Timber Structures

Tales of Engineering, Architecture, and Carpentry

Jim DeStefano, P.E., AIA, F.SEI

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Drawings by Ken Flemming

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Cover photo: Thompson Exhibition Building, Mystic Seaport
Photo credit – Jeff Goldberg / Esto

Dedication

I am proud to dedicate this book to my loyal and talented partners and colleagues at DeStefano & Chamberlain, Inc. who have tolerated, indulged, and embraced my passion for designing way cool timber structures.

The DeStefano & Chamberlain, Inc. team – Kevin, Rick, Ken, Priscilla, and Joe

Preface

Timber sunrise; *photo credit – New Energy Works*

There is something inherently spectacular about the look, feel, and smell of a timber structure. It is almost primal. When we walk into a timber structure, it captures us. We instinctively look up as our eye is drawn to the timbers in a way that steel and concrete structures will never experience. Perhaps it is the warmth of the wood or maybe it just reminds us of stately timber buildings that have sheltered and nurtured us for thousands of years.

Timber is a remarkably versatile and sustainable building material. Whether you are building a home, a barn, a church, or a school, there is a timber structure that is right for you. Timber is the material of choice when architectural drama is the objective and a more mundane structure just will not do.

Over the years there have been many popular books written about timber framing. Some give step-by-step instructions on how to build your own timber frame house or shed. But most people are as likely to build their own house as they are to build their own car in their garage. Other books are destined for the coffee table and are filled with marvelous photos of timber homes or barns – what is referred to as "timber porn" in the publishing world. This book is intended to be neither of those (although I might have slipped in a little bit of timber porn, I just couldn't help myself). This is my story from over 40 years of designing, engineering, restoring, and occasionally building timber structures of all shapes and sizes.

Since writing my first book, ***Antique New England Homes & Barns***, which was published in 2017, it has become evident that the age of print books is rapidly drawing to a close. Ever since Gutenberg invented his press with movable type in 1439, people have enjoyed and been enriched by reading print books. But all that is changing. Soon, print books will become quaint curiosities, like vinyl LPs, prized only by nostalgic collectors. Accordingly, ***Timber Structures*** is presented in a digital format for your reading pleasure.

Jim DeStefano, P.E., AIA, F.SEI
Fairfield, Connecticut

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Introduction

Structural Form and Architecture

I came of age during the era of modern architecture. That was an exciting time for architects and for structural engineers. The mantra of the modern movement was "*Form Follows Function*." Architects had cast off the shackles of traditional architecture and were now free to innovate with new architectural forms. The only rule was that the form must respond to the building's functional need. A popular manifestation of this doctrine was the architectural expression of the building's structural framework – exposing and celebrating the bones of the structure.

Some of the finest examples of modern architecture were the product of a design collaboration between a visionary architect and a creative structural engineer. There were a few rare individuals who wore both hats – serving both as architect and engineer. The individual who inspired me most was Pier Luigi Nervi (1891-1979). I first became aware of Nervi's work in 1976, when I was a graduate student at Cal Berkeley. At the time, a church was being built in San Francisco with a roof structure that Nervi had designed. It would be his last work before he died. I studied his work and couldn't get enough of it. The artistry of Nervi's designs blew me away.

Aircraft Hangar in Orvieto, Italy designed by Nervi, circa 1936

As a young engineering student, I had dreams and aspirations of a long career designing cool looking structures like those that Nevi had designed. Then, just about the time that I graduated in 1977 and started practicing, a tragic thing happened to the world of architecture – they called it Post-Modernism.

Post-Modern architecture changed everything. It seemed as if practically overnight, all the rules had changed. Architecturally exposed structures were no longer in vogue. Form follows function was discarded without a tear. Architects no longer collaborated with engineers on design. The structure was now to be concealed behind the veil of architectural ornamentation. The structural engineer's job was to make the architect's vision work – whatever it took. The structural engineer was to be seen but not heard and his structures were not to be seen at all. This presented a rather disturbing state of affairs.

Naked timbers against the sky

But throughout this dark period in architecture, there was one faint glimmering light that I was drawn to, like a moth to a flame – timber structures. It was still okay to expose a timber roof structure of a church, gymnasium, or library. In the day, these were mostly dull, uninspired, glued-laminated (glulam) timber structures, but that too would soon change as the ancient craft of timber framing would rise from the ashes and experience a revival over the next decade.

Since then, the dark age of Post-Modern architecture has faded as architecture has emerged into a more enlightened world. Modern architecture is back, but in a weird retro way. Mid-century modern architecture now has a strange nostalgic reverence. Mass timber structures are now fashionable for buildings of all shapes and sizes, even skyscrapers. Timber structures are finally back on top and it has been a wild ride. So, fasten your seatbelts and let me take you on the journey.

Chapter 1
A Short History of Timber Structures

Timber structures are not a new thing. We have been building them for over 4,000 years. From the time that Neolithic man and women first learned to fashion sharp tools from bronze, they were cutting mortise and tenon joints in timbers to join them together. These early prehistoric timber structures were undoubtably crude huts and hovels that were not much to look at. The fact that none of the early prehistoric timber structures have survived is probably not such a bad thing.

We tend to think of ancient Rome as being built of marble, but it was actually a timber city with a small handful of stone public buildings. The Romans were exceptional builders who perfected the technology of building timber structures. They refined the crude craft of carpentry practiced by the Greeks and their predecessors into an efficient structural system with precision joinery.

Leigh Court tithe barn, Worcestershire, circa 1325

It was during the medieval age that the craft and art of building with timber really came into its own in Europe. Trade guilds standardized the technology of carpentry. If you wanted to be a carpenter you had to be in the guild, and if you wanted to stay in the guild, you damn well better adhere to the guild standardized construction methods.

This resulted in regional styles of medieval timber framing with English, French, German, and Dutch buildings each having distinctively different types of timber joinery with distinctively different methods of laying out the joinery. The guilds tended to stifle innovation and the technology of building with timber remained unchanged for nearly five centuries.

While the vast majority of timber structures built in medieval Europe were simple, utilitarian buildings, during that period, the church commissioned magnificent cathedrals and tithe barns with timber roofs where carpenters could prove their devotion to the church by honing their skills and performing their finest work, embellished with decorative carving. Many of these buildings are still standing and are revered as some of the finest and most ornate examples of timber construction ever built, at least until recently.

When European carpenters emigrated to the New World in the 17th century, things started to change. North America became the melting pot of timber technology. There were English carpenters in Massachusetts, Dutch carpenters in the Hudson River valley, German carpenters in Pennsylvania, French carpenters in Quebec, and Swedish log builders in the Delaware River valley. They borrowed techniques from each other and an American style of timber construction soon emerged. Graced with a limitless supply of tall, straight trees, and free from the restrictions imposed by medieval trade guilds, carpenters innovated more efficient techniques. Times were good for American carpenters, that is, until the trees started to run out.

The industrial revolution was not kind to the craft of timber construction. Up until then, buildings were built with the raw materials harvested from the site. Foundations were built of stones cleared from the fields, bricks for the chimney were molded from clay dug from the ground and fired on site, and trees were felled, hewn, and milled for the frame and everything else. The only building materials imported from afar were the hand-forged iron nails and lime for mortar. Everything was shaped and assembled with hand tools right on the building site.

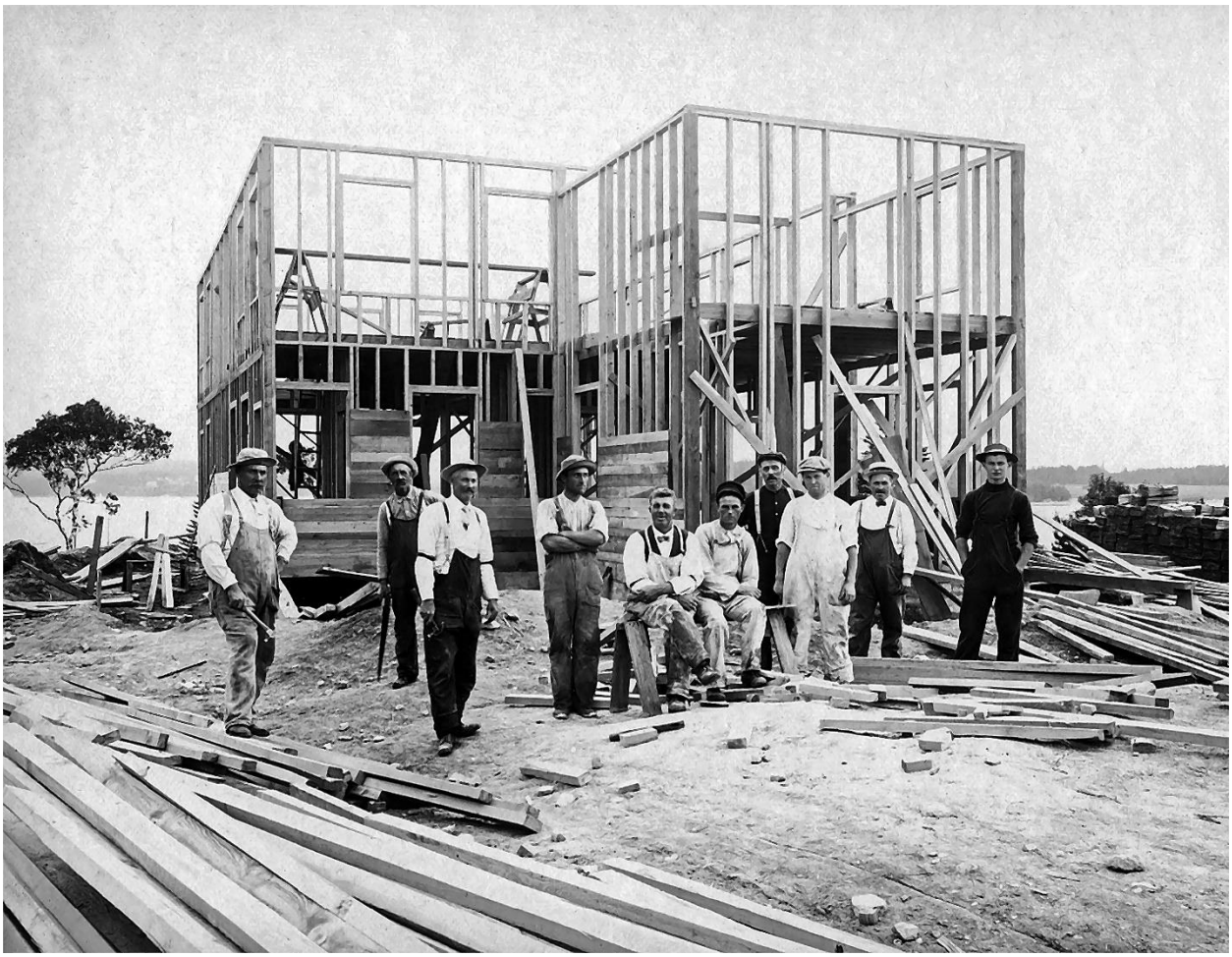
Medieval half-timber structure in Woebley, Herfordshire

First came the Erie Canal and soon the railroads followed. Building materials could now be transported across the land. Timber harvested from the forests of Michigan could be sold in the treeless prairie States where people had been building with mud, straw, and sod.

Then came the circular saw mills. Now trees could be cheaply milled into stacks of uniform dimension 2x4s, 2x6s and 2x8s that the railroads could ship anywhere. Finally, machines were developed that could manufacture inexpensive iron nails – at first, cut nails sheared from iron plates, and later common nails made from wire. The days of timber construction were now numbered.

It started in Chicago – a railroad hub in the middle of a treeless prairie. In 1832, a fellow named George Washington Snow built himself a warehouse there. He built it of wood, but he did not build it of timber. The frame was constructed entirely of small, uniform dimension lumber, spiked together with machine-made iron nails. Nobody had ever seen anything like it before. At first, they called it “Chicago construction.” Later they would refer to it as “balloon framing” because old-time carpenters claimed that it looked so light and flimsy that it would just blow away in the wind like a balloon.

It didn’t take long for balloon framing to catch on everywhere. Buildings could be built cheaper, faster, and with less skilled carpenters. By 1870, timber framing was nearly extinct for house construction. By 1890, the only things being built of timber were mills, churches, and bridges. As the old-time timber carpenters died off, the skills and technology of building with timber died with them. They left behind no how-to books explaining how they constructed the buildings that they built. It would take nearly a century before later generations would rediscover and remaster the craft of building timber structures.



Balloon frame house in Maine, circa 1913

Chapter 2
Traditional Timber Framing

The Timber Revival

If you can remember the 60s, you weren't really there – Wavy Gravy

I grew up in the 1960s and I remember those days as a tumultuous time. It was a time of social change, political upheaval, and conflict. The post-war innocence of the 1950s was replaced with a cynicism and an intolerance for social injustice. We believed that we could actually change the world and make it a better place, if only we were not afraid to stand up and fight for change. We felt more enlightened and perhaps a little more entitled than the generation that came before us.

It was a time of political movements that started with the civil rights movement. I was too young to join the marches in the street, but I did watch them on TV. Then there came the movement to stop the war in Vietnam. As I approached draft age, I took a very personal interest in that movement. Although I

supported the women's liberation movement, at least in theory, I didn't feel a part of it – that one was not my fight. The "alternative building technology" movement emerged in the 1970s. That was my cause and I leaped onto the bus.

The alternative building technology movement was a reaction to the mass-produced, sterile, sheetrock boxes that dominated the post-war suburban building boom. Houses devoid of design or a soul. We knew that we could do better – a home should be more than just a machine for living.

At the time, most homes were energy pigs. Fuel oil was cheap and nobody cared much about energy conservation. The oil embargo and the resulting energy crises of the 1970s changed all of that. Energy efficient and environmentally responsible design were the fundamental principles of the movement. We didn't call it "sustainable" or "green building" at the time – those terms would be coined by a later generation that believed it was their idea. We experimented with things like solar energy and recycled building materials.

There was a "back to the land" component to the movement, with people leaving suburbia to build their own handcrafted cabin, geodesic dome, or yurt in the country. Someplace far away from traffic jams, smog, and Building Officials. At the same time, there was an urban pioneering movement, with pioneers buying derelict homes in blighted inner-city neighborhoods and renovating them.

It wasn't long before the movement got around to rediscovering and remastering the lost craft of timber framing that had died out nearly a century before. It started in the hills of northern New England – a region where the countryside is speckled with antique timber homes, barns, and meetinghouses. At first it was just a small handful of devoted craftsmen, dismantling and repairing old barn frames, studying the joinery, and examining the tool marks. By trial and error (mostly error at first) they learned how to cut timber joints and hone their skills until they could do it as good as the old masters. But that wasn't good enough. Being passionate about their recently acquired skills, and having obsessive compulsive personalities, they then had to do it better than the old masters – cutting and rolling tight joints with extraordinary precision. The old-time carpenters never would have taken the time or effort for that level of precision – they were really only interested in getting the job done. But this was a new breed of carpenters, for them it was not just a job, it was a passion.

Old style frame raising

The first generation of timber frame revivalists have often been disparaged as a bunch of old stoners – aging hippies left over from the 1960s. But that is really not a fair characterization, although it is not entirely untrue. They are actually a terrific bunch of guys who are a lot of fun to hang out with.

Before long, craftsmen passionate about mastering timber framing started popping up everywhere. But it was still a back-woods craft, practiced in remote areas where there were few Building Officials. Pretty soon it was time to organize. In 1985, the *Timber Framers Guild of North America (TFGNA)* was formed to provide a forum for the exchange of information and wisdom about the craft of timber framing and to spread the word. They would later shorten the name to the *Timber Framers Guild (TFG).*

Then, in 1989, a magical thing happened to timber framing – television. *This Old House* aired a series, hosted by Steve Thomas, where they built a timber frame barn home in Concord, Massachusetts. They didn't originally set out to build a new timber frame – it was something that just happened.

The original plan was to restore an antique timber barn and convert it to a home, but that plan was not meant to be. When the notorious timber engineer, Ben Brungraber, examined the old barn frame and probed the old timbers, he discovered that the barn frame was nothing more than a hulk of rotten wood that was way beyond repair. It was time for a Plan B.

A new timber frame was built be a bunch of timber frame novices from the *TFGNA*, under the instruction and direction of Ted Benson and a small crew of experienced timber framers. The workshop participants were shown how to sharpen chisels to a razor edge and cut timber joints. The crescendo to the timber workshop was a celebrated Amish style raising bee. All the while, the cameras were rolling with millions of viewers watching it on TV. It would prove to be the most popular *This Old House* series ever.

Barn frame topped out on **This Old House** *photo credit – Steve Thomas*

The world of timber framing changed practically overnight. Television viewers across the country, who had never heard of timber framing before, had caught the bug and now wanted a timber frame home for themselves. Within a few years, the craft of timber framing became a serious building trade and entered the world of mainstream building construction.

Following the *This Old House* series, the market growth of timber frame buildings in the 1990s was nothing short of explosive. Small timber frame builders, who had been operating on a shoestring out of a barn or garage, matured into large timber manufacturing operations with in-house design divisions. To keep up with the growing demand, hand tools were replaced by sophisticated, Computer Numerical Controlled (CNC) timber fabricating machines. Ironically, the lost craft of timber construction, that had experienced a rebirth primarily due to people's appreciation of its handcrafted qualities, was now dominated by technologically sophisticated factory manufacturing. Of course, the manufactured timber frames still looked like they had been made by hand and that is what really mattered – there is no reality, only perceptions.

As timber framing matured and went mainstream, all of the rules changed. Timber framers were no longer building exclusively in remote areas, they were now building in urbanized areas where Building Officials actually enforced Building Codes. Since the craft of timber framing was not covered in the Building Code, timber framers were being told to find themselves an engineer to sign-off on what they were doing.

That is the part where I came in. Up until that time, I had pretty much been a spectator to the timber frame revival. After a brief apprenticeship, I had started my own structural engineering firm in 1981. I had spent my first decade in business, among other things, engineering glulam timber churches and restoring historic timber buildings. All of a sudden, in the 1990s, I had the opportunity to design and engineer timber frame structures – something that was a whole lot more fun than anything that I had done up until that time. I was now an essential part of the movement.

Timber Framing Today

The world of timber framing has come a long way since those early days of the revival. Today's timber structures bear only the faintest resemblance to the historic house and barn frames from centuries past. Timbers are sawn and planed smooth to tight tolerances rather than hewn with axes. The timbers are still joined with intricately cut, interlocking joints, but the joints no longer follow historical precedents.

The most significant difference between modern timber structures and their ancestors is that the timber frames of days gone by were built for function – to structurally support a building, not for show. Timber frames today are all for show and structural efficiency is a secondary consideration. In many instances, the timber frame does not even hold anything up except itself.

