Thermal Performance of Log Structures

Acceptance of Traditional, but "Alternative", Materials and Methods of Assembly

2006 National Workshop on State Buildng Energy Codes

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Historic Perspective

- Ancient settlements date to 700 BC
- Use of indigenous materials
- Relatively simple, often one room

Post Office, MN

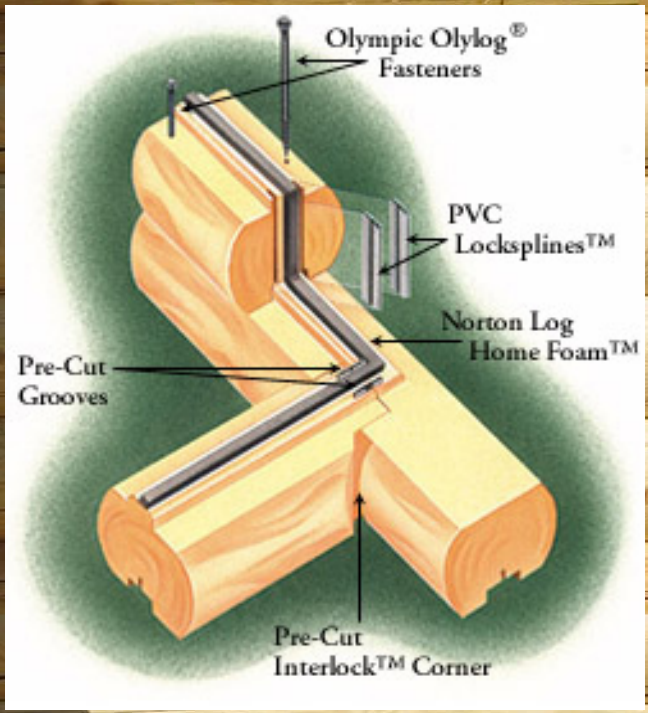
1785 hewn log cabin

Early Log Structures

- Full length logs extended at corners to delay the effect of decay
- Mud, straw, moss, and other materials used to seal between logs

Evolution of Technology

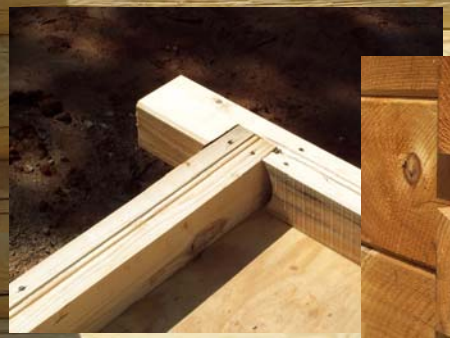
- Organic finishes from local ingredients
- 1920 -- Pre-cut log home "kits"
- Proprietary solutions to seal out air & moisture



