I. Construction Innovation Forum • NOVA Award Nomination

Instructions

Step 1 Enter a Descriptive Name for the Process/Method/Technique you are nominating on line A of this page.

Step 2 Complete this page,
"I. Construction Innovation Forum • NOVA Award Nomination"
a. Be sure to provide original signatures in Section B and E on this page. Your nomination cannot be reviewed without them.
b. If you need additional space for names and addresses you may attach additional pages for names and address information. You may attach extra pages only for sheet I.

Step 3 "II - Innovation Description" — attach one (one only) 8-1/2˝ X 11˝ page that gives a succinct written description of the innovation. Put the name of the innovation at top of page. Tell us what you think is innovative about this. You should include:
- What the innovation is
- Why it is innovative
- What it changed or replaced
- Where and when it originated, has been used, and is expected to be used in the future
- If the nomination is for an innovative project, specifically identify its innovation.

Please type, with 1˝ margins, 10 characters per inch, 6 lines per inch.

Step 4 "III - Innovation Illustration" — attach one (one only) 8 1/2˝ X 11˝ page that contains one or more photographs, drawings, tables, graphs, clauses, etc., that visually describe the innovation. Do not submit more than one page of visuals. The jurors will see only one sheet for review. Put the name of the innovation at top of page.

Other You must submit 12 (twelve) sets of sheets I, II and III (a total of 36 pages).

Nominations are due September 15 mailed or delivered to:
The Construction Innovation Forum, 1000 Campus Drive, Suite 100, Ann Arbor, MI, USA 48104-6792, Phone: 313-995-1855, Fax: 313-995-5002

A. Name of Innovation: FiRP™ Reinforced Glulam Technology

B. Person(s) and /or Organization(s) Primarily Responsible for the Innovation (Those to whom the NOVA Award should be presented.)

Name:	Dan A. Tingley
Title:	Executive Director
Affiliation:	Wood Science & Technology Institute (N.S.), Ltd.
Address:	850 SW 15th Ave., Suite 1B Corvallis, OR 97333
Phone:	(541) 753-4548
Signature:	

(Signature(s) indicate acceptance of the nomination and consent to have CIF research and make presentations on the innovation for the purpose of jurying and publicizing awards.)

C. Other Primary Sources of Information on the Innovation: (In addition to the persons nominated above.)

Name:	Robert Leichti	Bruce Pooley	Elizabeth Delo
Title:	Associate Professor		
Affiliation:	Oregon State University	Timber Design	Civil Eng. Research Foundation
Address:	FRL108, OSU, Corvallis, OR 97330	6261 W. 69th Place Arvada, CO 80003	1015 15th St. NW, Suite 600 Washington, DC 20005-2605
Phone:	(541) 737-4212	(303) 425-6722	(202) 842-0555

D. Independent Reference(s) familiar with the use of the Innovation

Name:	Paul Gilham	Timothy McCarthy	Charles McClaskey
Title:	Sr. Engineer	Business Development Mgr.	VP, Business Development
Affiliation:	Western Wood Structures	Dow Chemical Company	Reichhold Chemicals, Inc.
Address:	20675 SW 105th Tualatin, OR 97062	2040 Dow Center Midland, MI 48674	PO Box 13582 Research Triangle Park, NC 22709
Phone:	(503) 692-6900	(517) 636-9193	(800) 448-3482

E. Person(s) making nomination:

Name:	Dan A. Tingley	Robert Leichti
Title:	Executive Director	Associate Professor
Affiliation:	Wood Science & Technology Institute (N.S.), Ltd.	Oregon State University
Address:	850 SW 15th Avenue, Suite 1B Corvallis, OR 97333	FRL108, OSU Corvallis, OR 97330
Phone:	(541) 753-4548	(541) 737-4212
Signature:		

(Signature(s) indicate familiarity with the the innovation and signify that information contained in the nomination is correct to the best of one's knowledge.)

FiRP™ Reinforced Glulam Technology

Dan A. Tingley, Executive Director
Wood Science & Technology Institute (N.S.), Ltd.
850 SW 15th Avenue, Suite 1B
Corvallis, OR 97333
(541) 753-4548

D. Independent References

Andrea Dry
Marketing & Sales Engineer
Zoltek Carbon Fiber Business Unit
3101 McKelvey Road
St. Louis, MO 63044
T: (314) 291-5110

Steve Loud
Editor
Composites News International
Division of Composites Worldwide, Inc.
991 Lomas Santa Fe Drive, C469
Solana Beach, CA 92075-2125
T: (619) 755-1372

FiRP™ Reinforced Glulam Technology

FiRP™ Reinforced glulam are structural glued laminated timbers reinforced with high-strength fiber reinforced plastics (FRP). FiRP™ Glulams are having a major impact on the future of the glulam industry and the use of FRP composites in infrastructure and building construction. Glulams are an engineered wood composite used for structural members. Conventional glulam technology uses carefully rated wood laminae, appropriately positioned to satisfy anticipated loading requirements. Glulams enable more efficient utilization of forest resources because low strength material can be positioned in areas subjected to low stresses and have been widely used in the United States since the 1930's without major changes in the technology. Pressures on forest resources imposed by forestry constraints and population growth have made conventional glulam technology noncompetitive, a trend that FiRP™ Reinforcement technology has reversed.

FiRP™ Technology includes methods of design and manufacturing. The design method for FiRP™ Glulam is compression-based, much akin to that used for reinforced concrete, which is a radical departure from the tensile-based designs of conventional glulam structures. This new method is fully described and demonstrated in ICBO Report No. 5100, representing the first major model building code approval in the world for a reinforced wood product. In addition to the new design methodology, the 14-year long development and subsequent evolution of the FiRP™ Technology led to the development of a method for establishing and monitoring allowable design values for high-strength fiber-reinforced plastics, a method which is the first of its kind in the world.

FiRP™ Glulam has many potential structural applications including residential, commercial, and infrastructure. There are currently over 250 structures world-wide in either design, construction or service stages. Applications have led to substantial economies, in comparison to conventional glulam as less wood and lower grades are required when the FiRP™ Technology is used. The technology is especially well suited to structures such as bridges and domes wherein dead load is a large component of the total expected design load. A typical design with FiRP™ Glulam specifies 25 to 40% less wood fiber than would be needed to carry the same load with conventional glulam. FiRP™ Glulam is designed with single grade layups of lower grade materials. With its lower volume, the weight of the FiRP™ Glulam is substantially diminished. Less volume means fewer chemicals are required for preservative treatment, while weight reductions lead to lower transportation costs, superstructure weight is reduced, and foundation requirements are minimized. Furthermore, reduced chemical requirements allow the smaller members to be more completely treated, ultimately leading to an enhanced service life. These features combine for economy and enhanced performance.

The patented FiRP™ Glulam technology leads to enhanced productivity in manufacturing glulam and ease of use in construction. The inventor, Dan Tingley, currently holds four issued patents with one more allowed to be issued in the United States in the fall of 1996. Twelve additional patents are now pending; these patents are also being filed internationally. The patents cover every aspect of the FiRP™ Technology from adhesion of the FRP panel to itself and wood using conventional wood manufacturing adhesion products as well as design methods and processes of reinforced product manufacture.

FiRP™ Glulam is less variable in stiffness and strength, and therefore, considered more reliable than conventional glulam. The uniformity of stiffness means that girders can be expected to respond similarly to loads. For example, an HS-25 bridge with two 25-m spans was recently constructed at Clallam Bay, WA using FiRP™ Glulams for girders. When the girders were set in place, initial deflections of the six main girders differed by less than 3 mm. As a result, the construction crew spent less time installing and adjusting the members. This uniformity should ultimately also benefit the wear surface because the bridge will flex more uniformly.

Reinforced glulam is more efficient than conventional glulam because it can be more fully stressed. Conventional glulam design for the Clallam bridge would have given a preferred member size of 237 by 1524 mm using only 76% of the beam's bending capacity. The FiRP™ Glulam girders are 171 by 1651 mm, a 30% reduction in fiber volume, and at design loads, the girders are at 98% of allowable bending stress.

Environmental impacts of FiRP™ Technology are also very positive. Wood is an environmentally friendly, sustainable resource that serves our global environment. The FiRP™ Glulam technology leads to reduced pollution and energy usage when used in structures instead of metals and concrete. Conventional glulam requires a raw material base that originates from a relatively homogeneous forest resource, whereas the FiRP™ Glulam technology can utilize a highly variable raw materials supply. Plastic matrix reinforcement components can be made from recycled plastic.

FiRP™ Glulam technology will have an impact beyond design and construction. Its impact on wood fiber savings and its economic potential for synthetic fiber production is breathtaking. With the excellent performance and favorable economics of FiRP™ Glulam, it is reasonable to believe that FiRP™ Glulam will become the conventional glulam of the industrialized nations in the not-too-distant future.

Table 1. FiRP™ Glulam Beam Cost Comparison with Unreinforced Glulam of Same Species with a Similar Capacity for a 20m Span

Glued Laminated Timber Member	Actual Beam Width (mm)	Beam Depth (mm)	Volume of Wood Fiber (m^3)	Total Weight (kg)	FiRP™ Panel Length (m)	Wood Fiber Cost ($/$m^3$)	Glue Cost ($/$m^2$)	Wood Cost ($)	FiRP™ Cost ($)	Mfg Cost ($)	Total Beam Cost ($)	Savings ($)	Savings (%)	Weight Savings (kg)
Unreinforced	180	945	4.491	20.024	--	$900	$3.59	$4.042	--	$1166.02	$5.208	--	--	--
Reinforced	135	1015	3.617	16.131	12.000	$600	$3.59	$2.170	$196	$1002.71	$3.369	$1.839	35	3.89

Figure 1. Cross section of FiRP™ Glulam.