Contemporary timber frame

Timber framing is no longer a hobby craft – today it is a serious building trade and timber framers have become serious businessmen and women. While construction trades have been experiencing difficulty attracting and retaining young, skilled tradesmen, passionate craftsmen have been flocking to timber frame companies. It is not uncommon for individuals to leave stable jobs in corporate America for the romance and glamor of building with timber.

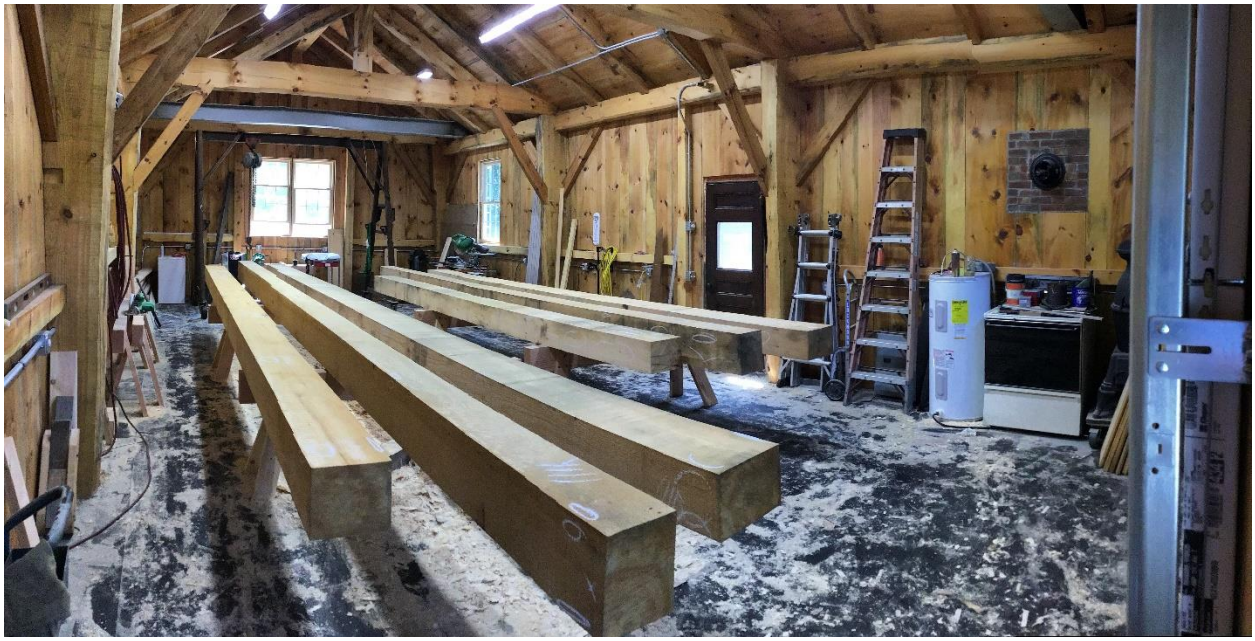
Today there are formal TFG sponsored apprenticeship programs and training where the craft is taught. There is also no shortage of how-to books that will teach you how to build your own timber home or shed (this is not one of them).

Timber framers and timber frame businesses have split-up into a few different tribes, or camps. There is the historical timber framing camp. Many of the surviving timber revivalists have joined this camp. They build and restore timber structures that are indistinguishable from the buildings built 200 years ago. They follow time honored, exhaustively researched, construction techniques. They use mostly historically accurate hand tools (usually antique tools scrounged up at flea markets and auctions). They cut timber joints that are replicas of documented historical timber joints, and they replicate the shape

and form of historic structures from a bygone age. Hewing a tree trunk into a timber with an axe is one of their favorite amusements and raising a timber frame by hand is their greatest pleasure. They are keeping the spirit of the ancient craft alive.

Time-honored traditional tools of the trade

They have formed an exclusive splinter group within the TFG that they call the *Traditional Timber Research Advisory Group (TTRAG).* They have a conference every year where they show off their latest projects and swap stories. Their businesses tend not to be particularly profitable, and they are proud of it. They have disdain for successful timber frame companies for having “sold out.” TTRAG has acquired a reputation for representing the lunatic fringe of the timber frame world. Although they may be lunatics, they are passionate about what they do and you have to admire that.



New England Timber Framers workshop in Westerly, RI

The largest camp is made up of the small, mom and pop style operations, typically comprised of between two and four guys. They run undercapitalized businesses out of a garage or barn. They work mostly with power tools and they usually have a pickup truck and a cell phone. It is hard to say exactly how many businesses like that there are out there, because they tend to fly under the radar. There are probably at least a hundred mom and pop style timber frame companies, but nobody knows for sure. They don't have websites and they can be tough to find. They only work on houses and they usually build three or four house frames a year.

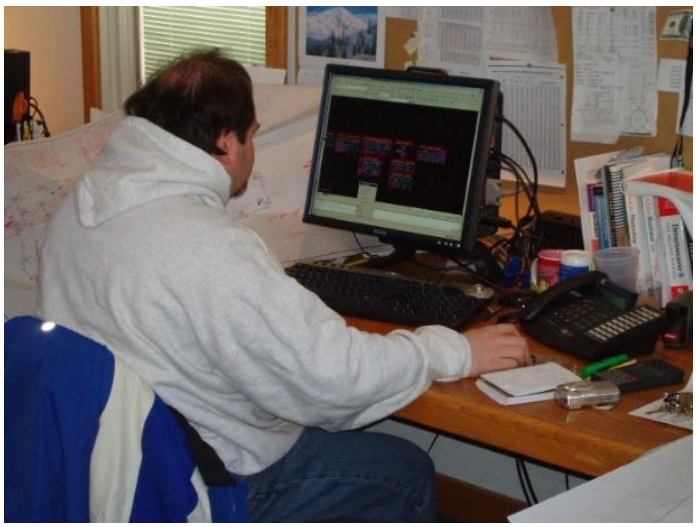
Then there are the serious timber frame businesses. I wouldn't describe them as corporate, but they do run their businesses like businesses, while still maintaining an enthusiasm for what they do. There are probably no more than two dozen companies that fit this description. Each company employs at least 20 individuals of which only half of them ever get to pick up a tool – the rest sit at desks, behind computer screens, preparing estimates and designing timber structures. The most successful companies are the ones that have their act together for providing comprehensive design services.

They still design and build timber homes and it is not unusual for a timber company to build 50 homes a year. But they are not afraid to build larger commercial or institutional timber structures like schools, churches, and libraries. They are also not afraid to work with glulam timbers when the need arises.

Timber fabrication has become highly automated. While every timber shop still has a few skilled craftsmen, who can cut an intricate timber joint, carving, or embellishment with sharp chisels and saws, most of the work is done by a CNC timber fabricator. The CNC machine of choice among timber companies is the German made Hundegger. It has computer-controlled saws and cutter heads. It is a marvel to watch in action. It can fabricate a complex timber in 10 minutes that would have taken a skilled craftsman all day to fabricate with ordinary power tools. It can do it all with a high degree of precision while still making everything look as if it had been hand-crafted.

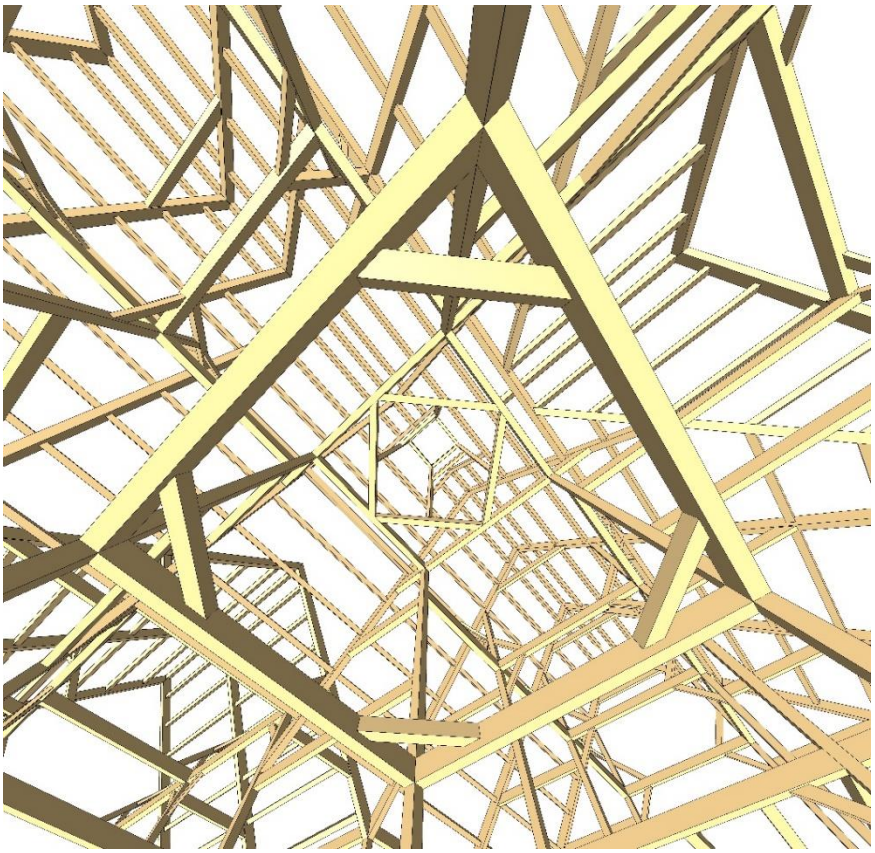
Timber Engineering

When I first started engineering traditional timber frame structures, there were only a few engineers scattered around the country doing that sort of thing. Unlike engineering glulam timber structures, there were no building code standards, design guides, or text books that told you how to engineer a mortise and tenon, truss heel, or scarf joint. Sizing the timbers was easy. Calculating how big a timber beam or post needs to be to support the load on it is child's play for an engineer. It was all about the connections or joints.



Timber engineer in his lair

We had to figure it all out for ourselves, applying engineering principals and what we knew about wood science, seasoned with a little bit of gut instinct and luck. Timber frame engineers were a pretty small club in those days. We all knew each other and would swap stories and advice at TFG conferences. There would be heated discussions and debates about arcane subjects like how strong an oak peg was.



3D computer model of a timber structure

By 2005, our numbers had grown and it was time for us to get organized. We formed the *Timber Frame Engineering Council (TFEC)* as a splinter group within the TFG. Since then, the TFEC has been busy, sponsoring university research into the behavior of timber structures, conducting timber engineering symposiums, writing building code standards, codes of practice, and timber design guides. I had a hand in writing most of those standards and design guides. Engineers today no longer have to figure it all out for themselves.

From Timber to “Trimber”

Not all timber frames built today are actually supporting the buildings that they are in. Sometimes they are just decoration and are only holding themselves up. Occasionally, it makes more sense to frame the structure of a house out of light wood framing and stick a great room timber ceiling in afterwards to create the illusion of a timber structure.

Non-structural timber framing is referred to as *“trimber framing”* – a blend of timber and trim. When I was younger and more idealistic, I had a bad attitude about trimber. I thought it was a travesty and a fraud. I have mellowed with age and now believe in whatever makes people happy.

A great room ceiling with reclaimed white oak *trimber* summer beam and joists
photo credit – E.M. Rose Builders

Feature Project

Spruce Peak

The glulam timbers at this ski resort in Stowe, Vermont are supporting a little bit of roof framing and some balconies, but they are mostly a *trimber* decorative façade on a steel frame building.

Glulam Timber – Goodfellow
Project engineer – Kevin Chamberlain
Photo credit - Alamy

Feature Project

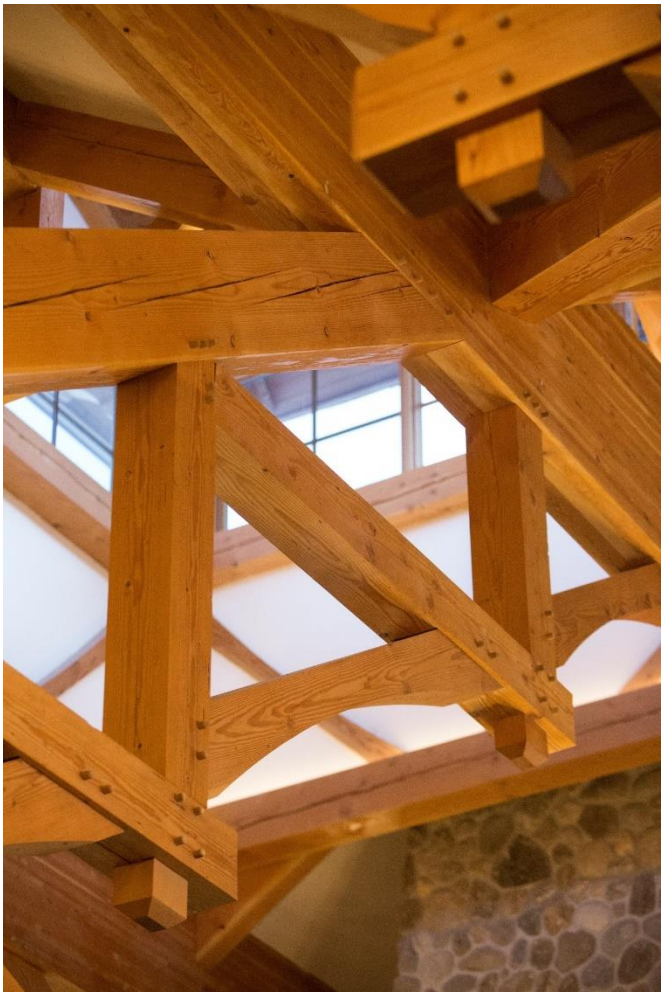
Darien Nature Center

The Darien Nature Center was one of the first timber frames that I designed that was not just a big house. The year was 1999. I had the pleasure of collaborating with the talented architect and artist, Sandra Vlock. The timber frame was built by Ted Benson who had acquired celebrity status after appearing on *This Old House*.

Architect – Arbonies King Vlock
Timber – Benson Woodworking
Project engineer – Kevin Chamberlain

Feature Project

Hermitage Club – Haystack Mountain



The Hermitage Club was a private resort for skiers at Haystack Mountain in Southern Vermont. The base lodge was the center of the resort and included a restaurant, a lounge, offices, and a fitness center complete with an indoor swimming pool. As you might expect, the timber frame is the main attraction.

The frame consists of robust Douglas Fir timbers with a couple of glulam timbers thrown in for the longer spans.

The design of the timber structure was inspired by hammer-beam timber trusses from medieval cathedrals in Europe. Although I believe we did it a little more elegantly than the medieval builders.

Sadly, despite having a kick-ass base lodge, the ski resort was not a financial success.

Timber Framing – South County Post and Beam
photo credit – Jim Westphalen

Feature Project
Winchendon School

The Winchendon School is a secondary school in Massachusetts.

The thing that was memorable about this project was the design process – it was a true collaboration between the architect and myself. For the schematic design of the timber structure, I had a design session with the architect. They built a balsawood models of the frame and we sat around the conference room table, hacking up the models with X-Acto knives, and gluing the timbers into different configurations until we eventually arrived at a timber configuration that the architect thought looked really cool and also happened to be structural sound. Those two objectives never seem to coincide on a project.

Timber – Vermont Timber Frame

Chapter 3
Glued-Laminated Timber

Glued-laminated (glulam) timbers are large, high-strength timbers, which are made by stacking up multiple laminations of 2x dimension lumber and gluing them together with a phenol-resorcinol adhesive. It is a clever way of making big timbers out of little trees.

The first glulam timber structure was a laboratory building at the USDA Forest Products Laboratory (FPL) in Madison, Wisconsin. It was built in 1934 as a research project by the FPL to see if glued-laminated timbers could be a viable and cost-effective building material for large structures.

Following World War II, with steel in short supply, glulam timber construction started to catch on. By the 1960s, glulam timbers had become the material of choice for church roof structures, as well as school gymnasiums and ice rinks. Any building where a long-span, architecturally exposed structure was desired.

When I first started practicing structural engineering in the 1970s, if you wanted a structure that looked like timber, glulam construction was your only option. Of course, that is no longer true.

Ironworkers on high timber

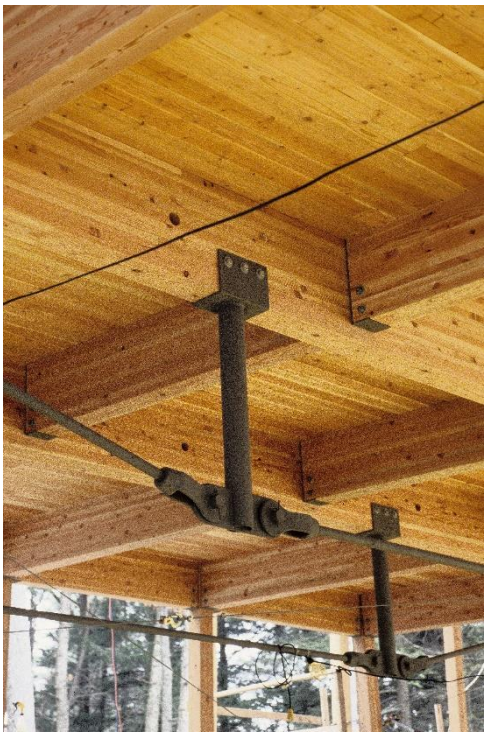
With the rise in popularity of traditional timber framing in the 1990s, glulam timber construction started to lose market share and began to go into a decline. In recent years, mass timber construction has been experiencing a dramatic increase in popularity. Since most mass timber projects have a lot of glulam timbers in them, the glulam industry is now experiencing its own revival.

What really differentiates glulam construction from timber framing is not so much how the timbers are made as the culture of the people that build them. Glulams are an industrial building material and are definitely not hand crafted. They are joined with industrial style connections that are not dissimilar to structural steel connections – steel side plates, called gusset plates, with a bunch of steel bolts. They are erected by ironworkers, not carpenters, since erecting a

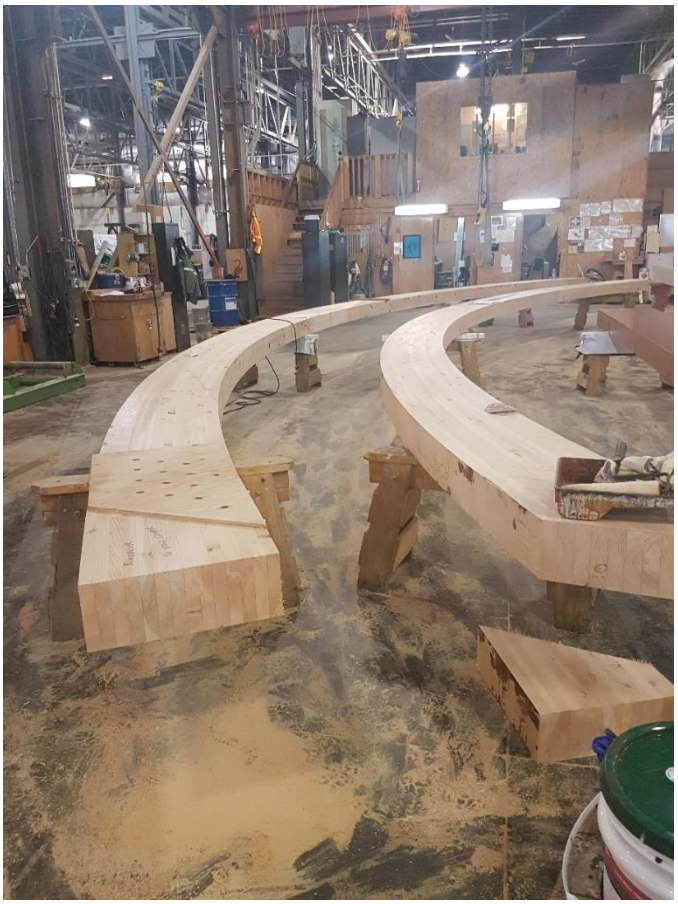
glulam timber structure is an awful lot like erecting a structural steel structure. If they need to make corrections in the field, they don't use chisels and handsaws, they use chainsaws.

