



SUSTAINABLE TIMBER DESIGN

MICHAEL DICKSON AND DAVE PARKER

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Michael Dickson
and Dave Parker

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Sustainable Timber Design

This new resource covers the material selection, structural design and connections detailing of truly sustainable timber buildings through:

- consideration of the nature of wood and the heritage of timber construction, including the importance of forestry and conservation
- a review of modern techniques to improve the durability, fire resistance and predictability of structural timber elements and their vital connections
- analysis of the many architectural and structural options, from roundwood shells through glulam arches and gridshells to long span hybrid structures
- case studies from around the world illustrating the principles discussed and the true potential of timber construction

Historically there has been an imbalance between the availability of information on structural timber design and the much more widespread familiarity with traditional structural materials such as steel and concrete. This book aims to help redress the balance by presenting the essential design principles involved in the creation of elegant, user-friendly timber buildings that are practical, economic, and thoroughly sustainable.

Designed to support specialist study into the benefits of 21st Century timber engineering, this book also offers architects, engineers and other construction professionals practical advice on all aspects of modern timber architecture.

Michael Dickson, C.B.E., F.R.Eng, F.I.StructE., F.I.C.E., Hon. F.R.I.B.A., was a Founding Partner of Buro Happold and Chairman 1996–2005. Buro Happold is an international multidisciplinary engineering and consultancy practice with offices in Europe, the Middle and Far East, and the USA. Michael is a Visiting Professor of Engineering Design at Bath University, School of Architecture and Civil Engineering, and was President of the Institution of Structural Engineers in 2006. He continues as a consultant to Buro Happold and a trustee of BRE.

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Dedication by Michael Dickson

To Effie Galletly, my wife
for all her love, and great support and friendship over many years
and to our daughters
Amy Isabel Frances and Sarah Rosamond Alice

Dedication by Dave Parker

To my wife Lesley and my daughter Jenny

Illustrations

Figures

I.1	Once a Tudor barn, the St Barnabas Centre in Thorley, Hertfordshire, UK, is now a very popular venue for church services, conferences and community events.	xix	2.3	A model procurement policy	16
I.2	Students at Hereford College of Arts in the west of England also enjoy the unique ambience of a timber building.	xx	2.4	Specification of sustainable timber by a client, architect or engineer	17
I.3	Interior, Winter Garden, Sheffield	xxi	3.1	Despite insect damage to its sapwood, this Tudor oak frame member is still in service.	19
I.4	Brunel's 45 m high, 291 m long Moorswater viaduct carried his broad gauge Great Western line over the Liskeard and Looe Railway below. It was replaced by a stone viaduct in 1881.	xxii	3.2	Wood tar and its derivatives have preserved this wooden stave church in Heddel, Norway, for more than 800 years.	20
I.5	Interior of workshop at Hooke Park	xxiv	3.3	Very early steam railways bedded their rails onto expensive stone, as shown in this 1838 view of Berkhamstead station.	21
I.6	The massive log and stone walls of the front entrance to the McMichael Canadian Art Collection beneath its sloping roof of western red cedar shakes, 2011	xxv	3.4	Creosote-impregnated softwood sleepers (ties) replaced stone – and were replaced in their turn by concrete.	21
I.7	Timber adds its own distinctive note to the internal ambience of the Bodegas Protos Winery.	xxvi	3.5	Thin section timbers have limited fire resistance, but can be treated to achieve required safety levels.	23
I.8	Shell roof to the Savill Garden Visitor Centre, Windsor	xxvii	3.6	Fire damaged five centuries ago, recycled, and still giving good service in the St Barnabas Centre in Hertfordshire, England.	23
I.9	The Richmond Olympic Oval's roof structure combines glulam and structural steel to stunning effect.	xxviii	4.1	Probably the best Allied warplane of World War II, the Mosquito's wooden structure gave it outstanding performance and a low radar cross-section.	25
1.1a	Cross-sectional view of a log	3	4.2	Cross-laminated from at least two layers of wood, the classic Roman scutum offered effective protection.	27
1.1b	Principal directions and planes of wood	3	4.3	An early rotary lathe produces veneers for plywood manufacture	28
1.2	Measuring the diameter of larch in the stockpile for Savill visitor centre	4	4.4	Many different timber species can be used for glulam production.	28
1.3	General strength properties related to density	4	4.5	Oriented strand board production utilises a higher proportion of each tree than plywood.	29
1.4	Change of shape of a cross-section of sawn timber	4	4.6	Prefabricated cross-laminated timber panels speed construction, as here at the Open Academy project in Norwich, UK.	31
1.5	Shrinkage of wood in its three principal directions	5	4.7	Thermal treatment can darken softwoods until they resemble high quality hardwoods, as in this 'Thermowood' sauna.	33
1.6	Organisation of a coniferous longitudinal latewood tracheid	8	5.1	2012 Hooke Parke 3D master plan for the Architectural Association	38
2.1	Larch from a sustainable plantation on its way to the mill	12			
2.2	Beginning of the procurement process – felling larch for the Savill building	13			

