HORSHAM STONE ROOFS

Stone Roofing Association
2009

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<u>Illustrations</u>

Ansell and Sons Ltd	Figures	4, 5, 6, 7, 8.
English Heritage	Figure	29.
Jane Jones-Warner	Figure	15.
Lisa Brookes	Figures	23, 27.
National Federation of Roofing Contractors	Figure	Scaffold.
Terry Hughes	Figures	1, 2, 3, 9, 10, 11, 13, 14, 16, 17, 18, 19, 20, 21, 22, 24, 25,26,28. front cover, inside front cover, back cover

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Introduction

This document was developed during a series of meetings and discussions with people experienced in the use of Horsham stone-slates and the problems of conserving historic roofs. It describes the current state of the art in 2007 and offers guidance on some of the issues which have caused problems in the past. Where there are differences of opinion on particular constructional details or the application of modern practice, it describes the issues for the alternative methods or techniques which should considered in conserving, specifying and constructing these important roofs. These are often complex and need careful thought to ensure the optimum solution is selected in relation to the sometimes contradictory building conservation, technical and environmental objectives and the specific circumstances of the building. In particular attention is drawn to the differing opinions on roof insulation and ventilation and the use of mortar. No guarantee is given that any technique given in this guide will be suitable in any specific situation. This, the second edition, was issued in 2009 to include further experience of mortar.

Terry Hughes Stone Roofing Association 2009

Choosing a system

There are two systems of roofing with Horsham stone-slates [1] (Fig 1) the 'normal' double lap system (Fig 2) and single lapping which is unique to Horsham stone roofs (Fig 3). Problems have arisen, including roof failure due to leakage, because of uncertainty about the precise details of each system and confusion between the two. Issues include the appropriate head and side laps and the mortar mixes used for bedding and at abutments etc. Additionally, with the introduction of insulation into roof structures and the consequent need for ventilation, the use of mortar bedding needs to be carefully handled.

Both systems use random sized slates which are arranged on the roof with the largest laid at the eaves and gradually diminishing to the smallest at the ridge. Traditionally, in both systems each stone-slate was top hung with wood pegs on split wood laths. Top hanging was essential when thin split laths were used but the usual modern practice is to nail to substantial sawn battens. It is conjectured that the earliest Horsham roofs – predating the 19th century - always used the 'normal' double lapping system, where course three overlaps course one, four over two etc. This is the system which is almost always used for sandstones, limestones and slates throughout the UK (Fig 2). Provided the head laps and side laps are large enough for the roof pitch and the driving rain exposure of the site, the roofs will be weather-tight and will also allow for thermal movement and air circulation through the roof construction.

Figure 1 Horsham stone-slates or flags are calcareous, flaggy sandstones. 'Nowhurst has been quarried for several hundreds of years but the roofing stone comes in patches. We find a stratum about three feet down with now and again a hard patch in it. This stratum varies in depth from two feet to five feet and it is from this that the roofing stone comes. The base of the stone is sandstone but for some reason there is lime in the roofing stone patches which hardens it into a granity stone. You can't split any stone for roofing. The natural cleave has to be there. If the stone has a tight cleave we let it stand in the wind and frost for some months, and the weather helps to split it perfectly.' (F. J. Dunkerton, 1945, Quarry Manager's Journal, p213)

In the Horsham single lap system [2] the stone-slates only overlap the slates immediately below – course two overlaps course one and so on (Fig 3). This leaves a gap along the perpendicular joints indicated by the red arrows in the figure. This is weathered with pieces of metamorphic (Welsh) slate, known as shadows or shading, and these and the Horsham stone slates are bedded in mortar. Thus the resistance to water penetration relies on both shadows which have to be of adequate size and mortar which has to have adequate properties of strength, flexibility and durability. The bedding mortar is also used to level up uneven stone-slates. Even if this system

1 Stone-slate is the generally used term for sedimentary roofing stones. In Horsham they are also known as Horsham flags or Horsham stone flags.
2 It is not known if the single lap system developed from double lap or why, but a plausible explanation is that as supplies of Horsham stone for roofing and re-roofing became inadequate, slaters stretched the head lap to make the available slates cover the roof area. As a result the head laps would be inadequate and mortar and/or shadows which act as soakers could be used to try to overcome the problem. Eventually the use of these two techniques was extended into the single lap system which completely relies on these two techniques to be effective.

There are two systems of roofing with Horsham stone-slates, the 'normal' double lap system (Fig 2) and single lapping which is unique to Horsham stone roofs (Fig 3). Both systems use random sized slates which are arranged on the roof with the largest laid at the eaves and gradually diminishing to the smallest at the ridge. In double lapping course three overlaps course one, four over two etc. In contrast, in the Horsham single lapping the stone-slates only overlap the slates immediately below – course two overlaps course one and so on (Fig 3). This leaves a gap along the perpendicular joints indicated by the red arrows in the figure. These are weathered with pieces of metamorphic (Welsh) slate, known as shadows or shades, and these and the Horsham stone-slates are bedded in mortar.

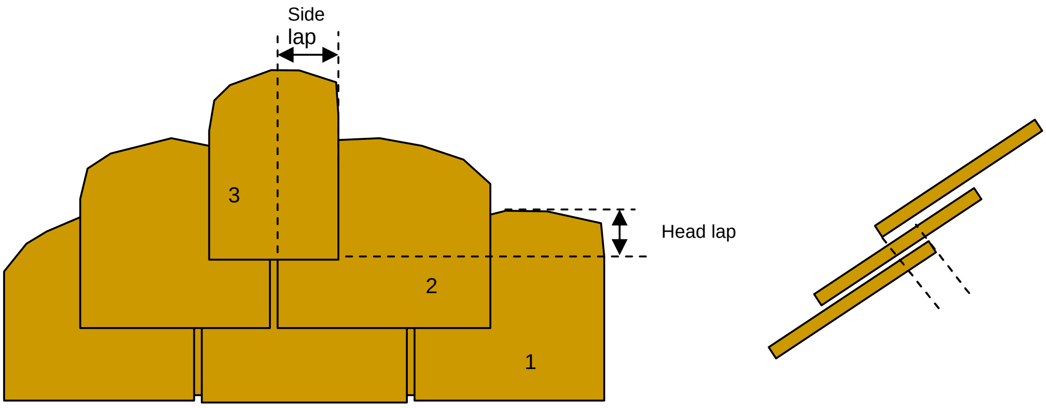


Figure 2 Double lap slating.