Glulam construction is ideally suited for structures with long spans and curved shapes. If you need a really big timber, all you have to do is pile on more laminations, you don't have to go into the forest looking for a giant tree. You can make a glulam timber any length that you want provided you can put it on a truck for shipping to the site.

Laminating curved timbers is no big deal as long as the radius of curvature is not too tight. For tighter curves, thinner laminations have to be used. For instance, a 1 ½ inch thick lamination can be bent to a radius no tighter than 27'-6", while a ¾ inch thick lamination can be bent to a 9'-4" radius. The only limit to the shape of a curved glulam timber is it can't be too wide to ship on a truck bed. Glulams can be curved in the vertical direction or the horizontal direction, but not both – a spiral corkscrew shaped timber is nearly impossible to make.



Industrial strength hardware



Glulam timbers are over twice the strength of a sawn timber. The higher strength is achieved by using high grades of lumber for the top and bottom laminations where the stresses are highest, and lower grades of lumber for the middle laminations where it doesn't matter as much.

Glulams are also more stable than sawn timbers since the lumber is kiln-dried before laminating. So, there is a lot less shrinkage and checking when the timbers season and you never have to worry about the timbers twisting.

Glulam timbers are available in three appearance grades. Architectural grade is most common and is suitable for most applications. Premium grade is a little more costly and is appropriate where a very polished look is desired. Industrial grade can be specified when you really do not care what the timbers look like.

The very first timber structure that I ever engineered was a public library in New Canaan, Connecticut. It was 1978 and I had been out of graduate school for less than a year. I was serving my apprenticeship at a local structural engineering firm. When the building was finished, I was really proud of the way it turned out. Today, I can't look back at this building without feeling a little embarrassed.

Timber engineering is all about the connections between the timbers. The timber connections on this project are characteristic of the way most engineers approach a timber project. What you see are steel angles and plates with a lot of bolts. This is exactly the way that structural steel beams, girders, and columns are connected. After some reflection on this, I concluded that it was not the best way to connect timbers and I could do better. I opened my own engineering firm in 1981 and took a fresh approach to engineering elegant timber connections.

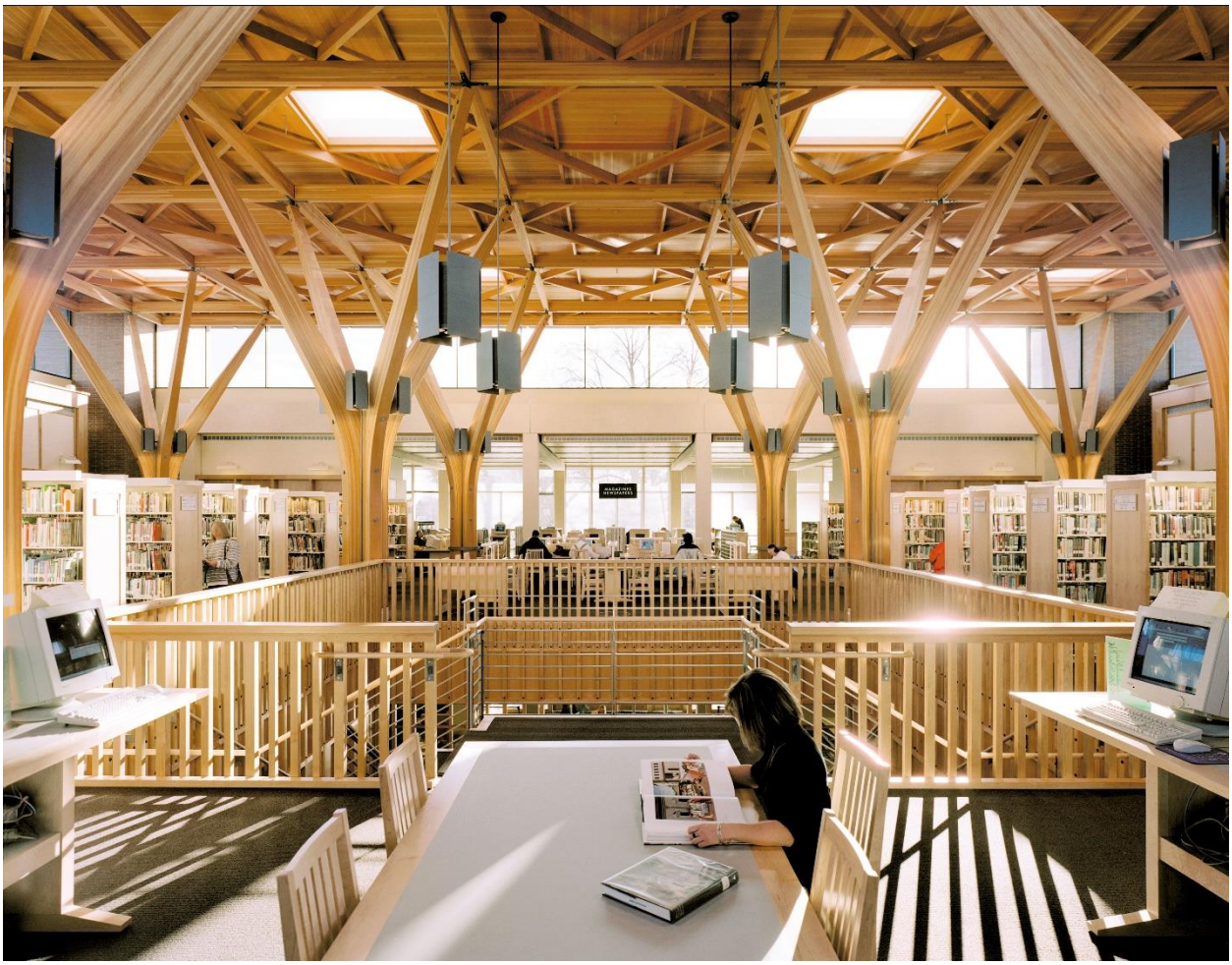
Traditional style glulam connection

Glulam timber structure with nearly invisible connections

In 1987 I designed the glulam timber roof structure for a Church in Brookfield, Connecticut. By then, I was really starting to perfect the art of designing timber connections that were structurally efficient and practically invisible. The roof structure is a space truss with intersecting glulam trusses that clear span 92 feet. The glulam timber connection details were inspired by timber trusses commonly found in mill buildings from the late 1800s.

Feature Project
Beaverton Public Library

The Beaverton Public Library is my all-time favorite glulam timber project that I had absolutely nothing to do with. Beaverton, Oregon was once a popular place for beavers and today is known as the “city of trees.” The library design was a collaboration between Hacker Architects and my old friend Art Johnson with KPFF structural engineers in Portland, Oregon. The design solution was nothing short of brilliant and I am embarrassed that I never thought of it. What they did was to take glulam Tudor arches and cluster four of them together to create columns that resembled trees with spreading branches. Tudor arches are a tired old glulam timber form that was popular in 1960s vintage churches that Hacker Architects used here in an entirely new way to create a truly marvelous building.



Feature Project

Hotchkiss School Biomass Boiler Plant

The Hotchkiss School is an affluent and prestigious prep school. We have been working with the school since 1990 and all of their projects have been cool buildings. This was more of a utilitarian building, but still, the school did not skimp on the design.

All of the buildings at the school are heated with steam. There is a network of tunnels and steam piping that runs under the campus to feed live steam to every building. They previously had a steam plant that was built in the early 1900s with three tired old steam boilers that originally burned coal and had been converted to burning No. 6 fuel oil shortly after World War II. The plant had a tall brick chimney that belched smoke all winter.

The school was planning on building two new dormitories and everyone agreed that the best location for the dormitories was where the boiler plant sat. It wasn't hard to convince the school to replace the boiler plant with a more efficient facility sited away from the dormitories and classrooms. It was even easier to convince the school to fire the new boilers with biomass rather than fossil fuels. The fuel would be waste wood and scraps from a local sawmill. Biomass is the most underutilized and underappreciated sources of energy. Between waste wood, forestry management debris, and trash, we are practically swimming in in the stuff. North America is like the Saudi Arabia of biomass fuel.

Photo credit – David Sundberg / Esto

While most institutions would relegate a boiler plant to an ugly pre-engineered metal building, the Hotchkiss School wanted it to be a signature building. It would house state of the art sustainable technology and they were proud to make it an attraction on the campus.

For the design of the building, we collaborated with the award-winning architect, Jeff Reilly with Centerbrook Architects. Jeff had a vision of an undulating roof that mimicked the rolling hills of the surrounding countryside. To further blend into the site, the roof was topped with soil and planted with sedums.

Glulam timbers were the natural choice for a roof structure with a lot of curves. The curved shape would have been difficult to accomplish with any other material. The architect passionately believed that a facility built to converted waste wood to energy should feature a timber structure. The school agreed.

The biomass boilers have been a huge success and have reduced the schools heating cost and carbon footprint significantly. The only problem with the building is that all of the steam piping, mechanical ductwork and equipment tend to obscure the view of a really cool timber roof structure.

Photo credit – David Sundberg / Esto

Architect - Centerbrook
Glulam Timbers – South County Post & Beam

Feature Project

Portland International Jetport

Air travel is seldom a pleasurable experience these days, but the Portland Jetport in Maine is one of those small airports that is actually enjoyable to fly in and out of.

I found myself in Portland a few years ago and I decided to stop by the Jetport. I had not seen it since the project was completed. I walked into the terminal with a camera and started taking some photos of the structure, minding my own business. Within moments, the TSA guys swarmed on me wearing bulletproof vests. But once I told them that I was the timber engineer, they got really friendly and started telling me stories about how much they enjoyed working in the terminal.

Photo credit – Robert Benson Photography

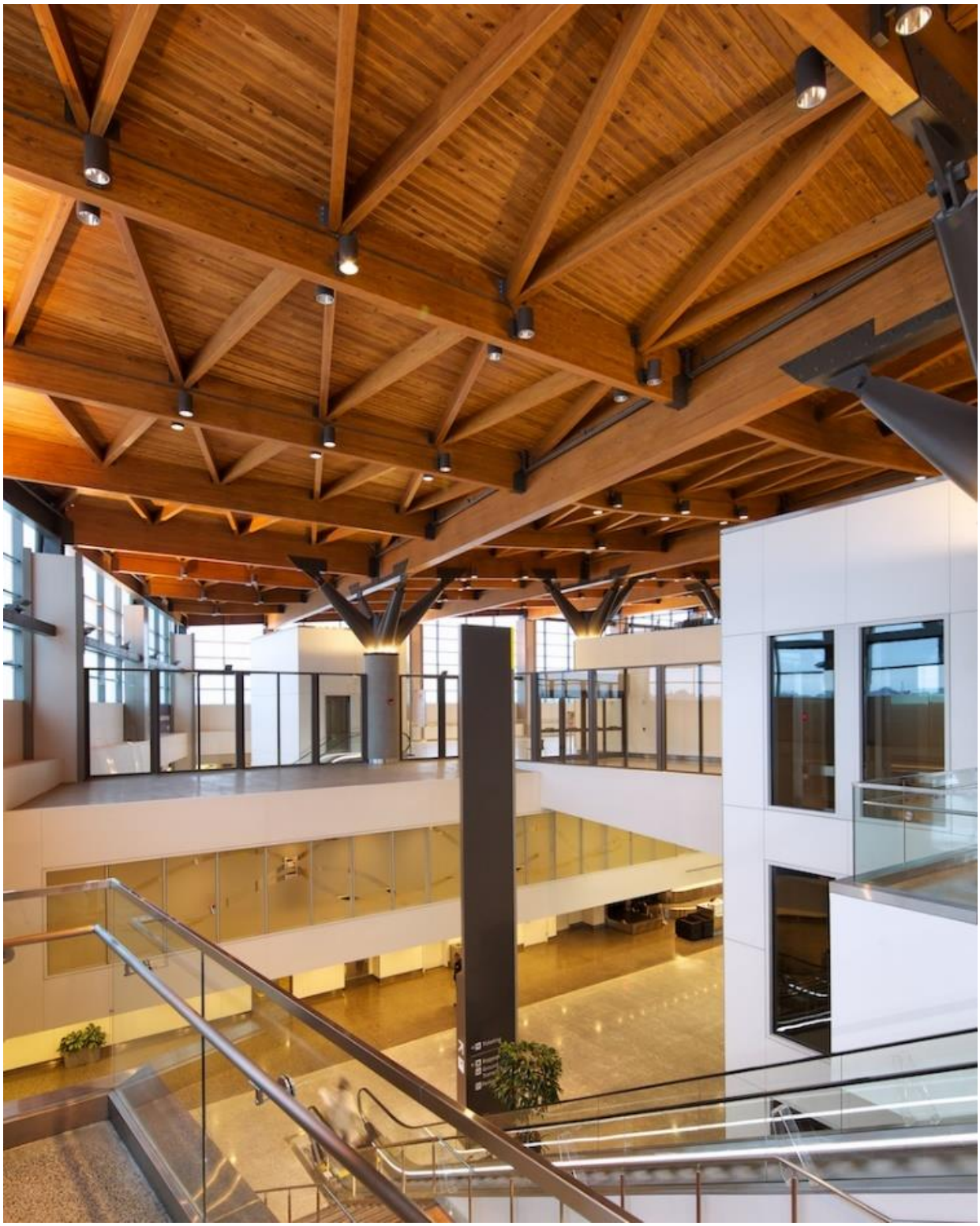


Photo credit – Dave Clough Photography

Glulam timber - Goodfellow

Feature Project

Mystic Seaport – Thompson Exhibition Building

Mystic Seaport is the oldest and most popular tourist destination in Connecticut. It is a living history maritime museum that celebrates New England's nineteenth century whaling and shipbuilding industries. The museum decided to build a new visitor's center and exhibition building to anchor the North end of its museum campus.

I collaborated with Chad Floyd of Centerbrook Architects on the design. While most architects would have opted for a traditional contextual design that emulated the architecture of the seaport village buildings, Chad had a bolder vision. Inspired by curvilinear images of breaking waves, rolling seas, billowing sails, and ship hulls, he designed a dramatic, fluid form building which has been christened the Thompson Exhibition Building.

The focal architectural feature of the building is its glulam timber roof structure. Upon entering the building, your eye can't help but being drawn to the majestic curved timbers, but what is most notable about the timber roof structure is what you don't see. There are no clunky steel gusset plates connecting timbers, instead you see elegant scarf joints inspired by traditional shipbuilding joinery.

Photo credit – Jeff Goldberg / Esto

Photo credit – Derek Hayn / Centerbrook Architects

Glulam timber – Goodfellow
Architect - Centerbrook
Project engineer – Rick Way

Chapter 4
The Mass Timber Movement

Something Old and Something New

Mass timber is not a new idea, just a new name. A lot of people have heard the term “mass timber” batted around in the last few years, but not everybody has a clear understanding of what it means. Mass timber used to be referred to as “heavy timber” in the Building Code. Most of the timber projects that I have designed over the past 40 years were mass timber, I just never called it that until recently.

Mass timber is a type of structure made up of big, fat, pieces of wood that, unlike light-wood frame construction, burn slowly. Because mass timber structures maintain their integrity during a fire without the need for layers of fire-resistant materials like sheetrock, they are suitable for big and tall buildings and the Building Code recognizes that.

So, what’s new? Timber panels are new – Cross-Laminated Timber (CLT) and Dowel Laminated Timber (DLT). CLT panels have been used in Europe since the 1990s, but have only been available in North America for just a little more than a decade. The availability of timber panels has stimulated interest and excitement within the architectural community for building big and tall buildings with mass timber.

Modern mass timber structures typically consist of a glulam timber frame supporting CLT or DLT floor and roof panels, often with CLT walls. This type a construction is extremely versatile and is suitable for both large and small structures – anywhere that an architecturally exposed structure is desired. It does not make much sense to build with timber and then cover it all up with sheetrock and hung ceilings. By the way, mass timber construction is also very sustainable – more about that later.