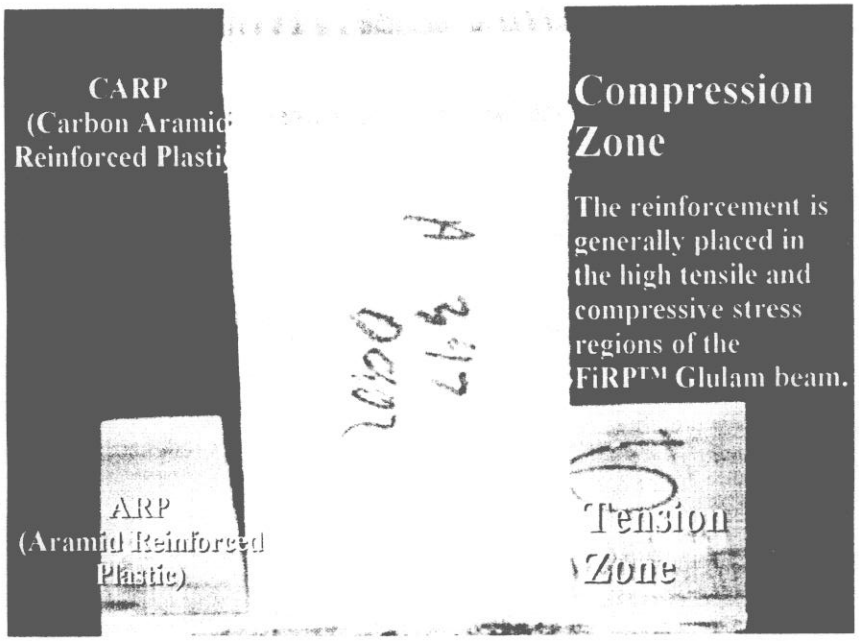


Figure 2. Clallam Bay Bridge located in Clallam Bay, WA. The first HS-25 FiRP™ Glulam bridge built in the United States. Designed and erected by Western Wood Structures, Inc., Tualatin, OR and manufactured by Duco-Lam, Drain, OR.



INVESTIGATOR'S SUMMARY
Nomination 9724
Investigator: Photios Ioannou

FIRP™ REINFORCED GLULAM TECHNOLOGY

The Innovation

Glued-laminated wood beams (glulams) are engineered wood composites that have been used widely as structural members. Conventional glulam technology uses carefully rated wood laminae that are appropriately positioned and glued together to satisfy anticipated loading requirements. Lower grade material is positioned in areas subjected to lower stresses, whereas higher grade material is confined to areas of high stress, thus enabling the efficient utilization of the available wood fiber resource. Glulam technology has remained relatively unchanged since its introduction in the 1930s. Pressures on forest resources imposed by forestry constraints and population growth, however, are making conventional glulam technology less competitive for reasons related to cost and material availability.

The innovation presented here is a new method for reinforcing glulams with *fiber reinforced plastics* (FRP) to produce a composite that has significantly improved mechanical and economic properties. The combination of FRP and glulam technology produces benefits are akin to those of steel reinforcement in concrete (i.e., the composite is better and cheaper). **At the heart of this innovation is the design and production of fiber-reinforced plastic (FRP) plates (in the form of long ribbons) that have the desired mechanical characteristics to serve as glulam reinforcement, and which can be glued to wood laminae using conventional adhesives as part of the standard laminating process with no change in the existing glulam beam fabrication technology**. The two products, FRP and reinforced glulam, are marketed under the trade names FiRP™ Reinforcement Panel and FiRP™ Glulam, respectively, and have been nominated for the CIF Nova Award.

Description of the Reinforcement

The idea of producing reinforced glulam beams is not new. The wood products industry has tried for years to use steel, aluminum, and fiberglass with no success. Even the inventor of the FiRP™ technology started by experimenting with piano wire before moving on to fibers. Fiberglass and carbon fibers have also been tried before, but in all previous attempts the reinforcement did not stick to the wood and did not bond well to the glues used to make laminated beams. Some other ideas involved expensive changes in the way glulams are made. Matching the strain of the FRP laminates to the wood was one of the keys to success after years of marginal performance in glulam composite programs.

The fiber-reinforced plastic (FRP) reinforcement plates embedded into the glulam are composed of 100% aligned high-modulus fibers—aramid, carbon, or fiberglass—at

approximately 66% by volume embedded in a thermosetting plastic matrix. Depending on glulam design and application, these fibers can be used in either pure (e.g., aramid only) or hybrid form (e.g., aramid-carbon). Recycled material (such as used soft drink plastic bottles) may be used as a component in the manufacture of matrix resin.

The resulting FRP plates (FiRP™) are in the form of long ribbons that tend to be the same width and length as the beam and range in thickness from about 6 to 10 mm (0.25-0.40 in.). The FiRP™ reinforcement plate is positioned between the first and second laminae of the glulam beam and is glued using conventional adhesives as part of the standard laminating process (to produce FiRP™ Glulam). The single wood lamina that covers the FiRP™ reinforcement (at the bottom and/or top of a beam) protects it from fire and gives FiRP™ Glulam fire ratings similar to conventional glulam.

The structural role of FiRP™ reinforcement within a glulam is similar to that of steel within reinforced concrete. Thus, FiRP™ reinforcement can be positioned in areas of positive stresses, (e.g. the bottom of a beam), in which case it acts as tensile reinforcement, or it may be positioned in both the bottom and top of a glulam in which case it acts as tensile and compressive reinforcement. The FiRP™ reinforcement panel may run the entire length of a beam (full-length reinforcement), or it may extend over areas of high stress only (partial-length reinforcement).

The type of reinforcement fiber used (aramid, carbon. or fiberglass) and the degree of beam reinforcement depend on loading and reinforcement requirements. Usually, carbon or fiberglass fibers are used in the compression zone at the top of a beam and aramid fibers are used in the tension zone at the bottom of a beam, but this varies. The degree of reinforcement is in the range of 0.3%-2.5%.

The process for producing FiRP™ reinforcement and its applications are described in five patents issued in 1994, 1995, and 1996. Twelve other patents remain pending.

Advantages of Reinforced Glulam Beams

FiRP™ Glulams have distinct advantages over conventional glulams, primarily due to two factors: a reduction in the required beam cross section and the use of lower grade wood material. A typical design with FiRP Glulam requires 25-40% less wood fiber than would be required to carry the same load with conventional glulam. Moreover, many combinations of conventional glulam require that as much as 60% of the total volume be higher grade (L1 &L2) wood fiber. These higher grades come from old-growth lumber that are becoming more expensive and more difficult to get in larger dimensions. In contrast, FiRP™ Glulam requires single grade layups of lower grade (L3) material that comes from less expensive newer-growth lumber.

The smaller beam cross sections of FiRP™ Glulams mean lower weights, reduced transportation costs, lower superstructure weights, and minimized foundation requirements. For those members that require chemical treatment, lower volume also results in lower overall requirements for preservative chemicals and more complete treating for smaller members, ultimately leading to an enhanced service life. Because reinforced glulams are smaller and lighter, they are easier to handle, both during fabrication and in the field. They require less lifting capacity, present less difficulty in handling and improve productivity.

Enhancement of Mechanical Properties

In terms of performance, FiRP™ Glulams are less variable in stiffness and strength, and therefore more reliable than conventional glulams, making both design and construction easier. Uniformity of stiffness means that girders can be expected to behave alike. A good example is the bridge built in Clallam Bay, Washington, which opened to two-way highway traffic use at the beginning of 1996. This bridge represents the first reported application of FiRP™ Glulams for the construction of a bridge capable of supporting HS-25 vehicular loads, using two 30 m (98.42 ft) spans, with each span being supported by three FiRP™ Glulam girders, each with a cross section of 171 by 1651 mm (6.75 by 65 in). When set in place, the initial deflections for the six main girders differed by less than 3 mm (0.12 in). As a result, the construction crew spent less time installing and adjusting the members. This uniformity should also benefit the rest of the superstructure and the wear surface because the bridge will flex more uniformly.

FiRP Glulams are more efficient than conventional glulams for long span applications, such as the Clallam Bay Bridge, because they can be more fully stressed. In this particular case, a conventional glulam design would have given a preferred member cross-section size of 237 by 1524 mm (10.75 by 60 in.) using only 76% of the beam's bending capacity at a predicted deflection of L/565 (where L is the span). The FiRP Glulam girders with a cross section of 171 by 1651 mm (6.75 x 65 in) represent a 30% reduction in wood fiber volume, and at design loads they are at 98% of allowable bending stress with a deflection of L/505.

The use of reinforcement in a glulam tends to increase its shear capacity. Reinforced Douglas-fir beams in use in the United States realize a factor of 1.21 increase in shear capacity over unreinforced Douglas-fir beams.

The use of reinforcement in a glulam beam also tends to increase the bending modulus of elasticity (MOE). Lower grades experience the highest increases, which are often greater than 30%. Higher grades experience a more modest increase, between 10 and 15%. During research, it was found that low grade laminations (Douglas-fir, L3) when reinforced with the FiRP™ Panel experienced a bending modulus of elasticity increase from 1.5×10^6 psi (unreinforced) to 1.8×10^6 psi (reinforced), a 20% increase.

During the testing required for code approval in the United States, the difference in moment capacity between low and high grade Douglas-fir reinforced with FiRP™ Panel was minimal. Finger joint strength (which is included in the reinforced design moment calculations presented in the ICBO ER5100), was more of a controlling factor than the visual grade. For the purposes of these calculations, a finger joint strength of 5000 psi (5% lower exclusion limit estimated with 75% confidence) was assumed. The average increase in design capacity for low grade lumber is nearly 100% (compared to the National Design Standard).

Because of the distinct advantages of using low grade lumber (larger increase in MOE while remaining equivalent in strength to high grade lumber), the majority of the reinforced beams manufactured in the United States, use Douglas-fir L3 grade (low grade) with less than 0.50% reinforcement (by cross section). Thus, the highest cost savings are realized when reinforced glulams are made of low grade lumber (reduced cross section and utilization of less expensive low grade lumber). Improvements in mechanical

properties, as described above, lead to overall cost savings that tend to exceed 25%, including the cost of reinforcement.

Code Approval — Design Methodology

The use of FIRP™ Glulam was approved in September, 1995, by the International Conference of Building Officials (ICBO), publisher of the Uniform Building Code, one of the three building codes used in the US. The code approval process was accomplished in 12 months, from the date of the first proposal to ICBO to issuance of the report number (ICBO ER5100).

The approved evaluation protocol, developed to demonstrate the design methodology as well as the technology, required the testing of more than 700 full-sized glulam, representing the major commercial wood species in the United States and Canada and the complete range of anticipated sizes and reinforcement strategies. The testing project was the largest of its kind in the history of glulam development in the United States.