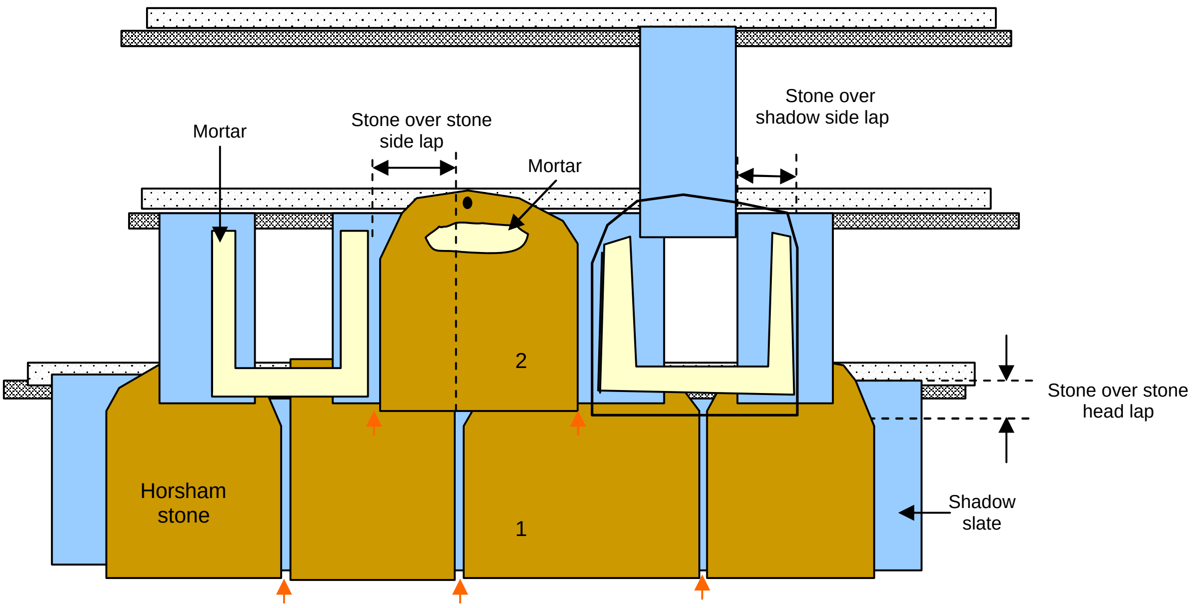


Figure 3 The arrangement of stone-slates, shadows and mortar in the Horsham single lap system

Figure 4 Mortar bed for a shadow slate. Note how it is held away from the edges of the stone-slate. The blue line marks the position of the tail of the overlying stone-slate.

Figure 5 Placing a shadow.

Figure 6 Shadow in position and mortar trimmed off at the edges.

Figure 7 Mortar bed placed to receive the stone-slate. These shadows are 300 mm wide.

Figure 8 Stone-slate in place. Note how the vertical mortar beds do not reach the batten where they would cause rotting.

Figure 9 If the bedding mortar reaches the battens moisture will be drawn to them causing rotting.

Figure 10 Mortar beds should be held back from the slates' edges or raked back (Fig 11). The former produces a tidier finish as shown here.

Figure 11 Raking back the mortar leaves loosely adhering flakes which will fall into the gutters (Figure 12).

evolved from double lapping, during and since the Victorian period some roofs were originally built single lapped. These should usually be conserved as found.

It is recommended that, wherever possible, double lap slating should be retained or re-instated as it is believed to be the original method and avoids many of the problems of single lapping. However, if the roof is to be changed from single to double lap (or the reverse) it will be necessary to review the roof loading and its structural stability. Building control approval will be needed and/or a church faculty. If any changes described in this document are proposed to listed buildings they will require listed building consent from the local authority.

Single lapping, requires the adoption of methods to ensure the roof is weather-tight and is well ventilated. If it is adopted it is recommended that –

- if there is a ceiling fixed to the rafters or a vapour permeable membrane is installed, counter battens should be used to provide a ventilation channel under the slating with ventilation at the eaves and ridge. Each rafter space will need to be ventilated or cross ventilation provided between rafter spaces, and care taken to avoid dead spaces. This is difficult along valleys and hips. Raising the level of the roof on counter battens can also lead to problems at verges and abutments. To overcome the problem in the latter situation a hidden gutter is often used in place of soakers. These need regular cleaning.
- ventilation should be provided at the eaves and ridge. In-slope ventilation is possible in principle but is difficult for random slating because of the need to make vents of variable sizes and thicknesses. The eaves ventilation can be in the form of a gap in the soffit or under the slating but should include an insect barrier. Some proprietary products are suitable. Ventilation with stone ridges is difficult (contact the SRA for advice). Ventilated clay ridges are acceptable where clay ridge tiles have been used on the existing roof.
- to weather the perpendicular joints between the Horsham slates, top nailed shadow slates should be laid under them, preferably on their own battens (Fig 3). They should be wide enough and positioned to provide at least 150 mm sidelap each side of the Horsham slates in the lower courses and 100 mm in the upper.
- mortar is applied as shown in the illustrations (Figs 4 to 8). The aim is to bed the slates and form a seal without the mortar squeezing out onto the slate's surface – a bead width of 25mm is suitable – and the top edge should be held down to prevent it

Figure 12 Loosely adhering mortar will eventually fall into the gutters but does not necessarily mean the mortar is failing.

Figure 13 The first choice for the roof covering should always be Horsham stone. This will usually be a condition of any grant.

Figure 14 It is quite common nationally for stone slate to have been replaced with some other locally traditional material such as clay tiles. This is recognised as a traditional technique and should be conserved.

reaching the battens which can result in them rotting (Fig 9). It should not be unduly visible and therefore should be held back and/or scrapped out about 25mm in the perpendicular joints to promote free drainage, and from the bottom edges of the slates to allow rain to drip off (Figs 10 - 12). Although bedding should be applied sparingly it does compensate to some extent for the unevenness of the Horsham slates.

- torching must not be used with single lapping because there is a risk that it will be forced into contact with the bedding mortar providing a route for moisture to be drawn into the structure.

Sources of further advice on the conservation of stone roofs is given below

Choosing the roof covering

Horsham stone

The first choice should always be to reuse as many of the existing stone-slates as possible. This will involve a careful process of cleaning off old mortar, dressing off any weakened or damaged portions of the slates and assessing their soundness. The process and the criteria for acceptance, rejection or redressing should be agreed between the supervising architect (or building owner) and the roofing contractor before work commences. Failure to control this issue can result in unanticipated shortages and delays to the contract.

If suitable new Horsham slates are available they should always be used to make up any shortfall. This option will always be preferred by English Heritage and may be a grant condition (Fig 13). The use of reclaimed slates off other buildings should be avoided whenever possible. It encourages the destruction of historic roofs, diminishes the regional roofscape and undermines the viability of the stone delph [3].

If the use of reclaimed slates from another source is unavoidable they should be put through a similar assessment to those reclaimed from the building under repair. The source of reclaimed stone-slates should always be checked to ensure they have been obtained legitimately.

Other stones or slates

There may be occasions where it is not possible to repair or re-cover the whole roof with Horsham slates. The building owner or architect will therefore have to consider alternatives and make a judgement based on the particular situation.

Occasionally, Carboniferous sandstones have been substituted for Horsham stone (see www.stoneroof.org.uk for sources). Although these are the most promising alternative stones, very careful selection is required as most are much smoother than Horsham slates. It is recommended that they should only be used to replace a few slates and if possible on the less visible areas of the roof.

Limestone slates should never be mixed with sandstones because there is a risk that the limestone will dissolve in rainwater and absorb into the sand-

3 For small-scale quarries the term delph is preferred to quarry because the latter are perceived as large intrusive operations.

stones. As they dry out the crystal growth can weaken the sandstone.

Random metamorphic slates are too dissimilar in colour, thickness and texture to be suitable substitutes. Sandstones will always be a better option.

Tiles

There are many examples in the area of roofs where Horsham stone slates now only cover the lower courses and clay tiles are used for the upper courses (Fig. 14). This has been a progressive process with less stone being available at each re-roofing. It should be resisted as far as possible. However it is a long established method in many parts of the country and where it exists is often formally conserved as 'traditional'. Also Arts & Crafts architects including Sir Edwin Lutyens at The Goddards, near Abinger, Surrey chose this combination for its picturesque qualities. These should be conserved as found. The alternative to using stone slates in the lower courses is to consolidate them onto fewer slopes and renew the others in an alternative material but unbalanced roof loading can preclude this option.

As well as selecting the slating system and the stone slates it is important that the appropriate and traditional details are used.

Roof detailing

Gauging the roof

Whichever system is used the roof must be set out to achieve the specied minimum head lap and that the courses diminish in height evenly and regularly up the rafter. This does not mean that when re-roofing the existing margins (the height of the exposed area of the slates) should be slavishly reproduced. The correct method is to calculate how many courses of each slate length can be achieved with the available slates and then calculating the gauging which this dictates (Fig 15). A correctly diminishing roof will never have a taller margin above a shorter one.

