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WOODINFORMATION

Timber I-joists: applications and design

The use of timber engineered structural components in the UK is growing; specifically timber I-joists which have been successfully used in North America and Scandinavia for over two decades. I-joists are now being produced in the UK. They are factory produced with extensive quality control checking to ensure reliability of performance. In the UK, the route to market is via third-party certification which establishes safe design values for use with British and European design codes.

Timber I-joists comprise a timber flange (typically solid timber or LVL - laminated veneer lumber) and a panel product web (usually OSB - oriented strand board).

Timber floor joist products are under increasing competition. The success of concrete beam and block floor in the ground floor market is a clear driver to find timber solutions to match these products. Recent TRADA Technology research, supported by DETR and TRADA member companies has examined the techno-economic opportunities for I-joists in the UK.

The first part of this Wood Information Sheet looks at the applications and uses of timber I-joists, whilst the latter sections outline some of the considerations and possibilities of utilising UK material for I-joist manufacture.

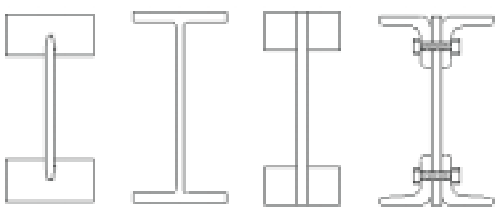


Figure 1 Timber and steel I-joists
left: factory produced, right: craft-based

Figure 2 I-joist with solid timber flanges and OSB web. Photo: James Jones & Sons Ltd

The Timber I-joist

Structural principles

Structurally the I-joist works on the principle that the greatest forces in a beam under bending are at the outer faces. Hence, if the stronger tensile and compressive material is positioned at the outside edges, the central zone can be reduced in size as it carries very little of the bending forces. However, the central zone (web) carries the reaction and shear forces. Commercially manufactured timber I-joists use high grade timber or structural timber composites for the flanges, routed to accept a timber-based board web (oriented strand board, K40 structural hardboard or plywood). The web is secured to the flange by an approved weatherproof, structural adhesive within the rout.

The high strength to weight ratio of timber composite I-joists means that there is no need for heavy lifting equipment and reduced requirements for temporary storage space. I-joists can be easily handled on site.

Applications of I-joists

Typical applications for I-joists are in floors, roof framing (rafters, purlins), wall framing (studs) and whole structural portal frames and roof trusses.

The need to radically improve the construction process in the UK, highlighted in the 1998 Egan report *Rethinking Construction,* is encouraging the uptake of products that improve construction and in-service performance.

Floors

Independent market research has identified that I-joists used for intermediate floors present cost-effective solutions, meeting user needs and being less costly than concrete alternatives, see Figure 4.

For ground floor applications the additional costs of oversite protection need to be considered, eg in England and Wales, 50 mm inert sand plus dpm or concrete over polythene (300 m) bedded on sand blinding.