Source: REAL LOG HOMES®

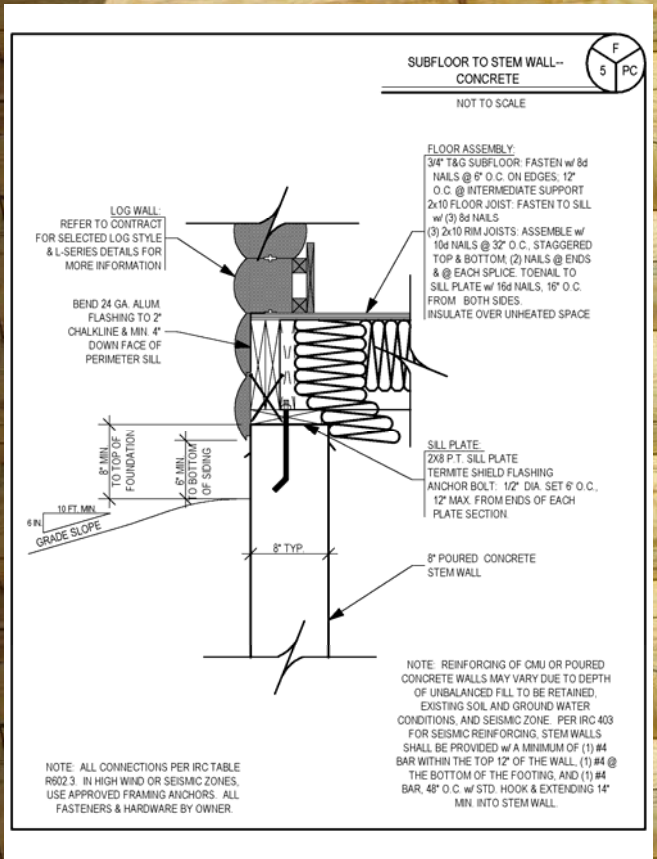
Modern Log Structures

- Offer variety of corner & log styles
- Incorporate sophisticated custom design & engineering
- Use modern methods & techniques – finishes, pre-cast foundations, insulation, etc.



Corner photos courtesy of Southland Log Homes Inc.

Principles of Construction



Detail courtesy of Southland Log Homes Inc.

Same as conventional:

- Project planning & preparation
- Design loads and deflection criteria
- Plumb, square and level construction
- Receiving, handling, and protecting materials

Tradition Mixes with Convention

- **Conventionally built systems except for log walls and log framing members…**
  - **Foundations, subfloors, partition walls, windows, doors, roofing**
  - **Plumbing, electrical, mechanical**

There's only one right way to build a log home…

Per the blueprints, details, and instructions (construction manual) provided with the log package.

Building System Variations

Structural headers and exterior flashing protect openings

Settlement allowance over openings is a function of the building system.

- Wall-Logs: Species, size, shape, treatments, MC
- Extent of processing: Lineal length, pre-cut, handcrafted
- Joinery: Corners, butt joints, openings, sealants
- Connections and fastening patterns
- Accommodating movement: Compaction and shrinkage

The Log Home Industry

Annual stats taken from industry publications:

- Over 25,000 log homes built from North American producers

Types of Producers	# of Co.s	Annual Production
Handcrafters	200-300	Up to 100 units/year; 85% < 25/yr.
Manufacturers of milled products	270-325	Up to 1000 units/year; 90% < 200/yr.

A Market Snapshot

- Over 400,000 log homes exist in North America.
- 7% of custom-built housing market
- $1.4 billion market
- Annual production of log home packages increased 41% from 1988 to 1995 and 46% since.

Building Systems Magazine's 2001 Excellence in Model Home Design – Appalachian Log Structures, Inc.

-- Log Home Living Institute survey, 2001

1977: The LHC First Meets

22 Charter Members form the Log Homes Council to respond to code issues

Photo courtesy of Kuhns Bros. Log Homes

- Develop and promulgate standards of quality and safety throughout the log home industry
- Disseminate information about developments in the log home industry to regulatory bodies, governmental agencies, the press, and the general public

Today's Log Homes Council

60+ LHC Members

- Subscribe to the Code of Ethics
- Represent about 20% of all North American log home producers
  BUT
- Produce 50% or more of new log home construction

LHC Milestones: Log Grading

1980: ASTM D3957 Standard Methods for Establishing Stress Grades for Structural Members Used in Log Buildings