It also has to be recognised that a change from single to double lap or the reverse will change the margins. This will significantly affect the appearance of the roof. As an example consider a course of 24 inch (600 mm) slates. In double lap with a 3 inch head lap the margin will be

(24 – 3) ÷ 2 = 10.5" (262.5 mm)

In single lap with 6 inch head lap the margin will be

24 – 6 = 18" (450 mm)

For smaller slates the difference will be less pronounced but still significant. For a 14 inch (350 mm) course the relevant head laps will be 3 and perhaps 5 inches (75 and 125 mm) and the margins will be 5.5 and 9 inches (137.5 & 225 mm).

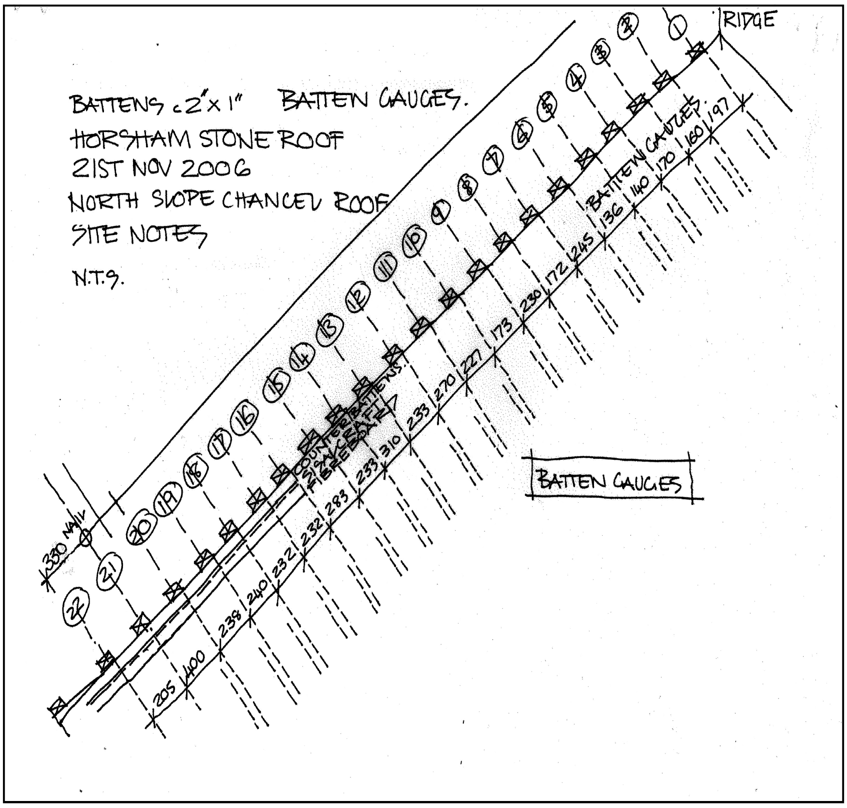


Figure 15 Careful recording of the existing roof will ensure the historic details are conserved and that any defects can be corrected.

Sorting and laying

In all slating it is important to avoid gaps under the slates and excessive unevenness of the roof surface to prevent water or insects getting in. In stone roofing some unevenness is desirable because it gives the roof character so care is needed in specifying this aspect. A number of approaches are possible.

The first option is to ensure the stone-slates do not have excessive thickness variation. This applies both within a single length group and over the whole set of slates although longer slates will normally be thicker than the shorter ones. This issue should be agreed with the supplier whether they are new or re-claimed.

Given a reasonably consistent thickness, a good slater will be able to select slates as they are laid so that they are a similar thickness to their neighbours. To ensure the standard of workmanship is acceptable in this respect a trial panel could be laid.

In some regions the slates are sorted

Figure 16 Hips are not very common on Horsham stone roofs but are often seen on gablets and dormers.

from thick to thin across the roof from right to left and then left to right in alternate courses. This has not been traditional for Horsham roofing. There are anyway limits to the technique because primarily slates have to be laid in a position which provides adequate side lap over the two slates below. Additionally, when re-roofing, because the number of available slates is likely to be small – just enough to cover the roof – there will be little choice of widths and therefore little opportunity to reposition a slate in a course relative to its thickness.

The perpendicular joints between the stone-slates should be slightly spaced. This aids water drainage and emphasises the texture of the slating. It should not be excessive and in double lap slating will have the effect of reducing the side lap. Recommended gaps are given in specification issues below. In single lapped slating the bedding should be held back from and/or raked out in the perpendicular joints to ensure free drainage and at the tails to provide a drip.

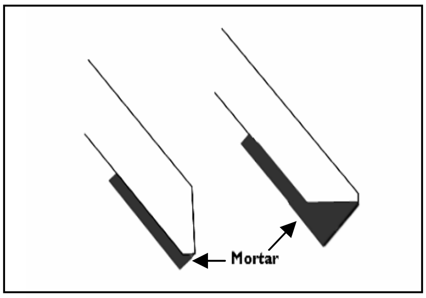


Figure 17 The minimum of mortar should show along the ridge. A vertical edge to the ridge wing allows a neater finish.

Valleys

Large stone slates are not easily formed into valleys and consequently the typical sandstone roofed building has a simple ground plan and a gable to gable roof. Where valleys exist they will need to incorporate lead sheets to ensure they are water tight and they may be open with a continuous lead lining or close mitred with soakers. The normal Lead Sheet Association recommendations apply and BS5534 provides advice on sizing of valleys and leadwork. Mortar should not be used to bed the slates onto the lead although in single lapping the overlying slate should be bedded onto each other and raked back as for the rest of the roof. In other parts of the UK valley types exist which are formed with the stones and without lead but such valleys are not known in south-east England. On some Arts and Crafts roofs clay tiles have been used to line the valley

Hips

Hips are usually close mitred although examples with hip tiles do exist especially on dormers (Fig 16). On mitred hips the raking cuts should be made with a reverse bevel to ensure the two sides can butt up closely. Lead soakers should be included, one per course. The joint can be mortared to form a neat edge and to hide the lead but the minimum of mortar should be used and prominent mortar rolls avoided.

Ridges

The ridge tiles may originally have been of stone but it is accepted that clay tiles are used today and they have the advantage that they can be ventilated. Ideally bedding mortar should not show along the ridge but this is often not possible for uneven stones-slates. However the depth of the visible mortar should always be kept as small as possible and to this end the ridge tiles or stones should be allowed to follow the ridge line rather than being bedded-up to try to achieve a straight ridge. Mortar should be neatly struck-off as work proceeds and not pointed up subsequently. Where new stone ridges are made a vertical wing edge allows a neater finish with less visible mortar (Fig 17).

Abutments

Where roofs abut against walls of significant height they will carry large amounts of water run-off so they need to be thoroughly water tight. They also need to be able to accommodate movement between the roof and the wall. Before the ready availability of lead, abutments were formed with mortar fillets which were often protected with a row of small stone pieces or tiles bedded-in (Fig 18). They are known locally as listings. This local detail should be conserved but they should be backed-up with lead soakers, one per course. Mortar fillets are particularly

Figure 18 Before the ready availability of lead, abutments were formed with mortar fillets which were often protected with a row of small stone pieces or tiles known locally as listings. This detail should be conserved.

Figure 19 Mortar fillets are particularly prone to cracking due to differential movement between the wall and the roof. This can be prevented by separating them from the roof surface and reinforcing them with stainless steel expanded metal

prone to cracking due to differential movement between the wall and the roof. Two techniques can help to overcome the cracking problem. The mortar fillet can be reinforced with stainless steel expanded metal (Fig 19) and the mortar can be separated from the roof surface by laying an arris-cut board up the abutment and forming the fillet onto it. When cured the board can be removed. It is also advantageous to use a flexible mortar.