5.2	Timber seasoning shelter under construction	38	7.5	External view of studio from garden	71
5.3a	Prototype house exterior	39	7.6	Interior finishes within exposed oak frame looking west onto garden	71
5.3b	Interior of prototype house, 1987	39	7.7	Section through studio looking east	72
5.4	Architectural section	39	7.8a	Detail of truss joint	73
5.5	Hooke Park workshop 1989	40	7.8b	Detail of wall roof construction	73
5.6	Detail of shell rib member to noggin joint	41	7.9	Refurbished interior to the Great Barn at Basing	75
5.7	Westminster Lodge structural model	41	7.10	The dormitory building in green oak at the Minstead Study Centre	76
5.8	The Westminster Lodge overlooking the woods	42	8.1	View of classrooms with tepee behind from playground	78
5.9	Interior of Westminster Lodge	42	8.2	Assembly hall, looking up at the oculus	78
5.10a	Counter-drilled hole with two part epoxy for eye bolt in hanging thinning	43	8.3	Model of structure showing the arrangement of the timber components	78
5.10b	Steel bolt in two-part epoxy for compression across A frame	43	8.4	View of school from playground	79
5.11	View out to Lake Bunyonyi through the finished structure	43	8.5	Cross-section through double grid structure at West Totton	79
5.12	Exploded axonometric of structure	44	8.6	Double grid on circular column and mast cross head arrangement	79
5.13	Connection of column to rafter and tie beam	45	8.7	Assembly of roof on the ground prior to craning in the grid in sections	80
5.14a	Finished roof structure before cladding	46	8.8	Pupils in the hall	80
5.14b	The finished clad hall	46	8.9	Hounslow East Station exterior	81
5.15	View up centre of roof at reciprocating ring	46	8.10	Lamella roof on raking circular struts and perimeter steel posts	82
5.16	The Big Shed exterior	47	8.11	Roof trusses of American white oak and stainless steel at Emmanuel College	83
5.17	Interior of the Big Shed	48	8.12	Exterior view of the concert hall	83
5.18	Node connection	49	8.13	Structural drawing of truss	84
6.1a	Balloon framing	52	8.14	Stainless steel connection of trusses and purlins around semicircular end	84
6.1b	Platform framing	52	8.15	Exterior of Collyer-Ferguson Performing Arts Centre	85
6.2a	TF 2000 under construction	53	8.16	Tied trusses to the roof of the concert hall	87
6.2b	Plan of TF2000	54	8.17	Purlins and Douglas fir boarding to the hall	87
6.3	Section, elevations and plans for the children's house, Brighton, Sussex	55	8.18	Finished shelter	90
6.4	Axonometric of framing system	56	8.19	Key section	91
6.5	Completed children's home	56	8.20	Corridor and mosaic	91
6.6	Bolted connection between square post and two rectangular beams	56	9.1	Two-pinned arches on buttresses in the cafeteria at Telford College	94
6.7	Floor plan of Little House at Laindon	57	9.2	3D structural model	95
6.8	Little House exterior in its garden setting	58	9.3	View of stepped construction showing V braces and purlins	96
6.9	View of eastern end elevation of the sailing club	59	9.4	End arch over glazed end wall with steel gutter to left	96
6.10	Interlocking truss of recycled boards and new purlins during construction	59	9.5a	Site plan at Crystal Bridges, Bentonville, Arkansas	97
6.11	Sailing club structural section	60	9.5b	Crystal Bridges at dusk	97
6.12	View of entrance to LLTNP HQ	61	9.6	Interior of Landside Gallery	98
6.13	Interior of atrium from office balcony	62	9.7	Interior of southern bridge cafe at night	98
6.14	Office/atrium frame under construction	62	9.8	Arrangement of bridge building roof structure in BIM	99
6.15	Exterior elevation BBA Mountain Academy	64			
6.16	Interior of common room	64			
6.17	Exploded isometric: (a) roof cladding, (b) wall cladding, (c) structure, (d) foundations	65			
7.1	The interior of the Globe Theatre in action	67			
7.2	Section illustrating radial frame	70			
7.3	Roof and frame showing shrinkage fissures	70			
7.4	Exterior of the Globe during construction	71			