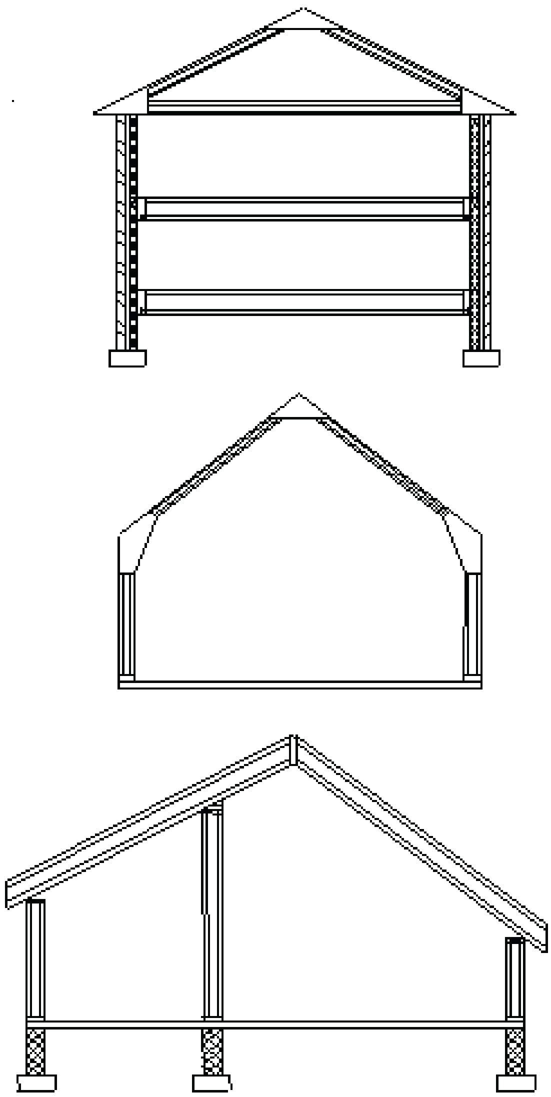


Figure 3 Possible applications of I-joists

Top: Triangulated roof and floor joists
Centre: Portal units
Bottom: Cantilever rafter roof and studs

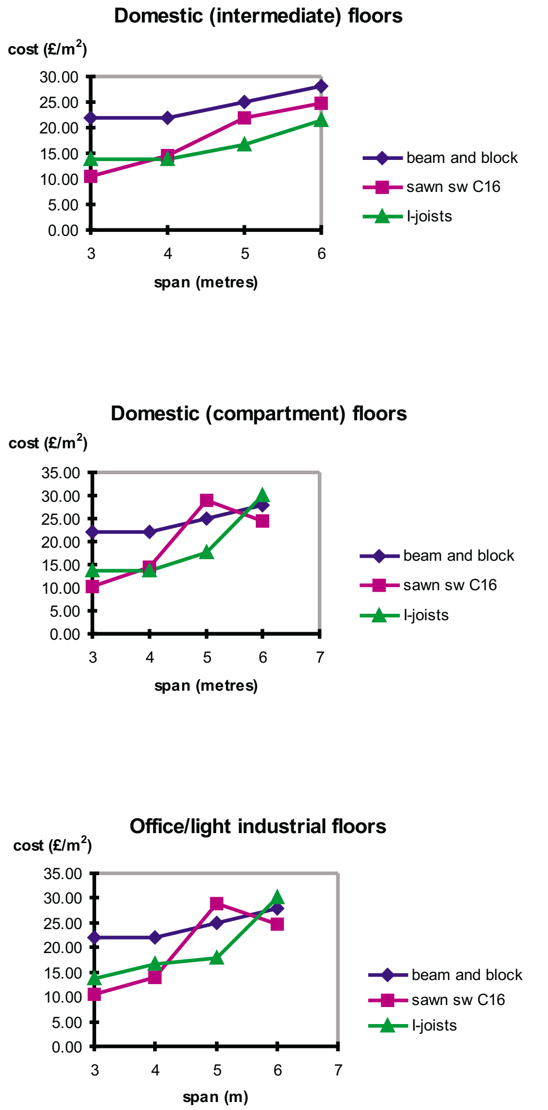


Figure 4 Cost comparisons of floor constructions
Costs based on 1998 prices, assuming a floor area of 6.6 x 6.6m. Includes incidental costs of additional perimeter walling for deeper joists, installation costs but does not include finishes

Benefits for floor construction

I-joists provide the designer and installer with reliable quality controlled structural products. The high strength to weight ratio means that light-weight long span solutions are available. Their factory controlled moisture content characteristics are ideally suited to avoid in-service shrinkage movements. The benefits to the construction process of timber I-joists are similar to concrete suspended floors (typically beam and block). A comparison of the two methods is summarised in Table 1:

Table 1 Comparison of concrete suspended floors with timber I-joist solution

	Concrete suspended floors	**Timber I-joist solution**
Design	From span tables. Flexible for different spans.	From span tables or from manufacturers' design programs. Flexible for different spans.
Span capacity	Typical market 4-6 m.	Typical market 4-6 m. Lengths available up to 12 m for continuous span support.
Type of construction	Wet trades might be involved. But use of OSB as a floating floor avoids wet screeds.	Dry material construction is the normal approach. Can use concrete screed finish if required.
Handling	Heavy	Light
Thermal insulation	Additional topping is needed for insulation.	Insulation can be included between beams.
Mechanical and electrical services	Specialist on site drilling for services or pre-planning in design and installation.	Simple on site carpentry drilling for holes in web. No notching of flanges permitted.
CDM Regulations	For high-level work use of wide span (plank) construction avoids use of temporary work platform.	For high-level work use of prefabricated panels (cassettes) to avoid temporary work platform.
Storage	Can be left out but wetting may cause moisture build up in the completed structure requiring drying out	To be kept dry by appropriate sheet covers or dry storage. If wetted or exposed to weather/moisture for a prolonged period the manufacturer should be consulted before use.
Fire resistance	Used as part of a system to give fire rating, eg. plasterboard ceiling	I-joists to be incorporated in a system to give fire resistance, eg 15 mm plasterboard ceiling for 30 minutes (subject to test).

A wider review of the application and optimisation of timber floors was undertaken in a separate TRADA Technology research project. The results are summarised in the report *Timber floors: improvements through process re-engineering*.

Some typical details for the use of I-joists for both timber frame and masonry construction in single dwellings are shown in Figures 5 and 6. Note: the drawings are for illustration only; they do not show all the constructional details which may be required for a particular floor, such as stiffeners, strutting etc.

