Japanese Larch in Wales

Investigating the potential to grow market share of Larch in Wales and the Marches with a view to utilising increased timber production due to *Phytophthora ramorum* sanitation fellings

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Executive summary

The Wales Forest Business Partnership, through its initiative Wood Knowledge Wales, has commissioned a report on potential uses of larch, in view of the possible spread of *Phytophthora ramorum* leading to substantially increased volumes coming to market. This report attempts to describe the status quo through a literature review and interviews of timber industry representatives. Examples of appropriate applications or new markets are made after consideration of the material properties of home-grown larch and the study of possible structural techniques.

There is a possibility that 3.5 million cubic metres of Japanese larch will be available from forests in Wales and the Marches over the next ten years as a result of sanitation felling taking place.

Potential annual intake of larch is approximately 500,000 cubic metres per annum of which 70% might go into low value markets such as energy and chipboard production. Annual intake for sawmilling and value added processing is unlikely to exceed 150,000 cubic metres. It is therefore possible that the easy option of selling larch into biomass markets will waste large quantities of this extremely useful structural timber which could be used in sustainable construction in line with Welsh Assembly Government aspirations.

Myths concerning durability and the strength of home-grown softwoods have taken precedent over good science. The principal mechanical properties of Japanese larch i.e. density, durability, strength and knot orientation all contribute to making this timber valuable for use in the built environment.
The historical example of Venice demonstrates the massive potential for larch in architectural applications.

There are some technical and cultural challenges in utilizing more larch; for instance, the logs may dry out making processing difficult. Also larch is hard, making nailing problematical. More research may find solutions to these challenges.

The ready availability, easier processing and extensive marketing of home-grown spruce has led to larch being undervalued and underutilized in Britain for several decades. Furthermore, the mechanical characteristics of larch and perceptions of it being a difficult timber act against larch being substituted for spruce. Therefore new markets need to be created which make use of its unique selling points in regard to durability, hardness and strength.
This report examines innovative options and applications which take advantage of the positive qualities of larch. Pragmatic potential applications are suggested which reflect the challenging timber processing business environment of Wales.

In concluding, the report notes a perceived need to strength grade larch above C16 in order to better market its unique high strength values which have only recently been confirmed by research in Holland and Scotland. This topic is emphasized as needing further research.

There is a significant need to take expert marketing advice in order to make best use of the positive attributes of larch, such as its strength and durability, in order to differentiate and position the timber in new markets for sustainable structural timber products.

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Recommendations

1.
There is a need to examine log storage protocols. Is wet storage of logs possible and if so under what criteria? Are there any other options for ameliorating the drying out of logs?

2.
Infected biomass co-products have low added value potential for sawmillers and their storage may incur significant costs especially when limited binning options are available. There is a need to re-evaluate the risk from infected biomass and study options other than burning.

3.
In order to make best use of structural grade larch we should examine options for strength grading above C16 for both large processors and SMEs. Characteristic strength values of larch need to be established.

4.
There is a need to examine material properties of larch in relation to fastening and connecting systems in order to make best use of its hardness.

5.
The durability of home-grown Japanese larch might be better exploited as a selling point. Comparison of durability characteristics with those of Siberian larch may help capture part of the market currently using imported material. Low cost near-infrared (NIR) technology from other industries could be examined with a view to evaluating durability.

6.
There is a need to seek expert marketing advice in order to examine marketing methods and evaluate new market opportunities.

7.
This is a major, once-only opportunity to utilise large quantities of a home-grown timber which is ideal for use in the built environment in order to replace high energy-embodied materials according to the stated aspirations of the Welsh Assembly Government. A small team of suitably qualified, creative experts could encourage greater take-up of larch timber in order to help deliver sustainable development in Wales.

Introduction and status quo

Introduction

The Wales Forest Business Partnership, through its initiative Woodknowledge Wales, has commissioned a report on potential uses of larch in view of the possible spread of *Phytophthora ramorum* leading to substantially increased volumes coming to market. This report attempts to describe the status quo through a literature review and interviews of timber industry representatives. Examples of appropriate applications or new markets are made after consideration of the material properties of home-grown larch and the study of possible structural techniques.

Three species of larch are grown in commercial plantations across the United Kingdom; European larch - *Larix decidua*, Japanese larch - *Larix kaempferi* (also known as *Larix leptolepis*) and Hybrid or Dunkeld larch - *Larix x eurolepsis*. The total area of British larch woodlands comprises 143,000 ha or 10% of conifer woodlands and is one of the largest larch resources in Europe outside of Russia[53]. Although this report is specifically concerned with Japanese larch it is useful to consider historical perceptions and applications of all three species in order to understand the potential for larch today. John, Duke of Atholl wrote in 1819 in The Philosophical Magazine that having cut and used fifty to sixty year old (European) larch, he considered it to be the most valuable timber ever introduced to Scotland. He described the use of larch thinnings for palings, rails and hurdles and larger, older material for boat-building and mill-work[19].

Many writers allude to the ubiquity of larch in the rise of Venice; the city has been called a “forest on the sea” because of the millions of trees used its construction. Larch is present under the city as foundation piles, within the structures of many of its famous buildings and Venice’s shipbuilding industry also depended on regular supplies of larch from neighbouring regions[4]. In Great Britain larch is mainly used for fencing[42], pallet making and external cladding[53], however much of the material for that particular application is actually imported Siberian larch – *Larix siberica* which has different characteristics to those of home-grown larch. Although larch was clearly valued in the early 19th century, its potential has never been realised here in Great Britain.

Furthermore although larch is better appreciated for its high strength, durability and hardness in North America and parts of Europe, it is nevertheless considered to be under-utilised in those countries[53]. In view of the possibility that large quantities of larch roundwood will be released from sanitation fellings across Western Britain over the next few years due to the outbreak of *Phytophthora ramorum* it may be prudent to examine new opportunities for utilising this useful timber.

1.1 Area and ownership of larch plantations in Wales and the Marches

The total area of all larch species in Wales according to latest figures is 22,384ha of which 13,228ha is Welsh Assembly estate which comprises 10,222ha Japanese larch, 2,791ha Hybrid larch and 215ha European larch[35]. The 2002 National Inventory shows 9,729ha of Japanese and Hybrid larch and 393ha of European larch in private ownership. There is possibly a total of 6,000ha of larch plantations in The Marches; precise breakdowns of ownership are unavailable[62].

1.2 Potential affected volume of larch

Chris Jones of Forest Research regards it as highly likely that *Phytophthora ramorum* will "run through the whole country"[34]. Forestry Commission are basing their volume calculations on an assumed stocking rate of 150 m^3/ha and therefore the area of Japanese larch on the WAG estate might yield 1,533,300 m^3 by the time it is all felled.

Owen Thurgate of Forestry Commission wrote "If our current response slows the disease to the extent we hope, it may take decades before all larch has been infected and felled". He also emphasised that as there is no mechanism for collecting private woodland mensuration data in Britain it was very difficult to gain an accurate picture regarding areas and stocking rates in private woodland[62]. However, the somewhat contradictory positions taken by FR and FC demonstrate the subjective nature of emerging information.

Therefore various production scenarios are set out below in Tables 1 and 2. Assuming similar area proportions of Japanese to Hybrid larch, the private larch woodlands in Wales might yield 1,050,000 m^3. According to Owen Thurgate "the jury is still out" regarding the susceptibility of Hybrid larch to *Phytophthora ramorum*[61]. If Hybrid larch proves susceptible to the pathogen there may be around 800,000 m^3 more to fell.

However, most of the interviewees who expressed an opinion regarding potential volumes assumed that there were large margins for error. Tables 1 & 2 (below) set out possible production scenarios based on various area percentages felled within a ten year period. No calculations have been attempted to generate annual figures, they will depend upon an accelerating rate of infection or disease curve which is currently being mathematically modelled by specialists[34].

1.3 Production levels, buyers

BSW Timber Ltd. of Newbridge on Wye has an annual input of 185,000 m^3 of roundwood. David Burd of BSW reports that up to 25% of their intake will be larch but this will be additional production as they do not wish to substitute larch for spruce[9]. Charles Ransford and Sons Ltd at Bishops Castle process 45,000 tons of mixed Japanese larch and Douglas fir plus 15,000 tons of Sitka spruce. They could substitute all of the spruce for larch if necessary[42].

