Forestry Commission

Research Report

Sustainable construction timber

Sourcing and specifying local timber

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Ivor Davies

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Enquiries relating to this publication should be addressed to:

Forestry Commission
Silvan House
231 Corstorphine Road
Edinburgh EH12 7AT
0300 067 5000
publications@forestry.gsi.gov.uk

The author can be contacted at:

Centre for Wood Science and Technology
Edinburgh Napier University
Merchiston Campus
10 Colinton Road
Edinburgh EH10 5DT
i.davies@napier.ac.uk

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Cover image: Scottish grown larch cladding on Culloden Battlefield Visitor Centre, near Inverness. Designed by Hoskins Architects. Photograph courtesy of Andrew Lee.

Contents

Introduction

Timber is a versatile and high performance construction material:

- It has a high strength to weight ratio.
- It is easily shaped and fastened.
- It is available in a wide range of colours, textures, densities and chemical compositions.
- It can be readily treated or modified to increase its resistance to biodeterioration.
- At the end of its initial service life it can often be reused or recycled.

Timber is also renewable. This means that – uniquely among mainstream construction materials – it can be produced in most parts of the UK (Figures 1 and 2).

In addition to a growing recognition of the immediate performance benefits of timber construction, the material's popularity is also being driven by an increasing awareness of climate change and the environmental consequences of development. Accordingly, government policies supporting timber construction span planning, forestry, sustainable development and climate change. Examples of where timber – and particularly local timber – can contribute to achieving these policies include:

- Minimising the carbon footprint of construction: timber is almost carbon neutral, has low embodied energy and can store carbon in the fabric of the building.

- Supporting the local economy: the use of locally sourced material supports a region's woodland managers, timber processors and manufacturers.

- Helping local woodland management: income from timber sales helps support woodland management and expansion, responsible management benefits wildlife and increased use of UK timber encourages more planting of trees.

- Stimulating timber demand: government policy in the UK – and particularly in Scotland – involves a significant expansion of forest cover and, in order to achieve the targets set, demand for timber products will have to increase.

Finally, let us not forget that knowledge of where the timber has originated from can generate additional interest in a building's design.

Figure 1 The headquarters building for Scottish Natural Heritage in Inverness uses locally sourced larch for the external cladding and solar shading. Keppie Design.

Courtesy of Michael Wolchover.

Figure 2 UK grown Douglas fir is used to spectacular effect in the roof trusses of Grizedale Forest Visitor Centre by Sutherland Hussey Architects.

Courtesy of Sutherland Hussey Architects.

What is a timber building?

In the UK, the term timber frame describes a construction system where all vertical and lateral loads are transferred to the foundations through a structural framework of small section timber studs sheathed with a wood-based sheet material such as orientated strand board (Figure 3). The framework is then clad with a largely non-structural skin, which can be made of several materials including masonry, cement-rendered mesh or timber. In principle, these cladding materials are often interchangeable. Confusingly, the timber frame system is known as light frame construction in North America where the term timber frame is reserved for the large section timber structures referred to as post-and-beam in Europe (Figure 4).

Timber-framed buildings can be constructed in-situ or be prefabricated in a factory. Off-site fabrication (Figure 5) is becoming increasingly common as it speeds construction and can deliver a high level of energy efficiency and quality assurance.

Figure 3 A timber-framed building during construction.

Courtesy of Norbord Europe Ltd.

Figure 4 A post-and-beam building during construction.

Figure 5 Delivery of a prefabricated timber frame wall panel to site.

Timber-framed construction is the most popular building method in the developed world. Unpublished research by the Structural Timber Association suggests that timber-framed construction currently accounts for 75% of new housing in Scotland, while the comparable figure for the UK as a whole is 25%. The UK figure is expected to grow considerably in the near future due to timber frame becoming increasingly popular in England and Wales.

In most countries timber-framed buildings are also timber clad. The UK is unusual in this respect because timber frame suppliers have tended to clad their houses in masonry-based materials, which means that the popularity of timber construction is not so readily apparent. Many people do not realise that it is a timber structural frame that holds up their roof (Figure 6).

Figure 6 A typical timber-framed house with masonry cladding.

Timber frame construction is currently permitted up to seven storeys in the UK; buildings using cross-laminated timber (CLT) panels can go above this limit. CLT involves making large laminated timber panels that are then assembled to form the walls, floors and roof of the building (Figure 7). Cross-laminated timber has several advantages for large buildings including speed of erection, waste minimisation and carbon storage. It is becoming increasingly popular in the UK.

Lancashire and Taylor (2011, 2012) give detailed guidance on the different types of timber construction in the UK. Off-site fabrication is described in Hairstans (2010).

Figure 7 A cross-laminated timber building during construction. Beattock Primary School, Moffat. DGDesign.

UK forestry and forest products

The woodland area in the UK is currently 3.15 million hectares. This is a remarkable achievement considering that our woodland cover reached a low point at the beginning of the 20th century when it was only 5% of the land area. It is now 13%, the coverage being highest in Scotland at about 18%. This compares with a European average of around 33% (Forestry Commission, 2015).

UK forests are a mixture of coniferous and broadleaved species. Conifers produce softwood timber, while broadleaved trees yield hardwood timber. The terms hardwood and softwood are historical and have no literal meaning. While there are exceptions to the rule, hardwoods are typically denser and more impact resistant than softwoods. Nowadays, softwoods are often preferred in general construction due to their wide availability, low cost and ease of working.

The main timber species grown in Great Britain are listed in Table 1. Some of these are native to all or part of Britain, whereas others have been introduced from abroad. Most of the UK's timber production is from introduced species because they offer faster economic returns for growers. Introduced species are also popular because they tolerate the poor upland soils that are commonly available to forestry.

The UK currently uses around 53 million cubic metres (m^3) of wood raw material equivalent each year; corresponding to approximately 0.8 m^3 of timber per person per annum. Of this material, 81% is imported; however, our forests do supply 38% of the sawn timber we consume and 52% of the wood-based panels. In 2014, 11 million green tonnes of UK roundwood were delivered to primary wood processors and others, with softwood species accounting for 96% of this production. UK timber production is anticipated to increase by nearly 50% by 2025 as more commercial forest reaches maturity (Forestry Commission, 2015).

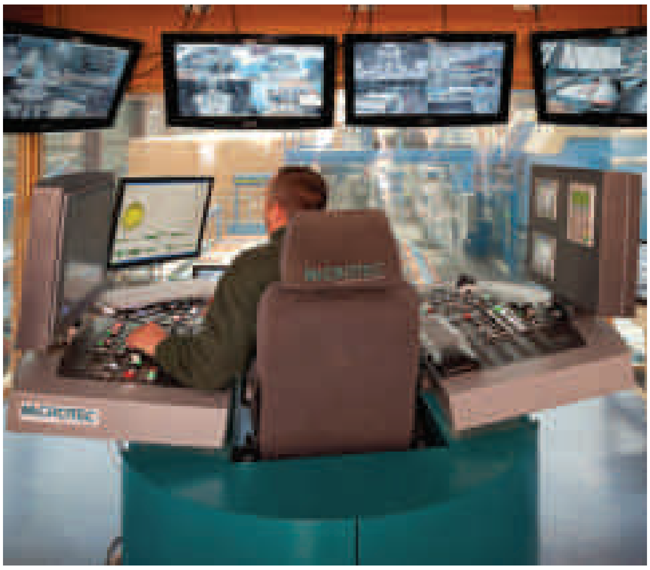
The UK softwood processing sector has invested heavily in recent years and is now a world class industry (Figures 8 to 10). The UK hardwood sector is less developed but is still an important part of the rural economy. There is considerable work under way to expand these industries by developing new products that can use UK timber. It is likely that additional timber products such as CLT will be manufactured in the UK in the near future (Figure 11).

Table 1 Main timber species grown in Great Britain (from Forestry Commission, 2015).

Common name	Botanical name	Woodland area (000 ha) in 2015
Coniferous species		
Corsican pine	*Pinus nigra* spp. *laricio*	46
Douglas fir	*Pseudotsuga menziesii*	46
Larch, European[a]	*Larix decidua*	
Larch, hybrid[a]	*Larix* x *eurolepis*	126
Larch, Japanese[a]	*Larix kaempferi*	
Lodgepole pine	*Pinus contorta*	100
Norway spruce[b]	*Picea abies*	61
Scots pine	*Pinus sylvestris*	218
Sitka spruce[b]	*Picea sitchenis*	665
Broadleaved species		
European ash	*Fraxinus excelsior*	157
European beech	*Fagus sylvatica*	94
Oak, pedunculate[c]	*Quercus robur*	219
Oak, sessile[c]	*Quercus petraea*	
Sweet chestnut	*Castanea sativa*	29
Sycamore	*Acer pseudoplatanus*	106

a. The three larch species have broadly similar physical and mechanical characteristics and so are usually sold together under the trade name UK larch (botanical abbreviation *Larix* spp.).
b. The two spruce species have broadly similar physical and mechanical characteristics and so are usually sold together under the trade names whitewood or British spruce (botanical abbreviation *Picea* spp.).
c. The two oak species have broadly similar physical and mechanical characteristics and so are sold together under the trade name European oak or one based upon their country of origin (e.g. Welsh oak). The botanical abbreviation is *Quercus* spp.

Figure 8 The computerised heart of a modern UK softwood sawmill.



Courtesy of James Jones and Sons Ltd.

Figure 9 Orientated Strand Board production in the UK.

Courtesy of Norbord Europe Ltd.

Figure 10 An I-joist factory in Forres.

Courtesy of James Jones and Sons Ltd.

Figure 11 Prototype cross-laminated timber shearwall made of UK spruce at the BRE Innovation Park, Ravenscraig. Kraft Architecture.

Courtesy of AgArchitectural photography.

Alongside the mainstream wood processing industries, UK timber is also used to construct spectacular one-off structures such as the Savill Building in Windsor Great Park (Figure 12). This gridshell roof structure is made of UK larch and combines complex engineering with craft skills.

Figure 12 Gridshell roof of the Savill Building by Glenn Howells Architects. Over 20 kilometres of finger jointed larch battens were used to form the four layer structural grid.

Courtesy of Warwick Sweeney.

Sourcing and specifying UK timber

There are several points to address when sourcing and specifying UK grown timbers and timber products. Attending to these will ensure that the use of local timber is as simple and straightforward as possible.

How to achieve fitness for purpose

All components used in construction need to be suitable for their end use. The goal when specifying the characteristics of timber construction products is to ensure that they are fit for purpose while not being overspecified. If the specification is too onerous, many perfectly acceptable timber products will be excluded, making an increase in both product costs and lead times more likely.

The most important fitness for purpose criteria applicable to timber construction products are usually a combination of two or more of the following:

- Appropriate moisture content for the end use (see the section on moisture content).
- Shrinkage and movement (see the section on dimensional change).
- Adequate strength and stiffness (see the section on structural timber).
- Acceptable fire performance (see the section on fire performance).
- Resistance to biodeterioration (see the section on wood destroying organisms).

Although designing and constructing with local timber is generally straightforward, there are circumstances where particular challenges arise. Two obvious examples of this are using such timber in repair of existing buildings and in self-build projects. The final two sections of this report cover these topics.

Carbon storage in construction materials is a further consideration and is becoming increasingly important for timber. This topic is addressed in Appendix 1.

The required material characteristics for most types of construction products are given in European and British standards. These documents formerly had a voluntary status but the implementation of CE marking throughout the European Union in 2013 means that the provisions of some European standards are now mandatory for manufacturers. The implications of these changes for UK timber are discussed in Appendix 2.

Design within constraints

If local sourcing is an objective it is important to ensure that the building uses timber components and grades that can be sourced in the region or, failing that, from another part of the UK. The main construction uses of the timber species available in the UK are given in Tables 2 and 3. The construction products currently manufactured from these timbers are given in Table 4. Pallets, paper, packaging and wood fuel are further significant uses for UK timber but are outside the scope of this publication.

Table 2 Main uses of UK grown softwoods in construction.

Common name*	Main uses in construction					
	Machine graded structural timber	Visually graded structural timber	Panel products	External cladding	Decking	Internal joinery (mainly flooring)
Corsican pine	–	–	○	–	–	–
Douglas fir	○	●	–	○	○	○
Larch	○	○	–	●	○	○
Lodgepole pine	–	–	●	–	–	–
Scots pine	○	○	●	–	●	○
Whitewood	●	–	●	○	–	–

● Major/regular use ○ Minor/occasional use

*Some of these timber species might need to be preservative treated or wood modified for use in particular applications. See Table 15.

Table 3 Main uses of UK grown hardwoods in construction.

Common name	Main uses in construction			
	Visually graded structural timber	Windows	External cladding and decking	Internal joinery (e.g. flooring)
European ash	–	–	–	○
European beech	–	–	–	○
European oak	●	○	●	○
Sweet chestnut	○	○	○	○
Sycamore	–	–	–	○

● Major/regular use ○ Minor/occasional use

The grades of structural timber produced in the UK are described later in this report in the sub-section on Strength classes. If a building designer wishes to use UK grown structural timber, it is important that these grades are borne in mind. The timber sizes available (see Appendix 3) are a further consideration. 19th century Scottish agricultural buildings were about 4.2 m wide as this was the often the maximum distance that could be spanned with a piece of local softwood timber. A span of 4 to 5 m is still a good maximum to keep in mind when designing a simple floor structure made of readily available timber grades and sizes (Figure 13). Larger spans can easily be achieved in UK timber but require a more complex structure, or engineered products such as I-joists (Figure 14). Some engineered products might contain a mixture of UK grown and imported timber.

Similar considerations apply to joinery. The main joinery products that can be produced in the UK are decking, external cladding and flooring along with occasional bespoke items such as stairs (Figure 15). The design and specification of such products should be appropriate to their characteristics. External timber cladding, for example, is sometimes designed and specified so that only knot-free timber is acceptable. Such timber can be obtained from virgin forests in, for example, the tropics or Siberia; but it is not available in commercial quantities from the UK. If the cladding aesthetic is changed to accommodate a slightly more irregular appearance, then using local timber becomes feasible (see Figure 16).

Some UK timbers have similar characteristics to imported species. Appendix 4 highlights the opportunities to use local timber instead of imports.

Figure 13 This house near Alness in the Scottish Highlands illustrates the floor span that can be achieved using readily available softwood joists. Neil Sutherland Architects.

Figure 14 Locally produced I joists were extensively used in this office building in Newtonmore in the Scottish Highlands. HRI Architects.

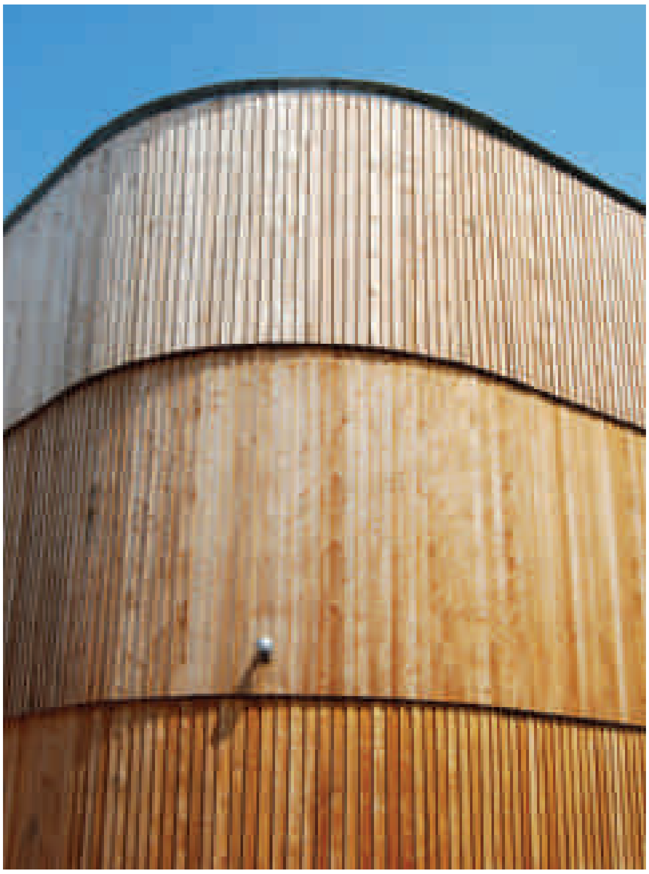
Courtesy of James Jones and Sons Ltd.