As the FiRP™ technology developed, it became clear to the project staff that the test data would support a major change in glulam design philosophy. The new FiRP™ Design method is compression-based, similar to that used for reinforced concrete, and thus is a radical departure from that used for conventional timber glulam design, which is tension-based. The compression-based design philosophy for reinforced glulam may in fact be more appropriate for wood than concrete because of the ability of wood to exhibit elasto-plastic behavior in the compression zone, whereas concrete experiences brittle failure in compression.

As part of the code approval process, evolution of FiRP™ technology also led to the development of a worldwide first-of-a-kind method for establishing and monitoring allowable design values for high-strength fiber-reinforced plastics (FRP), now included in the ICBO code approval. This is another important event for plastic composites in the structural products marketplace.

Background of Innovation

Inventor

This technology has been in the development stages for nearly fourteen years. The inventor is Canadian Dan Tingley, a native of Nova Scotia with bachelor's and master's degrees in forest engineering and civil engineering. Mr. Tingley has worked as a professional structural engineer for more than twenty years and has also taught limit state design courses in timber engineering at the Technical University of Nova Scotia. He started the Wood Science & Technology Institute twelve years ago in Eastern Canada, and worked for several years on the invention at his native Nova Scotia before finding the proper composition and orientation of plastic fibers that would bond to the wood using current glues and manufacturing methods. He then moved the company and further research and development to the U.S., in Corvallis, Oregon.

Development of the Reinforced Glulam Beam

The research, development, and implementation for the FiRP™ Glulam was accomplished by a consortium of academic, manufacturing, and engineering partners, orchestrated by the inventor, Dan Tingley, including the following:

- Wood Science & Technology Institute (NS), Ltd.
  The inventor's (Dan Tingley's) company acting as the lead organization.
- Oregon State University [Departments of Forest Products (R.J. Leichti, Associate Professor), and Civil Engineering (J. Peterson, Associate Professor)].
  Served the project with fee-based testing and analytical services including beam testing and stress analysis (experimental and finite-element).
- Elk River Enterprises, Inc., bore the cost of reinforcement development and testing, and provided all manufacturing of the FiRP™ Glulam. In exchange for providing the financial backing for the project, Elk River Enterprises, Inc. received the rights for technology use and sublicensing in the United States.
- American Laminators, Inc. (P. Martini, Executive President)
- Western Wood Structures, Inc. (P.C. Gilham, Chief Structural Engineer).
  Assisted with the development of the design method and review of the load test data, then designed and constructed bridges and building systems with the new technology.
- Advanced Materials Engineering Centre in Halifax, Nova Scotia.
  Pultrusion development and testing of primary FRP properties.
- IKV-Institute for Plastics Processing in Aachen, Germany.
  European testing of FRP properties.
- Omega Point Laboratories in San Antonio, Texas.
  Full-scale FiRP™ Glulam fire testing.
- Du Pont (Kevlar aramid fiber), Akzo-Nobel Fibres (Twaron aramid fiber), Akzo Fortafil Carbon Fibers, and Reichhold Chemical (vinyl ester resin).
  Provided assistance with fibers and resin.
- Other corporations involved with the auditing and verification of the new design formulas included the Weyerhaeuser Research Group, Warnock Hersey/ Inchcape Testing Services, and the American Institute of Timber Construction.

Reinforced glulams are manufactured commercially under the trade name FiRP™ Glulam by American Laminators, Inc., and Duco-Lam, Inc., both of Drain, Oregon, under sublicenses from the exclusive licensee Fiber Technologies, Inc. Many other companies in the US are also seeking sublicenses from FTI to use FiRP™ technology. Negotiations are under way with potential licensees in other countries to transfer manufacturing and sales for FiRP Glulams worldwide. Other applications using FiRP Reinforcement panels are now being developed and licensed.

Descriptions, Publications, and Past Awards

FiRP™ glulam technology has been presented in several civil engineering publications such as ASCE News, High-Performance composites, and Civil Engineering. The innovation and its applications and economics have also been discussed in a variety of technical papers and forums, such as the Pacific Timber Engineering Conference (1994), Structures Congress XIII (1995), Western Bridge Engineers' Seminar (1994), the 10th International Conference on Composite Materials (1995), the International Conference on Composites in Infrastructure (1996), the International Wood Engineering Conference (1996), and the September 1996 issue of Civil Engineering magazine.

In September 1995, an Evaluation Report for the commercial product was issued by the International Conference of Building Officials - Evaluation Service, Inc. (ICBO).

FiRP™ glulam technology has already won the Civil Engineering Research Foundation (CERF) Charles Pankow award for innovation in 1996.

Cost Comparison Examples

The following reinforced glulam versus unreinforced glulam cost comparisons represent an actual glulam manufacturing facility financial model for use of FiRP™ Panel as a reinforcement. All cost examples were supplied by Dan Tingley.

Unreinforced Beams Re-Engineered as Reinforced Beams

The following examples present the typical cost savings associated with using FiRP™ Glulams. The unreinforced Douglas-fir beams can be replaced with reinforced beams that meet or exceed the specified mechanical properties (shear, moment, and bending stiffness) and achieve the overall cost savings summarized below:

CASE	BEAM SIZE	CONTROLLED BY	OVERALL COST SAVINGS
(a)	5-1/8" x 36" x 60'	Deflection	21%
(b)	6-3/4" x 33" x 36'	Moment	39%
(c)	5-1/8" x 12" x 15'	Shear	23%

All unreinforced beams are simply supported and are fabricated using a 2,400 psi bending stress layup with a modulus of elasticity of 1.8×10^6 psi.

Table 1 contains the estimated design properties of the unreinforced beams given above, with the corresponding reinforced beam replacements. All the reinforced beams were designed using low grade wood and fiberglass-aramid reinforced plastic (FARP) FiRP™ Reinforcement.

The Beam "a" option was designed such that the bending stiffness was at least that of the unreinforced beam. Table 2 displays the cost comparison between the reinforced and unreinforced beams. The overall cost savings is estimated at 21%.

The Beam "b" option was designed to exceed the moment capacity of the corresponding unreinforced beam; although, the bending stiffness is close to the

unreinforced beam. Table 3 displays the cost comparison between the reinforced and unreinforced beams. The overall cost saving is estimated at 39%.

Beam "c" was designed to exceed the shear capacity of the corresponding unreinforced beam. Table 4 displays the cost comparison between the reinforced and unreinforced beams. The overall cost saving is estimated at 23%.

The reinforced beam options have smaller cross-sections and utilize inexpensive low grade lumber. According to these estimates, an overall cost savings of 36% can be realized. Note the assumptions of the wood cost: $400/MBF for low grade lumber and $600/MBF for high grade lumber.

The most important point to be made about the reinforcement technology is this: the use of minimal reinforcement (less than 0.5% by cross section) and low grade lumber in a glulam is more economical in most design situations than an unreinforced glulam. Also, reinforced glulams are often more economical than steel or concrete options.

Applications

FiRP™ Glulam has many potential structural applications including residential, commercial, and infrastructure uses. It is especially well suited to structures such as bridges and domes where dead load is a large component of the total expected design load. As of this time it has been used primarily for members subjected to bending loads.

Descriptions of three projects that used FiRP™ Glulams appear below. These real-world examples are interesting case studies of the technology's potential economic advantages over conventional glulams, steel, and concrete.

Zongas Bridge Cost Comparison

The Zongas Bridge is a vehicular bridge that is 4.3 m wide by 30.5 m long designed to carry HS20-44 loading. The bridge is on a private driveway near Puyallup, WA. The bridge girder layout calls for three girders placed 1525 mm on center. The exterior girders are 222 by 1600 mm FiRP™ Glulams. The design of the exterior girders required Douglas fir L3 laminations with three layers of 1.8 mm thick aramid-reinforced plastic (ARP) placed 38 mm above the soffit of the beam. The interior stringer was 171 by 222 mm FiRP™ Glulam also with three layers of ARP. The transverse deck panels were 130 mm unreinforced glulam, and these were used to make the roadway surface.

For comparative purposes, the Zongas Bridge was also designed in conventional glulam, steel, and precast concrete. A 130 mm glulam deck was assumed for both glulam systems as well as the steel system. The costs and dead weights of the bridge girders and deck are compared in Table 5 for the four structural systems. The cost figures must be interpreted with caution because the figures do not include treatments for the glulam systems, painting for the steel, delivery, pier costs, or erection.

If conventional glulam girders had been used on this project, the exterior girders would have been 273 by 1752 mm with the interior girder being 222 by 1752 mm. Thus, the reinforced girders used only 73% of the fiber required by the conventional glulam. This volume differential led to substantial saving in preservative treatment because less treatment chemical is required for the same preservative retention rate.

Taylor Lake Bridge

The Taylor Lake Bridge is the first reinforced glulam bridge to be put into service. This pedestrian bridge is owned by the Wasco County Planning Department and is located near the city of The Dalles, 85 mi. east of Portland, Oregon. The bridge is part of the first phase of The Dalles River Front Bike Train, which links Taylor Lake to the Crate's Point discovery center.

The deck components consist of 2x6 Douglas fir planks supported on 4x8 floor joists spaced 24 in. on center. The floor joists are supported on 4x12 floor beams spaced 8 ft on center. The floor beams are supported by fabricated steel hangers at each end, and each hanger is connected to the main bridge girders with bolts. The two main bridge girders are glulam beams reinforced with three layers of ARP. Partial length reinforcing was used over the middle 54 ft of each girder. The wood laminations in the reinforced glulam are AITC combination 2.

For comparison purposes, the bridge girders were designed using both unreinforced glulam and reinforced glulam. The reinforced glulam design resulted in a smaller section (in both width and depth). The total reduction in wood volume was approximately 32%. The total cost savings is estimated at 27%, as shown in Table 6. Figure 3 contains a picture of the Taylor Lake bridge.

Clallam Bay Bridge

The Clallam Bay bridge was recently constructed in Sekiu, Washington using FiRP™ Glulam girders. The bridge consists of two simple spans, each 24.8 m, for a total span of 49.6 m with an HS-25 load rating. Six Douglas fir girders (L2 grade), spaced 1.6 m center-to-center, were used for each span. A plan view of the girder layout is given in Figure 1. The exterior girders were 222 by 1459 mm with 15.2 mm of aramid-reinforced plastic as a tensile reinforcement placed between the outer two tension zone laminations. The interior girders ere 171 by 1459 mm and had 12.5 mm of carbon/aramid-reinforced plastic as a tensile reinforcement placed between the outer two tension zone laminations. The bridge deck was a conventional transverse glulam deck composed of 52 panels. Glulam was also used for deck stiffeners and curbs. All of the bridge components were pressure treated with pentachlorophenol.