Verges

Verges should be detailed to prevent water running down the wall as far as is possible. This can be achieved by tilting the slating into the roof slope by raising the battening slightly and by providing a reasonable overhang – about 100 mm is often specified – bedded onto a metamorphic slate undercloak or closed with a wood fillet (Fig 20).

Because of the thickness of Horsham stone-slates the bedding and pointing may be correspondingly thick. To prevent slumping or shrinkage thin slips of stone or slate can be inserted. If the bedding has to be pointed in after slating is complete it should be held or scraped well back to provide a good key. To prevent the batten ends rotting in contact with the mortar they should end well back from the bedding and/or pointing. To achieve this and a good fixing especially for the smaller slates in the upper courses it will be necessary to choose wider slates for the verge.

Ventilation

All roofs need to ventilate moisture. The gappy nature of un-bedded stone roofing allows a free flow of air through the roof construction and, where there is no underlay, through the roof space. In un-insulated buildings the passage of heat from the occupied areas also promotes the flow of moisture-laden air by convection from occupied areas out through the roof. Although this air carries moisture it is warm and the net result is to the benefit of the roof structure in preventing condensation and wood rot.

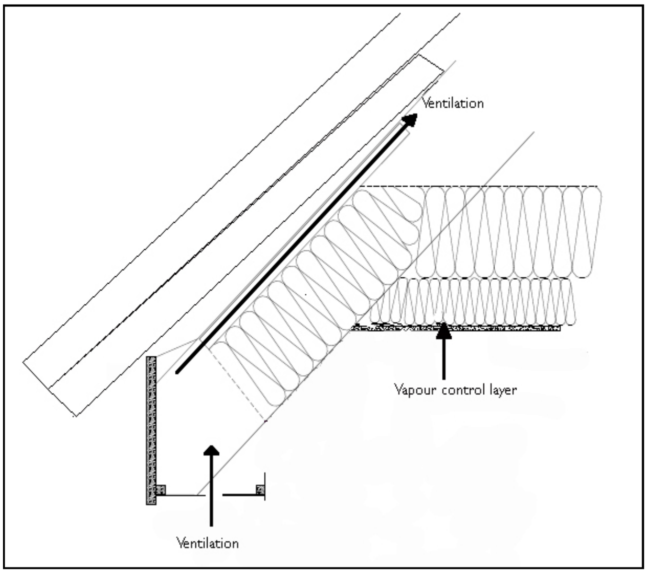
Where the slating is not sealed with mortar, that is where its use is limited to small spots for bedding or for securing wooden pegs, and an underlay is not installed, the natural ventilation is likely to be adequate.

Where a roof is ‘sealed’ with mortar or where insulation is introduced into the roof [4] either at ceiling level or along the roof line steps must be taken to avoid condensation and/or an increase in the moisture content of the timber (Fig 21). Detailed advice on avoiding condensation is given in BS5250 Code of Practice for Avoiding Condensation in Buildings and constructional recommendations are available in BS5534 Code of Practice for Slating and Tiling. English Heri-

Figure 20 Verges are commonly bedded onto a slate undercloak but the mortar often falls out. If the bedding cannot be struck off as slating progresses it should be left well set back or raked out so that there is a good key for pointing up.

4 Where more than 25% of the roof area is to be replaced the person intending to do the work has a legal obligation to contact the Local Authority Building Control department in relation to the upgrading of insulation to comply with the Part L of the building regulations. Places of worship are exempt.

Figure 21 Where insulation is introduced into the roof careful detailing is essential. In particular the routes and the effectiveness of the ventilation must be appropriate for the building and the roof construction. In the single lap system, because the roof covering is sealed, moisture cannot escape through the stone-slates and an alternative route must be provided.



tage is also preparing guidance for historic buildings on compliance with the Building Regulation Part L Conservation of Fuel and Power.

For the single lap system, because the roof covering is sealed with mortar, the underside of the slating must be ventilated. This can be provided from eaves to eaves where the roof space is open to the underside of the roof covering or if not, eaves to ridge or top abutment. In the latter case and especially over an underlay, dead spaces must be avoided so every rafter space must be ventilated including at valleys and hips. Proprietary eaves ventilators are often suitable. Ridge ventilation is difficult for stone ridges but ventilated clay ridges are suitable. Top abutment ventilation is typically provided under the lead apron.

Where insulation and an underlay, including vapour permeable membranes (VPM), also known as breather felts, are installed, there must be adequate ventilation on the cold side of the insulation. Where the rafter space is unobstructed it will typically provide an adequate gap for the eaves to ridge ventilation. If the rafter space is obstructed for example, by installing the insulation within it, an adequate flow of air can be achieved by installing 50 mm thick counter battens above or below the VPM. BS5250 gives more detailed advice. If counter battening is adopted the implications of the raised roof level at verges and abutments etc will need to be considered.

Normally insulation in the roof should be installed in conjunction with a vapour control layer to reduce the amount of moisture reaching the roof. To do this effectively as a retro-fit is very difficult and relies on seals at all junctions and a very high standard of workmanship. The Agreement Certificates of most, perhaps all, VPMs require a fully effective control layer to achieve their claimed performance. These documents should be carefully read before selecting a membrane to ensure they will provide the required level of ventilation and that the installation details are achievable.

Mortars

The use of mortar in roofing has been a very controversial issue in recent years with strong advocates for either cement based or hydraulic lime mortars to the complete exclusion of the other. What is clear is that any roofing mortar must be either protected from frost action (mainly by being located where it won't become wet) or it must be frost resistant. Hence, before the advent of modern cement, any mortar placed where it would become wet must have been naturally hydraulic (or made so by the use of a pozzolan [5]) or it would have failed and it's use would have ceased. (Of course, before the naturally hydraulic property of some limes was discovered they would not have been described as such.) Consequently their use in this way would have been restricted by 'natural selection' to those localities where naturally hydraulic limes occurred. In localities where they did not occur the use of mortar in roof coverings would have been limited to positions on the roof where they would not become wet.

Mortar must be specified to give the required properties for the situation in which it is used. For example, frost and slump resistance, compressive strength and adhesion are all important for bedding stone slates, ridges and hips, whereas, for torching, compressive strength is not. Similarly tensile strength is only important for bedding lightweight products such as clay ridge tiles which are not heavy enough to resist wind uplift on their own. Suitable mixes should be chosen with these properties in mind.

A balance needs to be struck between the technical properties of the mix (strength and flexibility etc) and the practicalities of slating. It is important to specify a mortar which does not hinder the slating process because it takes over-long to reach a set or needs elaborate or extended protection from heat, frost and drying out. Unless the building is completely over-roofed it can be difficult to provide suitable protection especially when bedding ridges. Bedding mortar must not be so hard or so adhesive that it damages the stone-slates when it eventually needs to be removed to relay the roof (Fig 22). It should also be flexible enough to accommodate roof movement.

Some of the confusion and failures which have resulted in the use of unsuitable mortars are the result of misunderstandings (or imprecise specification) of the materials or mixes intended to be used (Fig 23). In particular hydrated lime must not be confused with hydraulic lime. Many of the criticisms of lime mortars appear to be a result of the use of hydrated lime instead of the specified hydraulic lime.

5 The former use of breeze in bedding mixes would have had a pozzolanic effect.

In the mixes given below the following meanings are relevant. References to further explanations of the various limes and cements are given below.

Cement - Portland Cement class 42.5 to BS 12:1996.

Quick lime - calcium oxide (CaO) produced by burning limestone ($CaCO_3$). It may contain a variety of other compounds depending on the properties of the limestone. These may impart hydraulicity.