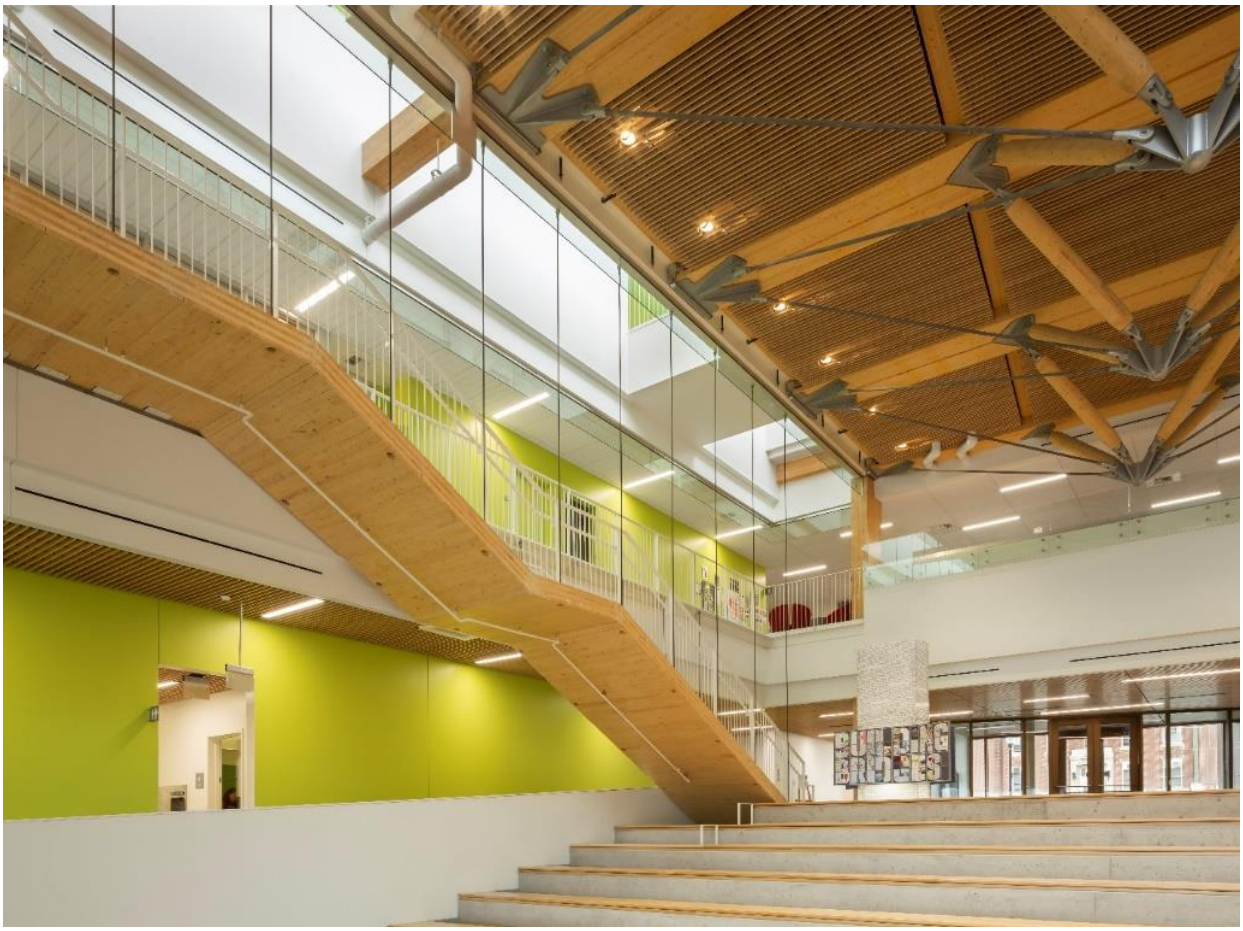
Nordic’s CLT plant
Photo credit – Stephane Groleau

Feature Project

John W. Olver Design Building

The John W. Olver Design Building at the University of Massachusetts was the first major mass timber building built in New England.

Architect - Leers Weinzapfel
Mass Timber – Nordic Structures
Photo credit – Stephane Groleau



Cross-Laminated Timber (CLT) panels and beyond

Cross-Laminated Timber (CLT) has often been described as plywood on steroids. It is made up of alternating plies of dimension lumber that have been planed to 1 3/8" thickness. Like plywood, each ply is oriented perpendicular to its adjacent plies. Common CLT layups are 3 ply (4 1/8"), 5 ply (6 7/8"), and 7 ply (9 5/8"). CLT panels are typically 8 feet or 10 feet wide and up to 60 feet long.

Nail-Laminated Timber (NLT) panels are made up of dimension lumber (typically 2x6s) laid side by side and spiked together with nails. NLTs are not a new thing and have been used infrequently for over a century. The advantage of NLT panels is that they do not require specialized fabricating equipment to manufacture and they can even be built on-site. The disadvantage is that NLT panels require a boat-load of nails that are labor intensive to install and make it impossible to cut the panels with CNC equipment without the embedded nails destroying the cutter-head.

Dowel-Laminated Timber (DLT) panels are the newest guy on the block. DLTs are similar to NLTs, except that they contain no nails. Transverse birch dowels are used instead of nails to bond the panels. Unlike NLTs, DLT panels lend themselves well to CNC fabrication.

Cross-Laminated Timber
Photo credit – www.naturallywood.com

CLT panels were used for the entire structure and everything else, including stairs, tables, and benches at the Common Ground High School designed by Gray Organschi Architects.
photo credit – David Sunderland / Esto

Feature Project
Brock Commons

Brock Commons is a dormitory building at the University of British Columbia in Vancouver. The floors are framed entirely of CLT panels that span directly to glulam columns.

High-rise construction has long been the exclusive domain of structural steel and reinforced concrete structures, but that is starting to change. Mass timber is now a player in the high-rise market. Brock Commons is currently the tallest mass timber building in North America, topping out at 18 stories. In the world of tall buildings, 18 stories may not sound all that impressive, but for wood construction it is a big deal. Sadly, all of the timber in the building is concealed behind drywall to achieve the required fire-resistance. So, it is not evident to anybody living in the building that it is actually a mass timber structure.

Even though the *International Building Code (IBC)* now permits 18 story mass timber buildings, it is unlikely that mass timber is going to completely displace structural steel and reinforced concrete for high-rise construction anytime soon. I expect that we will be seeing more tall mass timber projects and we will probably be seeing a lot of mass timber and structural steel hybrids.

Engineer – Fast + Epp
Photo credit – www.naturallywood.com

Feature Project

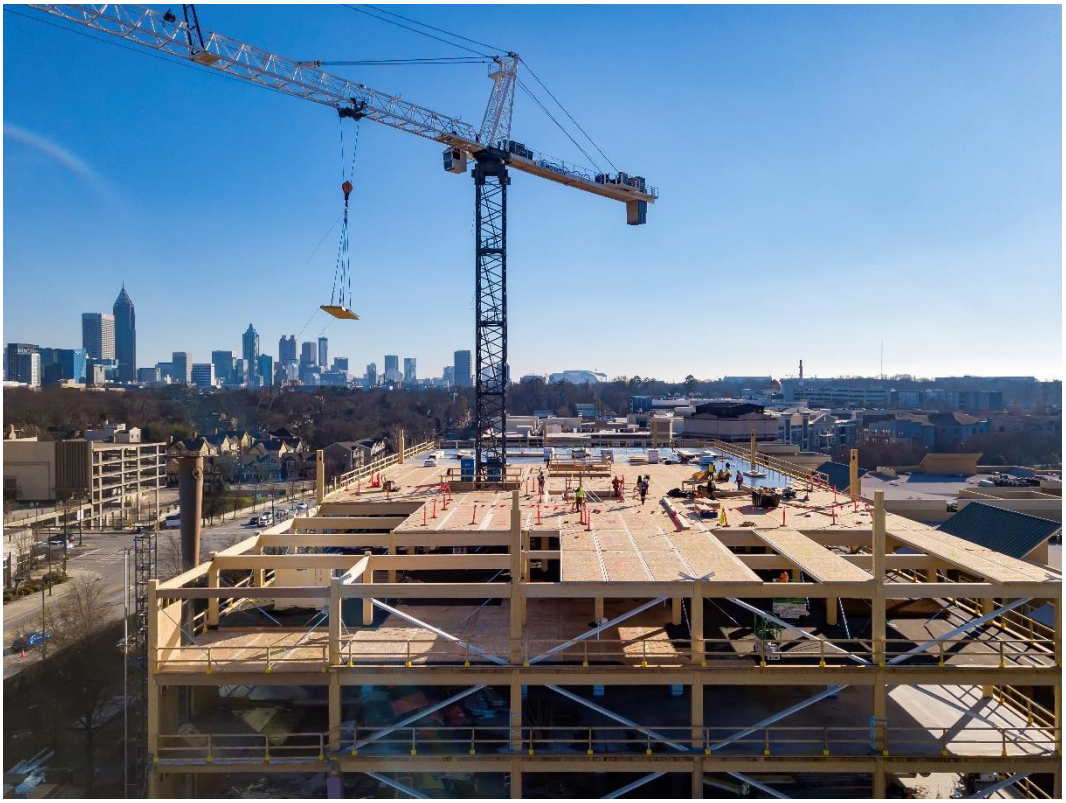
Soto Office Building

In Texas they do everything in a big way and mass timber is no exception. The Soto Office Building in downtown San Antonio is 6 stories with 120,000 square feet of office space. It is the most exciting thing to happen in San Antonio since the Alamo.

The structure is made up of Dowel-Laminated Timber (DLT) panels over glulam girders and columns.

Mass timber – StructureCraft
Photo credit – Lucas Epp

Dowel-Laminated Timber (DLT)



Timber and Fire

It is a common misconception that because wood is combustible, wood buildings perform poorly in a fire. While that may be true of most light-wood frame construction, it is not at all true of mass timber. Actually, mass timber structures perform better than unprotected structural steel during a fire.

Timbers will develop a char layer on the surface when exposed to a flame. The char layer progresses slowly and insulates the wood beneath it from the heat of the fire, permitting the timbers to continue to carry load. When timber structures do eventually fail during a fire, they do not fail suddenly. They typically give firefighters ample warning prior to a collapse by making loud cracking and hissing noises. The exception is when steel connection hardware is exposed to the fire, the connections will fail suddenly. The best way to protect steel connection hardware is to bury it inside the timbers where the wood can protect the steel from the fire. That is something that I like to do anyway so that nobody has to look at the ugly steel stuff.

Charred timbers

Hybridization

Mass timber plays well with other structural materials. While some people try to design mass timber buildings where the CLT panels do everything, often the right solution is a hybrid solution. CLT floor and roof panels sitting on top of glulam timbers, or maybe even on top of structural steel girders is usually a smarter idea than trying to make the CLTs go it on their own. Even concrete plays well with CLT panels and it is common to cast a concrete slab over CLT floor panels to reduce sound transmission and floor vibration.

CLT panels over glulam trusses with traditional joinery

Feature Project

Stamford Media Village

The Stamford Media Building is a five-story office building, built over the carcass of a 1920s vintage two-story factory building. It is a structural hybrid. The lower two floors are a reinforced concrete structure that required extensive concrete restoration and reinforcement. The upper three floors are constructed of CLT panels supported by structural steel girders and columns.

In the finished building, the timber, steel, and concrete structure were left exposed. It is a very unique space for luxury offices with harbor views and a micro-brewery on the ground floor.

Architect – CPG Architects
CLT Timber – Nordic Structures
Project engineer – Joe Gencarelli

Feature Project
Kick Ass Garage

The first CLT project that I designed was actually a garage that I built for myself. I prefer to experiment with new building technologies like CLTs on my own projects before using them on my client's projects. Most of my clients prefer not to be treated as guinea pigs, I don't understand why. I have found that when you actually build with a material, you come to understand its capabilities and limitations much better than if you just worked with it on paper.

Some people have the mistaken impression that mass timber components like CLTs are only suitable for very large projects. That is just not true, I have used CLT panels on projects of all sizes.

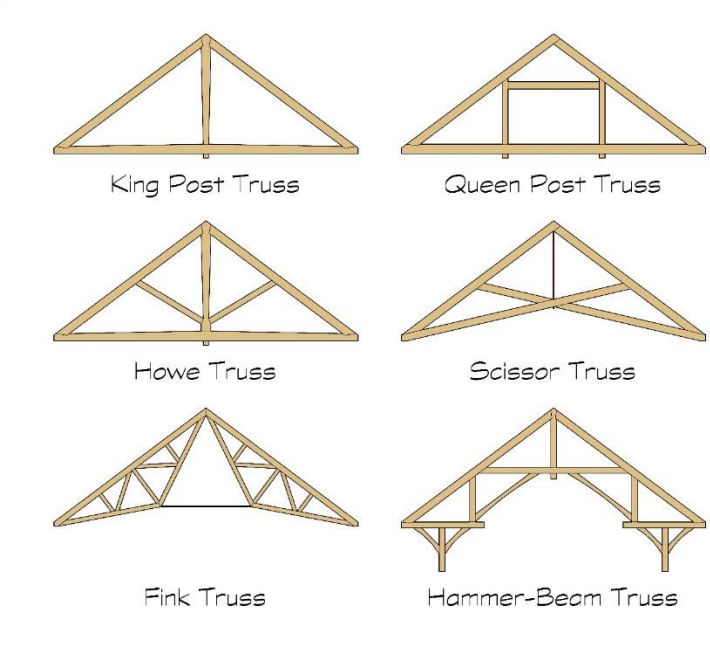
photo credit – Tim Lee Photography

Chapter 5
Timber Trusses, Domes, and Arches

Timber Trusses

There comes a time when you just can't span a wide space with a simple timber beam, no matter how big it is. That is when an engineer must resort to trickery. Often, the first thing that he pulls out of his bag of tricks is a common truss. A timber truss is made up of multiple timbers joined together in a pattern of triangles, but not just any random pattern of triangles will actually function as a truss.

There are just a handful of common truss shapes that actually work. They have been proven not just by engineering theory, but by a long track record, over centuries for some, of successful performance. All of the common truss shapes have names. Some are named after things that they resemble, like the scissor truss or the hammer-beam truss, others are named after people, such as Howe, Pratt, Fink, Warren, or Whipple. You may be wondering, "who are those guys," they don't sound like dead presidents.



The answer to that question goes back to the late 1800s, when railroad tracks were being laid, at break neck speed, everywhere across the country. The tracks had to cross countless rivers, streams, and ravines, each one of which required a trestle or bridge. This was the heyday of timber and iron truss bridge construction. But it was before there were bridge engineers, so the railroads had to resort to patented bridge designs. Every inventor or amateur engineer raced to patent his own unique truss design in hopes of making his fortune off of the railroads. Naturally, each one of them named their truss design after themselves to add fame to their anticipated fortune. Some truss shapes proved to be structurally efficient, smart truss designs that actually worked. Those are the ones with names that we recognize and still use today. Other patented truss bridge designs were not so lucky and ended in catastrophic train wrecks.

So, if you are an architect or engineer designing a timber truss, and you come up with a cool looking, unique truss shape that looks nothing like anything that anybody has ever seen before – watch out. Don't fool yourself into thinking that you are smarter or more creative than everybody that has come before you. There may very well be a truss just like yours laying in rubble at the bottom of a river gorge somewhere.

Fink truss

The simplest and most common timber truss is the king post truss and its spouse, the queen post truss. They are well suited to relatively short span conditions. For longer span conditions, the Howe truss is the truss of choice. For even longer spans, where a Howe truss becomes too wide to ship on a truck, the Fink truss is a practical choice since each half can be shipped separately and assembled on site.

Scissor trusses make for grand soaring spaces and are popular for church roofs. It is a particularly inefficient truss form and has the bad habit of tending to push the exterior walls outward when the trusses are loaded with accumulated snow on the roof.

Westminster Hall photo credit - Alamy

But there is no truss that is less efficient and more celebrated than the hammer-beam truss. The hammer-beam was first developed for medieval cathedral roofs such as Westminster Hall in London. The medieval cathedrals had massive stone masonry walls with flying buttresses to support the timber roof trusses and to resist the horizontal thrust from the roof structure. Modern timber framers have adapted hammer-beams to contemporary timber frames with slender timber post supports rather than stone masonry walls and buttresses. They look a lot like their medieval ancestors, but their structural behavior is something altogether different. But thanks to the marvel of timber engineering, most contemporary hammer-beam trusses are still standing.

When structural loads are applied to any truss, the individual members that make up the truss develop internal stresses that are either tension stresses or compression stresses. Tension is a force that tries to pull a timber apart while compression is a force that tries to crush a timber. In most instances the top chord of a truss is in compression and the bottom chord is in tension. The struts in the middle typically alternate between tension and compression depending on the truss shape. Truss members that are in tension are sometimes made of steel rods rather than timber. Slender steel rods are very good at resisting tension but useless in compression – remember, you cannot push a rope!

Arches and Domes

For very long span structures with tall soaring spaces, like a hockey rink, trusses just won't do the trick. It is time to resort to an entirely different bag of tricks – arches and domes. Arches are structures that rely on their curved shape to resist structural loads predominately in compression similar to the way that a suspension bridge resists structural loads purely in tension. A dome is really nothing more than a 3-dimensional arch.

The art of building arches and domes was developed and perfected by the ancient Romans. The Roman aqueducts never would have been possible without arches. Throughout history, arches and domes have been built of stone or brick masonry – materials that are very strong in compression but pathetically weak in tension.

The ancient Romans never built arches out of timber because they just couldn't figure out how to get trees to grow in the curved shapes that an arch requires. It was the development of glulam timber technology in the 20th century that made timber the perfect material for building arches. Laminating a curved glulam is no big deal.

Pantheon circa 126 AD

Feature Project
Richmond Olympic Oval

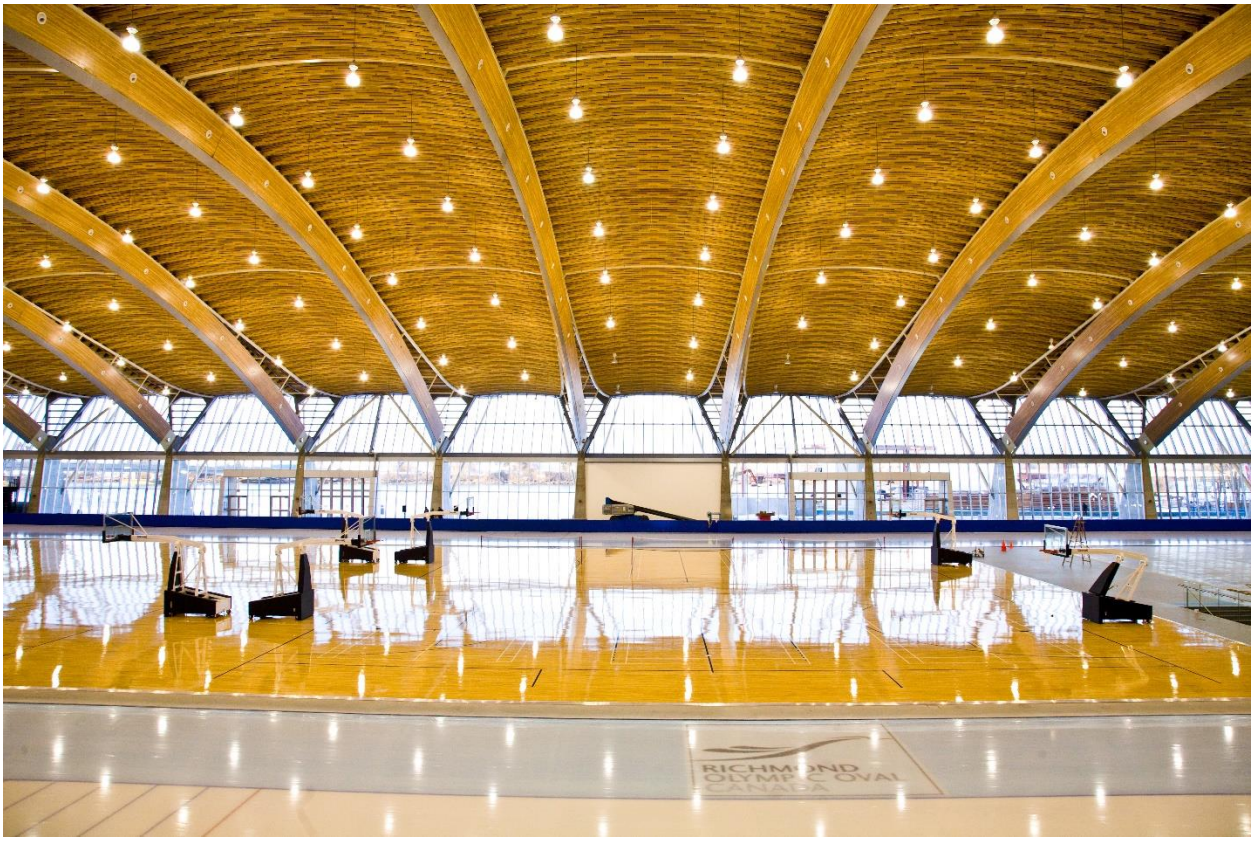


Photo credit – www. Naturallywood.com

The Richmond Olympic Oval was built for the 2010 Winter Olympics speed skating competition.