Figure 5 I-joists in block wall construction

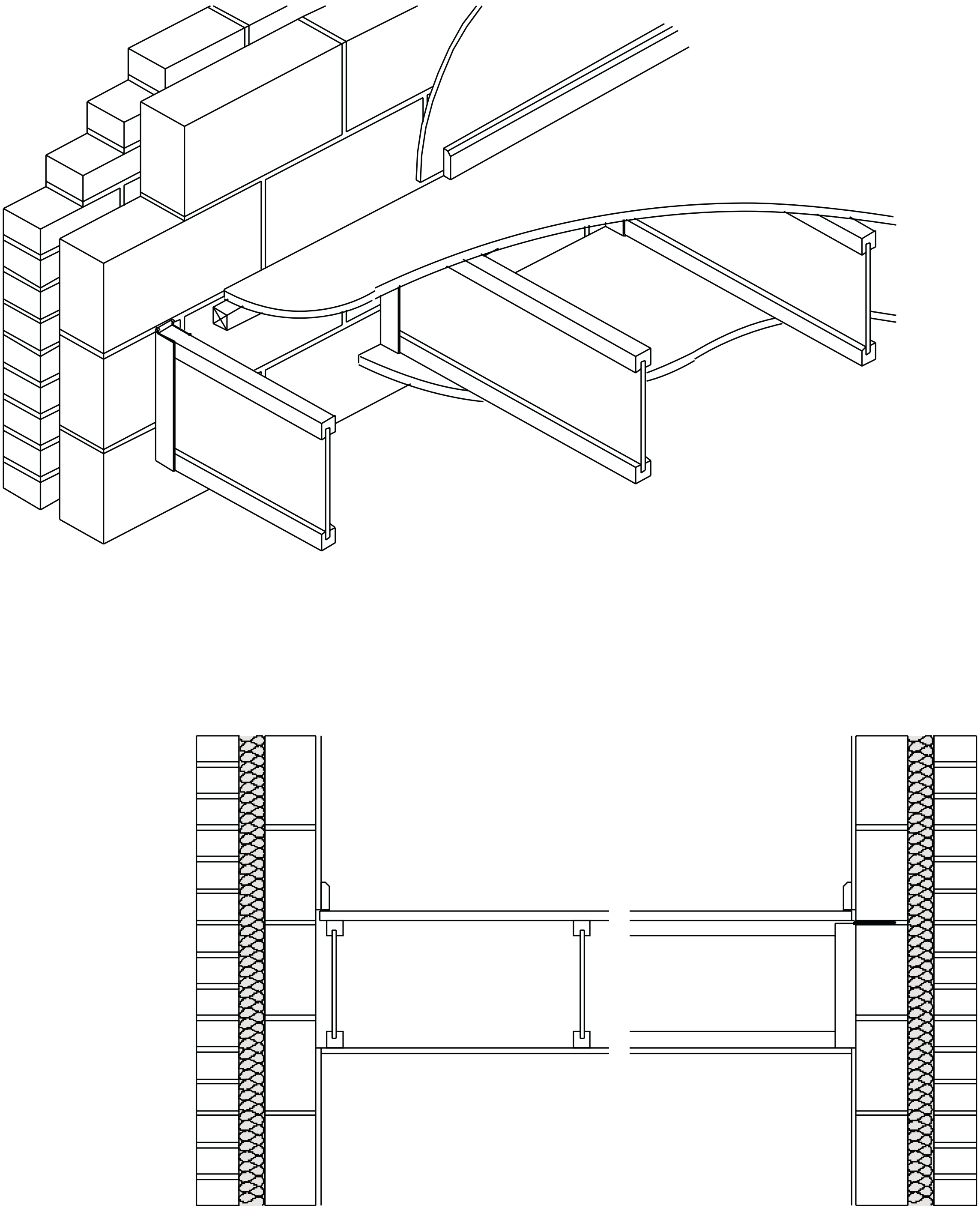
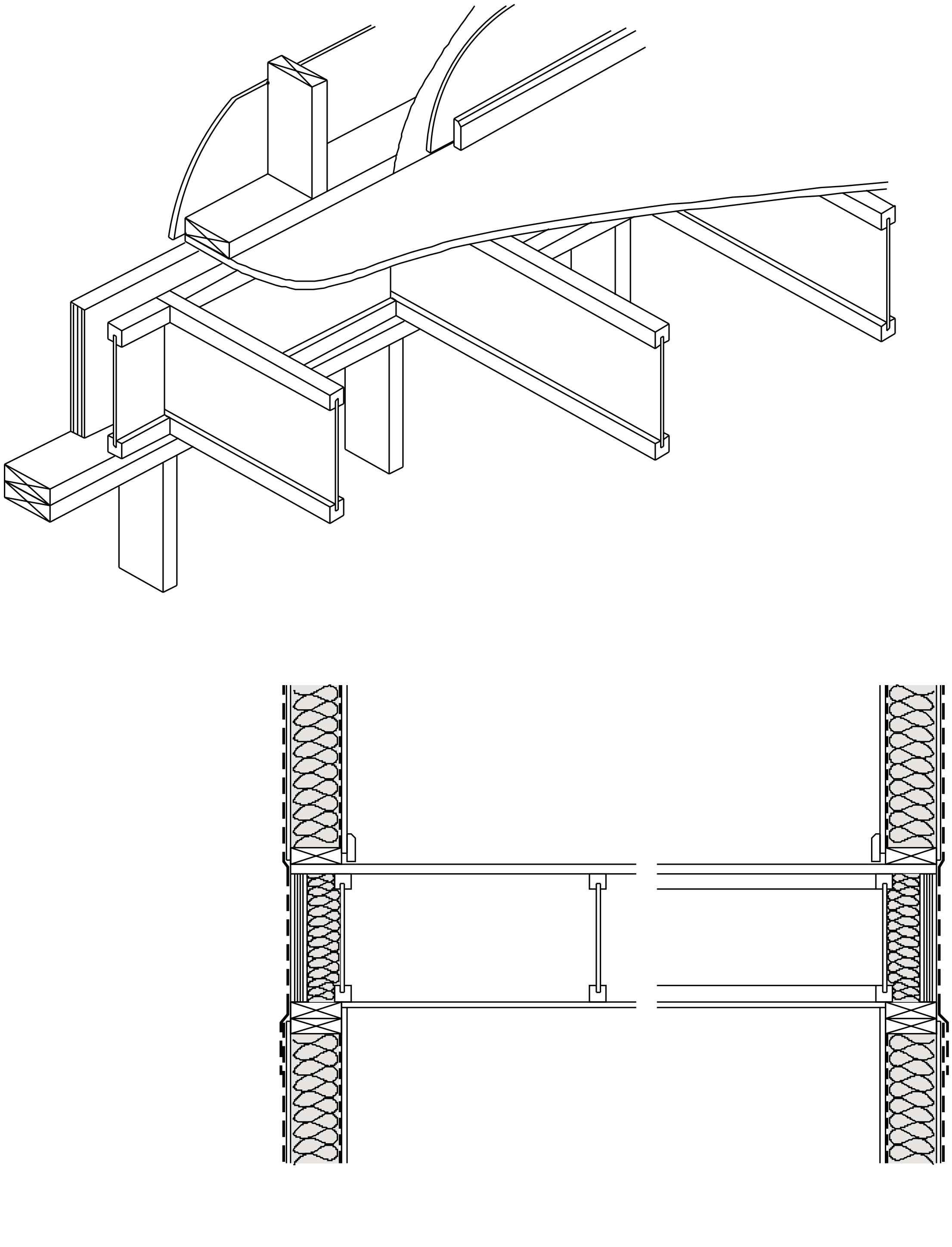