ETC Sawmills Ltd of Ellesmere process 96,000 m^3 per annum but only 3.8% of their present intake is larch[71]. Pontrilas Timber based near Hereford process around 160,000 m3 of roundwood per annum. Currently they are not buying diseased larch and the figure below is based on current intake of minor softwood species. Table 3 (below) lists most of the larger log buyers in or close to Wales and gives a rough indication of their capacity or reported intention to utilise diseased larch.

Some sawmillers with capacity to convert large quantities of diseased larch substituting for spruce (for instance in fencing products) have not yet started processing larch even though they have obtained licenses to do so. These processors may be waiting for the right trading conditions, for instance when diseased larch prices decrease thus compensating for the low value of co-products. In any case Table 3 is based on "best guesses" as well as precise reports and should be read accordingly.

Comparison of production scenarios in Table 1 (below) with processing capacity indicates that timber processors in Wales are capable of utilising most, if not all, of the diseased larch likely to enter the market over the next ten years, depending on rates of infection and the ability of forest contractors to fell and extract diseased material to roadside. Doubts were expressed by one interviewee concerning possible difficulties with extraction of diseased larch from sites where trees have been felled but not immediately de-limbed and extracted[52]. Later snedding and extraction is likely to be challenging on these sites.

Period	Scenarios	Volume m^3	Logs m^3	Bars m^3	Chip m^3	Fencing m^3
0-10 years	15% felled	554,625	221,850	194,118	110,925	27,731
0-10 years	30% felled	1,109,250	443,700	388,237	221,850	55,462
0-10 years	50% felled	1,848,750	739,500	647,062	369,750	92,437
0-10 years	70% felled	2,588,250	1,035,300	905,887	517,650	129,412

Table 1: Possible larch production scenarios at 150 m^3/ha, 85% productive area, Wales & Marches

Period	Scenarios	Volume m^3	Logs m^3	Bars m^3	Chip m^3	Fencing m^3
0-10 years	15% felled	739,500	295,800	258,825	147,900	36,975
0-10 years	30% felled	1,479,000	591,600	517,650	295,800	74,000
0-10 years	50% felled	2,465,000	986,000	862,750	493,000	123,250
0-10 years	70% felled	3,451,000	1,380,400	1,207,850	690,200	172,550

Table 2: Possible larch production scenarios at 200m^3/ha, 85% productive area, Wales & Marches

Site	Annual Intake total m^3	Potential Annual Intake larch m^3
BSW Timber Ltd	185,000	45,750
Pontrilas Timber	160,000	40,000
Charles Ransford and Sons Ltd	60,000	60,000
ETC Sawmills Ltd	96,000	8,000
James Davies Ltd	45,000	20,000
Other	30,000	30,000
Western Bio-Energy Ltd	166,000	130,000
Aberthaw Power Station	75,000	75,000
Kronospan	700,000	90,000
Potential annual larch sawmill intake		**173,750**
Potential annual larch biomass intake		325,000
Potential annual larch total intake		498,750

Table 3: Processing capacity in or near Wales

1.4 Creative applications versus biomass

It is clear from table 3 (above) that there is ample capacity to burn or chip most of the diseased larch about to enter the market. But should we allow this useful timber to be consumed in such a wasteful manner? We wish to look at the possibilities for adding value and using significant volumes for imaginative applications rather than accept that large volumes may be disposed of as cheap biomass.

The challenge to this aspiration is significant because larch is unfashionable, partly due to the ready availability of domestic and imported spruce and partly due to the assumptions regarding the material properties of home-grown softwoods. The section below sets out evidence to demonstrate that home-grown larch possesses more than enough positive attributes to justify its inclusion in the higher value-added range of the contemporary construction industry supply chain.

2 Properties of larch

2.1 Confusion between the properties of larch species

There is a long-standing history of confusion between the properties of European and Japanese larch even amongst researchers and experienced sawmillers. Whilst compiling data for this report several interviewees[21], including one researcher[29] assumed that European larch was more durable than Japanese larch. However, perhaps somewhat counter-intuitively, the scientific literature shows that European larch tends to be less durable than either the Japanese or Siberian species[70].

Despite this at least one Scottish sawmiller specialising in larch cladding seems to offer only European or Siberian larch. Japanese larch is not mentioned in their sales literature at all[58] and an English sawmiller claimed to cut only "native" larch (a mistaken description of European larch) "because it was more durable than Japanese"[69]. Experienced processors and end-users sometimes contradict one another in their observations of larch properties; some regard European larch as superior, others prefer Japanese larch.

2.2 Strengths; durability, strength properties, sawmilling and machining properties

Durability characteristics

Natural durability or decay resistance is defined as the ability of wood to resist biological degradation[20]. Decay resistance in the heartwood (the dead inner core of the stem) of larch species strongly correlates with concentrations of extractives (or extractable compounds) such as polyphenols[26] and resin acids[70]. Certain researchers note that Japanese larch has higher proportions of heartwood than European larch although the latter shows high variability in this respect.[26] Japanese larch also has darker heartwood than European larch, possibly indicating the higher concentration of deposited extractives which contribute to its greater durability.

As might be expected hybrid larch has intermediate characteristics[25]. There is considerable historical evidence demonstrating the long term durability of larch in certain applications; Venice is built upon millions of timber piles called tolpi, the preferred species being oak and larch[4] and massive quantities of larch were also used for shipbuilding in the Venice Arsenale[39].

The properties of wood vary widely and there exists considerable evidence to demonstrate the high variability and significance of extractive content in larch between and within trees, even between areas of the same board. Decay resistance is therefore highly variable in larch and may be influenced by age, site, species, provenance and genetic control.

Older trees seem to show more durability in the more dense outer heartwood zone and this demonstrates the need to compare like with like in respect to age when comparing durability between larch species. Past problems with the methodology, reliability and consistency of test procedures may have added to the variability of test results[24]. Nevertheless there now appears to be a consensual position regarding the greater durability of Japanese larch compared with European larch as demonstrated by research dating from post-WW2 to the present day carried out in Britain[29] and across Europe as far as Scandinavia[40].

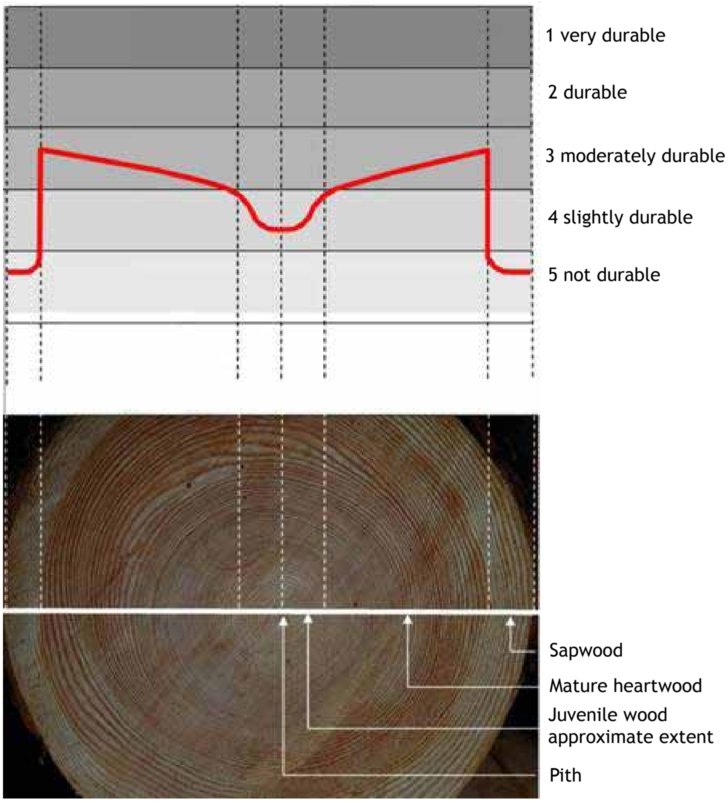
Recent reports by Ivor Davies et al from 2005[13] and 2009[15] reinforce European data which demonstrated that larch heartwood varied in durability between class 2 (durable) and class 4 (slightly durable).

