Wattle and Daub: Craft, Conservation and Wiltshire Case Study

A dissertation submitted by

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Synopsis

This study examines the nature of wattle and daub in English building and the techniques required for its conservation. The intent was to combine disparate literature sources so to provide a coherent and comprehensive guide on the craft. Additionally, to assist conservation work in parts of the country devoid of wattle and daub research, a study of one such area, Wiltshire, was undertaken.

It was evident from existing research that significant variation in wattle and daub resulted from a complex interaction of multiple factors such as geology, land use, woodland coverage and species. Documented techniques for conservation were found to be sparse and therefore an attempt was made to broaden them, in some instances by adapting methods established for the conservation of other materials.

Conservation principles were applied, thereby illustrating that wattle and daub need not be stripped if decaying or where structural investigations and repairs are required. An examination of the material characteristics helped explain the behaviour and durability of wattle and daub, including the development of a hypothesis that the lignin in dung may explain its role.

It was established that the craft varied enormously in England, the dominating factors being panel shape and local availability of materials. The research of Wiltshire tradition showed a predominance of hazel withy and oak staves, the latter often crudely nailed to the frame where access during construction was restricted. Daubs were of local soils, chiefly calcareous due to the geology of the county, using hay and hair as the fibre in addition to the commonly specified straw. The case study identified new evidence that is directly applicable to the conservation of the county’s timber framed buildings.

This study has been successful in so far as creating a platform that conveys all aspects of the wattle and daub craft, yet much continuing research is warranted, especially in the identification, categorisation and geographic mapping of regional variation. This may be accomplished through an increased interest in the subject that, in turn, may hopefully be stimulated by this work.

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Acknowledgements

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1 Introduction

Wattle and daub epitomises vernacular construction. Its continuous use for at least 6000 years owes much to cheapness and abundance of raw materials. It starts with primitive building and spans the entire history of England until the craft's demise during the 18th century. The craft was used across the world but the scope here is confined to English traditions.

There is a plethora of minor references to the craft and history of wattle and daub, yet extensive research, such as that published by Salzman (1952), Bowyer (1973) and Forrester (1959), is scarce. A primary objective of this dissertation was therefore to consolidate and contrast these isolated references with the intention of producing a consolidated and comprehensive guide that explores the materials used in wattle and daub, where it was used, diversity of form and to define the factors influencing variation.
Wattle and daub is dependant on the various styles of surrounding timber frame. However, brevity limits discussion of framing to only those factors directly affecting the craft. Styles such as close-studding and decorative panelling are only briefly introduced: a fuller comprehension can be acquired from sources such as Brunksill (1985), Clifton-Taylor (1962) and Mercer (1975).

The only title dedicated to the conservation of wattle and daub is the brief pamphlet by Reid (1989). Short chapters in Ashurst and Ashurst (1988a) and Wright (1991) are also valuable and supplemented by even briefer discussions of wattle and daub within the wider subject of earth building, (e.g. Houben and Guillaud (1994), Minke (2000) and Harrison (1999)). It is therefore unsurprising that academic understanding of the wattle and daub craft, its performance and preservation are poor in comparison to other historic building materials. Indeed, many surveyors and architects specialising in historic buildings still take the view that it is of secondary importance to the value of an historic building. As a result, wattle and daub is often unhesitatingly replaced where damaged and readily removed to facilitate a structural inspection or an alteration. A further intent of this dissertation was therefore to appraise the values of wattle and daub and thereby establish criteria for methods of repair and conservation. This necessitates a comprehension of the material characteristics of wattle and daub. For example, *why* was the inclusion of dung habitually specified and what was its active ingredient? What factors influence the cracking of a new daub and what are the likely consequences with respect to its durability?

Through a preliminary literature review, it also became apparent that most of the studies of wattle and daub relate only to specific areas of the country. From the author's viewpoint, living in Wiltshire, conservation using the techniques of local tradition would be made troublesome due to the lack of regional knowledge. Indeed, Wood (1965) in her review of wattle and daub, concluded that, 'much research, however, needs to be done in local methods of building', and the literature review demonstrated that this statement is still valid today. The final objective was therefore an appreciation of the craft as practiced in the County of Wiltshire. Sources included regional publications such as the journal of the Wiltshire Archaeological and Natural History Society and Victoria County History of Wiltshire, which were combined with case studies comprising site visits, recording and sample analyses.

2 History

The origins of wattle and daub stem from the primitive buildings, where huts were constructed of poles and earthen walls. Archaeology shows the techniques were numerous and their boundaries ill-defined. Earth walling could be used simply as a base for a roof, or higher walls could be formed to raise the roof away from the ground. The walls could be made with wattles, woven from brushwood or 'withies' (thin wands) coppiced from nearby woodlands. These wattle walls, bearing no significant difference to the construction of hurdles, used the same technique as fencing for boundaries, penning, wind-resistance and privacy and those laid flat as tracks [Figure 1].

Figure 1. Iron Age wattle used flat as a track, c.1800 B.C. From Brunning (2001).

The filling of these wattle walls to improve wind resistance could be achieved with anything that came to hand, but most frequently may have been straw, moss, leaves and earth. For easy layering, the use of turf and topsoil was common, but for binding into wattles, it was easier to use soil that could be pressed into position and would remain in place. This common form of wattle and daub walling was being practiced at least as early as the Iron Age. Archaeology from Meare near Glastonbury in Somerset shows structural vertical poles were driven into the earth and the wall completed with wattles and clay.[1] Occasionally the daub was burnt, either accidentally or deliberately, which hardened the surface like fired pottery. In areas rich in timber, a more sophisticated construction was used whereby a stone or timber cill provided a firm base for split timbers and holes for the staves provided a positive location for the wattles that may have kept them from bowing or coming detached in high winds [Figure 2].

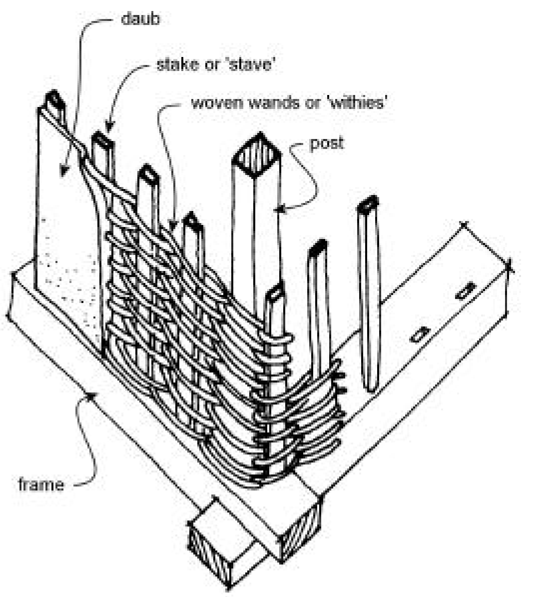

Figure 2. The principal method of wattle and daub walling, established by the Iron Age. From Bowyer (1973).

[1] Bowyer (1973), pp.48-51.

The arrival of the Romans into Britain did little to affect the use of wattle and daub since it was developed into their own Romano-British styles of construction. As indigenous materials they were highly suitable, yet, as Vitruvius describes, it was not the preferred method in their native Rome, [2]

> 'As for "wattle and daub" I could wish that it had never been invented. The more it saves in time and gains in space, the greater and the more general is the disaster that it may cause; for it is made to catch fire, like torches. It seems better, therefore, to spend on walls of burnt brick, and be at expense, than to save with "wattle and daub," and be in danger. And, in the stucco [plaster] covering, too, it makes cracks from the inside by the arrangement of its studs and girts [rails]. For these swell with moisture as they are daubed, and then contract as they dry, and, by their shrinking, cause the solid stucco to split. But since some are obliged to use it either to save time or money, or for partitions on an unsupported span, the proper method of construction is as follows. Give it a high foundation so that it may nowhere come in contact with the broken stone-work composing the floor; for if it is sunk in this, it rots in course of time, then settles and sags forward, and so breaks through the surface of the stucco covering.'

The bases of Anglo-Roman walls may often have been embedded in concrete and the surfaces plastered. Remains of daub from Verulamium, Hertfordshire, show herringbone keying of the daub surface that indicates it had a plaster finish.[3] Chopped straw, hay, vegetable materials and dung were added to the daub to improve binding and reduce shrinkage cracking.

The method prevailed through the Saxon period. A quantity of a Saxon plaster has been recovered from various sites in Wiltshire that has impressions of wattles and timber beams.[4] Excavations at Thetford found wattle and daub used in the 9th century building although evidence from excavations of 7th and 10th century buildings shows that the Saxons may have preferred planking.[5]

Wattle and daub was also widespread throughout many other countries, such as used by the Normans prior to their 11th century invasion of England. Although the surviving Anglo-Norman buildings are of stone, the majority were timber framed and so continued to utilise wattle and daub. These structures have all but gone although much archaeological evidence has been found, including a daub probably consisting wholly of animal dung.[6]

As the craft of the English carpenter evolved, so did the form of timber-frame construction. In areas with cruck construction, vertical walls were created by

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[2] Vitruvius (1960), pp.57-58.
[3] Davey (1961), p.40-41.
[4] In the 1970's, Roy Canham of Wiltshire County Council excavated Saxon plasters which are now preserved in the Swindon Museum stores.
[5] Wood (1965), p.212.
[6] Macphail, Cruise, Allen, Linderholm, Reynolds (2004).

creating panels dropping below the level of the cruck 'spurs' and these were then finished with wattle and daub. In these and other areas of the country, the initial abundance of wood allowed the structural framing to include a large number of supporting posts.[7] These 'close-timbered' or 'close-studded' walls required a different form of infill to their narrow panels. Instead of wattling, straight laths were held in place by channels formed in the sides of the posts and these were then daubed. The infill was always (and unfortunately still is) considered secondary to the timber posts and studs. It was only the scarcity of timber from the 16th century onwards that increased the ratio of infill to timber walling.[8] Ironically, the wider panels required intermediate support between studs, and therefore the use of staves and woven wattlework returned once more to substantial houses.
Also during the 16th century, it became common for new houses to have a fireplace rather than central hearth. This was formed by a smoke bay in which two trusses were extended downwards or by provision of a timber framed smoke hood, both filled with wattle and daub.[9]

Most histories of construction in England focus on the developing crafts of the yeoman's house and the great buildings of the wealthy: only cursory mentions of the cottage homes of the peasantry are provided. This is mainly due to the limited archaeological remains but it is clear that wattle and daub invariably completed the walls of the true cottages that existed throughout the country down to the 19th century.

In all buildings, a disadvantage of wattle and daub has always been its vulnerability to damp. If not kept dry, the wattles would rot or be attacked by beetles and the daub would crack and lose key due to wetting and frost. This would be worse along the bottom of the external walls and it has been suggested that the jettied frame evolved as a way to keep the walls drier. The effects of rain were retarded by the usual limewash finish but could be further reduced by finishing the panel with a lime plaster. This provided a more robust surface and sealed the cracks in the underlying daub. However, the inherent flexibility of the frame and the shrinkage of earth and lime materials meant that not even the finest work could seal the joint between panel and its surrounding frame. Compared to masonry walls, wattle and daub buildings were draughty and the panels required frequent repair or renewal. In the east of England improved weather resistance of both frame and panels came from plastering the entire wall, often accompanied by decorative plaster known as pargetting.

Salzman (1952) gives a comprehensive account of references to wattle and daub through the ages: it is also referred to as 'ruddle and dab' and 'wattle

[7] Greensted Church, probably dating from before the Norman conquest has adjacent timber posts which avoided the need for any intermediate 'beame fillyng'. However, according to Salzman (1952) p.192, it is likely such a construction would be beyond the reach of most owners and that some infill, to a lesser or greater extent, would be required in all buildings.
[8] Bowyer (1973), p.53.
[9] Slocombe (1988), p.36.

and dab'.[10] The withy or wreathing rods are mentioned in 1223 at Winchester as 'ad walduram', in Monmouth in 1370 as 'wyndend' and at Bath in 1435 as 'watyll'. In 1441 there is 'pro vrethying et dawbying' and in 1535 'frithying roddes'.
At York, in 1327, is recorded the mixing of earth with straw and stubble for use by a 'torcher' or 'dauber'. The term torching was often applied to the process of covering and was applied to walls as well as the insides of roofs and chimney linings (parging). The daubing was often referred to as 'rudyng' or simply as earthing or 'terrying' (from latin 'terrand') but most frequently as daubing ('dauband' or 'daealband').[11]

Figure 3. 'Lopping and topping' from coppice woods. 15th Century. From Nicholson and Fawcett (1988).

In primitive and peasant building the wattle and daub work would have been done by the house owner.[12] The peasant would construct his home from slender timbers and use the early customary right to 'lopping and topping' to provide wood, often oak or ash, for wattling [Figure 3]. From the 11th century, managed coppicing would secure a supplier of these underwoods. This may have been daubed with earth, straw and dung. Chalk or lime may have been added where available. For wealthier owners, the work may have been done by a dauber (torcher), the workmen often referred to as 'daubatores' or 'dealbatores'.[13] The position of the dauber within the crafts was well established, as illustrated as early as 1212 in a list of maximum daily wages,[14]

> 'Carpenters – 3d. and their food or 4d. without food; Masons and tilers, the same; Freemasons, 2 ½d. or 4d.; Plasterers, daubers, and puggers 2d. or 3d.; their assistants, 1 ½d. or 2d.'

and by the 1351 Statute of Labourers,[15]

> 'tilers 3d., and their mates 1 ½d.; plasterers and other workers of mud walls, and their mates, likewise.'

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[10] Reid (1989) states that 'ruddle and dab' was a reference to the 'stud and mud' of the northwest of England rather than wattle and daub: the former more accurately being a merger of wattle and daub and structural cob construction. Bankhart (1908) refers to the term 'dab' which was in use in Kent at the turn of the twentieth century.
[11] Salzman (1952), pp.188-189.
[12] Nicholson and Fawcett (1988), p.34.
[13] Salzman (1952), p.190, states that the term dealbatores more commonly referred to whitewashers.
[14] Ibid., p.68.
[15] Ibid., p.72.

This also shows that whilst considered skilled craftsmen, the plasterers and daubers were less well regarded than the carpenters and masons who may have designed the house as well as constructed it [Figure 4].
These skills were always in short supply and this meant that daubers would often travel. In 1487 at Urchfont, Wiltshire, there is reference to a dauber that came from outside the village,[16]

> ‘William Dicial – for daubing walls for 30 days at 4d. per day.’

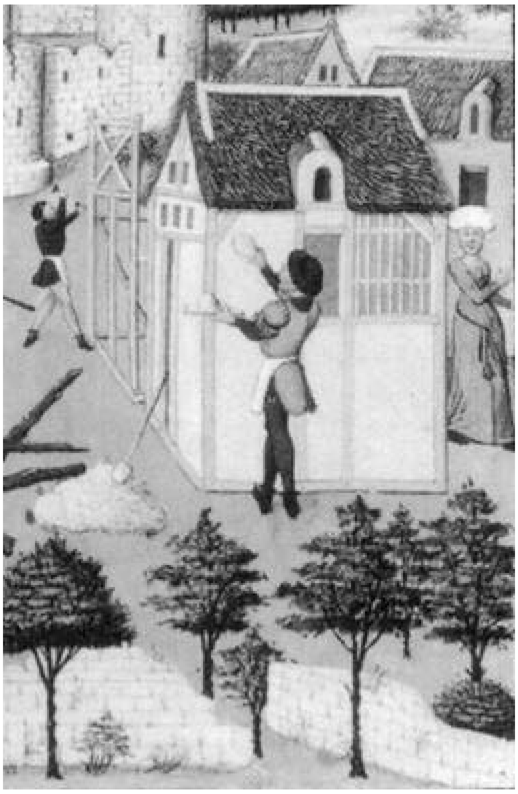

Figure 4. A 15th century artisan plasterer completing infill panels after the carpenter had finished his work. From Binding (2001).

The craft of wattling was also close to that of the thatcher and generally grouped as ‘helyers’ (helliers) or ‘cooperatores’. It is therefore likely that the crafts could be combined, as suggested by the payment of 17d. in 1500 at Grendon for new spars and wattling, although the latter could have been used under thatch rather than for walls.[17] The thatcher required coppice wood for spars and liggers, as did the plasterer for staves and withies. Both also most commonly used straw.

The demise of the craft of daubing was driven by several compounding factors. Firstly was the replacement with brick nogging.[18] Secondly, timber framing, using either new or reused timbers, diminished during the 17th and 18th centuries due to the inherent fire risk and the subsequent move to stone and brick: construction of half-timbered buildings had almost ceased by the turn of the 18th century. Thirdly, as half-timbering became less respectable through the 18th century Palladians’ desire for stone or brick façades, timber walls were frequently modernised by full plastering or by hiding behind mathematical tiles.

[16] Urchfont Parish Millennium Group (2001), p.113.
[17] Bowyer (1973), p.171.
[18] As brick production became increasingly economic during the 16th century, it became a common replacement for decayed wattle and daub panels and, in some districts, it was also used as infill for new timber buildings. The bricks would be laid either at an angle, in a herringbone pattern, but more commonly would be laid horizontally (Reid, 1989). The skill required to replace with brick was considerably less than wattle and daub, as has remained the case to the present day. However, a single brick thickness is draughtier than wattle and daub as it sits relatively loosely between the timber frame and is probably less resistant to the passage of moisture.

The poor image of wattle and daub was even conveyed through law: it is said that the term ‘breaking and entering’ comes from the ease with which criminals were able to enter a building by breaking through the infill.[19]
More recently, as new materials became abundant during the 20th century, many creative ways of replacing or ‘improving’ wattle and daub have been tried. Where the timbering remains exposed, panels have often been repaired with a cement render. Further, where not controlled by listed buildings legislation, instead of replacing with brick there has been a trend for using fibre board, expanded metal lath and similar backing materials.

It is remarkable that this method of walling remained one of the most common and unchanging forms of walling from primitive building down to its gradual demise during recent centuries. Throughout these periods of great changes and innovation, the craft remained almost entirely unaltered despite the huge developments in the carpentry of timber framing that surrounded each panel. Not only did the methods used for wattle and daubing remain consistent, but also did the majority of the materials used.

[19] Hanawalt (1986), p.34

3 Craft

The craft technique can best be described by reviewing the material's component parts and by exploring the various forms the wattle and daub had to take.

3.1 Diversity of Style

Identifying the origins of variation in wattle and daub is complicated by the multitude of influencing factors and their interactions. In fact, it was found that writing a full description was so prohibitively complex that the map of Figure 5 was depicted. Only a few of the secondary interactions (dashed lines) are shown, with others excluded for clarity.[20]

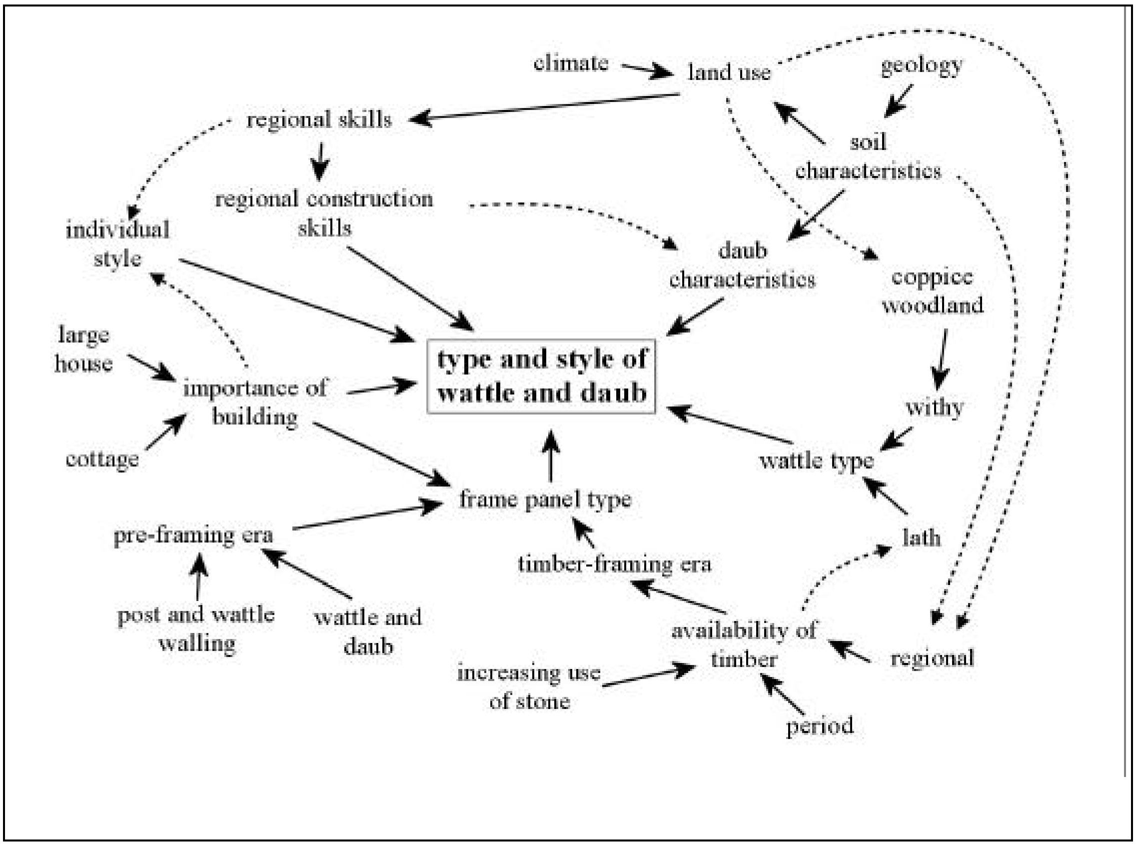

Figure 5. Interacting factors affecting the type and style of wattle and daub.

In considering some of the principal interactions, the dominating factor for wattle and daub style is panel type. This is primarily influenced by the type of construction, whether built during pre-framing or timber-framing eras and by the availability of timber. Access to suitable timber was regional, dependent on geology and past land use. The material chosen for rebuilding was increasingly influenced by availability of good building stone versus the scarcity of timber and the reluctance to timber due to fire risk. The distribution

[20] For example, climate also affects geology, such as the landscape of northern England being influenced by glacier action and deposits, but has been excluded for clarity.

of today's wattle and daub styles is compounded by the probability of building survival and, in turn, this is dependent on the eminence of the building.[21]

Where wattle and daub does survive, the materials used are dependent on the landscape and its historic uses. For example, the underlying geology not only determines whether a daub might contain chalk rather than other aggregate, but also determines the agricultural use of the land, such as shepherding on the downs versus woodland in the vales. Further, the availability of chalk or limestone would affect the likelihood of a daub being gauged with lime. It also follows that these factors affect demography, for example through the skill of hurdle-making for sheep penning, and is also recursive since the materials for penning take the sequence back to a dependence for coppice.

The availability of coppice woodland versus timber trees would also influence the use of withies versus riven (split) lath, but the latter is preferable for infill of close studding and hence selection is entwined with panel type.

Figure 6. Complexity of wattlework in arch-brace panel was avoided here by nailing three laths diagonally onto the staves (top-most lath is missing).

Figure 7. A lattice formed by weaving withies diagonally. South Cambridgeshire, c.1700 (Courtesy G. Murfitt).

Variation of wattle and daub is also affected by the multitude of methods available to the individual dauber or peasant cottage builder, even within a single locality. This may therefore mask the identification of regional variation since subtleties are difficult to identify without increasing the sample size of inspected buildings. Unfortunately, the scarcity of exposed wattle and daub makes studies difficult and the return on investment in time taken to increase

[21] Brunskill developed a model titled the 'vernacular zone' that describes the survival of historic buildings in terms of their status and age.

sample size by seeking out additional examples becomes increasingly poor. However, on the positive side, it is because of this diversity of methods and materials that it is still common to find new variations when investigating infill panels in historic buildings [Figure 6 and Figure 7].

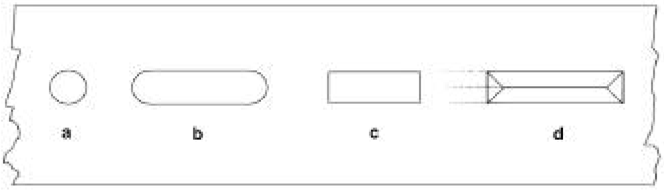

Figure 8. Soffit stave hole types: auger (a); augered mortice (b); chiselled mortice (c); V-groove either as a mortice or continuous (d).

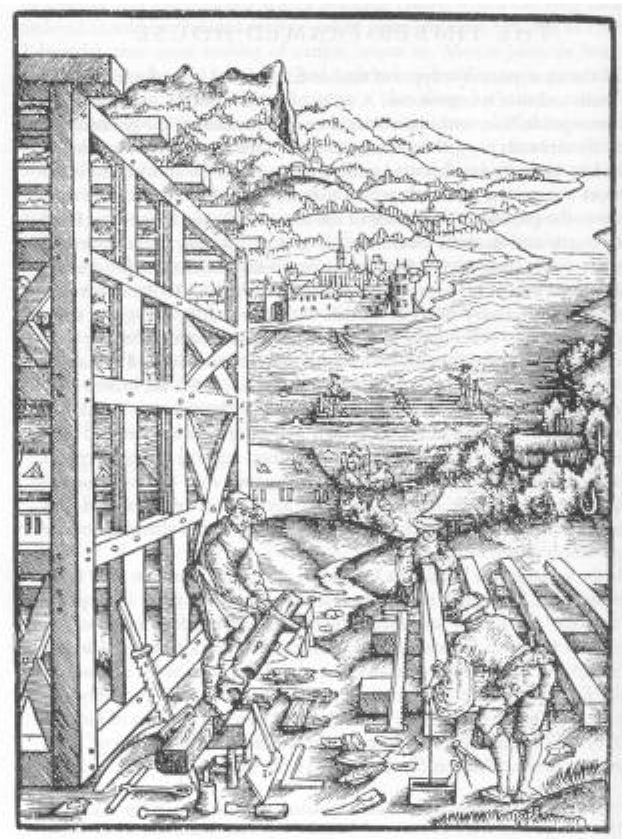

Figure 9. Studs with V-grooves, 1531. From Salzman (1952).