9.9	Full strength arch site connection in bridge roof arch	99	11.5	Structural model for Forum shell	125
9.10	The succession of end arches at the Bodegas Protos winery	101	11.6	Node connection	125
9.11	Section through vault over ground floor with basement below	103	11.7	Looking up at the multilayer larch grid with birch ply diaphragm	126
9.12	Plan of winery	103	11.8	Plywood diaphragm on the larch grid contained within the steel compression ring	126
9.13	Making wine beneath the arches and vaulted roof	104	11.9	Form finding and analysis model and setting out plan	127
10.1	Transportable Mongolian yurt made up of small section timbers	106	11.10	Construction detail showing cladding, structure, perimeter glazing and rainscreen	127
10.2	Interior of the main hall at Mannheim in 1886	107	11.11	Bolts take thrust to steel plate from LVL finger jointed to larch lath at perimeter	128
10.3	External view of entrance arch to main shell with adjacent banana shell reflected as a hanging form in the water feature	108	11.12	Finger joint in 80×50 mm larch lath	129
10.4	Four layers of hemlock laths with shear blocks and threaded rods with cup washers and nuts, galvanised wire ropes and nailing strips for roof membrane	109	11.13	A delighted construction team on completed structure of “my roof”	130
10.5	Restaurant shell on ground in foreground with main shell on erection scaffold towers behind	109	11.14	Three domes sit above the landscaping either side of the main entrance	130
10.6a	Edge detail	110	11.15	Park level view of Canary Wharf Crossrail station canopy	133
10.6b	Connection of double grid to circular glulam beam	110	11.16	Roof module build up	135
10.6c	Cable boundary	111	11.17	View from southeast	136
10.7	Single and double layer gridshell over entrance walkway	111	11.18	The canopy during construction	136
10.8	Site plan and architectural cross section	112	12.1	External elevation of the Graphite Apartments	138
10.9	Interior of workshop	112	12.2	Dartington’s classroom clusters	142
10.10a	Longitudinal section drawing of workshop floor structure	113	12.3	Roof panels during construction	142
10.10b	Detail of column and beam in archive store	113	12.4	Interior of a classroom	143
10.11	Computer simulation of the forming of the gridshell	114	12.5	Main entrance to the Open Academy	144
10.12	Four layers of oak laths at node connection with triangulating rib lath over	115	12.6	Aerial view during construction	145
10.13	Close up of gridshell during erection	115	12.7	Finished atrium area	145
10.14	End arch and entrance to workshop clad in western red cedar lapped boards	116	12.8	Atrium balustrade detail	146
10.15	The Centre Pompidou – Metz	117	12.9	Internal wall construction	147
10.16	Layered hexagonal grid of planks	118	12.10	Typical floor plan	149
10.17	Analysis model	119	12.11	Isometric of structural system	150
10.18	Structure at funnel support	120	12.12	Plated junction interior	150
10.19	Gridshell under construction	121	12.13	(a) Internal CLT partitions, (b) internal partitions with plasterboard lining	151
11.1	Structural solution for the Pods	123	12.14	Apartment with balcony	151
11.2	Interior looking up at dome structure and steel hub joints	123	13.1	Looking down on the cloisters of Norwich Cathedral and the Refectory	153
11.3	The Pods sports centre at Scunthorpe in its parkland setting	124	13.2	View down first floor refectory	153
11.4	Interior of the Forum beneath the timber grid infilling the space between buildings	125	13.3	Looking up to the oak cover strip to the steel I beam roof rafters	154
			13.4	Looking along the front elevation of the glulam frame	155
			13.5	Plan of the triangular site in North London	156
			13.6	Elevation to glulam frame	158
			13.7	Looking along the structure of ground floor walkway	158
			13.8	Close up of beam to column joint showing oval glulam spruce dowel	159
			13.9	Tamedia site plan	160

