# Aspects of timber quality in the United Kingdom

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## ABSTRACT

*Developments in the use of structural timber particular to the UK are discussed together with end user quality requirements. Case histories of problems resulting from poor specification, selection and understanding of wood behaviour are given. Particular reference is made to the qualities of British-grown Sitka spruce.*

## INTRODUCTION

Timber is a highly capable and versatile construction material, used in applications as diverse as roof tiles (shingles) to foundation piles. Aside from being man's only truly sustainable building material, timber is easy to work with being easy to cut and fix using a wide variety of connection types. Probably the biggest limiting factor in timber usage is its lack of dimensional stability on drying. Timber which distorts on drying can cause problems with fixings (eg joist hangers), result in cracks in plasterboard and creaking or uneven floors; whilst excessive differential movement of timber frame can lead to problems with windows, doors and services. These building defects can lead to extremely expensive remedial work, including re-housing of occupants.

For General Structural (ie C16) timber BS 4978 (2007) *Visual strength grading of softwood* which is often quoted in the UK by building designers, gives the following tolerances for distortion at 20% moisture content:

- bow not greater than 20mm over 2m,
- spring not greater than 12mm over 2m,
- twist not greater than 2mm per 25mm over 2m.

These are clearly considerable deviations from the ideal of timber which is straight, at least to the eye. In service moisture contents are typically around 12% for stud walls, but may be as low as 6% for intermediate floor joists exposed to effects of high levels of central heating or under floor heating. Distortion and shrinkage can therefore develop in service.

Timber is not the only material available for use in construction. Notable in the UK are recent developments in competing, alternative construction methods such large format thin joint masonry, light steel frame and Structural Insulated Panels. Off-site production methods using closed panel systems and modular units are now commonplace. Some system builders are known to have switched from timber frame to non-timber panelized systems specifically because of quality issues with timber. Good dimensional accuracy is needed to incorporate prefabricated bathroom and kitchen sub-assemblies. Even floor coverings are pre-cut in some instances to fit rooms. Although the proportion of timber frame construction has been increasing in recent years, particularly with the advent of multi-storey timber frame, on occasion there have been problems with differential movement caused by frame shrinkage. These problems can be caused in part by use of timber at high moisture content. For both timber frame and conventional construction there has been a significant move away from the use of solid floor joists to plyweb and metal web beams, specifically because of problems with timber distortion and shrinkage. These engineered wood products generally also require higher grades of timber such as TR26 or C24, as defined by BS 5268 (2002) *Structural use of timber.* Trussed rafters (which were invented in the 1950s by Shirley in Florida, and introduced into the UK in the late 1960's) also gravitate through design code requirements towards the usage of higher grade and better quality timber. BS 5268 Part 3 (2006) *Code of practice for trussed rafter roofs* stipulates much tighter limits for the distortion of timber used for trussed rafters:

- bow not greater than 10mm over 2m,
- spring not greater than 4mm over 2m,
- twist not greater than 1mm per 25mm over 2m.

The code also has other timber quality requirements for other defects such as fissures, wane and knots (with particular reference to their effect on connector plates).

## QUALITY OF SITKA SPRUCE

The properties of British-grown Sitka spruce were the subject of extensive study by the Forest Products Research Laboratory (FPRL) during the 1930's, with the overall conclusion that, with suitable silvicultural management, it ought eventually to become more comparable with imported spruce for "utility" purposes. The end uses of timber at that time are in many respects quite different to that of today, with pit props and trench-lining being examples of uses which no longer exist. Domestic Sitka spruce and imported European (or Norway) spruce can be compared by reference to the Ministry of Technology Forest Products Research publication Bulletin 50 (Lavers, 1969). On the basis of the small clear samples studied, mean density at 12% mc for UK Sitka spruce is given as 384 $kg/m^3$, whilst the density of European spruce is given at 417 $kg/m^3$. For MOE the values are 8100 $N/mm^2$ and 10200 $N/mm^2$ respectively; and for MOR 67 $N/mm^2$ and 72 $N/mm^2$ respectively. It is perhaps unreasonable to compare the properties of timbers which have been produced over different timescales and conditions, yet an established grading and design system is bound to look less favourably on newer sources timber which are inferior. Nevertheless the possible use of domestic Sitka spruce for trussed rafters has been the subject of some experimentation (Harrod, 1975). BRE recently carried out number of structural tests on trussed rafters fabricated from Sitka spruce on behalf of a commercial client, which passed the requirements of BS 5268 Part 3. British-grown Sitka spruce generally readily meets the requirements for C16, but where the higher grades such as C24 or TR26 are sought, the necessary strictures of the grading system results in a much higher level of rejects (Figure 1).