If this bridge had been constructed using conventional glulam, the dimensions for the interior and exterior girders would have been 273 by 1524 mm. Thus, the reinforced bridge used only 67% of the wood fiber that a conventional glulam design would have required. The cost savings, which included reduced wood fiber and treatment costs, was nearly 24% as compared to conventional glulam (Douglas-fir, 24F-V4). This does not include additional savings due to pier size reductions caused by reduced dead weight loads. Equivalent capacity precast concrete girders weigh 10-12 times more than FiRP™ Glulams. Figure 4 contains a photograph of the Clallam Bay bridge.

Global Impact of the FiRP™ Glulam Technology

The supply of timber for high grade tensile laminae used in the manufacture of conventional glulams has been decreasing in recent years with a corresponding increase in price. The FiRP™ Reinforcement Panel used in the FiRP™ Glulam beam has already had

an impact on the wood products industry with the potential to affect the wood framing market in the same way that reinforcing rebar changed the concrete industry.

FiRP™ Glulam technology is already being examined for implementation around the world. It is claimed that this technology can have an impact beyond design and construction through savings in wood fiber and its economic potential for synthetic fiber production. FiRP™ technology is not limited to glulams and is being evaluated for use in several other applications, such as floor-and-beam composites, I-beams, joists, laminated veneer lumber, plywood panels, etc.

The following list highlights the global impact of FiRP™ technology:

- It is anticipated that consumption of carbon and aramid fibers for glulam applications in the United States will double the global market for high-strength/high-modulus synthetic fibers. This demand will lead to jobs beyond the construction and forest products sectors of economies in countries around the globe.
- Wood is an environmentally friendly, sustainable resource that serves the global environment. The FiRP™ Glulam technology leads to reduced pollution and energy usage when used in structures instead of metals and concrete.
- Conventional glulam requires a raw material base that originates from a relatively homogeneous forest resource, whereas the FiRP™ Glulam technology can utilize a highly variable supply of raw materials.
- Plastic matrix reinforcement components can be made from recycled plastic.
- The first reinforced beams were recently produced and test in Italy confirming the design formulas with local species.
- In Japan, the FiRP™ Technology has been used in several bridges.
- In Southeast Asia, Japan, and Australia, work on application of FiRP™ Technology to plywood is now underway.
- In American Society for Testing and Materials (ASTM) Committee D07, a task group in Section 07.02.02 is drafting a standard for establishing and monitoring structural capacities of fiber-reinforced glulam.
- The American Institute of Timber Construction (AITC), an association of glulam manufacturers, has voiced a commitment to make this technology generally available to its member companies.
- AITC has established a task committee to develop a reinforcement supplement to the American National Standards Institute (ANSI) glulam standard.
- Western Wood Structures, Inc. now bids 75% of its glulam jobs with FiRP™ Glulam.
- In the United States, FiRP™ Glulams are being used in the design and construction of more than $100 million in building and infrastructure structures. Already $30 million in bridges and building structures are completed in the United States and Japan. ICBO code approval is expected to impact sales growth significantly.
- On average, unreinforced glulams cost 22% more than steel and 12% more than concrete. Same-strength reinforced glulams can be made for 25-35% less than conventional beams. Sales of US-made glulams are about $300 million per year (tiny

by forest-products industry standards). However, the precast concrete industry is a $10 billion a year market, so the potential for FiRP™ Glulams (if they can compete in price and strength) is enormous.

With the excellent performance and favorable economics of FiRP™ Glulam, it is reasonable to believe that FiRP™ Glulam may become the conventional glulam of the industrialized nations in the not-too-distant future. FiRP™ Reinforcement applied to glulam beams appears to have the same potential to revolutionize glulams as steel reinforcement has done for concrete.

TABLES AND FIGURES

Table 1: Size comparison between the unreinforced and reinforced options

Unreinforced Beams

Beam ID	Span (ft)	Depth (in.)	Width (in.)	Section Modulus (in.3)	Design Extreme Fiber Tension Stress (psi)	Design Shear Stress (psi)
a	60	36	5 1/8	1,107	2,400	190
b	36	33	6 3/4	1,225	2,400	190
c	15	12	5 1/8	123	2,400	190

Beam ID	Unreinforced Design Bending Moment (ft-lb)	Unreinforced Design Shear Force (lb)	Modulus of Elasticity (psi)	Moment of Inertia (in.4)	Bending Stiffness EI (lb-in^2)
a	178,600	23,370	1,800,000	19,926	3.59E+10
b	204,130	28,215	1,800,000	20,215	3.64E+10
c	24,600	7,790	1,800,000	738	1.33E+09

Reinforced Beams

Beam ID	Span (ft)	Depth (in.)	Width (in.)	FARP Reinforcement Layers †	Percent Reduction in Cross Section††
a	60	36	5 1/8	1	0
b	36	31 1/2	5 1/8	2	28
c	15	15	3 1/8	1	24

Beam ID	Reinforced Design Bending Moment (ft-lb)	Reinforced Design Shear Force (lb)	Reinforced Modulus of Elasticity . (psi)	Composite Moment of Inertia (in.4)	Composite Bending Stiffness EI (lb-in^2)
a	257,940	33,210	1,800,000	2.14E+04	3.85E+10
b	205,040	29,059	1,800,000	1.48E+04	2.66E+10
c	26,480	8,438	1,800,000	9.60E+02	1.73E+09

† Reinforcement layer thickness is 0.07 in.

†† Compared to the unreinforced option

Tabe 2: Beams of equivalent size where the reinforced beam is composed of all low grade wood and exceeding the high grade unreinforced glulam in bending strength, shear strength, and bending stiffness.

Glued Laminated Timber Member	AITC Combination	Beam Width (in.)	Beam Depth (in.)	Beam Length (ft.)	Weight (lb)	Bd. Ft. of Wood Fiber (bd ft)	FiRP™ Panel Length (ft)	MBF ($ / Bd. Ft.)
Unreinforced	24F-V4 (D-fir)	5 1/8	36	60	2,691	1440	--	$ 600.00
Reinforced	#14 (Hem-fir, L3)	5 1/8	36	60	2,696	1440	32	$ 400.00

Glued Laminated Timber Member	AITC Combination	Wood Cost ($)	FiRP™ Material Cost ($)	Manufacturing Cost ($)	**Total Beam Cost ($)**	**Savings ($)**	**Savings (%)**	**Weight Savings (lb)**
Unreinforced	24F-V4 (D-fir)	$ 915.84	--	$ 288.00	**$ 1,203.84**	--	--	--
Reinforced	#14 (Hem-fir, L3)	$ 610.56	$ 49.50	$ 288.00	**$ 948.06**	**$ 255.78**	**21**	**-6**

Notes:

1. Reinforced beam wood fiber cost based on $400/MBF for HF L3, AITC Combination #14 (Hem-fir, L3)
2. FiRPTM cost based on circulated FiRPTM Panel Cost shown in Schedule 7.6. For FARP, $1.10
3. Unreinforced beam wood fiber cost based on cost of $600/MBF for 24F-V4 (D-fir)
4. Manufacturing costs estimated at $200/MBF

Table 3: Beams of equivalent moment and shear capacity.

Glued Laminated Timber Member	AITC Combination	Beam Width (in.)	Beam Depth (in.)	Beam Length (ft.)	Weight (lb)	Bd. Ft. of Wood Fiber (bd ft)	FiRP™ Panel Length (ft)	MBF ($ / Bd. Ft.)
Unreinforced	24F-V4 (D-fir)	6 3/4	33	36	1,949	1056	--	$ 600.00
Reinforced	#14 (Hem-fir, L3)	5 1/8	31 1/2	36	1,419	756	32	$ 400.00

Glued Laminated Timber Member	AITC Combination	Wood Cost ($)	FiRP™ Material Cost ($)	Manufacturing Cost ($)	**Total Beam Cost ($)**	**Savings ($)**	**Savings (%)**	**Weight Savings (lb)**
Unreinforced	24F-V4 (D-fir)	$ 671.62	--	$ 211.20	**$ 882.82**	–	–	--
Reinforced	#14 (Hem-fir, L3)	$ 320.54	$ 62.40	$ 151.20	**$ 534.14**	**$ 348.67**	**39**	**530**

Notes:
1. Reinforced beam wood fiber cost based on $400/MBF for HF L3, AITC Combination #14 (Hem-fir, L3)
2. FiRPTM cost based on circulated FiRPTM Panel Cost shown in Schedule 7.6. For Aramid, $1.20
3. Unreinforced beam wood fiber cost based on cost of $600/MBF for 24F-V4 (D-fir)
4. Manufacturing costs estimated at $200/MBF

Table 4: Beams of equivalent moment capacity, shear capacity, and stiffness.