3.2 Frame Preparation

Before the dauber could carry out his craft, it was necessary for the carpenter to provide the correct detailing to his frame in order to accept the staves of the wattle panel. The bottom timber would be either part of a cill beam, mid rail (bressumer) or nogging and, before construction, the carpenter would gouge a long continuous groove along the centre-line of its upper face. The top of the panel may similarly have been formed by a mid rail or wall plate, onto which the carpenter would use an auger to prepare holes spaced approximately 250-450mm apart, ensuring that one was placed 0-50mm in from each end. Less commonly, the stave holes were made into rectangular mortices, rough v-groove mortices or a continuous v-slot gouged on the soffit (underside) to match the lower rail [Figure 8].[22] Sometimes, the end staves were run into the same mortice as the adjacent structural timber.[23] The carpenter frequently provided additional grooves along the inside faces of the posts or studs to accept laths or, occasionally, the ends of withies [Figure 9].

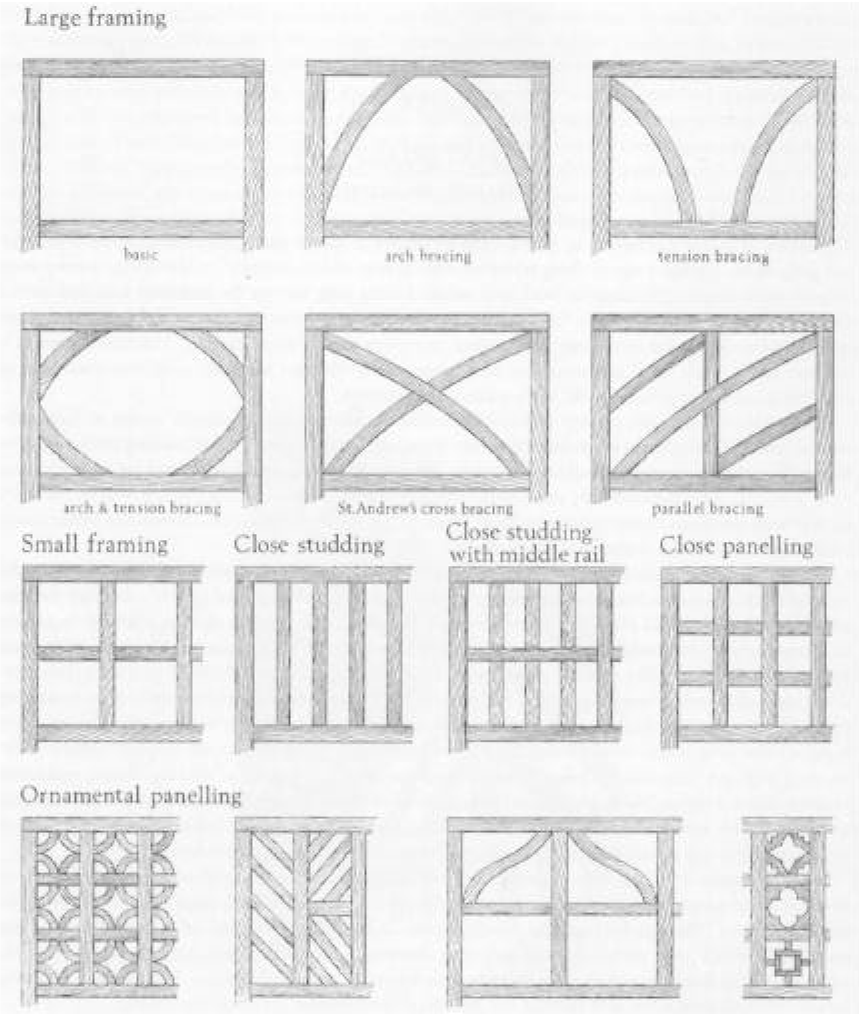

Figure 10. Variety in panel shape required different techniques to infill. From Mercer (1975).

[22] The grooves and stave holes often provide archaeology that indicate where a wattle and daub panel has been removed or where a timber has been reused for another purpose.
[23] Thompson (2003), p.2.

Figure 11. Configuration of staves and wattle in a braced panel. From Reid (1989).

Figure 12. A braced panel wattled by altering the angle of the withies.

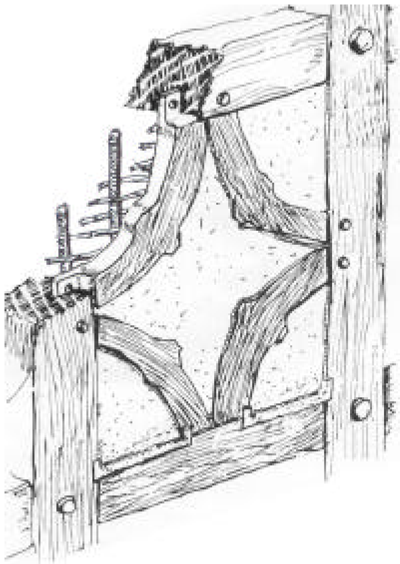

Figure 13. Decorative panel bracing applied in front of wattle. Adapted from Reid (1989).

3.3 Panel Types

The form of a wattle backing is chiefly determined by the shape and size of the spacing between the frame since it is necessary for the panel to be sufficiently rigid against physical damage such as from wind and being leant upon. Most were rectangular, such as the majority in post and truss and box-

frame constructions: non-rectangular panels required special consideration.[24] The dauber would need to be able to fill a great variety of panel shapes, depending on location within the frame, decoration, bracing and panel size [Figure 10].
Narrow panels either result from close studding or where a stud, such as for a window or door jamb, breaks a larger panel. Two approaches to the infill were either to rotate the construction so that the staves were horizontal and withies vertical or, more frequently, especially for close studding, was to use lathing instead of wattle. The laths were either sprung into grooves made in the sides of both studs or nailed to fillets of oak which themselves were nailed to the sides of the studs.
Where the latter technique was used the daub was often absent, replaced with a haired plaster applied directly to the laths.[25] The reason for omitting the daub may have been due to the laths being nearer to the surface of the frame, being located on the faces of the fillets rather than in the grooves on the frame centre-line. Alternatively, this method may have been coexistent with a regional preference to use only plaster instead of daub.

Braces introduced tapering and curved panel edges that caused complexities in the wattling. Where laths were used, the nailed fillets could simply follow the line of the brace with varying length of lath applied between them. However, where staves were used, they needed to be short near the corners and consequently their insertion required much skill, as did the wattling if it were to be fit tightly and to fill the full height of the panel [Figure 11]. Many other methods of providing a compact wattlework were used, such as running the withies diagonally, following the line of the brace [Figure 12]. The thicknesses of struts (non-structural decorative timbers) used in ornamental bracing were often less than the thickness of the structural frame. Where wattled, the staves would often be in a plane behind the struts, thereby keeping the staves and wattling simple [Figure 13].

3.4 Staves

The staves were usually oak, but hazel, holly, birch, alder and ash were also used.[26] Chestnut was quite durable but use was limited since supply was generally restricted to the southeast. The staves were either selected as coppice in the round or riven from the heartwood of larger timbers.

For wattle panels it was important that the staves were of the correct thickness so that the withies or laths could be easily worked around them without splitting or creating a panel that was too thick, as this would protrude too closely to the surface of the frame. Riven oak staves were usually 15-25mm deep by 60-90mm wide whereas hazel staves were typically 20-30mm diameter. Bark was often removed to reduce the risk of beetle attack. To

[24] Clifton-Taylor (1962) provides a comprehensive explanation of differences between post-and-truss and box-frame construction. Superficially, both may appear similar externally, with rectangular panels, but differ in the structural load paths.
[25] Reid (1989), p.3. However, Clifton-Taylor (1962), p.320 states that laths were covered with daub.
[26] Wright (1991), p.97.

assist weaving, the outside pair of staves was often thicker and shaped to a truncated wedged section and intermediate staves shaped to a truncated diamond section. This allowed each withy or lath to lie more flatly against the side of the stave, rather than touching just the protruding corners of an unshaped rectangular-sectioned stave. If nailed laths were to be used, the staves needed to be thicker, typically 50mm by 75mm and looking more like studs.[27]

The tops of all staves were prepared to fit the underside of the rail. For an augered hole, they were roughly pointed by chamfering on all four sides or chamfered on just two sides to fit the width of a mortice. The bottoms were shaped to fit the groove in the lower rail by chamfering the front and back to almost a point, and the sides just slightly chamfered to allow the stave to be swung more easily into position [Figure 14].

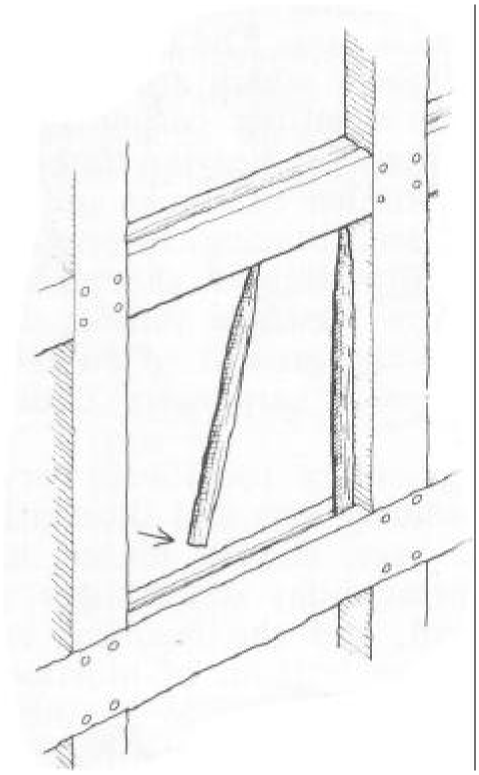

Figure 14. Method of stave insertion. From Harris (1997).

3.5 Withies and Laths

The malleable twig withies (or 'wandys') were woven around the staves in the same manner as a hurdle or a basket weave, their direction of entry alternating with each course. The elasticity of the green withies provided stiffness to the panel. Green cleft oak lath could be woven in a similar manner, as could thin bark strips.[28] Wattle panels were initially of withies, used in the round or split into halves or slats. Evidence suggests that laths may not have been used until the 14^{th} or 15^{th} century and such early use may

[27] Thompson (2003), p.1.
[28] Reid (1989), p.3.

have been a Wessex practice, although withies also continued to be used wherever the craft prevailed.

For buildings that survive today, the predominant withy material found is hazel. This may not have always been the only wood routinely used. There is evidence that the use of willow (sallow / osiers) was also common, together with a variety of other slender rods of ash, birch, lime and almost any other flexible green woods that were to hand. Reed was also utilised and was particularly suited to close studding.[29]

Laths from the middle ages were usually of oak or beech.[30] During the reign of Edward III, the size was regulated by statute as 1" x ½" and again by statute in 1528 as 5' x 2" x ½" but are often as wide as 4". Briggs (1925) states early lathing was nailed on to the frame surface and daubed so the timbers were not on show, but evidence of this practice is not given. Where the laths were nailed to thick staves or studs, the daub was often applied like plaster and the panels were therefore hollow. The void was often filled with straw or bran.

[29] Clifton-Taylor (1962), p.320, suggests that originally willow (osier), reed, unbarked hazel or ash were all used. He also suggests that laths took over from withies at widely varying dates between the 15th century, possibly earlier, and the 19th century. Bowyer (1973), p.53, says that for square panels (after the demise of close studding around 1550), early work used laths and later work used hazel or ash withies. Wood (1965), p.226 and Salzman (1952), p.188, describe evidence of lathing as early as 1347 at Clare, Essex, Paignton and Winchester and it may have been primarily a Wessex practice at that time. Salzman also offers 'small braches', hazel rods, osiers, reeds, thin strips of wood, or other 'pliant material'. Rackham (1994), p.45, observes that hazel and sallow (willows) are commonest in surviving buildings and has also found elm, aspen, birch, maple and lime. Thompson (2003) has evidence of laths of oak, Scots Pine, and withies of hazel and many other materials including birch, ash, etc. Wright (1991), p.97, has evidence of reed used for close studding.

[30] Briggs (1925), p.233.

The supply of withies from coppice woods was often in the form of underwood that shared space with timber trees. Managed coppicing was well established by the middle ages, especially in areas of intensive sheep farming such as Hampshire, Wiltshire, West Sussex and Dorset where hurdles were used as fencing [Figure 15].[31] Whilst it is generally accepted that large timbers may have been transported significant distances for the construction of the more substantial house, coppice wood may also have been transported to supply

Figure 15. Wattle fencing in Hampshire, as used by sheep farmers.
From Edlin (1949).

woodless areas, even during the medieval period when the coverage of woodland was not significantly declining. Where managed woods were not available, a local source may have been found from great lengths of hedgerow.[32] The coppice cycle was typically four to eight years, although underwood may also have been taken when required. Growth of approximately seven years was ideal for producing withies. Since a practical width is approximately 12 to 25mm, large sections could be quartered and small sections or the finer ends could be used whole. The wood was best cut during the winter since there was less sap which weakened it and made it prone to insect and fungal attacks.[33] However, it needed to be used before it seasoned, otherwise it became too stiff to weave and would snap when bent. On cold days the withies could be softened by warming over a fire.[34] The removal of bark might have been to further reduce the risk of rot and beetle attack, but frequently it was retained.

The withies were often worked using a spar hook (or 'spar knife'), a smaller version of a billhook. It has a thin blade which is easier to position within narrower withies. The tool has almost completely vanished, except for a few thatchers and hurdle makers who prefer them to the larger family member.

[31] Moir and Letts (1999), p.87.
[32] Rackham (1994), pp.40-45.
[33] Moir and Letts (1999), p.87.
[34] Wright (1991), p.97.

Where a groove was provided in the sides of the posts, the ends of the wider withies may have been reduced to fit by cutting diagonally or removing half of the section using the spar hook or axe [Figure 16].

Figure 16. Halving of withy ends to fit grooves in studs.

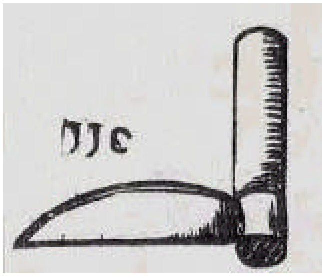

Figure 17. A 17th century illustration of a lath-maker's froe. From Holme (1972).

Figure 18. Evidence of string used to tie withies. From Rackham (1976).

Lath was riven using a drawknife or a lath-maker's froe, also known as a lath axe [Figure 17]. Where laths were secured by nailing, a gap was required between adjacent laths to provide a key for the daub. However, when woven, they would be packed tight against each other, as were the withies, since gaps would be created naturally within the weave thickness. Clifton-Taylor (1962) suggests that laths were *always* nailed yet Rackham has observed the bast fibres (phloem) from lime used as string.[35] Thompson (2003) suggests that both nails and string may have been used to secure laths to the staves.[36] Contradictorily, Wright (1991) says the presence of nails, string or wire indicate later repairs, but evidence of tying both laths and withies suggests otherwise [Figure 18].

3.6 Daub

The term *to daub* derives from the Old French term *dauber* meaning to plaster, paint or whitewash: the roles of plasterer and whitewasher were closely related. The modern meaning of "to dab" is probably derived from the act of daubing clay earth onto buildings. The modern sense of doing a job clumsily or crudely is not without relation to the processes of daubing infill panels since the initial placement of the clay onto the wattle is not a precise craft. Success is more reliant upon careful preparation, detailing and aftercare of the daub.

As an unbaked earth, daub shared much in common with solid earth walling such as cob, pisé and clay lump, yet the primary difference was that daub is non-structural and hence was less

[35] Alec Clifton-Taylor (1962), p.97; Rackham (1994), p.45.
[36] Thompson (2003), p.1.

precise. There were, however, variants that fell between the two such as 'stud and mud' walls. These had vertical timber studs between which solid earth was rammed to provide load-bearing assistance to the structural timbers. However, only daub is considered here.

Daub was principally earth. Not any earth was suitable, since it had to be generally free from organic topsoil, contain some clay as a binder, yet also contain sandy aggregate so not be too clayey, as otherwise the daub would shrink excessively. It is generally accepted that the dauber would use the earth immediately surrounding the building and so the daub mirrored the local geology. Since the practice spanned many geological areas, the types of earth varied greatly. However, Warren (1999) claims that if the earth was unsuitable then materials may have been transported significant distances.

To enhance the performance of a daub it was usual for the dauber to add dung, fibre and to mix various earth types. The determining factor in selection of materials was probably more related to what was readily available rather than any specific regional variation. In 1530 it was written,

> 'daubing may be with clay onely, with lime plaster, or lome that is tempered with heare or strawe'.[37]

The desire to strengthen the daub with fibre seemed to be sufficiently important for materials to be bought in.[38] The straw, hay, or occasionally flax stick reed, was usually chopped to enable workable amounts to be extracted from the mass. Fibre may also have helped reduce the weight of the material.[39] Straw was the most usual, flax stick being more frequently adopted in the Midlands. The stick was the inner stem that remained after removal of the outer fibre that was taken to produce linen.[40]

The daub was mixed by foot or by ox hoof.[41] Manure was commonly added to make the earth workable in preference to water that would result in excessive shrinkage. It has been said that the introduction of dung may have been accidental as a result of using oxen, but since its use was so regular and is frequently mentioned in historic texts it is likely that its inclusion was intentional. A few references are made to the use of horse manure, but this variation may only have developed as the use of horses in agriculture became widespread during the 17th and 18th centuries.[42] The addition of salt to retard drying and gauging with lime are also known.[43]

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[37] Salzman (1952), p.190.
[38] Forrester (1959), p.35. Also, in 1286 'white straw' was bought for Cambridge Castle; in 1375 eight loads of straw for Leeds Castle; in 1477 at Bath the churchwardens of St. Michael's bought hay and straw for daubing; and in 1491 at St. Mary-at-Hill in London they bought 'strawe to make mortere with to the dawbere'. (Salzman, 1952: 191).
[39] Wright (1991), p.98.
[40] Powys (1929), p.66.
[41] This is widely stated, such as by Wright (1991), Salzman (1952), Harrison (1999) and others.
[42] Horse manure is mentioned by Thompson (2003) and inferred by Ashurst and Ashurst (1988a).
[43] Ashurst and Ashurst (1988a), p.117.

To apply the daub, it was common for a small palm-full, or 'cat', to be pushed into the wattle. This work would usually be done from both sides of the wall simultaneously. Alternatively, a wetter daub could be thrown onto the wattle in a similar way that a render was often hurled rather than trowelled.


Figure 19. The daub of sheltered internal partitions was often crudely finished, with cracking left unattended.

The finish to panels varied greatly. The simplest was nothing more than a limewash. In this case the surface of the daub was either slightly recessed at the edges of the panel or finished flush and its surface crudely smoothed. For exterior work, the inevitable cracking would have to be reworked whilst semi-dry or filled with extra daub before limewashing. Durability was frequently improved by coating with plaster since it filled any cracks and could be worked into the gaps which would consistently appear around the panel edge due to shrinkage of the daub. The surface of the daub was often keyed using a lath scratcher or dimpled with the end of a lath or withy. The plaster applied to this varied by region, either being plain sand:lime, with gypsum or earth-based and may have also included dung, hair or straw.[44] Invariably the panel was finished with limewash.
Where the work was hidden and was not to be exposed to the weather, such as in roof truss partitions, the evidence of large cracks suggest the dauber readily accepted the crude finish and did little to rework the panels [Figure 19].

The above descriptions of daub arise from historic texts or visual interpretation. Scientific analyses of the constituents of historic daub are sparse with the only reliable published results coming from English Heritage's Research Technical and Advisory Services (RTAS) of the mid 1980's in which samples from the Weald were investigated.[45] The results, although of small sample size, provide details of the types of earth and additives used in that region. All earths analysed were found to contain a small proportion of clay (5-10%), mainly comprising silts and fines and some with larger aggregate including flint and chalk. Additives found were dung, grass (hay) and animal hair. There was no evidence of gauging with lime.

[44] Reid (1989), p.2.
[45] Ashurst and Ashurst (1988a), pp.121-126.

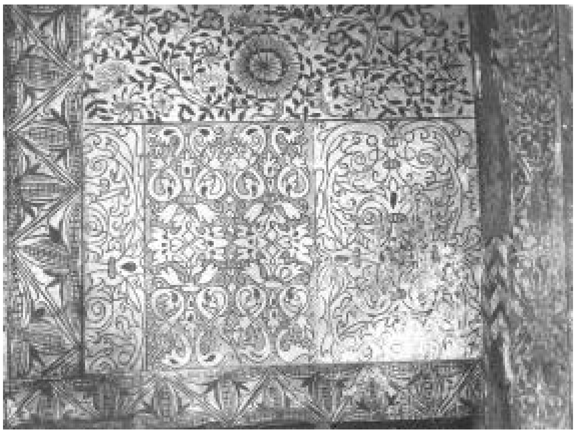

Figure 20. 16th Century wall painting of a daub panel and surrounding frame. From Weald & Downland Open Air Museum (2002).

Figure 21. Medieval daub decorated with combed pattern, Sussex. From Warren (1999).

Figure 22. Incised pargetting, Suffolk. From Clifton-Taylor (1962).

Figure 23. Raised pargetting. The Ancient house, Clare, Suffolk. From Clifton-Taylor (1962).

3.7 Decoration

Although most daub work was left plain, decoration was common across many regions and could be either painted or profiled. Simplest was the colouring of the limewash with either a cow dung tint, a richer pigmentation using ox blood or earth-based pigments.

Internally, the panels may also have been pigmented, but wealthy house owners sometimes had the completed panels decoratively painted. Examples of medieval work survive including floral patterns, chequers and heraldic detailing. Repeating patterns could be extended over the timbers so that the whole wall was covered [Figure 20].[46]

Panels may have been given interest by lightly combing the finished surface prior to limewashing [Figure 21]. From the 16th century, external walls were frequently decorated with incised patterning, a rudimentary form of pargetting also known as ‘stick-work’ or ‘combed work’. The patterns would have been formed by crude wooden combs, a stick or large nail [Figure 22].[47] Gypsum was used for plasterwork where available, such as the Isle of Purbeck, around Knaresborough in Yorkshire and the Trent Valley. Since its properties were conducive to modelling (‘raised’ work), it is not surprising that ornamented pargetting was developed. It became particularly fashionable from the 16th century and into the 17th century, especially in East Anglia where the whole frame would be covered and intricately decorated. [Figure 23].[48]

[46] Slocombe (1992), pp. 77-78 and Weald & Downland Open Air Museum (2002), p.51.
[47] Clifton-Taylor (1962), p.358.
[48] Ibid., pp. 252-354.

4 Material Characteristics

The craft of grading and mixing daub materials, such as by listening for the crunching of well-mixed clay and aggregate under foot, has all but gone.[49] However, the loss of skill can to some extent be compensated for by the application of science. With conservation of historic buildings positioned centrally between engineering and the arts, daubing also falls between these disciplines.

The selection of materials for daub is not so critical as for solid earth walling since wattle and daub is not structural. However, an appreciation of the materials and their characteristics provides many benefits: it is the basis for an understanding and appreciation of historical methods; it is required for the analysis of historic materials in archaeology and in conservation work; and is helpful in maximising the reliability and repeatability of repairs and new work.

The description of the soil content of a historic daub or of an earth that is to be sampled for new daub is an important part of an investigation, firstly because the description may form the only evidence on which an archaeological record is based, long after any samples have been lost. Secondly, descriptions of soils help conservators to share their knowledge of daubs in a meaningful way and classification may assist in predicting the subsequent behaviour of a particular soil. Samples can be taken from historic daub and from the ground. A rigorous approach to sampling and the description of soils is given by BS 5930:1999.

4.1 Soils

The physical characteristics of a daub are primarily dictated by its main constituent – the earth. It is therefore important to understand this material and its basic properties. The soil properties that are key to the performance of daubs are:

- constituents and particle sizes
- plasticity, as a modulator of linear stability [50]
- strength

These properties may be measured on-site (in the field) or in a laboratory and can be used to understand the historic selection and mixing of soils or in the specification and selection of materials for new daub.

[49] The crunching of aggregate was noticed during hand-mixing at Bowhill, Devon. Whether this was a rediscovery or an entirely new observation may never be known. Harrison (1999), p.20.

[50] Unlike solid earth construction, the key characteristics of the clay in a daub panel can be described by two dimensions. Since the orientation, i.e. height and width, of effects such as cracking are of little relevance, the properties can be described most simply through a linear shrinkage characteristic.

4.1.1 Constituents

The essential components can be crudely described as aggregate and binder. The binder is the clay, but requires water to enable it to become mobile so that it may coat the particles of aggregate.
The term *soil* is frequently used, but it must be stressed that daub generally excludes organic soils such as 'topsoil' and peat. Soils with greater than ~20% organic matter have altered characteristics and must be treated differently. The reference to daub as 'clay' is common, but a soil that is predominantly clay is not widespread and in any case would be undesirable because of shrinkage problems.

Soils are generally distinguished as being one of two types, either cohesive or granular. After removal of an initial compressive load (such as squeezing a sample), an undrained cohesive soil tends to bind together due to a combination of friction between the particles and the negative pore pressure produced by the water content. A granular soil has no such inherent compressive strength.

A soil is never composed entirely of a single particle size, but has a distribution of sizes. This is best described as continuous rather than discrete and has particles ranging from clay (of diameters 2 ì m), through silts (2 - 60ìm) and sands (60ìm -2mm) up to gravels (2mm) [51]. The attributes of a soil depend greatly on this distribution.

Because a soil is most likely to contain particles that are both cohesive and non-cohesive, its properties cannot be described by any one particle size: it is the combined effect of the various particle sizes that will determine the overall behaviour. To overcome this problem the terms 'coarse' and 'fine' are also applied to a soil as whole. If a soil contains fine particles that fill the voids between the coarse particles, then this soil as a whole is described as 'fine'. More analytically, a coarse soil can be distinguished from a fine soil as having the majority of particles having a diameter greater than 60ìm. [52] A particle size of 60ìm also happens to be the approximate point at which particles become visible to the naked eye.

Within the fine soils, the boundary between clay and silt is also significant to its performance. Other than particle size, clay differs from silt in that it is primarily a hydrous silicate of aluminium.[53] Clay has further specific considerations that affect the performance of a daub.

4.1.2 Plasticity

The effects of water on the physical properties of a clay can be seen in the form of cracks in almost all contemporary and historical daub panels. It is also important that a daub, after any cracking, must have a residual strength in the

[51] The scale continues up to cobbles and boulders, but in the context of soils for daubs these are of no concern.
[52] The accepted boundary is 65% coarse particles and 35% fine particles, although this is not a reliable predication of soil behaviour.
[53] combined with other impurities such as iron oxides, magnesia and lime.

clay that resists failure. Where a daub may be considered to have failed locally due to a crack or within its structure in the form of micro-cracks, the overall panel strength is assured by the added fibres such as straw or hair.