Table 4 Construction products made from UK timber.

Product	Availability
Structural timber	
Machine graded structural timber	Machine graded whitewood is readily available; machine graded larch and Scots pine can be produced.
Visually graded structural timber	**Softwoods:** visually graded Scots pine, whitewood, larch and Douglas fir can be produced. **Hardwoods:** visually graded oak and sweet chestnut can be produced.
Non-structural timber	
Carcassing	Whitewood is available for non-structural uses such as internal studs.
Sarking, slating battens	Whitewood and other softwood timbers are widely available. They are normally preservative treated for use where there is a risk of wetting.
Decking	Preservative treated softwood decking is widely available. Oak and sweet chestnut can be supplied in parts of the UK.
Windows	Oak windows manufactured from UK timber are occasionally available. The timber used in softwood windows is imported.
Flooring	Strip flooring of oak, sweet chestnut, larch, Douglas fir and other timbers is available in parts of the UK. End-grain blocks are also produced.
External cladding and shingles	Larch is the most common timber although oak, sweet chestnut and western red cedar can be supplied, plus preservative treated Douglas fir, Scots pine and whitewood. Shingles are available from a few suppliers.
Specials	Other joinery components can sometimes be made as specials.
Panel products	
MDF (medium density fibreboard)	Three UK manufacturers produce several products for non-structural applications in shop fitting, flooring, kitchen units etc.
OSB (orientated strand board)	One UK manufacturer produces four types of OSB. It is used for structural applications such as sheathing, plus non-structural products.
Particleboard	Three UK manufacturers make a range of products for floor panels, kitchen units and other non-structural applications.
Pin board	One manufacturer makes pin board from recycled newsprint.
Engineered wood products	
I-joists	One UK manufacturer produces I-joists; the thin central web is made from local OSB, while the flanges use imported softwood.
Glulam	There is currently no UK producer of standard glulam sections. A few firms can make specials using oak, sweet chestnut or other timbers.
Laminated structural panels	SIPS (structural insulated panels) are manufactured in the UK using rigid foam insulation and OSB; some of these firms use UK produced OSB. CLT (cross-laminated timber) and brettstapel (dowel-laminated timber) can be produced as specials on a small scale.
Other products	
Wood turning, pole rounding	Craft-scale and high volume architectural wood turning is available. A few firms pole-round timber for structural and non-structural uses.
Log buildings	Several small firms make log buildings to order.
Landscaping and fencing	Landscape products such as bollards and acoustic barriers are produced, plus fencing and gates. They mainly use preservative treated softwoods.
Bridges	Pedestrian and light vehicular bridges are made from preservative treated larch, Douglas fir or Scots pine. Oak is also used.
Civil and marine	Large section oak timbers are used for dock structures, canal gates etc.

Figure 15 Joinery products and furniture made of Welsh oak.

Figure 16 This facade is clad with Scottish larch and has an aesthetic and detailing that suit the timber. John Hope Gateway, Royal Botanic Gardens, Edinburgh, by Edward Cuillinan Architects.



Know who sells what to whom

There is no single supply route for all timber products and so it is important for specifiers to understand relevant issues that affect the sourcing of a particular product.

Standard size softwood structural timbers (see Figure 17) are sold via distributors such as builder's merchants and timber merchants. These businesses stock a mixture of imported and UK grown timber and rarely differentiate between the two. Salespeople in these companies may not know where their timber comes from. In most instances this will not matter because, as long as structural timber is graded as fit for purpose (see the section on 'Structural timber'), timbers from several species or provenances can be used. Although distributors do not ordinarily differentiate between UK grown and imported timber, many are able to do so if a sufficient volume is ordered. Industry volatility can mean that the minimum order may be as little as one pallet load of timber. Some UK softwood sawmills might consider supplying timber direct to the customer. To achieve this, it might be necessary to list particular suppliers in the specification.

Mainstream distributors only sell a limited range of hardwood timbers and these are usually of tropical origin. They do not generally sell UK hardwoods – these are

Figure 17 Packs of standard size softwood timber, wrapped and ready for dispatch.

purchased direct from a hardwood sawmill or via a specialist distributor. Many of these latter firms are small and do not carry extensive stock. Sawmills and specialist distributors are also the best source for softwood decking, cladding and large section structural timber. Once again, these companies may sell both UK grown and imported material.

The UK is a major producer of wood based panels such as OSB. These products are sold via mainstream distributors. Engineered wood products such as I-joists and SIPS (Figure 18) are sold direct from the producer or via specialist distributors.

Figure 18 Structural Insulated Panels (SIPS) being used to construct walls and roofs of a housing development.

Courtesy of Norbord Europe Ltd.

Ensure the timber is legal and sustainable

The implementation of the European Timber Regulation (European Union, 2010) means that individuals and organisations that trade in timber and wood-based products within the European Union must ensure that products they sell are harvested in accordance with the applicable legislation in the country of harvest. Local sourcing can be an effective way of obtaining legally felled timber. However, procurement issues are particularly complex to address within public building contracts and local sourcing may not be possible in all cases.

Procurement of goods and services for most publicly funded buildings in the UK should comply with national and European procurement policies. Restrictive practices such as nominating the geographical origin of timber, or a maximum travel distance, are generally prohibited. The main opportunities for using local timber on public buildings are where the products are internationally competitive in terms of value or performance or are being donated. Appendix 5 gives further guidance on legal and sustainable timber.

Begin the procurement process as early as possible

There is at present no single comprehensive source of information on suppliers of UK forest products. There are several relevant organisations (see Appendix 6), although some of these only represent particular groups of suppliers or cover a limited geographical area. Because there is no single site that includes all relevant suppliers it is advisable to supplement guidance obtained from internet sources with a web search using project-specific keywords such as 'UK manufactured I-joists', 'sweet chestnut beams' or 'home grown larch cladding'.

While items such as wood-based panel products or machine graded structural softwood are easy to find and are available off the shelf, others, such as large section structural timber, are not so straightforward. In such cases, the specifier might have to ensure the product can actually be supplied and the contractor will need to allow sufficient time for delivery.

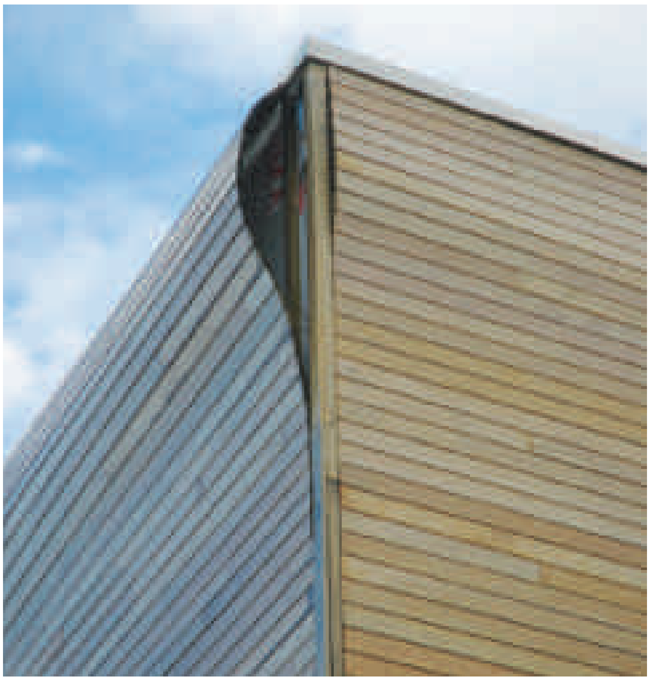
The earlier a supplier can be found and involved, the more chance there will be of securing the best and most cost-effective results. Even so, there will be occasions when some products cannot be obtained within suitable deadlines. Remember: regional availability varies. The timber products that can be sourced in northern Scotland are different to those that can be found in Kent. Some UK timber products, such as I-joists or wood-based panel products are distributed nationally while others, such as large section Douglas fir (see Figure 19), are only available through a few regional suppliers. The organisations listed in Appendix 6 can often advise on the manufacturers of UK timber products. These companies are then the best source of advice on who distributes their products.

Figure 19 Large Douglas fir timbers were used to construct this forest visitor centre at Glentress near Peebles. Gaia Architects.

Ensuring appropriate moisture content

Most failures of timber construction products are either caused by the timber being supplied or installed at the wrong moisture content for its end use or because it became wet after installation due to poor detailing, construction or maintenance (Figure 20). Ensuring the timber is supplied and maintained at the correct moisture content is therefore very important.

Figure 20 Failure of external timber cladding due to the boards being installed with inadequate expansion gaps.



Moisture content

The amount of water contained in a piece of timber is termed its moisture content. This is usually expressed as the mass of moisture in the component as a percentage of its mass when fully dry. Moisture content can be measured in several ways, of which the most accurate is the oven-dry method. To do this the wood sample in question is weighed, fully dried, and then weighed again. If this is done in accordance with BS EN 13183-1, the moisture content percentage (ω) can be calculated as:

$$\omega = \frac{m_1 - m_0}{m_0} \times 100$$

where m_1 is the timber sample's initial mass and m_0 is its mass after oven drying.

The oven-dry method is impractical for rapid measurements on-site and so electronic moisture meters are often used instead; these are normally hand-held although automatic data-loggers for connection to permanent sensor installations are available. These meters do not measure moisture content directly but instead use an electrical property that varies according to the mass of water in the timber. At moisture contents between 6% and 25%, a measurement accuracy of ±2% can be achieved using these meters providing the procedure follows standard practices (BS EN 13183-2 and BS EN 13183-3); the meters become less accurate outside this range. This level of accuracy is sufficient for most scientific investigations of buildings.

Moisture content affects timber's characteristics in many ways. The most important effects are usually upon density, mechanical performance, dimension and the risk of attack by wood destroying organisms.

Fibre saturation point

As timber dries it reaches a condition where all water in cell cavities has gone and further drying involves removal of moisture from the cell wall; this is termed the fibre saturation point (FSP). The fibre saturation point varies between species; in nearly all temperate timbers it occurs at a moisture content of 26% to 32% (Skaar, 1988). Most timber characteristics are stable at moisture contents above the fibre saturation point, whereas below this value many of them change in approximate proportion to moisture loss or gain. Indeed, the fibre saturation point can be defined as a moisture content zone below which timber properties start to change.

Equilibrium moisture content

Timber is hygroscopic at moisture contents below the fibre saturation point. This means that if timber is drier than its surroundings it absorbs atmospheric moisture, while if wetter it tends to dry out. In stable conditions timber will eventually settle to an equilibrium with the temperature and relative humidity of the surrounding air. This is termed the equilibrium moisture content (EMC). The equilibrium moisture content of timbers in a building can be predicted and is used to define target moisture contents for drying.

Timber drying

When timber is freshly felled, its moisture content can, depending upon species and other factors, vary from around 30% to over 200%. The moisture content of timber in buildings is lower than 30%, which means that construction timber normally has to be dried before it can be used. The exception to this is where timber is sold 'green', which means that it has a moisture content at or above the fibre saturation point. Solid timber over 100 mm thick is sold green as it cannot be uniformly dried; green timber is also occasionally used for external uses such as cladding. All other construction timber is normally offered for sale either air dried or kiln dried:

- Air dried: If timber has been stored in a ventilated shed for some time (Figure 21) it may be described as air dried; this is a slow process (approximately one year per 25 mm of thickness) and the lowest moisture content that can be achieved by drying in an unheated shed in the UK is around 16%.

- Kiln dried: In order to get to the low moisture contents required in modern buildings most timber is dried in an insulated chamber where temperature, relative humidity and ventilation can be carefully controlled; this is known as kiln drying (Figure 22).

Figure 21 Air drying shed at a furniture maker in Cumbria. Air drying is mainly used to reduce the moisture content of hardwood timber prior to kiln drying.

Figure 22 A modern drying kiln.

Courtesy of James Jones and Sons.

It is not sufficient to just specify kiln-dried timber as the term has a range of meanings. The target moisture contents for kiln drying depend upon several factors including whether the component is to be used as structural timber or joinery:

- Standard section structural softwood: These components are exposed to wetting as the building is erected and so are usually only dried to a maximum mean moisture content value of 20%; the timber dries further in-situ after the building is completed. Specific structural components, such as ring beams, might be kiln dried to a moisture content of around 12% in order to minimise shrinkage in-situ.

- Joinery: This should be dried to near the equilibrium moisture content of timber in the location where the component is to be used. BS EN 942 gives general recommendations (Table 5) although some products have more specific criteria. Floorboards, for example, should be dried to the following moisture content ranges, as recommended in BS 8201:

  - Unheated rooms: 15% to 19%
  - Intermittently heated rooms: 10% to 14%
  - Continuously heated rooms: 9% to 11%
  - Underfloor heating: 6% to 8%

Pratt, Maun and Cody (1997) give detailed guidance on timber drying.

Table 5 Recommended moisture contents for joinery timber (after BS EN 942).

Location		Recommended moisture content (%)
External joinery		12 to 19
Internal joinery	Unheated buildings	10 to 16
	Heated buildings with room temperatures of 12°C to 21°C	9 to 13
	Heated buildings with room temperatures over 21°C	6 to 10

Dimensional change

Temperature change can cause many materials to expand and contract. In wood, however, dimensional change due solely to temperature is minimal and can usually be ignored. Instead, temperature change causes wood and wood-based materials to lose or gain moisture and this will lead to dimensional change.

Shrinkage and movement

Below the fibre saturation point, timber shrinks as it dries and expands if it gains moisture; dimensional change being broadly proportional to the amount of water lost or gained (Figure 23). By convention, reductions in dimension as timber initially dries out are termed shrinkage, while subsequent changes due to fluctuations in equilibrium moisture content are known as movement. These changes are not uniform in all directions. For a given change in moisture content below the fibre saturation point, timber will expand or contract about twice as much along an axis tangential to the growth rings as in a radial axis (Figure 24). In normal timber, there is virtually no dimensional change in a longitudinal direction and so it is usually ignored. Shrinkage is larger than movement but is only a concern when green timber is used. In most cases therefore only movement needs to be assessed.

Shrinkage and movement characteristics vary between species. Table 6 gives the shrinkage and movement characteristics of the main UK timber species. These values can be used to estimate the approximate dimensional change that occurs in timber due to moisture content fluctuation. For convenience, the movement characteristics of most species have been assigned into one of three movement classes (Building Research Establishment, 1982). These classes (Table 7) correspond to the sum of tangential and radial movements that occur in most softwoods when their equilibrium moisture content fluctuates between 12% and 21%.

Figure 23 Idealised relationship between moisture content and shrinkage behaviour in Sitka spruce (after Moore, 2011).