Glued Laminated Timber Member	AITC Combination	Beam Width (in.)	Beam Depth (in.)	Beam Length (ft.)	Weight (lb)	Bd. Ft. of Wood Fiber (bd ft)	FiRP™ Panel Length (ft)	MBF ($ / Bd. Ft.)
Unreinforced	24F-V4 (D-fir)	5 1/8	12	15	224	120	--	$ 600.00
Reinforced	#14 (Hem-fir, L3)	3 1/8	15	15	172	100	32	$ 400.00

Glued Laminated Timber Member	AITC Combination	Wood Cost ($)	FiRP™ Material Cost ($)	Manufacturing Cost ($)	**Total Beam Cost ($)**	**Savings ($)**	**Savings (%)**	**Weight Savings (lb)**
Unreinforced	24F-V4 (D-fir)	$ 76.32	--	$ 24.00	**$ 100.32**	--	--	--
Reinforced	#14 (Hem-fir, L3)	$ 42.40	$ 15.00	$ 20.00	**$ 77.40**	**$ 22.92**	**23**	**52**

Notes:

1. Reinforced beam wood fiber cost based on $400/MBF for HF L3, AITC Combination #14 (Hem-fir, L3)
2. FiRPTM cost based on circulated FiRPTM Panel Cost shown in Schedule 7.6. For Aramid, $1.00
3. Unreinforced beam wood fiber cost based on cost of $600/MBF for 24F-V4 (D-fir)
4. Manufacturing costs estimated at $200/MBF

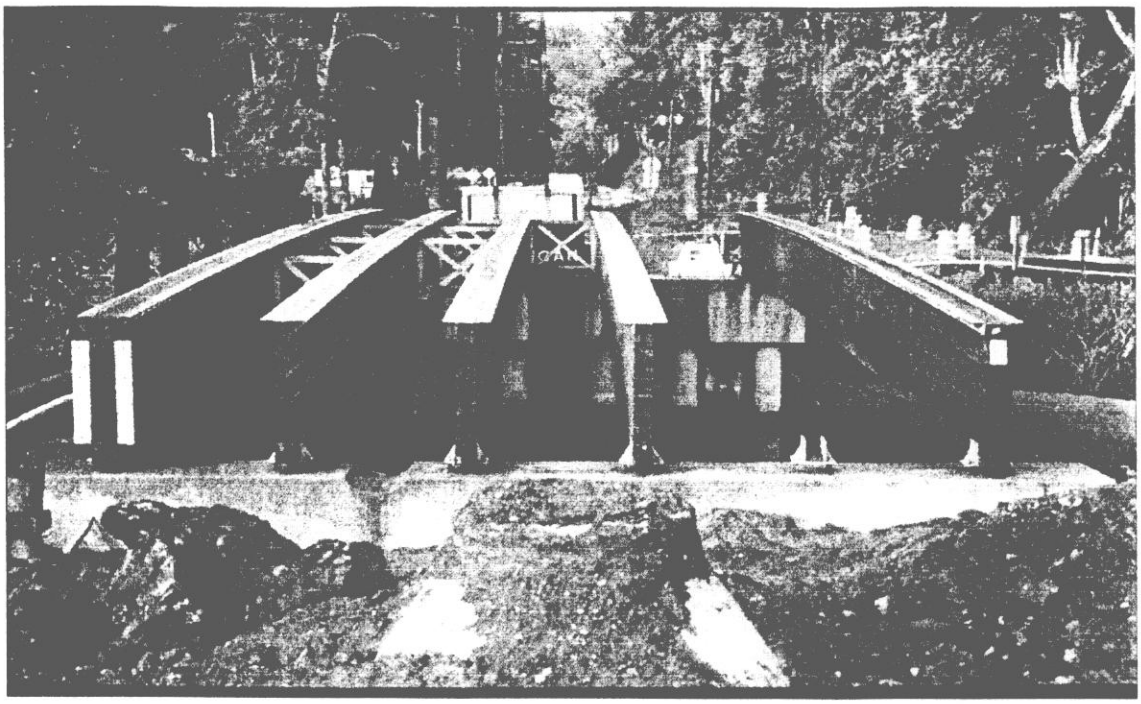
Table 5: Cost comparison of the Zongas bridge.

Girder Option	Total Bridge Dead Load(less rails)(kN)	Estimated Cost of Superstructure (girders and deck)
Reinforced glulam	369	$27,100
Conventional glulam	456	$33,420
Steel	372	$30,470
Precast concrete	1112	$28,000

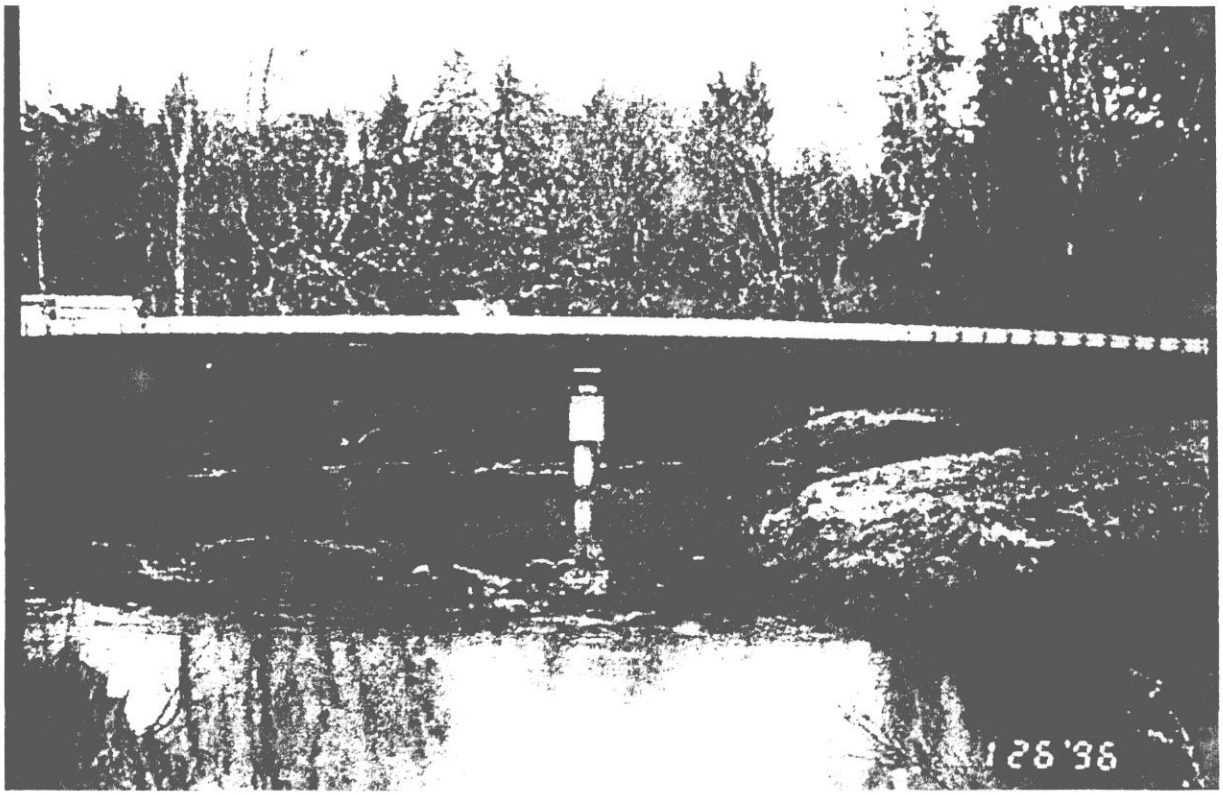
Table 6: Cost comparison for the Taylor Lake bridge.

Item	Standard Unreinforced[1]	FiRP™ Reinforced	Cost Savings	Percent Savings
Cross section (in.)	8-3/4 x 52-1/2	6-3/4 x 46-1/2	---	---
Weight per Beam (lb)	10846	7411	3435	32
Cost of Beams ($)	8402	6187	2215	26
Treatment Cost ($)	1531	1046	485	32
Total Cost ($)	9933	7233	485	27

[1] Standard 24F-V4



End view of the girders during construction



Elevation of the bridge after construction

Figure 1. Photographs of the Clallam Bay bridge

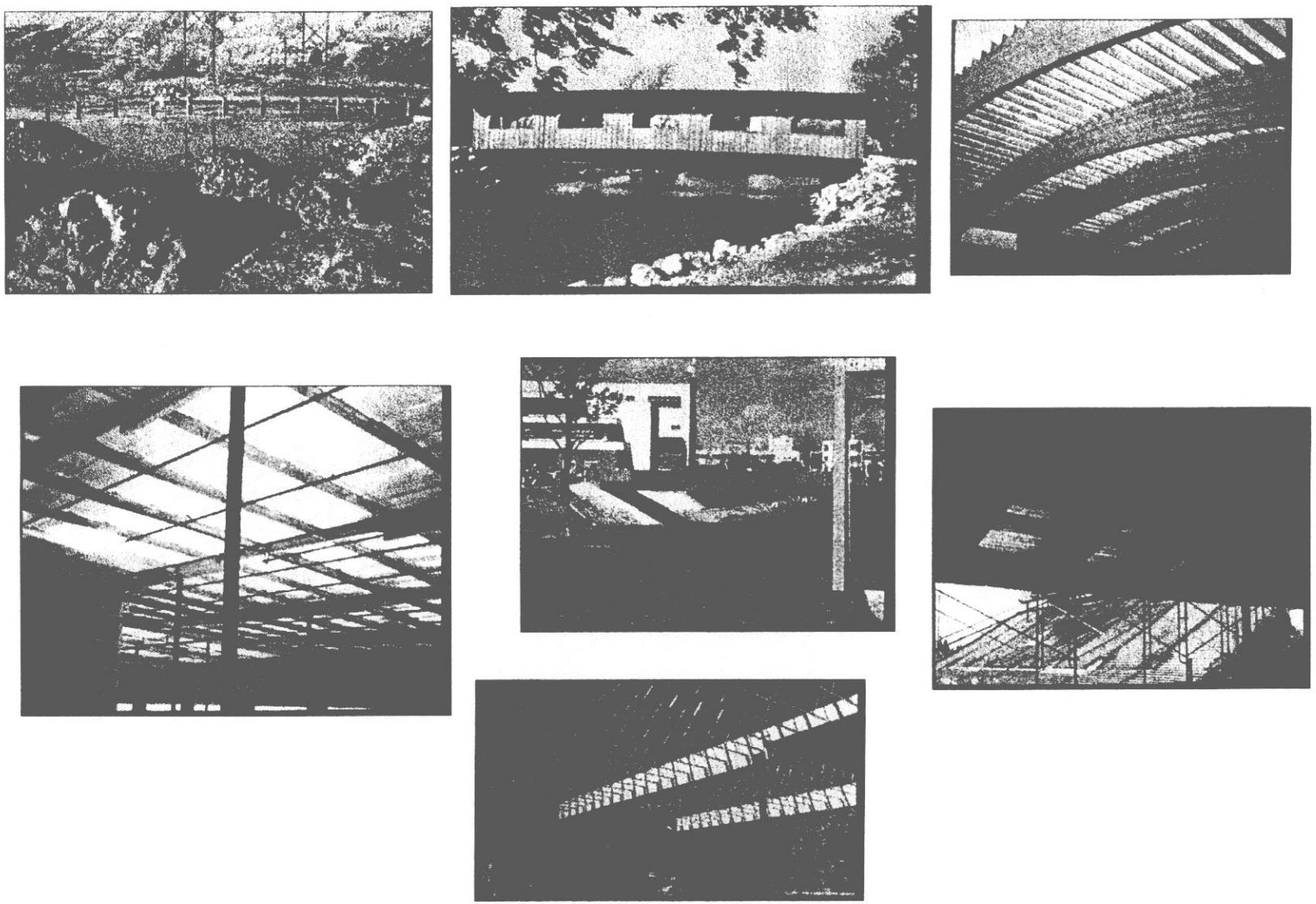


Figure 2: Photographs of structures containing reinforced glulams.