13.10	Part fourth floor plan and section 2 of the offices, showing timber frame	160	15.5	18th-century roof trusses	186
13.11	Frame under construction	161	15.6	Wedged tenon and wedged dovetail tenon	186
13.12	Detail of construction of intermediate space overlooking city	161	15.7	Compound cross sections of the Shuepbach Bridge	187
14.1	View of sinusoidal roof to Cork Airport	162	15.8	Schaffhausen Bridge	189
14.2	Circular column, raking steel tubes and sinusoidal glulam beams	163	15.9	Relative design load capacity for nails, screws and bolts	190
14.3	Structural elevation of composite timber and steel beam	163	15.10a	Toothed connector	191
14.4	Derix connector in place	163	15.10b	Split ring connector	192
14.5	Interior view of roof over landside accommodation	164	15.10c	Shear plate connector	192
14.6	Looking up the glazed timber geodesic shell at Portcullis House	165	15.11	The Cowley Connector with bleed hole for glue and threaded rod into cylindrical connector	193
14.7	Close up of nodal connection	165	15.12	Cylindrical node connecting members in the shell for the Forum at Exeter	193
14.8	Long view of the visitor centre in Alnwick Park	166	15.13	Effective transfer of loads by multiple screw-bolted connections and shear planes of inset steel plates	194
14.9	View of the interior of the visitor centre showing larch and flitch plate columns and double larch members	167	15.14	Experimental multi-bolt cast iron connecting forks for glulam birch members for a space frame	195
14.10	Garden entrance to the John Hope Building with overhanging roof of CLT on diagonal glulam beams	168	16.1	Pinned base to arch with raking struts at the Winter Garden, Sheffield	196
14.11	Underside of CLT first floor on composite four angled steel columns, double glulam beams with the nearest with bolted steel flitch for the larger span	169	16.2	Bolted connections and central steel flitch plate in larch column heads at LLTNP HQ	197
14.12	Four angled steel columns and connecting plates for tapered roof beams	169	16.3	Cuphead nuts, washers on 20 mm diameter stainless steel studs with 67 mm diameter shear plate connectors set out diagonally for flitch plates for tie rods at corbel support for the roof truss at Emmanuel College	198
14.13	First floor cafeteria in the finished building	170	16.4a	Indicative separation distances for small fasteners	199
14.14	Spiral plywood stair and interior at ground level	171	16.4b	Nomograph for load interpolation between capacities parallel (P_0) and perpendicular to the grain (Q_{90}) with angle α to the grain (after the Hankinson formula)	199
14.15	Exterior of Hereford Arts Centre	172	16.5	Graphite Apartments – CLT panel plan	200
14.16	Preferred structural arrangement	173	16.6	Connections in CLT panel construction: (a) floor lap joint, (b) wall–floor joint	201
14.17	Interior space showing structure as part of the exhibition space	174	16.7	Roof plan of Police Training Academy, Cwmbran (1970)	202
14.18	The Oval at night	176	16.8a	Section through assembly hall roof	203
14.19	Composite glulam arches support wave form panels over the skating oval	177	16.8b	Section through dining hall roof	203
14.20	Cross section through arch	177	16.9	15 m cruck truss over swimming pool at PTA Cwmbran	205
14.21	Isometric of wood wave panel	178	16.10	15 m dining hall truss at Police Training Academy	206
14.22	Looking along wave panel during construction	179	16.11	Dining hall bolted connections with steel gusset plates for main truss	207
15.1	Exterior of the original 1954 hand hewn log home of the McMichaels at Kleinberg	183	16.12	Roof and floor beam connections to column at the John Hope Gateway, Edinburgh	208
15.2	Interior of the later Gallery 8 with paintings hung on the inside face of the logwood construction with internal masonry walls in the background (2010)	184			
15.3	Traditional joints in historical frame	185			
15.4	Pegged floor frames at the Globe	185			

