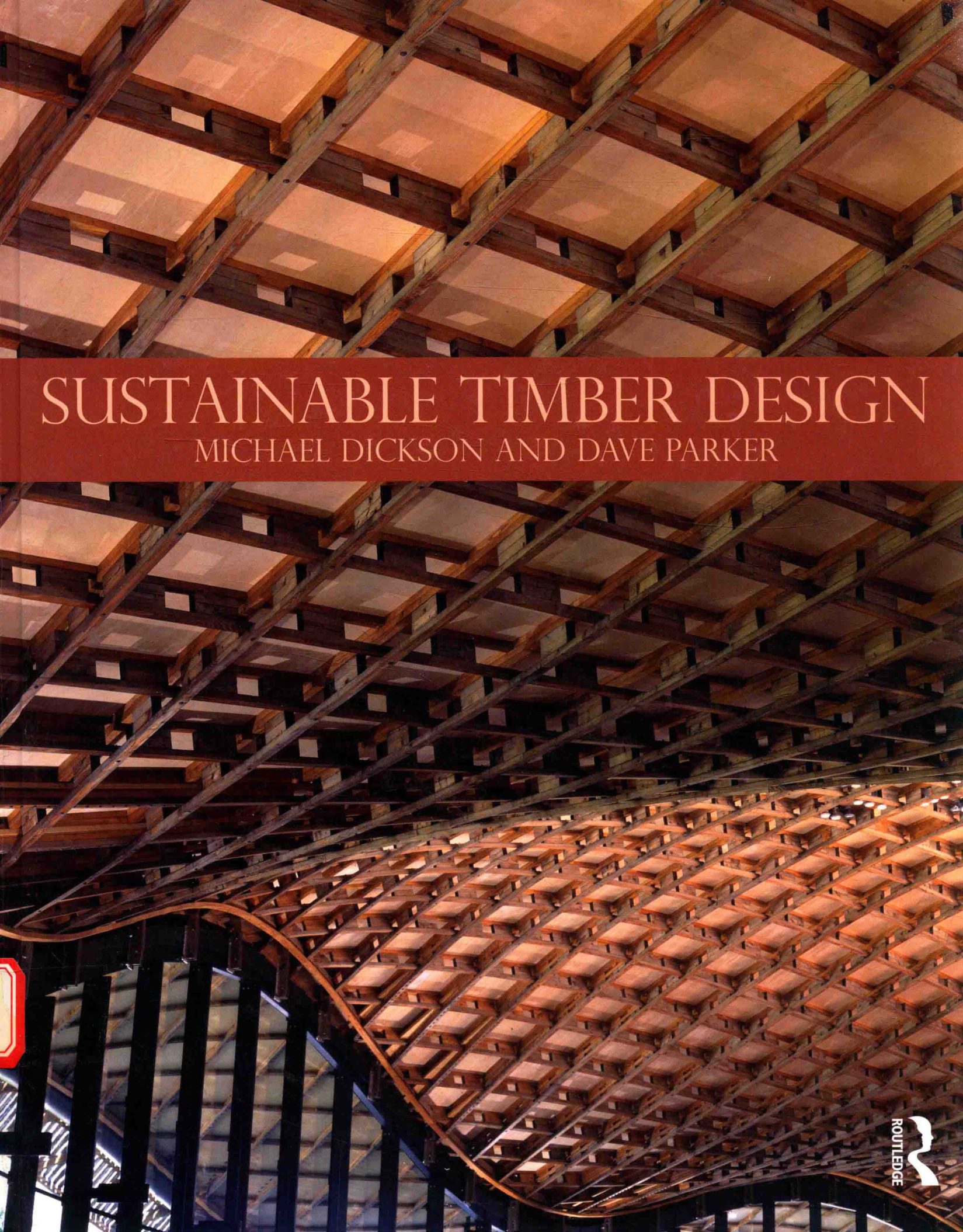

SUSTAINABLE TIMBER DESIGN

MICHAEL DICKSON AND DAVE PARKER

ROUTLEDGE

Sustainable Timber Design

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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.

Dave Parker, B.Sc., C.Eng., F.I.C.E., F.R.S.A., F.I.Q.A., was Technical Editor of *New Civil Engineer* magazine for 12 years before leaving in May 2006 to become a freelance author and journalist. He is a former Visiting Professor of Civil Engineering at Queen's University Belfast, and his interests include renewable energy and the history of construction. In 2014 NCE asked him to return as technical editor emeritus.