With better tree selection processes and application of scanning technologies, high reject rates could be avoided when using higher grade combinations. Boards with spiral grain, and high proportions of juvenile wood or compression wood are fundamentally prone to distortion on drying (Figures 2 and 3). Scanning technologies can also be used to segregate the worst of this timber. Battens with central pith (termed "box pith") are prone to twisting even at low levels of spiral grain angle. A particular problem noted of British grown Sitka spruce is that the majority of boards twist in the same direction, regardless of their orientation. This can cause problems with glue-laminated timber. Compression wood can also cause problems with laminated timber particularly when fabricated at high moisture content (Figure 4). Board scanners can be used to sort timber on the basis of knot content, and can also be used to cross cut timber so that defects are avoided in critical areas such as at connections or nailing points.

FR1 100mm

| | | |
|---|---|---|
| C16/R | C16 | 100% |
| | R | 0% |
| C24/C16/R | C24 | 38% |
| | C16 | 32% |
| | R | 30% |

FR1 150mm

| | | |
|---|---|---|
| C16/R | C16 | 97% |
| | R | 3% |
| C24/C16/R | C24 | 40% |
| | C16 | 27% |
| | R | 33% |

FR1 200mm

| | | |
|---|---|---|
| C16/R | C16 | 98% |
| | R | 2% |
| C24/C16/R | C24 | 25% |
| | C16 | 25% |
| | R | 50% |

FR2 100mm

| | | |
|---|---|---|
| C16/R | C16 | 92% |
| | R | 8% |
| C24/C16/R | C24 | 60% |
| | C16 | 18% |
| | R | 22% |

FR2 150mm

| | | |
|---|---|---|
| C16/R | C16 | 93% |
| | R | 7% |
| C24/C16/R | C24 | 40% |
| | C16 | 25% |
| | R | 35% |

FR2 200mm

| | | |
|---|---|---|
| C16/R | C16 | 78% |
| | R | 22% |
| C24/C16/R | C24 | 0% |
| | C16 | 11% |
| | R | 89% |

FR3 100mm

| | | |
|---|---|---|
| C16/R | C16 | 98% |
| | R | 2% |
| C24/C16/R | C24 | 57% |
| | C16 | 28% |
| | R | 15% |

FR3 150mm

| | | |
|---|---|---|
| C16/R | C16 | 100% |
| | R | 0% |
| C24/C16/R | C24 | 73% |
| | C16 | 12% |
| | R | 15% |

FR4 100mm

| | | |
|---|---|---|
| C16/R | C16 | 97% |
| | R | 3% |
| C24/C16/R | C24 | 77% |
| | C16 | 10% |
| | R | 13% |

FR4 150mm

| | | |
|---|---|---|
| C16/R | C16 | 89% |
| | R | 11% |
| C24/C16/R | C24 | 50% |
| | C16 | 14% |
| | R | 36% |

**Figure 1. Example of Cook Bolinder strength grader reject and pass rates for stands of Sitka spruce.**

**Figure 2. Bow of timber dried unrestrained, caused by juvenile wood and compression wood.**

**Figure 3. Twisted timber caused by spiral grain and high proximity to pith.**

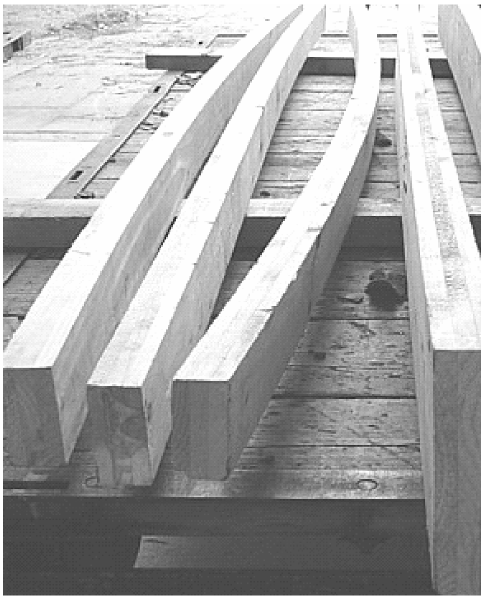

**Figure 4. Bow of 3-ply glue-laminated elements caused by compression wood.**

In comparative studies carried out by BRE, home grown Sitka spruce was found to be more prone to distortion that imported timber destined for the timber frame market, and to contain higher levels of knots (Figure 5 and 6).