Engineer – Fast + Epp
Timber structure - StructureCraft

Feature Project

Kroon Hall

Kroon Hall is home to the Yale School of Forestry and Environmental Science and it is all about timber. Many of the most accomplished foresters in the world have passed through its halls. It is only fitting that the forestry students be sheltered below a canopy of timber arches.

Architect - Centerbrook
Glulam Timbers - Goodfellow

Lamella Roof Structures

A lamella roof is an arched vault made of short pieces of 2x10 arranged in a diamond pattern. The system was patented in 1910 by German engineer, Friedrich Zollinger and it was once referred to as a "Zollinger roof." It became popular for long-span structures such as aircraft hangars during and after World War II when steel was in short supply. In the 1950s, the lamella system was adapted to dome structures. The Houston Astrodome, built in 1965, was a structural steel version of a lamella roof.

The Ice Casino in Rye, NY was built in 1929 and was declared a National Historic Landmark in 1987

Feature Project

Botanical Garden - Taiyuan, China

The Botanical Garden in Taiyuan features three timber gridshell domes, each with its own climate – tropical, desert, and aquatic. The largest of the three domes has an impressive clear span of 300 feet.

Timber Structure – StructureCraft
Photo credit – Lucas Epp

Chapter 6
Timber Homes of Distinction

There is something special about living in a timber frame home that is unlike living anyplace else. It seems that timber homeowners never want to leave, preferring to be carried out in a box. I live in a timber frame home built in 1809 that I have restored – for more on that, you have to read my first book, *Antique New England Homes and Barns*. In my part of the country, antique timber homes are not unusual. Virtually every building built prior to the Civil War is a timber structure. Many years ago, I purchased a forested 91-acre site, out in the country, as a weekend getaway. After doing some long overdue forestry management, I built myself a timber barn for a workshop, and then built myself a timber frame saltbox house.

In my structural engineering practice, among many other things, my office works on over 100 homes a year - mostly homes for the rich and famous. Some of those are lucky enough to be timber homes and those are the projects we have the most fun with.

A modest weekend lake home; *photo credit – Catherine Truman / Ann Beha Architects*

Feature Project
Spring Hill Farm

photo credit – Michael Biondo

Spring Hill Farm is a weekend retreat located on a bucolic 300-acre farm in Connecticut's Litchfield Hills. The project's dream team consisted of premier builder, Eric Rose, and an award-winning architect, Reese Owens. Both Eric and Reese are passionate perfectionist and their passions sometimes collided, making for a memorable, "never a dull moment," kind of project. The attention to detail in the house is unrivaled and, as you might expect, the timber framing is the main attraction.

Photo credit – Tim Lee Photography

photo credit – Tim Lee Photography

Architect – Reese Owens
Builder – E.M. Rose Builders
Project engineer – Kevin Chamberlain
Timber – New Energy Work

Feature Project

Saltbox Colonial

You don't have to be rich and famous to own a timber frame home, although it does help. I built this reinterpreted colonial saltbox home for myself as my weekend country home. The timbers are Eastern White Pine. The design and detailing of the house was inspired by traditional Connecticut homes from the 1700s.

Photo credit – Tim Lee Photography

Photo credit – Tim Lee Photography

Chapter 7
Timber Mill Structures

America was built on the backs of its mills. From the earliest days, trees were sawn into timbers on water-powered “up and down” sash saw mills. The saw mills relieved carpenters of the back-breaking chore of hewing timbers with axes. The water powered sawmills would later be replaced by steam powered circular saw mills. Today, bandsaw mills convert logs into timber in a matter of seconds. Water powered grist mills came on the heels of the early sawmills. With large spinning millstones, they ground wheat grain into flour and corn into cornmeal. It wasn’t long before iron mills were built with blast furnaces that smelted ore into iron.

The industrial revolution of the late nineteenth century brought mill towns with large factories that manufactured textiles and everything else that a person could desire. Sears Roebuck catalogs were filled with useful and not so useful household items, all of which were being manufactured in mill towns. With the availability of consumer goods, people’s lifestyles changed and you couldn’t keep them down on the farm anymore. Young girls, farm boys, and European immigrants flocked to the mill towns to take low paying factory jobs.

The mill buildings, built mostly in the northeast, had robust timber structures supported on thick brick or stone masonry bearing walls. They were built to be fire resistant and sturdy. Following World War II, these marvelous mill buildings became vacant as manufacturing industries moved to the southeast and eventually overseas.

Today, many of these derelict old mill buildings are ripe for repurposing into offices, apartments, restaurants, or retail. They are buildings that adapt well to practically any use and people love the look of the exposed timbers and brick walls.

Feature Project

Arch Street Teen Center

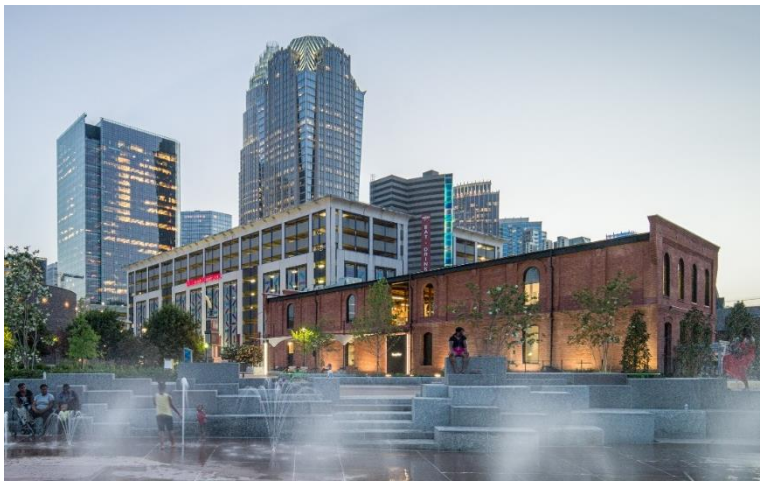
This tired old brick and timber mill building was converted into a Teen Center for the Town of Greenwich, CT in 1991. Portions of the floor framing were strategically removed to create an open, soaring space.

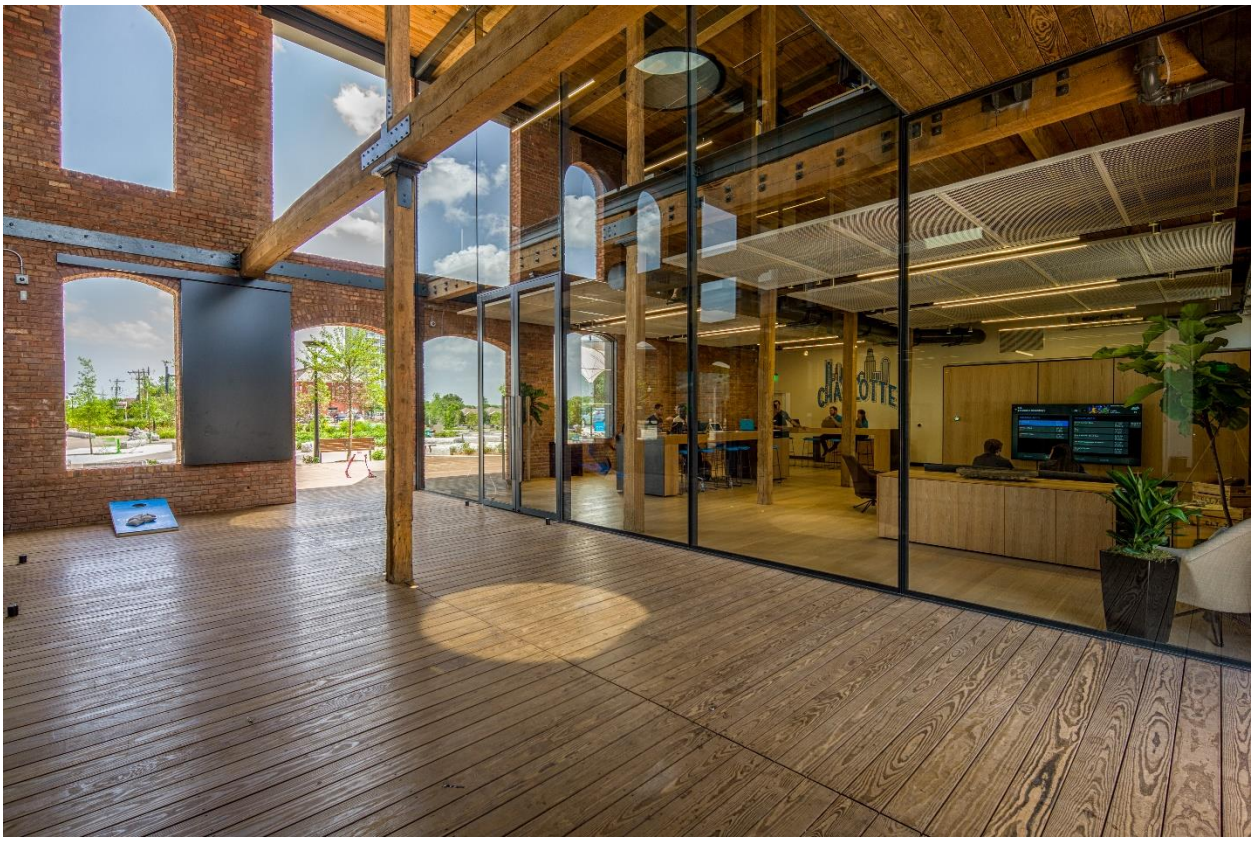
photo credit – Durston Saylor Photography

Architect – Shope Reno Wharton

Feature Project
Google Fiber

Charlotte, North Carolina is a fast-growing city with a skyline dominated by tower cranes. Businesses are flocking to the area to enjoy its warm, business friendly, climate. When Google Fiber was looking for a home for its operation in downtown Charlotte, it could have had its pick of shiny new glass office towers. Instead, it chose to be in a funky old brick and timber mill building. They wanted a unique space with character.





Timber restoration – Carolina Timberworks
Photo credit – Carolina Timberworks

Feature Projects

Tale of Two Mills

South Norwalk, CT was a vibrant industrial center in the late nineteenth century, but by the 1960s it had fallen victim to urban decay and had become a blighted, high crime area, with deserted mill buildings and storefronts on every block. In the 1970s, the City of Norwalk embarked on an ambitious urban redevelopment program for South Norwalk. But unlike urban redevelopment projects in nearby cities, Norwalk did not bulldoze its crumbling historic buildings, it set out to renovate and restore them to their former dignity.

In 1987, I helped restore a former Corset Factory that had been built in 1887 and was down on its luck with rotted roof timbers and a failing foundation. The building was converted into luxury residential condominiums for its centennial birthday.

A decade later, I worked on the restoration of a former lock factory located a block away from the old Corset Factory. The Norwalk Lock building had similar problems with deteriorated timbers and crumbling brick masonry. The building is now premium office space with shops and restaurants. Our longtime and favorite client, Shope Reno Wharton Architects, is now a tenant in the building.

It is the exposed timbers and brick that make mill buildings special. As energy codes have become more stringent in recent years, it is becoming increasingly difficult or impossible to expose the brick walls in these old mill buildings. The insulating properties of brick masonry are not very impressive. To comply with the energy code, it now usually necessary to build an insulated wall on the inside of the brick, but at least we can still show off the timbers.

Shope Reno Wharton designs signature buildings in a space where door locks were once manufactured

Feature Project

Carolina Timberworks

When Carolina Timberworks started out crafting timber structures in 2003, its shop was housed in a rusty old pre-engineered metal building in Boone, North Carolina. Eric Morley, the company founder, often lamented to me that his own shop did not represent the type of building that he was proud to craft for his customers. When his operation finally outgrew the Boone facility, Eric was excited about building a new state of the art timber shop that he and his craftsmen could be proud of.

The former shop in Boone, NC

State of the art timber shop in West Jefferson, NC

Photo credit – Carolina Timberworks

Feature Project
Sprain Brook Sawmill

photo credit – Reese Owens Architect

This historic up and down sawmill was built in 1756 and remained in operation, sawing logs into boards, up until 1926. It is powered by a unique style of waterwheel called a "flutter wheel" because it makes a sound like a bird fluttering its wings. The mill was in pretty rough shape when the current owners fell in love with it and decided to restore the mill to a fully operational condition and make it their home. The flutter wheel, gears, and millworks were accurately reconstructed with the help of architect, Reese Owens and restoration millwright, Jim Kricker.

Sawing logs in the living room; *photo credit – Bill Seitz*

Feature Project
Sutter's Mill

A lot of people know that gold was discovered at Sutter's Mill in 1848, sparking the California Gold Rush, but not many people know the whole story. John Sutter was a Swiss immigrant who in 1841 received a land grant from Mexico to build an adobe trading post at what is today Sacramento. At the time, California was part of Mexico. The United States did not acquire California until 1846. Had gold been discovered a few years earlier, Mexico might have fought a little harder to hold on to California.

Scarf joint in the streak sill

Sutter hired James Marshall, a carpenter and millwright, to build and operate a sawmill along the South Fork of the American River in 1847. While building the sawmill, Marshall noticed some shiny stuff in the tailrace. He showed the gold nuggets to Sutter and they agreed not to tell anybody about it. But word got out anyway, and before you know it, the sawmill site was overrun with gold seekers. The sawmill never actually got to saw very much timber since it was difficult to get anybody to work the mill when there was gold to be had in the river. Sutter never made any money off of the mill or off of the gold discovered at the site. The US courts denied his claims since his land grant was from Mexico, not the US. He would die penniless.

Photo credit - Alamy

Then, in 2014, I got a call from my friend, Paul Oatman, a timber framer in California. Paul had been awarded a contract from the State Park Service to reconstruct Sutter's Mill. With little more to go on than a blurry old black and white daguerreotype of the mill from 1853, Paul and I worked out the timber joinery details that were historically correct for the period and also met California's stringent seismic building codes. The reconstructed mill is now part of a California State Historic Park.

Some would fail and some would prosper
Some would die and some would kill
Some would thank the Lord for their deliverance
And some would curse John Sutter's Mill

- Dan Fogelberg

Chapter 8
Barns – For Farming and Everything Else

It is easy to get nostalgic about barns, there is just something about them. Perhaps they remind us of our agricultural roots, when everybody was a farmer and you only ate what you grew or raised. Farm life was hard, but they were simpler times, at least that is the way we like to think of them. Timber barns are the iconic monuments to those wholesome days of life on the farm.

Barn building came into its own in America. The feudal farming practices in medieval Europe did not promote the building of grand barns, except for a few English tithe barns owned by the church. Hay was stored under open structures called “hay ricks” and farm animals stayed outdoors. In inclement weather, the animals were brought into the farmhouse to bed down with the farmers. But things were different in America.

In America, everybody owned his own farm and there was a lot of land available for farming. The climate was harsher than in Europe and farm animals, hay, and crops needed shelter from the weather. Life was centered on the farm and the barn was the center of farm life. Barns needed to be large if a farm was to be prosperous, and they needed to be sturdy. There was no shortage of trees needing clearing, so the barns were built of timber.

Nowhere in early America did farms prosper the way that they did in Pennsylvania. The soils were richer and the climate was milder than in New England which suffered from long winters and boney soils. Farming life was good for the early German immigrants to Pennsylvania. Their farms produced a surplus of crops that could be sold to the city dwellers in Philadelphia for a handsome profit. So, it is not surprising that the finest and grandest timber barns can be found in Pennsylvania.

Pennsylvania barn with stone end walls

Timber barn building prospered in America. Regional barn styles evolved – New England barns were frugal, Virginia tobacco barns were crude, Pennsylvania barns were grand, and the prairie barns in the Midwest were huge. Barns were built of timber up through the late 1800s. But technological advances in agriculture would doom timber barn building.

hay track peeking out through hay doors

William Louden was an innovator in agricultural technology whose accomplishments rival those of Cyrus McCormick and John Deere. In 1867, he formed the Louden Machinery Company in Fairfield, Iowa, to develop and manufacture equipment for the dairy farming industry. They made milking stalls, barn roof ventilators, manure trolleys, and a variety of other products. But Louden's most significant accomplishment was the development of the hay track and grapple fork. Prior to that, hay had to be laboriously pitched by hand up into a barn's hay mow with a pitch fork. The hay track mounted on the underside of the barn ridge and had a trolley that ran along it with a grapple fork suspended. The fork could grab a wagonload of hay and lift it up into the hay mow effortlessly, powered by a horse pulling on a rope with pulleys.

Soon every farm needed a Louden hay track and every timber barn was retrofitted with one. The problem was, the timber tie beams were in the way of the operation of the grapple fork. So, farmers did the only practical thing, they cut out the tie beams, without consulting an engineer first. Before you know it, magnificent old timber barns began collapsing. But William Louden had the solution for that too. He realized that if he could convince dairy farmers to replace their tired old timber barns with new and bigger barns, they would have to buy more of his stuff to fill them up. He published a book of barn plans that farmers could build from with minimal carpentry skills. The Louden barns had gambrel roofs made from crisscrossed 2x6 rafters spiked together. They had a milking parlor on the lower level and a vast hay mow above. Over the next 50 years, thousands of Louden barns were built and the days of the timber barn were numbered. When people think of a barn, they envision a gambrel roofed Louden barn.

A sure sign that the tie beams were cut out

Today, many surviving timber barns have fallen into disrepair. When they were no longer needed for farming, people stopped maintaining them. It wasn't long before roof leaks were neglected and timber decay set in. Timber barn frames in good condition are a rare commodity and are sought after. They are routinely disassembled, refurbished, and relocated to begin a new life as a home, a wedding venue, a restaurant, or sometimes as just a barn.

Feature Project
Barn Transplant

photo credit – Nat Rea Photography

Every early New England home had a farm and a barn to go along with it. I was called in a few years ago to assist architect Catherine Truman with the restoration of a historic 1730s antique house in western Massachusetts. The plan included the restoration of the old barn out back. Sadly, the old barn frame was in pretty sad condition and beyond repair. So, we set out to find an antique timber barn frame that we could transplant to our site to replace the original barn. A few decades ago, it was not hard to find old barns in Vermont or New Hampshire that were looking for a new home. But the stock of old barns in New England have been pretty well picked over and we had to look further away to find a suitable timber barn frame. We eventually located the perfect barn in Ontario that was the just right size and in reasonably good condition. We had the barn dismantled, restored, reassembled, and fitted out as a guest house.