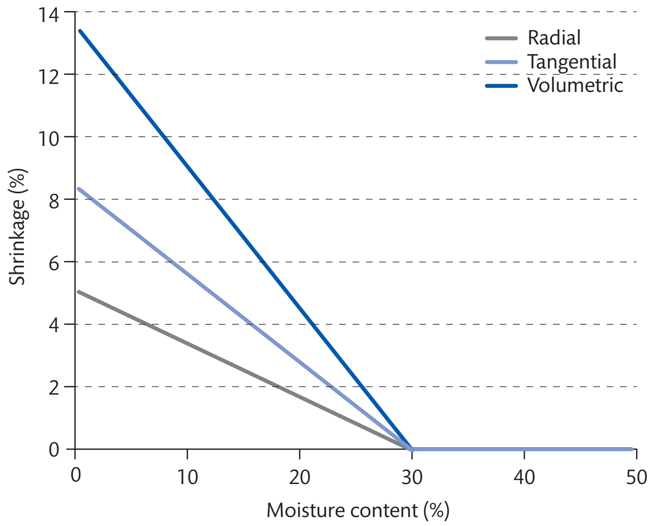
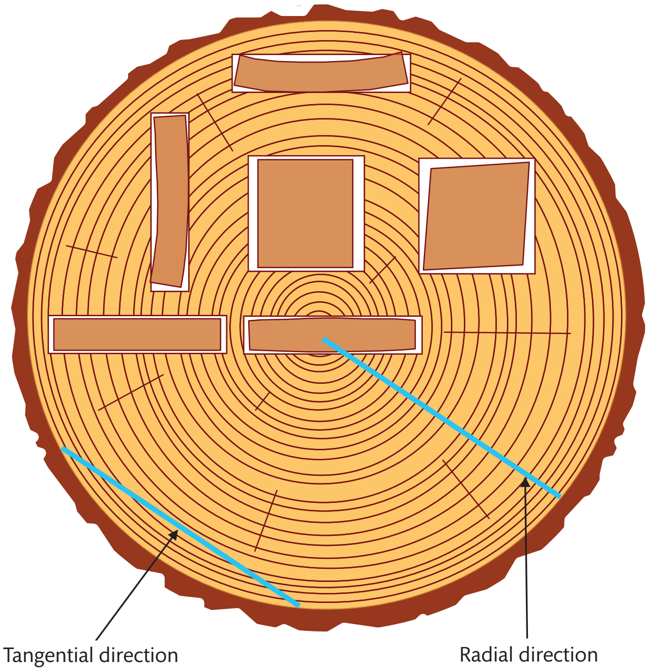


Figure 24 Change of shape of various timber cross sections due to differential radial and tangential shrinkage.



Although the data in Table 7 are a useful starting point, dimensional change in timber cannot be estimated solely from shrinkage and movement characteristics. This is because the dimensional changes are strongly influenced by natural variation in their underlying mechanisms; these include grain angle, knots, cell dimensions and molecular properties (Wimmer and Johansson, 2014). Problems can occur when heterogeneity of shrinkage and movement within individual timbers lead to warping.

Dimensional changes are also influenced by how the timber was sawn. Timber sections that are sawn on a tangential axis (often termed through-and-through or plain sawn) are less stable than those sections sawn radially (often termed quarter sawn). Quarter sawn timber is more expensive to produce than boards sawn through-and-through and is often unobtainable.

Table 6 Shrinkage and movement characteristics of UK grown timbers (After Building Research Establishment (1977) and Farmer, Maun and Coday, (2000)).

Species	Tangential shrinkage (%) from green to a moisture content of 12%	Movement class (see Table 7)
Coniferous species		
Corsican pine	5.5	Small
Douglas fir	4	Small
Larch	4.5	Small
Lodgepole pine	4	Small
Norway spruce	4	Medium
Scots pine	4.5	Medium
Sitka spruce	5	Small
Broadleaved species		
European ash	7	Medium
European beech	9.5	Large
European oak	7.5	Medium
Sweet chestnut	5.5	Small
Sycamore	5.5	Medium

Note: Some characteristics may differ from those found in imported timber of the same species.

Table 7 Movement classes of timber (after Building Research Establishment, 1982).

Movement class	Sum of radial and tangential movements as relative humidity changes from 60% to 90% at 20°C	Approximate across-the-grain dimensional change at moisture contents below the fibre saturation point
Small	< 3%	1% for every 5% change in moisture content
Medium	3 to 4.5%	1% for every 4% change in moisture content
Large	> 4.5%	1% for every 3% change in moisture content

Construction detailing

The construction detailing required to accommodate dimensional change varies with the type of component involved. For example:

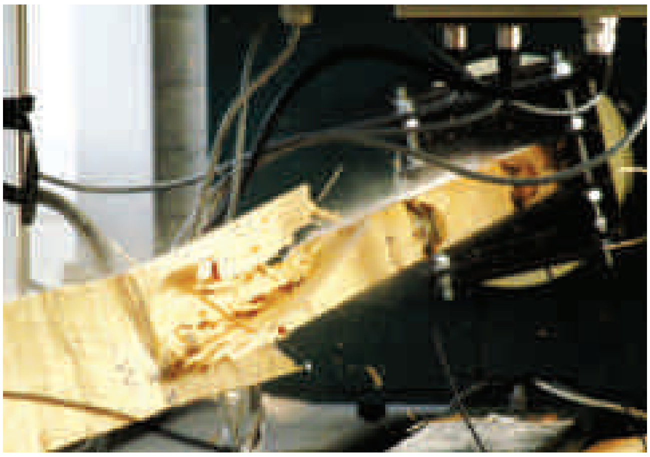
- Timber-framed buildings might need to accommodate differential movement between the timber structure and some types of heavyweight cladding. Lancashire and Taylor (2011) give guidance on this.
- Nowadays, product manufacturers often laminate small sections of clear timber together to form panels and structural members that have superior stability and strength than solid timber.
- If laminated timber is unavailable it can be worth selecting quarter sawn boards for door stiles and other components where stability is particularly important.
- Narrow boards tend to distort less than wider boards and so are preferred for many applications.
- External components such as cladding need to accommodate a wide moisture content range and, depending upon board width, dimensional stability and wood density) this might require details such as oversized fastener holes (Figure 25). The BS 8605 series gives guidance on this.

Figure 25 External cladding of green oak detailed to accommodate shrinkage as the timber first dries.

Structural timber

In engineering terminology, stress is the force per unit area in a material and strain is the change of shape that materials undergo in response to stress. The strength of a material describes the stress needed to cause a material to break (Figure 26) or reach a limit of useful load-carrying ability. The term stiffness, meanwhile, describes resistance to a change of shape; for example the ability of a beam to resist deflecting when loaded. This type of stiffness is commonly known as the elastic modulus (modulus of elasticity, MOE or E).

Figure 26 A softwood batten breaking during a laboratory torsion test.

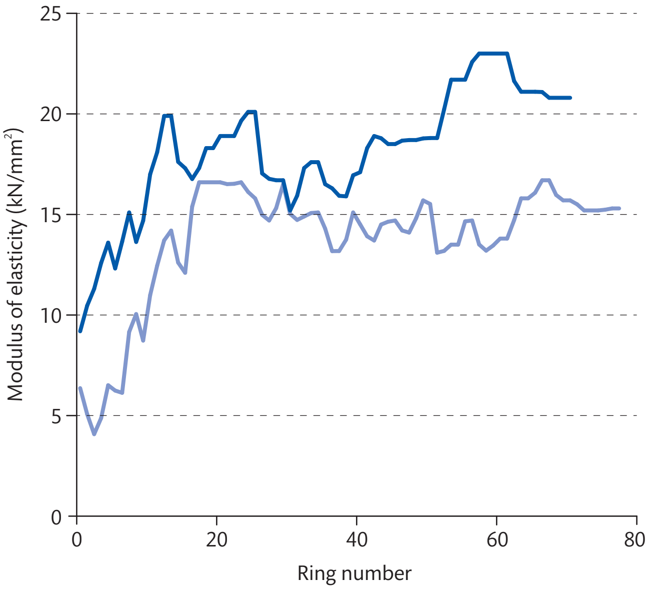


Strength variation in timber

The strength characteristics of timber vary according to the species and growth region and are affected by direction of grain and irregularities such as knots, position within the tree, microstructure of the wood and the presence of juvenile wood (wood formed in the inner growth rings of any stem cross section).

Juvenile wood has different properties when compared to wood from the outer part of the stem which is known as mature wood (not to be confused with sapwood and heartwood, see the sub-section on 'natural durability'). The number of growth rings of juvenile wood vary by species and environment but is usually reported as ranging from 12 to 20 years. Juvenile wood typically has a lower strength and stiffness than mature wood (Figure 27) and so the relative proportion of juvenile and mature wood in a piece of timber can affect its mechanical performance. Longitudinal shrinkage and natural durability are also affected.

Figure 27 Example of radial variation in modulus of elasticity for two specimens of Sitka spruce. Note the change at around year 20 (after Moore, 2011).



Strength grading

All materials vary to one extent or another and grading is the process of sorting samples of a material into groups, based upon appearance or mechanical performance, so that marketing can be rationalised and selection for a specific use is simplified. Timber grading is divided into appearance grading and strength grading. Appearance grading assesses the suitability of timber for non-structural uses. It should not be confused with visual grading (see below). This publication does not consider appearance grading in any detail. Further guidance on appearance grading of UK hardwoods is available in Davies and Watt (2005).

Although strength variation in timber has been recognised in general terms for thousands of years, it is only in the past 70 years or so that a scientifically based grading assessment has been possible. Strength grading, also sometimes called stress grading, assesses the suitability of timber for load-bearing applications.

The European structural design code for timber is BS EN 1995 (Eurocode 5). This is published in three parts, of which part 1 (BS EN 1995-1-1) gives general rules for structural design of timber in buildings. BS EN 1995-1-1 requires that all load-bearing timber is strength graded so that there are defined strength and stiffness properties on which to base engineering design calculations.

There are two types of strength grading: machine grading and visual grading. Both approaches are acceptable for use in buildings, although machine strength grading is often favoured by larger sawmills because it is faster.

Most softwood construction timber in the UK is now machine graded. This involves passing each piece of timber through a non-destructive testing machine that can sense its structural properties (Figure 28). The grade-determining properties are strength, stiffness and density. Machine strength grading measures one or more indicating parameters, such as stiffness or X-ray information about density and knots, which are correlated to these grade-determining properties. A visual over-ride is used to take account of any strength reducing characteristics that are not automatically detected by the grading machine.

Although the basic principles of machine strength grading are the same for all machines, new equipment is being introduced. This includes various types of acoustic tool (Figure 29) that can be used to grade timber at a sawmill or on-site. The principles of acoustic grading are outlined in Mochan, Moore and Connolly (2009).

Visual grading involves visually assessing all surfaces of each piece of timber against limits set for strength reducing characteristics such as knots, sloping grain or fungal attack. Large section structural timbers (Figure 30) are normally visually graded, as are virtually all hardwoods. Many sawmills employ visual graders but specialists can also be hired in to grade timber at a sawmill or on-site.

Figure 28 Timber bring machine strength graded at a sawmill.

Figure 29 A hand held acoustic grader being used to measure a piece of timber.

Figure 30 Visually graded Douglas fir timbers with their ends prepared for receiving metal connectors.

Strength grading is covered by the BS EN 14081 series, which replace all machine grading standards previously used in the UK. Visual grading is done according to a number of national standards or other published rules, although these must conform to the BS EN 14081 series. In the UK, softwoods continue to be visually graded using BS 4978 while temperate hardwoods are graded to BS 5756. Timber that has been visually graded to other standards can also be used providing the method conforms to the requirements of BS EN 14081-1. For example, Ross, Mettem and Holloway (2007) give visual grades for oak which are more specific than those in other visual grading standards and so are preferred by some oak frame manufacturers. These grades have been adapted from those in CP 112-2 (1971) which was withdrawn many years ago. Grading standards are constantly evolving and so readers should ensure that the method they use conforms to the latest revision of BS EN 14081-1.

Strength classes

The modern approach to strength grading is not tied to specific timber species and source but instead uses categories called strength classes. These are the result of the classification of timber based on particular values of mechanical properties and density. The benefit of this approach is that engineers are free to design using strength classes without having to specify which timber species and source to use, or the method of grading.

Strength classes are based upon what are termed characteristic values. These use statistical methods to ensure that timber graded to a strength class has physical and mechanical properties defined for that strength class. Several characteristic values are included within a strength class.

Most of the common strength classes are given in BS EN 338 and are summarized in Table 8. In this table, the strength classes are C14 to C50, mainly for softwood species, and D18 to D70 for hardwood species. Less dense hardwoods, such as poplar may be assigned to the C classes. The latest revision to BS EN 338 includes several amendments. These include changes to some characteristic values, adding further D classes and introducing new tension grades which are given the letter T. The T grades are intended for use in making laminated products, particularly glulam. Not all of the strength classes in BS EN 338 are readily available.

In addition to the strength classes listed in Table 8, the UK uses the TR26 grade for trussed rafters. This grade does not appear in the BS EN 338 series because it is not part of the C and D strength class system. BS EN 14081-4 (2002) gives the main characteristic values of TR26:

- Characteristic bending strength = 28.3 N/mm^2.
- Characteristic mean bending MOE parallel to grain = 11.0 kN/mm^2.
- Characteristic density = 370 kg/m^3.

Table 8 Strength classes and their characteristic values (after BS EN 338: 2009).*

	Strength classes in BS EN 338: 2009 — Weakest ⟵												⟶ Strongest	
Softwood strength classes	C14	C16	C18	C20	C22	C24	C27	C30	C35	C40	C45	C50	–	–
Hardwood strength classes	–	–	D18	–	–	D24	–	D30	D35	D40	–	D50	D60	D70
Characteristic values for strength (bending parallel to grain, N/mm^2)														
Softwoods	14	16	18	20	22	24	27	30	35	40	45	50	60	70
Hardwoods	–	–	18	–	–	24	–	30	35	40	–	50	60	70
Characteristic values for stiffness (mean MOE parallel to grain, kN/mm^2)														
Softwoods	7	8	9	9.5	10	11	11.5	12	13	14	15	16	–	–
Hardwoods	–	–	9.5	–	–	10	–	11	12	13	–	14	17	20
Characteristic values for density (kg/m^3)														
Softwoods	290	310	320	330	330	340	350	270	380	400	420	440	–	–
Hardwoods	–	–	460	–	–	475	–	530	540	550	–	620	700	900

*BS EN 338 also gives characteristic values for other strength, stiffness and density parameters. The values are for timber conditioned to a moisture content of 12%. BS EN 338 is being revised and so some of the information in this table might change. Check the current standard for the most up to date values.

The determination of characteristic values requires destructive testing of a representative number of timber pieces for each species, grade and source. This is slow and expensive, which means that very few UK grown timber species have so far been included in the latest structural standards for timber.

It is essential that structural timber being offered for sale carries evidence of its strength classification. It is normally a requirement that each piece of strength-graded structural timber is marked with this information (Figure 31). The only exception is where, for aesthetic reasons, a customer requests that visually graded timber is supplied without grade markings. In this case the timber may be grade marked as a package. This exemption only applies to timber to be used on a single project. Package marked timber carries a risk of being misidentified and so a UK national annex to Eurocode 5 (NA to BS EN 1995-1-1) applies an increased safety factor to such timber. This reduces the design strength that can be used in engineering calculations.

Strength classes of UK timber

The strength classes that can be achieved using UK grown timber are shown in Table 9. For commercial reasons only C16 grade spruce is readily available as machine graded timber although this is likely to change in the near future.

Figure 31 Machine graded spruce that has been piece marked with its strength class (C16) and other relevant information.

Courtesy of James Jones and Sons Ltd.

Table 9 Assignment of UK timber to strength classes (after BS EN 1912 and PD 6693-1).