Hydrated Lime - calcium oxide slaked with just enough water to convert it to calcium hydroxide ($Ca(OH)_2$) and is supplied in powder form in bags. (Also known as hydrate or bag lime.) If produced commercially it may have been sieved to remove over-burnt lime or unslaked lumps. Hydrated lime must be fresh before mixing — the manufacturing date will usually be on the bag. Failure to ensure this risks the lime having taken on a partial, or even full, set before mixing resulting in a weak mortar. To promote effective mixing into the mortar it can be pre-mixed with water and allowed to stand for 48 hours.

Putty lime - calcium oxide slaked with more water than for hydrated lime producing a soft mass. It is usually supplied in tubs.

These limes set by the process of carbonation when calcium hydroxide ($Ca(OH)_2$) is converted to calcium carbonate ($CaCO_3$) through a slow reaction with atmospheric carbon dioxide. They are also known as pure limes or air limes for this reason. They are used in torching mortars or to improve the workability of cement mortar but in the latter case they should not be relied upon to provide additional tensile strength.

Pure hydrated lime or putty lime mortars should only be used where they would not become wet and susceptible to frost damage. In practice, this restricts their use to torching. In all other roof situations they should only be used as a component of a cement mortar.

Hydraulic Lime is not pure calcium oxide but contains compounds such as clays which cause a set primarily based on calcium silicate. These compounds may occur naturally in the limestone from which the hydraulic lime is produced (known as natural hydraulic lime NHL) or may be added deliberately (hydraulic lime HL). It is distinctly different from quick or hydrated lime and should not be confused with them. Hydraulic limes set by a process involving both carbonation and water evaporation. They can be defined descriptively as feebly, moderately, or eminently hydraulic or by use of a numerical designation – naturally hydraulic limes typically range from NHL1 to NHL5. The descriptive and numerical designations do not correspond exactly. Specification by NHL number is preferred. Hydraulic limes are sometimes supplied as putties. To avoid confusion it is recommended that the following terms are not used in roofing specifications: fat lime; coarse stuff; non-hydraulic; feebly, moderately, or eminently hydraulic.

Figure 22 Bedding mortar must not be so hard or so adhesive that it damages the stone-slates when it eventually needs to be removed to relay the roof. Hard mortar being removed with a jack hammer.

Mortar mixes

The following bedding mixes are given as examples which are being used and any one mix is not recommended in preference to another. When choosing a mix the advice of roofing contractors experienced in laying Horsham roofs can be helpful and they should be able to show roofs where their suggested mix has been successful over a number of years [6].

Mortar for bedding heavy ridges and stone-slates, for forming fillets, pointing verges and lead flashings and for flaunching over soakers

In all cases sand should preferably be a mix of 50/50 soft and sharp. Thames Wash is a suitable, locally available, sharp sand.

Cement mortars with hydrated lime or lime putty added as a plasticiser have been successfully used for roofing throughout the UK. These mixes have the advantage of not needing special precautions to protect them from heat, and drying out until they have set. Pure cement mortars are not recommended.

1 : 1 : 6 or 1 : 1 : 5 or 1 : 2 : 6 cement : hydrated lime : sand with the 1 : 2 : 6

6 The National Federation of Roofing Contractors operates a registration scheme for slating and tiling companies skilled and experienced in heritage roof work including for Horsham roofs. See www.nfrc.co.uk/heritageservices.aspx

mix preferred by some slaters for its usability.

1 : 1 : 6 or 1 : 1 : 5 cement : putty lime : sand

1 : 2 : 9 mix has been used in the past but is considered by some to be too weak and therefore not suitable.

For verge pointing the stronger options are most suitable. The above mixes are not suitable for bedding lightweight products such as clay ridge tiles. A mix having adequate tensile strength and adhesion should be used instead.

Hydraulic lime mortars are increasingly being used in stone roofing but experience in a roof situation is limited at present. An NHL 3.5 hydraulic lime will give a more flexible mix and will be preferable when the weather is suitable but in cold weather it will be too slow to reach a full set and may well hold up work. A stronger NHL 5 mix will set sufficiently quickly in cold weather but may be too fast in the summer. It may also prove to be too hard – there is insufficient experience so far to know.

1 : 2.5 NHL 3.5 hydraulic lime : sand for warm weather use. Some Horsham slaters prefer a 1 : 3 mix.

1 : 4 NHL 5 hydraulic lime : sand for cold weather use [7].

Mortar for torching

The traditional mix given below has been satisfactory over hundreds of years and there is no reason to change it. It should however only be applied when there is no frost risk. Torching should only be used with double lap slating. Horse hair is not suitable. Cow, goat or yak are preferable.

1 : 3 lime putty : soft sand and cow hair.

Mortar preparation

Poorly prepared mortar has been the cause of many roof failures. It is essential that the components of all mixes are clearly specified and must always be accurately measured using a gauging box. Correct mixing is critically important and ideally this work should be allocated to someone trained in the correct techniques and properly supervised.

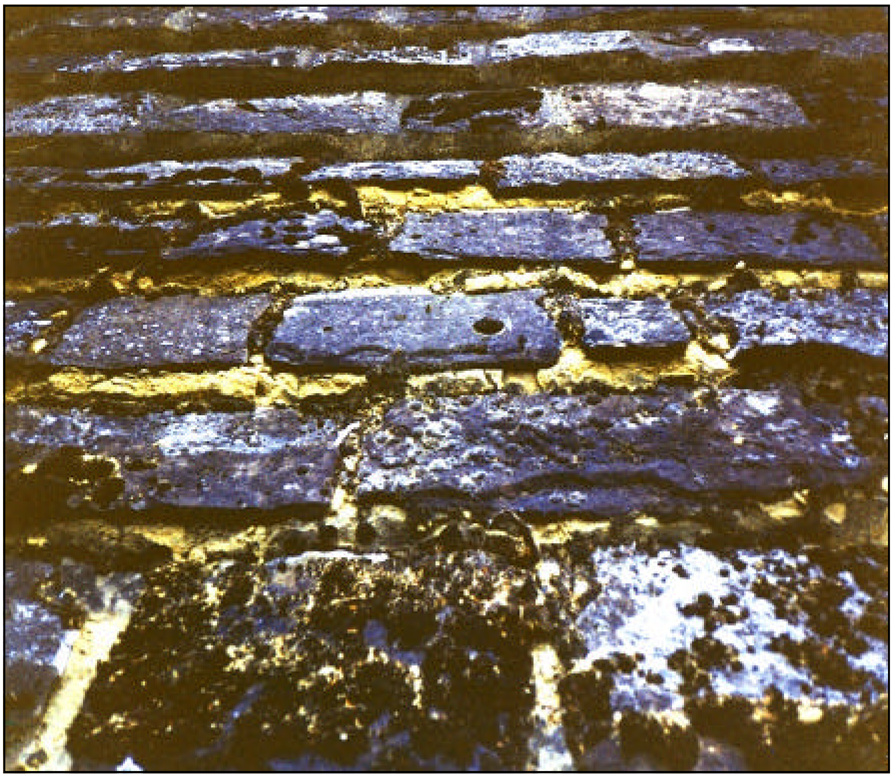


Figure 23 Single lap Horsham roofs rely on the mortar to be weather-tight. To avoid failures such as the disintegration of a weak mortar as shown here it is essential to ensure the correct constituents are accurately measured and carefully mixed.

Mixing methods

Cement with hydrated lime or pure hydrated lime mortars. Hydrated lime can be added to the mix as a slurry (preferably after standing for 48 hours) or as a dry powder but in the latter case the following mixing recommendations become critically important.