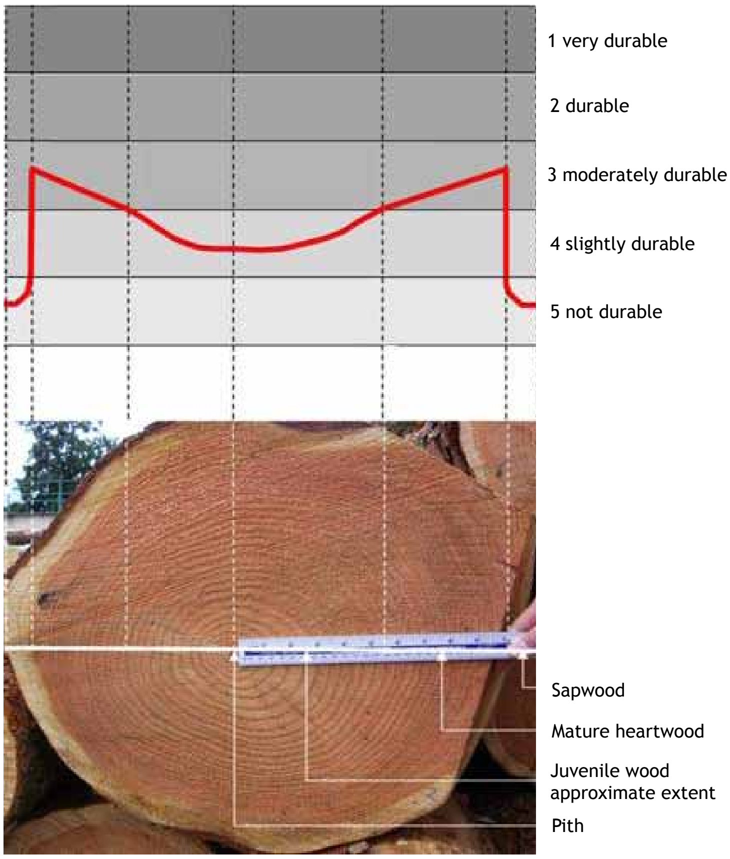
The unpublished 2005 report notes that there is no evidence to support the notion that growth rates affect natural durability thus contradicting popular opinion and possibly undermining claims that slow-grown imported Siberian larch is more durable than UK-grown larch species; the Siberian material may simply be better selected. Furthermore, extractive content and therefore durability varies between juvenile or inner core heartwood and mature or outer heartwood and also from the butt to the crown of the tree. Roughly speaking durability increases radially from the pith outwards and decreases towards the crown-wood[13] (see Figs. 1 & 2 right).

Therefore, special cutting patterns and selection of outer heartwood boards after milling could theoretically produce higher durability material for special applications although this might be difficult to achieve in practice. Anyway, it is possible that the difference between juvenile and mature heartwood is less important in use under hazard class 3 conditions (no permanent ground or water contact)[12] and so sensible design detailing in cladding applications may be far more important than inherent durability variations within the wood.

Notburga Gierlinger states in his 2003 thesis that NIR spectroscopy using a fibre-optic probe on solid wood may prove to be a fast, reliable method to assess phenolic extractive levels within larch heartwood in order to predict durability[24]. Gierlinger concludes in a related paper that phenolic content, an important indicator of decay resistance, strongly correlates with the reddishness of larch heartwood[25] but a 2009 report from Edinburgh Napier University found no correlation between colour and phenolic content. However the Napier work found that NIR analysis strongly predicted durability[15].

If this method could be implemented using low cost technology from other industrial processes, selection of quality, higher-durability larch for demanding applications could become viable.





Strength characteristics

Larch has a long history of use as a structural timber, for instance in Venice[4], and some early engineers claimed that larch was stiffer and stronger than oak[67]. However, both European and Japanese larch displayed somewhat low modulus of elasticity (a measurement which determines the deflection of a beam under load) when tested at the Princes Risborough laboratory during the late 1960s. Gwendoline Lavers' *The Strength Properties of Timber*[41] shows 9.9 kN/mm^2 for European larch (around C22 strength class) and 8.3.kN/mm^2 for Japanese larch (just over C16 strength class).

The results for Japanese larch were surprisingly low, reinforcing the need for new data. Professor Richard Harris of Bath University reports that the larch used in the gridshell of the Savill Building was considerably stronger than and stiffer than the values shown in the superseded BS 5268 data[31] (and also the Lavers data[41]) although that was slow-grown material from large, old trees.

Sawmiller Tommy Evans of G & T Evans in Newtown reports that at his premises recently 200 lengths of 75 mm x 75 mm sawn larch were visually graded and 185 passed the stress grading test, therefore 92% passed[22] to GS grade (which equates to strength class C16 under the superseded BS 5268). Side branches of larch tend to occur randomly and die-off with canopy closure, large branches (and therefore large knots) may only be found on edge trees or those in free-growth.

Fig. 3: Growth whorls and knot clusters do not appear on larch, knot sizes are restricted

James Ramsay of Edinburgh Napier University reports that "growth units and separate growth whorls are very difficult to determine"[53]. This would tend to suggest that larch might achieve good results under visual strength grading routines because knot clusters are rare (see Fig. 3 above). The recent results reported by Tommy Evans suggest this to be the case; Mr Evans noted that in comparison Douglas fir gave "very disappointing" results under visual grading. Craig Leitch of Charles Ransford and Son Ltd routinely carries out visual grading to strength class C24 on structural posts used in motorway sound screens. Posts up to 5 metres long and 250 mm x 250 mm cross section cut from home-grown larch are strength graded at Ransford's for special applications[42].

Dr John Moore and James Ramsay are currently testing mechanical properties of Scottish-grown Japanese larch at Napier University and recent bending tests showed modulus of elasticity (MOE) results of around 12 kN/mm^2; far exceeding Lavers' 1960s results. As these values are taken from only 25 observations the results cannot be assumed to be a reliable representation of characteristic values for larch in general. However they are a guide and suggest anyway that these samples sit in the C27-C30 strength class. John Moore thinks that probably there are reasonable yields of C35 material to be had but many more samples are needed to demonstrate this. The Napier researchers reported that the tested material is heavy to handle and anticipate that measurements will confirm reasonable density[47]. Wood density is also an indicator of strength and often correlates with MOE.

A recent project at Delft University of Technology set out to determine modulus of elasticity and bending strength of Japanese larch round-wood grown in The Netherlands. Low value, small diameter larch thinnings normally used for chipwood displayed characteristic MOE values of 15.4 kN/mm^2 placing this Dutch larch roundwood in strength class C35 although it was clear that under favourable knot conditions strength class C50 was achievable.

The main challenge associated with utilising roundwood of this type lies in finding methods to air dry the poles whilst minimising cracking along the grain. In this case cracks between 3 mm and 15 mm formed[17] and although they do not affect bending strength appreciably they present a problem when designing connections between poles in order to form engineered structures. Nevertheless, the utilisation of small larch roundwood in engineered structures could represent a significant value adding opportunity because suppressed small diameter larch poles are normally sold into low value markets which do not utilise the potential of their extremely high strength and stiffness.

The stems of suppressed larch tend to be free of large knots because of the species' shade intolerance and ring width can be very small, sometimes comparable to material grown in Boreal zones. American researchers have found suppressed small diameter Douglas fir to have superior hardness and yield higher percentages of select structural lumber than would be expected from larger, similar aged but better managed trees[28]. Richard Harris of Bath University emphasises the importance of small ring width in connection with high strength values for larch from larger logs[31]; there is every reason to expect that suppressed small diameter logs will perform similarly as long as large proportions of reaction wood are not present.

Larch species are exceptional for the high content of extractives in their heartwood; ranging from 5% to 30%, the dominating substances are water-soluble arabinogalactans as well as up to 3.5% of flavonoids. Some authors are now relating the strength properties of larch to their high arabinogalactan content which increases from the pith radially outwards, reaching the highest content at the heartwood/sapwood boundary. It is possible that mechanical loading perpendicular to grain may be better resisted by arabinogalactan-filled cells less prone to buckling, thus MOE of the timber may be increased[27]. The presence of high proportions of arabinogalactans may have a negative influence on the sawmilling characteristics of larch, building up on blades as "resin", causing blade oscillation, inaccurate cutting and shorter working life between blade servicing.