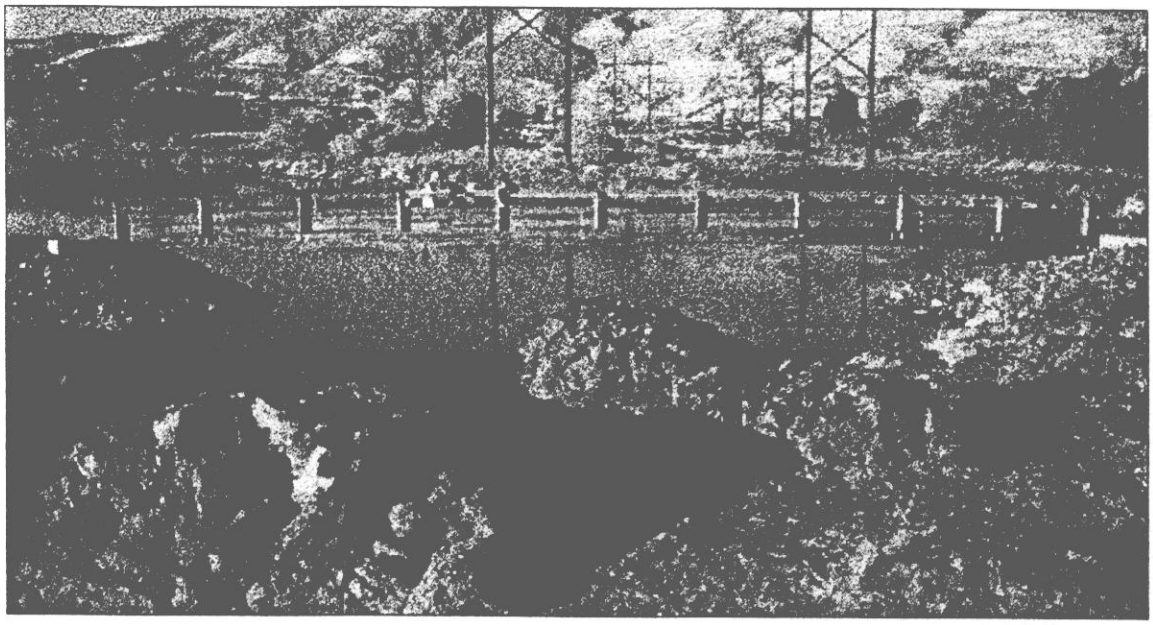


Figure 3: Photographs Taylor Lake bridge.

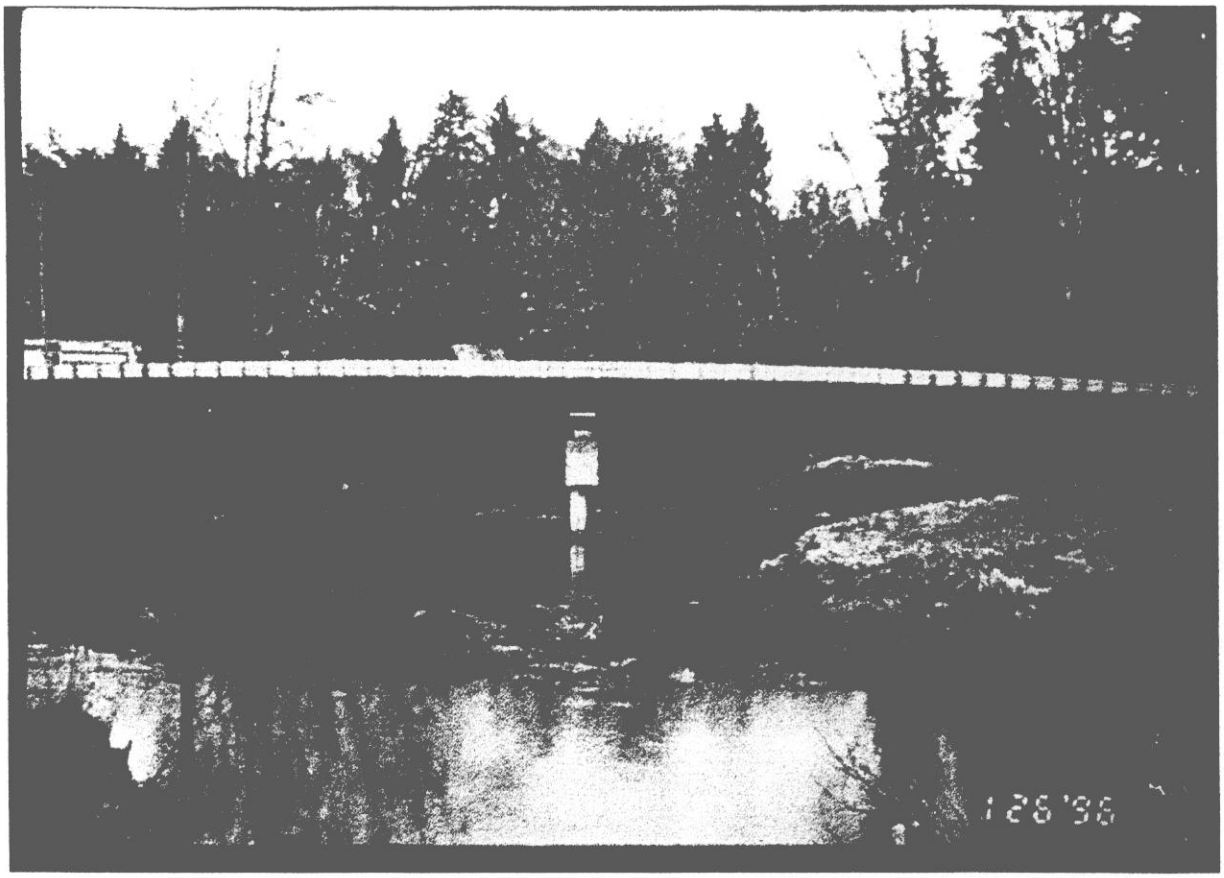
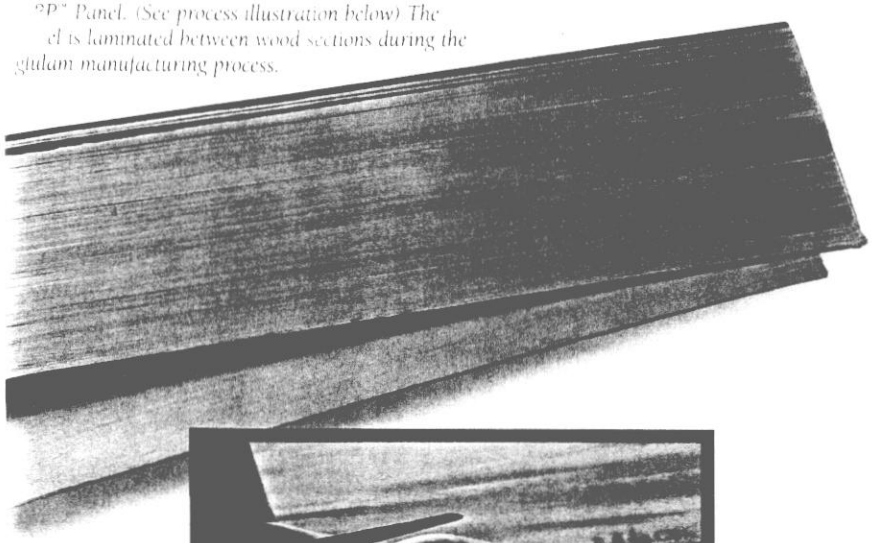


Figure 4: Photograph of the Clallam Bay bridge.

EXHIBITS

The Technology

Combinations of synthetic fibers are aligned parallel to one another and encased in resins to create the FiRP™ Panel. (See process illustration below) The panel is laminated between wood sections during the glulam manufacturing process.