Photo credit – Catherine Truman Architects / Jane Messinger Photographer

Feature Project
Vermont Welcome Center

The Vermont Welcome Center stands at the gateway to Vermont along Interstate I-91. It is intended to resemble a New England barn. The timbers were surfaced with broadaxes to resemble hand-hewn barn timbers. I had nothing to do with the project, but it was built by my friend Doug Friant at Vermont Timberworks. I can't drive to Vermont without stopping in for a comfort stop, because I just love the building.

Photo credit – Vermont Timberworks

Feature Project
A Barn for Cars

To call it a mere garage just would not be right. We are occasionally called upon to design a barn to house and display a client's vintage car collection. While the cars in this barn may not be vintage, the barn is so much more than a garage.

Architect – Haver & Skolnick
Project engineer – Kevin Chamberlain
Timber – Carolina Timberworks

Photo credit – Carolina Timberworks

Feature Project
A Horse Farm

Most working farms today do not spend a lot of money on their farm buildings. There is no need for fancy barns to house cows, hogs, and chickens. That is not at all true of equestrian farms. Nothing is too lavish or luxurious for riding horses, although sometimes I suspect that the horses don't even notice. One thing is for sure, horses with discriminating taste do prefer timber stables. They like the smell and taste of the wood.

Architect - JBMP Architects
Project engineer – Kevin Chamberlain
Timber frame – Mid-Atlantic Timberframes
Photo credit – Landino Photo

Feature Project

A Post and Beam Barn

Post and beam barns are an affordable alternative to a true timber frame barn. Post and beam construction may look a lot like timber framing to the untrained eye, but it lacks the joinery. It might contain an occasional mortise and tenon joint, but mostly the timbers are square cut and held together with timber screws. Post and beam barns are ideally suited for a utility barn, workshop, or garage, but they may not be polished enough for a fancy structure.

Feature Project
A Party Barn

A barn is a perfect place for a celebration, whether it is a birthday party, a wedding, or a hoedown. Located on a 700-acre working farm in the mountains of western North Carolina, this party barn is actually a barn within a barn. It shares space with a herd of Black Angus and Belted Galloway beef cows inside a pre-engineered metal cattle barn. The steel structure of the cattle barn did not have the right ambiance for a party, so the crew from Carolina Timberworks built a timber barn inside with reclaimed antique timbers salvaged from a dismantled Pennsylvania barn.

Photo credit – Carolina Timberworks

Feature Project
Barn Workshop

Sometimes a barn is just a barn. This is a barn that I built for myself as a man cave workshop and to keep my tractors out of the weather. Queen-post timber trusses support the roof and second floor for a column free space on the ground floor. Timbers are rough-sawn Hemlock and were milled from standing-dead trees that had been killed by the Woolly Adelgid tree parasite.

Photo credit – Tim Lee Photography

Chapter 9
Meetinghouses and Churches

At the center of every colonial American town stood a meetinghouse. They were not just houses of worship, they were also the center of municipal government, predecessors to town halls. Everybody was expected to attend services on the Sabbath there, but it was also where town meetings were held as well as social gatherings.

Every colonial meetinghouse had a robust timber structure supporting the roof and steeple, but parishioners never got to see it since it was always concealed behind a plaster ceiling. The only person that ever did get a glimpse at the timber structure was the engineer that would be called in when the steeple started to lean.

When I first started practicing engineering in the late 1970s, glulam timber roof structures were all the rage for new churches and some of the first timber structures that I designed were for churches.

Steeple work is not for the faint of heart or for those with a fear of heights or bats

Feature Project
Saint Patrick Church

For the design of the Saint Patrick Church, I collaborated with my old rugby buddy and architect, Dan Conlon. Dan let me talk him into a timber hammer-beam truss structure. I didn't want it to be like every other boring hammer-beam truss church, so I added a second tier to the trusses. Nobody had ever tried that before and I thought that it would look cool.

Architect – Daniel Conlon Architects
Project engineer – Kevin Chamberlain
Timber frame - Vermont Timberworks

Chapter 10
Treen Framing – Timbers in the Round

While most timbers buildings are constructed of squared up timbers that have been sawn out of tree trunks, sometimes you just want to use the whole tree and celebrate its naturally round shape. That is called “treen framing.”

The roots of treen building go back to the days of log building. Log construction was first introduced to America by Swedish immigrants that settled in the Delaware River valley. Swedish log construction was later adopted by pioneers moving west. A pioneer, with no carpentry skills, could build himself a modest log home in a few weeks with nothing more than an axe, as long as there were plenty of straight trees around.


handcrafted log construction

When Abraham Lincoln campaigned for the presidency, he bragged that he was born in a log cabin to show that he was not just another aristocratic politician that was out of touch with the common man. This would always mortify his high-born wife, Mary, who would apologize and explain that they actually had a very lovely proper house in Springfield.

Log homes are still popular today, particularly in the Rocky Mountain States and the Great Lakes region. While there are companies that manufacture affordable log homes made from logs that have been machined to uniform shapes, handcrafted log homes are what people really love.

Handcrafted log builders are a lot like timber framers in some ways, but they could not be less alike in other ways. They both have a passion for building with big pieces of wood, but that is where the similarity ends. While timber framers love to cut precise joints with sharp chisels and saws, log builders only have one tool – the chainsaw. They do everything with the chainsaw - cutting notches and scribing logs. They are true artists and some of them actually fashion bear sculptures with a chainsaw in their free time. While it is exciting to watch them at work, it is also a little scary. I am sometimes tempted to pull out my phone and dial 91 holding my finger over the 1 button waiting for the blood to spurt. Fortunately, OSHA safety inspectors rarely visit log building sites.

log scissor truss

real men build with chainsaws

Feature Project
Big Rock Boathouse

This boathouse in the Adirondacks was not built on the lake, it was built in the lake. True to Adirondack style architecture, all of the framing was treen. The biggest challenge on this project was not the treen framing, it was designing the concrete foundation piers that are anchored into bedrock so that they would not be crushed by ice in the winter.

Architect – Shope Reno Wharton
Project engineer – Joe Gencarelli
Photo credit – Durston Saylor Photography

Feature Project

Fresh Air Fund Camp

The Fresh Air Fund runs a summer camp in upstate New York for inner city kids. Underprivileged kids are exposed, for the first time in their lives, to trees, streams, canoes, and squirrels – things that they don't see in their New York City neighborhoods. For some of them, it is a life changing experience.

We designed a dining hall structure that used logs rather than square timbers wherever practical for an Adirondack look. Whole logs are actually stronger than sawn timber since the grain of the wood always runs straight and flows smoothly around knots.

Timber framing – Vermont Timberworks

Feature Project
Lakefront Lodge

Perched on a ledge of bedrock overlooking a pristine lake, this lodge features treen framing on the outside and timber framing on the inside. The timbers were surfaced with an adz to create a unique texture. The timber structure features hand-forged ironwork crafted by a local blacksmith.

Architect – Reese Owens
Photo credit – Tim Lee Photography

Chapter 11
Timber Bridges

Covered Bridges

There is nothing more iconic of early America than the covered bridge. They were covered for a very practical reason, the roof and siding helped to keep the timbers dry, extending their service life. If the timbers were left exposed to the elements, it would not have been long before they rotted away. Over the years, I have read a variety of different explanations. One of the most frequently repeated myths goes like this - a horse riding into a covered bridge would think he was riding into a barn and would not get spooked by the river below. Well, horses don't scare that easily and they are just not that dumb.

The most common covered bridge structure was the Town Lattice truss. It made for a robust bridge structure that was easy to build. The Town Lattice was patented in 1820 by Ithiel Town, a prominent architect from Connecticut. Town never actually built a bridge himself, but he sold the rights to use his design to covered bridge builders. He charged a royalty of one dollar for every foot of bridge span. If he caught someone building a Town Lattice bridge without having purchased the rights to the design, he would impose a penalty of two dollars per foot of span.

West Cornwall bridge

Worrall Bridge, Rockingham, Vermont; *photo credit - Alamy*

The only covered bridge that I have actually worked on in my long engineering career was the rehabilitation of a bridge in Rockingham, Vermont. My involvement was limited to the replacement of the timber bridge deck, the approach spans, and the timber guardrails. All in all, not a very challenging assignment. A little more than a year after the project was completed, hurricane Irene made landfall in New England. The heavy rains from the storm had all of the rivers and streams in Vermont at flood stage. I watched the evening news in horror as they showed a clip of the Rockingham covered bridge being washed downriver. I later breathed a sigh of relief when I learned that there had actually been two covered bridges in Rockingham and my bridge was still safe and sound.

Modern Timber Bridges

We do not build covered timber bridges much anymore. With the technological advances in the preservative treatment of timbers, we no longer need to cover up the bridge timbers. It is now okay to leave them out in the rain. Treated timber bridges are more durable than steel and concrete bridges since deicing salts don't seem to bother them.

While timber bridges are not well suited to interstate highways with heavy truck traffic, they are ideal for short span bridges on secondary roads. The bridge structures that we have designed are mostly preservative treated glulam structures. The timber bridge decks are usually paved over with asphalt. Drivers seldom even notice that they are driving on a timber structure. You never actually get to see the timbers unless you were to climb down the embankment and look up from the river bed. Unlike older timber bridges whose deck planks would make clapping noises as you drove over, modern timber bridges don't make a sound.

Country lane bridge

Vehicle bridge designed by Gray Organschi Architects; *photo credit – Paul McGuirk*

Feature Project

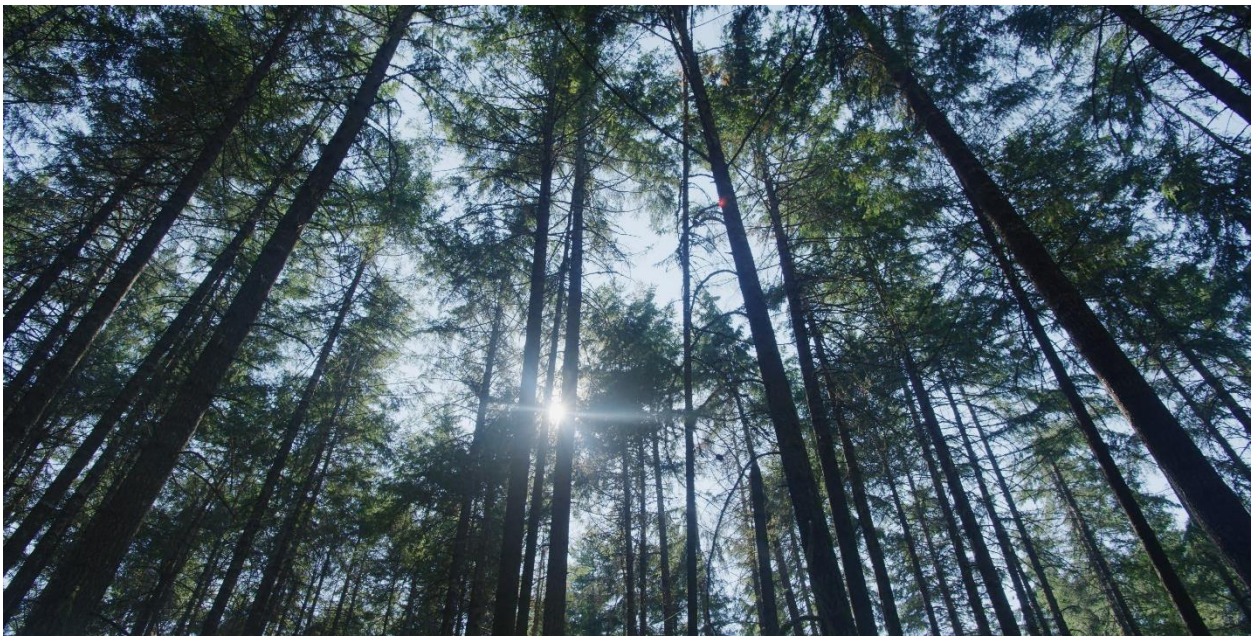
Bow River Pedestrian Bridge

This slender and elegant timber bridge is set in the Canadian Rockies and bridges the Bow River in the heart of a Canadian National Park. It has an impressive clear span of 80 meters (260 feet).

Engineer – Fast + Epp
Photo credit – www.naturallywood.com

Chapter 12
It Starts with Trees

Trees are the answer! Could you please repeat the question?



Coastal Douglas Fir forest; *photo credit – Ainsworth Communications / www.naturallywood.com*

Timber and Sustainability

It is natural to feel just a little guilty about cutting down magnificent trees to build timber structures. It is easy to get emotional about trees. There is just something about trees that make you want to throw your arms around their trunk and give them a big bear hug. But when you think about it, when you harvest trees, you are not really killing them, you are giving them a whole new life.

It is actually good for the health of a forest to harvest mature trees that are past their prime, making room for younger trees to grow and prosper. It is essential to responsible forest management to periodically thin the trees in a forest and harvest the less vigorous older trees. If a forest is neglected and not managed sustainably, the health of the forest will degrade and not only will the trees suffer, but the wildlife living in the forest will also suffer.

The logging industry has gotten a lot of bad press over the past couple of centuries, and some of it has been well deserved. In the 1800s, everybody thought that there was a limitless supply of trees and you could cut down an entire forest and move on without ever looking back. But the logging industry today has really cleaned up their act, at least in North America. We still hear stories about tropical rainforests in Brazil being destroyed and that is inexcusable. But such crimes against the environment are not characteristic of the logging industry as a whole. Today, sustainable forestry is a number one priority.

Early days of logging in the Pacific Northwest

Everybody has a different idea of what sustainable forestry really means and how you measure it, but there are a few things that everybody can agree on. It is all about healthy trees, protecting streams and rivers, minimizing soil erosion, protecting natural forest ecosystems, avoiding catastrophic forest fires, and enhancing wildlife habitats.

It is important to protect old growth forests. An old-growth forest is a forest where the trees have never been harvested. Old-growth forests contain a diverse mix of tree species of various ages which provide unique wildlife ecosystems. Not all of the trees in an old-growth forest are actually old. All trees have a finite life span and they die of natural causes when their time comes. Not all large mature trees are old-growth. Most large trees that are harvested for timber come from second and third growth forests. There are actually very few surviving old-growth forests in the United States and most of them are in National Forests that are protected from logging operations.

The science and technology of managing forests and harvesting trees is called “silviculture.” Foresters have developed a variety of silvicultural strategies for managing a forest. Every forest has a unique blend of tree species, soil conditions, terrain, and climate. The strategy that is most appropriate for a particular forest depends on the site conditions and the type of trees being grown. Some tree species love full sun and are intolerant of shade, such as Douglas Fir, Eastern White Pine, and Oak. Other tree species love the shade and avoid full sun, such as Maple, Hemlock, and Spruce.

A common forest management strategy is called “selection cutting.” Individual, mature, overstory trees that are approaching the end of their natural life are selected for harvesting. This allows the younger understory trees to thrive and prosper since they no longer have to compete with the older trees for sun light and nutrients. Selection cutting is an effective method for promoting the growth of shade tolerant tree species.

A clear-cut site may look like a crime scene at first, but in a year, it will be a lush meadow, and in 10 years it will be a vibrant young forest

Another common forest management strategy is “clear-cutting,” also referred to as “even-age forestry” since all of the trees that regenerate will be of a similar age. As you might imagine, all of the trees in a prescribed area are harvested, allowing new trees to grow in full sun conditions. Clear-cutting is actually the only way to regenerate a forest of shade intolerant trees. The practice of clear-cutting has gotten a bad rap from environmentalist and the public in general because a recently harvested site looks like a disaster area to the untrained eye. But actually, a properly executed clear-cut is beneficial to wildlife, particularly deer and wild turkey that need forest fringe ecosystems. Clearcutting mimics natural forest disturbances such as forest fires and windfalls that are essential to the regeneration of forest ecosystems.

A variation on even-age forestry is called “shelterwood cutting.” Similar to clear-cutting, most, but not all of the trees in an area are harvested. A few tall trees are left behind to drop their seeds on the cleared area for tree regeneration. Once the new seedlings have become established, the large shelter trees are harvested. This method is effective when the cleared area is not manually replanted.

Some people have an aversion to any type of tree harvesting out of principle. They confuse logging operations with deforestation. If you cut down a forest and pave over it to build a shopping center, that is deforestation. If you harvest mature trees to promote new tree growth, that is forest management. They are not the same thing.

Sustainable timber harvest

Whatever forest management strategy is used, sustainable forestry requires that measures be taken to minimize any potential adverse environmental impacts. So how do you know if the timber being used for a particular project was harvested from a sustainably managed forest?

There are certification programs that verify that particular certified wood products have been harvested from sustainably managed forests. The two most common certification programs are the *Forestry Stewardship Council (FSC)* and the *Sustainable Forestry Initiative (FSI)*. There are subtle differences between the two programs, but you can't go wrong with either one. As you might expect, there is a modest upcharge to purchase certified timbers.

Carbon Sequestration

The environmental issue on everybody's mind these days is climate change and carbon in the atmosphere. When you listen to politician, scientists, and environmentalists talk about halting climate change, they talk about measures that will reduce the rate that we throw more carbon into the atmosphere. But you will never hear them talking about ways to remove carbon from the air. They have no idea how to do that. We only know of one way to remove carbon from the atmosphere – growing trees. Trees are the answer.

Trees are made up of hollow fibers of cellulose bound in a matrix of lignin – and that stuff is mostly carbon. By the magic of photosynthesis, trees extract carbon dioxide from the air and water from the ground to manufacture carbon rich wood tissue powered by energy from the sun. At the same time, trees release oxygen into the atmosphere. You couldn't ask for a better deal.

A young vibrant forest

In a young forest, the growing trees consume a lot of carbon dioxide out of the atmosphere. But as a forest ages, and growth slows, the rate of carbon removal slows also. Older trees will eventually die and fall to the forest floor where the wood decays and releases its carbon back into the atmosphere. So, when a forest reaches an age of between 100 and 120 years old, it stops removing carbon from the air. There is still tree growth, but the amount of carbon being extracted from the air to support new growth is balanced by the amount of carbon being released by decaying trees. That is why it is so important to harvest mature trees before they die of natural causes and decay. It is especially important in forests that have been decimated by disease or tree killing insects like the pine bark beetle or the emerald ash borer. Dead trees that are still standing in the forest should be harvested before they can decay or fall victim to fire.

If you harvest older trees from the forest, and mill them into timbers for building magnificent timber structures, the carbon in the wood tissue will remain sequestered as long as the structure is standing. So, as you can clearly see now, harvesting trees to build timber structures is a noble act.

Different Woods for Different Folks

Every species of wood and every tree has its own unique characteristics and personality. It is important to be able to understand and deal with those different wood personalities when selecting the right wood for a timber project. You can build a timber structure out of practically any species of wood, but there actually only a handful of wood species that are commonly used for timber construction.