Sawmilling and machining properties

Walford Timber Ltd, sawmillers near Ross-on-Wye, were well-known for sawmilling larch until about 15 years ago when the company closed their sawmilling facility. Gerald Smith (who was managing director at the time) stated that Japanese larch was their preferred species; it converted well, cutting was "easy", it remained straight, had good consistency, no massive knots, was a very stable timber and was especially useful for ground contact applications. Mr Smith remembered that European larch was much more difficult to cut. Craig Leitch of Charles Ransford and Son Ltd had no problems to report with milling larch "after 25 years of using the material it was second nature". He selected Japanese larch particularly for its strength characteristics[42].

2.3 Weaknesses; poor recovery, reaction wood formation, distortion during conversion and drying, presence of dead knots, resin seepage from boards, resin build-up on machinery, nailing issues

No interviewees reported severe problems in processing Japanese larch but the consensus of opinion was nevertheless that Japanese larch is harder to cut than Sitka spruce and therefore in comparison production rates are significantly decreased. David Burd of BSW Timber reported reduced cutting speeds with knock-on effects; more saw blades and significant problems with resin build-up. Nevertheless BSW are reporting better than expected recovery[7]. All sawmillers reported that cutting problems were exacerbated when cutting dry logs[9]. David Mills of Pontrilas Timber called larch "the worst softwood we cut", citing slow cutting speeds and "springing from the saw"[46]. Quinton Davies of James Davies Ltd. thought there might be as little as 60% production in comparison to Sitka spruce[16]. Martin Bishop reported significant resin build-up problems when processing Japanese larch through A. J. Charlton's five-head resaw but thought that increased lubrication would resolve the issue.

The high arabinogalactan content in larch heartwood is considered by some researchers to be the principal cause of resin build-up. Resin deposition on saw bandwheels can alter the tracking of blades, in severe cases causing oscillation, inaccurate cutting and short service life. However, because arabinogalactans are water-soluble, increased water-based lubricant application/spraying may ameliorate this problem[27]. One sawmiller considered diesel to be more effective although generally no longer used[16]. It is possible that biogenic silica may be present in Japanese larch[38] which could contribute to tooth blunting. High levels of extractives, especially tannin, tend to chemically erode tooth edges[43]; this may be the case with larch.

Fig. 4: Brown patches of resin build-up on a primary bandmill blade

Poor recovery can be an issue with larch. Exposed and steep sites can cause poor stem conformation and growth of reaction wood leading to distortion during conversion sometimes called "spring" (Fig.5). Spiral grain may also be present. Cyril Hart mentions the tendency for larch to distort, split and check on drying, and dead knots loosening with the possibility of falling out. Loose knots can cause loss of production in planer/moulders when the knots dislodge and get jammed against machine edges.

Cladding material should ideally be selected in order to exclude boards with dead knots which may fall out (see below in Larch Quality). David Burd of BSW Timber feels that builders will prefer spruce to larch because of the latter's hardness and tendency to split[9]. The hard and brittle nature of dry larch can present significant problems when nailing, often it is necessary to pre-bore[32]. Japanese larch does not suffer from presence of resin pockets or resin-filled shakes to the extent of European larch, but when excess resin is encountered it is, nevertheless, a significant problem, especially when processing with planer/moulders.

3 Obstacles to increasing utilisation

3.1 The economy and innovation

According to the Timber Trade Federation's "Statistical Review 2010", the volume of timber and panels consumed in the UK fell to around 13,000,000 m^3 in 2009 from 18,000,000 m^3 in 2007. However, softwood imports fell to a level of 64% of total consumption whilst market share of home-grown softwood rose to 36% of total consumption[68], implying that UK producers were able to maintain or even grow their own market share at the expense of imports. Whilst UK sawmillers gained somewhat at the expense of foreign competition because of the weak pound, timber frame companies downstream have been suffering. Both Neil Smith of Holbrook Timber Frame Ltd. of Bridgend and Andy Mason of Ecoframes Ltd. of Welshpool described the last two years of trading as "really difficult". It is against this backdrop that markets will need to be found for high volumes of what is essentially a new sawn timber product which few producers see as a substitute for existing products such as Sitka spruce because the the two timbers have such different working properties[9].

Fig. 5: A slab "springing from the saw", distortion on conversion

The wood products industry is a technologically mature industry and competitive edge is maintained through process efficiency and improved cost performance. It is not possible to maintain competitive edge through production technology alone because competitors have equal access to technology. Therefore timber businesses focus on strategy, process innovations and to a lesser extent differentiation in order to survive[56]. Product innovation is often glibly cited as the solution to business challenges but the timber industry's low R & D intensity and risk-averse character makes product innovation problematical.

Furthermore, timber users take the easy route when specifying and are often resistant to trying new products or even different wood species[48]. A 2006 academic report concerning the timber frame industry reads like wishful thinking in 2011.

The report mentions acetylated timber, modern methods of construction and vertical integration between sawmilling and timber frame manufacture[56] all of which were tried and largely abandoned by at least one major sawmiller within those five years. However one important point is raised; there is a lack of sub-product and component suppliers able to serve construction companies and drive product development according to perceived client needs[36]. Could there be an opportunity for the right timber components in the marketplace? Even if the right product can be designed, the route to market is problematical; innovative products may enjoy a brief warm welcome initially but if they fail to gain acceptance within the mainstream market of the pragmatists and conservatives then they fall into the chasm. The mainstream market requires a fully developed product or solution and may be defined as the minimum set of products and services necessary to ensure that the target customer will achieve their compelling reason to buy[37].

Timber businesses striving for radical innovation face high risks, the higher the degree of novelty, the higher the risk of failure[36] but anyway the timber industry's generally risk-averse character tends to exclude explorative innovation[50]. Faced with high failure rates for novel developments a mature, generally family-owned, industry with no indications of radical breakthroughs in technology or products is necessarily careful[23]. Furthermore timber products tend to be of low complexity and easily imitated therefore any competitive gain through product development may be easily lost[56]. Against this rather bleak outlook the UK timber industry needs to find a niche for what may be a short burst of an additional timber product into a somewhat depressed, saturated market.

3.2 Customers' perceptions

Architects

At least one architect understood that "home-grown larch wasn't particularly durable" but was definitely interested in utilising it if the durability concerns could be addressed[11], others assumed European larch was the more durable[6]. Michele Lucarelli of NBS[1] and Peter Chlapowski[10] of PCKO Architects expressed concern regarding EU Public Procurement Regulations preventing the specifying ofaparticular sources of wood within the EU. However, in principle both were committed to the idea of utilising home-grown larch in construction and were interested in exploring possibilities. Dafydd Tomos of George and Tomos Architects in Machynlleth reported "disappointing" results when utilising larch in window and other joinery, appearance and stability were both a problem[64]. Architect Pat Borer although enthusiastic about using larch in appropriate applications found it problematical for joinery; "much too open textured"[6].

Timber Framers

Neil Smith of Holbrook Timber Frame Ltd. reports that they use only imported spruce CLS and could not foresee taking any significant quantities of larch to substitute for spruce especially in view of its hardness and liability to split when nailed[60].

3.3 Sawmillers' perceptions

Larch quality

David Burd of BSW Timber Ltd., Phil Wilkinson of ETC Saw Mills Ltd., Ellesmere and Martin Bishop of A. J. Charlton & Sons Ltd. in Somerset all expressed doubts about the use of larch for feather-edge boards because of the possibility of dead knots falling out on drying. Martin Bishop also reported problems with larch taking up CCA treatment evenly across boards, sometimes leaving unsightly patches of differing shades[5]; this may be related to the high content of extractives found in larch as well as pit aspiration. Phil Wilkinson mentioned the poor conformation found in some larch logs but did not see this as major problem providing that these logs were cross-cut in order to reduce "sweep"[71]. They all emphasised the problems associated with cutting logs which have dried out.

Strength grading

With no affordable, calibrated small scale strength grading tools available at present, numbers of visual strength graders available in Wales will be a factor limiting volumes of visually strength graded larch available to specialist end-users. Affordable strength testing equipment is needed along with the characteristic strength values for Welsh-grown larch derived via the BS 14081 process.

Problems with standards

Timberlab Report 50 of 1972 stated that the larch species grown in the UK have variable durability; between classes 3 and 4. Following on from that report, BS EN 599 Part 1 and BS EN 460, BRE Digest 494 recommended that larch should receive preservative treatment before use as external cladding. Some building officers insist that home-grown larch be preservative treated whilst Siberian larch (which is also variable in durability) is accepted untreated[14]. This treatment requirement is contradictory in another way; larch heartwood is refractory and described as extremely difficult to treat by TRADA[66], thus treatment does not penetrate more than a few millimetres anyway.