Figure 6 I-joists in timber frame construction



Market acceptance

From the results of a market survey, key user requirements for market acceptance can be summarised as shown in Table 2.

I-joists satisfy all of the requirements; those relating to floor construction have already been discussed.

Table 2 Key requirements for market acceptance

Supply Chain 'Customer'	Principal Customer Needs	
Specifier	Easy to design/specify	Flexible for different applications/layouts
	Reliable performance	No call back problems
Supplier	Easy to sell	Easy to deliver
	Easy to stock	No call back problems
Contractor	Easy to order	Low complexity process
	Easy to install	No call back problems
End-user	Comfort levels Defect free (in service)	Safe

Practical details for successful I-joist use

To ensure that the potential construction gains and performance are actually achieved in practice, designers and contractors need to be aware of some key points:

- **Stability of I-joist during construction**
  The depth to breadth ratio of an I-joist is relatively high and overturning of unrestrained beams can occur. Temporary bracing before decking (floor) or sheathing (walls and roofs) is usually required. Fixing of the floor deck or roof battens etc to the top flange of simply supported joists provides essential lateral restraint to the compression flange. The maximum centres for restraint are typically 450 mm but manufacturers' literature should be consulted.
- **Joist hangers**
  The joist hangers should be matched to the I-joist width and fixing requirements. There are proprietary BM TRADA Q-marked joist hangers that are specifically designed to support I-joists.
- **Nailing to flange**
  The depth and size of nails should be minimised to avoid splitting of the timber flange. The use of nail guns may be difficult on high density flange material. Due to the composite nature of an I-joist only nominal loads should be supported by the bottom flange alone.
- **Protection**
  Timber I-joists stored on site should be stored vertically, out of ground contact and protected from extreme weather wetting.
- **Dimensional stability**
  Because the flange is either a structural timber composite or small dimension timber the potential for cross grain moisture movement is reduced compared to solid rectangular timber beams. Care is needed, however, to understand the comparative dimensional stability performance at lintel and timber frame header support locations. A possible solution is to use I-joists or a material such as LVL for headers and lintels or to use hangers where floor members abut the wall framing).
- **Cold bridging**
  Running I-joists through the header joists on the outside of timber frame can create cold bridging if appropriate detailing is not applied.
- **Strutting**
  Manufacturer-designed floors typically design out the need for strutting. If strutting is required, metal strapping is suggested although care should be taken to avoid the straps touching where they cross. I-joist sections could also be used as solid blocking.
- **Services**
  There is greater scope for the provision of

larger holes for services in the webs of I-joists than in solid timber sections. However, the location of holes in the web reduces the shear capacity and the manufacturers limitations should be followed. No notching or cutting of the flange is permitted.

Engineering design

There are some aspects of designing with I-joists which require different treatment from solid rectangular timber due to their geometry and the fact that they are a composite assembly of different materials. These affect the actual behaviour of the I-joist in terms of strength and stiffness and the detailing plus handling and storage.

Each I-joist brand has specific strength characteristics which are presented in third-party certification literature (often repeated in the manufacturers literature). This contrasts with solid timber which is strength-graded to common grade values presented in British Standards and Eurocodes. Most I-joist manufacturers have comprehensive design and drawing software to produce specifications and cutting schedules.

Strength capacity

In common with solid timber beams in some applications (eg floors, rafters), the strength values provided by the third party certification and included in manufacturers' literature should allow for load sharing and should be used without application of the normal K factors in BS 5268-2. The strength values will have been determined through a combination of calculation and testing and can be provided for use in Service Classes 1 and 2. In Service Class 1 most timber is defined as attaining a maximum moisture content of 12% and in Service Class 2, 20%. I-joists can thus be targeted for both intermediate and ground floors respectively.