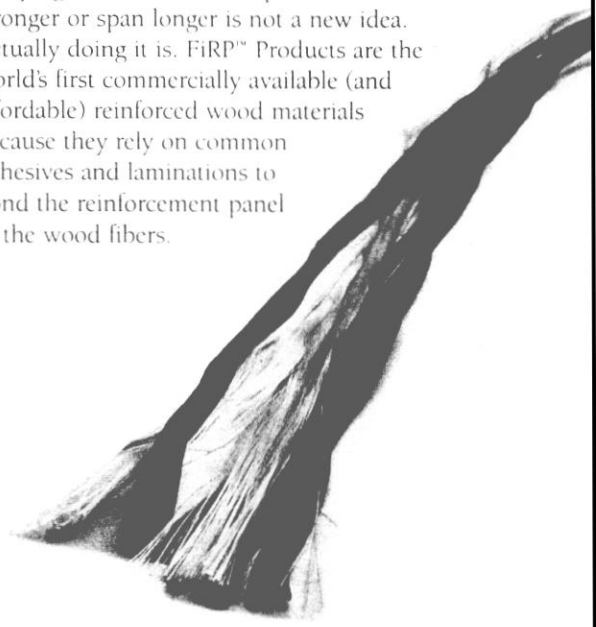


The Fiber

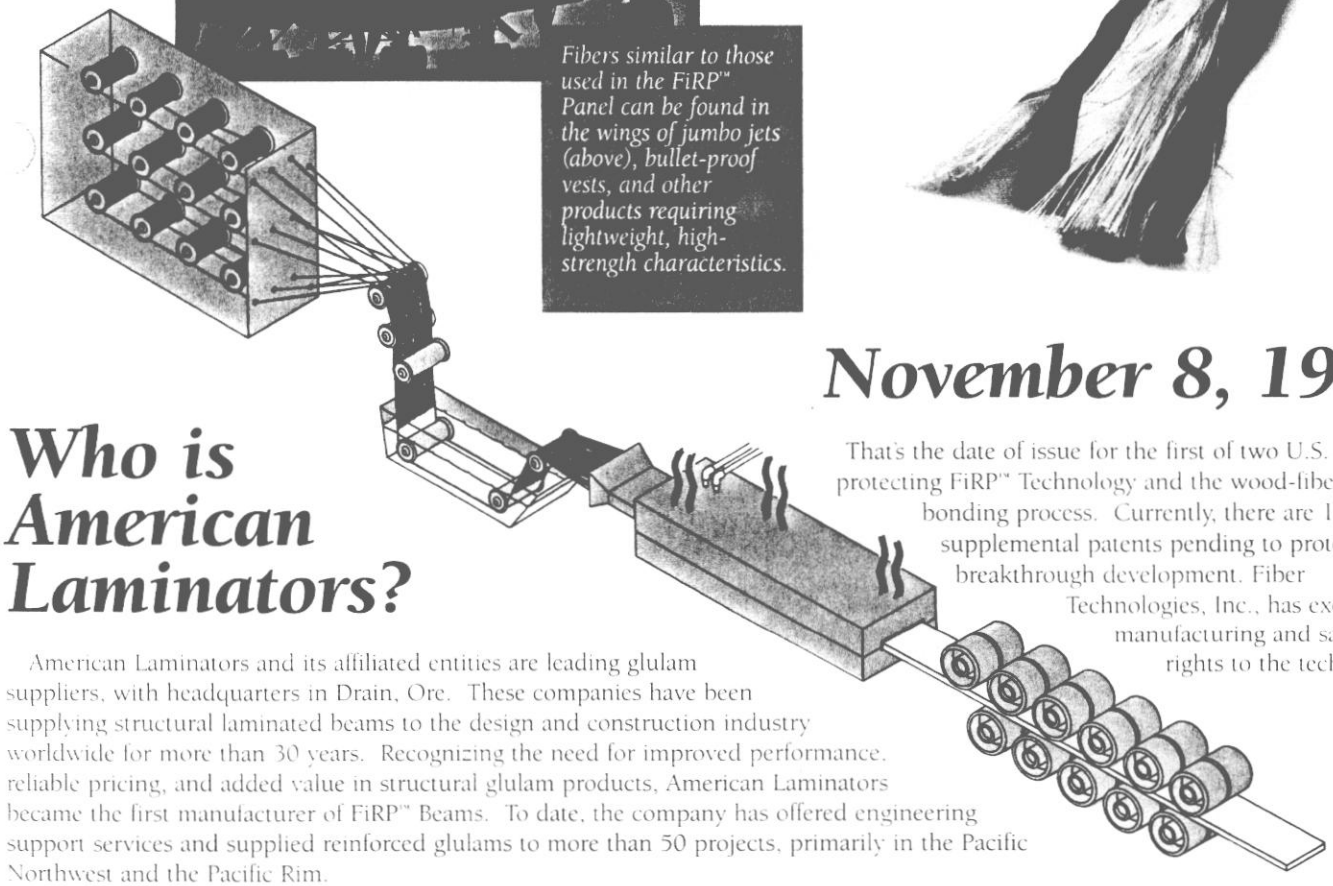
The technology behind FiRP™ Beams is a mix of synthetic fibers — such as carbon, aramid, and glass — that are combined to create a thin, flexible, high-strength panel. The panel is placed along the length of laminated wood sections and bonds to the wood fibers.

Trying to reinforce wood products to make them stronger or span longer is not a new idea. Actually doing it is. FiRP™ Products are the world's first commercially available (and affordable) reinforced wood materials because they rely on common adhesives and laminations to bond the reinforcement panel to the wood fibers.





Fibers similar to those used in the FiRP™ Panel can be found in the wings of jumbo jets (above), bullet-proof vests, and other products requiring lightweight, high-strength characteristics.



November 8, 1994

That's the date of issue for the first of two U.S. patents protecting FiRP™ Technology and the wood-fiber bonding process. Currently, there are 13 more supplemental patents pending to protect this breakthrough development. Fiber Technologies, Inc., has exclusive manufacturing and sales rights to the technology.

Who is American Laminators?

American Laminators and its affiliated entities are leading glulam suppliers, with headquarters in Drain, Ore. These companies have been supplying structural laminated beams to the design and construction industry worldwide for more than 30 years. Recognizing the need for improved performance, reliable pricing, and added value in structural glulam products, American Laminators became the first manufacturer of FiRP™ Beams. To date, the company has offered engineering support services and supplied reinforced glulams to more than 50 projects, primarily in the Pacific Northwest and the Pacific Rim.

Did You Know?

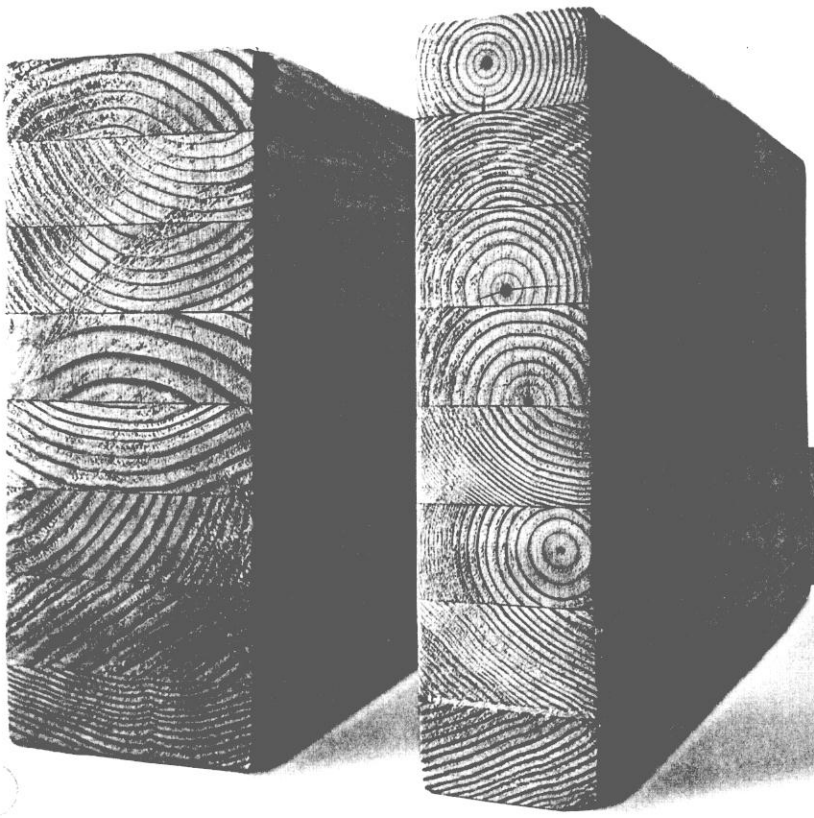
Q: Do the synthetic fibers or resins used to make the FiRP™ Panel contain any recycled material?

A: We closely monitor the raw materials content of the reinforcement panel, and we are aware that recycled plastics, such as those derived from soda bottles, occasionally have

Stronger

A Better Beam

Imagine a glue-laminated beam that spans the same distance and carries the same load, but is significantly smaller in dimension. That's what you get with a FiRP™ Glulam compared to conventional laminated beams — a product that is two to three times as strong right out of the box. The thin sheet of reinforcement panel, measuring as slight as .07 inches, can increase a glulam's load-bearing capacity by up to 50 percent. Take your pick: Longer spans from the same-size beam, or the same strength from a smaller glulam.



The difference is dramatic: With the FiRP™ Panel bonded to the laminated wood sections, a reinforced glulam beam of a much smaller dimension (right) can match the strength of a larger, conventional glulam.

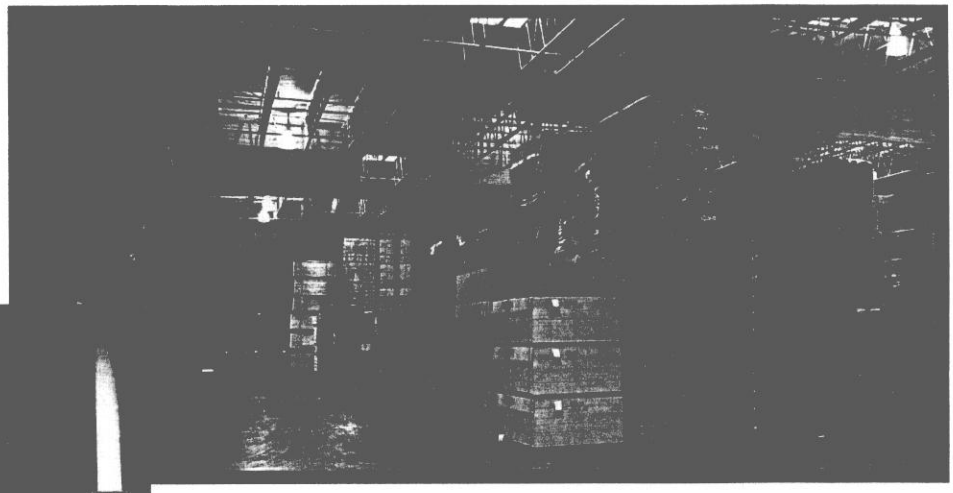
The FiRP™ Panel employs the strongest synthetic fibers yet known. In conjunction with a laminated beam, it creates a structural product that spans longer and carries more load than any product on the market.

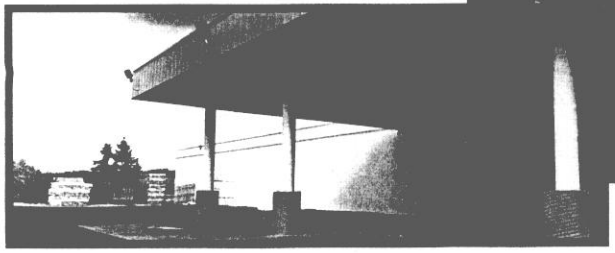
They Said It

"There's tremendous potential here because the reinforcement (allows) smaller cross sections ... and reduced costs." — news release issued by the American Institute of Timber Construction (AITC) regarding FiRP™ Glulam beams. AITC is establishing standards for reinforced wood products.