4 The potential impact of *Phytophthora ramorum*

4.1 Predicting future larch production volumes

Larch production on the Welsh Assembly estate in Wales during the year from March 2010 to March 2011 will total around 170,000 m^3, 40% of that total is to be released before March 2011 and the remainder will be released after that date. There is an intention on the part of Forestry Commission Wales to manage the sale of diseased larch logs in order to preserve prices[34]. Furthermore, FCW intend to offer larch as a substitute for Sitka spruce to those processors who will accept the material as a further safeguard against causing a glut of roundwood. Mathematical modelling of disease spread is being carried out at the time of writing; the results may assist in generating estimates of future volumes of material from sanitation fellings but error margins will be significant[34].

4.2 Mills licensed to process diseased larch

There is a detailed list of licensed processors (and qualified agents offering services to woodland owners) at: <http://www.forestresearch.gov.uk/forestry//INFD-876D2B>

4.3 Licensing process accessibility

No interviewees reported any problems with the licensing process; some expressed a view that the Forestry Commission were "making the best of a bad job". David Burd of BSW Timber reported that FC were helpful.[9]

4.4 Options for the use of by-products from diseased logs

David Mills of Pontrilas Timber and Martin Bishop of A. J. Charlton & Sons expressed doubts about the viability of bark disposal. At present, A.W. Jenkinson Forest Products do not offer payment for diseased bark collected from processors; some sawmillers report that this will depress larch log values[16]. There is a need to understand how serious a risk infected bark poses because sawmillers require the bark market to be normalised if at all possible in order to valorise the bark[5] (prices for undiseased bark of up to £20/ton were reported[16]). However, Simon Bullock of A.W. Jenkinson reports that they are still waiting for a protocol to be formulated for their own processing of diseased bark[8]. Sawmills may not have enough flexibility in their binning layouts to easily manage diseased co-products within their handling facilities, making disposal of diseased larch bark and chipwood relatively expensive in comparison with other species.

Furthermore, the larch co-products may have to be stored in bins reserved for other species thus effectively halting production of those species until the diseased co-products are collected[46]. In some mills diseased bark with no economic value may need to be stored at the cost of production of species whose co-products have a significant market value.

4.5 Storage of diseased larch logs

In order to manage larch roundwood volumes entering the market Forestry Commission Wales will be storing logs at the woodland sites where felling took place. Larch does not suffer from blue-stain and so dry storage of logs in situ is seen as a satisfactory solution by FCW[34]. However BSW and Pontrilas Timber were extremely concerned that larch logs might dry too much and consequently cause production problems. Craig Leitch from Ransford's also considered the dryness of logs a major issue; he said "he would not buy anything left roadside for months"[42]. Therefore timing of log release from sites will be a crucial issue requiring careful management. Wet storage of diseased logs is not considered to be a safe option[34] by FCW. The RAPRA risk assessment, written by several EU and US institutions[54] points to the risks posed by *Phytophthora ramorum* present in soil, foliage and bark but its findings have not been communicated to the industry. Questions raised by processors are:

1. *How much is known about timing of sporulation from foliage?*
2. *Can safe wet log storage procedures be formulated?*
3. *What temperature is needed to destroy spores when composting bark?*

The RAPRA risk analysis is available here[55]; <http://rapra.csl.gov.uk/SUMMARY_pra_26feb09.pdf>

4.6 Substitution of larch for spruce

Both BSW Timber Ltd.[9] and Pontrilas Timber[46] regard diseased larch as additional production rather than a substitute for spruce; BSW may increase capacity by up to 25% but this will need planning consent[9]. Craig Leitch of Charles Ransford and Sons Ltd saw no problem in taking larch as substitute for spruce and possibly Douglas fir also[42]. Martin Bishop of A. J. Charlton stated that they could take a 90% intake of larch rather the present 30% level. However, he added that they do not buy Welsh grown larch as the price is not viable[5], this view was reiterated by Sharon Poynton of Pontrilas Timber[51]. Phil Wilkinson of ETC Sawmills raised no objections to substituting larch for spruce but mainly for fencing posts rather than cladding. However, larch comprises only 3% of their input and ETC's log storage facilities give little scope to increase volumes of larch significantly[71].

5 The potential for fast and efficient utilisation of large volumes of larch and value-adding possibilities

5.1 End-users and specifiers; sawmillers, timber frame firms and architects. Can they react sufficiently to take advantage of the resource?

Neil Smith of Holbrook Timber Frame Ltd. saw little potential for home-grown larch in open panel timber frame construction unless nailing issues could be resolved. This could be a topic for further research with nail manufacturers because blunt nails may be a viable option. Andy Mason of Ecoframes Ltd. in Welshpool considered the availability of C16 strength graded larch as an opportunity to offer a moderately durable framing timber to more "environmentally aware" customers who might seek an alternative to preservative treated spruce. He considered the hardness of larch and tendency to split to be an issue that might be resolved with adjustments to the nailing process[44].

Architect Dayfydd Tomos has used larch in exemplar buildings recently such as that at Harper Adams College in Shropshire (Fig. 6); this post and beam construction also uses larch cladding[64]. Another architect, Pat Borer, has used massive section larch post and beam in constructions at the Centre for Alternative Technology near Machynlleth using local material sourced from Charles Ransford and Son Ltd. He reports that there is a larch boarded roof on the station there which has been in service now for around twenty years, confirming that selected home-grown larch can survive in demanding applications[6]. Post and beam construction using large cross section visually-graded larch is an immediately available straightforward building method which could use significant quantities of material if costings could be managed to suit mass markets such as housing construction. Post and beam construction also has a simple timeless quality which can appeal to contemporary tastes. David Burd of BSW reported that they would be producing larch sleepers[9]. Generally these massive section baulks are cut at 125 mm x 250 mm up to 3 metres long and could offer significant design opportunities, especially if strength graded for construction.

Fig. 6: Post and beam larch structure at Harper Adams College

5.2 Applications with a view to finding new end-users

New applications for home-grown larch in Britain will be constrained by funding availability. It is no coincidence that large exemplar timber-built projects such as the Savill Building in Windsor Great Park tend to be constructed for wealthy clients such as the Crown Estate. Even this expensive 90m long and 25m wide timber gridshell building only used 30 tonnes of finger-jointed larch in the roof [72]. In order to move the volumes of larch which may become available, access to mass markets will be essential. However, during an economic downturn cheaper and hence more straightforward structural options will need to be considered. Historical structures may give clues to finding simple options in timber structures which suit the characteristics of larch timber components.

Foundation piling

Venice demonstrates an immediate application; timber piles under St. Mark's campanile are nearly 1000 years old[33]. Timber is an ideal piling material[63] and larch is particularly suitable due to its hardness and durability characteristics. Timber foundations in wet places also offer the fashionable option of storing carbon within structures for centuries. Furthermore modern concrete capping can offer some moisture resistance, increasing longevity of the wet timber piles beneath.

Chain arched truss structures

During the Second World War in America timber rather than steel was used to build catenary arch Pratt trussed structures with huge clear-span spaces. The airship hangar at Tillamook (Figs. 7, 8, 9) is 1114 feet long and 297 feet wide but constructed from simple sawn Douglas fir timber elements with cross sections no larger than 75 mm x 350 mm bolted together with split ring connectors. At either end of the structures two concrete towers support a massive full-width timber box beam (not shown) 22 feet by 12.5 feet cross-section. The towers sit on concrete caps over timber piles rated for 30 tons. These structures, covering an area of around 7 acres, were amongst the largest timber structures ever constructed in North America, built at a time of severe material shortages. The joints between joists were bolted and reinforced with simple split ring connectors[49].