Control of deflection

Deflection of an I-joist is a combination of strain due to both bending and shear. Unlike solid rectangular sections, shear deflections in I-joists can be 10% and more of the total deflection and must be included. For an I-joist under a uniformly distributed load this is given by

total mid span deflection, u = bending deflection, u_{EI} + (shear deflection, u_G) x creep factor, K_c

where EI is the bending stiffness of the flanges only and GA is the shear rigidity of the web (provided by the manufacturer), L is the span and w is the load per unit length on the beam. Values of EI and GA are normally presented in the certification literature.

K_c is a coefficient which is based on the load duration and the relative creep properties of the web material. For commercially certificated beams (BBA or BM TRADA Q-Mark), the K_c co-efficient has been incorporated in the GA values presented.

Due to the lighter weight and longer spans of a typical I-joist floor, vibrations may be higher than for floors of solid joists and designers should consider reducing the deflection limit. This is particularly important in main activity rooms such as kitchens and living rooms or in office areas.

In the UK the normal deflection limit for solid timber domestic floors is 0.003 times span (L/333) or 14 mm, whichever is the lesser. This limit should not always be assumed to be acceptable for lightweight I-joists, particularly in long spans.

Subject to proprietary data on I-joist performance, it is recommended that the deflection limit is increased for I joists and, in common with North American guidance, the following is more applicable:

Limit on live load (variable actions) = L/480
Total load
(permanent and variable actions) = L/360

Further guidance on deflection limits and floor vibration, particularly in relation to Eurocode design, is given in the Wood Information Sheet 4 – 24 *Serviceability limit states for timber in buildings* and in the Timber Engineering Guidance Document GD 6 *Vibration in timber floors*.

I-joists and efficient use of the timber resource

The UK has an increasing and sustainable supply of softwood timber resulting from continuous replanting strategies. Making the best use of this growth in wood supply depends on identifying new ways of using this natural resource. One such approach is to use small roundwood arising from forestry operations for the manufacture of OSB and another is to select high grade solid sawn material for specialist applications.

The current wood supply from UK sources is approximately 9 million m^3 of which around 600,000 m^3 goes into construction. The projected increase for the next 20 years in wood supply from UK forests is in the order of 70%. Roughly 50% of this material will be sawlogs capable of being turned into structural products such as studs, joists and rafters. Sawlog timber for construction represents high value to the UK forest industry. However, the strength range of UK-produced material is relatively low compared to the price competitive imports. Considering stiffness as a measure of usability in construction, Table 3 shows a comparison between the predominant UK and imported material.

Table 3 Typical span range for floors

Product	Span range
38 x 220 C24 solid timber joist	3 - 4.8 m
220 deep I-joist	3.5 - 5.5 m
300 deep I-joist	4.0 - 6.5 m
350 deep I-joist	4.0 - 7.5 m

Note: For actual product performance, reference should be made to the proprietary I-joist literature

For the UK supply chain the use of its natural stock for the C14-C18 category is a viable and practical market. To enter into the C24 range of material requires significant product selection. I-joist products typically fulfill the higher joist grade market of C24 and above. The substitution of an I-joist in the C24 and above market range is therefore not a significant threat to the UK wood material supply chain. Hence the growth of I-joists in UK construction will encourage UK manufacture of I-joists using local material.

References

BS 5268-2: 1996 Structural use of timber. Part 2 Permissible stress design, materials and workmanship.

TRADA Technology publications

Structural Timber Composites. *Design Guide 1*. 1996

Timber floors: Improvements through process re-engineering. *R Bainbridge and M Milner. Report 3/99*. 1999

Vibration in timber floors. *Timber Engineering Guidance Document GD6*. 1998

Floor joist span tables (to Eurocode 5). *Timber Engineering Eurocode Design Aids EDA 1*. 1994

Wood Information Sheets

1-36 Timber joist and deck floors – avoiding movement
1–41 Strutting in timber floors
2/3–29 British structural softwood and span tables to BS 5268
4–7 Guide to strength graded softwood
4–21 European strength classes and strength grading
4–24 Serviceability limit states in timber buildings
4–26 Strength graded British softwood

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