UK grown species	Strength class (expressed as characteristic value in bending N/mm^2)									
	14	16	18	20	22	24	27	30	35	40
Coniferous species										
British spruce	GS	–	SS	–	–	–	–	–	–	–
British pine	GS	–	–	–	SS	–	–	–	–	–
Douglas fir	GS	–	SS	–	–	**SS**	–	–	–	–
Larch	–	GS	–	–	–	SS	–	–	–	–
Broadleaved species										
Oak	–	–	–	–		TH2	–	TH1 **THB**	–	**THA**
Sweet chestnut	–	–	–	–	–	TH1	–	–	–	–

Strength classes which have machine grading settings in the UK. In practice only C16 grade spruce is commonly sold although this could change in the near future.
GS, SS, TH-: Visual strength grades that can be produced from UK timber. The three grades highlighted in **bold** are only available in particular sizes.

In Table 9, the letters GS (general structural) and SS (special structural) refer to the visual strength grades for UK-grown coniferous species (see BS 4978). Thus, SS grade spruce, for example, is equivalent to C18. The designations beginning TH (temperate hardwood) refer to visual grades for UK-grown oak and sweet chestnut (see BS 5756). In Douglas fir and oak the visual grades highlighted in bold are only obtainable in cross-sections where the area is greater than 20 000 mm^2 and both cross-sectional dimensions are at least 100 mm.

The machine grade settings for UK larch are a recent introduction in response to the large number of larch trees on the west of Britain being felled due to an attack by the fungus-like pathogen *Phytophthora ramorum* (Forestry Commission, 2012). The timber is unaffected by *P. ramorum* attack and so is suitable for structural use.

Another recent development is that some UK sawmills are considering introducing a C16+ strength class. This user-defined classification suits the characteristic properties of UK grown spruce better than the basic C16 (Moore *et al.*, 2013). The strength and density values of the C16+ strength class are slightly higher than those for C16 and comprise:

- Characteristic bending strength parallel to grain = 18.5 N/mm^2 (higher than C18).
- Characteristic mean bending MOE parallel to grain = 8 kN/mm^2.
- Characteristic density = 330 kg/m^3 (equivalent to C20).

Specifying UK grown strength graded timber

Most coniferous structural timber used in the UK is either C16 or C24, with the latter grade usually being imported. This means that specifying C24 softwood will tend to exclude most UK grown timber by default. In many cases a requirement for timber that is strength graded to C24 is unnecessary because C16 would be perfectly adequate for purpose.

Over-specification can occur because some people believe that UK grown C16 timber is inferior to imported timber of the same grade – this is not correct. Strength class C16 timber has the same guaranteed mechanical properties wherever it is produced. As wall sections become thicker to meet changing energy efficiency requirements there are growing opportunities to use C16 material instead of a higher strength class. Similarly, a slight increase in the thickness of a floor joist may make it feasible in C16 grade timber.

Growth rate and density

Another common misconception concerns the relationship between growth rate and timber density. While it is widely held that slow growth tends to produce dense timber and vice versa, this is usually not the case. Moreover, density is not necessarily well correlated with strength and stiffness; the relationship is heavily influenced by factors such as species, cell wall composition, grain, knots and climate.

Table 10 outlines the six types of relationship that are found between growth rate and wood density. In this table, the terms earlywood and latewood describe, respectively, the portion of the growth ring that is formed during the earlier or later stage of a growth period; earlywood is usually paler in colour and less dense than late wood. The relative proportions of earlywood and latewood can be important factors in some circumstances. For example:

- In the UK and Scandinavia, both the density and the growth rate of many softwood species decrease with latitude; the reduction in the length of the growing season appears to lead to a reduction in the proportion of latewood and therefore density. A recent analysis of data from Jeffers and Dowden (1964) found that latitude accounted for approximately 22% of the variation in wood density in UK grown Sitka spruce; density decreased by 6 kg/m^3 for every one degree increase in latitude (Moore, 2011).

- In some hardwood species the width of the earlywood zone is relatively constant and the variation in ring width is due to changes in the thickness of the high density latewood. In these species, density therefore increases with increasing ring width. In ash, for example, timber with growth rings between 1.5 and 6 mm wide is recommended for exacting purposes such as tool handles (FPRL, 1972).

Barnett and Jeronimidis (2003) and Tsoumis (1991) review these relationships in more detail.

Service classes

The strength of timber and wood-based products is affected by the moisture content of the component. Most strength and stiffness properties are at their maximum when the moisture content is low. As the moisture content rises, strength is reduced. Engineers want to optimize the strength of timber in a structure and so it is usually dried before use to a moisture content similar to that which it would reach after time in service. In cases where a timber section is too large to be uniformly dried, or the timber is to be used in

Table 10 Growth rate and density.

Anatomical characteristics	Relationship between growth rate and density	Example species
Softwood species with no visible growth rings.	No correlation between growth rate and density.	Some tropical and southern temperate timbers including most species in the Podocarpaceae, Cupressaceae and Andcupressaceae families.
Softwood species where the growth rings have a gradual transition from earlywood to latewood.	Density might decrease with increasing growth rate. The relationship is not consistent, however, as density is affected by the genetic makeup and growing conditions of a tree, and can be influenced by its stage of development. Therefore, particularly for timber of mixed origins, ring width alone is not an accurate predictor of density.	The spruces (*Picea* spp.) and the firs (*Abies* spp.).
Softwood species where the growth rings have an abrupt transition from earlywood to latewood.	No correlation between growth rate and density.	The larches (*Larix* spp.) and the hard pines (*Pinus* spp.).
Hardwood species where the growth rings have fairly evenly distributed vessels. These species are termed diffuse porous hardwoods.	No correlation between growth rate and density.	Most tropical hardwoods along with temperate species such as the birches (*Betula* spp.) and the evergreen oaks (*Quercus* spp.).
Hardwood species where the growth ring characteristics are intermediate between ring porous and diffuse porous. These species are termed semi-diffuse porous (a.k.a. semi ring porous) hardwoods.	Little correlation between growth rate and density.	European walnut (*Juglans regia*).
Hardwood species where the growth rings have earlywood with a more or less continuous zone of vessels of greater diameter than those formed later in the growing season. These species are termed ring porous hardwoods.	Within limits, fast growth produces relatively dense, strong timber and vice versa.	These species are always deciduous and include European oak (*Quercus robur* and *Q. petraea*), European ash (*Flaxinus excelsior*) and sweet chestnut (*Castanea sativa*).

Note: Not all timbers neatly fit these categories. Teak, for example, can be semi-diffuse porous or ring porous depending upon the growth conditions.

damp conditions, engineers have no alternative but to design the structure on the basis of the reduced strength associated with wet timber. BS EN 1995-1-1 assigns timber to three categories reflecting variation in strength and stiffness due to moisture. These categories are termed service classes (Table 11).

Strength graded timber is sometimes sold dry-graded. This means that it has been checked for fissures and distortion at an average moisture content of no more than 20%. Dry-graded timber is most appropriate for service classes 1 and 2. Timber for use in service class 3 will reach a higher moisture content in service and so non-dry-graded timber is adequate. The term dry-graded is not synonymous with the moisture condition at time of delivery of the timber, which is specified as part of the contractual arrangement.

Table 11 Service classes for structural timber (after BS EN 1995-1-1).

Service class	Environmental conditions and associated timber moisture content
1	A temperature of 20°C and a relative humidity below 65% for most of the year. The corresponding moisture content in most softwoods is no more than 12%.
2	A temperature of 20°C and a relative humidity below 85% for most of the year. The corresponding moisture content in most softwoods is no more than 20%.
3	Climate conditions leading to a higher moisture content than in service class 2.

Fire performance

Wood burns, even when treated with a flame retardant. Despite this, finished timber buildings can more than meet the fire safety requirements of building regulations. BS 9999 and BS 9991 give an introduction to the design, management and use of buildings to achieve fire safety. The fire risks during construction can also be addressed; guidance on this can be obtained from the Structural Timber Association (see Appendix 6).

Fires in completed buildings have two main stages: the growth phase is followed by what is known as the fully developed fire where all exposed combustible materials are burning. The transition between these phases is rapid and is known as flashover. The behaviour of building components during the growth phase is termed reaction to fire, which includes ignitability and flame spread across a surface. In the second phase, fire resistance becomes important – this describes the ability of a building element to perform its function when exposed to the power of a fully developed fire.

BS EN 13501-1 and BS EN 13501-2 give test procedures and performance classifications for reaction to fire and fire resistance, respectively. National classifications are published in the BS 476 series although these are being increasingly superseded by the European standards. These fire test classifications apply to complete construction assemblies and not to their components in isolation. This means that components might be given different classes depending upon the test conditions.

Fires in cavities are a further issue. Cavities occur in virtually all types of construction but are a particularly important consideration with timber.

Reaction to fire

Internal linings and external cladding can both contribute to the growth phase of a fire and so might need to achieve a specific reaction to fire classification. Different classifications are used for floors, walls and roofs. Table 12 outlines the national and European reaction to fire classifications for wall surfaces (see the BS 476 series and BS EN 13501-1). Most timber wall assemblies can achieve a reaction to fire classification of Euroclass D (national class 4). Where required this can usually be upgraded to a Euroclass B (national class 0) classification using flame retardant treatment (Figure 32).

Table 12 Transposition of UK and European reaction to fire classes for walls.

Examples of product assemblies	Classifications for internal linings and external cladding on walls[a]	
	BS 476 series[b]	BS EN 13501-1[c]
Products made completely or largely of inorganic materials	Non-combustible or slightly combustible	A1 or A2
Timber tested after flame retardant treatment	Class 0	Euroclass B
	Class 1, 2 or 3	Euroclass C
Timber tested without flame retardant treatment[d]	Class 4 or 5	Euroclass D or E
Untested timber	Unclassified	Euroclass F

a. This table is only for information as the transposition between these classifications is not exact. Moreover the classification achieved may vary depending upon the exact product assembly.
b. Class 0 does not exist as a classification in the BS 476 series. Instead, it is used in documents supporting building regulations in England to describe a particular performance level within class 1. The equivalent term in Scotland is Low Risk.
c. In BS EN 13501-1 some product assemblies may be within the scope of 'Classification without Further Testing' in which case they can be assigned a Euroclass without testing. Other products will need testing.
d. Timber with a density of below 400 kg/m^3 (at 12% moisture content) tends to achieve a lower classification than denser timber.

Flame retardants only affect how fire propagates and spreads; there is no treatment that can make timber non-combustible (Euroclass A1 or A2). Consequently, timber products may be excluded in some situations although the exact requirements vary in different parts of the UK depending upon the factors of fire safety in different national building regulations. Documents supporting the Scottish Building Regulations, for example, prohibit external timber cladding within 1 m of a property boundary (Figure 33), whereas in the rest of the UK it has to be flame retardant treated for use in this location (Dept. for Communities and Local Government, 2014; Dept. of Finance and Personnel, 2014; Scottish Government, 2014; Welsh Government, 2014). The Wood Protection Association (2011b) gives guidance on flame retardant specification.

Sprinklers provide an alternative means of controlling the growth phase of a fire. The increasing use of sprinklers is creating new opportunities for timber construction.

Figure 32 Blaenau Gwent Learning Zone in Ebbw Vale makes extensive use of locally sourced Japanese larch for the internal linings and eaves cladding. The timber was impregnated with a flame retardant to make it suitable for use on a public building. Designed by BDP.

Courtesy of BDP

Figure 33 Fibre cement cladding has been used on these gable ends. This is because Scottish Building Standards do not permit combustible cladding on facades that face onto an adjacent ownership boundary.

Fire resistance

Large section timbers can perform exceptionally well in a fully developed fire. This is due to a layer of insulating char forming on the exposed surface, which serves to protect the timber underneath. Timber will only lose its load-bearing capacity when the non-fire-damaged residual section is reduced to a size where the stress resulting from the applied load is greater than the strength of the timber. There is an almost linear relationship between charring rate and time. A constant charring rate is therefore assumed for fire resistance calculations.

BS EN 1995-1-2 gives several methods of calculating fire resistance, the most frequently used of which are outlined in Table 13. In the simplest (and most conservative) method, the charring rate β_0 can be used without the need to consider how the edges of an element round over during a fire. A more accurate method assesses the residual cross-section resulting from a slower charring rate β_n that allows for edge rounding. In either case, char depth is calculated by multiplying the relevant charring rate by the duration of fire exposure.

Table 14 gives charring depths calculated in accordance with Table 13. For a 60-minute single-sided fire exposure, for example, the loss of structural thickness is approximately 40 mm for most softwood timbers and 30 mm for the denser hardwoods. Engineers can make allowance for these losses by increasing the timber section accordingly.

Table 13 Charring rates given in BS EN 1995-1-2.

Type of timber	Charring rate (mm/min)	
	β_0 (single-sided exposure)	β_n (multi-face exposure)
Softwood and beech		
Glulam (density ≥ 290 kg/m³)	0.65	0.7
Solid timber (density ≥ 290 kg/m³)	0.65	0.8
Hardwood		
Solid timber or glulam (density ≥ 290 kg/m³)	0.65	0.7
Solid timber or glulam (density ≥ 450 kg/m³)	0.5	0.55

Note 1: Beech is regarded as a softwood for the purposes of this table.
Note 2: With solid hardwoods, except beech, charring rates for densities between 290 kg/m³ and 450 kg/m³ can be obtained by linear extrapolation.
Note 3: Density is at a moisture content of 12%.

Table 14 Depth of charring calculated from Table 13 (after Bregulla, Enjily and Lennon, 2004).

Type of timber	Charring depth (mm) after 30 mins		Charring depth (mm) after 60 mins	
	β_0	β_n	β_0	β_n
Softwood and beech				
Glulam (density ≥ 290 kg/m³)	19.5	21	39	42
Solid timber (density ≥ 290 kg/m³)	19.5	24	39	48
Hardwood				
Solid timber or glulam (density ≥ 290 kg/m³)	19.5	21	39	42
Solid timber or glulam (density ≥ 450 kg/m³)	15	16.5	30	33

If the structure uses small section timbers, the required level of fire resistance can be achieved by shielding the timber using cladding or a non-combustible material such as a rock fibre batt. Flame retardants can be used to reduce the participation of timber in the early stages of a fire, but will not, by themselves, be sufficient to ensure fire resistance.

Cavity fires

Spread of flame within cavities is a concern with most types of construction. Accordingly, documents supporting building regulations recommend the installation of cavity barriers at specific locations in a building. In the case of external timber cladding it is important that these barriers do not impede cavity ventilation except during fires. This might require the use of special construction details such as intumescent cavity barriers (i.e. barriers that expand when heated). Test methods for ventilated cavity barriers are not fully standardized at present although work is ongoing.

Resistance to wood destroying organisms

Various organisms can degrade wood and wood-based products by spoiling their appearance or causing loss of strength. In order to use these products successfully it is important that the biodeterioration threats are understood and properly addressed.

Fungal decay and insect attack

The main agents of timber biodeterioration in UK buildings are various species of fungi. Fungi spread by microscopic spores and in the summer these are widely dispersed. In order for a spore to colonize wood, a film of water is needed on the cell walls. This means that timber with a moisture content over the fibre saturation point is susceptible to fungal attack while drier timber is not (Zabel and Morel, 1992). The fibre saturation point of most temperate timbers is at a moisture content of 26% to 32%, whereas the equivalent range in most tropical timbers is between 19% and 26% (Rijsdijk and Laming, 1994). Accordingly, the decay threshold is normally quoted as a value of 20% to 23% to accommodate virtually all timber species and to take account of moisture content variability and inaccuracies in measurement.