The amount of shrinkage of a pure clay can be characterised using two laboratory variables – the 'liquid limit' and the 'plastic limit'. The liquid limit is the point at which the water content is sufficient for the clay to flow as a liquid. This cannot be determined visually, since the point is at a transition between solid and liquid. However, definitions have been set and a standard test is defined in the BS 1377-2:1990 standard.[54] The plastic limit is defined as the moisture content that causes a clay to transition from being malleable to being friable. The test is based on controlled experiments where samples are rolled down to a breaking diameter of approximately 3mm. The limit is the moisture content at which the sample shears rather than remaining intact at this

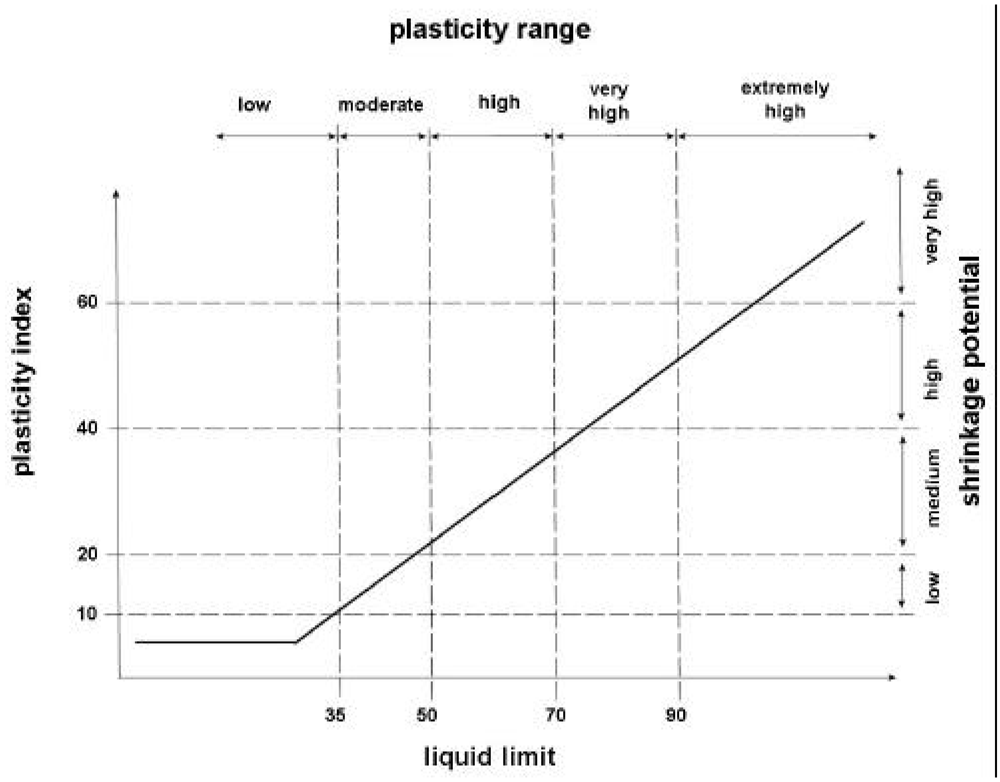

Figure 24. Shrinkage potential of clay.

diameter. These data can be used to derive a plasticity index, which is simply the liquid limit minus the plastic limit. This can then be plotted to show the potential for the clay to shrink [Figure 24]. Most clays fall close to the line.

[54] The cone penetrometer method defines the liquid limit as the water content at which the cone penetrates a soil sample to 20mm.

A direct characterisation of shrinkage can also be performed. This requires measurement of the 'shrinkage limit', defined as the moisture content below which a clay ceases to shrink, and the 'shrinkage ratio', which is defined in terms of the volumetric change versus change in moisture content.[55] The linear shrinkage is also particularly relevant to the cracking of daub panels. Figure 25 shows a typical relationship between volume change and water content for a clay. Below the shrinkage limit, air replaces the voids that had been filled with water. Above the shrinkage limit the clay is said to be 'saturated'. This means that the voids are full of water and have displaced all the air. In this context, saturation does not mean the maximum water content, as the soil will continue to take on water until it becomes a slurry (above the liquid limit). A dry daub is generally kept below the shrinkage limit and so contraction and expansion is negligible after the initial drying.

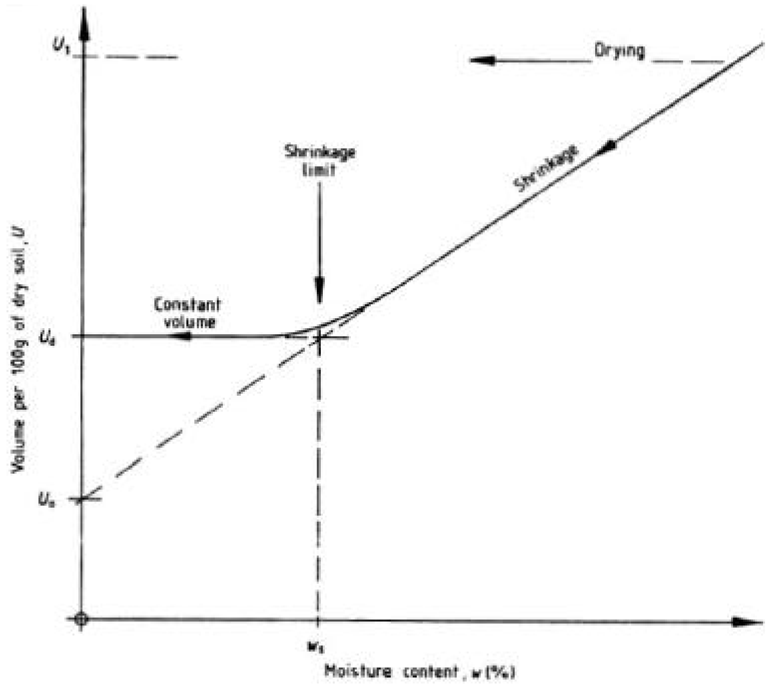

Figure 25. Clay moisture content versus volume. From BS 1377-2:1990.

[55] BS 1377-2:1990, p.14.

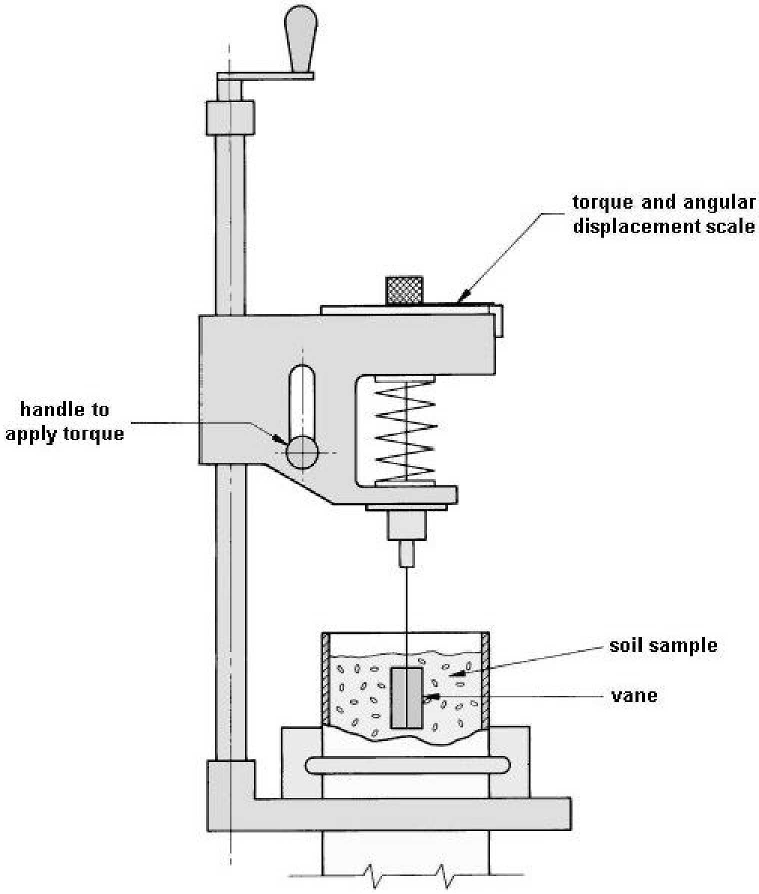

Figure 26. Vane test for soil strength. (Adapted from BS 1377-7:1990)

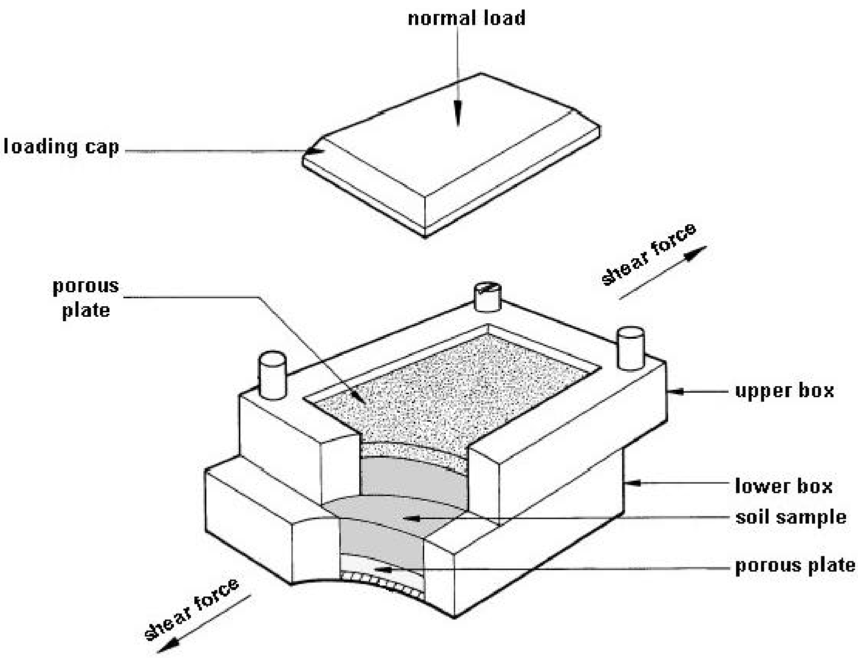

Figure 27. Shear box soil test. (From BS 1377-7:1990)

4.1.3 Strength

A weak daub may fail if it has insufficient cohesive strength to prevent it delaminating from the wattle or from failure within the body of the clay. In a vertical panel the critical stress is shear. The strength of a soil sample can be measured in the laboratory using either the vane method or small shear box.[56] After application, a daub is not under a compressive load and will therefore fail in shear if its 'apparent cohesion' is exceeded.[57]

4.1.4 Field Testing

Samples of dry historic daubs need to be removed from the site in sample bags and analysed in the laboratory.[58] However, a reasonable characterisation of a soil can be readily performed on-site where a quick assessment is required or where laboratory tests are not justified.

Coarse and fine soils can be distinguished by whether a damp soil sticks together. The sample may require drying in the palm of the hand or wetting in order to perform this test.
The sand/silt boundary can be judged by comparing the particles that are visible with the naked eye versus the proportion that become visible only with a loupe magnifier.[59]

Figure 28. Compact packet sieves for field use. (Courtesy of Endecotts Ltd)

Gravels and sands are distinguishable visually, since particles sizes of 2mm can be roughly judged by eye. The critical dimension of an elongated particle is its smallest diameter, which determines whether is may pass through a 2mm sieve.
The proportion of fines can be judged by spreading a sample and inspecting with a loupe magnifier. A more detailed field test can be done using a set of 'pocket sieves'. Similar to their larger counterparts used in the laboratory, they can quickly grade the gravels, sands and silts of a small soil sample on-site [Figure 28].

A sand can be identified by attempting to roll a thread in the hands. Since sand is not cohesive, it will not be able to form a thread with any residual strength.
A cohesive soil can be identified by squeezing a damp sample in the palm of a hand. If it forms a firm mass with residual strength then it is cohesive. It is

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[56] BS1377-7:1990.
[57] The apparent cohesion can be determined as the y-intercept from a graph of peak strength versus normal (compressive) stress.
[58] The ethics of conservation must be considered. Historic fabric should not be removed unnecessarily or where it affects the character of the building. Removal might be justified only after careful consideration to the objectives of the investigation.
[59] An eye lens.

the requirement of firmness that is important here since the ability to hold a shape (without strength) is a test of coarseness, as described above.
Plasticity of a soil is demonstrated by its ability to deform to some extent without cracking.
Both silts and clays may act plastically. The presence of clay can be determined by smearing a damp sample with the finger. Clays tend to bind to the skin and leave a stain. A further test that distinguishes a mainly silt/sand soil is its ‘dilatancy’. This is performed by taking a moist flattened sample in the palm of the hand and jarring it against a wall or other hand until water forms a film on the top. If the sample dulls again when pressed with a finger, followed by stiffening and eventual crumbling, then this indicates the predominance of silt/sand rather than clay.[60]

The approximate strength of fine soils can be determined on site using Table 1.

Table 1. Field test for strength of fine soils (from BS 5930:1999)

Test	Term	Approximate Strength (kNm^{-2})
Easily moulded or crushed in the fingers	un-compact	0
Can be moulded or crushed by strong pressure in the fingers	compact	0
Finger easily pushed in up to 25mm	very soft	<20
Finger pushed in up to 10mm	soft	2 to 40
Thumb makes impression easily	firm	40 to 75
Can be indented slightly by thumb	stiff	75 to 150
Can be indented by thumb nail	very stiff	150 to 300
Can be scratched by thumb nail	Hard (or very weak mudstone)	>300

4.1.5 Selection

The soil often varies across a site or by depth. If an unsuitable soil is found by excavating at a specific location, a better soil may be located either above or below it or elsewhere on the site. Soils of varying properties can be selected in this way for blending to give the desirable properties for a daub. If a suitable earth cannot be created from materials on site, then appropriate materials can be bought in. Suitably graded aggregates can be selected using an appropriate guide, such as the English Heritage Directory of Building Sands and Aggregates.[61]

[60] BS 5930:1999, p.116.
[61] Chapman and Fidler (2000).

4.2 Dung

Cow dung was habitually used in daub and so one may suppose there were particular benefits in its inclusion. Unfortunately, there appears to be no historic reference as to the properties of dung that encouraged its specification. Recent publications suggest that dung may improve workability and durability or may act as an additional binder, but supporting evidence is not given.[62]

Knowledge has also been lost as to whether fresh, old or weathered dung was used.[63] Since there is no historic reference to the dung being old or weathered, it is conceivable that this is a recent invention resulting from modern attitudes toward odour and hygiene. In any case, dried and fresh dung differ mainly in the water content and so are likely to effect only the amount of water, if any, added during mixing of the daub.

Additionally, it has recently been proposed that the mucus in cow dung has two effects on earth used for walling: it reacts with lime to form a gel, increasing strength prior to carbonation of the lime and it stabilises clay.[64] However, most cobs and daubs do not contain lime and so the formation of a gel seems unconvincing as to why the dung was added.

This illustrates how the literature is unclear as to the active dung component in daub. Therefore, as an attempt to identify the active constituent(s) of dung, a more thorough review of this topic was undertaken, the results of which are presented below.

4.2.1 Evaluation of Dung Ingredients

The digestion of ruminants and the composition of cow faeces are explained in Appendix 1. Most ruminants have similar digestive function and therefore it is likely that horse and cow dung have many comparable properties. The main constituent of cow dung is debris from cells within the digestive tract and secretions from the body such as salts, sloughing of animal cells and mucus. Faeces also include undigested diet comprising cellulose and lignin, originating from the cell walls of the plants. In the analysis of dung, it should also be considered that cowpats and slurry often contain urine as well as faeces. In an attempt to identify the components of dung that may be beneficial to daub, possible candidates were selected for review, namely lignin, urine and microbial debris.

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[62] Ashurst and Ashurst (1988a), p.117 suggest dung was added to improve workability and durability. Pearson (1992), p.6, and Holmes and Wingate (1997), p.163, both suggest dung modifies plasticity, acts as a binder and so improves durability. Wright (1991), p.98, also offers benefits as being improved strength and resistance to damp. Minke (2000). pp.44-46 states that manure and urine improve binding, undigested fibre acts as reinforcement and ammonia compounds are a disinfectant..

[63] Ashurst and Ashurst (1988a), p.117 suggest 'old or weathered dung' was used, yet fresh dung is stated by Reid (1989) and Forrester (1959), p.37. Minke (2000), p.45, suggests dung should be left one to four days to ferment but does not state a historical precendent.

[64] Ashurst and Ashurst (1988a), p.96.

4.2.2 Lignin

The modern study of lignins has identified many useful properties and they are increasingly being used in modern manufacturing. Two of the uses are as a binder and a dispersant. One such use of lignin's binding properties includes the stabilisation of soils. Dispersants attach themselves to particle surfaces and so prevent the particles from being attracted to each other. As a result, a dry mix requires less water than would otherwise be needed to make the material workable. For example, lignin may be used in cement mixes as a dispersant.[65]

The fraction of lignin in cow faeces is dependent on the feed. Historically, the predominant fodder was pasture and hay, which recently has been estimated to have a lignin content of approximately 2 to 8%. Legume fodder often has a higher lignin content of up to approximately 12%. The lignin is almost wholly indigestible and so is passed directly into the faeces.[66]

In considering the analysis of dung and the qualitative evaluation of the effects of lignin on daub, it must be realised that modern cattle feeds are often different to those used historically. Where cattle graze on pasture, the modern perennial ryegrass has been bred from improved strains developed by the Ministry of Agriculture Fisheries and Foods during the 1950's.[67] As fast growing species, these are likely to have less lignin that historical ryegrass. The desire to maximise digestible content of cattle feeds has also led to the reduction in the fraction of indigestible cellulose and lignin. The Acid Detergent Fibre (ADF) laboratory test represents a measure of the non-digestible feed and comprises some of the cellulose and nearly all of the lignin from the food. Since ADF figures are readily available and ADF has a reasonable correlation to lignin content, these data may therefore be used to identify possible trends in lignin content. Table 2 shows how modern feeds have a lower ADF content than traditional feeds.

Table 2. Comparison of acid detergent fibre in traditional and modern cattle feeds. Adapted from Stanton (2004).

Feedstuff	Traditional or modern feed	Typical ADF (Acid detergent fibre) / %
Barley straw (modern strains)	Traditional	57
Wheat straw (modern strains)	Traditional	56
Orchard grass hay (improved strains)	Traditional	40
Oat hay	Traditional	38
Linseed meal solvent	Modern	18
Corn gluten meal	Modern	9
Soybean meal	Modern	6

Therefore, in the evaluation of advantages of adding dung to daub, this downward trend of lignin content should be considered: if lignin led to the

[65] Lignin Institute (1992).
[66] Van Soest (1982), pp.43-44.
[67] Farm Direct (2001).

benefits observed by historic daubers then the same effect may not be reproducible using dung resulting from modern feeds.

4.2.3 Urine

As well as faeces, dung also frequently contains urine. The main component of urine is urea, which is broken down in the soil into ammonia gas or is mineralised.[68] This may increase the acidity of a soil but does not constitute a benefit to a daub.[69]

4.2.4 Microbial Debris

The microbial debris makes up the majority of the faeces. It has been established that such organic matter helps bind soil aggregates, yet an organic soil also has the undesirable property of being volumetrically unstable and so may shrink in a manner similar to clay.[70] It is possible that the faecal microbial debris in daub is prevented from decomposition by becoming biochemically-protected (chemical compounds that are not subject to decomposition), silt- and clay-protected, or microaggregate-protected (physically protected), although the function of the latter is known to predominate. However, a soil may become saturated with organic material due to limits of these protection mechanisms. Therefore, if too much dung is added to a soil it is likely that a proportion of the organic matter will be unprotected and may then decompose and damage the daub.[71] Protection mechanisms therefore assist a soil to stabilise added microbial debris (i.e. to nullify the affects of organic matter) but do not represent a benefit in their addition to a daub.

4.2.5 The Role of Dung

This brief review suggests that the small proportion of lignin present in cow dung may represent a beneficial additive to a daub. Unfortunately, it was not possible to establish the benefit conclusively through a literature review due to the complexity of this multi-discipline topic. However, the process has served to demonstrate its suitability for further research.

Until the interaction of cow dung and soil is scientifically characterised, it would be prudent to include dung in conservation work due to the evident durability of historic daubs that incorporate it.

4.3 Fibre

The primary role of fibre is to provide reinforcement of the daub, which is usually required due to the volumetric instability of the clay. Cracks that are

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[68] Petersen, Simek, Stamatiadis and Yamulki (2003).
[69] Minke (2000) suggests that urine may act to disinfect a soil against microorganisms, but since growth is likely to arise mainly from the addition of dung, this represents no net benefit.
[70] New Zealand Ministry of Agriculture and Forestry (2004).
[71] Six, Conant, Paul and Paustian (2002).

able to form across the total thickness of the daub would jeopardise the structural stability of the panel if not compensated by the inclusion of fibre. The role of steel rod in reinforced concrete is a good analogy to the primary role of fibre in a daub.

It has been proposed that the fibre also helps by dissipating the shrinkage of daub during drying.[72] This may be likened to 'bed joint reinforcement' of masonry walls and functions by embedding a ductile material within the fabric. Under a tensile stress, the reinforcement deforms (strains) uniformly along its length rather than at a single point. This results in micro-cracking of the surrounding fabric along the length of the reinforcement, rather than causing a visible crack at a single location.

Minke (2000) has shown that straw may decrease linear shrinkage by approximately 25% per 1% of added fibre. However, it has also been demonstrated that the addition of fibre in large proportions (i.e. 6-8%) may cause a decrease in compressive and tensile strengths.[73] There is therefore an optimum proportion of added fibre of approximately 2-4%.

[72] In the context of conservation, Harrison (1999), p.102, documents a theory originating from Duncan (1947), p.124, that straw, 'takes up the shrinkage in the wall and distributes it about the mass of the wall, so that no exterior cracks are caused.' In the context of new work, Minke (2000), p.44, Houben and Guillaud (1994),p.82, also support this.

[73] Houben and Guillaud (1994) showed fibre affects compressive and tensile strengths, whereas Minke (2000) discusses only a decrease in compressive strength.

5 Conservation

The archaeology of timber-framing has been extensively studied by architectural historians as antiquities important to the English landscape and our social history. However, with the evolution of conservation ethics throughout the twentieth century, we have now arrived at a situation where the great knowledge of timber-framing is disproportionately great against the scant knowledge of the wattle and daub panels that wee used to transform every frame into walling.[74] The relatively recent development and recognition of the buildings archaeologist has partly addressed this imbalance, yet our understanding of wattle and daub is mediocre in comparison. This is disappointing since it has been claimed that, 'wattle and daub often contains more archaeological evidence than the timber frame'.[75] For example, Rackham (1994) has found that withies are often, 'excellently preserved, down to the very lichens which grew on the rods when they were alive'. Additionally, the blackened surface of daub may provide evidence of an open hearth, the location of a smoke-bay or the remnants of a smoke hood.

5.1 The Value of Wattle and Daub

The historic value of a building is often realised not only by recognition of its architectural style, but also the superimposed effects of patina and decay, manifested as an 'age-value'.[76] Wattle and daub may emanate this value by way of its cracked and undulating surface, partial decay that exposes its underlying core of withies or by way of its soft limewashed finish. This lies in stark contrast to the flatness of a cement rendered panel, producing a lifelessness that appears disturbingly rigid within the flowing distortions, grain and shakes of the enclosing timbers.

UK legislation serves to protect these values as part of the 'special character' of listed buildings, yet much damage is still done through insensitive repair by contractors and owners. Unfortunately, many conservation architects and surveyors (and perhaps a proportion of conservation officers) also fail to appreciate the contribution made by wattle and daub to the special character and so share the blame through their inappropriate specifications of work. It is therefore important that government guidance should be adhered to, stating that, [77]

> 'traditional fixing and repair methods should be perpetuated. Proper attention should be given to the in-filling panels which are an integral part of any timber-framed building'.

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[74] The claim that knowledge is 'scant' is supported by the oft-conflicting accounts presented by the authors in the attached bibliography.
[75] Bouwens (1997).
[76] Ruskin (1880), pp.189-190 describes how age-value thrives on historic decay through his definition of the picturesque as 'parasitical sublimity'.
[77] Planning Policy Guidance Note PPG-15, paragraph C.16.

5.2 Defects and Decay

Wattle and daub has a reputation for being friable and unable to endure the damp British climate, yet this is something of a myth: it is generally the lack of respect for the fabric which has led to neglect and lack of maintenance. Where sheltered, wattle and daub may last almost indefinitely, as demonstrated by intact 14th century panels. Even when in exposed locations, a daub panel will survive indefinitely if appropriately maintained.

The proper diagnosis of defects should form a part of an ordered appraisal of the structure as a whole. It is extremely important to note that where a timber frame has deteriorated, the load paths may have altered. Stability of the building may have become dependent on one or more vertical staves taking a vertical load. Where such a stave is subsequently removed there is a risk of structural instability or collapse. It is therefore imperative that this matter is considered as part of the appraisal process, when choosing repair options and when writing schemes of works.

5.2.1 Decay of Daub and Plaster

The most significant cause of daub decay is caused by water absorption and erosion.

Erosion

An unprotected daub is essentially exposed soil. Direct contact with rain may therefore cause the clay matrix to be dissolved. The loss of binder may then lead to the remaining aggregate rapidly falling away. A daub that is predominantly sand/silt has characteristics making it especially prone to such erosion.[78] Wind may also contribute to loosening unbound aggregate. A daub is protected by the shedding effects of a limewash, but the lime additionally provides a binder to the surface of the daub in the form of calcium carbonate. A lime render also protects daub from erosion.
Erosion by water may be significantly accelerated by run-off from impervious materials situated above exposed daub such as impermeable modern paints and cement renders.

Water Penetration

The action of absorbed water is probably the single most damaging cause of daub failure. The linear and volumetric expansion and contraction of the clay causes cyclical fatigue of the daub, leading to increased cracking and eventual failure. Cracks may run either perpendicular to the plane of the panel surface or parallel to it. The former are visible on the surface and will themselves allow increasing levels of water penetration into the daub. Cracking parallel to the surface is manifested as delamination. This may occur within the bulk of the daub (especially at residual interfaces remaining from where cats were melded together) or where the daub protrudes between the withies (or as 'nibs' between laths).