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

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Acknowledgements

This book discusses the design and construction of many projects arising from the skills and work of many contributors – architectural friends, engineering colleagues and of course clients and constructors. In particular I must acknowledge with great thanks the contributions made by those engineers alongside of whom I have had the privilege to work over many years on a wide range of timber and other structures and from whom I have learned a great deal. Specifically I learned much from the late Sir Ted Happold and my partners Ian Liddell and Terry Ealey, going back to the construction of the Mannheim Gridshell and beyond when at Ove Arup and continuing through the thirty five or so years together at Buro Happold, and, while at Arup, Malcolm Millais.

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.

A sincere thank you to my personal assistants; first, over some fifteen years, Barbara Towers, and, more recently, Lorraine Milne – A great thank you also to the contributors, credited within the text, whose projects have we hope broadened the appeal of this book to future designers. Finally I have greatly enjoyed being a co-author with Dave Parker on this endeavour.

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, FCIOB, 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.

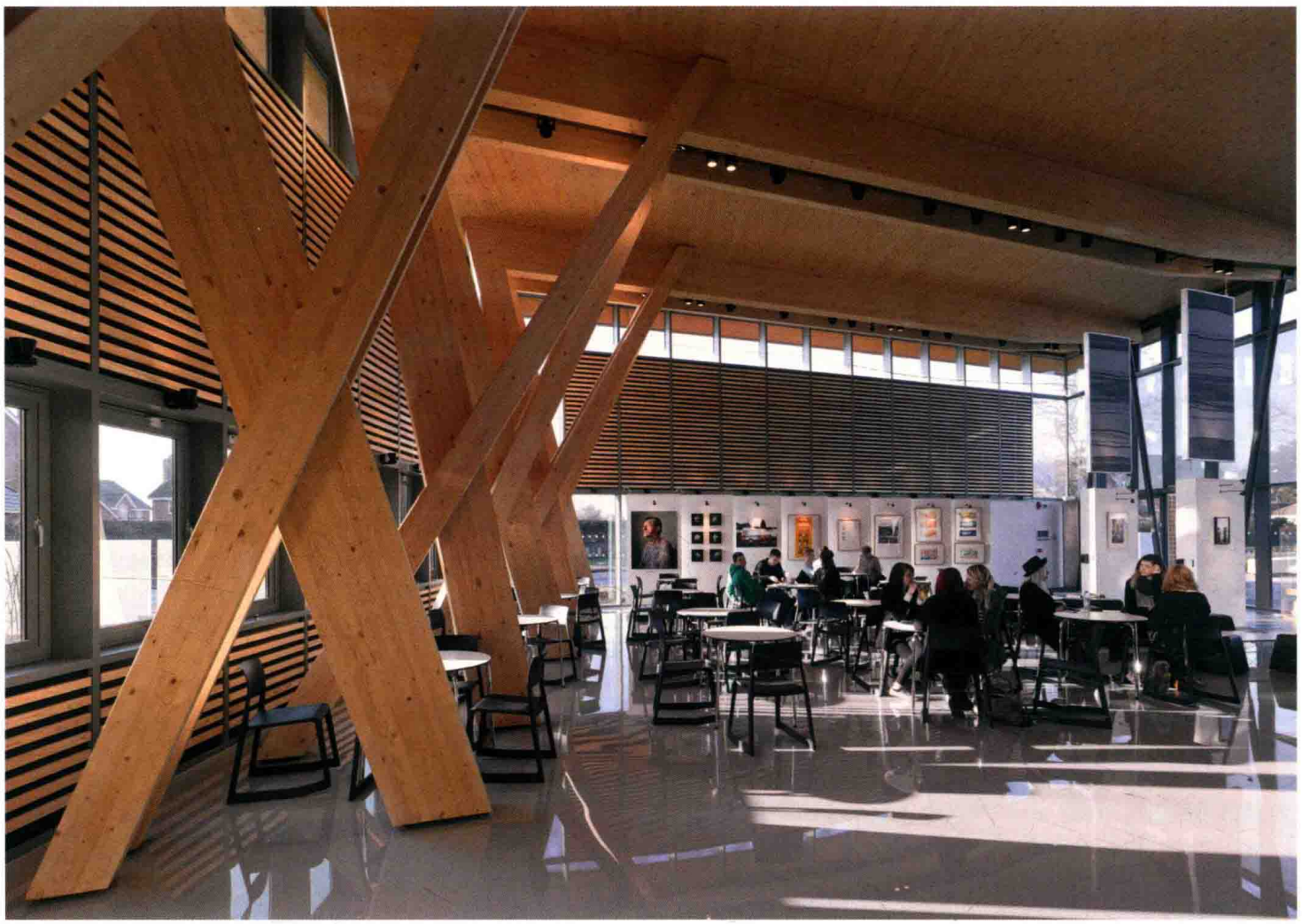

Figure I.2 Students at Hereford College of Arts in the west of England also enjoy the unique ambience of a timber building.
Credit: Lance McNulty.