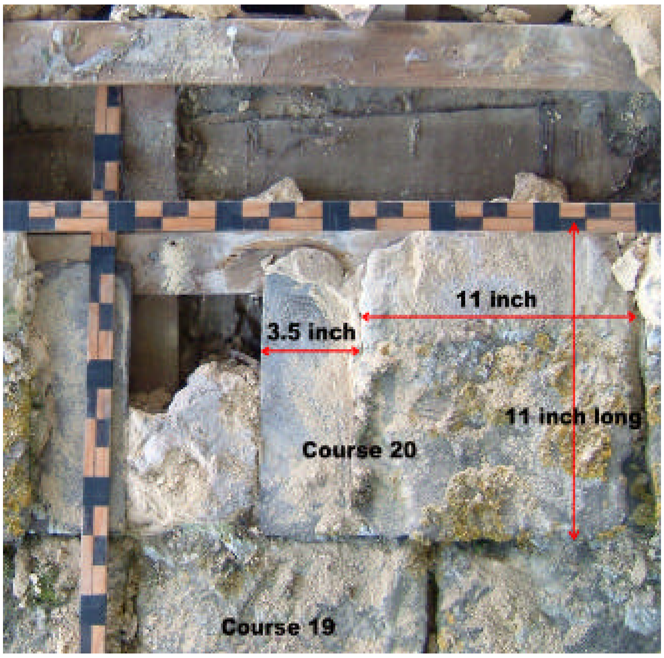
Mixing hydrated or putty lime and sand is best done by hand or in a mortar mill or pan mixer. Thorough mixing is essential, the objective being to smear all of the aggregate particles with a coating of lime without adding excess water.

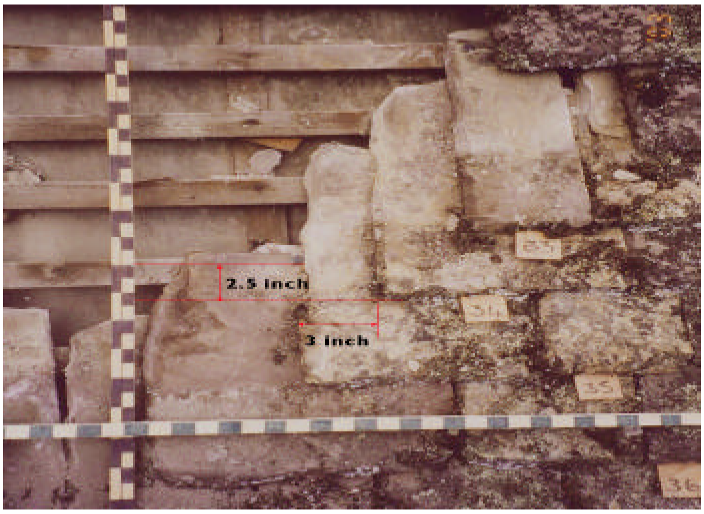
Hand mixing involves continuous turning and spreading with a shovel or a special rake. It is important to achieve suitable workability by mixing rather than adding excessive amounts of water.

A mortar mill is preferable for large quantities where it is physically too demanding to prepare the mortar by hand. If a pan mixer is used additional water may be required. However a drum mixer is the most common method available but, unless specially adapted, will tend to form lumps. If one is used the drum should be tilted well forward during mixing. The smearing and spreading process is improved by adding 3 or 4 large rounded stones which can be retrieved from the mix when it is complete. These will be carried by the paddles to drop into the mix, breaking up the lumps, spreading the lime and improving the workability.

For best results with lime putty mortars the completed mix should be allowed to stand for several hours before final mixing prior to use. The manufacturer of the lime will advise on the time required. It should be covered during this period to avoid evaporation and to keep out air to prevent premature carbonation. A well prepared mix, if stored correctly, may be re-mixed for use after several

7 A 1:4 mix NHL5 St Astier lime : Washington sand, Chichester grit has been used recently and has proved durable over two severe Winters.





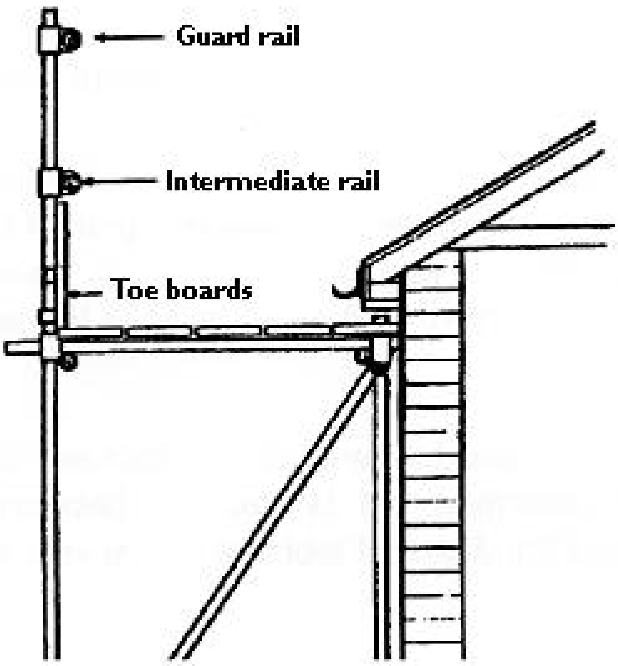
Figures 24 (single lap) & 25 (double lap) When renewing a roof it is important to specify head and side laps that are appropriate for the system being used. A careful investigation of the existing roof will establish what laps have been used but more importantly whether they have been satisfactory. Scales 25mm.

days.

Hydraulic lime mortars should follow the same method of mixing. The type of hydraulic lime will dictate the standing period of the mix, although this may not strictly be necessary. There will also be a period after which the hydraulic lime should not be re-mixed or used. Seek advice from the manufacturer.

Where mortar is to be exposed a consistent colour may be important. The finished appearance of mortar is dependent on many factors which make colour matching of mixes very difficult. It is always best to form all adjacent exposed mortar in one operation with the same mix.

Mortar work should not be carried out when the temperature is likely to fall to 4°C or lower whatever the mix used. For this reason it is best to schedule single lap re-roofing or major repairs for the warmer months. Unfortunately, other constraints such as bat protection may make this impossible. To ensure good adhesion any dust attaching to the stone-slates should be brushed and/or washed off before they are laid. Wetting them immediately before laying can also be helpful.



Preparing a Horsham roof for re-slating involves a lot of handling of large, heavy pieces of stone. To do this safely and efficiently it is preferable to provide a substantial load-bearing scaffold at the eaves with a three plank toe board or an extra rail against which to stack the slates. To avoid an awkward step-up onto the roof slope the working platform should be set just below the eaves (see the National Federation of Roofing Contractors Guidance Sheet A: Working on traditional slate and tile pitched roofs). As slating progresses up the roof slope intermediate scaffolds should be provided and if they are built off the slating they must be supported on soft, flexible material which spreads the load. Short lengths of scaffold board are not suitable.

Specification clauses

To ensure weather-tightness and a long life for the roof a number of issues need to be specified precisely but they differ for the two systems. It is essential that the appropriate details are specified for the system which is to be used (Figs 24 & 25).

