faces due south, and gets the heat of the sun in full force, as well as the coolness of night time and shaddow periods.

There is insufficient provision for expansion and contraction and as a result there is cracking in the lead sheet, where it gives way. These are primarily in places where the lead has been kinked, to be dressed up and over the wooden rolls, or along the lead rolls.

The lead sheet will expand and contract in both its width and its length. The greatest contraction will be in its length, but at the same time the width will be expanding and contracting. The lead rolls are a fixing location, either due to resistance, or by nail fixing.

The reason the cracks occur across the lead rolls, or across the sheets, is that the length of the sheets cannot accommodate the expansion and contraction stresses.

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Photos 11 and 12

The Nave Roof, showing the north face and the ridge. The two strips on the south side, are probably fixing locations in narrower substrate boards, so that the lead over sheet covers them.

Even discounting the length of the fixing locations and allowing for the reduction of length of the lower section sheets as against the total overall pitch length, the sheet lengths are 3752mm when they are recommended to be 2250mm. The sheets are 40% longer than recommended.

There are leaks in this section of the roof.

Photos 13 and 14

The North aisle roof.

These photos show an overall picture of the north aisle roof, and a detail of the line along the length of the roof slope, where there is cracking and damage along the line of what appears to be one particular lay-board.

This roof face is the worst case of exceeding the recommended length of the lead roof sheets. Discounting a margin for fixing and guttering, the lead sheet length is 4353mm, when it is recommended to be 2250mm. In this case the sheets are 48% longer than recommended.

This is the north face, and the least vulnerable to excessive sunshine or driving rain, and it appears to be just holding out, because at present there are no known leaks in the north aisle. On the other hand the roof sheeting appears to be in the worst condition, and it is only a matter of time when the long surface crack penetrates the full depth of the lead sheet and causes a series of leaks along the roof slope.

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Conclusions

1 The lead sheet roof leaks in various places. It is cracked and metal fatigued.

2 Although much of the lead sheeting appears on the surface to be in reasonable condition, although old, examination beneath the lead rolls, shows longitudinal cracks in the lead, and transverse cracks as well. These will not be waterproof in times when the water levels exceed the location of the defects.

3 The water penetrations may well exceed that which drips into the church below. There may be small quantities of water which dampen the substrate boards and the ceilings but do not reach the point of penetration. This is a serious risk because of the possibility of dry rot occurring in the roof and ceiling structure. Needless to say this risk is also present in the locations where there are identifiable drip leaks.

4 What is the decision point regarding the replacement of the roof sheeting? Does one wait until there is a catastrophic deterioration of the roof sheeting and then consequentially the roof structure, or does one take the stitch in time saves nine approach and replace the sheeting when it is obviously damaged but not yet in a catastrophic state?

5 There are so many places where the roof has been patched because the roof sheeting has cracked, and the patches themselves have cracked again.

6 All this is because the lead of the roof sheets is too long for their application. This is an inbuilt flaw in the construction of the lead sheeting on the roof. Until that is addressed, there will be inevitable and growing problems, causing leaking and on-going maintenance.

7 The conclusion is that the plan to replace the roof sheeting with the best type of metal sheeting, stainless steel, which was not available when lead sheeting was one of the only types of metal sheeting available, is a very sound plan, and should be pursued for the benefit of this fine building.

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