| | | Average values (mm) | | | | |
|---|---|---|---|---|---|---|
| | | Twist | Bow | Spring | Cup | Moisture (%$H_2O$) |
| Imported | High m.c. | 1.31 | 1.98 | 0.7 | 0.14 | 22 |
| | Medium m.c. | 5.49 | 2.37 | 1.03 | 0.32 | 16.9 |
| | Low m.c. | 6.24 | 2.53 | 1.12 | 0.35 | 14 |
| Home grown | High m.c. | 2.76 | 1.44 | 0.81 | 0.02 | 22.6 |
| | Medium m.c. | 4.97 | 2.78 | 1.61 | 0.32 | 16.8 |
| | Low m.c. | 7.44 | 2.99 | 1.75 | 0.3 | 14 |

**Figure 5. Comparison of distortion measured in batches of timber studding during drying.**

| | Knot cover (%) | Average no. of knots per batten face | Average knot size ($mm^2$) |
|---|---|---|---|
| **Imported** | **0.52** | **6.1** | **185** |
| **Home-grown** | **0.82** | **8.4** | **206** |

**Figure 6. Comparison of knot content in batches of timber studding.**

**Figure 7. Battens used in timber frame panel manufacture. Imported timber (left), domestic (right).**

## PERFORMANCE PROBLEMS WITH TIMBER

Timber distortion can, on occasion, cause problems in service. In the examples given below, both imported and home-grown timber were involved.

The uneven gallery walls of a museum were investigated by BRE. The wall linings consisted of square edge butt jointed MDF panels fixed to timber studwork. In several places the boards were out of line with differences in the studwork alignment of up to around 8mm over 1m. The Architect's specification for un-graded softwood for framing out and non-structural use generally had referred to regularised timber; whilst the specification for cross section dimensions of structural softwood and hardwood timber referred to both BS EN 336 Tolerance Classes T1 (for sawn surfaces) and T2 (for further processed surfaces), but also to the use of timber generally at 20% moisture content. The lack of alignment horizontally along the length of the walls was determined to have been caused by a combination of shrinkage and distortion of the timber since installation together with poor carpentry. The builder had chosen to use rough sawn un-graded timber, probably at high moisture content initially.

Similar problems were reported at a timber frame office development in Ireland, where the 3.6m high wall panels and long corridor lengths extenuated the effects of timber distortion and movement. Wall panels were installed at high moisture content following attempts to prefabricate on the same site. The specification had not been clear on the quality of the timber used, with a non-standard size being quoted. The use of Canadian Lumber Size (CLS) timber which is machined at around 20% moisture content would have avoided many of the problems caused by the use of timber which was rough sawn at green.

Distortion in the form of twist and cup, together cross grain shrinkage, were noted to have caused problems of unevenness and creaking of timber floors in a catering development. The joists were determined to have been installed at high moisture content and were not well fixed in their hangers. Heat from the ovens had caused the timber to dry to 6% moisture content. Movement in the floor had caused a linoleum floor covering to leak cleaning water, resulting in a need to replace the decking and refit the kitchen.
Similar problems were caused for the extension of a hospital where solid timber joists had been used for an additional storey. The joists had been fixed without restraint from strutting. High levels of central heating caused cross grain shrinkage resulting in the floor becoming uneven.

## DISCUSSION

Whilst British sawmills can and do provide high quality timber, large amounts of low grade timber are also sold in structural sizes. Non-discerning builders have been known to select and use low quality timber at inappropriate moisture contents, resulting in problems developing in service. Architects and developers, on occasion, have also been noted to specify in an illogical or unrealistic manner. Properly conditioned and regularized timber is available. Inadequate consideration for the movement and distortion of timber can cause serious problems in construction. These defects can result in expensive remedial work.

## CONCLUSIONS

Items such as trussed rafters generally require high stiffness material with low knot content and low levels of distortion. Markets such as timber frame also prefer timber with low knot content. High reject rates have been noted when British grown Sitka spruce is graded for higher quality structural timber. In a comparative study, domestic timber was also noted to have a higher level of knots and distortion than imported. With better tree/log selection processes and application of scanning technologies, high reject rates could be avoided when using higher grade combinations to produce timber suitable for markets such as trussed rafters and other engineered wood products. Boards with spiral grain, and high proportions of juvenile wood or compression wood are fundamentally prone to distortion on drying. Scanning technologies can be used to segregate the worst of this timber, directing it to usage such as wood-fuel. Board scanners can be used to sort timber on the basis of knot content, and can also be used to cross cut timber so that defects are avoided in critical areas such as at connections or nailing points.

## ACKNOWLEDGEMENTS

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For BS and EN standards see British Standards Institution, London.