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[78] Robson (1999), pp.32-33.

At the base of a panel, the groove to accept the staves can act as a water trap if maintenance is neglected. If cracks are left unattended or impervious materials used, water may accumulate in the groove and cause accelerated rot of the timber. The problem is avoided by appropriate maintenance of the wattle and daub so that rain cannot penetrate into cracks or into gaps adjacent to the surrounding timber frame. By filling the gaps with daub or lime mortar, any accumulating moisture is quickly reabsorbed into the bulk of the panel and is removed by evaporation through its large surface area.

It is imperative to the conservation of wattle and daub that a survey or routine inspection correctly identifies the source of the damp. The universal moisture tester based on electrical resistance is not a reliable guide since it only measures surface conditions and is affected by changes in electrical conductivity caused by any natural or added salts in the daub. The presence of moderate moisture levels is also not automatically indicative of a problem unless decay is evident.[79] For example, moisture content will be higher after rainfall or during the winter months. Damp is often caused by the trapping of moisture, such as by the use of impermeable paints, cement renders (including repair patches), proprietary wood treatments to the surfaces of timbers, or by excessive moisture due to poor detailing or maintenance of rainwater goods, flashings, etc.

<u>Frost Action</u>

At temperatures of 0°C and below, water within the pores of a daub will freeze and expand, forcing the daub apart. This may appear as cracking or spalling (‘blowing’ of daub by an outward force). Once this type of decay has started, water may accumulate within the cracks and cause the process to accelerate.

<u>Organic Growth</u>

The effect of plant growths on wattle and daub may vary from those that add interest and patina, through plants that have little effect, to those that cause complete failure of a panel.

Growth of algae and lichen may occur where local conditions are favourable. There is potential for harmless growth on a limewash surface due to casein or tallow proteins added to some limewashes, but is often counteracted by the causticity of limewash. Regular limewashing is likely to minimise growth.

Lichens are unlikely to cause harm. Small quantities of moss are also likely to be harmless but, where excessive, they may trap moisture and should be removed. Fungal growth may be an indication that decomposition is occurring due to excessive dung or organic matter within the daub and excessive levels of moisture.

The sprouting of small plants from the daub is also an indication of excessive moisture and there is a risk that their root systems may cause fragmentation of the daub. The underlying problem should be rectified and the plants removed. Larger plants, especially ivies and creepers, should not be planted in the proximity of wattle and daub. Such plants easily find their way into crevices between daub and frame or into cracked daub, the root system

[79] A thorough discussion of the monitoring and assessment of damp is presented by Ashurst and Ashurst (1988a), pp.1-21 and by Oxley (2003), pp.137-157.

quickly establishing within the daub and around the withies. The roots are likely to breakdown the daub and cause delamination from the wattle. Existing growth should not be forcibly removed since this will cause further damage. Instead, the plant should be killed by severing the main stem at its base and removing a 2-3cm section to prevent it regrafting. Dead growth may be carefully removed where loose, but where it remains bonded to the daub it should be left and limewashed over.[80]

Mechanical Damage

The strength of wattle and daub tends to decrease with time due to localised decay, but usually retains sufficient strength to support its own weight. Imposed lateral loads may damage a panel by cracking or deformation. A typical cause is that of leaning of ladders onto a panel, such as by contractors or window cleaners. Weak, but otherwise sound panels may be damaged by a person leaning their hand on them. Damage can be prevented by informing contractors of the risk and ensuring ladders are rested only on the timber frame.[81]

The effects of ground and air-borne vibration have been assessed for masonry and plasters, but not for daubs. Vibration is of legitimate concern due to the large number of historic buildings that were built close to the highway and due to the increasing levels of passing traffic. Other sources include nearby railways, mine-blasting and nearby building works, especially pile driving and on-site use of jackhammers.[82] Nailing, such as during the repair of laths, also presents a significant concern. The risk is of cracking or failure of the panel by debonding with the wattle and since the effects are cumulative, exposure should be minimised.

Animals

Rats and mice may find their way into panels, but are likely to do little harm to wattle and daub compared to solid earth walls.[83] However, an infestation should be eradicated since rodents may damage electrical wiring and thatch. Masonry bees are unlikely to significantly harm a panel since the relative thinness of daub makes an unattractive home. The occasional hole can be repaired with lime plaster.

[80] Ashurst and Ashurst (1988b), pp.20-24.

[81] Ladders may also damage the surface of a timber frame, especially where frassy or where shakes lie close to the timber edges. A stout lateral board should be attached to the top of the ladder side rails to prevent excessive pressure on the timbers.

[82] Hulme (1985) summarises recent research on vibration and concluded that traffic is unlikely to cause significant damage to masonry and plasters. Snider (2003) similarly concludes that the effects of blasting are several orders less than the thermal effects of the weather. However, daubs are weaker than lime renders and plasters and so published research cannot be directly applied to the performance of daubs.

[83] Rat runs in earth walls can cause structural damage. Ashurst and Ashurst (1988a), p.98.

5.2.2 Decay of Withies, Lath and Staves

The wood within the panel is susceptible to fungal rot and beetle attack. The surrounding frame may be similarly affected.[84]

Dry Rot

Dry rot is most likely to affect softwoods and usually only encroaches into hardwoods where conditions are particularly damp. Any fungus is likely to be localised to the wattle or stemming from carpentry within the building.

Wet Rot

Wood must have moisture content above 20% for the development of wet rots. The withies and staves are therefore likely to have been affected by a wet rot only if they have been exposed to prolonged periods of damp. In new wattle work or repairs, the risk of wet rot can be reduced by the use of preservatives, but such treatment does not address the root cause of damp. The benefits of treating withies and staves with preservative are therefore questionable. To compound matters, wet rot causes a structural change in the timber making it more susceptible to attack by Death Watch Beetle.

Wood-boring Insects

In the case of attack by wood-boring insects, it is essential to correctly diagnose the level of activity and the type of beetle.[85] The most common infestations are Furniture Beetle and Death Watch Beetle.[86] In historic wattles, it is unlikely that the infestation is still active due to the limited source of wood unless recent neglect has led to renewed dampness of the wattle or frame. Reducing the level of moisture should be the first course of redress. If there is no sign of recent activity, treatment is unlikely to be required. Furniture Beetle is more commonly found in softwoods, whereas Death Watch Beetle is at home in most hardwoods.

Death Watch Beetle can attack wood for many years, often unseen, and can cause severe damage to structural timbers, staves or lath before any infestation is apparent. The level of moisture in an external wattle and daub panel may enable a colony to survive until the total decay of wood exhausts their supply of nutrients. The presence of Death Watch Beetle is via the evidence of frass and flight holes. In the case of wattles, the simple technique of prodding them with a screwdriver is probably adequate to determine their condition.[87]

Common Furniture Beetle can survive at lower moisture levels than Death Watch Beetle and will attack the sapwood of most of the species of wood from which wattles and pole staves have traditionally been made. Diagnosis is by

[84] Descriptions of rots and beetle attack are adapted from course work previously submitted by the author.

[85] Description of beetle type and its treatment are discussed in Ridout (2000).

[86] Lander (1992), pp.198-203.

[87] A control process that correlates moisture levels to beetle activity is useful in addressing the problem. Chemical treatments are available but their effectiveness is often dubious and has considerable environmental considerations. Also, the treatment of historic wattle is almost impossible without complete destruction of the panel. Where diagnosis suggests chemical treatment may be effective, recent developments using deep-penetrating ‘mayonnaise’ may be considered. For further information see Demaus (1995).

the same manner as Death Watch Beetle. Eradication is difficult without the use of chemicals and therefore an infestation localised to the wattle should probably be left to run its course. Failure of the panel is unlikely to occur due only to wood-boring insects since a residual proportion of wattle left after decay may still be sufficient to secure the daub.

<u>Corrosion of Lath Nails</u>
Nails that hold laths to fillets or to the frame may eventually corrode. If sufficient laths become detached from the frame, the whole panel may become loose. The problem is often not easily rectified and should be addressed using the repair techniques discussed in Section 5.3.

5.2.3 Maintenance

The conservation of wattle and daub relies on the 'traditional performance' of buildings, as described by Oxley (2003). In practical terms, the primary consequences of this approach are the need for buildings to 'breathe' and to enable flexing of materials.[88]

Table 3. The visual inspection of wattle and daub.

Observation	Defect
Flaking, thin or missing limewash	Lack of regular limewashing
Cracked panel surfaces	• Localised or general failure of render or daub. • Damp • Poor workmanship of new work • structural movement of the timber frame
Missing render and/or daub	• Local failure of daub • Damp, frost damage or erosion • Delamination or physical damage.
Daub projecting beyond the surface of the frame[89]	• Delamination, i.e. debonding from wattle or lath • Failure of wattle or lath • Poor workmanship • Physical damage
Cement render or patches	Inappropriate materials
Modern impervious paints or coatings	Inappropriate materials
Use of impervious gap fillers such as expanding foam or mastic sealants	Inappropriate materials
Dampness	• Water or moisture due to other building defects. • Loss of 'traditional performance'.
Organic growth	• Inappropriate planting or lack of weeding around footings. • Damp

[88] Traditional performance, conservation philosophy and the use of limes are each large subjects. Further information is available from Oxley (2003), pp.71-95, Thomas, Williams and Ashurst (1992) and Homes and Wingate (1997).
[89] Exposed daub edges allow accelerated wetting of the daub, especially at the top of the panel, leading to accelerated decay.

Table 3 provides a guide to the identification of problems. Minor defects should be quickly remedied as part of an ongoing building maintenance programme. This scheme of regular inspection ensures minimal loss of historic fabric and reduces the long-term maintenance costs. Where buildings are in public ownership or managed by large organisations, there should be a documented property maintenance policy and the criteria for inspecting wattle and daub should be annexed to it.

It is essential to note that the identification of a defect does not automatically require remedial action in every case. For example, cracked daub in a sheltered internal location is unlikely to cause problems nor decay further and so may be left.

5.3 Repair

Poor understanding of the values, materials and techniques for conserving wattle and daub all too often leads to the unnecessary replacement of partially decayed panels, or even the removal of intact panels to improve access for frame repairs. In part, this is due to the lack of respect for the material and these views are still common within the conservation industry. More frequently, those that specify and carry out the works on daub have little understanding of the principles of conservation. What they have in common is the poor realisation that values change over time: the value of wattle and daub today may (hopefully) be different to its value in the future, especially as it becomes increasingly scarce. The principles therefore demand that every effort should be made to preserve wattle and daub. For successful care of the buildings, this approach must be understood not only by the primary custodian but also by all those involved in identifying problems, specifying the need and type of repair and the execution of those repairs. The principles governing the repair of wattle and daub may therefore be summarised as: [90]

1. Purpose of repair: to eliminate the causes of decay in daub, wattle or lath and to stabilise the present condition of the panel as a whole.
2. The need for repair: to prevent further decay threatening the stability of the panel; to insure against its failure damaging other fabric, such as pargetting or wall paintings.
3. Avoid damage: bias towards repairing the existing wattle and daub fabric rather than replacement - preferably by minimal disturbance or removal of historic fabric.
4. Use proven techniques: endeavour to match the traditional methods used in the original construction of the panel.

A disciplined approach to conserving wattle and daub will help to ensure implementation of good conservation practice.

<u>Recording</u>

Prior to starting any work, it is important to record the existing fabric. Where a building, historically, was of social importance, then good records of the

[90] A full discussion and categorisation of the principles is found in Brereton (1995).

structure might be available. Plans, sketches and details of past repairs (e.g. schedules of work and invoices) may exist that assist with appraisal. Such items might be available from the owner, land registry, local study groups, county records office (tithe maps, court rolls, estate records, etc.) and the National Monuments Record. Appendix 2 includes a template for the recording of wattle and daub.

Opening Up

The degree to which intact daub and wattlework can decay is often an unnecessary cause of alarm: if the panel is still doing its job of closing the gap between the frame then, by definition, it is functioning correctly. In this case, the stripping of the daub is unwarranted and must be avoided since, once started, it is often impossible to replace the daub without first renewing much of the wattlework.

Impact of Timber Frame Repairs on Panels

When considering structural repairs to a timber frame, the choice of repair method should consider the disturbance to the wattle and daub. For example, steel straps, braces and ties fixed to the surface of the frame will avoid disturbing the infill panel and may be more reversible. However, where it is necessary for structural stability to take precedence over conservation of historic fabric, it may be essential to remove frame members that surround wattle and daub or access frame parts hidden by the panel. In these circumstances, removal or temporary support of the intact wattle and daub may be possible, and in any case should always be attempted.

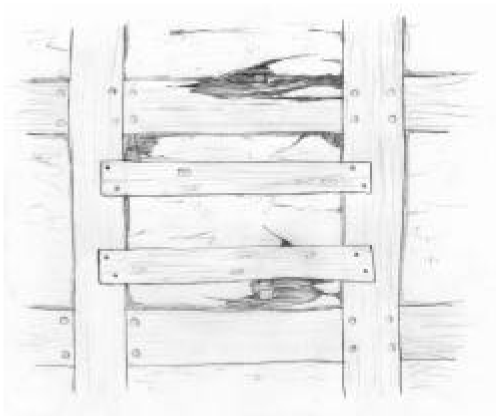

Figure 29. Temporary support for wattle panel, enabling repair of upper rail. Timber boards are temporarily screwed to frame.

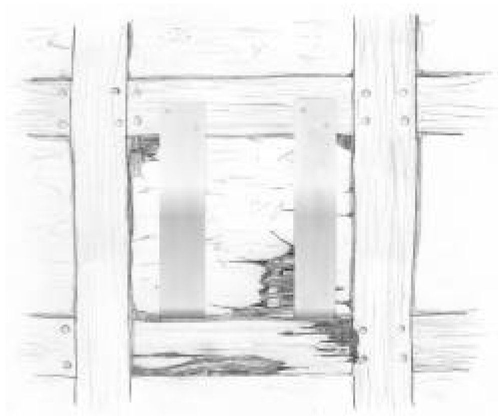

Figure 30. Removal of bottom rail for repair by providing temporary vertical support for wattle. L-shaped metal sheets are pushed inwards between bottom of wattle and frame and screwed to upper rail.

As temporary bracing, a scheme of lateral support or shuttering may be devised to fasten the infill in position [Figure 29]. It may be necessary to support the panel on both faces. Where the bottom rail or cill is to be removed, a system of bent aluminium or steel cramps screwed to the upper rail can be assembled [Figure 30].

Where whole sections of the frame are to be dismantled, daub panels may be sandwiched between shuttering prior to disassembly of the frame. After recording the locations of each panel and tagging each one for later identification, the wattle and daub may be removed for safe storage in a dry storeroom. The carpentry of repaired or replacement frame members must precisely reproduce the position of staves and groove(s) in order that refitting of the wattle and daub requires zero insertion force. Any attempt to adjust the position of staves or wattle will damage the daub. Some cracking may be expected by the disturbance, but can usually be repaired using the methods discussed below.

<u>Cracks</u>

The causes of cracking in historic daubs and plaster have already been discussed in Section 5.2. Cracks in the faces of external panels must be repaired as soon as possible using like materials (e.g. a lime plaster) to prevent water penetration. Internal faces may be repaired in the course of routine maintenance.

<u>Delamination of Daub.</u>

Most historic panels have small areas of delamination and should not be cause for concern. Where large areas of the panel have delaminated there is a risk that the daub may fall away. In this situation, the following repair options should be considered:

1. If there is no risk of water penetration and further decay, the fault may be left to run its course. Replace missing daub if or when it falls away.
2. Small areas of loose daub can be removed and replaced using new or recycled material.
3. Tying in of large sections of loose daub.
4. Grouting to re-bond large delaminated areas.

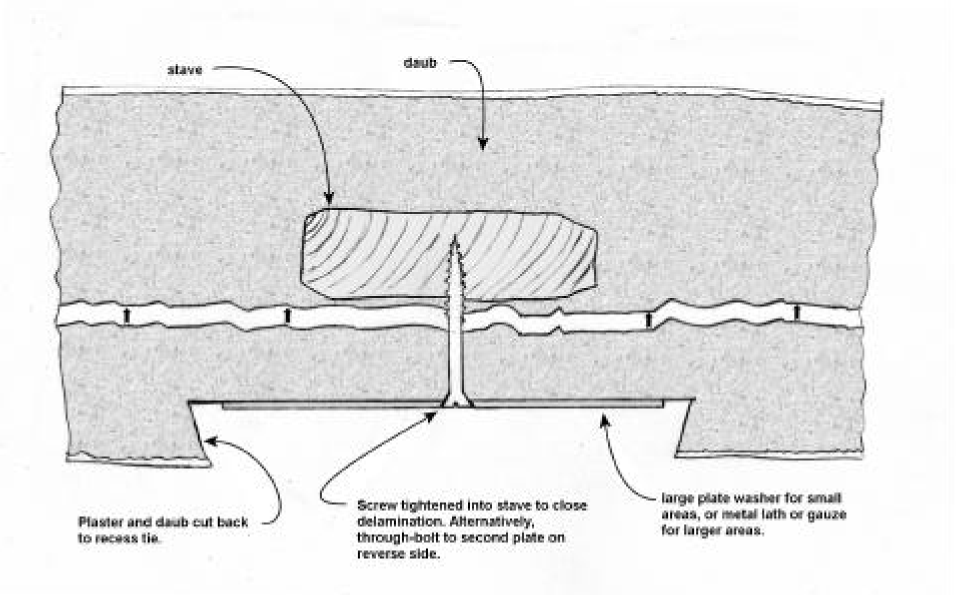

Figure 31. Cross-section showing repair of delaminated daub by tying.

Daub that has delaminated across a limited area of the panel can be re-secured using ties. The methods used to re-attached the daub should be selected based on each particular scenario and should not be prescriptive. The method will also be guided by the type of backing and whether access is available from both sides. A typical repair is shown in Figure 31. The fixing for the loose daub can be either the wattlework, one or more staves, or plaster on the opposite face of the panel. It is important to spread the load of the fixing across as large an area of daub as possible to prevent the daub cracking and the tie 'pulling through'. Suitable candidates for tie end plates are large washers, rigid metal 'lath' or gauze of a non-corrosive material such as brass or stainless steel.[91]

If several large areas of a panel have become delaminated where the use of tying is impractical, there have been reports of successful attempts to re-establish the integrity by grouting.[92] Suitable methods are grouting by injection or by hand.

To inject grout, holes should be drilled through one face of the panel into the top of each area of delamination. A suitable grout is made from a hydraulic lime and pulverised fly ash (PFA). This should be mixed to a suitable consistency for application by injection gun. Drill-holes are then made good by plugging with a lime mortar.

[91] The cutting to size of galvanized sheet exposes unprotected areas of steel that are prone to corrosion. This may eventually weaken the gauze or cause further delamination due to 'corrosion jacking'. Where the cut gauze is near the surface of the panel, rust stains may spoil the finish.
[92] Harrison (1999), p.80.

Hand grouting has the benefits of not disturbing the faces of a panel, which may be desirable where decorated. However, there is a significant risk that escaping grout may spoil the finish. It also relies on access to the void at the top of the panel. A suitable procedure is shown below.[93]

1. Cover timber frame with plastic sheeting, with a run-off provided at the base of the panel and attached as far as possible to the inside face of the timber frame. A clear mastic may be used on sound timber as a temporary fixing to avoid grout running underneath the run-off.
2. Lateral support in the form of shuttering should be provided for large areas of delamination to prevent bulging. Boards fixed across the timber frame on both sides, padded out with timber wedge off-cuts perform well.
3. Rinse loose dust from inside the cavity by using a controlled quantity of water. Saturation must be avoided.
4. Grout using a slurry of hydraulic lime and PFA. Propriety grouts may also be used where their composition has been checked as suitable: cement grouts must not be used.
5. Feed grout into the top of the panel, paying close attention for leaking grout and to the quantity used.
6. Where grout seeps from the bottom edges, these should be stopped with clay until the grout has set.
7. Grouting continues up the panel, stopping the edges with clay, until the panel is full.
8. Shuttering can be removed once the mortar has set.

Treatment of Edge Gaps

The intrinsic shrinkage of clay results in a narrow gap at the interface between daub and timber frame. This has always been stated as a weakness of wattle and daub. However, where a panel is correctly finished flush or recessed within the frame, then the probability of rain penetration is minimal. The remaining concern is therefore primarily one of draughts. The gap may therefore be filled with a suitable material. Where panels are not plastered, daub may be used as the filler if small quantities are available to hand. The subsequent shrinkage of the filler may require two or three iterations of the process in order to completely close the gap. Alternatively, the gaps may be closed by first dampening the edges of the daub and timber, then filling with a sacrificial lime mortar (e.g. 1:3 lime:sand mix using a non-hydraulic lime and well-graded fine but sharp aggregate). This may be used for both bare daub or plastered panels.

Seasonal movement of the frame may be caused by thermal expansion, changing moisture content of the timber, settling or cyclical movement of soils,

[93] Adapted from Beckmann (1995), Ashurst and Ashurst (1988b), Ashurst and Ashurst (1988c) and Feilden (1982).

or by live loads such as wind or snow. It is therefore highly likely that such movement will result in the edge gaps returning and so requiring ongoing remedial action. This should be considered an aspect of routine maintenance. The use of mastics or expanding foams is not recommended. Such materials, being impermeable to water, can result in moisture being trapped inside the edges of a panel or against the timber frame exacerbating decay.

Detailing

The base of an infill panel is particularly vulnerable to the trapping of water. Where a panel is recessed from the frame on all four sides, water may collect on the top surface of the timber. If the water is then conveyed inwards, it may result in fast decay of the timber and the base of the staves.

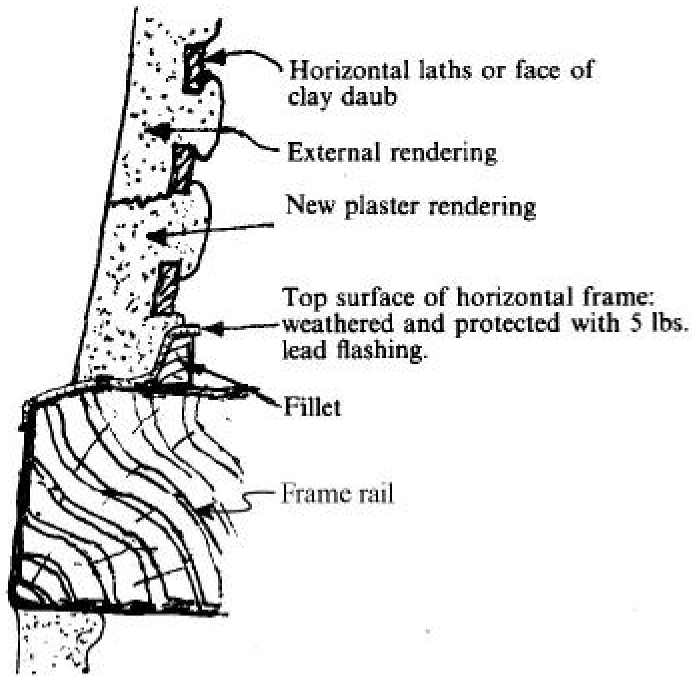

Figure 32. Lead flashing repair may trap water against the frame causing accelerated rot. Adapted from Reid (1989).

A system of using a timber fillet and lead flashing has been proposed to expel water from the base [Figure 32]. Unfortunately, any moisture finding its way under the lead may cause decay of the underlying timber and may block deep-penetrating water that falls behind the timber fillet (such as via cracks or missing daub). Moisture on the underside of the lead, including that caused by condensation, may cause it to corrode if organic acids are also present from the timber.[94]

[94] Bordass (1998).

An alternative approach is use a sacrificial fillet of mortar to dress the edge of the panel so that it forms a run-off to the vertical face of the timber. During rainfall, the mortar is likely to allow more water ingress than a lead flashing but will quickly re-absorb moisture via capillary action and then expel it into the atmosphere during drying. These wetting-drying cycles are likely to cause early failure of the mortar fillet, but if accepted as being sacrificial, it is easily replaced from time to time and secures the longevity of the historic wattle and daub and frame.

5.3.1 Partial Renewal

The most frequent repair scenarios are cases where a significant proportion of a panel remains sound. The failed parts may require remedial work to the wattlework, lath, daubs, renders or, most commonly, a plaster top coat.

Plaster Coat

Where only a top coat of plaster has become loose, it may be replaced as follows:

1. Remove cracked and loose plaster using a scraper or small trowel, being careful not to pull off secure plaster or daub.
2. Remove dust and organic matter.
3. Where the daub is smooth, provide a key on the daub surface by dampening with a sprayer or brush, then lightly scratch with the corner of a trowel or comb scratcher.
4. Dress ragged edges of intact plaster using a sharp knife. Undercutting is not essential.
5. ‘Prime’ the daub and exposed edges of plaster with limewater or a thin slurry made from fine stuff.
6. Prepare new plaster to match existing, with sufficient hair (or straw or hay, etc) for strengthening.
7. Dampen daub with a hand sprayer or brush. Apply plaster and finish to match existing (e.g. with wooden float, leaving an open-textured surface). Cover with sacking or cloth. Evaporation and absorption of moisture by the daub may require further dampening to ensure slow drying and proper carbonation.
8. Dry plaster should be finished with limewash to match the existing work.

Where the plaster had been decorated, several principles of conservation can conflict. On the one hand, it is recommended that the historic decoration should not be imitated where the craft has been lost and so the plaster is left plain or an ‘impression’ of the decoration is used. Conversely, such detailing of buildings is often important to their appearance and one should endeavour to employ crafts such as decorative plastering and pargetting so they are not lost. In this case, one might re-instate the decoration, perhaps dating it to prevent confusion with regards to authenticity.

Wattlework

Withies and woven lath are often friable due to decay. However, the principles for the repair of wattlework are as follows:

- the need for repair is limited to situations where wattle decay is the underlying cause of daub failure or where it is unable to withstand the applied forces during subsequent redaubing.
- repairs should endeavour to be like-for-like: hazel withies should be repaired with green hazel; cleft oak replaced with similar.
- the use of modern materials should be limited to only those situations where traditional methods would cause greater loss of historic fabric.