By far, Douglas Fir is the most common wood for timber construction. It is not because it is such a beautiful wood, it looks okay, it is because of its strength. Since Douglas Fir is substantially stronger than most other wood species, you can use smaller timbers to carry the structural loads. That means that the timbers will look more graceful and you also end up needing to use a lot less wood.

Douglas Fir trees grow mostly in the Pacific Northwest – Oregon, Washington, and British Columbia. They grow tall and they grow big, some rivalling the size of California Redwoods. Technically they are not a true Fir tree. At one time, they were called Oregon Pines. Some hard-core dendrologists refuse to use the name Fir and will call them “Douglas Trees”. But I refer to them as Douglas Fir anyway and everybody seems to know what kind of wood I am talking about.

Douglas Fir queen post trusses

Eastern White Pine is another popular wood for timber structures. It grows mostly in the Northeast and it also grows tall and big, though not quite as tall as Douglas Firs or Redwoods. It has a very pale color that darkens with age to a honey color that is referred to as “pumpkin pine”. It proudly displays lots of knots which give it character but also diminishes its strength. An Eastern White Pine timber has approximately 50% of the strength of Douglas Fir timber of the same size. Consequently, it tends to be used mostly for residences where the spans are modest.

Eastern White Pine sapling

Knots in Eastern White Pine are unlike knots in other types of wood because of the way that the tree grows. Every year, the Pine tree will grow a new cluster of branches that all join the trunk at the same spot. This is referred to as a whorl of branches. When the tree is eventually milled into a timber, the timber will have clusters of knots where the branches had been. These are called “whorl knots” and they result in weak spots in the timber.

Whorl knots

Eastern White Pine is susceptible to blue-stain which is caused by the sap-stain fungus that begins growing inside the wood shortly after the tree is felled. The fungus grows quickly if the tree is harvested during warm weather. That is why some mills will only cut Pine in the winter. The fungus leaves blotchy blue-grey stains in the wood that do not wash off with bleach. Blue-stain was once considered a defect and was cause for rejection of a timber until the lumber industry decided to market it as a feature. They called it “denim pine” and started selling it at a premium price.

Red Oak king-post truss with Denim Pine ceiling

Oak is the king of the hardwoods. It is used for everything – furniture, architectural millwork, railroad ties, pallets, and sometimes even timber frames. Oak is a wood that breaks all of the rules. It is very hard, but it is not particularly strong. There is a belief that timber from trees that have grown slowly in an old-growth forest are denser and stronger than timber from trees that have been grown quickly. While that is generally true of most softwood timber, it is absolutely not true of Oak timber. Slow grown Oak is brash, or brittle, and a poor choice for a structural timber.


White Oak weathers to a silver grey

Most tree species will grow and prosper only in specific geographical regions and in very specific climates. Oak trees grow everywhere, as long as they have full sun, soil, and water. They are tough trees and can adapt to practically any growing condition.

Oak trees grown in North America are classified as either Red Oaks or White Oaks. There is a subtle difference in the color of the heartwood. As you might expect, Red Oak is redder and White Oak is whiter. But there is a much more important difference. When exposed to the weather, Red Oak will suck up water like a sponge, turn black, and rot. White Oak does not. It will turn a silver grey and take a long time to rot.

When used in a timber frame, Oak behaves badly. As it dries and seasons, Oak timbers will twist and form prominent seasoning checks, but they don't do it quietly. In the first few years, you will hear snaps, crackles, and pops. Occasionally you might even hear a bang which can scare people. It is all part of Oak's quirky personality. You either love it for its little quirks, or you hate it.

When it comes to glulam timbers, you have fewer choices of wood species to pick from. You can get glulam timbers in Douglas Fir or Southern Pine. Both species look similar and have very similar strength characteristics. Southern Pine takes preservative treatments better than Douglas Fir, so if you are building a timber bridge, Southern Pine is your best bet. If the project is located in one of the Confederate States, south of the Mason-Dixon Line, Southern Pine is the best choice because that is where it is grown. If the project is located anywhere else in North America, Douglas Fir is usually the best choice.

Reclaimed White Oak cruck frame

Wood Science 101

It is important to know a little about wood science if you want to avoid making big mistakes when designing or building a timber structure.

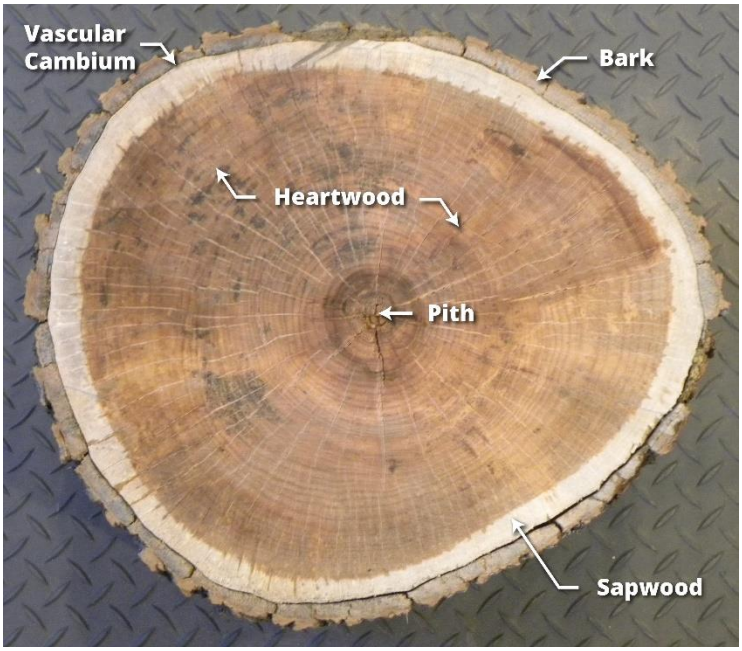
There are two types of trees, deciduous trees and conifers, also called evergreens. Deciduous trees grow a new set of leaves every spring and discard them in the autumn so that you can rake them up. Conifers have needles instead of leaves and they keep them for life. The wood from a deciduous tree is classified as a hardwood and the wood from a conifer is classified as softwood. Just to confuse everybody, some softwoods are actually harder than some hardwoods, for instance, Balsa is classified as a hardwood and it is softer than everything.

It is important to remember that wood was not made for woodworking or for building with, it was made to hold up and support the life functions of trees. Building things with wood is a secondary use that wood was not originally intended for.

Most people think that trees grow from the ground up, but actually, they grow from the inside out. If you examine the stump of a recently felled tree, you will see a bunch of concentric circles which we all call tree rings. At the very center, or heart of the stump, is the pith, also referred to as juvenile wood. The pith is the oldest part of the tree. It was formed when the tree was just a young sapling in the forest. The juvenile wood is weak and unstable, it is the troublesome child.

Every year, a tree will grow a new ring of wood on the outside. That happens just inside the bark in a thin layer of living tissue called the vascular cambium. If you examine an individual tree ring, you will see a wide, light colored band, called spring wood or early wood, and a thinner, dark band, called summer wood or late wood. In the springtime, there is a lot of rain and trees grow rapidly, creating the early wood. By mid-summer, things are starting to dry up and growth slows. That is when the late wood is created. Late wood is denser and stronger than early wood.

If you examine the tree stump further, you will notice a band of wood inside the bark that is light in color. This is called the sapwood. The wood is darker in the core of the tree, and that is the heartwood. The sapwood is the younger part of the tree and serves as the tree's plumbing. Water from the roots rises up to the branches and leaves through the hollow cells of the sapwood as sap is conducted back down. The heartwood structurally supports the tree, flexing in the wind. The cells of the heartwood contain oily compounds called extractives. The extractives impart color, fragrance, and decay resistance to the wood.



Tree anatomy

Wood has a love-hate relationship with water. All wood contains some water. Freshly cut wood contains a lot of water. When a tree is felled and milled, the wood is saturated with water and is referred to as green. Some of the water is contained inside the hollow center of the wood cells and this is called free water. The cellulous wood cell walls also contain water and this is called bound water. As a timber seasons and dries, the free water is the first to evaporate. Once all of the free water is gone, but the cell walls are still saturated, the wood is said to be at its Fiber Saturation Point (FSP). The FSP is a moisture content (MC) of approximately 30%. As the timber continues to season and dry below the FSP, the wood will start to shrink in size, but it does not shrink the same amount in every direction. It does not shrink at all along its length, it shrinks across the grain and it shrinks less in the radial direction than it does in the tangential direction. It is the difference in shrinkage rates that cause a timber to twist and warp as it seasons. Eventually, the timber will season to a stable moisture content that has acclimated to the temperature and humidity of the space. This is called the Equilibrium Moisture Content (EMC). For timbers within an air-conditioned and heated space, the EMC typically ranges between 6% and 8%.

Moisture meter

Seasoning checks follow the grain

As a timber seasons and shrinks, seasoning checks will form in the timber. Checks are radial separations of the wood that form along the grain. They are widest at the face of a timber and diminish in width as they approach the heart of the timber. Checks are often mistaken for splits and can sometimes frighten people who think that the timber is failing. Seasoning checks are perfectly normal and do not impair the strength of a timber. In fact, it is unusual to find a timber that does not exhibit some seasoning checks. They are not something that needs fixing. So, if you see a seasoning check in a timber that wasn't there last week, just relax, everything is going to be alright.

The vast majority of timber frame structures are built from unseasoned, green timbers that season over a few years after the structure is completed. The timber joinery must be designed to accommodate the anticipated timber shrinkage and seasoning checks are expected. But for some fussy projects, that just isn't good enough and seasoned timbers must be used. An obvious solution is to use older, reclaimed timbers that are already fully seasoned. Reclaimed timbers have a patina that only comes with age and make for marvelous timber structures, but sometimes it is hard to find the exact timbers that you need. There is an entire industry that has sprung up of reclaimed timber venders. They are scroungers that scour the countryside looking for derelict barns and mill buildings to salvage timber from.

Kiln drying is the common method for drying lumber. A wood kiln is like a huge oven that lumber is cooked in for several weeks to accelerate the seasoning. Problem is, you can't kiln dry a large timber. If you try, the outside of the timber will dry a lot faster than the core of the timber and that creates big problems. There is another way though – radio frequency drying. Radio frequency kilns are like huge microwave ovens that dry timbers from the inside out. It doesn't work with all species of timber, but it does works great on Douglas Fir.

Radio frequency kiln; *photo credit – FraserWood Industries*

With glulam timbers, you don't have to worry so much about the timbers seasoning. Glulams are fabricated from lumber that has already been kiln dried to a 15% moisture content. It is still higher than the eventual EMC, so you still have to detail the connections to accommodate some shrinkage and if the structure is in a damp environment, such as an exterior canopy, or over a swimming pool, you need to consider the effect of timbers swelling and expanding.

Wood and water get along with each other just fine as long as it is in moderation. But, if they start seeing too much of each other, and the wood stays too wet for too long, fungal decay can set in and that seldom ends well. More on that later.

Making the Grade

All timbers used for structural applications are required to be graded and must bear a grade stamp that attests to the grade that has been assigned to it. Certified graders examine each timber as it comes down the line at a sawmill and they assign a grade to each timber based on established grading rules. The grading rules put limits on the size and quantity of common wood defects which the lumber industry prefers to call “natural growth characteristics.” While some wood defects described in the grading rules are primarily cosmetic concerns, others influence the strength of a timber.

The strength limiting features of a timber are knot size and straightness of the grain. The strongest timbers have small knots and the grain of the wood runs straight down the length of the timber. Grade limiting features such as wane, skips, pitch pockets, and pin holes are purely appearance concerns and have no effect on the strength of a timber.

Douglas Fir timbers are readily available in a #1 grade or Select Structural grade which is the highest strength grade. Most other timber species are available in #2 grade. Timbers graded as #3 are not suitable for structural applications but make good firewood.

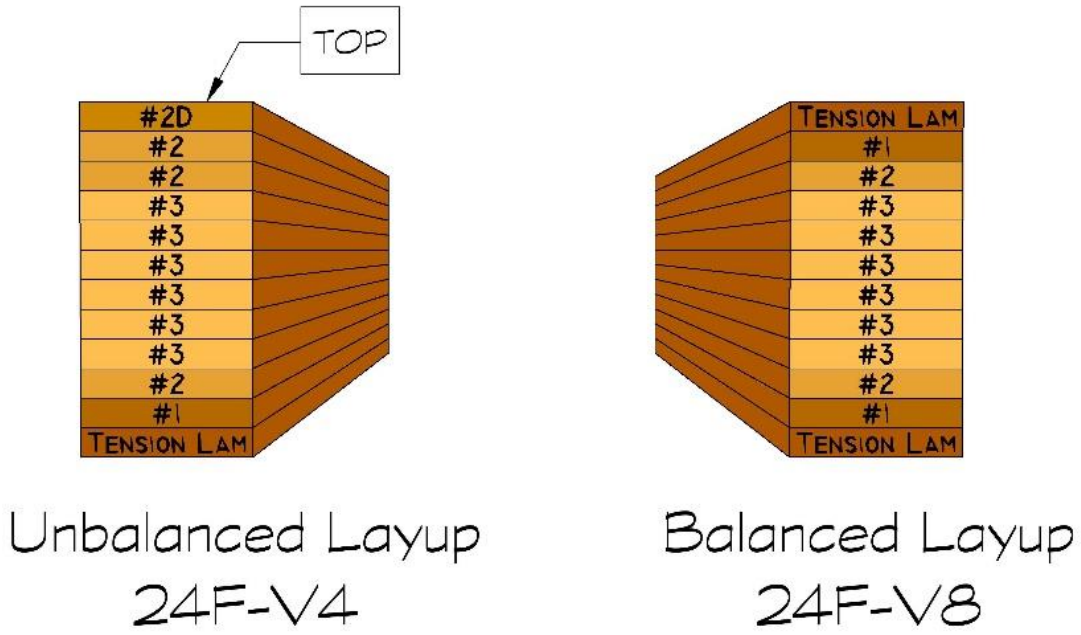
Rare specimen of #1 Eastern White Pine; *photo credit – Joe Turco, New England Timber Framers*

Things get a little more complicated with glulam timbers. Glulams are manufactured from laminations made from several different grades of lumber with the highest grades used where the stresses are highest and lower grades used where the stresses are not as high.

Most glulam timbers have an unbalanced lamination layup. The strongest grade lumber, referred to as tension lams, are only on the very bottom. Unbalanced timbers are suitable for simple span conditions where high tension stresses only occur on the bottom of a beam. The top of each timber is stamped with the word “TOP” so that the timber is positioned in the correct orientation. If you ever look up at a glulam timber roof structure and see the word “TOP” stamped on the bottom of a timber, that is not a good thing.

This side up

Glulam timbers with a balanced lamination layup have tension lams on both the top and bottom of the timber. They are suitable for continuous span conditions or beams with cantilevers where high tension stresses occur in both the top and bottom of a timber.



Glulam timber lamination layup

Chapter 13
Making Connections

The trick and art to designing a timber structure is how you put the timbers together. The rest of the stuff is easy. It has often been said, mostly by me, that a timber structure is really nothing more than a bunch of timber joints that happen to be separated by beams and posts.

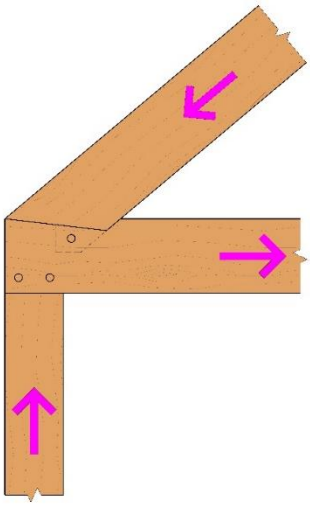
Structures with practical connection details are usually cost-efficient and easy to fabricate and assemble. Whereas, poorly conceived connection details will often result in an overly costly structure plagued with difficulty.

Traditional Joinery

With traditional timber framing, the joinery details are inspired by historical joinery that has been used for centuries. The time-honored, noble, mortise and tenon joint, secured with oak pegs, is still the workhorse for simple timber connections, but there are actually scores of historic timber joints, each one suited to a specific application. Through centuries of trial and error, these joints have been tested by time and their performance and shortcomings are well documented. But the historic joints only work on the easy stuff.

Traditional English tying joint

For most of the timber structures that I work on, the timber joinery looks very little like the historic joints used a couple of centuries ago. I seldom have the luxury of just copying something that has been done thousands of time before.



The engineering of timber joinery is not a cookbook process of following overly prescriptive codes and standards. It requires no small measure of ingenuity, creative energy, and experience.

The most challenging joints to design are truss joints which often must be capable of resisting substantial tension forces. The trick is to configure the joints so that tension forces are resisted by notches and shoulders that are in compression. You can't always make that trick work, but it is great when you can.

Computer Crafted Joinery

Most of the larger timber shops today have automated their production with Computer Numerical Controlled (CNC) fabrication. The German made Hundegger has become the machine of choice. CNC joinery looks a lot like hand-crafted joinery on the outside, but if you peak into the inside of a joint, there are subtle differences. For instance, CNC cut tenons have rounded ends instead of square corners. There are some types of joints that are easy to cut with the Hundegger, but are virtually impossible to cut by hand and there are other joints that can be easily hand-crafted but the machine just can't duplicate them. The machine doesn't do a better job than a skilled craftsman, it just works a whole lot faster with fewer coffee breaks.