Various insects can also degrade timber, although in the British Isles our cool climate limits the wood destroying insects that can survive. Larvae of the common furniture beetle (*Anobium punctatum*) are the main insects that attack timber inside buildings in the UK. This organism is a forest floor species and so it requires a timber moisture content of over 18% to thrive. The larvae can survive for a time at moisture contents down to 12% but in these conditions their growth is slow and the colony will eventually die out. A few other insect species can attack timber in UK buildings in particular circumstances. The house longhorn beetle (*Hylotrupes bajulis*), for example, can infest softwood roof timbers although it is only found in a small area southwest of London; specific building regulations apply in that risk zone.

Bravery *et al*. (2003) give detailed guidance on diagnosing and treating fungal decay and insect attack.

Use classes

BS EN 335 employs the concept of a use class (Table 15) to describe the biodeterioration risks associated with different moisture conditions. The risks increase from negligible in use class 1, up to use class 5 where they are very high.

Table 15 Use classes for timber (after BS EN 335).

Use class	Moisture condition	Biodeterioration organisms
1	Interior timber, not exposed to wetting	Minor risk of beetle attack
2	Interior timber, exposed to wetting from condensation or leaks	Localised risk of beetle attack and fungal decay
3	Exterior timber, out of ground contact, but exposed to occasional or frequent wetting	Fungal decay is the main threat, stain fungi and beetles also occur
4	Exterior timber in contact with the ground or fresh water	Fungal decay is the main threat
5	Timber permanently or frequently exposed to sea water	Marine borers are the main threat

Notes: Subterranean termites (*Reticulitermes* spp.) are locally present in some parts of Europe but not in the UK. These use classes do not fully correspond with the service classes in Table 8; this is because the two systems are designed for different purposes. In general:

- Use class 1 is similar to service class 1.
- Use class 2 is similar to service class 2.
- Use classes 3 to 5 are similar to service class 3.

Moisture contents over 20% can occasionally occur in use class 2, become frequent in use class 3 and are near permanent in use classes 4 and 5. The term use class replaces hazard class, which was used in earlier standards.

Natural durability

Timber's inherent resistance to wood destroying organisms is termed natural durability. This varies between species and within a log. In cross-section, a large log consists of two main zones – the heartwood is at the centre and is surrounded by a sapwood zone beneath the bark. Sapwood is usually paler than heartwood (Figure 34) although this is not the case in all species. Heartwood forms when the innermost sapwood layer ceases to be active in fluid transport and undergoes a chemical and physical transformation. In many tree species this transformation increases the decay resistance of the interior wood so that it can continue to have a role in supporting the tree. Sapwood has little resistance to biodeterioration, whereas the natural durability of heartwood varies between species.

Natural durability is mainly due to the presence of compounds known as extractives in the heartwood. These compounds are not just associated with hardwood species. Some hardwoods, such as birch (*Betula* spp.) have a low natural durability, whereas softwoods such as European yew (*Taxus baccata*) and western red cedar (*Thuja plicata*) can be highly durable.

Figure 34 Cross section of an oak log with the heartwood and sapwood clearly distinguishable.

Natural durability can vary within a species due to differences in growth conditions and other factors. Juvenile wood has lower natural durability than mature wood when it is converted to heartwood and so the extent of juvenile wood is often the most important factor. This can be manifested in differences in natural durability between timber from plantation grown trees and those from near-natural forests. The effect is largely due to differences in the age of the tree when felled. Plantation grown teak (*Tectona grandis*), for example, has a lower natural durability than teak from near-natural forests. Similarly, imported western red cedar and Douglas fir that have been sourced from near-natural forests tend to be more resistant to wood destroying organisms than UK plantation grown timber of the same species. These differences are acknowledged in BS EN 350-2.

Durability classification

BS EN 350-2 assigns separate natural durability classifications depending upon the type of wood-degrading organisms involved. The standard lists the fungal decay resistance of most commercially important timber species using five classes reflecting the relative durability of their heartwood (Table 16). All sapwood is assigned to class 5 (not durable).

The desired service life estimates in Table 17 are from BS 8417 and only apply to degradation by fungi. These categories are included in this table to give an approximate indication of the relative performance of the natural durability classes in different moisture conditions. Readers should bear in mind that service life prediction in use class 3 is poorly understood (Suttie, 2012) and so these estimates might considerably underestimate the performance that can be achieved in practice (Figure 35). The distinction between occasionally and frequently wet, for example, is not exact – construction details that minimise wetting and promote drying tend to increase the service life whereas water traps and other sources of wetting will reduce it. Some types of surface coating might help keep timber dry although this is difficult to guarantee. Maintenance is also important.

Figure 35 Completed in 1834, Swiss Cottage near Fochabers is believed to be the oldest surviving timber-framed and –clad house in Scotland. It was built using local plantation grown Scots pine; the timber was not preservative treated. Buildings such as this suggest that the desired service life values quoted in Table 16 considerably underestimate the performance that can be achieved in practice.

Table 16 Durability classes against fungal attack (after BS EN 350-2 and BS 8417).

Natural durability class	Description	Examples of desired service life of the timber (years) in UK conditions		
		Use class 3		Use class 4
		Occasionally wet	Frequently wet	
1	Very durable	60	Over 60	60
2	Durable	30	60	30
3	Moderately durable	15	30	15
4	Slightly durable	–	15	–
5	Not durable	–	–	–

Table 17 Natural durability class of the main UK grown timbers (after BS EN 350-2).

Common name	Natural durability class against fungi				
	1 (very durable)	2 (durable)	3 (moderately durable)	4 (slightly durable)	5 (not durable)
Coniferous species					
Corsican pine	–	–	–		–
Douglas fir	–	–			–
Larch	–	–			–
Lodgepole pine	–	–			–
Norway spruce	–	–	–		–
Scots pine	–	–			–
Sitka spruce	–	–	–		
Broadleaved species					
European ash	–	–	–	–	
European beech	–	–	–	–	
European oak	–		–	–	–
Sweet chestnut	–		–	–	–
Sycamore	–	–	–	–	

Notes: BS EN 350-2 recommends that where a species spans more than one durability class it should be assumed to be in the lowest durability class within its range. Natural durability might differ from that found in imported timber of the same species. These classes only apply to heartwood, all sapwood of all species is classified as class 5 (not durable).

BS EN 350-2 uses a two class system to describe the resistance of wood to attack by beetle larvae of *Anobium punctatum* and three other insect species. The classes are D (durable) and S (susceptible). It is assumed that all heartwood is durable except where indicated SH (susceptible heartwood). With the exception of Norway spruce, all commercially available UK timber species are classed as S, which means that their sapwood is susceptible to attack by *A. punctatum*, while the heartwood is resistant. Norway spruce is classed as SH, meaning that the heartwood is susceptible as well as the sapwood. No service life estimates are published for resistance to insect attack.

Table 17 gives natural durability classes for the most important UK grown timber species. The durability of some of these timbers might be reclassified in the near future because the BS EN 350 series is in the process of being revised.

Preventing biodeterioration

To prevent biodeterioration of timber, building design should provide conditions which:

1. Prevent wetting of timber wherever possible.
2. Ensure rapid drying (by drainage and ventilation) wherever it is impossible to prevent periods of wetting.
3. Use biodeterioration-resistant timber where it is impossible to prevent exposure to persistent wetting.

This staged approach is known as 'design for durability' or 'detailing for durability' (Sagot, 1995) and is particularly important in use class 3. The first two stages require careful attention to detailing and installation, while stage three involves specifying appropriate timber for the use class (Figure 36).

The general approach to selecting appropriate timber can be illustrated using BS EN 460 and is summarized in Table 18. If it is decided that the natural durability of the timber species originally proposed is insufficient, then either a more durable species should be used or the timber needs to be given additional protection. If such protection is required there are, nowadays, two alternatives:

- **Preservative treatment:** This is the more common approach. It involves pressure-impregnating the timber with compounds intended to control wood destroying or wood disfiguring organisms; the mode of action is normally biocidal.
- **Wood modification:** This involves using a chemical, physical or other process to modify the timber in order to achieve a desired property change during its service life. If the wood modification process confers improved resistance to biological attack, then its mode of action should be non-biocidal.

Figure 36 UK sourced oak shakes clad the roof of Brockholes Wetland Visitor Centre near Preston. Oak shakes were selected for their appearance and durability. Adam Kahn Architects.

Table 18 Selecting appropriate natural durability against fungal attack (after BS EN 460).

Use class (see Table 15)	Natural durability class (see Table 16)				
	1	2	3	4	5
1	Green	Green	Green	Green	Green
2	Green	Green	Green	Lime	Lime
3	Green	Green	Lime	Yellow	Yellow
4	Green	Lime	Orange	Red	Red
5	Green	Orange	Orange	Red	Red

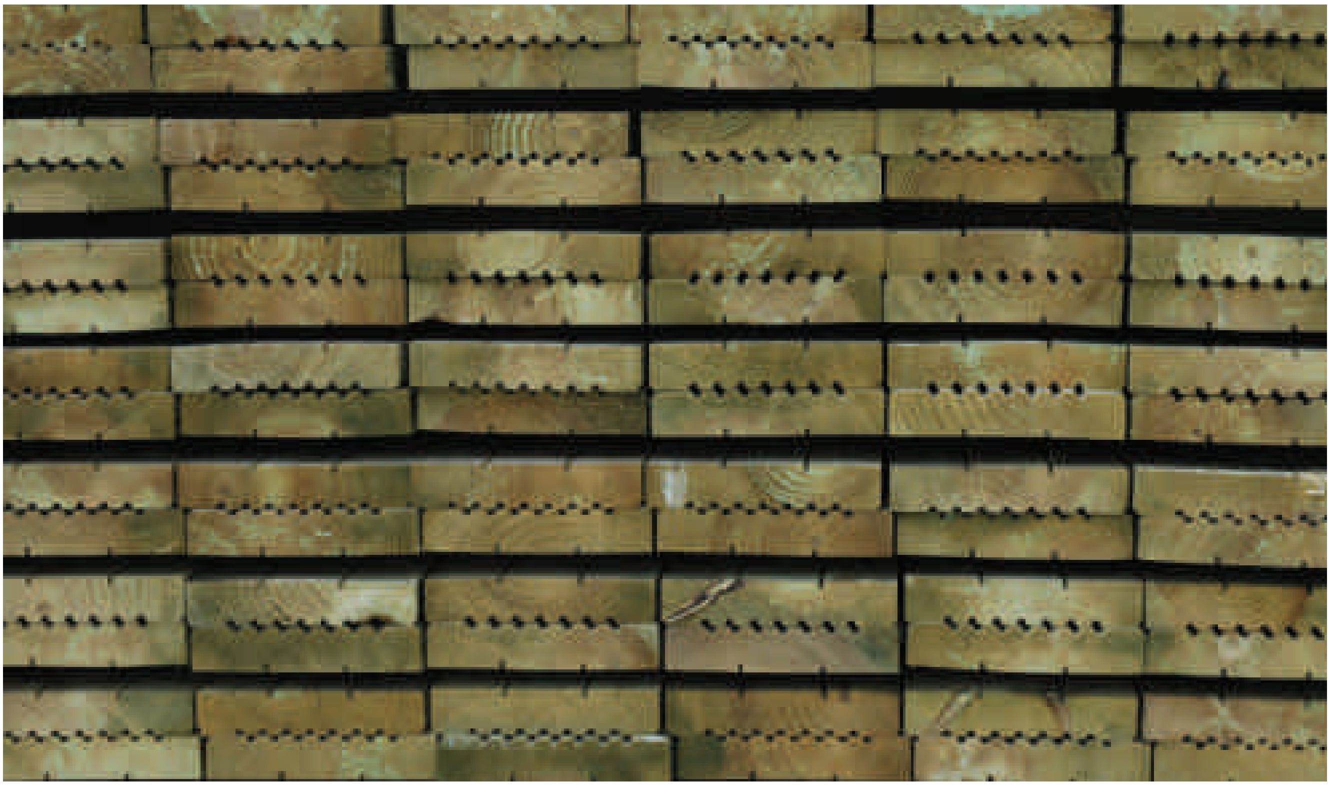
- (Green) In these conditions natural durability is always sufficient and there is no requirement for preservative treatment.
- (Lime) Natural durability is normally sufficient in these conditions but, for certain uses where condensation is likely, preservative treatment is advised.
- (Yellow) Natural durability might be sufficient in these conditions but, depending upon the wood species and end use, preservative treatment may be needed.
- (Orange) Preservative treatment is normally advised in these conditions but natural durability may be sufficient in some cases.
- (Red) Preservative treatment is always necessary in these conditions.

Preservative treated timber products are produced at many UK sawmills (Figure 37). Where preservative treated timber is required it should be specified in accordance with the BS EN 599 series. The appropriate preservative should be used and its retention in the timber should be equal to or better than is required for the use class. All machining and cutting of the timber component should be completed before preservative treatment. If post-treatment cross-cutting, notching or boring is unavoidable, the timber should be re-treated with an appropriate end-grain preservative. Rip sawn boards should be returned to the treatment plant for retreatment. BS 8414 gives preservative treatment recommendations which are in accordance with the BS EN 599 series. Additionally, the Wood Protection Association (WPA) have produced a set of simplified preservative treatment specifications which are suitable for use in the UK (Wood Protection Association, 2012).

Wood modification involves a rapidly changing group of proprietary technologies and is not yet fully standardized. The WPA has issued guidance on modified woods (Wood Protection Association, 2011a) although recently introduced modified woods might not be included. The WPA recommends that modified woods are specified as if they are timber species of equivalent natural durability. The most common types of modified wood are chemical modification (e.g. Accoya™) and thermal modification (e.g. Thermowood™). There is no UK producer of chemically modified timber, but thermally modified timber is being produced on a limited scale in Wales.

Thermal modification involves heating the timber to around 200°C for several hours in an oxygen-free environment. The process should not be confused with heat treatment, which uses lower temperatures to sterilize wood against pest infestation. Heat treatment is used with wood packaging such as pallets (FAO, 2009) and to control specific insect infestations.

Figure 37 A pack of preservative treated softwood decking.



Timber in repair and refurbishment work

Most British and European standards for construction are aimed at new buildings; so too are the building regulations. Many issues affecting existing buildings are not addressed by these publications. Consequently, repairing and conserving timber in buildings of traditional construction or historic importance raises issues that are not discussed elsewhere in this report.

BS 7913 gives guidance on the principles of conserving historic buildings, and the websites of government building conservation agencies (see Appendix 6) also have useful guidance. This section does not attempt to reproduce this existing information but instead adds a number of points that are not readily available elsewhere. The focus is upon repair and refurbishment of timber in historic buildings but many points are applicable to work on any existing building or structure.

History of timber use in the UK

Most of England's woodland had disappeared by 1066 when the Doomsday book chronicled a woodland cover of 15% (Rackham, 1996). Evidence for the extent of woodland in other parts of Britain is more fragmented, although the situation is believed to be comparable. Woodland cover declined to less than 5% by 1815. This limited area of woodland means that the UK has had to use a high proportion of imported timber for a long time. Scotland, for example, was importing timber from Europe and Scandinavia as far back as the 14th century (Smout, MacDonald and Watson, 2005).

The timbers used in construction changed over time. Up to the 17th century, European oak was the most common building timber in most of Britain although other species were also used. Oak supplies in Scotland were limited and so Scottish builders relied more on Scots pine. Availability of Scots pine was also restricted, in part due to the costs of overland transport to the Lowlands.

