Designing with timber

ARUP

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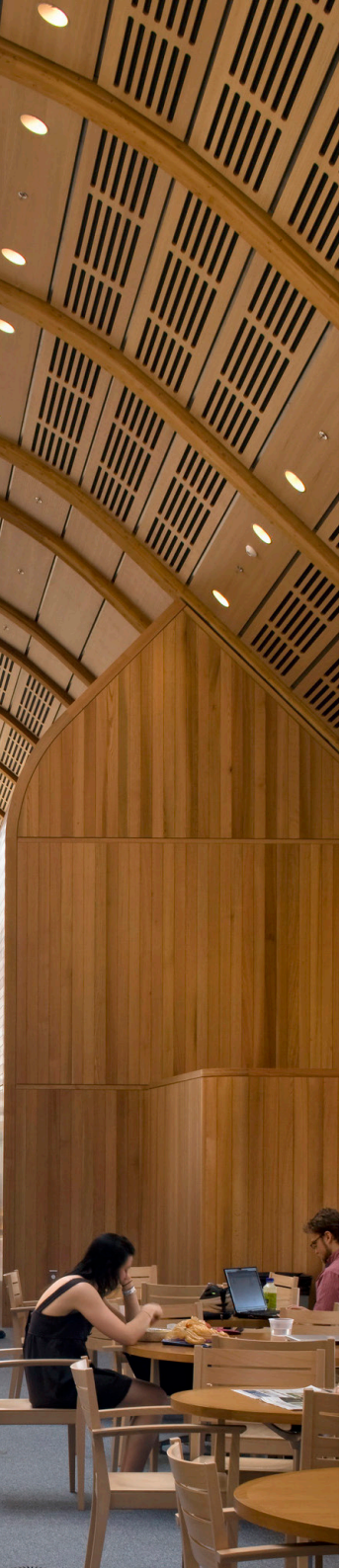

Timber construction is gaining popularity for a wide range of building types and sizes. As a natural cellular material, it is strong and light, making it easy to transport and erect. It can also be machined to very high tolerances, making it ideal for prefabrication. Recent advances in computer controlled manufacturing and stronger and larger engineered wood products like cross laminated timber (CLT), mean that timber construction can now achieve shorter programme times often at lower overall cost, while providing safer, cleaner and quieter environments on site. It is also our only renewable construction material and it locks away carbon dioxide for the life of the building.

To realise all of these benefits we need to take full advantage of timber's unique properties from the very start of a project. We also need to understand and anticipate its performance in fire, its vibration and acoustic properties, its contribution to envelope behaviour and energy use, and its integration with building services systems. This is where Arup's multidisciplinary approach can offer a real advantage to help deliver efficient and reliable overall designs.

We are excited by the opportunities that timber can offer and believe that our wide range of skills and experience can help create timber structures that are beautiful, sustainable and affordable at the same time.

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Metropol Parasol, Spain © Arup

Independent advice

Arup is an independent firm, with no ties to specific manufacturers or suppliers. Our understanding of the full supply chain for timber buildings helps us guide clients through the important strategic choices.

We have designed many ground-breaking timber structures. The Mannheim Multihalle, built in 1974, remains the largest timber gridshell ever built. The Metropol Parasol in Seville is one of the largest timber structures in the world and the Sky Believe in Better Building is the UK's first entirely timber open plan four-storey office.

All materials have advantages that make them best suited for particular applications. Wood is a reliable and proven construction material, whether used alone or in combination with steel and concrete. We want to help our clients make the best choice for their particular project.

The Oita Prefectural Art Museum, Japan © Arup

Our multidisciplinary approach

To ensure cost-effective use of timber, it must be designed-in from the start of the project. We have all of the necessary specialists in-house.

Our **Structural Engineers** and **Materials Scientists** have a long track record working with large timber structures of all types, addressing safety, strength, stiffness, prefabrication and constructability, as well as species selection, durability, weathering, and issues of sustainable sourcing and carbon sequestration.

Arup's **Fire Engineers** work to ensure that both life safety and property protection expectations are met. We are collaborating with fire research institutes across the world to improve our understanding of how the new generation of multi-storey timber buildings will behave in a real fire.

Having tested and back-analysed the behaviour of many real timber buildings, our **Vibration** and **Acoustics** specialists can help us predict how new designs will perform. While the lightweight nature of wood is a real advantage for prefabrication and speed of construction, care is needed to ensure that floors are not too lively and provide adequate insulation against noise and impact.

Arup's **Building Physics** specialists help ensure the building envelope will perform as required, considering occupant comfort, energy targets, and weather effects, including condensation risk. Our **Building Services Engineers** are well experienced at optimizing systems to meet performance requirements and at configuring layouts to achieve the best fit with other systems such as structure and façade.