DOUBLE LAP	SINGLE LAP
Stone-slate thickness Either select slates with a tight tolerance or sort and lay them to avoid gaps and excessive unevenness (see below). Given this, small spots of mortar placed well away from the area of water spread can be used to even up the roof surface.	Use the bedding mortar of the stone-slates and the shadows together to level the roof surface. Avoid very thick mortar beds.
Head lap Specify the lap - typically 75 to 100 mm although it should be reduced where it would be more than one third of the slate length for example in the upper courses. The batten gauge must be adjusted to maintain this lap at change courses ie where the slate length reduces (Fig 26).	Specify the lap. Typically, in the lower courses, 150 mm below the bottom edge of the stone-slate batten in the course below. In the upper courses it may reduce to 80 mm. Provided the battens are set out to achieve the specific head lap, there is no need to adjust their gauge at changes of slate length as for double lap slating.
Side lap Specify the minimum side lap. The position of perpendicular joints should aim to be approximately central over the slate below.	Specify the minimum side lap of stone over stone. Although this doesn't have the significance that it does in double lap slating it is important for appearance that the perpendicular joints should be approximately central over the slate below. A reasonable minimum value for the lower courses would be 100 mm. Specify the side lap of the stone over the shadows - between 150 and 100 mm.
Perpendicular joints Specify the gap – typically 5 to 15 mm.	Specify the gap – typically 10 to 15 mm – with the bedding mortar held back and/or raked out. Do not point up (Fig 27).
Counter battens Specify where a vapour permeable membrane (VPM) is to be installed.	Specify to provide a clear ventilation route for example from eaves to ridge where any form of underlay is installed.

Typically these will be 75 x 50 mm but narrower battens may be used. Where counter battens (or battens) are fixed directly to boards the nails should not penetrate to their underside. Also see the sections on ventilation and the problems of raising the level of the roof.

DOUBLE LAP	SINGLE LAP
Battens Specify the size. Typically 50 x 25 mm. but 75 x 25 mm is preferable for larger slates.	Specify the sizes for both the stone-slate – typically 50 x 25 mm but 75 x 25 mm is preferable for larger slates - and the shadow battens – typically 38 x 15 mm. The shadow battens should be thin enough that the shadows do not push up the stone-slates. Stone-slates laid single lap span a larger unsupported distance than double lap so, for the larger sizes, additional battens can be used to provide intermediate support.

Batten fixings

Galvanised or sherardised nails with round or ring shanks are suitable but stainless steel is sometimes used. A typical size is 65 x 3.35 mm for battens up to 25 mm thick. Larger sizes will be needed for thicker battens. BS5534 has further advice and a table of pull out values.

Figure 26 In double lap slating if the roof is not gauged to achieve the minimum head lap with adjustments where the slate length reduces, the head lap will be too small and the roof will leak. The resulting long margins over shorter margins are known as pigs.

Figure 27 The mortar in the perpendicular joints and under the tail of the stone-slates should be raked out rather than left showing as here.

DOUBLE LAP	SINGLE LAP

Sorting and laying

Specify how excessive gaps and unevenness are to be avoided. Consider a trial panel to establish workmanship quality.

Slate fixings - peg hanging

Specify wooden or non-corroding metal pegs (Fig 28). Copper is the preferred metal for pegs and nails. Stainless steel and aluminium are also acceptable. It is recommended that aluminium should not be used in contact with mortar. The shank diameter for metal pegs is typically 4.5 mm or larger. The shank length should be sufficient to extend from the slate to the back of the batten but they must not touch any underlay or VPM. To avoid this counter battens may be needed.

With wooden pegs, small amounts of mortar around the pegs will help to hold them in place.

New holes for metal pegs should be slightly larger than the peg's shank diameter. To avoid pegs tilting in old, large peg holes a nail or peg with a large head can be used. This locks against the slate's surface.

Slate fixings - nailing stone-slates

Specify fixing with non-corroding nails - preferably copper (Fig 28). The shank diameter 4.5 mm or larger. The shank length should provide adequate penetration into the battens but should not be so long that it touches or penetrates any underlay or VPM.

	Nailing shadow slates For the shadows thinner nails will be satisfactory – about 3.0 mm diameter.

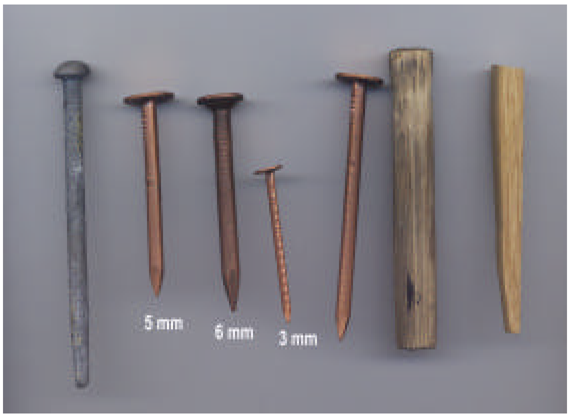
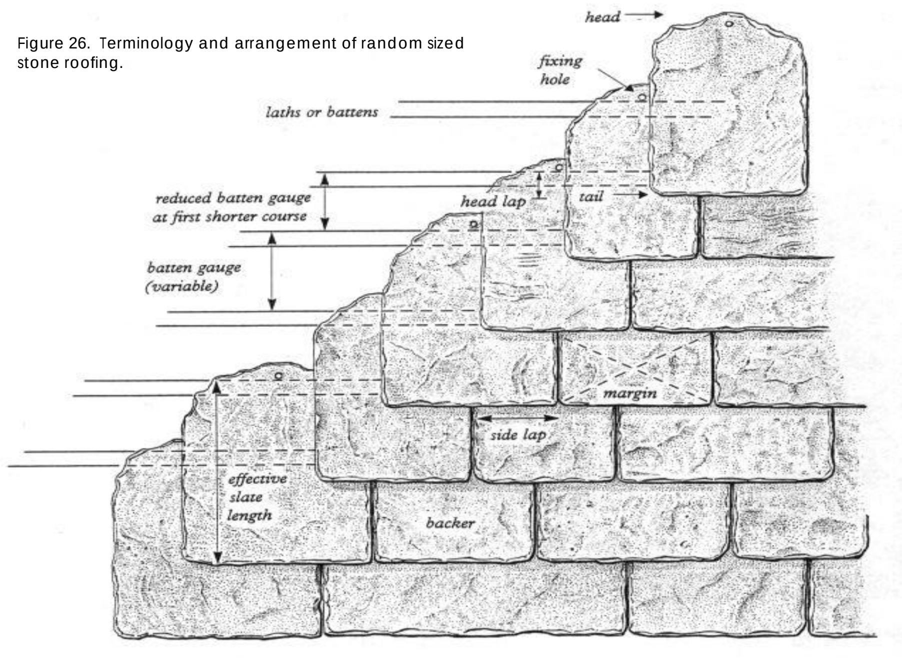


Figure 28 Many different pegs and nails have been used to fix stone-slates over the years. Stout copper nails or pegs are preferred for strength and durability.