Tables

1.1	Relative characteristics of softwoods	5	10.1	Case study: Centre Pompidou – Metz	117
1.2	Durability classifications	7	12.1	Case study: Dartington Primary School	141
1.3	Relative physical characteristics of hardwoods	10	12.2	Case study: The Open Academy, Norwich	144
2.1	Typical boundaries for a life cycle analysis	14	12.3	Case study: Graphite Apartments, Murray Grove, London	149
5.1	The Big Shed	47	13.1	Case Study: Mossbourne Community Academy, Hackney	156
6.1	Case study: Burr and Burton Academy	63	13.2	Case study: Tamedia New Office Building, Zurich	159
8.1	Case study: The Colyer-Fergusson Performing Arts Centre, Sevenoaks, Kent, UK	86	14.1	Case study: Hereford College Arts Space	172
8.2	Case study: Chedworth Roman Villa, Gloucestershire, UK	88	14.2	Case study: The Skating Oval, Richmond, British Columbia	175
9.1	Case study: Bodegas Protos	102			

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The designs of Frei Otto are also discussed in this book and I owe him and his colleagues at the Atelier Warmbronn, in particular Ingrid Otto and Christine Kanstinger, a great deal. This inspiration has I hope led to subsequent projects with a good level of innovation and elegance. The same can be said of those many architects with whom I have worked closely over the years – in particular Richard Burton, William Moorwood and Annie Crosbie; the late Sir Colin Stansfield Smith, Bob Wallbridge and Tina Bird; Ted Cullinan, Sasha Bhavan, Robin Nicholson and Roddy Langmuir; Sir Michael Hopkins, Jim Greaves and Mike Taylor; Shigeru Ban and Glenn Howells, and many others.

To be successful in this quest requires the skills, courage and confidence of colleagues as well as

the trust of the client. Among those clients to whom I owe a particular debt for their inspiration, I must mention the furniture designer John Makepeace, those at the Hampshire County Architects, as well as the late Christopher Zeuner at the Weald and Downland Museum, Philip Everett at Savill Gardens and Andrew Holloway of Green Oak Construction.

Within Buro Happold, I have great admiration for my fellow engineers with whom I worked on some of the projects in this book – among my younger partners Dr Michael Cook, Eddie Pugh, Angus Palmer and Paul Rogers, and also while at Buro Happold, Richard Harris, now Professor of Timber Engineering at Bath University, Tim Mander, Geoffrey Werran, Olly Kelly, James Rowe, Neil Dely, Cristobal Correa, Ian Hargreaves, Ken Jones and Jonathan Rognon, Bethan Davies, Neil Harvey, and others too many to mention. Thanks also to Tony Waters and Phil Lawrence for their help in preparing some of the illustrations in the book.

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Michael Dickson
February 2014

Foreword

Sustainable timber design

As a consequence of a growing emphasis on sustainability, timber and wood products are increasingly being used in the design, engineering, construction and fitting out of a wide array of building types. In many countries around the world, as in Scandinavia and the USA, the use of timber in buildings has always been preferred, whereas here in the UK there is still a need for engineers, architects, clients, constructors and others to become more familiar with and confident in the use of timber and wood products in buildings.

Sustainable Timber Design addresses this need. It highlights the up to date information required to use timber in today's and tomorrow's built environment. It enables, provokes and inspires innovative thinking, by bringing together the disparate, yet related factors required for sustainable buildings. These include more traditional elements of wood properties, engineering, performance in fire and preservation, along with the sustainable sourcing, environmental impacts, innovative jointing, modified wood products and innovative design and engineering approaches needed in the built environment of today and the future. This is the new system of factors that must be considered in designing

and engineering sustainable buildings. It is new knowledge relevant both to those working in countries that already have strong cultures and experience of using timber, along with those with more limited experience. So, this book is valuable to all.

Sustainable Timber Design brings its extensive information together in an excellent style. It is a good read – a flowing text that is accessible and absorbing. It brings theory and principles to life through a superb array of case studies, beautifully illustrated, which show how to use timber and wood products in practice. It inspires innovative thinking.