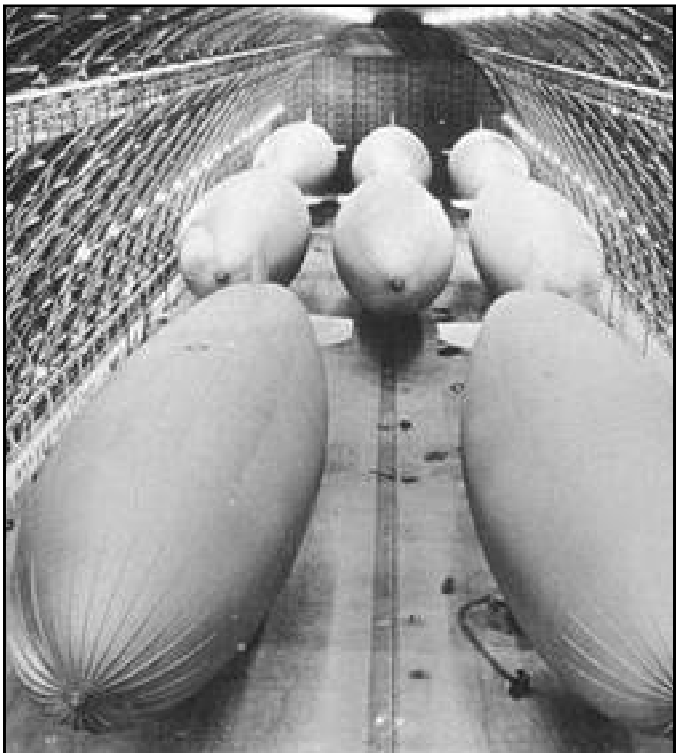


Fig. 7: Tillamook chain arch timber-built "blimp" hangar

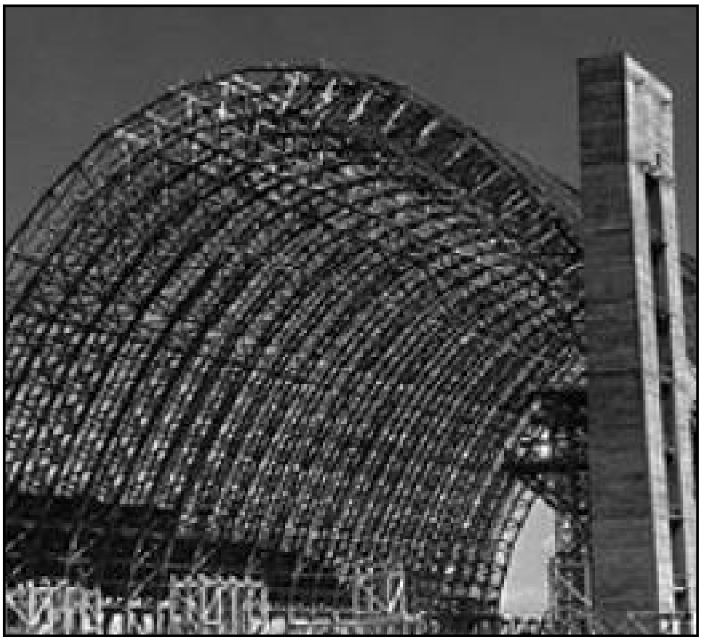


Fig. 8: The catenary arches under construction[49]

Although Douglas fir was used in the arch structures of these airship hangars, the strength and hardness of larch make it ideal for this type of application. Larch is suited to connections using bolts and split ring connectors because of this hardness.

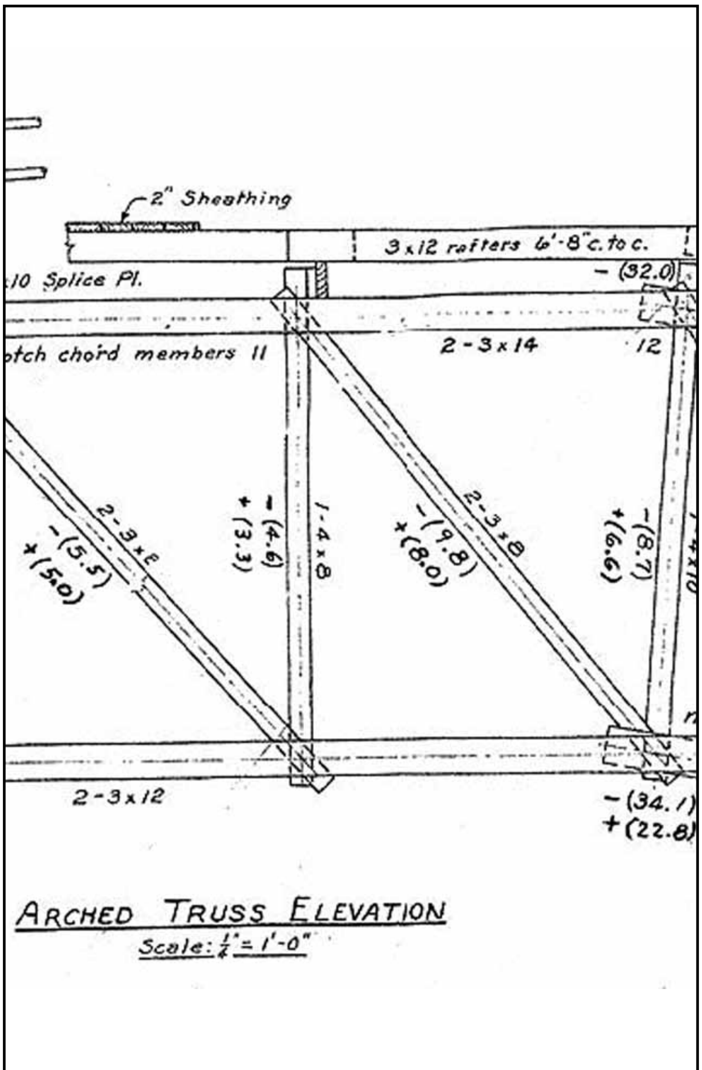


Fig. 9: The simple Pratt truss utilised for the hangar catenary arch [49]

Lamella structures

Catenary arch and barrel roof lamella structures were originally designed by Friedrich Zollinger around 1921[59].They need no special processing lines or heavy investment and may be built using sawn, strength-graded joists and simple bolted connections.

Short, portable and identical larch glulam elements could be manufactured in small workshops and utilised to construct large span lamella structures. The roof over Hounslow East Station in London (see Fig. 10) was constructed using Laminated Veneer Lumber (LVL)[65] but glulam could have been utilised. This technique has potential for increased uptake; modern 3D CAD and finite element analysis software can speed up the design stage considerably and could make this technology accessible to mass markets.

It may be possible to construct contemporary housing, commercial and public buildings using standardised glulam components produced in several already-existing small workshops rather than within a large expensive purpose-made facility providing that production quality can be assured. Research might be focused on innovative end connection systems in order to speed up assembly and erection processes although some proprietary solutions are already available “off the shelf”.

Lamella timber structures were, like the massive American airship hangars, built during challenging times. They were a creative response to constructional needs using standardised components in order to build large structures efficiently. There are few constraints on applications and the following examples are imaginative solutions to the problem of constructing wide-spans using short timber components (see Fig.13). The diamond shaped interstices offer opportunities to include insulating and/or stiffening materials. The Lamella roof demonstrates the value-adding potential of innovation but without the drawbacks of risk from heavy investment.

Fig. 10: Lamella barrel roof at Hounslow East Station

Figs. 11 & 12: Lamella roof at Nørrebro station, Copenhagen (image 12 by T. Worm)