Where decay is localised, new sections of withy or lath should be ‘slipped in’ to the existing wattle so to avoid unnecessary stripping of sound daub:

1. Test the soundness of each area of wattle using a very light pressure on the palm of the hand to emulate the forces during subsequent redaubing. Unusable wattle will either fall into dust or will crack.
2. Evaluate remaining sound wattlework for suitability for redaubing. The occasionally spaced missing withy is unlikely to affect the soundness of a repair and may be left as found.
3. For unsound areas of wattle, prepare replacement withies with matching materials. Repair sections should be cut to length:
    a. Where there is access across the full width of the wattle, new withies of full length can be threaded through from one end.
    b. Where access across the wattlework is limited by sound daub, access for new withies is limited to the side. The minimum length of withy that can then be used is guided by the spacing between staves. The maximum length is determined by: the access to the hollow daub ‘tube’ remaining after removal of the decayed withy; the lateral access for feeding the flexed withy into to the existing wattlework; the spacing between two adjacent staves.
4. Tying-in should not be required If the repair withy is of sufficient length to be held in tension between staves and adjacent withies.
5. Where a repair withy is short and loose, it should be tied into adjacent wattle work and onto staves using twine or copper wire.

When introducing new wattle or lath to a building, there is a risk of introducing a new infestation of wood-boring beetle. Where a previous infestation has been found and there are no signs of recent activity, it is likely that that the remaining timber has become unsusceptible: either the conditions are unfavourable or vulnerable wood has already been attacked and the beetles’ supply exhausted. However, where a timber frame might remain vulnerable to attack, pre-treatment of the new wood with insecticide represents a sensible precaution. With withies and laths, pre-treatment should be highly effective since the slender sections can be saturated with the active insecticide. In this situation, the treatment is perfectly targeted and the (valid) concerns relating to the treatment of historic timber are not applicable. There are many proprietary formulae, commonly using permethrin as the active ingredient, which may be water or solvent based and suitable for brush or spray application.

Lath

The approach to repairing lath is similar to that of wattlework in that replacement is limited to the need for forming a sound backing to failed daub or render. Repairs should be from similar material to existing. Sound laths that have loosened due to corroded nails can be reattached. It is essential that the laths are not re-nailed since the vibration may cause daub or friable plasters to crack. Instead, they should be secured using brass or stainless-steel screws. Splitting of the laths is not a concern in new work but movement of laths may disturb attached daub. Therefore, the drilling of pilot holes in the lath is recommended.

Daub

Cracked or loose daub should be conserved as far as practicably possible. If external daub has cracked, eroded or delaminated from its backing, then attempts to secure it should first be tried before considering replacement. Where decay only affects part of a panel, replacement can be limited to the unsound area. Cracked daub, where otherwise sound, can be consolidated using a lime mortar:

1. Prepare the crack by removing fragments of loose daub and dust.
2. Thoroughly dampen the edges of the crack with a sprayer or brush.
3. For hairline cracks, fill with pure lime putty. Wider cracks to be filled with fine stuff (1 part non-hydraulic lime to 3 parts well-graded fine sand.). Large cracks can be filled with haired coarse stuff or new daub.

Where a regular programme of limewashing is established, hairline cracks may be left: the cracks are likely to be filled as part of the cycle in which a limewash of ‘creamy’ consistency should be used (e.g. 1 part mature lime putty to 5 parts water).

Where large pieces of daub have become detached, they should be replaced like-for-like using daub, rather than filling the void with lime mortar. If mortars are used habitually to replace daub then the cumulative effect will be the loss of integral wattle and daub panels and may encourage the demise the craft of daubing.

Where the detached daub has been salvaged, it can be reused to avoid unnecessary labour. It should be prepared by breaking into pieces and saturating in a bucket of water, stirred, and then left to resettle. The scum of old straw, hair and dung should be removed from the top. The daub should then be laid out until its water content is suitable for use. Hair or chopped straw and cow dung may then be added and the mix reapplied.

The preparation of new daub is described in Section 5.4.2. When replacing onto historic wattles, it may be wise to prepare the mix so it is a little wetter than compared to a daub for new work. This should make it more malleable and help prevent damage to friable withies. The risk is increased cracking of the daub, but this may be simply rectified by reworking the surface when green.[95]

After considering all repair options, it may occasionally be decided that a panel cannot be saved due to the poor condition of its wattlework. In this case, a panel may require complete renewal.

5.3.2 Removal of Impermeable Paints and Coatings

It is often found that wattle and daub panels have been covered with impervious coatings such as exterior emulsions, masonry paints and high-build ‘construction paints’. This may cause rapid decay of wattle and daub and it is therefore desirable to remove them and replace with limewash.

Modern paints will often delaminate after approximately five to ten years after application. They may then be removed by carefully lifting off with a small trowel or scraper.

Where modern paint remain firmly bonded to the plaster or daub, the choices are either to leave the paint and attempt to monitor the condition of the wattle and daub or to use a more aggressive method of removal. Latterly, there has been much research into the removal of paint for the conservation of stone and brick. The industry has developed its experience in the use of chemicals, dry abrasives and poultice strippers. Unfortunately, there is very little experience in paint removal from earth materials such as wattle and daub and cob.[96]

[95] The term ‘green’ refers to a state during drying where a daub or render has firmed up but still appears damp. It is also the state where the material is still workable with a pallet knife or modelling tool without causing the surface to break up, but does not cause the bulk of the material to shift.

[96] There is no published reference to active paint removal from wattle and daub. Enquiries to well-established operators dealing with chemical and dry-abrasive solutions indicated they had no experience of wattle and daub.

Paint Removal Case Study

A timber frame building in Wiltshire had been 'modernised' during the 1980's. The panels were of hazel wattle, daub and a lime plaster top coat. Some panels had been painted using an exterior emulsion, some with a high-build 'construction' paint and some coated with proprietary textured wall coating. The following conservation work was performed during 1999 and 2000:

- The emulsion had become flaky. Small sections were easily peeled away with a scraper, but many areas remained bonded. The thinness of the paint made it difficult to position a blade underneath without damaging the panel. The construction paint appeared intact but had delaminated in large areas. Once a pallet knife was under the paint, large areas were easily removed. Some areas remained tightly bonded to the plaster. The wall coating was thick and remained well bonded to the plaster.

- Chemical stripping of the two paint types was attempted. Firstly, the timbers were protected to avoid bleaching and staining. The formula selected was a combination of solvent and caustic strippers comprising methylene chloride and ammonia, which was applied by brush. A scraper was used for the cleaning, followed by hand rinsing with water using a sponge. A water lance was not used. The dwell time was adapted so that the resulting 'jelly' could easily be scraped away, but not left so long that it began to dry. The method was particularly successful on both paints. No residue was noted and the panels readily accepted a limewash. The stripper had no effect on the wall-coating.

- A caustic poultice stripper based on sodium hydroxide was tested. Removal of both paints was successful. However, the residue was harder to rinse away than the chemical product and it left an odour in the panel that indicated a residue had been left in the plaster. These panels also accepted a limewash after priming with limewater. There was no effect on the wall-coating.

- Dry-abrasive was thought to be a possible candidate for sensitive removal of the paints. Careful control by skilled operators can often remove coatings without damaging the substrate. It was felt that limited damage to the plaster could be tolerated since it could be easily repaired. This method was not tested and so its capabilities on wattle and daub remain unproven.

- The wall-coating had been used only on the upper storey of the leeward side of the building and where the panels were sheltered under the eaves of thatch. It was decided to take a pragmatic approach by leaving the wall-coating on. The panels would be monitored for dampness. It was decided that if, in the future, decay was noted, the coating could be removed along with the plaster and refinished.

5.4 Replacement

The basis of renewal should be like-for-like replacement using traditional materials and methods: wattle and daub should not be substituted by materials that are more commonly understood by modern contractors, such as lath and plaster. Various schemes involving the introduction of modern materials have been suggested by certain conservation publications, but the justification for these is usually unfounded.[97] The only scenario under which upgrading wattle and daub is warranted is a change of use of an unlisted building. In this case, the upgrading may be required to meet the requirements of the building regulations (See Section 5.5).

5.4.1 Brick Infill

Brick nogging is often found to have replaced earlier wattle and daub. This frequently occurred due to the wattle and daub craft waning during the 17th century and brick becoming increasingly cheap and freely available. It should be noted that some brick infill may be original or may enhance the appearance of a building in which case every effort should be made to preserve it. However, it may be found that the replacement brick infill was of poor workmanship and may hold water against the timbers, especially if the top edge of the nogging protrudes beyond the face of the frame. In these situations, restoration may be appropriate if *all* the following conditions are met:

1. The majority of other panels in the same building retain their historic wattle and daub, the appearance of which will be enhanced by the re-instatement of the remaining panels.
2. Archaeology is available to prove that the panels had originally been filled with wattle and daub (e.g. stave holes and groove).
3. The replacement infill does not contribute to the special character of the building, is of poor quality and requires remedial action.[98]

Where restoration is being considered, consent will be required if the building is listed. Conservation officer advice should be sought before any work is started. An appraisal of the structure must be performed before removal of the nogging to ensure that it has not become load-bearing. Where this work represents an alteration rather than repair, the labour and materials may presently be zero-rated for VAT where certain criteria are met.

5.4.2 Renewal

Before a panel is renewed, it is important to first record the existing infill. This should include: the wattle type, including wood species, sections and type of weave; the carpentry to the frame for attaching the wattle; the type and spacing of laths including the method of fixing; an analysis of the daub

[97] An analogy would be to consider replacing the base of a decayed but hidden historic timber post with a reinforced concrete column since it improves durability of the structure as a whole!

[98] Criteria for re-instatement are presented in PPG15, Section C.6

including its constituents; the type of plaster, if any; panel detailing or decoration.[99]

Analysis of Daub

The analysis of a daub creates a record for archive and provides information required to specify new work. However, analysis can prove expensive and so the level of detail sought may be guided by the importance of the building. A thorough analysis is performed using a combination of field tests for soils (as described in Section 4.1.4), microscopy, sedimentation, particle size analysis and chemistry. A suitable procedure is illustrated in Figure 33.[100]

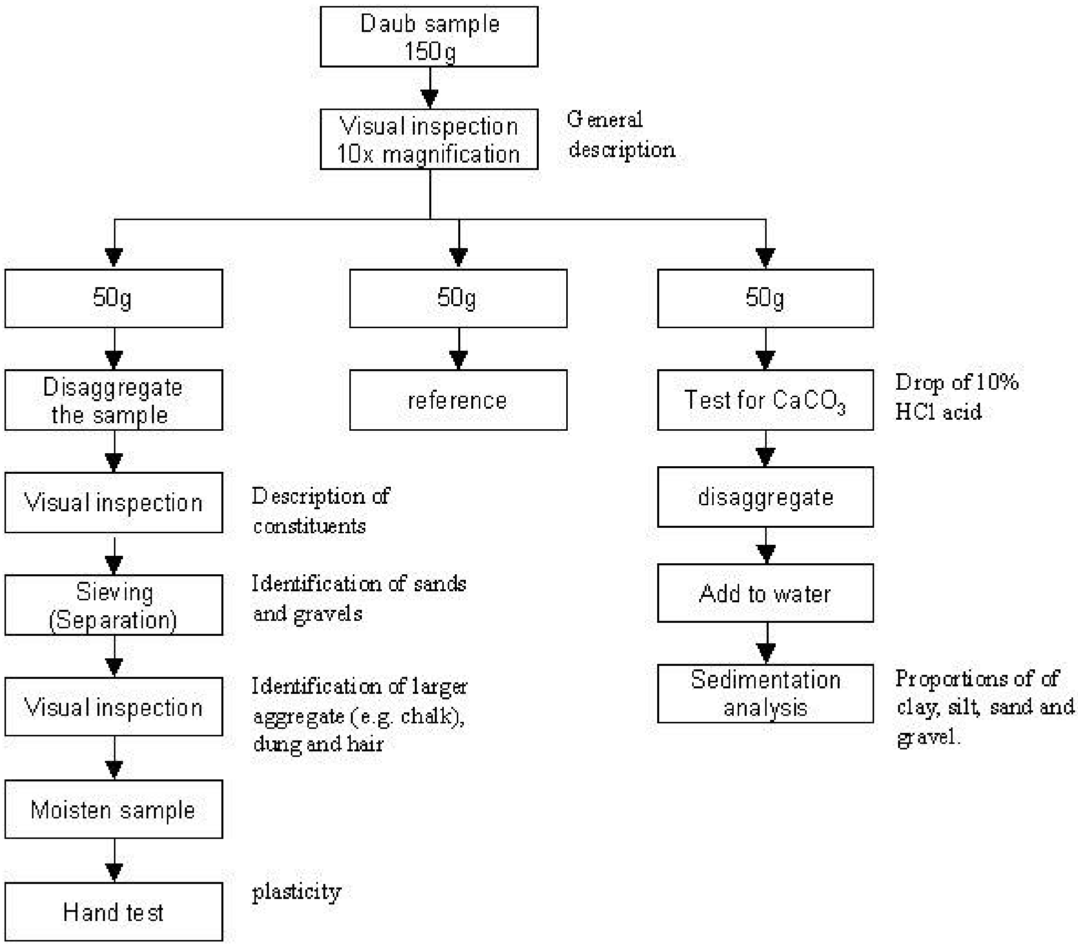

Figure 33. A flowchart for the analysis of daub.

The quantitative results can be displayed diagrammatically either by plotting as a cumulative distribution chart as per BS 1377-2:1990 or using a stacked bar graph. This should be accompanied by a description of the daub: visual inspection (colour(s); additives; appearance (e.g. cracks)); strength (breaking sample); sedimentation observations; constituents identified after sieving; plasticity (how thin a length could be rolled before breaking); summary.

[99] From Ashurst and Ashurst (1988a), p.119.
[100] Adapted from Ashurst and Ashurst (1988a), p.121.

After the appraisal process is complete, including a structural evaluation and recording, the panel may be stripped in preparation for renewal.

The Wattle

A backing of withies is formed by the following process:

1. Prepare staves by splitting heartwood of oak using a froe.
2. Sharpen tops to fit stave holes.
3. Bevel the bases to fit the groove.
4. Insert staves by sliding base sideways [Figure 34].
5. To provide the withies, coppice and split sufficient hazel rods, preferably during winter when there is less sap.
6. Ensure correct length by weaving a reference withy. Prepare remaining withies by cutting to same length as the reference.
7. Narrow the ends if fitting into stud grooves.
8. Weave withies, alternating the side of the staves with each row [Figure 35].[101]
9. Tamp down withies to base of panel to make compact.
10. Complete insertion of withies up to the top of the panel.
11. Leave the panel to season. Tamp down and add additional withies to fill any resulting gap at the top.

Figure 34. Insertion of a stave into a test panel.

Figure 35. Weaving of withies.

Preparation of Daub

The earth should ideally be cut from the grounds of the building to avoid unnecessary transport. For a small number of panels, digging may be done by hand using only a spade. Topsoil should be stacked separately so that it may

[101] Unlike hurdle fencing, the flat face of split withies may face *both* directions to provide even keying of daub on both sides.

later be returned to the top after the hole is filled in. Suitably well-graded earth is most frequently found at the transition just below topsoil and above underlying heavy clay or chalky beds.

Prior to removing the required quantity of earth for the daub, a sample should be taken. This should be compared with any analysis performed on the historic daub using the tests already described. Where a match is not required, the objectives of the sample tests are to ensure the daub will have the appropriate properties to ensure easy application and a durable daub that is free from significant defects: i.e. to keep the clay content as low as possible so to avoid cracking but to produce a mix that binds. For new work, an approximate guide to a suitable earth is: [102]

Clay	5-15%
Silt	20-55%
Sand	20-55%
Gravel	0 to 20%

Excavated soils that are overall suitably graded may contain a small number of coarse gravel particles and the occasional cobble. The maximum aggregate size is defined by the need to form cats of workable size, the ability to drive a daub through the gaps in the withies or lath, and ensuring aggregate particles do not project beyond the surface of the daub. Ideally, the largest gravel and cobbles should be removed from the earth prior to mixing, although this is not vital since they can continue to be picked out during mixing, whilst forming cats or when being pressed into the backing.[103]

A suitable working area must be found. This will depend on whether the daub is to be mixed by hand (and foot) or mechanically. For hand mixing, it is preferable, albeit not a necessity, to create a wooden frame to enclose the daub so it is not gradually dispersed and lost. The frame can also be used to scrape material from boots and tools. For mechanised mixing, the expense of losing material is not so high in terms of effort and therefore can be mixed on the open surface of a yard or track. Because of the imprecise nature of the constituents of daub, a small amount of contamination, such as topsoil, is unlikely to cause a problem. Therefore, a suitable mechanical method is simply to squash it on the ground by tractor tyre, fork-lift truck, roller, caterpillar track, etc. Where available, a pug mill is stated to be ideal.[104] The traditional method of using cattle could be tried if there is a farmyard nearby to the building, although there seems to be no documented cases where this has been recently attempted. The use of a drum cement mixer has been tried for mixing cob on several occasions but runs into the same limitations as has

[102] Due to the imprecise nature of the material, the suggested constituents vary: Thompson (2003), p.2 suggests percentages for clay:silt:sand:gravel as 5-10:20-50:20-50:0-20; Ashurst and Ashurst (1988a), p.119, suggest 5-15:20-55:20-55 (sand and gravel combined). Reid (1989), p.12 reports a specification as simply a, ‘stiff sandy clay’.

[103] Since earth for a few panels does not require much soil, the hole may often be filled in later using spare material from the grounds. Alternatively, hardcore may be used. The stacked topsoil should then be replaced.

[104] Ashurst and Ashurst (1988a), p.120.

been found more frequently with lime renders: the constituents are mixed superficially but the binder is not well integrated with the aggregate. This results in a friable mix that will yield poor results if not processed further. Drum mixing followed by hand mixing was tried and this was more successful but the advantages of this appear minimal compared to other processes. Adding extra water has also been tried but this then introduces new concerns with shrinkage cracking or necessitates controlled drying before use.[105]

Before mixing in, straw may require chopping with an axe if it is very long, whereas animal hair may be added directly. These days, hair is often bound or packaged when bought and the fibres must be separated so not to create ‘knots’ in the mix. This can be done by beating the hair with a stick whilst it is laid upon the surface of the daub.

Cow and horse dung might behave similarly in daub, but handling of the latter is wholly undesirable due to its overpowering odour that lingers on the wall, tools, boots and hands for many weeks: cow dung has a sweeter smell which is less tenacious. Conservators, especially those employing operators, should note that safe handling of dung and daubs containing dung require the use of protection due to the potential health risks such as ingestion of E. Coli. Overalls and gloves should be worn at all times. Additionally, boots and eye protection should be used when handling fresh dung.

The constituents of a daub should complement the soil and will depend on locally available materials. However, some example mixes are shown in Table 4.

Table 4. Example daub mixes shown as ratios of constituents.

Constituents /parts						Source
soil	cow dung	straw (dense)	hair	lime	chalk	
12	1	1	-	-	-	Ashurst and Ashurst (1988a), p.120
8[106]	1	1	-	-	-	Reid (1989), p.12.
4	1	-	yes	1	-	
12[107]	1	2	-	-	-	
2[108]		1	-	2	3	
12[109]	1	2	-	-	-	Wright (1991), p.100.
7-9	1[110]	yes	-	-	-	Thompson (2003), p.2.
1[111]	1	yes		1		Lander (1986), p.210.

105 Harrison (1999), pp.24-26.
106 Stiff sandy clay soil.
107 6 parts clayey soil plus 6 parts sharp sand. Dung specified as fresh.
108 1 part clay soil plus 1 part sand.
109 6 parts clayey earth (<15% clay) plus 6 parts sharp sand.
110 cow or horse dung.
111 stated as being a ‘repair mix’.

Mixing should preferably be done in a single batch to avoid unnecessary labour and to give a consistent product. Large projects may necessitate batching to avoid uneven mixing. A suitable hand method is shown below:

1. Place the earth into the mixing frame.
2. Pick out any coarse gravel.
3. Add additional aggregate or clay, as necessary, distributed evenly across the surface.
4. Mix thoroughly by 'treading' with the heel of the boot [Figure 36]. When compacted, the daub should be lifted and turned using a shovel or 'cob-pick'. Continue treading and turning.
5. Inspect the daub at regular intervals during treading: the result should be a well-mixed 'sandy clay'.
6. A little water may be required to permit the clay to coat the aggregate and to make the daub workable, but the daub must be kept as dry as possible.
7. Add cow dung and mix by treading. Add only sufficient dung to make the daub feel plastic.
8. Fibre, such as hair, chopped straw or hay is scattered evenly onto the earth.
9. Further treading and to complete the mixing [Figure 37].

Figure 36. Mixing of daub by 'heeling'.

Figure 37. Treading straw into daub.

An alternative sequence is to include the fibre at the beginning so that some of the straw may be laid under the earth prior to mixing.[112] However, this is likely to make the initial turning and mixing more difficult. It would appear that both have benefits and disadvantages and so should be regarded as a matter of preference.

A daub may be stored, but should be covered with plastic sheeting or placed in sealed containers to avoid drying out. Storage life of a completed daub is

[112] The process is described by Harrison (1999), p.22-23.

limited to a few weeks because of the risk of decay of straw or other fibre. If storage is anticipated, the addition of the fibre may be delayed until immediately prior to application. After storage, a daub will require ‘knocking up’ by way of a final mix during which the straw may be incorporated.

Figure 38. Knocking up a cat in the hand.

Figure 39. Cats form a homogenous daub.

. Figure 40. Consolidating the daub surface and edges of cats using a damped pad

Figure 41. Using a piece of lath to bring the daub up against the frame edges.

Application of Daub

Prior to daubing an historic building, it is advisable to create test panels with which to verify the performance of a daub. Alternatively, a single panel should be used to evaluate the materials and workmanship prior to carrying out large-scale works. Application was either by throwing or by placing of cats.[113] From the evidence of large cracks in historic daub, throwing of a wetter mix may indeed have been a common technique but, for conservation work, it would be judicious to choose the dryer mix, placed as cats, so to minimise cracking and maximise strength.

The method by which daub cats are applied to a wattle or lath backing is as follows: [114]

1. Thoroughly dampen the withies or lath with a sprayer. They should not be dripping with excess water.
2. Form a cat of daub in the hand and kneed it to ‘knock it up’ [Figure 38].
3. Working from the base of the panel, press the cat *in* and *down* into the wattle so to ensure the daub is well keyed into the backing.
4. Work along the panel, then upwards, merging each cat with adjacent ones so to form a homogeneous mass [Figure 39].
5. Build up additional layers of cats to the thickness of the timber frame.
6. *Roughly* flatten the surface using a damp (but not wet) sponge wrapped in chamois leather [Figure 40]. Alternatively, a ‘bagger’ can be used.[115]
7. Using the end of a piece of lath or a suitable modelling tool, compress the outer 20mm of the panel against the timber frame [Figure 41].
8. Finish the panel to the local tradition before drying commences:
    a. If panels are not to be plastered, add detail or decoration.
    b. To accept a plaster, key surface of daub with a comb scratcher.

Cracking of new daub is not a sign of poor workmanship but is caused by drying of the clay. Large cracks, those greater than, say, 2mm, may be a result of a highly shrinkable clay, excessive fines in the soil, or indicative of too much added water. Even so, lateral cracking does not necessarily mean poor bonding to the wattle: cracks are likely to be reinforced by the fibre and may therefore be considered as cosmetic. They may subsequently be filled either by reworking the re-dampened surface of the daub or by filling with fresh daub after rewetting the cracked edges. Where panels are to be plastered, cracks in the daub will subsequently be filled and may be considered positively in providing an additional key.
Evidence of intermixing at the interface of plaster and daub has been found, suggesting that plastering was sometimes done immediately after daubing. Experiments to duplicate this method at Bowhill gave satisfactory results, with

[113] Lander (1986), p.210, suggests throwing a daub that has been made soft using plenty of water.
[114] Thompson (2003), p.3.
[115] Harrison (1999).

few cracks transmitted up through the plaster. It was concluded that the lime might stabilise the daub at the interface, thereby inhibiting cracking.[116]

Suppliers

Supply of materials and tools to the conservation industry has much improved over the past decade and now most items required for wattle and daub renewal and repair are available from multiple sources. A guide is provided in Appendix 3.

5.5 Building Regulations

The legislation defines 'building work' as including extensions, 'material alterations' (substantial changes that make matters less satisfactory) and 'changes of use' and such work must comply with the Building Regulations.[117] They are particular relevant to wattle and daub in the requirements relating to Part A (structure), Part B (fire safety), Part C (resistance to moisture), Part E (resistance to the passage of sound) and Part L (conservation of fuel and power).[118] Fortunately, Parts B, E and L have specific provision for 'historic buildings', defined in the 'approved documents' as: listed buildings; buildings situated in conservation areas; buildings which are of architectural and historical interest; those which are referred to as a material consideration in a local authority's development plan; buildings of architectural and historical interest within national parks, areas of outstanding natural beauty, and world heritage sites. Most importantly, recent amendments to approved documents have extended the definition to include 'vernacular buildings of traditional form and construction'. This, therefore, embraces *all* construction in which wattle and daub is likely to be found or specified. However, the phrase is presently limited to Parts E and M (access).

Additional UK legislation protects listed buildings and, due to the nature of the listing criteria, most timber framed buildings which survive in anything like their original condition will be listed.[119] Superficially, these two sets of legislation appear to conflict, but when properly understood they provide capacity for the proper conservation of wattle and daub. Therefore, when planning work, it is important for the architect, owner or conservator to understand the compensations for historic properties within the legislation so that the special character of a building is not harmed. The majority of circumstances under

[116] Harrison (1999), pp.88-89 suggests that further experiments would be help test this hypothesis and characterise the effect.
[117] A full definition can be found in the legislation, The Building Regulations 2000, paragraphs 3 - 6.
[118] The relevant part of the requirement is to limit the amount of heat lost through the building fabric.
[119] These criteria are described in PPG15, Paragraph 6.11. In a situation where work on an unlisted building of unknown origin results in discovery of timber framing, ethics suggest that work should cease and the local conservation officer be consulted.

which the building regulations need to be considered can be categorised as: [120]

1. Repairs requiring ‘substantial replacement’ of existing wattle and daub.
2. Reinstatement of wattle and daub infill to a listed building.
3. New build (including an extension to an existing property).
4. Change of use of an unlisted building.

An overview of the considerations is presented below, although a working knowledge of the approved documents and PPG15 is required for a full appreciation.[121]

Repair

In considering Part L, the approved document states that the requirement can be met, [122]

> ‘when substantially replacing complete external walls or replacing their internal renderings and plaster, [by] providing a reasonable thickness of insulation and incorporating reasonable sealing measures.’