During the 17th and 18th centuries imported softwoods became the main construction timber throughout Britain. Thus Adam Smith, writing in 1776, describes timber use in the building of Edinburgh's New Town: 'In the new town of Edinburgh, built within these few years, there is not, perhaps, a single stick of Scotch timber' (Smith, 1776, p. 152). The main timber supply during this period comprised Scots pine imported from Norway and the Baltic. Imported Scots pine timber was recorded under several trade names derived from either the region of growth (e.g. Baltic fir), the port of origin (e.g. Memmel pine), the colour of the timber (e.g. redwood, yellow deal) or some combination of these (e.g. Kara Sea redwood). From the late 18th century onwards North American species such as Douglas fir, American white oak (*Quercus* spp.) and American pitch pine (principally *Pinus palustris* and *P. elliottee*) became increasingly available along with a range of tropical hardwoods (Figure 38).

Improvements in overland transport meant that by the middle of the 19th century imported timber was available in all but the most remote rural areas. Estate sawmills continued to supply timber for local use on farm buildings and similar applications, but virtually all structural and joinery timber used in house construction was imported.

Figure 38 Aultnaslanach Railway Viaduct at Moy near Inverness was completed in 1897 and is the only surviving structure of its type on a main railway line in Scotland and possibly in Britain. The trestles are made from imported pitch pine and have been preservative treated.

Until the introduction of modern forestry practices during the 18th and 19th centuries most timber came from sources where the continuity of woodland cover was relatively unbroken. These woodlands were either primary, meaning that they existed continuously since before the original forest in the area was fragmented, or secondary, referring to woods that appeared on unwooded ground since that time. Most primary woodland in the UK disappeared in prehistoric times whereas many other countries retained significant areas of woodland throughout their history (Peterkin, 1996). From the early to mid-20th century most temperate timber used in the UK came from plantations or similar sources.

People sometimes assume that plantation grown timber is inferior to that from primary or semi-natural woodland, but this is not necessarily the case. Plantations are normally designed with the structural quality of timber in mind; there are no such assurances with timbers from natural woodlands and so their load bearing characteristics can be more variable. Natural durability can, however, be adversely affected. This is generally due to the presence of a high proportion of juvenile wood within the log.

The large section timbers found in old buildings often have a lower proportion of juvenile wood than equivalent sized logs sourced from plantation grown timber of a normal rotation length of 35 to 60 years. A Scots pine log from a large old tree of near-natural origin, for example, will tend to be mostly mature heartwood, whereas a plantation grown log of the same species is likely to have a high proportion of juvenile wood. This means that construction practices (e.g. beam ends embedded in a masonry external wall) that were suitable in the past may result in impaired performance if plantation grown timber is used. Juvenile wood also tends to be less stable than mature wood and this can be in issue in panelling and similar finishes.

Selecting the appropriate timber for repairs

Timber used in repairs should be selected to match the characteristics of the existing material. This is often quite simple to achieve although there are several points to consider.

Wherever possible new timber should be of the same species as the components being repaired. Species identification might be unnecessary for minor repair works but should always be attempted for timber in historic buildings and significant structural components. Identification of a timber species often requires specialist skills and equipment. It might not be possible to identify the exact timber species in all cases although it should be feasible to determine a species group.

Load-bearing timbers should, as a minimum, have the appropriate moisture content and visual strength grade (see earlier); natural durability can also be important. The considerations for non-structural timbers include moisture content, natural durability, movement class and grain orientation. Appearance grade might also be relevant. It is rarely feasible to grade out juvenile wood because the line of the pith is often not straight and so, where this is a concern, designers should consider their options carefully.

There are four main options when selecting timber for repair work:

1. As a building is being refurbished, some existing timbers might have to be removed. In which case it may be possible to reuse this timber elsewhere in the building. This is usually the best option especially for small repairs. Any timber that has to be removed should therefore be stored in the dry in case it is subsequently needed (Figure 39).

2. If option 1 is not available, the new timber should be as similar as possible to that of the in-situ material. This may simply involve selecting particular pieces of timber at a mainstream distributor. In other cases a specialist timber merchant might be able to help. New timber should be certified as being legal and sustainable (see Appendix 5).

Figure 39 This timber store serves a large architectural conservation project. It contains boards that have been removed from buildings under renovation and are being stored for reuse, along with new timber sections machined to match traditional profiles. Sørgjeslingen, western Norway.

3. It may be possible to reuse timber from another building although this raises several practical and ethical difficulties. Structural timber may have already distorted in its previous frame and so an old timber member might not be easily compatible with a new component. Also, in the case of an oak frame, the old timber will be dry and therefore much more difficult to work than new green timber. The most important ethical consideration is to ensure that the building is not being repaired with wood taken out of a listed building without consent. This is a difficult topic, however, as the Listed Building Consent process only authorises the work, not the fate of components. Although recycled timber merchants should be able to document the provenance of timber they are selling, this trade is largely unregulated and, in any case, reclaimed timber can be difficult to obtain. A further problem arises because reusing timber from other old buildings might be architecturally misleading.

4. If none of the above options are available then designers need to define what timber characteristics are required and source another timber species that closely matches this specification. This performance-based approach raises two issues:

   - UK grown timber is rarely of a quality suitable for fine joinery. Although adequate for some flooring and panelling, there is little evidence that UK grown Scots pine was ever widely used for windows and similar purposes. UK grown oak was used for joinery, although imported timber was the more common choice from the late medieval period onwards. Nowadays oak joinery is produced on a small scale from UK timber. Homegrown Douglas fir is also an option although it should be remembered that UK grown timber of this species might not be as durable as imported supplies (see BS EN 350-2). UK grown larch may be suitable for some joinery products, particularly flooring. Other timbers might be locally available.

   - Architectural conservation tends to use a prescriptive (do this, do that) approach that prioritises the historical authenticity and integrity of the building (ICOMOS, 1999). It can be difficult to combine this ethical approach with a performance-based specification which, by definition, only addresses verifiable material characteristics. To take a practical example, replacement sash windows could be made from a modified wood (see the subsection on 'Preventing biodeterioration') as an alternative to a traditional timber species. But, although some modified woods such as Accoya™ perform exceptionally well in this application, it can be argued that the use of such timber would be no more authentic than using a replacement plastic window.

Moisture content of timber used in repairs

Drying timber accurately in controlled conditions is a modern development. Timber in historic buildings was used green or air dried. The timber then dried in-situ although the equilibrium moisture content of timber in unheated rooms was not as low as that found in a centrally heated building (Table 5). These changes have implications for anyone repairing timber in old buildings.

It is important that the moisture content of existing timber is measured before any work is undertaken. Wet timber in buildings should, wherever possible, be dried out before a repair is carried out. Ideally the moisture content of new timber should match that of the existing component. If green or air dried timber is attached to a component that has dried in-situ, the junction may experience problems such as splitting or distortion as the new timber dries. Problems can also occur if dry timber is fixed to a component that has become wet in-situ.

Grading structural timber in-situ

Where structural timber has been damaged or the loading conditions changed, it is essential that the load-bearing characteristics of these elements are assessed and a judgement made as to their suitability or need for repair. TRADA Technology (2011) outlines the main methods of assessing and repairing structural timber in-situ and it gives a decision sequence to guide the investigation (Figure 40). Ross (2002) also gives guidance on assessing and rectifying damage to structural timber. Visual strength grading (see the section on 'Structural timber') should be employed. The general procedure involves recording the timber species and grading features (e.g. knots, slope of grain) and from this assigning a visual strength grade. The species/grade combination is then used to determine the strength class using BS EN 1912. The moisture content of the timber should also be assessed. Replacement structural timber should always be strength graded (Figure 41).

Current visual strength grades are not specifically designed for assessing timber in-situ. Consequently, Ross (2002) gives visual grades that are intended for building conservation purposes; they update the grades in CP 112-2 (1971) and are equivalent to those in Ross, Mettem and Holloway, (2007). Note, however, that the guidance in these documents might not be fully compatible with the latest revision of BS EN 14081-1.

Figure 40 This flow chart gives a decision sequence for use when assessing structural timber in-situ (after Slavid, 2010).

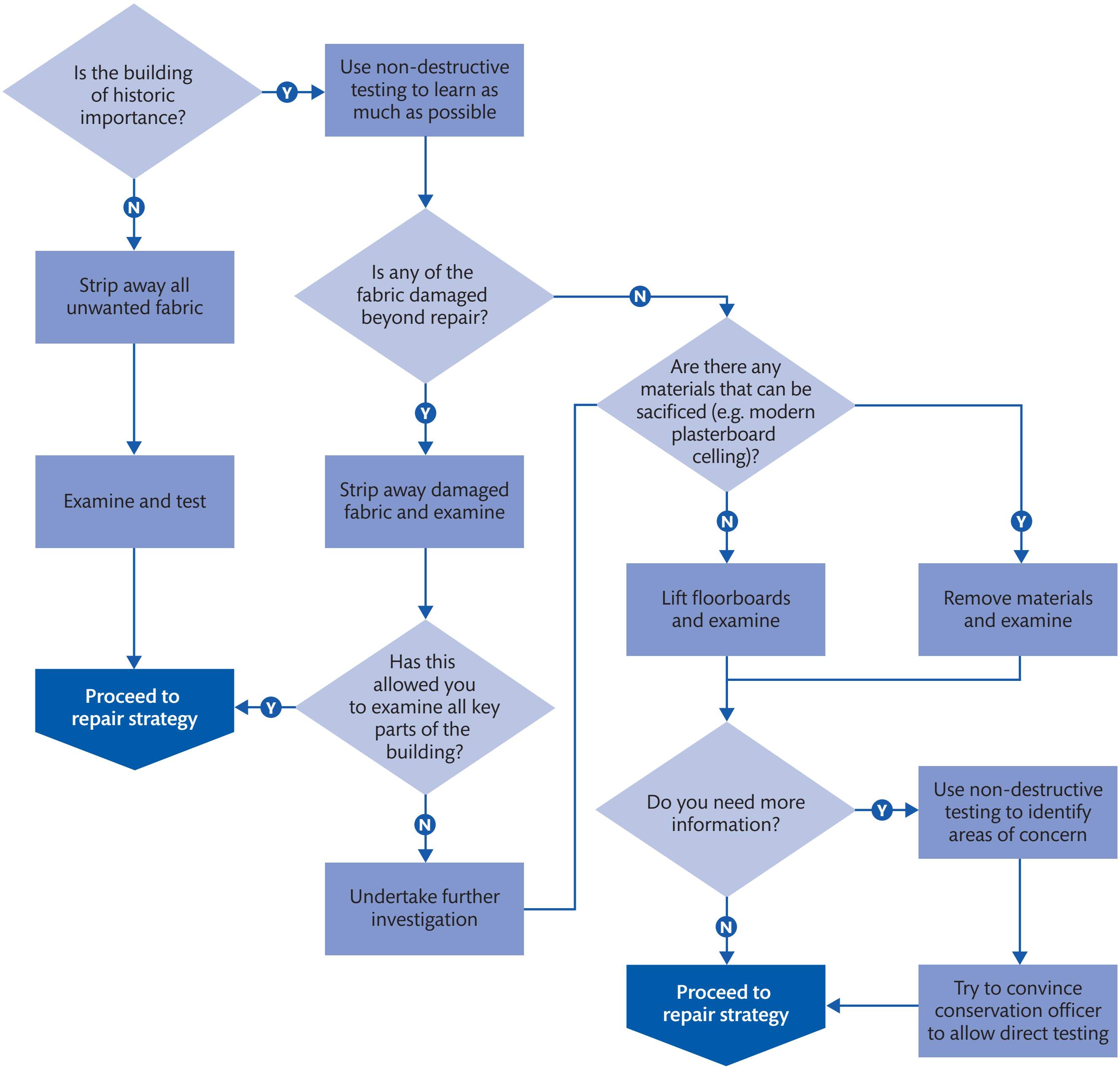


Figure 41 Visually graded oak used for new roof trusses over the south transept of York Minster. Ove Arup & Partners.

Hygrothermal materials

Understanding of moisture conditions in buildings, and their associated risks, has improved considerably in recent years. It is becoming clear that moisture moves through the fabric of buildings by a combination of mechanisms, all of which should be addressed (Table 19).

The moisture carrying capacity and vulnerabilities of different building materials will, together with the use of the building, determine how much moisture ingress can be tolerated without the fabric or occupants experiencing ill effect. Most materials used to construct traditional buildings are relatively open to moisture flow, whereas many modern materials are not. This suggests two quite different approaches to moisture control in the fabric of buildings (May and Sanders, 2014):

Table 19 Moisture transfer mechanisms in building fabric (after May and Sanders, 2014).

Mechanism	Description
Vapour diffusion	Movement of water molecules from areas of high to low concentration.
Condensation	Water droplets can be deposited on cold surfaces and this may cause problems particularly when it occurs within the building structure (interstitial condensation).
Liquid flow	Hygroscopic materials are porous and can absorb water from the air, as well as from rain, groundwater and other sources.
Capillarity flow	Water is drawn into and through the pores of materials due to surface tension, this is a particular issue with rising damp.
Gravity	Liquid water is carried into holes and upward-facing rebates where it accumulates as a moisture reservoir.
Hygroscopic buffering	Some materials take up and release considerable amounts of water as temperature and relative humidity change.
Air movement	Gaps and cavities in the structure allow large amounts of moisture to be transferred.

- **Moisture-closed:** This approach is used in most modern buildings. It attempts to eliminate moisture risk in walls, floors and roofs by the installation of impermeable materials.

- **Moisture-open:** This approach is found in most traditional buildings. It allows moisture to move in and out of materials through the transfer mechanisms listed in Table 20.

The main British Standard addressing moisture transfer in the building fabric is BS 5250, although it mainly discusses vapour diffusion and condensation. This might be adequate for modern moisture-closed construction that is correctly designed and perfectly constructed, but a wider risk assessment is valuable in existing buildings. Moreover, many new buildings are not constructed as designed, or incur subsequent damage. In such cases the moisture risks associated with impermeable materials can increase. A moisture-open approach is therefore preferable in traditional buildings and can be the more robust option in new construction as well (May and Sanders, 2014).

Assessing moisture risks in existing buildings

The moisture conditions that are characteristic of most existing buildings are slightly different to those of new construction. The occurrence of moisture in timber within new buildings is adequately described through the use class system (Table 15), but Ross (2002) argues that additional sub-categories are beneficial when assessing traditional construction (Table 20 and Figure 42). For example:

- Attack by the common furniture beetle usually indicates a localised moisture problem caused by a building defect or poor ventilation. Thus, a poorly ventilated attic (i.e. sub-class 2A in Table 20) might have a high enough

Table 20 Applying the use class concept (see Table 15) to existing buildings (after Ross, 2002).

Use class	Moisture condition and sub-class for existing buildings	Risk
1	Moisture content range is typically 6% to 16%. Two subclasses can occur: • **Class 1A:** areas heated for occupancy tend to have an equilibrium moisture content of 6% to 12%. • **Class 1B:** unheated but ventilated areas (e.g. suspended ground floors or cold roofs) tend to have an equilibrium moisture content of 12% to 16%.	At these low moisture contents timber is immune from fungal decay. Insect attack by the species occurring in the UK is unlikely but possible in subclass 1B.
2	Moisture content will vary but might go over 20%. Three subclasses can occur: • **Class 2A:** Cold, poorly ventilated areas. • **Class 2B:** External walls with low permeability and built-in timbers. • **Class 2C:** Areas exposed to leaks.	The dry rot fungus is a significant threat in use class 2. Wet rot fungi are locally present, especially in subclasses 2B and 2C. Beetle attack can occur.
3	The moisture content is frequently above 20%. Three subclasses can occur: • **Class 3A:** Vertical or near vertical surfaces shed water rapidly and have minimum retention. • **Class 3B:** Horizontal or near horizontal surfaces, less well drained, cracks retain water. • **Class 3C:** Upward-facing rebates and similar joints act as a reservoir (see Figure 28). Surface coatings slow water uptake and so offer a degree of protection in subclass 3A. They have less benefit in subclasses 3B or 3C.	Wet rot is the main decay risk, especially in subclasses 3B and 3C. Stain fungi occur in timber exposed to sun and rain and contribute to weathering discoloration in timber. Beetle attack is possible but is less of a risk than decay. Dry rot is unlikely to survive.
4	The moisture content is permanently above 20% and might be much higher. Two subclasses can occur: • **Class 4A:** Ground level (e.g. sole plates). • **Class 4B:** Below ground level – lack of oxygen inhibits fungal decay.	Fungal decay (wet rot or soft rot) is inevitable in the long term unless prevented by lack of oxygen.