Our S**tructural, Building Services** and **Façade Engineers** are now taking full advantage of Building Information Modeling (BIM) to ensure that all these aspects are fully coordinated as the design develops. This is of particular value for timber, where there is often a higher degree of prefabrication, hence greater reliance on 'virtual testing' of layout and geometry. We have been party to many 'paperless' projects where documentation passes direct from designers' models to fabricators' computer fabrication (CNC) systems. No construction material is better suited to taking advantage of such BIM/CNC efficiencies than timber.

Finally, our **Sustainability Consultants** can help maximise the overall sustainability of the project, from material sourcing, fabrication and construction, through operation and maintenance, to end of life.

Minimising costs

We are collaborating with manufacturers and suppliers to produce designs that are safe, durable and cost-effective. Our knowledge and experience of the latest design ideas, materials and fabrication techniques is shared through our global network of timber designers. Every project enables us to deepen our global knowledge and to continually improve our designs. We believe there are three key ways to ensure a cost-effective timber structure.

Minimise the cost of the overall building, not just the structure. Do not just think of wood as a substitute for another construction material. Develop efficient integrated designs that address fire, acoustics, vibration and ease of services integration.

Think wood from the start. Base the building grid around standard section or panel sizes to minimise wastage. Every material has different characteristics so the most efficient member sizes, spans and layouts in timber will differ from other materials.

Design for ease of fabrication and erection. The cost of timber structures is dominated by the connections. Consider larger pieces to reduce the number of connections and to speed up erection. In timber, minimum material is not the same as minimum overall cost.

Image | Netball Central Headquarters, Australia © Arup

Creating new possibilities in Schools, Offices and Healthcare

All materials have their advantages. While wood is a popular choice for residential buildings and long span roofs, our multidisciplinary approach and understanding of the material is helping to create new possibilities with new building types.

For example, wood has real potential to help reduce cost and construction time in the commercial office sector. By combining a glued laminated timber frame with timber slabs, we can now create completely dry lightweight prefabricated buildings that lend themselves to safe rapid erection. If required, the wood can be left visually exposed, saving on the cost and time of installing finishes and at the same time adding to the visual appeal. Fit out is also quicker because it is easy to screw into the wood. We believe that Sky's four-storey Believe in Better Building will be the first of many of its type across the world.

There is growing evidence of both perceived and real health benefits linked to wooden structures and this is one reason we are now starting to look at applications in the healthcare sector. In the USA we are also looking at the potential for larger timber structures in seismic regions – because they are lightweight they experience less load in an earthquake. Swimming pools, sports halls and gyms also work well in timber. Their roof solutions can be attractive and durable, and advanced dynamic modeling techniques mean that timber floor vibration need not be an issue if it is properly considered from the outset.

Image | Sky Believe in Better Building, UK © Arup

Roofs, Exhibition Structures and Experimental Structures

Alongside the growing multi-storey sector, wood will continue to be a compelling choice for exposed architectural roofs. Its beauty and ease of machining lends itself to complex geometries and unique architectural structures. Every element of the Timber Wave was different, thanks to early adoption of BIM/CNC technology. This could not have been economically achieved in any other material.

Modern software makes three dimensional forms like the Timber Wave increasingly simple to model. Arup is well known for working with architects to explore what can be achieved with different materials, without compromising buildability.

Our teams are experienced in a variety of software for structural analysis and 3D modelling, making the exchange and coordination of designs easier. The Alvaro Siza Serpentine Pavilion was designed and constructed in just 16 weeks thanks to a seamless interface between designers and fabricator.

The Endless Stair was the first project to use hardwood cross laminated timber. The delivery of the project required significant understanding of gluing and manufacturing methods and testing of the new material. New modelling methods were also developed to deal with the geometrical complexity and non-linear behaviour. All of these issues have relevance for larger projects.

Image | Endless Stair at Tate Modern, UK

Research

We are working with the timber industry in Europe, the USA and Australasia to develop new codes and standard specifications for timber, helping to make it a standard construction material, to reduce building costs.

Arup believes that investment in research and collaboration with academic and industry partners is crucial to developing our understanding of design and fabrication. We have strong links with many of the world's leading professional and academic bodies specialising in timber.

The LifeCycle Tower project was developed in partnership with CREE and Graz University in Austria, and required an understanding of composite behaviour between timber and concrete as well as practical ways of connecting the two materials.

Arup were also consultants to the Structural Timber Innovation Company (STIC), a research consortium comprising three universities in Australia and New Zealand. The research output from this has been applied to the Netball Central HQ in Sydney. In the UK, we have close links to the fire engineering research team at the University of Edinburgh, where world-class research is being carried out into the behavior of timber buildings in fire.

In the USA, Arup is a research team member in a major National Science Foundation (NSF) funded research programme at Washington State University to study the performance of various CLT-based shear wall systems under seismic loading. We are also working with key industry suppliers of both hardwoods and softwoods to help introduce new materials into the marketplace.

Image | LifeCycle Tower, Austria © Norman A. Müller

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