Glossary of stone roofing

- Backer: narrow slates laid roughly centrally over a wide slate to accommodate the increasing number of slates in each course as work progresses up the roof.
- Batten: sawn wooden support for hanging or nailing stone slates. Synonym: lath. In this document, the word lath is reserved for split supports.
- Bedding of rocks: a plane parallel to the surface of deposition of a rock. The plane along which stone slates often, but not invariably, split.
- Bedding of slating: use of mortar in spots or fillets to prevent stone slates from rocking. In some areas, it is used to improve weather tightness.
- Breeze: a mixture of clinker and lime or cement. When used to bed slates it could be crushed down to fill any gaps without excessive separation of the slates.
- Cleavage: slaty cleavage is developed in fine grained rocks following metamorphism. Under the influence of pressure and heat the pre-existing platey minerals are partially recrystallised and aligned perpendicular to the pressure. Slates cleave parallel to the platy minerals.
- Diminishing: the system whereby slates are sorted by length and laid with the longest at the eaves, diminishing to the smallest at the ridge. It is essential that the minimum head lap is maintained when there is a change of slate length between two courses. This also ensures that each successive margin is the same size or smaller than those below (see pigs).
- Double lap: stone slates laid so that each course overlaps the course next but one below. In some regions and in some special applications, triple lap slating (where each course overlaps the course next but two below) is adopted.
- Dressing: the process of shaping the stone slate and producing the edge detail using either a chisel-edged hammer or a bladed tool. Regional differences exist for the edge detail which may be square or bevelled. Synonyms: trimming, fettling (Yorks, Lancs).
- Eaves, of stone slates: the short course laid at the eaves under the first full course.
- Fissile: rock which can be split along bedding planes.
- Fixings: nails or pegs.
- Gallet: small pieces of stone slate or metamorphic slate bedded in lime mortar at the head of a slate to support the slate above. Synonym: shale.
- Gauge: the spacing of laths or battens up the roof slope. In stone slating, the gauge is always variable.
- Head: the top edge of a stone slate as laid.
- Head lap: in double lap slating (the normal method), the amount by which a stone slate overlaps the stone slate in the course next but one below. In single lap slating such as diamond pattern it is the amount by which each slate overlaps the one immediately below.
- Lath: split wooden support for hanging stone slates. Synonym: batten. In this guide, the word batten is reserved for sawn supports.
- Listing: tiles, slates or stone pieces set into mortar fillets at abutments with walls.
- Margin: strictly the area, but more commonly the length, of the exposed part of the slate.
- Metamorphism: the process, involving heat, pressure or both, which changes the direction in which sedimentary rocks split. Metamorphic rocks such as true slates split along cleavage planes which are unrelated to their original bedding. Sometimes the cleavage and bedding are parallel. True slates are formed by low grade metamorphism - not much heat or pressure involved. Higher grades of metamorphism produce rocks with larger mineral crystals which can be seen without magnification. Examples include schists, quartzite and gneiss. Generally such rocks cannot be split thin enough to use for roofing, but some examples do exist.
- Pig: a course with a longer margin than the course(s) below resulting from poor setting out and a failure to maintain an adequate head lap.
- Pitch: the angle of the rafters to the horizontal. The pitch of the stone slates will be significantly less because they are resting on each other, but this is taken into account by the traditional rafter pitch and lap relationship for the slate and the locality.
- Pointing: use of mortar to fill the vertical joints and to seal the tail gap of stone slating. Pointing may show (undesirable) or be raked or held back. Often associated with bedding.
- Random, of stone slate: variable length and width.
- Random, of roofing: slates laid with reducing length up the roof slope and the widths selected and placed so that they provide at least the minimum side lap over the slates in the course below.
- Regularly (of diminishing or random slating): the system whereby each successive margin is the same size or smaller than those below. It does not mean that there are an equal number of courses of each margin size.
- Sedimentary: rocks which have been formed from other rocks which have been broken down by weathering, or rocks formed by biological or chemical actions. If they can be split to make roofing (fissile) it will be along bedding planes. See metamorphism.
- Shade, shading: synonym for shadow especially in Horsham roofing
- Shadow: a thin piece of slate used in the Horsham district to improve the weather resistance of the roofs when the head lap is reduced to less than the normal minimum. Originally the shadow was a thin piece of Horsham stone but it is now normally a Welsh slate. It was always used in conjunction with mortar bedding and pointing. Synonym: shade.
- Shale: small pieces of stone slate or metamorphic slate bedded in lime mortar at the head of a slate to support the slate above. Where they are used with heavily shouldered stone-slates (especially limestones) they have the effect of preventing wind driven rain passing through the slating. Synonym: gallet.
- Shoulder, shouldering: the absence or deliberate removal of the top (as laid0 corners of slates or stone-slates. The technique increases the amount of stone which can be used for roofing, makes it easier for uneven or twisted slates to lie flat and reduces the roof loading.
- Side lap: the lateral amount by which a slate overlaps the slate in the course below.
- Slate: People have different preferences for terms to describe sandstone, limestone and similar non-metamorphic roofing products. The most frequently encountered, traditional and colloquial terms are stone slates or grey slates but they are also called flags, flagstones, thackstones, stone

Figure 26. Terminology and arrangement of random sized stone roofing.



tiles, sclaites or grey sclaites (in Scotland), slats or slatts. Each of these terms is used to distinguish them from metamorphic, Welsh or 'blue' slates. The objection to the term stone slate is that sandstones and limestones are not, petrographically, slates. That is, they have not been metamorphosed and consequently they split along bedding rather than cleavage planes. This is certainly true and some geologists prefer the retronym tilestone to distinguish them from real slates. However the term slate, meaning any 'flat rectangular' roofing product has historical precedence, since it predates the science of geology by hundreds of years and is the term in common use. In this document we use 'stone slates' for preference but in geological texts 'tilestones' will be encountered and don't be surprised if you find any of the other synonyms.

- Sprocket: the lower pitch of the roof slope at the eaves; the additional piece of rafter fixed to the main rafter to give the tilt at the eaves. The sprocket can arise naturally due to the rafter footing on the inner face of the wall or can be deliberately constructed to carry the eaves away from the outer face.
- Square: one hundred square feet of slating laid on the roof.
- Tail: the bottom edge of a stone slate as laid.
- Tiering: see torching.
- Tilt: the lift provided to the tail of the eaves course to ensure that successive courses lie correctly without gaps at the tail. In double lap slating, on the main areas of the roof slope, the tail of each stone slate rests on two thicknesses of stone slate in the course next but one below. At the eaves, the first full course rests on only one thickness - the eaves slate. Essentially, the tilt replaces the missing thickness. In single lap the tails rest on one thickness and at the eaves there is no slate to rest on so there is still a need for a tilt.
- Torching: lime and hair mortar applied to the underside of stone slates to render them wind proof. Synonym: tiering.
- Torching: half torching: application of lime and hair mortar between the top edge of the lath or batten and the underside of the slates. Synonym: single torching.
- Torching: full torching: application of lime and hair mortar between the top and bottom edges of the laths or battens and the underside of the slates.
- Torching: single torching: see half torching.
- Unweathered, of stone slates: rock which is too deep to have been subjected to weathering and consequently has to be split by mechanical action or frosting after extraction.
- Weathering (of rocks): the process by which rocks are broken down and decomposed by the action of external agencies such as wind, rain, temperature changes, plants and bacteria. In the development of weathered stone slates, it is often very thin clay or mica beds which are weathered out.
- Weathering (of stone roofing): the processes of mineralogical change, particle deposition and plant growth which change the appearance of slates on the roof.
- Weathering (of a roof): the arrangement of the parts of a roof covering - the slates, soakers, flashings, mortar fillets etc - which prevent water getting into the roof.

Further information

- BS5534 Code of Practice for Slating and Tiling
- BS5250 Code of Practice for Avoiding Condensation in Buildings
- Roger Birch, Sussex Stone: The story of Horsham stone and Sussex Marble, 2006, rdb@collyers.ac.uk
- Bennett and Pinion, Roof Slating and Tiling 1935 (reprint 2000) Donhead Publishing, Donhead, St Mary Shaftsbury
- English Heritage, Technical Advice Note: Stone Slate Roofing www.english-heritage.org.uk/server/show/nav.1630
- English Heritage, Stone Roofing Best Practice Guide (in prep to be available at www.stoneroof.org.uk/best)
- English Heritage Research Transactions volume 9 Stone Roofing (Product code 50749)
- English Heritage, Identifying and Sourcing Stone for Historic Building Repair
- English Heritage, Practical Building Conservation Slate and Stone Roofing (in prep)
- English Heritage, Energy Efficiency in Traditional Buildings (in prep)
- Institute of Historic Building Conservation, Stone Slate Delphs: A guide to making a mineral planning application for a stone-slate quarry or delph
- National Federation of Roofing Contractors, Guidance Sheet A – Working on traditional slate and tile pitched roofs

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NFRC Heritage Roofing.
www.nfrc.co.uk/heritageservices.aspx

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Building Limes Forum
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