Case in Point

For a new, 38,840-square-foot lumber products warehouse in Tualatin, Ore., the contractor selected FiRP™ Glulams, which span 66 feet — a testament to the strength capabilities of these high-performance, reinforced beams over long distances.





Did You Know?

Q: How much stronger are FiRP™ Beams compared to ordinarary glulams?

A: Typically, a reinforced glulam beam carries 30 percent more load than a traditional glulam, with less deflection and sag over time. Using these stronger, more reliable beams means your building designs will feature more open interior areas and maximum space flexibility.

Safer

A Safe Haven

Of all the benefits and advantages of FiRP™ Products, the most compelling is the safety these reinforced wood products provide. While traditional, unreinforced glulam beams perform well under several stress conditions, FiRP™ Beams are even better. They take longer to fail under extreme stress, such as earthquakes, and absorb significantly more seismic energy. For commercial structures and bridges near earthquake faults, the benefits are clear.

The strength of the FiRP™ Panel also mitigates wood's natural defects, such as pitch pockets and slope of grain; reinforcement along the length of the beam helps resist sagging over time. It adds up to a more predictable and reliable product and, in turn, a safer warehouse, bridge, building, or home.



FiRP™ Glulam beams form the roof of a new business park structure near Portland, Oregon.

Tale of the Tape

	Wood	FiRP™	Steel
Moisture sensitivity	Loses strength with moisture gain	Up to 8 percent with little or no loss of strength	No loss of strength
Environmental	Resistant to mild acids and salts; susceptible to mild decay	Excellent versus a broad range of elements	Poor; susceptible to oxidizing in moisture environments
Machinability	Excellent factory and on-site workability	Best of all high-strength fibers	Need special equipment and tools
Strength to weight ratio	Very high	Good/excellent	Very low
Thermal conductivity *(Btu inches/hour/square foot)*	0.85 (slow rate of thermal transfer)	0.0858 (same rating as traditional glulams)	310.00 (high rate of thermal transfer)
Fire Resistance *(nominal 6x6 dimension)*	Loss of strength properties at 150 deg. F., slow rate of charring at 212-482 deg. F.	Loss of strength properties at 300 deg. F., maintains 50 percent of its strength for seven days at 492 deg. F.	Loss of strength properties at 200 deg. F., substantial failure at 350 deg. F.
Weight per lineal foot *(lbs.)* **for equal design value**	FiRP™ Glulam: 64 lbs./lineal foot Traditional glulam: 73-86 lbs./lineal foot Steel: 85 lbs./lineal foot Prestress concrete: 550 lbs./lineal foot Cast-in-place concrete: 900 lbs./lineal foot		

A Test of Strength



Since 1993, we've broken more than 700 FiRP™ Glulam and control beams to back up our claims about the strength, reliability, and safety of FiRP™ Products. In addition, testing facilities around the world evaluated the "in service" characteristics and long-term load capabilities of our reinforced fiber. Freeze-thaw, impact loads, fire, moisture, ultraviolet radiation — you name it, we've tested for it. And passed.

Did You Know?

Q: In an earthquake, how do FiRP™ Glulam beams react?

A: Though wood is regarded as the preferred structural material in an earthquake, traditional glulams aren't designed to absorb much seismic energy. FiRP™ Glue-laminated beams, however, deflect up to three times as much as unreinforced beams, in essence "moving" with the force of the energy instead of failing under the stress.

FiRP™ Technology Patent Portfolio

Through extensive research and testing at the Wood Science & Technology Institute (N.S.), Ltd., Tingley has developed several patentable inventions in the technology. Four patents have been awarded for the innovative FiRP™ Technology and its applications, with two other patents allowed to issue by December 1996 and nine other patents are pending (See Appendix F).

Table 11 shows a listing of the first nine patents in the current patent portfolio. All patents will be prosecuted internationally.

Table 11. Patent Applications

International Publication #	United States Patent #	International Publication Date	Field of Use	Matter #
WO94/21851	5,362,545	9/29/94	General FiRP™ Technology including Panel Manufacture and FiRP™ Glulam	300
WO95/23690		9/8/95	Adhesion Methodology	301
WO95/23692		9/8/95	Adhesion Methodology	302
WO96/08366	5,498,460	3/21/96	Adhesion Methodology	303
WO96/00653	Allowed, awaiting issuance	1/11/96	Design Methodology Reinforced SCL including Glulam	304
WO96/03280	5,547,729	2/8/96	Manufacturing FiRP™ Glulam	305
WO96/03276	5,456,781	2/8/96	Manufacturing SCL's Reinforced including FiRP™ Glulam	306
WO96/13378		5/9/96	Manufacturing SCL's Reinforced	307
WO96/28298	Allowed, awaiting issuance	9/19/96	Wood I-Beam	308

The patent portfolio covers a broad range. The most powerful aspects of the patent coverage are as follows. There are many more important aspects of patent claiming structure in over 500 claims in 15 patents issued or pending.

1. The use of any high strength fiber with an SCL will infringe a patent if it is machined in any way after applying the reinforcement, regardless of matrix used, fiber type, adhesive, etc. All current SCL production facilities world-wide machine the product after assembly prior to shipment.

2. Several adhesion methods for reinforcement to reinforcement and reinforcement to wood using typical wood type adhesives, i.e., resorcinol based, PVA and melamine are patented.

3. Design methodology covered by patent.

4. Partial length reinforcement patented.

5. Method of producing reinforcement and reeling for shipment protected by patent.

6. Multiple layered reinforcement protected by patent.

7. Use of reinforcement in I-beams protected.

Paul Angello at Stoel Rives can be contacted for more information about the patent portfolio.

Paul S. Angello
Stoel Rives
900 SW Fifth Avenue, Suite 2300
Portland, OR 97204
Tel: (503) 294-9314
Fax: (503) 220-2480

Summary of Patent Descriptions

The following is a summary of patents, either issued or awaiting issuance. The patents vary greatly and cover a broad range. They are summarized in Matter number order.

The first patent, Matter #300, is entitled "Aligned Fiber Reinforcement Panel for Structural Wood Members." This patent covers the invention of a reinforcing panel and a process for making the same, for use in the reinforcement of wood structural members. Some examples are laminated beams, wood I-beams and trusses. This process uses tension on the fibers during manufacture of the FiRP™ Panel, so that the fibers of the reinforcement panel are maintained in a state of tension during the resin cure, thereby keeping all parallel and longitudinal fibers aligned. The surface of the reinforcing panel is treated so fibers closest to the surface are caused to "hair up" and therefore may be used with non-epoxy adhesives. The date of issuance on the patent was November 8, 1994. The patent number is 5,362,545.

The next patent pending, Matter #301, is entitled "Use of Synthetic Fibers in a Glue Line." This invention uses discontinuous aramid fibers in the adhesive layer of laminar wood beams. This process then improves the shear strength of the adhesive, reduces creep of the adhesive and therefore reduces the sag of the wood beam. Further, the fibers can be used in phenolic matrices in reconstituted wood fiber products such as parallel strand lumber (PSL) to provide dimensional stability and sag resistance.

Matter #302, is a patent pending, entitled "Cellulose Surface Material Adhered to a Reinforcement Panel for Structural Wood Members." This patent covers providing a reinforcement panel of reinforcement fibers in a polymer encasement with a cellulose-fiber surface that has a monomer in it. This in turn is adhesively affixed to a wood structure at an area of high stress so the cellulose fiber surface is sandwiched between the polymer encasement and the wood structure. This provides dimensional stability and protection against moisture degradation. It also provides improved adhesion to the wood structure by conventional gluing processes.

The next patent, Matter #303, is entitled "Surface Treated Synthetic Reinforcement for Structural Wood Members." This invention is a synthetic reinforcement comprised of many continuous fibers that are held in position by a resin encasement. The surface of the reinforcement has recesses that are generally in a random pattern, which increases the surface area of the resin encasement. This in turn is suitable for adhering wood laminae

together with reinforcement using conventional mechanical type adhesive. This patent was issued on march 12, 1996, patent number 5,498,460.

Matter #304, is allowed, and awaiting issuance. Entitled "Method of Manufacturing Wood Structural Member with Synthetic Fiber Reinforcement," it covers providing wood structural members with improved stress-resisting capabilities as well as providing such members with tensile and compressive portions adopted to stresses imposed by a predetermined load. This is done by having at least one layer of resin-enclosed fibers adhered to at least one of the wood segments in the tension portion of the structural member. It also provides a method of manufacturing these wood structural members. Basically, compression based design is covered by Matter #304.

The next patent is Matter #305, entitled "Glue-Laminated Wood Structural Member with Synthetic Fiber Reinforcement." It covers a glue laminated structural wood member for bearing transverse structural loads. The structural wood member includes a synthetic compression reinforcement in the area subject to compressive stresses. Partial reinforcement longitudinally of wood composites is covered by this patent. This patent was issued on August 20, 1996, patent number 5,547,729.

The patent entitled "Method of manufacturing Glue-Laminated Wood Structural Member with Synthetic Fiber Reinforcement," Matter #306, covers a method of manufacturing a glue laminated structural wood member for bearing a structural load. The synthetic fiber reinforcement consists of multiple synthetic fiber strands held within a resin matrix. Also covered by this patent is the machining of a reinforced wood product after reinforcement is placed. This patent was issued on October 10, 1995, patent number 5,456,781.

Matter #307 patent is still pending. It is entitled "Reinforced Wood Structural Member." This invention is an improvement on prior reinforcements in laminated wood beams and other wood structural members. It covers a panel with a multitude of fibers arranged parallel with each other and aligned with the longitudinal axis on the reinforcing panel. This allows the panel to adhere to a wood structure with nonepoxy adhesives. In summary, this patent covers hybrid fiber reinforcement used with wood regardless of the type of adhesive and multiple layers of reinforcement.

The final patent, entitled "Wood I-Beam with Synthetic Fiber Reinforcement," Matter #308, is allowed, and we are awaiting issuance. The invention covers reinforcement of wood I-beams with wood or wood composite flanges having synthetic fiber reinforcement. It also provides the metal web reinforced flange wood I-beams with improved capability of bearing shearing forces and pressures exerted on the flanges by the pins securing the metal web. The reinforcement reduces susceptibility to total beam failure resulting from flange failure.