CNC fabricated timbers

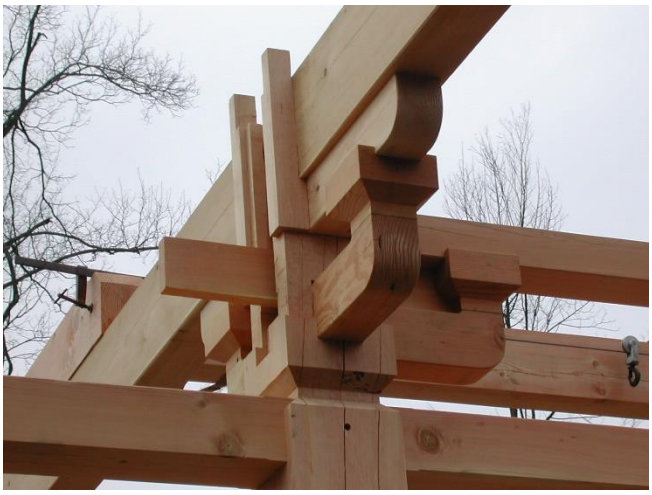
Rounded dovetail joints are easy with a Hundegger

The Hundegger in action; *photo credit – South County Post & Beam*

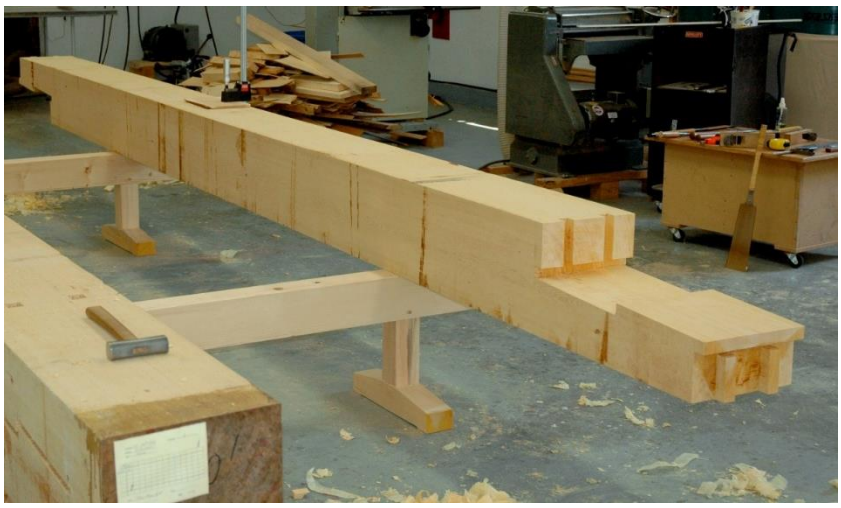
Some hand work is still needed; *photo credit – South County Post & Beam*

Traditional Asian Joinery

All the while that timber technology was developing and evolving in Europe, a radically different type of timber frame construction was evolving in Asia. China and Japan each developed their own unique ways of building with timber. Somethings were the same – mortise and tenon joints were the preferred method of joining timbers. The tools even looked similar, but there were subtle differences. Chisels were pushed rather than struck with mallets and saws were pulled instead of pushed. The timber traditions that evolved in Japan were characterized by timber joinery that was far more intricate and precise than anything that was being built in the West.



Timber detail from a Zen temple



Japanese Kanawa Tsugi scarf joint; *photo credit – Torii, Inc.*

Until a couple of centuries ago, there was very little communication or technology exchange between the West and the Far East, so Asian timber framing was not influenced by European practices at all. Today there is a renewed interest in Asian timber traditions and on the West Coast, traditional Japanese timber construction has something of a cult following.

Japanese style timber frame with purlins lashed to the rafters; *photo credit – Antique Barn Company*

Glulam Connections

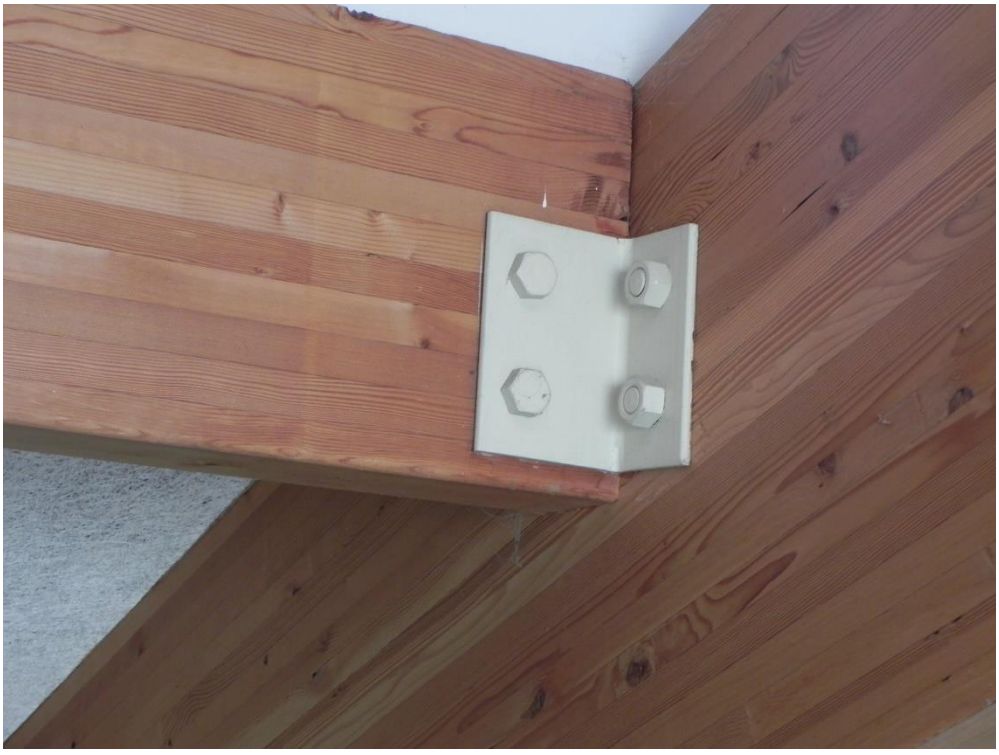
Glulam timber connections are inspired by twentieth century structural steel construction. The reason that glulam timber connections emulate structural steel connections is that most structural engineers know a lot about designing a structural steel frame and practically nothing about designing a timber structure. So, when faced with the challenge of a timber project, they approach it the same way as a steel project.

Traditional glulam connections are characterized by exposed steel gusset plates with a lot of bolts. It is also traditional to paint the plates black just so that they are really in your face. Personally, I don't care for the look and am not a glulam traditionalist. In fact, some old-time glulam fabricators think that I am a bit of a rebel. I have spent most of my career trying to get away from exposed plates and bolts in glulam structures.

Besides the aesthetic issues associated with exposed steel plates, angles, and bolts, these types of connections sometimes perform poorly, particularly with deep timbers where there are several bolts in a row. The steel connection plates or angles tend to restrain the seasoning shrinkage of the timber and can cause the timber to split.

This stiffened seat connection is secured to the timber column with timber rivets

Common structural steel connection with steel angles and high-strength bolts



Glulam timber connections often emulate structural steel connections

Nuts and Bolts

Steel bolt and a hardwood peg

All timber connections require some type of fastener to hold the joint together, and sometimes to transfer structural forces through the connection.

For traditional timber joinery, the fastener of choice is a hardwood peg, traditionally called a tree-nail or trunnel. They are usually made from straight grain, seasoned oak, and are typically one-inch diameter with a tapered end. Traditionally, the peg holes in the mortise and tenon were offset slightly so that the peg would pull the joint together as the tapered end was driven through the offset holes – a technique called “draw boring.”

For glulam timber construction, the humble steel bolt is the most common and versatile fastener. A bolt is substantially stronger than a hardwood peg. When the fasteners are used to transfer structural forces, a hardwood peg can’t compete with a steel bolt.

Cast iron ogee washers perform better than flat washers where a bolt head or nut is bearing on the face of a timber. They also look cool.

Ogee washer

Timber rivets are well suited to connecting steel hardware to the side of a glulam timber. Timber rivets are nail-like fasteners with flattened oval shanks and tapered heads. They are driven through round holes in thin steel plates, and the tapered rivet heads nest tightly in the drill holes. The steel plate should be no thicker than ¼ -inch. The rivets are used in groups with the rivets spaced one-inch apart. They are usually driven with a pneumatic impact nailer that is suited to shop fabrication, but you can also use a hammer.

Timber rivets

Timber screws

High-strength, self-drilling timber screw have become popular in recent years and they come in a wide variety of shapes and sizes. Unlike lag screws, they do not require a pilot hole, making them much easier to install in the field.

Feature Project
The Depot

The Depot is a retail complex in Kent, Connecticut. It features a timber truss roof structure that was designed by my old friend and structural engineer David Kufferman. What Dave did was to use steel castings for the timber connections. I think that it was a clever solution and it looks pretty cool. By a stroke of luck, the owner of the building was a wealthy industrialist who happened to own an iron foundry in German where he produced the castings.

Cast steel connection hardware

Chapter 14
Little Details for Big Timbers

Curves, Tapers, and Chamfers

The great thing about building with timber is that it is a lot like woodworking. Think of it as a really big piece of furniture. You can taper the timbers, form them into curves, and apply decorative carvings. How cool is that?

You can even add texture to the surface. It is common to plane timbers smooth and apply a penetrating oil finish. My preferred penetrating oil for timbers is a blend of paraffin wax and citrus oil, manufactured by Heritage Natural Finish. It makes the structure smell like oranges – truly a mouth-watering experience. But if you want something a little less refined, a rough sawn finish might just be the thing. For a truly rough and rugged look, the timbers can be surfaced with axes and adzes to resemble hand-hewn timbers.

Hewn texture; Photo credit – Vermont Timberworks

Curves add a touch of elegance. Timbers can have a curve cut into one face with a bandsaw. This results in a graceful taper. You always want to leave the opposite face of the timber straight so that its strength is not diminished.

Curved knee braces add a touch of elegance

Grain matched curved truss bottom chord

Shipbuilders from days gone by were old hats at steam bending timber planks to compound curves. For the ship's ribs, they would hunt for bent trees to cut their curved ribs from. Today, if you want a curve in a timber, it is best to use a laminated timber. Forming curved shapes is like falling off a log for a glulam manufacturer. But sometimes you don't want to see the lamination stripes that are characteristic of a glulam. If you want it to look like it was always one piece of wood, then it calls for a "grain-matched" laminated timber. You start with a full-size sawn timber and then you saw it into a stack of thin slicers that are glued back together in the desired curved shape. It's like magic.

The lamination lines in this grain matched timber are subtle

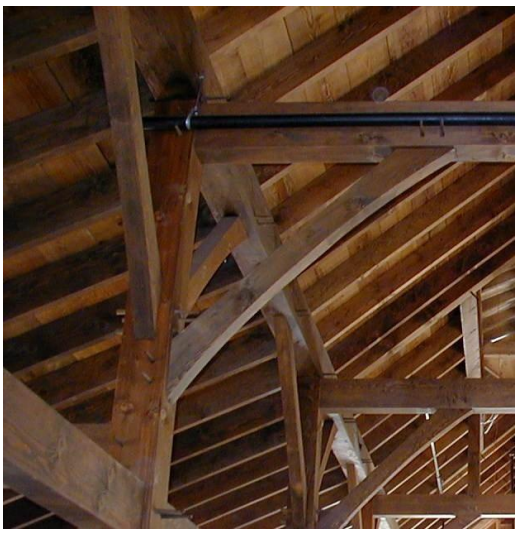
Nothing dresses up a timber like a chamfered edge. Chamfers are not just decorative, they are also practical, particularly where people can bump into the timber. A square edge can look a little ratty after it has been bumped into and chipped a few times. A chamfered edge always looks crisp. Chamfers also improve fire resistance – a sharp edge will ignite sooner than a chamfered edge. For an added touch of elegance, scrolled stops, called lamb's tongues, can be carved at the terminations of the chamfers, just like a cabinetmaker would do.

Chamfered timbers with *ski tip* stops on the joists and *lamb's tongue* stops on the posts and girders

Light and Lighting

Architecture is all about manipulating light. You can start out with a spectacular looking timber structure, but if you fail to consider how light plays off the structure, you can end up with something that looks dull. Don't mess this up – it is not that hard to get it right!

Color contrast is crucial. Timbers need a backdrop that they can stand out against. Without that, the structure does not pop. The biggest mistake that most architects make is to have a wood ceiling over a timber structure that is made of the same type of wood and is the same color as the timbers. If you add a dark stain to everything, it gets even worse. It is like dressing the structure in camo – everything blends together into a brown blur. You can get away with putting a dark stain on the timbers if you stain the ceiling white to create visual contrast.



Dark stained timbers are dreary and dull

Proper lighting is also crucial. Recessed downlights are fine for general illumination. But for drama, mount fixtures on top of the timbers pointing up and bounce light off of a light-colored ceiling.

Light fixtures mounted on top of the timbers bounce light off a plaster ceiling; *photo credit – Tim Lee Photography*

Design for Durability

A timber structure can last for centuries as long as you take care of it and don't do anything stupid. Timbers like to be kept warm and dry. They really don't like to be left out in the rain. If timbers get wet frequently, and cannot dry out, fungal rot will turn them into a mass of useless, spongy mush before you know it. Any outdoor structure needs a roof over it to keep the timbers out of the rain and should be built from a naturally decay resistant wood.

Fungal decay behind an exposed gusset plate

Certain wood species contain extractives in their heartwood that make them naturally decay resistant – Cedar, Redwood, Cypress, Black Locust. But it is just the heartwood that is decay resistant, the sapwood will rot just like any other wood. For timber structures, Alaska Yellow Cedar is the wood of choice when decay resistance is desired. It weathers to a rich silver-grey. Alaska Yellow Cedar comes mostly from British Columbia, despite its name. Douglas Fir is a marvelous wood with many fine qualities, but decay resistance is not one of them. Avoid using Douglas Fir outdoors unless it has been preservative treated.

Alaska Yellow Cedar log heading for the sawmill; *photo credit – Bruce Lindsay / Evergreen Specialties Ltd.*

If a timber structure is fully exposed to the weather and not protected by a roof. Preservative treatment is a necessity.

Preservative treatment goes back to the days of the Romans who would soak their ship timbers in olive oil dregs to preserve them. It was once common to treat wood roof shingles with used motor oil. I remember when there was no finer wood preservative than creosote if you could tolerate the smell. But preservative treatment technology has come a long way since then.

Pressure treatment technology has changed everything. Preservative chemicals are infused into a timber rather than just being a thin film sitting on the surface. The most common and familiar preservatives are water borne salts such as CCA and ACQ. That is the type of pressure treated lumber that you find at the lumber yard for building decks and outdoor structures. It leaves the wood a gross green color and is corrosive to nails and other metal objects. Southern Pine is the preferred wood for treating with these types of preservatives.

Pentachlorophenol, commonly referred to as “Penta”, is a solvent based preservative that is used on bridge timbers and guardrails. It leaves the wood a dark brown color with a surface that is sometimes slimy.

There is a new generation of preservative treatments that are permethrin based and are becoming popular for timber structures. The preservative is clear and colorless and does not change the appearance of the timber. The problem is, the preservative is clear and colorless, so you can never be absolutely sure that it was actually treated.

Careful detailing is important for durability. It is important that the structure’s feet be kept dry - post bases need to be raised off of the ground. Never bury timbers in the ground or encase them in concrete. Mortise pockets need drip holes to allow water to drain out of them. External steel gusset plates should be avoided since the wood behind them cannot dry out easily.

Granite plinth keeps the timber post base high and dry

It is not that hard to get the details right so that your timbers can live long and prosper.

Chapter 15
Wrapping it Up

The timbers form the skeletal frame of a building and they need a skin to enclose them. That usually means a Structural Insulated Panels (SIP) system for the roof and exterior walls. SIPs are a sandwich of oriented strand board (OSB) faces that are bonded to a rigid foam core. The most common SIP core is expanded polystyrene (EPS), although extruded polystyrene (XPS) and urethane cores are also popular.

SIPs create a very energy efficient building envelope. The panels have a high insulating R value with minimal thermal bridging and are extremely air-tight. Sealing of the panel joints is crucial and is accomplished by injecting expanding foam into the panel joints.

The disadvantage of SIPs is that if you fail to do a thorough job of sealing all of the joints, the associated air leakage can result in condensation and durability issues. The other thing is that electricians hate them because it is tricky to run electrical wiring inside them.

SIPs with XPS core (pink) and EPS core (white)

SIP roof panels

SIP panels enclose and support a restored barn frame

SIP wall panels

SIPs have poor fire-resistance and this has disqualified them from being used on some larger mass timber projects where the Building Code has stringent requirements for fire endurance.

Floor systems require special attention. If you were to lay floor planks directly over a timber structure, you will have sound isolation problems and you will tend to hear every footstep above you. It is more practical to build up a false floor on top of the timbers. This not only provides acoustical isolation, but it also gives you some place to hide HVAC ductwork, plumbing pipes, electrical wiring, and recessed ceiling lights.

Cross-Laminated Timber (CLT) panels have been a game changer. CLTs have seen increased use for floor, roof, and wall panels on timber buildings in recent years. CLTs do not have the durability or fire- resistance issues that have plagued SIPs. Of course, with CLTs you have to add insulation to the outside of them.

False floor provides a space for utilities

CLT floor panels with curvilinear shapes

Feature Project
Stone Chapel

This former historic stone church was abandoned and lay derelict for half a century before being acquired by the neighboring homeowners who have converted it into a guest house. The original roof structure was rotted and falling in. I designed a replacement timber roof structure for the chapel. Timber Howe trusses are supported on the original stone masonry bearing walls and CLT panels, made from Austrian Spruce, serve as the roof deck system.

Builder – Renaissance Partners
Timber – South County Post & Beam
CLT timber – KLH
Project engineer – Ken Flemming
Photo credit – Ted Sihpol

Epilogue
Zen and the Art of Timber

Well, now you have heard my stories and made it to the end. Maybe you have been bitten by the timber bug and are itching to build something out of timber yourself. You certainly will never look at a timber building the same again. You will find yourself noticing little details that would have never caught your attention before. You may be a little more critical also. You might find yourself looking at a particular detail and say to yourself "Jim never would have done it that way!"

As you have probably figured out by now, there is some science to designing and building timber structures, but it is mostly an art. There is also something Zen about it all, it can't be explained, only experienced. It is not a coincidence that all of the ancient Zen temples were timber structures.

I feel very lucky to have been able to do what I do for a living. Designing a cool structure and watching it rise from the ground is a real thrill. Certainly, the most fun that I have had with my clothes on. I have also been very fortunate to have been able to collaborate with so many talented architects and timber craftsmen over the years. But this is not a memoir – I am not ready to hang up my spurs. I believe that the best works of my career are still yet to come. Today there are so many architects and engineers that are designing mass timber buildings for the first time – something that I have been doing my entire adult life. I have found myself settling into the role of the wise old Zen Master of timber.

Resources

WoodWorks – Wood Products Council
www.woodworks.org

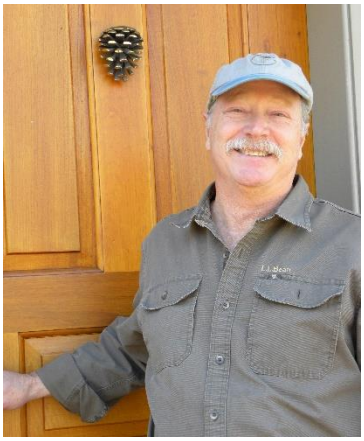
Timber Framers Guild
www.tfguild.org

Timber Frame Engineering Council (TFEC)
www.timberframeengineeringcouncil.org

Timber Frame Headquarters
www.timberframehq.com

DeStefano & Chamberlain, Inc.
www.dcstructural.com

The Author



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Jim is a Fellow of the *Structural Engineering Institute (SEI)*, a founder of the *Timber Frame Engineering Council (TFEC)*, and the past-chairman of the *Structure Magazine* editorial board.

He is the author of *Antique New England Homes and Barns – History, Restoration, and Reinterpretation* as well as countless technical publications on timber design and construction.