Sustainable Timber Design will sit comfortably on a coffee table or an engineer's and designer's bookshelf, in a university or local authority library, in the reception area or offices of any company working within the wood sector, or in any organisation seeking to apply innovative and sustainable thinking in the built environment.

As I have done, I am sure you will enjoy and derive benefit from *Sustainable Timber Design*.

Dr Peter Bonfield, OBE, FREng, FICE, FIMMM, FCIQB, FIWSc, Chief Executive, BRE Group

Preface

In these early decades of the 21st century, timber is enjoying a renaissance as a mainstream structural material. Projects that once would have been executed in steel or reinforced concrete are now featuring timber in their primary load bearing structures. Buildings constructed largely of high quality timber and timber products are appearing regularly on short lists for major architectural and engineering awards. Designers even now are planning timber residential towers higher than ever believed possible just a few years ago. There has been a massive sea change in the construction industry's attitudes to timber structures, driven largely by one factor – sustainability.

Every human being on the planet has a vested interest in mitigating the unpredictable effects of the climate changes that are now inevitable. Construction in all its aspects, from raw material extraction and processing to erection, maintenance and demolition, is a major consumer of fossil fuels and hence a significant contributor to the greenhouse effect. Anything that can be done to reduce this impact on the environment should be seriously considered by clients, specifiers, designers and contractors alike. And one of the most effective options is to switch to timber.

Unfortunately, this option is still not as straightforward as it should be, due largely to the imbalance between the knowledge and understanding of timber design and engineering techniques and the much more widespread familiarity with traditional architectural and structural materials. This book aims to help redress this balance by presenting the principles of design necessary to achieve elegant and user-friendly buildings in structural timber that are practical and economic as well as thoroughly sustainable.

Such efforts to improve the awareness of timber's potential are supported by the increasing availability of advanced computer aided design and 3D virtual prototyping techniques. New design codes have been introduced, improved timber products based on advanced modern adhesive technology are coming onto the market. Timber's traditional weaknesses – inflammability, variability, susceptibility to insects

and fungi – can now be largely nullified by informed design and specification or by using thermal or chemical processing to transform the basic material into something more stable and durable.

Additional support comes from an increasingly sophisticated and integrated timber supply industry. In Europe and North America there have been significant improvements in the efficiency and sustainability of forestry, with 'weed' trees and thinnings no longer discarded or burnt but now seen as potentially valuable raw materials for engineered timbers such as oriented strand board (OSB) and laminated veneer lumber (LVL). High quality timber products ranging from floors through doors and windows to massive long span structural frames are now widely available, all contributing to lower carbon footprints.

At the same time there has been a return to the origins of timber construction, albeit with the benefits of computer aided design and modern adhesives and machine tools. Green oak construction is flourishing, for homes as much as for theatres and galleries, with traditional craftsmen working hand in hand with 21st-century designers. Roundwood, in the form of debarked softwood thinnings, is perhaps the earliest structural material, yet it still has a worthy place in the modern design palette, as several landmark projects can testify.

To achieve elegant, efficient and robust structures in all forms of timber it is advisable to remember the words of 20th-century US architectural icon Frank Lloyd Wright. In 1928 he wrote 'To use wood with intelligence, we must first understand wood.'^{*} In other words, a thorough understanding of the consequences of the natural variation in timber grain, density and moisture content is essential if a successful, durable and visually pleasing outcome is to be achieved. This is particularly relevant to the design of the connections between timber components.

It has been said that a timber structure in reality is an array of connection devices separated by timber elements. Recent research has developed a vast range of connections, many involving groups of small diameter

metal bolts or self tapping screws acting in conjunction with separate metal plates. Using such techniques, complex three-dimensional structures can be assembled with confidence and without disfiguring the aesthetic qualities that make timber buildings so appealing to their users and occupants.

Sustainability is not just about reducing the carbon footprint of our current construction activities. As the world's population continues to grow, the challenge is to provide decent yet sustainable habitation for all these new members of the human race. Advanced timber design and construction techniques can be at least part of the answer, and a significant part as

well. Sourcing timber from sustainably managed and stewarded forests not only allows societies across the world access to plentiful supplies of renewable and versatile construction materials, it also encourages the conservation of the forests, with long term benefits to local populations both human and animal. In view of all these benefits, this book will conclude that structural timber should be the very first option considered by any designer seeking to create a truly sustainable building.