The key is the phrase ‘substantial replacement’, meaning that all minor repairs may continue to use the traditional craft methods. The provisions for all ‘historic buildings’ means they should also continue to use craft methods so not to jeopardising the building’s character or its long-term durability. Consequently, the need for improved wall insulation is limited to substantial replacement of infill in those few properties not presently within the Part L definition of an ‘historic building’.

With regards to Part A, replacing staves must not reduce the structural performance of the building. This must be borne in mind when assessing the load-bearing role that staves may have adopted in the event of the poor condition of a timber frame.

[120] Work that triggers application of the regulations is outlined by English Heritage (2002), p.7.
[121] Approved Documents are available from the Office of the Deputy Prime Minister (ODPM).
[122] ‘Approved document L: Conservation of Fuel and Power’, ODPM.

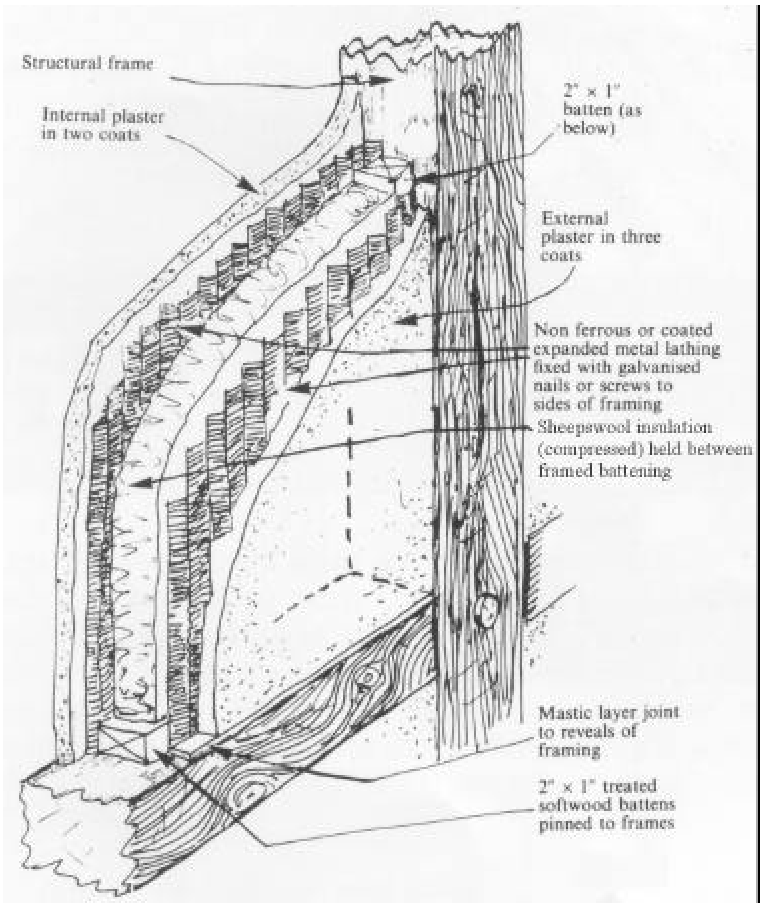

Figure 42. Panel upgrade using central sheepswool fibre. Adapted from Reid (1989).

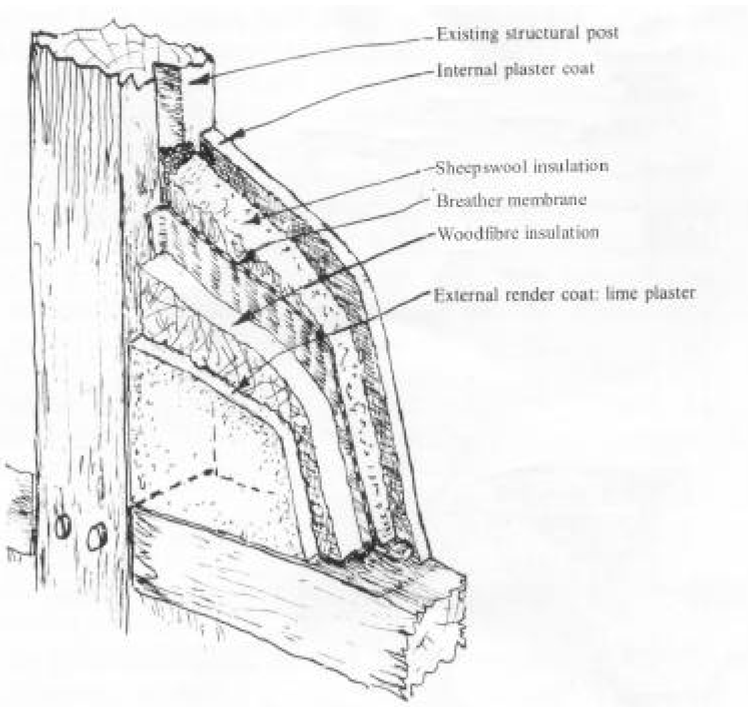

Figure 43. Upgrading with rendered woodfibre board and sheepswool insulation. Adapted from Reid (1989).

Reinstatement

The restoration of wattle and daub into an 'historic building' is likely to be straightforward from a regulations perspective due to the provisions for such buildings in the approved documents to Parts B, E and L. The requirements regarding Part A outlined for repairs also apply to the removal of brick infill.

New Build and Change of Use of Unlisted Buildings

In these circumstances, it is frequently a challenge to find ways in which wattle and daub can be made to meet the requirements of the building regulations.

Part A should not be problematic if a new timber frame is properly designed: the wattle and daub bares no structural consideration.

For Part B, a 'fire engineering approach', i.e. a solution designed specifically for the individual building, is most likely to be needed in order to get a building incorporating traditional wattle and daub to meet the requirements.

The fourth requirement of Part C (for walls to resist the passage of moisture to the inside) is often troublesome for traditional buildings. However, since the requirement is, 'limited to securing the health and safety of persons', a timber frame building may still be able to meet the requirement through its reliance on traditional performance (i.e. allowing the walls to breathe): wattle and daub panels that are properly maintained are unlikely to conduct excessive moisture to the inside of a building. The main considerations for this requirement lie not with the elevated wattle and daub panels, but with the brick or stone footings.

Since Part E, as amended and effective from 1st July 2004, now has added provision for all 'vernacular buildings of traditional form and construction', the performance of wattle and daub should not inhibit its retention or specification.

Part L presents the most troublesome issues since the thermal conductivity of wattle and daub is almost certainly relatively high and it hence has a poor U-value.[123] There appears to be no published research on the thermal properties of wattle and daub and so remains an area that would benefit from further study. A few tests have been performed on cob, but, unfortunately, wattle and daub and cob are too dissimilar for an extrapolation of thermal performance to be valid.[124] It may be possible to compensate for the thermal performance in other aspects of the building design so that the requirement can be met. However, if this is not feasible, then the panel design may need to be 'upgraded'. It is under these circumstances that the use of modern materials can sometimes be justified. Several methods are described by Reid (1989), two of which are shown in Figure 42 and Figure 43 having been modified to use sustainable materials.

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[123] U-values are a measure of the transmittance of thermal energy for a given wall material of given specification (e.g. of a particular thickness). The present minimum requirement for new construction of exposed walls is 0.45 $Wm^{-2}K^{-1}$.

[124] The thermal performance of wattle and daub is reliant on the composite performance of the earth with the wattle and may also be modulated by edge-effects at the outside of a panel. Preston (1991) reports an evaluation of a cob wall with a U-value of 1.49 $Wm^{-2}K^{-1}$. Pearson (1992), p.54, reports U-values of 1.12 $Wm^{-2}K^{-1}$ and 0.67 $Wm^{-2}K^{-1}$ for cob walls of 300mm and 600mm, respectively.

Where a change of use is being considered, the principles of conservation may lead to a more radical solution: it may be preferable for the long-term survival of the historic wall fabric to dry-line and insulate the walls internally, leaving the wattle and daub ‘as is’. The dry-lining is here considered a reversible measure to meet present regulations. The disadvantages are the closing-in of the frame and loss of character, but since regulations change and technology improves, this approach may buy extra time for the historic fabric.

6 Wattle and Daub in Wiltshire

From the viewpoint of a West Country timber building conservator, the national knowledge base on wattle and daub cannot immediately be applied since its relevance to the region is not usually stated. This problem does not arise when working in The South, East or West Midlands since much information is explicitly stated as applying to one or many of those areas. For this reason, it is useful to study an area such as Wiltshire in order to validate the applicability of national knowledge, reject other nationally-based data and add local knowledge based on new discoveries.

The intent of this study was to look at variations of wattle and daub across the county. Different styles were anticipated due to the diversity of geology, density of woodland and agricultural practice and social development.

An initial l review of the literature indicated that detailed information did not exist and therefore fieldwork would be necessary. In the absence of any guiding factors, a random sample of buildings was planned, for which any exposed wattle and daub would be recorded and analysed. To assure a comprehensive and consistent method of description, use was made of the recording template (Appendix 2).

Where samples of loose daub could be taken (i.e. where they had fallen from the wattle), these would be analysed by the methods described in Section 5.4.2 and so provide a more detailed understanding of the material. Further, if sufficient samples were available, it might be possible to test the opposing hypotheses stating, on the one hand, that soils from around the building would be used, and, on the other, that transportation of materials was frequently practiced. This could be tested by looking for a correlation between daub soil types with the underlying ground, the latter established using geology maps. To allow for localised deviation from the maps, such as caused by outwash, the house owner was also asked for a description of the soil.

6.1 Documentary Evidence

Information on the history of building in Wiltshire is increasingly comprehensive, with new material frequently published. A primary source remains the Victoria County History of Wiltshire. Surveys, such as by the Royal Commission on the Historical Monuments of England (RCHME) and books focussing on specific towns or villages are also available. Other sources investigated were the records of the archaeology department and museum objects of Wiltshire County Council Library and Museum Services, Wiltshire Archaeological and Natural History Society (together with their journal Wiltshire Archaeological Magazine) and private archaeological businesses in the county. Unfortunately, these all stop short of providing documentary evidence of any detailed construction methods and so give little insight into the use of wattle and daub beyond stating where it was used as infill.

However, the county is fortunate in having the Wiltshire Building Record (WBR), an archive invaluably organised by location, accompanied by three books by Pamela Slocombe published in association with The Record. These books provide an invaluable insight into the development and regional variation of Wiltshire's buildings. Unfortunately, they do not provide specifics on wattle and daub, other than stating that during the 17th century a few buildings appear to have used decorative brick nogging as the original infill, often in a herringbone pattern.[125]

A review of the WBR records were found to be limited with respect to wattle and daub in that only a cursory mention is provided, if any. However, the record was useful in identifying buildings that represented likely candidates for the retention of the material and so formed a basis for organising the fieldwork.

[125] Slocombe (1988), p.9.

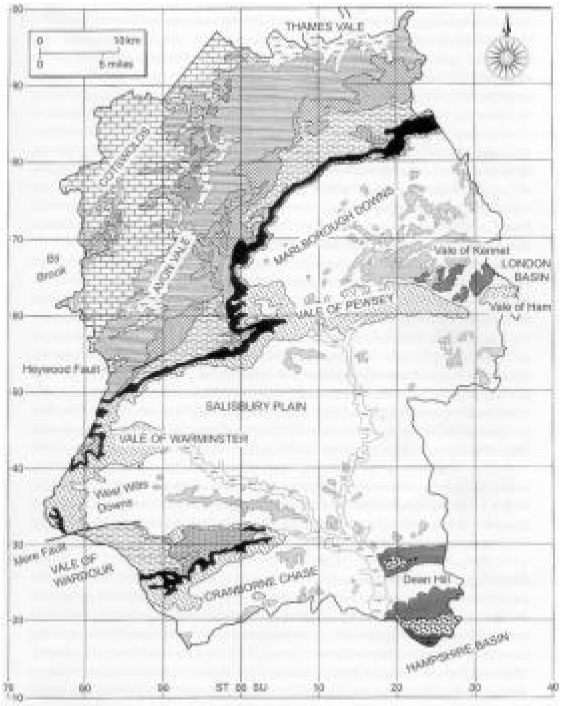

Figure 44. The geology of Wiltshire. From Geddes (2000).

Figure 45. Predominant building materials of Wiltshire. From Slocombe (1989).

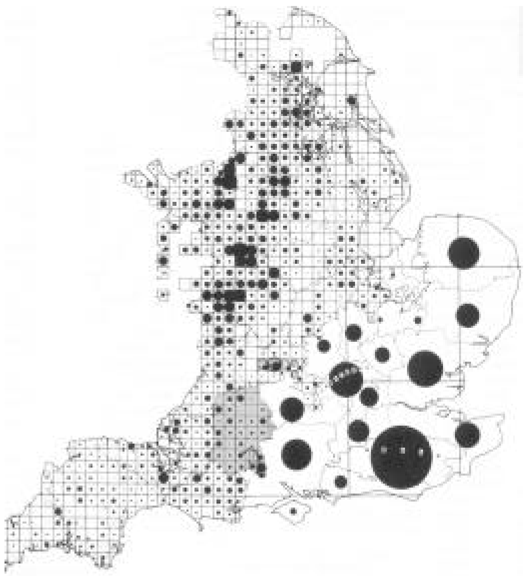

Figure 46. Woodland density shown by circles at 10 times map scale, with Wiltshire and the west mapped by a 10km grid and south eastern districts by county. Amesbury (marked ‘A’) was unique in owning woodland in other parts of the county. From Rackham (1976).

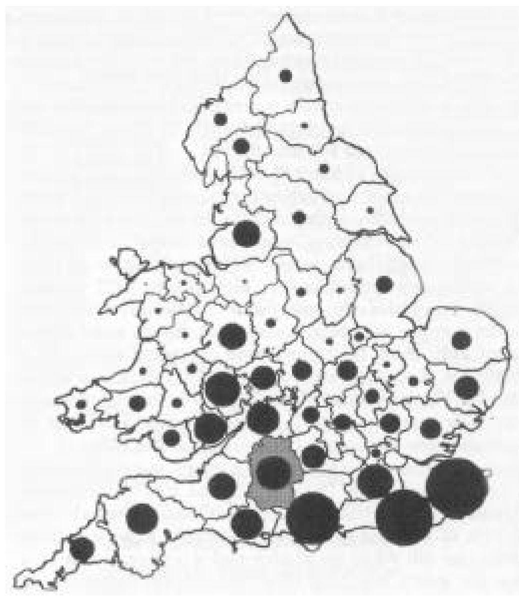

Figure 47. Density of coppice woodland, showing Wiltshire rich in underwood. From Rackham (1976).

6.2 Geology and Land Use

Wiltshire has a diversity of geology and this reflects historic differences in land use.[126] The northern parts of the county are at the edge of The Cotswolds within the belt of oolitic limestone, incorporating the Bath Stone of the west, around Bradford-on-Avon and Box. To the southeast of the limestone belt lies an area of sands and clay before reaching the chalk of the Marlborough Downs and Salisbury Plain. Chalk is also the predominant rock of the southern parts, although the southwest also includes an area of Jurassic rocks. These areas are cut through by vales containing river deposits such as the Avon in Salisbury and Amesbury and the Wylye in Wilton [Figure 44].[127]

Much rebuilding in stone occurred in the county, with vast quantities of limestone used in the north and west, chalk 'clunch' in the south and brick refacing throughout the county [Figure 45]. These materials often disguise timber framing, making it difficult to predict where wattle and daub might be found. Surviving structural frames exist throughout the county, although the majority are clustered in areas where stone was not initially available, such as to the east in the Pewsey Vale and the towns of Marlborough and Devizes. The medieval City of Salisbury also has a large number of surviving frames. This information was used to ensure fieldwork covered all main geological areas of the county.

It was explained in Section 3.1 that the timber-framing and materials used in wattle and daub reflect the distribution of timber trees and coppice in the vicinity. Domesday records show that Wiltshire had a high density of woodland in the north-western and south-eastern parts and varying amounts in others: the county was not as wooded as areas such as the Weald and West Midlands but neither was it devoid of timber [Figure 46]. However, Wiltshire was rich in coppice woodland, probably due to its use for sheep penning as well as fuel [Figure 47]. The predominance of coppice over timber woodland may be used to predict that withy would be more common than lath in the wattle and daub of Wiltshire buildings and could be tested by the fieldwork.

6.3 Fieldwork

The extent of the work was limited by time: two weeks allocated to preparation, two weeks in the field and one week to assemble apparatus and perform analysis of daub samples. It was anticipated that coverage would be limited by the speed at which the county roads could be traversed.

Preparation included identifying suitable timber buildings and their location. The WBR records were used in conjunction with the list descriptions of listed buildings. Whilst a local dataset would have been preferred, this was not available. However, the 'Images of England' web site provides a manner of

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[126] The phrase 'chalk and cheese' originates in Wiltshire from distinct districts of farming practice. These reflected the suitability of the chalk and Cotswold hills to sheep and corn farming versus the clay and sand Avon Vale to dairy cattle farming.
[127] A detailed description of rock throughout the county is given by Geddes (2000).

basic online search.[128] The query used was defined by county and administrative district together with the keyword ‘daub’ in the list description text. This provided a list of buildings that were known to contain wattle and daub at the time of listing survey or resurvey, although due to the limitations of the listing process it was expected that this would represent a small proportion of the buildings in the county containing wattle and daub.

Figure 48. Locations of inspected wattle and daub. Several buildings were surveyed in some locations.

6.4 Surveyed Buildings

Figure 48 shows the locations of surveyed wattle and daub. A full inspection of the panels was only possible in a limited number of cases due to a variety of factors: often the daub had been removed or, where the panels were complete, the wattle was not visible. Included in the survey were daub and withy museum objects that were from a known origin and so could be studied in context with the frame from which they had been removed. Appendix 4

[128] Images of England (2004) is intended as an online photographic record of listed buildings. However, the system also incorporates the list descriptions of all listed buildings and, for registered users, searchable fields include building materials (i.e. ‘timber’), locality, address and free text. Unfortunately, due to the nature of web pages, the output is ‘flat’ (i.e. the organisation by field name is lost) and the full list description is only viewable after user input on the individual records retuned by the query. A dedicated online database of listed buildings was stated by the Department of Culture, Media and Sport (DCMS) in July 2004 as, ‘Phase One - making the database available to the general public will take place sometime in 2003’. However, as of 1st August 2004, all references to these plans have been removed from the DCMS website. The future of an online listing system therefore seems uncertain.

presents the extent to which each wattle and daub panel could be surveyed. Appendix 5 provides details of the analysis of eight collected daub samples. Highlights from the fieldwork are described below.

Watson's (William Russel's House), Queen St., Salisbury
Originally an open hall dating from 1306, of post and truss construction. There is exposed wattle and daub in one of the side walls that now abuts the later structure of The House of John A' Port, but the external face of this arch-braced panel remains intact between the two building frames.

The outer face had a top coat of approximately 1mm and disaggregation indicated that it consisted of sharp sand, lime and cow hair. The internal face was similarly plastered, but with a red ochre limewash, possibly only covering parts of the panel, which would then indicate the remains of a wall painting.
The wider panel of those under the arch brace was wattled by gradually inclining the hazel withies until parallel with the soffit of the brace. The withies were widely spaced, even where the panel narrowed on the right hand side.

Figure 49. Wattle tensioned in a narrow two-stave panel by entwining pairs of withies.

Figure 50. Sparrow-pricking to an internal panel. (The pegs in adjacent panels were to provide a key for plaster block work, now removed.)

The daub was reddish-brown, with patches of dark brown. It was of moderate strength and consisted of a very clayey fine sand with chalk and flint. Organic matter consisted entirely of dung residue. Analysis found that no fibre had been incorporated into the mix. The geology under the medieval city is complex. From maps, it is likely that the building rests on Brickearth and

Valley Gravel, which would correspond with the daub characteristics.[129] However, Alluvium, Plateau Gravel and Lower Chalk are also close by, any one of which may also have been used in the daub.

The soffit of the brace had augered holes for the staves, with a continuous V-groove along the bottom rail. A lower panel utilised a short stave nailed to the soffit of the brace where access made the use of an auger hole troublesome. This and the adjacent narrow panel had sufficient width for only two staves that alone cannot provide tension in a wattle. The problem was overcome by entwining pairs of withies as shown in Figure 49. Whilst not a documented technique, it appears to form an effective and efficient solution for narrow panels.

A further example of wattle and daub present in the building was a panel of an early false hammer-beam truss spanning the centre of the hall. Believed to be in its original form, both the plaster top coat and surrounding timber was decorated with sparrow-pricking [Figure 50].

Figure 51. Outer staves nailed against soffit of frame.

<u>Laburnum Cottage, Stanton St. Bernard.</u>

The cottage is a post and truss structure, probably early- to mid-17th century. The half-hipped roof contains a usable attic. A central truss holds wattle and daub panels that form a partial partition, which may at one time have completely closed the truss.
The remaining wattle and daub forms triangular panels between principals and diagonal braces and rectangular panels below rails.
Both panels inspected were found to contain a mix of whole, halved and quartered hazel withies woven around oak staves. The outer staves of the triangular panels were affixed by nailing against the soffits of the principal rafter and brace. Staves were secured into the base timber using V- mortices. The position and detailing suggests these panels were probably added after the original construction. No plaster was evident.
The daub was light grey with chalk particles mainly of 1-2mm diameter and straw in lengths up to 30mm. It was of moderate strength. A full analysis could not be performed due to a small sample size.

[129] Ordnance Survey (1903).

Figure 52. Smoke-blackened wattle and daub at apex of cruck.

Figure 53. Cross-section of a stave. Other evidence indicated this was intentionally chamfered rather than representing the wany edge of the riven timber.

Church Farmhouse, Urchfont

The house, previously a farmhouse, is cruck-framed and dates from c.1450 with later alterations. A central truss was found to have been closed with wattle and daub between the blades down to tie-beam level. Only a small area was plastered, possibly an indication of a repair. The remainder of the partition was roughly finished with daub and, since it was heavily smoke-blackened, may have formed part of the original construction [Figure 52]. The wattle was of whole hazel withies woven around long staves running the full length between blade and tie-beam. In places, these had been roughly chamfered, which was most visible where staves had been cut to enable access along the roof space [Figure 53].

The daub was a creamy-beige with very few cracks and was extremely difficult to break by hand. There was no indication of chalk or lime particles and the only fibre visible was straw of 10-27mm lengths. Particle size analysis showed the daub to be a clayey sand with straw, hay and evidence of dung.

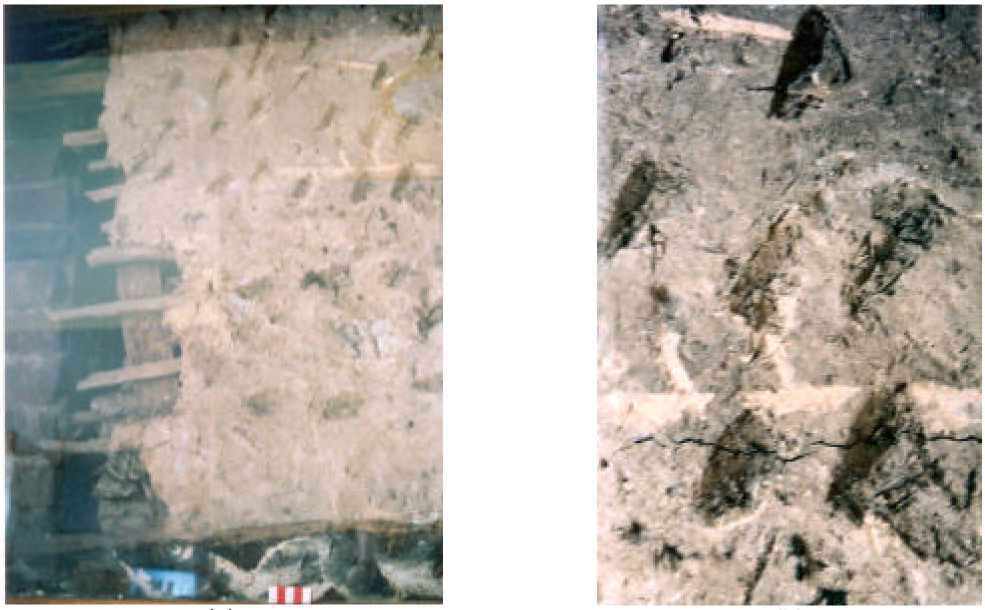

Figure 54. Wattle of whole and split withy (a) and enlargement of sparrow-pricking (b).

Retreat Inn, Milford Street, Salisbury

Room N$^{o.}$ 4 of the 15th century inn retains encased wattle and daub, probably an external panel dating from the time of construction. Visual inspection showed the external face to have plaster of approximately 5mm, with the appearance of a lime:sand mix. Internally, there was no evidence of plaster and the surface of the daub had been decorated with sparrow-pricking, spaced randomly and approximately 5-8mm apart [Figure 54]. The daub was light brown and contained visible particles up to approximately 10mm diameter, although most where ≤2mm. Straw fibre was noted.

66 St. Anne Street, Salisbury

The post and truss structure, probably dating from c.1480, has wattle and daub remaining within a central truss above collar level. There was no evidence that the daub had been plastered and was smoke-blackened. The seven staves were oak, or possibly chestnut and their tops were nailed to the soffit of the principal rafters. Evidence showed that the outer-most staves were orientated diagonally, being nailed along the soffits. The stave bases were held by the collar using a continuous V-groove. No

Figure 55. Staves attached to soffit of principals, whole withies and smoke-blackened daub, c.1480.

evidence of stave chamfering was visible. Withies were of whole hazel [Figure 55]. The daub was light brown with a rough surface and quite friable. Analysis showed it to be a clayey sand with chalk, straw, a little hay and dung.

6.5 Evaluation

A comprehensive evaluation of Wiltshire practices was precluded by the small sample size of the study. However, consistency in certain limited aspects of the study did allow the following deductions to be made.

<u>Decoration</u>
Whilst most panels were plain, one external and two internal faces had sparrow-pricking – an incised stick-work decoration.[130] The external work had been subsequently covered by plaster and it was initially considered that the indentations could have been a key for plaster. However, the orientation of incision was inappropriate for such a function so it was concluded that the external daub of The Crofts was decorated with sparrow-pricking prior to the later addition of a plaster top coat.
Two internal plastered panels were observed to have been washed with red ochre. It was not possible to determine if these formed a part of the original scheme, although this may have been determinable through paint analysis.