Figure 42 Mitre joints can act as a water trap in use class 3 and so are prone to wet rot.

relative humidity to support attack by the common furniture beetle. This can usually be remedied quite simply by improving the ventilation so that the moisture conditions change to sub-class 1B. The colony will then die out over time. This can be monitored by painting an area of infested timber with emulsion paint or gluing on a layer of tissue paper; the covering is then checked annually during the late summer to see if any new flight holes appear. If ventilation is adequate, it is rarely necessary to apply insecticidal treatment. BS 7913 recommends that these products should only be employed as a last resort because they can cause environmental damage and their use might require licences for protected species such as bats. Precautionary insecticidal treatment should not be applied to timbers unaffected by beetle attack.

- Many traditional materials, especially mortars and plasters, can handle short-term water saturation after which they dry by vapour diffusion. This is especially important when considering the drying out of fabric and finishes following a saturation event (i.e. sub-class 2C in Table 20). In many cases timber finishes and structural elements do not need to be uncovered to achieve drying although the fabric may need to be monitored as it dries (e.g. using a borescope or data-logged moisture sensors) to ensure that drying is happening and moisture-related problems do not occur.

- The dry rot fungus (*Serpula lacrymans*) is a particular challenge in use class 2. In temperate climates the species does not occur outside buildings and it is likely that it was introduced here by timber imports. Although dry rot can be very destructive it might not be necessary to remove all timber that has been affected by the organism because, like all other fungi, it becomes inactive when the level of moisture is reduced to below 20%. Rotten timber should of course be replaced if it is load bearing or has another important function. Chemical treatment is usually unnecessary, although a fungicidal barrier is sometimes advisable to prevent fungal spread while the building dries. It usually takes a period of months for a building to dry and timbers should be monitored during this period. (BS 7913)

- When shop fronts and other joinery in use class 3 are being repaired, the detailing should ensure that water traps and other defects are avoided and the timber is drained and ventilated. This may require that a component that has decayed (typically sub-class 3B or 3C in Table 20) is redesigned so that it is no longer exposed to wetting or, if this is impossible, its decay resistance should be increased by selecting a more durable timber.

The extent of fungal and insect damage to timber should be assessed during any remedial investigation. Riddout (2000) and Bravery *et al*. (2003) give guidance on recognising and dealing with wood rot and insect damage in existing buildings.

Sourcing and processing timber yourself

Building professionals, contractors and their clients do not normally have the capacity to source unprocessed timber themselves or to make it into finished products. In most instances the purchasers and designers of buildings will only be interested in sourcing the finished article. Occasionally, however, circumstances arise in which people wish to use their own timber to construct a building or there are occasions when a design-build route involving timber processing seems appropriate. These approaches are perfectly viable providing a few points (see below) are borne in mind.

Appropriate design

The proposed design should be compatible with small-scale on-site processing. Post-and-beam type construction (Figure 43) might, for example, be preferable to conventional timber frame because the dimensional tolerances required are often not so demanding and it is less labour intensive to cut large timber sections than the small pieces needed for modern timber frame designs. Virtually all new buildings will need to comply with the applicable building regulations and their supporting documentation; the main exceptions being some small or temporary buildings.

Log conversion

The range of mobile sawmills (Figure 44) that can be hired locally needs to be established (some of the forestry and timber organisations in Appendix 6 can advise). Each type of mobile sawmill has a different capacity and characteristics and these may determine what can be achieved. Discuss the costs, space requirements and sawn timber production per day with the operator and remember that small-scale sawmilling generally recovers only about 50% of the log volume as usable timber. In general, it is not cost effective to process logs with a diameter of less than 300 mm on a mobile saw and larger diameters are preferred; the upper diameter limit varies with the type of saw. A few specialist mobile saws such as double-slabbers are economic to use with small roundwood although their availability is limited. Chainsaw mills (Figure 45) might be suitable for use on small jobs and are highly portable.

Figure 43 Strathnairn Shelter near Inverness uses a post-and-beam construction formed from local timber. Neil Sutherland Architects.

Figure 44 A mobile saw being used to process timber on-site.

Strength grading

Timber will need to be strength graded before use in a structure. Visual grading is the normal choice for self-build projects and similar circumstances although hand-held acoustic graders are becoming available. See the subsection on 'Strength grading' for guidance.

Drying

Because timber shrinks as it dries, it is advisable to dry the sawn timber to near its anticipated equilibrium moisture content. If a ventilated shed is available, it may be possible to air dry timber down to around 16% during the summer, but if drier timber is required it will need to be kiln dried. Low cost drying kilns are available for purchase; alternatively, drying space can be sometimes be rented at a sawmill. Mobile saw operators should be able to advise on timber drying.

Machining

Timber usually needs to be machined to its finished size after it has been dried and allowance should be made for this by sawing the timber oversize. Davies and Watt (2005) give typical waste allowances for the processing of hardwood timber into joinery (Table 21).

Resistance to wood destroying organisms

The risks of biodeterioration by fungi and insects are usually quite low in a modern building although certain areas, such as sole plates and exterior cladding, are at greater risk than elsewhere. There is no requirement to use biodeterioration-resistant timber in-situations where the risks are low, but where they are higher it is necessary to ensure that the timber is either the heartwood of a naturally durable species or can be made resistant through timber preservation or wood modification. Guidance is given above in the sections on 'Resistance to wood destroying organisms' and 'Using timber in repair and refurbishment'.

Table 21 Waste percentages due to processing (after Davies and Watt, 2005).

Type of plank or board	Percentage waste
Square edged	35 to 45
One waney and one square edge	55 to 65
Waney-edged on both sides	100 to 130

Figure 45 A chainsaw mill being used to saw timber for a small community building.

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Appendix 1: Carbon impacts of timber

Trees absorb and store atmospheric carbon dioxide (CO_2) as they grow. When trees are felled the carbon is either returned to the atmosphere as the wood rots or is burnt, or it is stored for a further period within timber products. Eventually these products will themselves be broken down and the carbon realised but this may not be for many decades – or even centuries. Timber products not only store sequestered carbon but can require only low energy inputs in production. Quantifying these carbon impacts is becoming increasingly important as people seek to estimate the impacts of construction on climate change.

Carbon storage

BS EN 16449 gives a method for calculating the amount of carbon dioxide sequestered by the growing tree, which is then stored as biogenic carbon in wood products until the end of their life. Oven-dry timber contains approximately 50% carbon. Although this is only a measure of carbon in the timber, it can be translated into the equivalent amount of atmospheric CO_2 using a calculation based on the atomic weights of carbon (12) and CO_2 (44). The formula is:

$$P_{CO_2} = \frac{44}{12} \times cf \times \frac{\rho_\omega \times V_\omega}{1 + \frac{\omega}{100}}$$

where P_{CO_2} is the biogenic carbon (kg) oxidised as CO_2 at the end of the timber component's service life, cf is the carbon fraction of the woody biomass when oven dry (0.5 is the default value), ω is the moisture content of the product, ρ_ω is the density (kg/m^3) of woody biomass at that moisture content and V_ω is the solid wood volume (m^3) at that moisture content.

To take a practical example, consider 25 m^3 of cross-laminated timber (CLT) used in a building, 95% of which is home-grown Sitka spruce and 5% of which is glue. BS EN 350-2 states that the density of UK grown Sitka spruce (at 12% moisture content) is 400 kg/m^3 (assuming that UK spruce is at the low end of the quoted density range). By these assumptions, the atmospheric CO_2 locked up in the CLT amounts to 15.55 tonnes. The calculation is:

$$P_{CO_2} = \frac{44}{12} \times 0.5 \times \frac{400 \times 25 \times 0.95}{1 + \frac{12}{100}} = 15\,550 \text{ kg } CO_2$$

By the same calculation, a typical three-bedroom semi-detached timber frame house containing approximately 6 m^3 of softwood timber and timber products and is equivalent (depending upon timber species etc) to locking up around 4 tonnes of atmospheric CO_2.

MacKay (2009) discusses how these figures sit in the wider context of carbon storage.

Embodied energy

A simple calculation of carbon storage is of course an oversimplification as it is important to consider all the greenhouse gas emissions associated with products. In the case of timber, these include the fuel used in forestry, transportation, processing and packaging. In combination, these can have the effect of increasing the greenhouse gas emissions. The key questions are how much energy is embodied in the product during its manufacture and supply and if this has contributed to greenhouse gas emissions.

Mackay (2009) gives indicative embodied energy values for a range of timber and non-timber products (see Table A1.1). A more comprehensive database has been produced by Hammond and Jones (2011). Although both sources give comparable values they need to be interpreted with caution because:

- Some data are quite old and therefore might not reflect current best practice.
- Variation in forest management practices, transportation and timber processing mean that there will always be considerable spread in the greenhouse gas emissions resulting from the embodied energy of timber products. If, for example, a wood drying kiln is powered by fossil fuel the embodied energy of the timber will be greater than if locally produced woodchips were used.
- Embodied energy is generally quantified as energy per unit mass (MJ/kg). This disadvantages low density materials, such as timber, relative to those, like concretes and metals, which are denser.

Table A1.1 Embodied energy of construction materials and products (after Mackay, 2009).

Material or product	Embodied energy (MJ/kg)	Indicative mean embodied energy per product group (MJ/kg)
Kiln-dried sawn softwood	3.4	Sawn timber 2 MJ/kg
Kiln-dried sawn hardwood	2	
Air dried sawn hardwood	0.5	
Hardboard	24.2	Wood based products 13 MJ/kg
Particleboard	8	
MDF	11.3	
Plywood	10.4	
Glue-laminated timber	11	
Laminated veneer lumber	11	
Stabilised earth	0.7	Earth and stone 7 MJ/kg
Imported dimensioned granite	13.9	
Local dimensioned granite	5.9	
Gypsum plaster	2.9	Plaster, concrete and brick 3 MJ/kg
Plasterboard	4.4	
Fibre cement board	4.8	
Cement	5.6	
In situ concrete	1.9	
Precast steam-cured concrete	2	
Precast tilt-up concrete	1.9	
Clay bricks	2.5	
Concrete blocks	1.5	
Autoclaved aerated concrete	3.6	
PVC	80	These plastics 84 MJ/kg
Synthetic rubber	110	
Acrylic paint	61.5	
Glass	12.7	Glass and glasswool 20 MJ/kg
Fibreglass (glasswool)	28	
Aluminium	170	These metals 90 MJ/kg
Copper	100	
Galvanised steel	38	
Stainless steel	51.5	

Mackay (2009) also compares the embodied energy of various types of construction assembly (Table A1.2). Timber-framed and -clad walls have a much lower embodied energy than most of the other wall assemblies he assesses, although the exact values may have altered in recent years as construction practices change.

Morison *et al* (2012) review the carbon balance of UK forestry although they do not compare it with that of imported timber. An earlier study by Edinburgh Centre for Carbon Management (2006) suggests that locally sourced timber products tend to have lower CO_2 emissions than imports (see Table A1.3).

Embodied energy raises complex questions subject to much debate. Some topics are addressed in the Wood First Plus online database hosted by Wood for Good (see Appendix 6) and in BS EN 15804 and BS EN 16485. The ISO 15686 series of standards provide guidance on life-cycle assessment, while Hill (2011) gives a thermodynamic perspective on sustainable resource use.

Table A1.2 Embodied energy of various wall assembles (after MacKay, 2009).

Type of wall assembly	Embodied energy (kWh/m^2)
Timber frame, timber cladding, plasterboard lining	52
Cement stabilised rammed earth	104
Timber frame, aluminium cladding, plasterboard lining	122
Timber frame, clay brick veneer, plasterboard lining	156
Steel frame, clay brick veneer, plasterboard lining	168
Double clay brick, plasterboard lining	252

Table A1.3 Timber transport emissions (after Edinburgh Centre for Carbon Management, 2006).

Journey	Modes of transport	Total tCO_2 per tonne of timber transported	Multiple of the CO_2 used for the journey within Scotland
Within Scotland (Fort William – Perth)	44 tonne lorry	0.007	–
Sweden to Scotland (Vaxjo – Gothenburg – Newcastle – Perth)	60 tonne lorry, large ship, 44 tonne lorry	0.038	x 5.4
Latvia to Scotland (Gulbene – Riga – Newcastle – Perth)	Train, small ship, 44 tonne lorry	0.128	x 18
Canada to Scotland (Shawingan – Montreal – Liverpool – Perth)	44 tonne lorry, large ship, 44 tonne lorry	0.134	x 19

Appendix 2: CE marking and local timber

British standards used to have a purely voluntary basis but the introduction of harmonised European standards means that many products are now within the scope of mandatory norms. Harmonised European standards list key performance characteristics (such as strength or fire resistance) and give measurement procedures for each, the goal being to harmonise how performance requirements are defined across Europe in order to remove unnecessary barriers to trade.

If a product is within the scope of a harmonised European standard, its performance has to be declared by the manufacturer using a CE mark. CE marking is not a quality mark as such but instead certifies that a product is fit for purpose as defined in the relevant harmonised standard. The CE marking requirements applicable to small firms tend to be less onerous than those for large manufacturers. Moreover, one-off products, such as timber components made for a building repair, are usually exempted.

People sometimes assume that the introduction of harmonised European standards mean that building regulations should be the same throughout the European Union; this is not the case. These norms merely harmonise how key characteristics are defined and measured. The levels of performance are set nationally in response to local conditions. Thus, while a harmonised standard might give a classification and test procedure for surface spread of flame, documents supporting national building regulations specify which class is required in particular circumstances. Unlike other types of product, such as toys, the performance characteristics of those used in construction are defined in terms of the finished works as installed in a building.

Blackmore (2012) gives detailed guidance on CE marking.

Appendix 3: Timber sizes produced in the UK

Timber is often produced in a range of standard sizes and so specifying to these dimensions is the easiest and most cost-effective option. The sizes depend upon the type of product involved.

Sizes of softwood sawn timber

Sawn softwood timber in the UK is sourced from many countries and as a consequence the range of standard sizes available can be confusing. The sections can vary depending upon how the timber has been machined.

Softwood sizes are given in two main standards. BS EN 1313-1 covers all structural and non-structural sizes with recommended UK sections listed in the national annex. BS EN 336 covers structural softwood sizes; a national annex gives sizes for timber that is either sawn, machined on the width, or machined on all four faces. In practice most UK softwood sawmills do not produce timber that is machined on the width. The most common sections for UK produced sawn structural softwood are shown in Table A3.1, while Table A3.2 gives the equivalent sections once the timber has been machined on all four sides.

Table A3.1 Common sections for UK produced sawn C16 grade timber.

Thickness (mm)	Width (mm)						
	75	100	125	150	175	200	225
47	●	●	●	●	●	●	●
75	○	●	○	●	●	●	●

● Widely produced ○ Produced by a few sawmills

Table A3.2 Common sections for UK produced C16 grade timber planed on all sides.