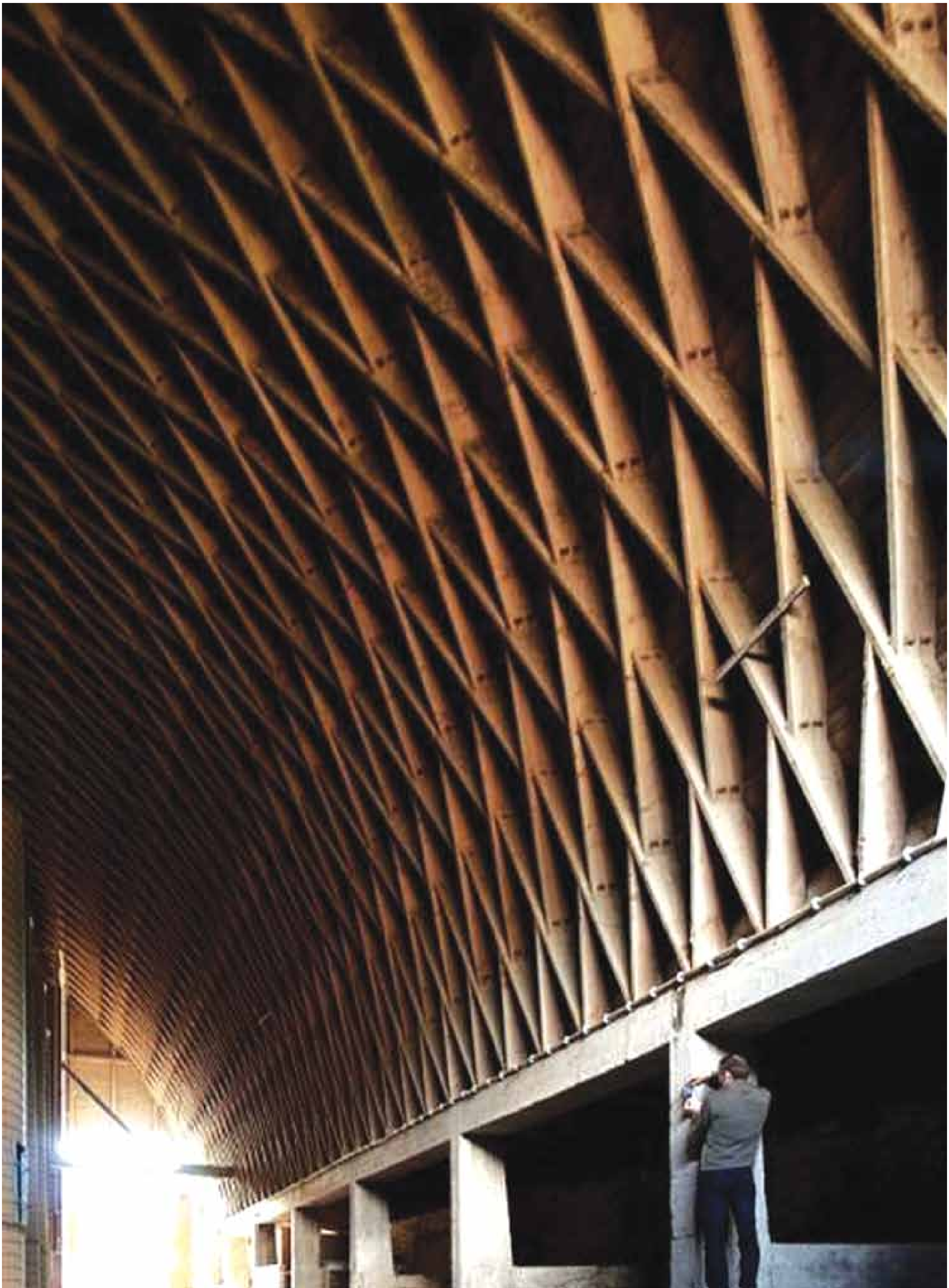


Fig. 13: Gut Garkau lamella structure barn designed by Hugo Häring (image Seier + Seier)

Bolted connections can be clearly seen at the joints in this 1924 barn by Hugo Häring (Fig. 13).

When major sawmillers such as BSW Timber start production of kiln dried C16 strength graded larch, simple glulam elements may be a viable option for production by British SMEs. As no major manufacturers actually produce glulam in Britain currently and the technology does not need to be complex or expensive at smaller scales there may be scope for bespoke manufacturers to start production. Specialist timber laminating businesses such as Cowley Timberwork in Lincolnshire demonstrate that a niche market for bespoke glulam components already exists. It is not inconceivable that increased availability of strength-graded larch and consequent market push by sawmillers and timber merchants could result in innovative business activity based around the new resource. TRADA Technology and Buro Happald Timber Engineers are convinced that glulam could be manufactured from timbers other than spruce and in particular British grown larch for the following reasons [45]

1. *Larch is within the small movement class of timbers*
2. *Hardest and toughest of home grown softwoods*
3. *Suitable for work where durability is important*

The larch glulam arches used in the Sheffield Winter Gardens (Fig. 14 below) were produced by W. u. J. Derix GmbH & Co. in Germany[3]. No technical barriers exist in Britain to prevent manufacture of glulam structures such as this from home-grown larch. The question is does anyone want to do it here? Perhaps the different industrial investment patterns in Germany allow more opportunities for manufacturers of engineered timber products; this could be a topic for further research.

Fig. 14: Larch glulam chain arches at Sheffield Winter Gardens [30]

The transition to structural design in timber using Eurocode 5 makes the process much more accessible to home-grown species such as larch once the species characteristic strength values have been established. Could the emergence of a new strength-graded larch timber resource combined with the new design process create new market opportunities?

5.2 Strength grading of larch to improve marketability

Strength grading of larch will open up opportunities for innovative applications of larch in structural applications such as those already discussed above. David Burd of BSW Timber reported that they will be producing C16 strength tested larch by March 2011 in sizes up to 47mm x 150mm[9]. David Mills of Pontrilas Timber also reported that they would be able to strength-grade larch to C16 when the machine grader setting data becomes available[46]. Larch is considered to be one of the hardest of softwoods but this may exclude it from some markets; Neil Smith from Holbrook Timber Frame Ltd. of Bridgend stated that Holbrook used around 1000 m^3 of exclusively imported spruce. The only exception was the small quantity of home-grown material used for individual exemplar projects. Smith felt that larch might be more useful to their business where larger C24 material was needed in lintels and floor joists; perhaps sawmills could consider producing larger cross-section material in order to try this latter market. He also wondered whether trussed rafters might be an appropriate application if larch could be strength graded to the required TR26 grade. Furthermore, trussed rafters use tooth-plate fasteners that may perform better than nails within end connections on larch[60], this needs further investigation.

Some recent reports from the COST E53 academic working group such as the study of Dutch-grown Japanese larch roundwood[17] suggest that there could be new possibilities for small diameter larch components.

These extremely strong larch pole elements could form the basis for large structures such as “spaceframes” built from standardised components. A massive exemplar larch-pole spaceframe was built for The Earth Centre near Doncaster during the late 1990s (Fig.15). The establishment of a strength-testing protocol for British larch roundwood could create new market opportunities for this low cost timber. SMEs are more likely to take advantage of innovative design opportunities utilising larch structural components when small-scale strength grading equipment becomes the norm.

In order to take advantage of the high strength of larch, characteristic strength values of Welsh larch are required so that grading over C16 might be carried out routinely rather than as an exception as is the case currently.

Fig. 15: Solar canopy at The Earth Centre, larch space frame construction

A portable low cost timber grader could be of use to sawmillers wishing to select higher strength logs before milling or smaller downstream businesses wishing to utilise home-grown larch within structures. There are options available already such as the "Brookhuis MTG" and "fibre-gen Hitman" products (www.machines4wood.com/mall/productpage.cfm/scottandsargeant/BHMTG/80949) and (www.fibre-gen.com/lg640.html). However, they are relatively expensive and are not integrated into the British strength grading process.

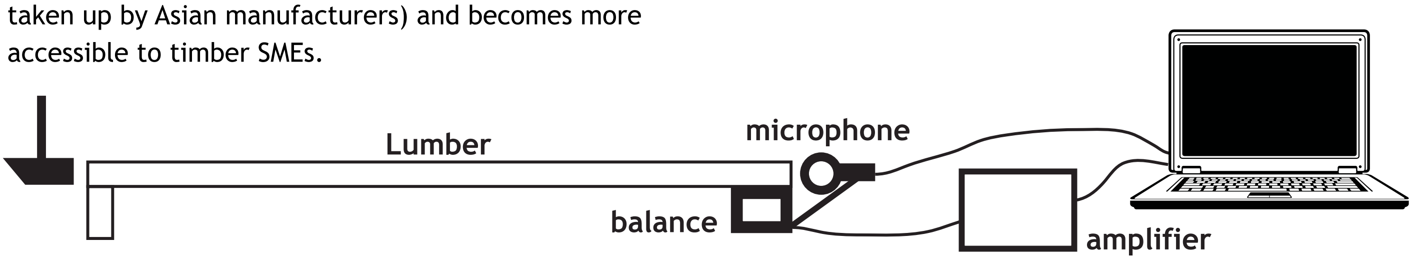
Therefore, because characteristic strength values of UK timbers have not been generated for these tools, they are only useful for guidance. A grader such as that used by Hungarian researchers (Fig 16 below) assembled from ready-made components may be a cheaper option until the technology matures (or is taken up by Asian manufacturers) and becomes more accessible to timber SMEs.