<u>Plaster Top Coats</u>
From twelve internal partitions, eight were unplastered and the others, mainly in living areas, had coats varying from a thin skim of <1mm up to 7mm. It is therefore possible that living spaces were generally plastered and other partitions such as attic storage would mostly be left plain.

The difficulty in studying external panels was that the detailing of most were necessarily hidden, repaired or replaced. Since only two panels inspected were known to have survived in their original form – one daub plastered and the other plain – it was impossible to infer any regional tradition.

All top coat plasters appeared to be lime:sand mixes, although fibres included any one or a mix of hay, straw and, most commonly, animal hair.

[130] Innocent (1916), p.199, states that ‘sparrow’ is a Surrey word for a thatching ‘spar’.

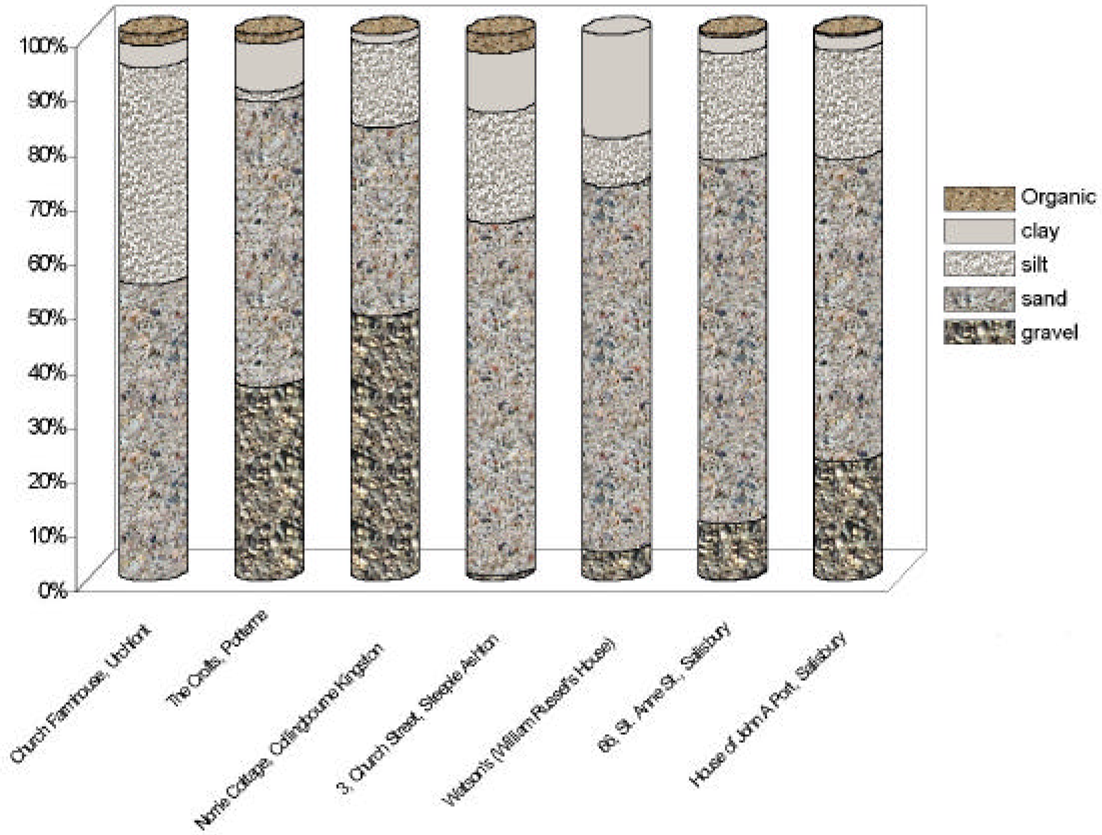

Figure 56. Particle size analyses of daub samples.

<u>Daubs</u>

The characteristics of the daubs varied greatly in both appearance and composition. Some were heavily crazed and held together mainly by the fibre, whilst others had few cracks.

The soils were, on average, clayey sands, the mean clay content being 7% and a mean sand component of 57% [Figure 56]. These figures are consistent with those presented in the literature as being suitable for repairs, as discussed on page 63. The strongest sample had no aggregate larger than 2mm and conformed to the recommended proportions for repairs. However, the sample from William Russel's House demonstrated that a durable and mainly crack-free daub could be created from a soil with high clay content (19%) and using no fibre. The three most friable samples corresponded to those with the highest proportions of gravel. These were noted to be outside the 20% upper limit for gravel recommended by the literature.

All samples contained a significant proportion of calcium carbonate, although its form – calcareous aggregate, chalk or lime – could not be determined using the available apparatus. Visual inspection showed four of the seven samples to contain chalk, abundant in many parts of Wiltshire. Lime would have been readily available throughout the limestone and chalk districts that together dominate the county's geology.

In order to determine whether the soils were from the building site or transported (see Section 3.6), a comparison was made between daubs and geological survey maps. It was found that soils for the daubs in most cases

could have been excavated from the site of construction and in all cases from within a radius of 2km. Due to the suitability of all soils observed in this study, it was neither possible to validate nor invalidate the hypothesis made by Warren (1999) that soils were readily transported large distances to areas lacking suitable materials.
Analysis found that in addition to straw and hair, grass, probably dried as hay, was commonly incorporated. This corresponds to analyses of daubs from the Weald, as described by Ashurst and Ashurst (1988a). The proportion of dung could not be determined using the available apparatus.

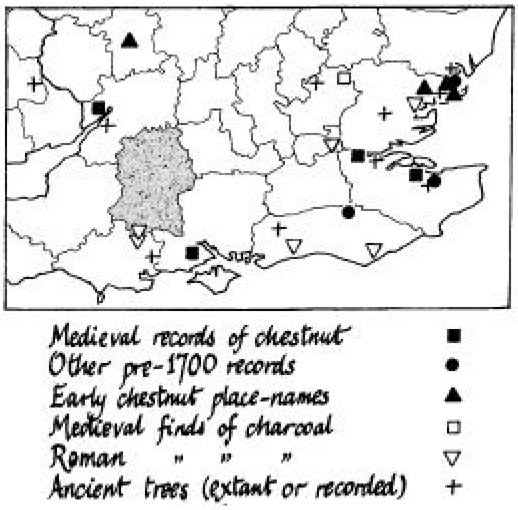

Figure 57. Chestnut may have existed on the southern fringes of Wiltshire since Roman times. From Rackham (1976).

Staves and Frames

Nearly all staves were found to be riven oak. One panel, from a Salisbury building, may have used chestnut. Whilst apparently unusual for Wiltshire, there is evidence that chestnut was at some time grown in the area, but its use may have been restricted to the south of the county [Figure 57].
Dimensions of staves varied greatly, with little attention, if any, given to chamfering the corners [Figure 58].
For simple panelling, the only detailing of stave holes in the soffits of the frame were augered holes or chiselled mortices, the former being the most common. For non-rectangular panels, such as closed-trusses and bracing, staves were often crudely nailed to the non-orthogonal frame member.

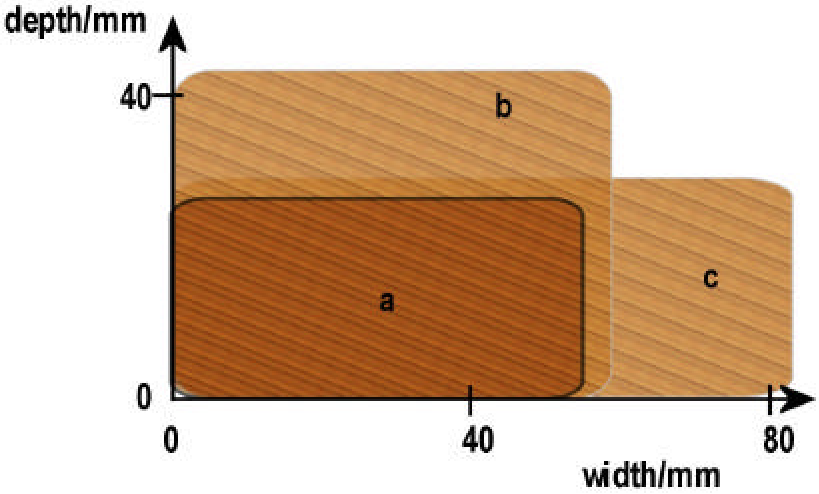

Figure 58. Cross-section dimensions of surveyed riven staves: (a) average; (b) deepest; (c) widest. Approximate scale 1:1.

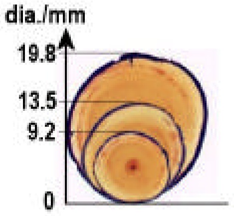

Figure 59. Withy diameters: minimum, average and maximum. Approximate scale 1:1.

Wattles

Hazel is clearly the prevalent material in Wiltshire for wattle work. One example of birch was also noted. No riven lath wattling was found. This is compatible with the hypothesis that choice was determined by local availability of coppice versus timber woodland.

Diameters of withy in a single panel were on average 13.5mm and typically varied between 9mm and 20mm, which is not at odds with the 12-25mm suggested by the literature (Section 3.5) [Figure 59]. However, extremes of 5mm and 30mm were observed.[131] The hazel was frequently used unsplit, but often mixed in a panel with halved or quartered stems. There was no evidence that any attempt was made to remove the bark from the withies to reduce risk of decay.

6.6 Wiltshire Conclusions

Wattle and daub in the county largely comprised oak staves, hazel wattle and plain daub. Daubs were of local soils with hay, straw and occasionally hair. All were calcareous, due either to the nature of the aggregate, chalk or the inclusion of a lime binder. Plaster top coats may have been more commonly used for living spaces and external faces of panels. Decoration included incised stick-work, to either plain daub or plastered finishes.

This study of wattle and daub was limited chiefly by the ability to locate and gain access to exposed panels. Knowledge could be enhanced through continued and systematic recording of wattle and daub using a methodology similar to that described above and by striving to record temporarily exposed external panels during repair.

A fuller understanding of the relationship between daubs and the soils surrounding a building could be gained through soil samples being taken at each site together with a larger sample of buildings. Additionally, more detailed soil analyses, including identifying the form of calcium carbonate, may have been possible if a soil mechanics laboratory service could have been used.

[131] Full details of withy dimensions are illustrated in Figure 62 of Appendix 4.

7 Conclusion

The study found that wattle and daub was a craft extremely resilient to the evolving pattern of timber construction, possibly more so that any other building material or technique. Examination of previous works showed the most widespread form in England was a woven wattle covered with a plain daub, practiced since the Iron Age and prevailing to the end of the Tudor period, after which it suffered a slow demise. The infill often comprised oak staves and hazel withies with daub routinely consisting of soil, dung and fibre. Frames of close-studding demanded the adaptation of the wattle to suit, such as the introduction of lath, and further changes were required for braces and decorative framing. However, during the course of the research it was established that the craft is described better by its diversity than by its regularity: the complexity in categorising and describing this variety was an underestimated aspect of the study. For example, illustrating the variations using geographical distribution maps might have assisted the reader.

The forms of naïve decoration had been d escribed thoroughly by the main works: raised pargetting, incised work, and internal wall painting. However, little attention had been given to describing the applicability of each form to those areas of the country less renowned for timber building yet still rich in surviving buildings. This topic remains worthy of future examination.

The examination of material characteristics was found to provide a deeper insight into explaining the choice of materials, historically and with regards to conservation work. Soil mechanics were used to demonstrate how clayey soils were chosen for daub to provide a workable and strong fabric. However, shrinking clay invariably caused cracking and it was shown how the inclusion of fibre acted as reinforcement as well as dispersing large cracks within the daub. The reasoning behind the ubiquitous specification of dung was more illusive. Several hypotheses had been documented as to the beneficial properties, yet little supporting evidence was provided to substantiate them.
A study of the ruminant digestive system resulted in the development of a new hypothesis: that the indigestible lignin in cattle feed, originating from plant cell walls and passed into the faeces, improves the stability and workability of a daub. However, as a field unfamiliar to the author, it is acknowledged that the treatment of this topic was somewhat crude and so remains an area requiring further research. In addition, since access to and handling of cow dung is being increasing controlled by legislation, its continuing use in conservation work is being threatened. It is therefore becoming increasingly urgent to verify the reasons for its inclusion and whether modern alternatives exist.

It was found that discussion of the values and the principles of conservation specific to wattle and daub is not well attended to by existing works. A description in terms of patina, decay and age-value was therefore defined. In association with these values, it was shown how UK legislation operates to encourage the retention of historic wattle and daub. Within this framework, principles for conservation were established and causes of decay and methods of repair explored. The action of absorbed water was noted to be the singly most damaging cause. It was illustrated how most wattle and daub can be conserved using carefully chosen traditional methods and thereby demonstrating that replacement with other infill material is usually unjustified.

The Wiltshire case study showed a great diversity of methods was used in the county. It revealed previously undocumented variations such as a method that enables withies to be woven using only two staves and a robust 14th century daub that contained no fibre. Most panels were based on hazel withy woven around oak staves. A frequent solution for placing staves within braced panels or within trusses was to simply nail them to the soffits of the sloping timber. Further work is required to establish the extent to which Chestnut was used, especially in the southern part of the county.

Wiltshire daubs were found to be clayey sands and calcareous, due to either the use of chalk or the addition of slaked lime. The soils in proximity to the building or within easy carting distance were used. There was no evidence of long-distance transportation of earths.

Examples of decoration were minimal. However, the three examples, from 14th, 15th and 17th centuries, were all of the same style and so it is reasonable to conclude that that sparrow-pricking was probably common in the region.

All aspects of the case study were limited primarily by the scarcity of existing and exposed work. This illustrates the need for ongoing and systematic recording. Adopting the recording template developed for this study, or a similar tool, would help integrate data from disparate sources and so assist in identification of regional variation.

Through this investigation, the following practical observations for conservation work in Wiltshire were identified:

1. Wattle and daub repairs should aim to use only materials from the vicinity of the building.
2. Care is needed to avoid incorrectly identifying incised daub decoration as keying for a plaster top coat.
3. Staves may be nailed or screwed to the soffits of the frame where access is limited, as long as vibration will not damage historic daub.
4. The most durable of Wiltshire’s calcareous daubs tend to have a small proportion of gravel (0-10%).
5. Strength of a daub may be improved without causing cracking problems, by increasing the clay content up to 19% (or above, subject to further research).

This study demonstrates the current inadequacy of professional knowledge within the conservation industry and highlights the lack of interest in one of the most historically widespread building techniques. If nothing else, it has been shown that many a conservation professional concerned with timber framed construction is missing out on an essentially unexplored subject in which further research is likely to be very rewarding. One might say, “If you don’t look, you don’t know what you’re missing”. If the current custodians of historic buildings incorporating wattle and daub fail to take an interest then we will leave nothing of this tradition for future generations.

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Appendix 1: The Composition of Cow Dung

Cow dung is described by the study of ruminant anatomy and the nutrition of cattle. Ruminants such as cattle, horses, sheep and goats are herbivores able to digest plant material and are often seen chewing which forms part of the digestion process [Figure 60].

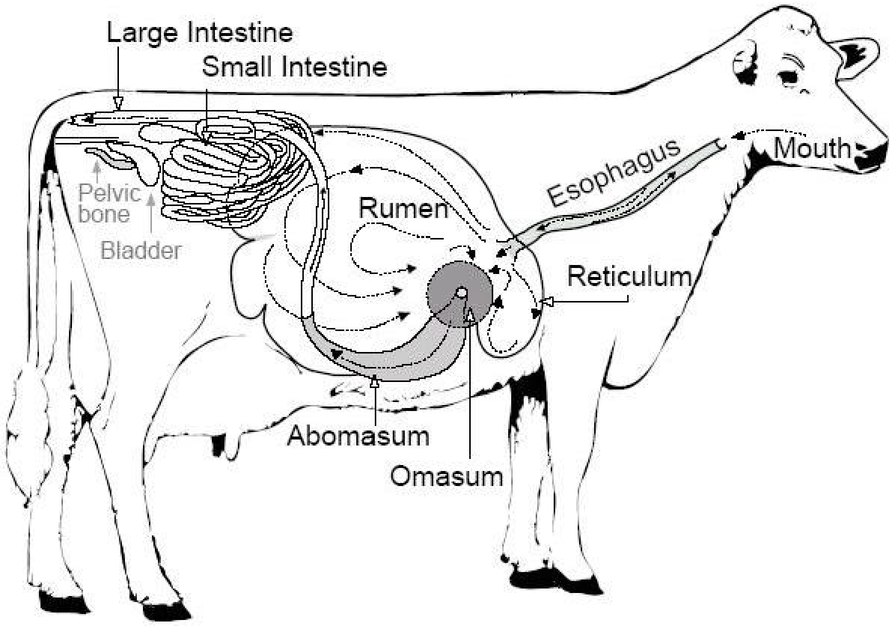


Figure 60. Ruminant digestive system.

The four stomachs of the cow include the reticulum, rumen, omasum and abomasums. The digestion of plant cells starts in the rumen, where microorganisms break down the feed by fermentation. These microorganisms eventually pass through the gut and are expelled, mainly dead, in the faeces.[132] The reticulum works to sort the contents of the rumen, passing on digested feed to the third stomach. The stems of plants and grasses contain fibre for rigidity and are composed of complex sugars such as cellulose and hemicellulose. These are mostly digestible, but cells walls also contain lignin, mainly insoluble, that is passed into the faeces.

The omasum recovers minerals and water and feeds these back into the rumen. The abomasums is similar to the stomach of non-ruminants in that it contains a strong acid and digestive enzymes. The small intestine secretes digestive enzymes for the digestion of carbohydrates, proteins and lipid and also absorbs some water, minerals and products of digestion (glucose, amino acids and fatty acids). The large intestine absorbs water and contains a small quantity of microbes that ferments the unabsorbed products of digestion. The remains are formed into faeces.[133]

[132] Hungate (1966), pp.1-7.
[133] Wattiaux and Howard (2000).

The main constituents of faeces are metabolic excretions (from living tissue) and undigested diet. The majority of these excretions include microbial debris (from microorganisms within the rumen and includes insoluble and soluble nitrogenous matter) and endogenous secretions (from the body of the cow) that include salts, sloughing of animal cells and mucus. The insoluble nitrogenous matter comprises cellulose and lignin that originate from the cell walls of the plants [Figure 61].[134]

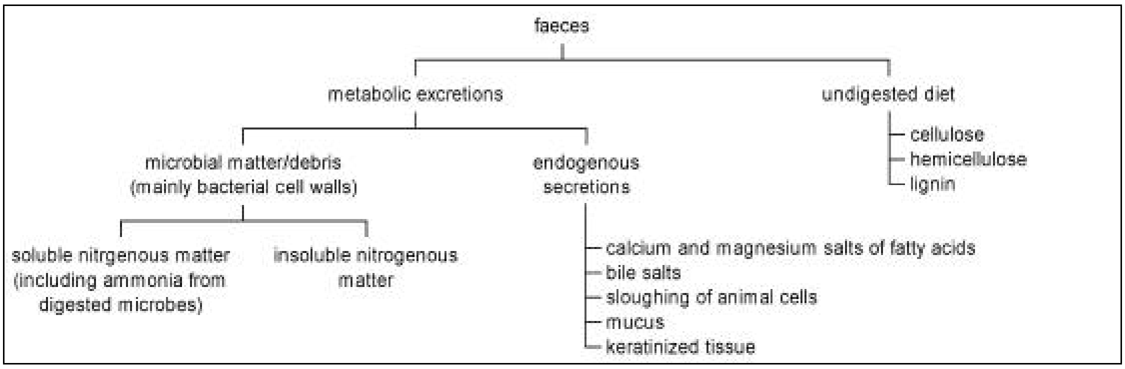
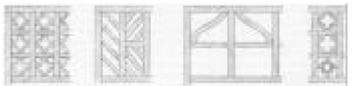
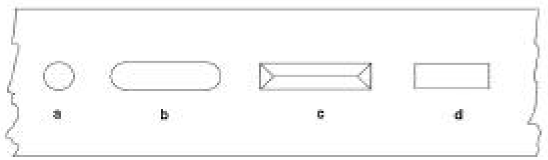


Figure 61. Composition of cow faeces.

[134] Van Soest (1982), p.39 and p.47.

Recording Sheet Reference Number: ________________		Recorded By: ___________________________
House name and address:		Location in Building of Recorded Panels [sketch]
O.S. Grid Ref: _____________________		
Frame Type	cruck ❒ post and truss ❒ box-frame ❒	
Approx. date of construction: _______________		
Recorded panel type (s): Basic ❒ Tension bracing ❒ Scissor bracing ❒ Small framing ❒ Close panelling ❒ Ornamental panelling ❒ 	Close Studding ❒ Arch bracing ❒ Arch tension bracing ❒ Parallel bracing ❒ Truss partition ❒	
Panel Location: Internal (partition) ❒ External ❒		
		Comments
Plaster Top Coat	Thickness (approx): ______mm Type: Lime-Sand ❒ Daub ❒ Decoration: (e.g. colour-wash, interior wall-painting, scratch pattern, pargetting): ___________	Description:
Daub	Fibre Type: Straw ❒ Hay ❒ Animal Hair ❒	Description (In-Situ):

	Sample Lab. Analysis? Yes ❒, Ref. Number: ________ No ❒		
	Owner’s or custodian’s description of subsoil:		
Wattle	Type: Lath ❒ Withy ❒	Material: ________________ (e.g. hazel)	
	Withies debarked? Yes ❒ No ❒ Partly ❒	Withy ends halved? Yes ❒ No ❒ Some ❒	
	Withies split? (tick multiple): Whole (round) ❒ Halved ❒ Quartered ❒		
	Orientation Vertical ❒ Horizontal ❒ Diagonal ❒	Diameter (mm) Min. __________ Max. __________ Avg. ___________	
Staves	Number of Staves: 0 ❒ 3 ❒ 4 ❒ other: ___	Stave Type: Poles (round) ❒ Riven ❒	
	Shape (x-section), if riven: End Staves: Central Staves:		
	Width: _____	Depth: _____	
	Distance between post and first stave: ______		
	Material: ____________________		
	Stave bottoms [sketch]:	Stave tops [sketch]:	
Timber Frame	Soffit stave holes:  	augered hole [a] ❒ augered mortice [b] ❒ V-mortice [c] ❒ chiselled mortice [d] ❒ Other: _______________ ❒	
	V-Grooves for withy/lath ends? Yes ❒ No ❒		
	Bottom V-groove: Continuous ❒ Other: ________________		

Sheet Ref. Number: _____________	Panel Recording Sheet Ref: Number: _________

Visual Inspection [Description of sample, 1x and 10x magnification, colour, cracking, additives, particles, breaking strength]:[135]

Visual Inspection of Disaggregated Sample [10x magnification]:

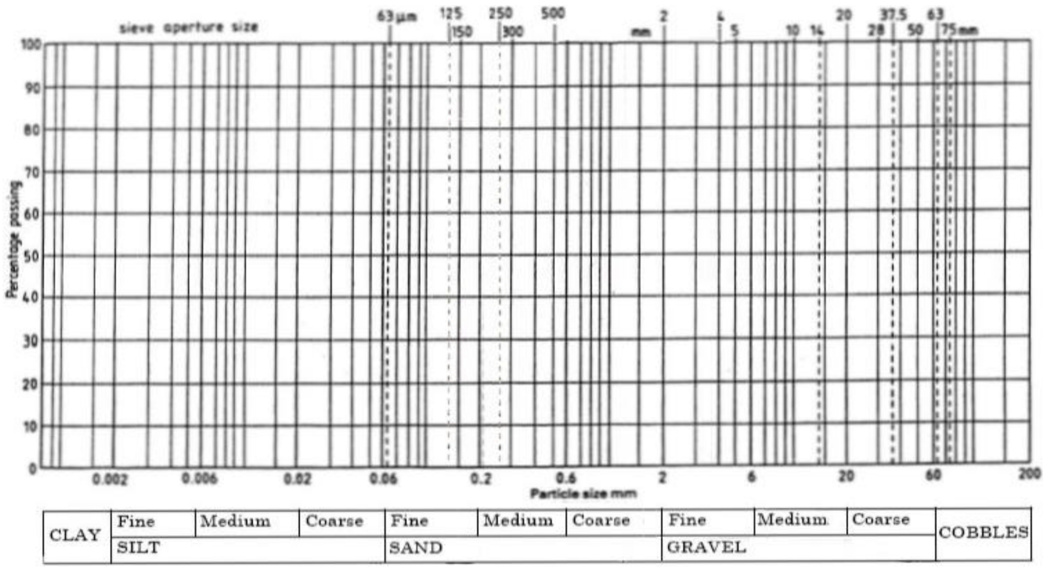
Sedimentation Analysis

Water (g): ________	Volume (ml)	Fraction (%)
Organic:		
Clay:		
Silt:		
Sand/Gravel:		

Sieve analysis

	Weight (g)	Fraction (%)
Total:		
Passing 4.0mm sieve:		
Passing 2.0mm sieve:		
Passing 500ìm sieve:		
Passing 250ìm sieve:		
Passing 125ìm sieve:		
Passing 63ìm sieve:		

Lime test [10% HCl] Effervescence: None (<1% $CaCO_3$) ❒
Visible (>1% $CaCO_3$) ❒ Violent (>20% $CaCO_3$) ❒



Plasticity [Hand Test results:]

Summary:

[135] See BS 5930:1999, pp.113-121.

Appendix 3: List of Suppliers

The most sustainable approach to the supply of woodland products is to uphold the tradition of local coppicing. Staves, withies and riven lath may be purchased from a woodman or, having sought prior permission from the landowner, hazel is easily coppiced by the conservator from local woodland and hedgerows. Coppice products are also available from conservation suppliers, but it is important that withies and lath are supplied green so to be sufficiently pliant. Local earths should always be used where suitable graded, thereby continuing the tradition and avoiding unnecessary transportation. The use of pre-mixed daub should be limited to those few situations where local material is no longer accessible, such as where valuable ornamental gardens now cover the whole site. The most sustainable and traditional source for fibre and dung is a local farm.

Tools required for the conversion of wood and the preparation of daub are all available from general hardware suppliers or specialist conservation suppliers, but with one exception: the spar hook. They can no longer be purchased new, but can occasionally be located second-hand. Alternatively, a billhook can be used, but its thicker blade makes controlling the split of narrow withies more taxing.