Thickness (mm)	Width (mm)						
	72	97	120	145	170	195	220
44 or 45	●	●	●	●	●	●	●
72 or 73	○	●	○	●	●	●	●

● Widely produced ○ Produced by a few sawmills

Machine graded softwood timber that has been machined on all four sides might have had its sharp edges rounded off. This practice originated in North America and so the resultant profiles are often in imperial dimensions and termed CLS or ALS (Canadian Lumber Standard or US equivalent). These profiles are sometimes produced in the UK although it is more common to find that the sections listed in Table A3.2 are rounded off. In such cases the timber is either termed regularised or sold under a company brand name.

The most common lengths available for UK produced machine graded softwood are 2.4, 3.0, 3.6, 4.2 and 4.8 m, although lengths of 1.8, 5.4 and 6 m are available from some suppliers. Other lengths held by distributors are normally imported.

Sizes of visually graded timber

Visually graded timber is not produced in standard sizes; instead it is cut to order. The sizes that can be sawn vary between mills and might be species dependant. Sections up to 300 x 300 mm are usually obtainable, while a few mills will saw sections up to 500 x 500 mm. The lengths similarly vary. Most sawmills who offer visually graded timber can supply lengths up to 5 or 6 m with a few mills offering lengths up to around 10.5 m. Douglas fir and larch are the main UK grown softwoods that are visually graded while the equivalent hardwood species are oak and sweet chestnut. Lengths over 5 m can be slow to source. So too can particularly large sections.

Sizes of external cladding timber

The most common sections for UK grown softwood cladding timber are between approximately 90 mm to 150 mm wide by 18 mm to 25 mm thick. In general, a thickness–width ratio of no more than 6:1 is recommended to minimise splitting, although a ratio of 4:1 is even better. Hardwood cladding boards should also adhere to these ratios in most cases. The moisture content of external cladding is a key consideration as are the movement characteristics of the timber. BS 8605-1 and BS 8605-2 give specifications and design recommendations for external timber cladding in the UK.

Appendix 4: Substituting UK timber for imports

There are many opportunities where UK grown timber can be substituted for imports. See Tables A4.1 to A4.3 for guidance. The timbers in these tables have been selected based upon their mechanical and physical characteristics.

The colour and appearance grades available in UK timber may not always match those of the imported timbers.

Table A4.1 Softwood substitution.

Imported timber	Nearest UK equivalent
European whitewood A trade name for several *Pinus* and *Abies* species. The most common machine grades are C16 and C24 though grades up to C35 are available.	**Whitewood** A trade name for UK grown Sitka spruce and Norway spruce. The only machine grade currently available is normally C16.
European redwood The trade name for imported Scots pine. Mainly used for joinery, the timber is available in several joinery grades and as laminated sections.	**Scots pine** The term for UK grown Scots pine. Most is made into panel products or fencing. A few sawmills in Scotland can supply visually graded timber and joinery timber.
Western red cedar The durability of Canadian timber is rated class 2 (durable). Several joinery grades are imported mainly for cladding, decking, and shingles. Shingles are normally preservative treated for use in the UK.	**Western red cedar** Small quantities of UK grown western red cedar are available, particularly in western Britain. The timber durability is rated class 3 (moderately durable). It is usually quite knotty.
Siberian larch A trade name for the species *Larix sibirica* and *L. gmelinii* imported from Siberia. The timber is often relatively knot-free and is used for external cladding. Although some importers claim that the timber is particularly durable, test evidence shows it is class 3 (moderately durable). Its long service life in Siberia is due to a low rate of fungal decay in that cold climate.	**UK grown larch** There are three larch species grown in the UK: European, Japanese and hybrid. All are rated as being of variable durability ranging from class 3 (moderately durable) to class 4 (slightly durable). Preservative treatment is advisable for some applications. The timber is more knotty than Siberian larch. Nonetheless, it is suitable for most external cladding.
Douglas fir North American timber can be strength graded to C16 or C24. It is rated durability class 3 (moderately durable).	**Douglas fir** UK grown Douglas fir is visually strength graded to C16, C18 or C24. It is rated durability class 3 to 4 (moderately to slightly durable).

Table A4.2 Temperate hardwood substitution.

Imported timber	Nearest UK equivalent
American white oak (*Quercus* spp.) European oak	UK grown oak is often called Welsh oak, English oak etc. depending upon its country of origin. It is the same species as the European oak imported from the continent. The range of appearance grades available from UK oak may be more restricted than with imported material.
European beech	UK grown beech is the same species as European beech although it tends to be darker and more variable in appearance.
European ash American ash (*Fraxinus* spp.) Hickory (*Carya* spp.) Tulipwood (*Liriodendron tulipifera*)	UK grown ash is the same species as European ash. It has similar properties to American ash and hickory but is slightly heavier than tulipwood.
Maple, rock (*Acer saccharum*) and maple, soft (*A. saccharinum*)	Sycamore has broadly similar characteristics to the American maple species. Sweet chestnut could also be considered.

Table A4.3 Tropical hardwood substitution.

Imported timber	Nearest UK equivalent
Sapele (*Entandrophragma cylindricum*)	European oak or sweet chestnut
Utile (*Entandrophragma utile*)	Sweet chestnut
Meranti, dark red and light red (*Shorea* spp.)	European ash or sycamore

Appendix 5: Ensuring timber is legal and sustainable

Specifiers and contractors must ensure that the timber they are sourcing is from legal sources. To ensure the timber is sustainable, further evidence is required. This is usually straightforward, although there are several issues to consider.

European Union timber regulations

In 2013, the European Timber Regulation (EUTR) and its accompanying legislation (European Union, 2010, 2012) introduced obligations affecting all those who first place timber on the European market or who subsequently trade in such timber. Under this legislation, individuals and organisations that first place timber and wood-based products on the EU market are termed operators, while those who distribute such timber are termed traders. Operators must ensure that their products are harvested in accordance with the applicable legislation in the country of harvest. Traders are required to maintain a system ensuring traceability to the operator or trader from whom they obtained their timber or wood-based products. PAS 2021 gives guidance on this legislation.

Placing UK timber on the European market

The UK has a very low incidence of illegal logging, and effective compliance and enforcement mechanisms. The UK Forestry Standard (Forestry Commission, 2011) is the benchmark for sustainable forestry in the UK. The Standard outlines relevant legislation affecting forest management in the UK and the Forestry Commission states that 'this equates to the applicable legislation under the (EUTR) Regulation' (PAS 2021, p. 43).

UK grown timber is generally first placed on the market during the sale or transfer of felled logs following harvesting (Figure A5.1). The Forestry Commission in Scotland and England and their equivalent bodies in Wales and Northern Ireland are responsible for awarding felling licences. These controls effectively minimise the risk of the timber being illegal and they verify that checks have been completed and the appropriate legal permission obtained.

Figure A5.1 Hardwood logs harvested from a forest managed in accordance with the UK Forestry Standard.

Forest certification schemes

Forest certification schemes were introduced in the early 1990s to help protect forests from destructive logging and to promote their sustainable management. The certification process provides independent verification that a forest is managed to defined environmental and social standards. In the context of the EUTR this means that forest certification schemes can play an important role in ensuring that the risk of the timber being illegal is minimised, but cannot, by themselves, meet all requirements. The EUTR applies regardless of the certification status of a forest.

The most widely known certification schemes in the UK are run by the Forest Stewardship Council and the Programme for the Endorsement of Forest Certification. These schemes have two components:

- **Forest certification:** an independent system of forest inspection (or auditing) according to predetermined standards.
- **Chain-of-custody certification:** a way of tracking timber and wood products through a documented supply chain from the forest to the final user.

Virtually all timber from the national forest estate is certified, as is timber from most of the larger private sector producers in the UK (see Figure A5.2). This means that UK grown timber can be an effective way of obtaining certified material.

Figure A5.2 Forest certification label on a pack of UK grown softwood timber.

Timber procurement in the private sector

Building projects funded wholly or mostly by the private sector have considerable freedom regarding the sourcing of timber. Providing the products comply with European Union timber regulations, an individual or organisation commissioning a building is free to ignore timber sourcing issues entirely or, conversely, can insist on specific requirements such as geographical origin or a particular certification scheme.

The private sector therefore has the option to go beyond the requirement of public bodies to specify sustainable timber. For example, the sustainability credentials of many large buildings are independently audited under BRE's BREEAM schemes, which can nowadays award extra discretionary points for local sourcing. Although BREEAM covers both privately and public funded buildings the latter may not be able to be credited with these discretionary points since public sector procurement rules preclude specifying the local sourcing of timber in most cases (see below).

Timber procurement in the public sector

The objectives of all UK public sector procurement processes include the need to:

- **Achieve value for money:** defined as securing the optimum combination of whole-life costs and quality to meet the customer's needs.
- **Award contracts through open competition:** contracts above certain thresholds have to be advertised in the Official Journal of the European Union (see Appendix 6).
- **Promote fair and open competition within the EU single market:** this necessitates avoiding discrimination on the grounds of nationality.

Public procurement policies throughout the UK require that all timber and wood-derived products used in public buildings are from verifiably legal and sustainable sources. Although this is a policy and not a law, breach of contract is illegal.

Accordingly, the public sector now has very specific procurement rules that limit what can be stated in a contract. Any UK building project for which more than 50% of the funding comes from public sector sources must use procurement practices that comply with European Union law. It will also need to comply with public procurement policies in England, Scotland, Wales or Northern Ireland, as applicable. Autonomous bodies such as universities, housing associations and local authorities are also bound by these policies as they are largely publicly funded.

The Department for Environment, Food and Rural Affairs (Defra) has established a Central Point of Expertise on Timber (CPET) procurement (see Appendix 6) to assist government procurement managers and their suppliers. CPET gives detailed information on its website, offers training courses and operates a telephone helpline for public sector buyers and their suppliers.

While UK public procurement policies provide for sourcing certified timber and therefore opportunities for UK timber, it is important that these contracts avoid restrictive practices that contravene UK and European laws. Consequently, providing the scheme is approved by CPET, no particular certification method can be specified in preference to others, nor can public contracts be awarded on the basis of a preferred scheme. This is because such practices would be discriminatory, for example on the grounds of nationality, or because other suppliers might provide timber to similar standards but choose not to be a member of a particular scheme. Similarly, while UK timber can compete with imported material in terms of sustainability, public procurement rules about non-discrimination do not permit such timber to be considered as being more sustainable just because it is local.

The main circumstances where specification of UK grown timber might be acceptable within a publicly funded contract is when the building has been specifically designed to highlight the characteristics of local forests (e.g. a visitor centre or educational facility). This type of exemption does not apply where buildings are also used for administration or other general purposes and so its use is likely to be rare. Another circumstance in which exemption might be possible is a building project for which the timber is being donated gratis.

A further complication arises because public sector specifications need to be based on measurable performance attributes such as size, strength or durability. It might therefore only be permissible to specify a particular timber species when it can be shown that the technical characteristics of that species make it particularly suitable. Discrimination cannot be made in favour of timber from a particular geographical source, nor can the specification nominate a particular product brand. Specific timbers or brands can be listed in a specification as examples of the type of performance required.

In virtually all cases therefore a public sector client's desire to use local materials can be stated in the introduction to a tender but cannot form part of the specification or other contractual requirements. Once the contract has been awarded, the purchaser can invite the contractor to consider supplying local timber products providing this does not involve a price increase or other alteration to the contract. It is then up to the contractor to decide whether or not to agree. This negotiation is voluntary and takes place after the timber specification has been issued.

It can be argued that by preventing local sourcing these public procurement policies are in conflict with initiatives to minimise greenhouse gas emissions caused by transportation – the arguments are complex, however. If, for example, local sourcing was permitted as a condition of contract this would damage businesses in the UK and throughout Europe that rely on exports. Similarly, it would tend to exclude producers from the developing world and thereby cut across the UK's international development objectives.

Although public procurement policy can appear to preclude local sourcing there are still opportunities to do so, particularly where the products are internationally competitive in price or performance (Figure A5.3). Moreover, there will occasionally be circumstances where specifying local is justified on cultural or educational grounds, providing this is central to the purpose of the contract/project.

To maximize the opportunities for public procurement from local sources it is important to ensure, wherever possible, that the specification does not preclude local suppliers by default (e.g. by requiring a timber grade that is locally unavailable). It may also be beneficial for public sector agencies to work with local businesses to ensure that they have the skills and capacity to be able to compete against more established suppliers. This does not mean that producers of UK timber products are inevitably small and constrained; far from it. There are suppliers of local timber products in most parts of the UK who are more than capable of competing against imports (Figure A5.4).

Figure A5.3 The walls of this timber-framed house on Skye are lined with UK produced orientated strand board. Rural Design Architects.

Courtesy of Alan Dickson.

Figure A5.4 Locally sourced larch was used to clad this lookout tower on the RSPB's Forsinard Flows nature reserve in Sutherland. Icosis Architects.

Courtesy of Sjoerd Tel.

Appendix 6: Sources of further information

Forestry, timber and timber products organisations

Association of Scottish Hardwood Sawmillers	www.ashs.co.uk
Confederation of Forest Industries	www.confor.org.uk
Confederation of Timber Industries	www.cti-timber.org
Grown in Britain	www.growninbritain.org
Scottish Forest & Timber Technologies	www.forestryscotland.com
Structural Timber Association	www.structuraltimber.co.uk
Sylva Foundation (My Forest)	www.sylva.org.uk/myforest
UK Forest Products Association	www.ukfpa.co.uk
Wood for Good	www.woodforgood.com
Wales Forest Business Partnership	www.wfbp.co.uk
Wood Panel Industries Federation	www.wpif.org.uk

Government forestry agencies

Forestry Commission England	www.forestry.gov.uk/england
Forestry Commission Scotland	http://scotland.forestry.gov.uk
Forest Service of Northern Ireland	www.dardni.gov.uk/forestry
Natural Resources Wales	http://naturalresourceswales.gov.uk

Government building heritage agencies

Cadw	www.cadw.wales.gov.uk
English Heritage	www.english-heritage.org.uk
Historic Scotland	www.historic-scotland.gov.uk
Northern Ireland Environment Agency	www.doeni.gov.uk/niea/built-home

Building regulations and technical documents

England	www.planningportal.gov.uk
Northern Ireland	www.dfpni.gov.uk/index/buildings-energy-efficiency-buildings
Scotland	www.gov.scot/Topics/Built-Environment
Wales	http://gov.wales/topics/planning/buildingregs

Timber certification and procurement

Central Point of Expertise on Timber	www.cpet.org.uk
Forest Stewardship Council	www.fsc-uk.org
Programme for the Endorsement of Forest Certification	www.pefc.org

Information, research and consultancy on timber

Bangor University	www.bangor.ac.uk/senrgy
BRE	www.bre.co.uk
BM TRADA	www.trada.co.uk
Edinburgh Napier University	www.napier.ac.uk/instituteforsustainableconstruction
Forest Research	www.forestry.gov.uk/forestresearch
University of Bath	www.bath.ac.uk/ace/research/cicm/timber-materials

Sustainable construction

Alliance for Sustainable Building Products	www.asbp.org.uk
Association for Environment Conscious Building	www.aecb.net
BREEAM	www.breeam.org
Scottish Ecological Design Association	www.seda.uk.net

Timber is a versatile and high performance construction material that can be produced in most parts of the UK. 'Sustainable construction timber' has been written to help building designers and contractors source and specify local timber products. The report explains why local sourcing of timber is important, reviews the range of timber species and products currently obtainable in the UK and explores the ways in which local sourcing can be achieved within a construction project. Sustainable construction timber is applicable to designers and contractors wanting to source and specify UK grown timber products, people considering using their own timber on a construction project and those involved in building refurbishment or conservation.

Forestry Commission
Silvan House
231 Corstorphine Road
Edinburgh
EH12 7AT

£13.00

www.forestry.gov.uk