* In the Cause of Architecture: Wood, by Frank Lloyd Wright, *Architectural Record*, May 1928 page nos

Introduction

Given a free choice, human beings prefer to live and work in buildings that feature visible and accessible timber. Timber's sensual qualities: its distinctive colours, surface textures and aromas, speak to something fundamental in the human psyche. Metal and concrete fail to resonate in the same way; only stone has something of the same appeal. This preference may be hardwired into our genes, the legacy of countless generations over the millennia who have turned to timber for shelter and warmth, and who learned how to recognise and exploit the diversity of physical and chemical properties available in the world's forests. Despite this instinct, however, timber as a primary structural material went into decline in the late 19th century, swamped by the new technologies of iron, steel and reinforced concrete with their more easily predictable properties and inherent incombustibility. Nevertheless, the basic human desire to live surrounded by timber never went away, and exposed oak beams and stripped pine floors continued to be highly desirable features in domestic housing.

As this book will show, this preference is now finding fresh expression. There is an exciting revival of large scale timber construction throughout the world. Many fine architectural designs are now to be seen across Europe, in North America, in Australasia and elsewhere. Timber is moving out of the domestic housing market and is now a realistic alternative to steel and concrete in large scale roof and frame structures, as the examples and case studies that follow will demonstrate. Timber's versatility and resilience as a structural material can now be fully exploited by modern design techniques. Indeed, there is an increasing body of expertise available to ensure successful production and fabrication of timber elements. Educational and perceptual barriers are falling slowly so that architects and engineers are becoming more aware of the benefits timber can offer. And as clients and occupants become increasingly familiar with the realities of timber buildings, demand for them can only increase.

This revival has solid foundations. By the turn of the 21st century, even newer technologies were

transforming the structural landscape. Advanced adhesives, preservatives and fire protection were making it possible to manufacture 'engineered timber' products such as glue-laminated (glulam) beams and arches, laminated veneer lumber and I-joists. More on engineered timber can be found in Chapter 4, but the key factor is that such products are considerably more predictable and stable in their properties than traditional sawn sections, and so structures can be designed and analysed with a much higher degree of confidence for resilient, predictable performance and enduring elegance.



Figure I.1 Once a Tudor barn, the St Barnabas Centre in Thorley, Hertfordshire, UK, is now a very popular venue for church services, conferences and community events.

Credit: Dave Parker.



Figure I.2 Students at Hereford College of Arts in the west of England also enjoy the unique ambience of a timber building.
Credit: Lance McNulty.

Despite this, timber still struggles to gain recognition as a viable structural option. Two other factors hold it back. Engineered timber structures are still perceived as more expensive than conventional designs. Also there is still the lingering feeling that timber construction is a craft-based process. This is a perception that is now being rectified by improved familiarisation and training in timber design for engineers and architects and better organised support from industry.

That there is still a place for the craftsman is perhaps best shown by the revival of green oak construction, most notably in the recreation of London's Globe Theatre, but also in many new private homes and other buildings. These still depend mainly on the traditional mortise and tenon joint and its relatives, but set within the constraints of modern standards of performance. However attractive the final results may be, such projects are not yet seen as in the mainstream. A better example are the parabolic arches glue laminated from Polish larch that frame the stepping

glazed enclosure of the Winter Garden in the centre of Sheffield, England – ironically, a city renowned for high quality steel production.

Such large scale timber structures are becoming increasingly common across the world, encompassing schools, arenas, swimming pools, theatres, air terminals and many others. Originally, the driver was almost entirely architectural: now another factor has entered the equation, one that makes the structural timber option even more attractive. As the world warms, the climate changes unpredictably and human populations continue to grow, the sustainability of each and every human activity comes under scrutiny. Looked at from that point of view, timber's potential as a realistic alternative to steel and concrete is undeniable.

To fully appreciate and take advantage of timber's inherent sustainability, it is necessary to begin by considering the role woodland plays – or should play – in the global environment. Growing trees extract carbon from the atmosphere and lock it up in their structure,



Figure I.3 Interior, Winter Garden, Sheffield
Credit: Adam Wilson.