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,

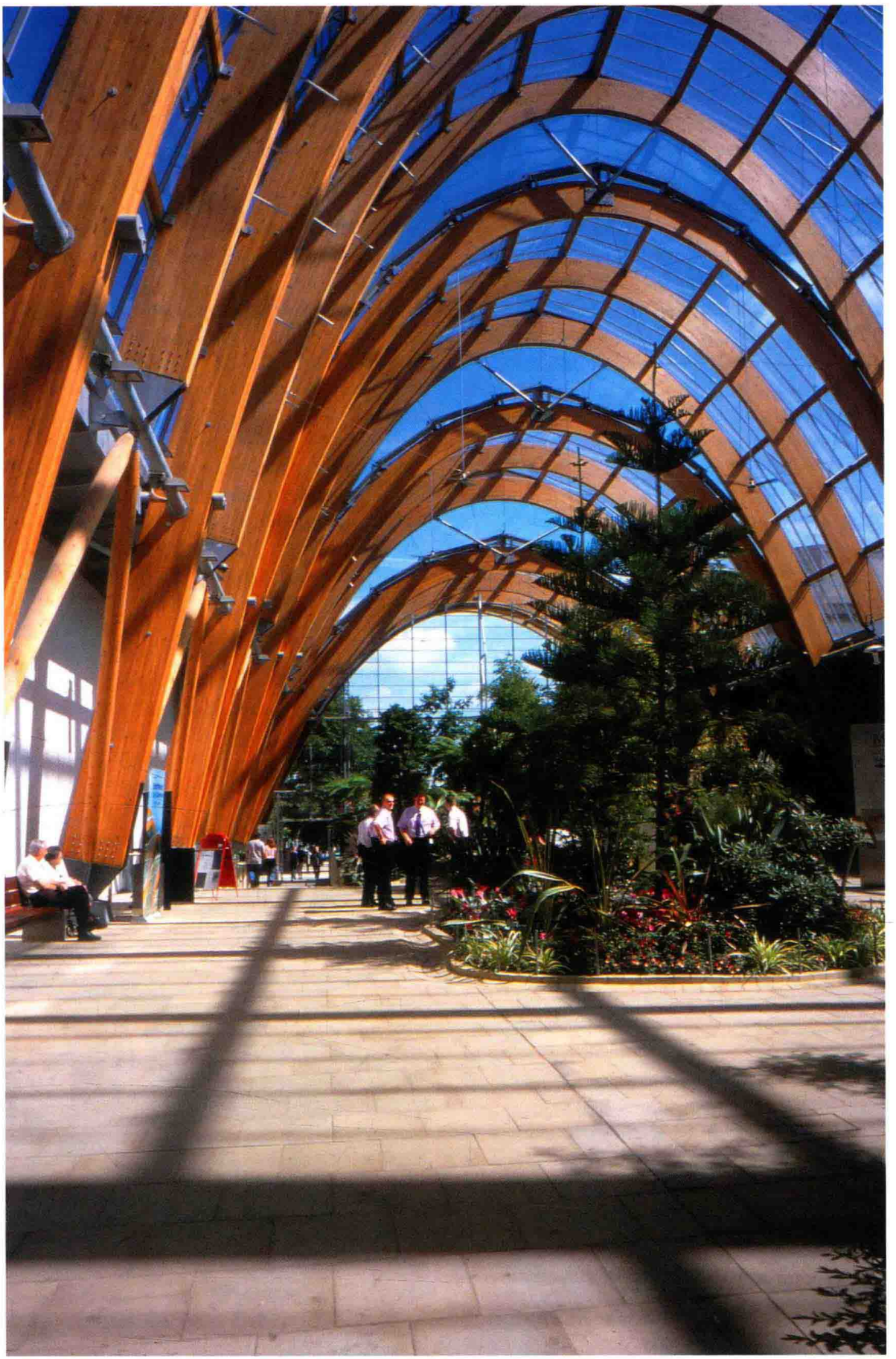

Figure I.3 Interior, Winter Garden, Sheffield
Credit: Adam Wilson.