Some materials and equipment may need to be bought in, such as from the sample of suppliers shown below.

<u>Tools</u>

Spar hooks, billhooks, cob-picks; axes and froes with high quality steels:

Pennyfarthing Tools Ltd 26, Pennyfarthing Street Salisbury SP1 1HJ http://www.pennyfarthingtools.co.uk	The Old Tool Store The Red Lion Inn East Kirkby Spilsby PE23 4BX http://www.oldtools.free-online.co.uk

Also online auctions, e.g. http://www.ebay.co.uk

Test sieves are readily available in the UK conforming to BS 410-1:2000. However, the cost of these certified sieves may be prohibitive where only occasional use is anticipated. As an alternative, a set of economy sieves may be purchased, presently available only from U.S. manufacturers and distributors. These conform to U.S. ASTM standard mesh sizes, but relate to equivalent sizes in European and British standards. Appendix 6 provides a means of conversion between standards.

Endecotts Ltd (Manufactuerer).
9, Lombard Road
London
SW19 3TZ
http://www.endecotts.com

A. Daigger & Co. (International distributor)
620 Lakeview Parkway
Vernon Hills, IL 60061
U.S.A.
http://www.daigger.com

Glenammer Engineering Ltd
Glenammer
Dalrymple
Ayrshire
KA6 6AP
http://www.glenammer.com

Hubbard Scientific (Manufacturer).
401 W. Hickory Street
P.O. Box 2121
Fort Collins, CO 80522
U.S.A.
http://www.hubbardscientific.com

Ready-mix Daub

Old House Store
Hampstead Farm
Binfield Heath
Henley-on-Thames
RG9 4LG

Chalk Down Lime Ltd
102, Fairlight Road
Hastings
TN35 5EL

Riven Lath

Carpenter Oak and Woodland Co. Ltd
Hall Farm
Thickwood Lane
Colerne
Chippenham
Wiltshire
SN14 8BE

Mike Wye & Associates
Buckland Filleigh Sawmills
Beaworthy
Devon
EX21 5RN

Coyle Timber Products Ltd.
Bassett Farm
Claverton
Bath
BA2 7BJ

The Lime Centre
Long Barn
Morestead
Winchester
SO21 1LZ
http://www.thelimecentre.co.uk/

Chalk Down Lime

Old House Store

Animal Hair

Potmolen Paint
27, Woodcock Industrial Estate
Woodcock Road
Warminster
BA12 9DX

Chalk Down Lime

The Lime Centre

Old House Store

Mike Wye & Associates

Aggregates

Local builders' merchants should be able to help locate local sources of aggregate. Sharp sand for daubs may be termed 'grit sand' or 'concreting sand' but must be washed (in case of salt) and selected on the basis of sharpness and grading.

A catalogue of national aggregates that are particularly suited for conservation work is provided by Chapman and Fidler (2000).

The Lime Centre (address as above) also supplies a small selection of suitable aggregates.

Infill Upgrade Insulation

Green Building Store
Huddersfield Road
Meltham
Holmfirth
HD9 4NJ
http://greenbuildingstore.co.uk

Natural Building Technologies Ltd
The Hangar
Worminghall Road
Oakley
HP18 9UL
http://naturalbuildingproductscouk.ntitemp.com

Ty-Mawr Lime Ltd
Ty-Mawr Farm
Llangasty
Brecon
Powys
LD3 7PJ
http://www.lime.org.uk/

Other suppliers exist. Inclusion does not indicate recommendation.

Table 5. Details of Wiltshire buildings surveyed.

Building location	Name/Address	Frame type	date of construction	Extent of recording
All Cannings	Burden's Cottage	Post and Truss	c.1600 + later	.
All Cannings	White Rose Cottage	Post and truss	?17^{th}	Wattle and daub section museum object
Alton Barnes	Maslen's Farm	cruck	Late 14^{th}	Full, excluding frame
Ashton Keynes	Cocks Thatch	Post and truss	Late 17^{th}	Daub and withy samples, written building survey
Bratton	East Marsh Farm	Post and truss	c.1500.	Daub sample and photographs
Colerne	Daubeney's	Cruck	c.1270 + late 14^{th}	Photographs and written description
Collingbourne Kingston	Norrie Cottage	Cruck	c.1500	Photographs and sample
Devizes	51, Long Street	Post and truss	?17^{th}	Lath and plaster sample, possibly earthen; photographs
East Kennet	Orchard Farm	Post and truss	16^{th}	Wattle sample only
Keevil	Little Talboys	Cruck	? 14^{th}	section of wattle and daub excluding staves and frame
Langley Burrell	Langley Green House	Cruck	? 15^{th}	Photographs
Potterne	10, Coxhill Lane	Cruck	Early 16^{th} - early 17^{th}	Photographs (chimney)
Potterne	Porch House	Post and Truss	15^{th}	Full
Potterne	The Crofts	Post and Truss	Late 17^{th}	Inspection from distance
Rushall	The Old House	Post and truss	Late 16^{th} / early 17^{th}	Photographs
Salisbury	4, Guilder Lane	Post and Truss	?15^{th}	Inspection from distance
Salisbury	66, St. Anne St.	Post and Truss	c.1480	Full
Salisbury	Cloisters (formerly The Bell and Crown)	Post and Truss	C14th	Panel excluding daub
Salisbury	Retreat Inn, Milford St. (Room No. 4)	Post and Truss	15^{th}	Full, excluding frame
Salisbury	The King's House ('Vestibule')	Post + truss	c.1600	Panel excluding daub
Salisbury	Watson's, Queen St. (House of John A' Port)	Post and Truss	1425	Full
Salisbury	Watson's, Queen St. (William Russel's House)	Post and Truss	1306	Full
Stanton St. Bernard	Liburnum Cottage	Post and Truss	Early/mid 17^{th}	Full
Steeple Ashton	3, Church St.	Box-frame	Mid 16^{th} + 17^{th}	description and daub sample
Tilshead	Primrose Cottage	Post and Truss	?	Frame and staves only
Urchfont	Church Farmhouse	cruck	c.1450 + later	Full
Warminster	10, Vicarage St.	Post and truss	?	Photographs

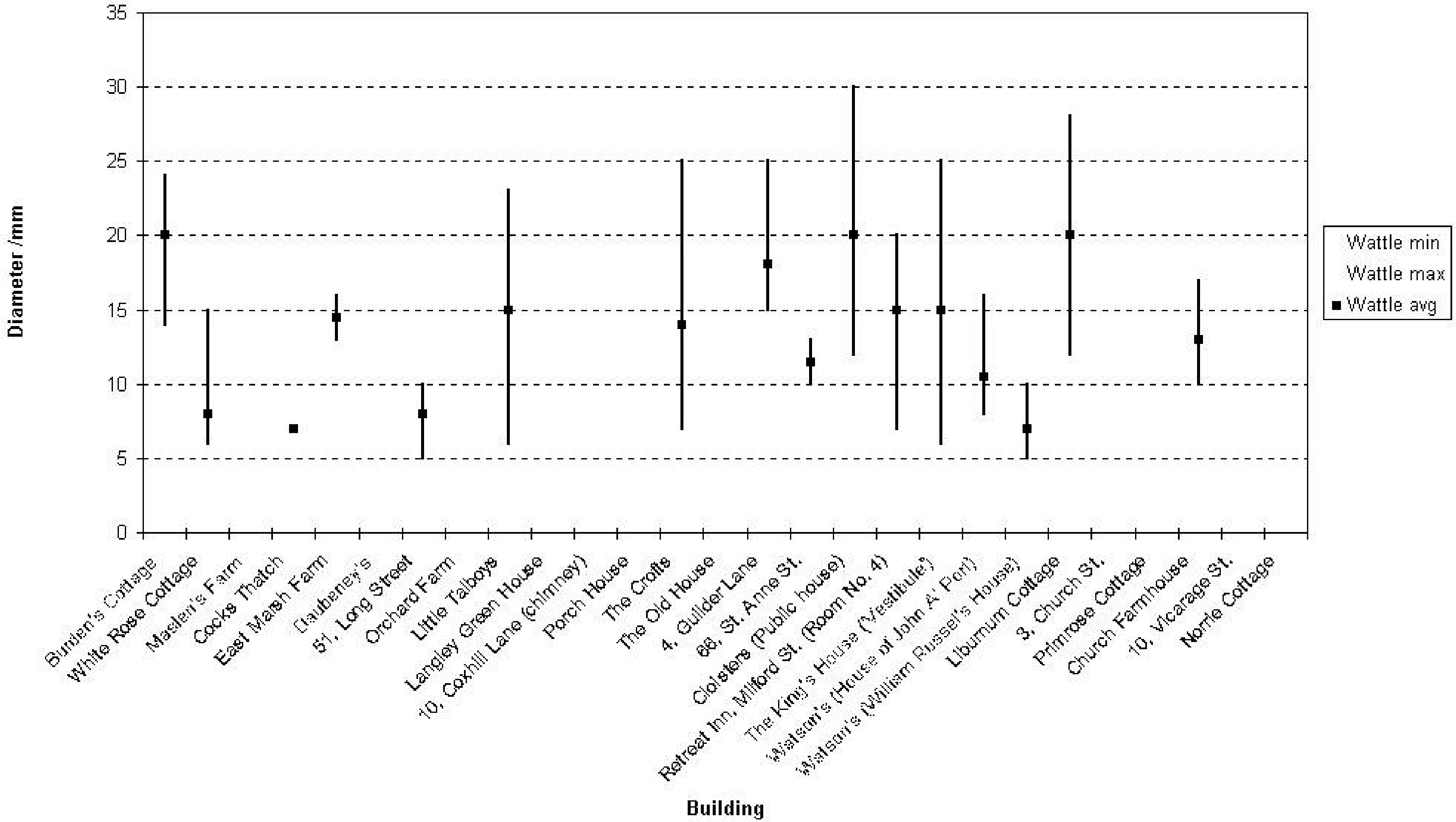
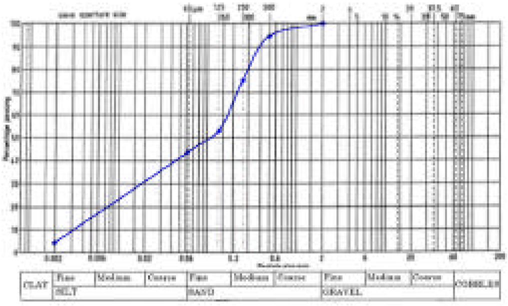


Figure 62. Dimensions of withies.

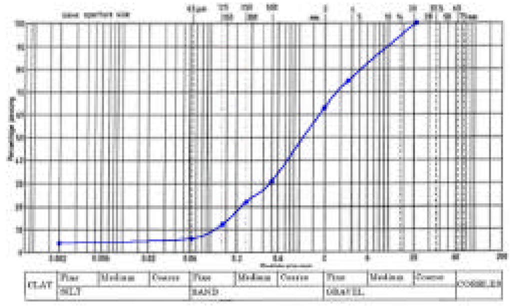
Appendix 5: Analyses of Wiltshire Daubs

The analysis of daub samples was carried out in accordance with the procedure described in Section 5.4.2. However, BS1377-2:1990 recommends that the plot of ‘cumulative percent passing’ versus particle size should be completed using an s-curve to join the data points. For several daub samples, such a curve was not a good fit. This could be expected if the soils had been modified (e.g. by adding aggregate or clay) during construction. Graphically, adding aggregate may shift one or more data points. A smoothed line was therefore chosen instead of an s-curve so that these effects were appropriately preserved.

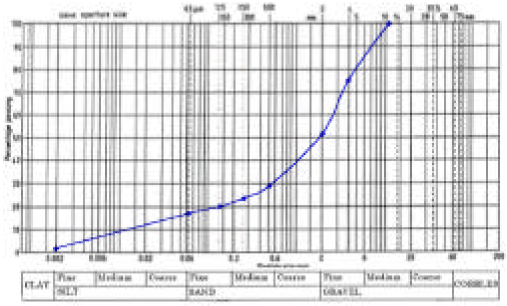
Eight samples were analysed, the results of which are summarised below.



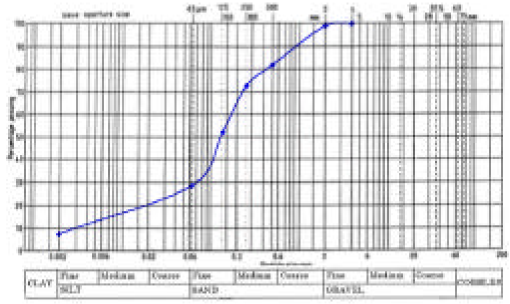
a. Church Farmhouse



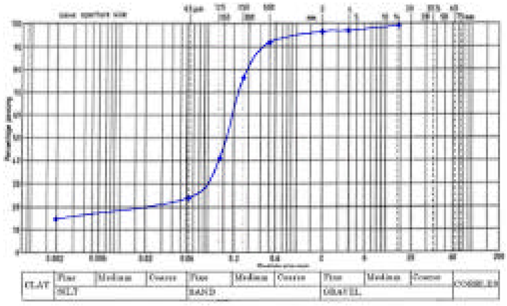
b. The Crofts



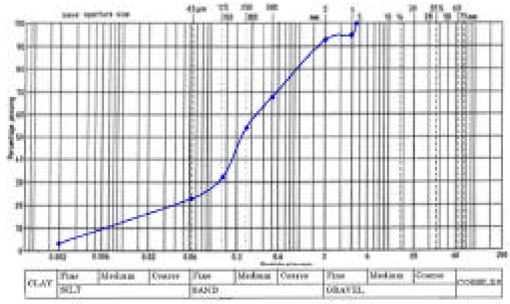
c. Norrie Cottage



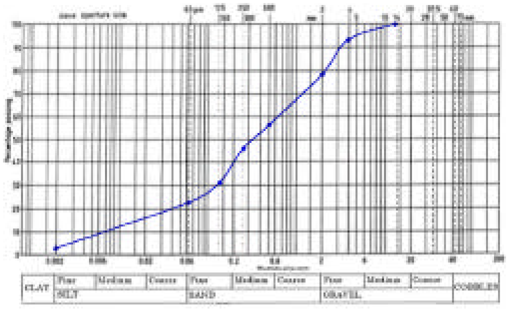
d. 3 Church Street



e. Watson’s – William Russel’s House



f. 66 St. Anne Street



g. Watson’s – House of John A Port

Figure 63. Daub particle size distribution graphs.

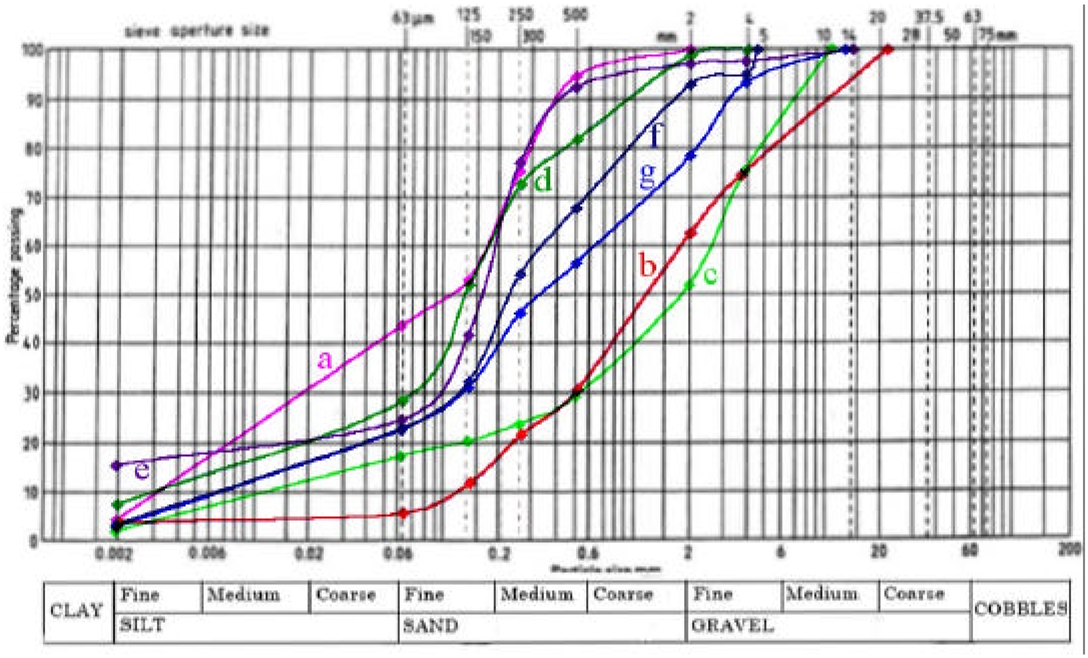


Figure 64. Plots a-g of Figure 63 combined for comparison.

<u>Church Farmhouse, Urchfont</u>

The daub was a creamy-beige with very few cracks. It was extremely difficult to break by hand. There was no sign of chalk or lime particles and the only fibre visible was straw of 10-27mm lengths. Water used in the sedimentation test was turned a browny-orange colour. Hydrochloric acid caused violent effervescing, indicating a significant quantity of calcium carbonate. The plasticity test showed long threads of less than 2mm diameter could easily be rolled. When slightly dried so to break at 3mm, a thread failed only by applying a notable force, suggesting it was moderately plastic.
Sieve and sedimentation analysis showed the daub to be a *clayey SAND*, lacking any gravel, with straw, hay and evidence of dung [Figure 63a].

The underlying soil is Upper Greensand (containing calcareous rock), with Lower Chalk and Gault Clay both available within approximately 0.5km of the building.

<u>The Crofts, Potterne</u>

The daub was a pale creamy-grey with a large degree of cracking. The daub was friable and so easily crumbled by hand. A significant amount of straw and hay was visible. Within the fines was some large aggregate up to 22mm diameter. Disaggregating revealed straw in lengths up to 70mm and many shorter lengths, plus hay, seedpods and a little animal hair. Larger aggregate was found to be cream coloured and could be scratched with the fingernail, albeit it with difficulty. Microscope inspection showed it to have a grainy

structure, possibly oolites. It was identified as probably being a soft limestone. Water was turned greeny-yellow. Sieve and sedimentation analysis showed the daub was heavily fibred (5% by volume) with evidence of dung [Figure 63b]. Hydrochloric acid showed a large quantity of Calcium Carbonate to be present.
A moistened sample was easily rolled into threats of less than 2mm. When a fibreless sample was made sufficiently dry to break at approximately 3mm it was found to initially stretch and required notable force to cause failure. It was therefore determined to be very plastic (‘ very clayey’).
It was concluded that the daub comprised a *very clayey gravelly SAND*, well-graded and mixed with lime or crushed chalk, plus straw, hay and a little animal hair.

The underlying soil is known to be Gault Clay and sandy silt alluvium. The building is sited very close to a source of Upper Greensand and a source of Lower Chalk is available within 2km.

Norrie Cottage, Collingbourne Kingston

The daub was a creamy colour, with little cracking and significant amounts of visible straw but no sign of hair or hair. Larger aggregate (2-5mm) was embedded within the surface. The daub was easily crumbled by hand.
After disaggregation, a little animal hair became apparent, together with two pieces of flint, the largest being 12mm diameter.
Particle analysis showed the daub to be well-graded, with evidence of dung and a large quantity of straw, mainly in lengths of 10-15mm [Figure 63c]. Water was turned pale greeny-yellow/cream.
Hydrochloric acid caused violent effervescing.
Long threads of moistened daub were easily rolled to diameters of less than 2mm. 3mm threads broke only with moderate force – clayey.
The daub was concluded to be a *clayey sandy fine GRAVEL*. It was well-graded, possibly chalk, was highly fibred using straw and had a little hair and probably had only a small proportion of dung.

Norrie Cottage lies on River and Valley Gravel and Middle Chalk but has nearby areas of Lower Chalk, Upper Chalk and Clay-with-Flint (superficial deposits).

N^{o}. 3, Church Street, Steeple Ashton

The daub was a light orangey-brown with patches of brighter orange and had small particles (<500um) visible in the surface. Straw and hay were visible. The daub was difficult to break by hand: only larger lumps could be broken.
Inspection of the disaggregated sample showed hair fibres bound within the white particles and so they were concluded to be lime. The test for $CaCO_3$ supported this, showing violent effervescing.
Sedimentation showed little evidence of dung. The water was turned a mid-brown colour. Particle analysis showed the daub to be well-graded [Figure 63d]. A moistened sample retained its orangey-brown appearance and felt sticky. 3mm threads were easily formed and were tough.

The daub was concluded to be a *clayey SAND*. It was well-graded with lime, straw and hay. There was little evidence that any significant amount of dung had been incorporated.

Steeple Ashton lies on Corallian Beds (oolitic limestones, sands, sandstones and some iron stone) and situated close to Oxford Clay which often weathers to a deep brown.

<u>Watson's (William Russel's House), Queen St., Salisbury</u>
The daub sample was reddish-brown, with patches of dark brown. Large pale aggregate was visible. The daub was of moderate strength, broken by hand using moderate force. Inspection of the disaggregated sample showed the larger particles were flint (up to 15mm) with smaller particles of chalk (mainly 1-2mm). No fibre was visible. The daub was noted to effervesce violently with hydrochloric acid solution, causing pitting and so confirming areas of high $CaCO_3$ content as chalk. Sieve and sedimentation analysis showed the daub to be a *very clayey fine SAND* with chalk and flint, but poorly graded [Figure 63e]. The organic matter consisted entirely of the residue of dung and it was therefore confirmed that the daub had no fibre.

It was not possibly to determine if the daub was extracted from underlying soils due to the complexity of the soils in the city area. Available data, taken primarily from the Ordnance Survey geological maps, showed the soils are most likely to comprise of Valley Gravel or Brickearth, but Alluvium, Plateau Gravel and Lower Chalk are also close by.[136] There are also nearby chalk 'pipes' filled with orange-brown plateau gravel.[137]

<u>66 St. Anne Street, Salisbury</u>
The daub was light brown with a rough surface. Rounded white particles of 1-5mm diameter were visible. The sample was easily broken by hand. The particles were confirmed to be chalk by further visual inspection and by the hydrochloric acid test. Straw fibres were visible, with lengths up to 55mm. The daub was of low plasticity, being difficult to roll into a thread of less than 15mm without crumbling. The sedimentation test left the water stained orange with evidence of dung, straw and hay forming the organic matter. The analysis showed the daub to be a *clayey SAND* with chalk, straw, some hay and dung [Figure 63f].

It was not possible to evaluate how the daub corresponded to the underlying soils due to the complexity of the local geology (alluvium, valley gravel, chalk, river terrace deposits, plateau gravel).

<u>Watson's (House of John A Port), Salisbury</u>
The daub was a creamy-beige with a rough and open surface. Very few fibres were visible, limited to a few lengths of hay (7-12mm) and animal hairs. The

[136] Ordnance Survey (1903).
[137] Geddes (2000).

sample was friable and so was easy to break by hand. After disaggregating, visual inspection found that the course sand and gravel particles appeared to be mainly chalk (up to 14mm). Hydrochloric acid confirmed the presence of chalk. The sample also included a single piece of red clay (10mm), possibly being a fragment of fired brick or tile.
Sieving and sedimentation showed short straw had been incorporated but were only in lengths up to 4mm [Figure 63g]. Very little fibre was noted. The water was turned a greeny-brown with evidence of dung.
Rolling a thread of moist daub was difficult: it was cohesive, but a minimum diameter of 15mm was reached before it would fracture. The daub was bordering only clayey and silty.
The daub was a *gravelly SAND* of low plasticity. Much of the aggregate was chalk with a small but undetermined proportion of brick, with little fibre comprising hay and short fragments of straw.

The soils in this part of Salisbury may include alluvium, valley gravels, chalk and river terrace deposits, as discussed above.

<u>Laburnum Cottage, Stanton St. Bernard.</u>
A visual inspection was made of the daub but the sample was of insufficient mass to perform a full analysis. It was light grey with white particles (1-2mm) and could be broken by hand using moderate force. Further inspection showed two red 2mm particles, possibly fired clay but representing a negligible proportion of the aggregate. Straw of up to 30mm was observed. The owner described the soil as brown clay on chalk which is reflected by geological surveys. In addition, maps show areas of Upper Greensand and Clay-with-flint lie within 1km of the site. However, it is likely the clayey chalk underlying Stanton St. Bernard was the source of the observed daub.

Appendix 6: Sieve Mesh Conversion

Table 6. Sieve comparison table.

ISO 565:1987	*DIN 4188:1977*	*US Std/ASTM E-11-1987*	*Tyler®*	*BS 410:1986*
mm	*mm*	*US Mesh*	*Mesh*	*Equivalent BS Mesh*
		Inch	*Inch*	
		3" .		
		2".		
26,5	25	1.06"	1.05".	
25	22,4	1"		
22,4	20	7/8"	0.883"	
19	18	3/4"	0.742"	
16	16	5/8"	0.624"	
13,2	14	0.530"		
12,5	12,5	1/2 "		
11,2	11,2	7/16"	0.441"	
9,5	10	3/8"	0.371"	
	9			
			Mesh	
8	8	5/16"	2.5	
6,7	7,1	0.265"	3	
6,3	6,3	1/4"		
		Mesh #		
5,6	5,6	3 ½	3.5	3
4,75	5	4		3 ½
	4,5			
4	4	5	5	4
3,35	3,55	6		5
	3,15			
2,8	2,8	7		6
2,36	2,5	8	8	7
	2,24			
2	2	10		8
1,7	1,8	12	10	10
	1,6			
1,4	1,4	14	12	12
1,18	1,25	16	14	14
	1,12			
1	1,0	18	16	16
Microns (µm)	*Microns (µm)*			
850	900			18
	800	20	20	
710	710	25	24	22
	630			
600		30	28	25
	560			
500	500	35	32	30
	450			
425	430	40	35	36
	400			
355	355	45	42	44
	315			
300		50	48	52

ISO 565:1987	*DIN 4188:1977*	*US Std/ASTM E-11-1987*	*Tyler®*	*BS 410:1986*
	280			
250	250	60	60	60
212	224	70	65	72
	200			
180	180	80	80	85
	160			
150		100		100
	140			
125	125	120	115	120
106	112	140	150	150
	100			
90	90	170	170	170
	80			
75		200	200	200
	71			
63	63	230	250	240
53	56	270	270	300
	50			
45	45	325	325	350
38	40	400	400	400
	36			
32	32	450	450	440
25	25	500	500	
20	20	635	635	
16	16			
10	10			

Source: International Starch Institute (1999).