This process can be carried out using proprietary software which would probably be the most expensive element within this system but there may also be freeware options available. If setting data was available could a strength-testing tool of this type could be calibrated using standard test pieces held by TRADA or BRE?

5.3 Marketing

David Burd of BSW sees major challenges in marketing Japanese larch from sanitation fellings because this is a "once-only opportunity" and markets will have to be built up rapidly against the knowledge that after a few years there will be no more product available[9]. However, creative solutions emerge against adversity. For instance; in marketing blue-stain infected pine from British Columbia the positive, fashionable, connotations of the name "denim pine" and description "naturally-stained" have been used to sell the material stained through the actions of the Mountain Pine Beetle[2]. The "natural" characteristics of home-grown Japanese larch; hardness, durability and warm reddish colour could surely be marketed, perhaps this is topic for further investigation and possible specialist advice. New marketing opportunities have already been alluded to, for instance floor joists which take advantage of the high strength of larch. However, because the larger sawmillers will only strength grade to C16 on timber up to 150 mm deep, other strength grading options need to be explored. Flooring may be appropriate from selected material because of the hard, abrasion-resistant nature of larch.

Although most of the Japanese larch in Western Britain may have to be felled, it is possible that significant areas will survive in other parts of the UK.



This setup uses a simple combination of microphone, amplifier and notebook computer for data acquisition. An ordinary hammer can be used to hit the end of timber test pieces in order to cause the longitudinal vibration which is sampled in order to generate the dynamic modulus of elasticity measurements using Fourier Transformation of the frequency spectrum.

The larch available over the next few years due to sanitation fellings will need pioneer marketing which may lead to permanent value-added product lines being established based on the remaining larch resource.

6 Conclusion

Japanese larch has excellent durability and strength characteristics which allow its utilisation in many applications. Although a number of negative attributes sometimes make this timber difficult to process, the positive attributes can make the effort worthwhile. The large quantity of larch from sanitation fellings entering the market over the next few years represents a once-only opportunity to use home-grown strong softwood in structural applications which have generally required imported softwoods in order to fulfil the demands of the building regulation process.

The most useful characteristics of larch are its high modulus of elasticity and bending strength. However, although the latest data from Edinburgh Napier University and Delft University of Technology indicates that home-grown larch may be very strong, there is no machine grading protocol above strength class C16. Therefore new characteristic strength values will be required in order to utilise the structural characteristics of larch to its full potential.

Marketing simple larch products into new applications

BSW Timber's intention to mill 125 mm x 250 mm section "garden sleepers" from larch presents immediate design opportunities in post and beam or other structures utilising massive section material. Larch agricultural purlins, normally cut to 75 mm x 175 mm section up to 4.88 m long may also offer design possibilities beyond their intended use. There may be opportunities to present somewhat mundane sawn larch products in a different light in order to gain the attention of creative designers and end users. This certainly applies to foundation piling; the simplest combined with the most outstanding longevity of all applications, this is a larch product waiting for the right innovator to position it in the sustainable construction sector. It offers massive potential for carbon storage over centuries, a unique selling point in a culture focused on carbon within structures. What is more, timber foundations have immediate application in a Britain where flood plains are increasingly becoming part of the built environment.

Larch cladding might also be a marketing opportunity but quality control will be essential bearing in mind the weaknesses reported by processors. If NIR analysis for predicting durability could be implemented using low cost technology from other industrial processes, then selection of higher-durability larch for demanding applications could become viable and home-grown larch could be positioned alongside Siberian larch in the marketplace. Coed Cymru are considering stockpiling sawn larch at their "Timber Stores" in Monmouthshire and Pembrokshire[57]. This may give some early opportunities to gauge the potential for marketing larch.

Design of new structural products

There is an identified lack of sub-product and component suppliers able to serve construction companies according to their needs. Availability of large volumes of sawn larch surely presents Welsh SMEs with new opportunities for production of timber components appropriate for modern methods of construction whether they be glulam, brettstapel, spaceframe, lamella or others. None of these techniques require high investment but they do require strict quality control measures and an educated workforce. Woodknowledge Wales is the obvious channel for this training. There is also a continuing need to inform and influence end users and specifiers, and again specialist training workshops could assist the process. More direct co-operation between designers and processors is necessary in order to create desirable timber components, this is also achievable through existing channels.

Information required

There are distinct areas requiring further information or research:

1. *Protocols for log storage*
2. *Protocols for bark composting*
3. *Market research*
4. *Characteristic strength values needed for machine grading above C16*

Strength	Weaknesses	Opportunities	Threats
high strength values	need strength testing tools	massive section wood	imported alternatives
hardness	need careful selection	visual grading possible	development costs
durability	difficult nailing	glulam	customer perceptions
low moisture movement	splitting	post & beam structures	lack of design skills
low cost	loose knots	lamella structures	log drying problems
long beams possible	variable characteristics	spaceframes	large biomass capacity
"local, green" resource	variable machining	trussed rafters	
large quantities	variable processing	floor joists	
many applications	diseased bark liabilities	brettstapel	
		bridges	
		flooring	
		cladding	
		decking	
		foundation piling	
		window/door joinery	
		staircases	
		substitute other wood	

Table 4: SWOT chart for larch

Table 4 (above) outlines strengths, weaknesses, opportunities and threats for marketing of larch. Although there are obvious weaknesses, few are insurmountable. Furthermore, they are clearly outweighed by the positive attributes and new design possibilities. Perhaps the biggest threat to the creative use of larch is the massive biomass capacity available in Wales which will be seen as the default option for easy disposal of large quantities of diseased logs, whether or not they have added value potential. The difficulty of sawmilling logs which have dried in storage is a threat; sawlogs rejected by sawmillers can easily be disposed into the biomass market and there is little doubt that much useful material will be lost in this way. Careful management and release of logs from affected forest sites will be essential in order to get fresh logs to sawmillers, but this will be dependent on the disease curve and FCW's ability to respond under pressure.

Once only opportunity

There is a need to consider how we might make the best of this once only opportunity to use massive quantities of home-grown larch in the most creative manner. Larch is considered to be an underutilised material across Europe and North America. There is a chance here in Wales to design and construct structures in a timber which historically has been recognised as having huge potential that has so far in Britain only been achieved in exemplar constructions. Perhaps now is the time to demonstrate the British ability to work imaginatively under adversity. The massive timber catenary arch hangars built in America during WW2 demonstrate how simple techniques can be utilised to build inspirational timber structures. If there is a genuine will to more fully utilise timber in the built environment of Wales then this could be a major opportunity to harness that will creatively.

7 Recommendations

1. There is a need to examine log storage protocols. Is wet storage of logs possible and if so under what criteria? Are there any other options for ameliorating the drying out of logs e.g. could the ends of more valuable logs be sprayed with a cheap water-soluble polymer sealant such as PVA and might this make a significant difference?

2. Infected biomass co-products have low added value potential for sawmillers unless they operate their own plant for burning biomass, e.g. for kiln drying. Their storage may incur significant costs especially when limited binning options are available. There is a need to re-evaluate the risk from infected biomass so that value adding options other than burning might be considered.

3. In order to make best use of structural grade larch it is necessary to examine options for strength grading above C16 for both large processors and SMEs. Characteristic strength values of larch would need to be established for mechanical graders already in use at larger sawmills and for hand-held grading tools such as those discussed above in section 5.2.

4. The hardness of larch may work in favour of certain jointing systems such as bolt and split-ring but against some nailing systems. There is a need to examine material properties of larch in relation to fastening and connecting systems in order to make best use of its characteristics.

5. The durability of home-grown Japanese larch might be better exploited as a selling point. Comparison of durability characteristics with those of Siberian larch may give opportunities to capture some of the UK market for imported Siberian material. Low cost options could be examined for evaluating durability of larch using NIR technology from other industries e.g. food processing.

6. There is a need to seek expert marketing advice in order to examine marketing methods and evaluate new market opportunities.

7. This is a major, once-only opportunity to utilise large quantities of a timber which is ideal for construction and use in the built environment in order to replace high energy-embodied materials according to the stated aspirations of the Welsh Assembly Government. Could a small team of suitably qualified, creative experts work together in order to generate imaginative applications for larch which could lead the way to greater take-up of timber in order to help deliver sustainable development in Wales?

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