1981: NES QA-154: Accredited LHC as a rules-writing grading agency

1984: Mandatory Log Grading implemented

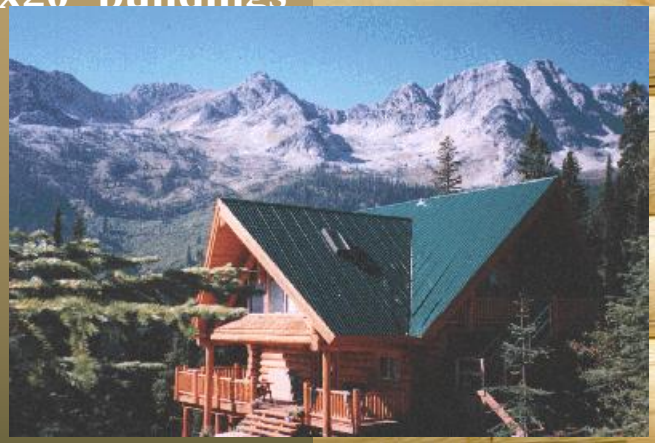
2006: Code requirement published

- IBC (2303.1.10) / IRC (R602.1.3, R802.1.5)

LHC Milestones: Energy Codes

1983: Thermal Testing

- National Bureau of Standards tests 6-20'x20' buildings w/90" walls:
  - 2x4 insulated R-12
  - 2x4 without insulation R-4
  - masonry internally insulated R-14
  - un-insulated masonry R-5
  - 7" solid square log R-10
  - masonry externally insulated R-12



1989: MEC 502.2.1.1.2 Mass Walls

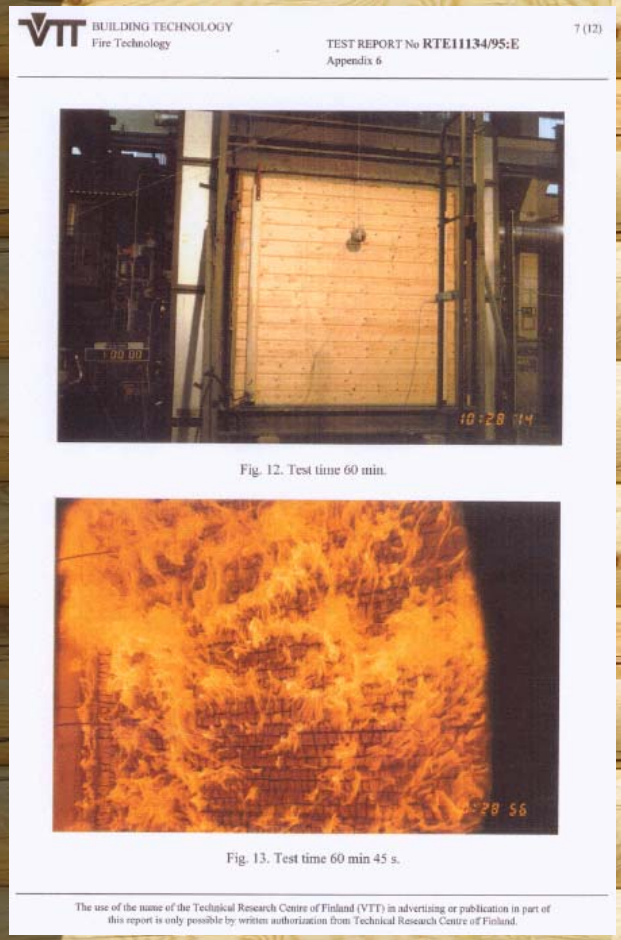
- Thermal mass credit when density ≥ 20 lb/ft2

2005: ORNL Whole Wall Test Program

LHC Milestones: Fire Codes

1997: Urban-Wildland Interface Code

- "Log Wall Construction" defined and recognized as a one-hour-rated fire-resistive exterior wall
- "…where the smallest horizontal dimension of each solid wood member is at least 6" (152mm)."



VTT BUILDING TECHNOLOGY
Fire Technology

TEST REPORT No RTE11134/95:E
Appendix 6

7 (12)

Fig. 12. Test time 60 min.

Fig. 13. Test time 60 min 45 s.

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Test report photos at the 60-minute mark, courtesy of Honka Homes USA, Inc.

LHC Milestones: Construction Standards

1995: LHC Guide for Construction Manuals

- Response to HUD for guidance in the review and acceptance of Structural Engineering Bulletins to aid Federally-insured mortgage programs

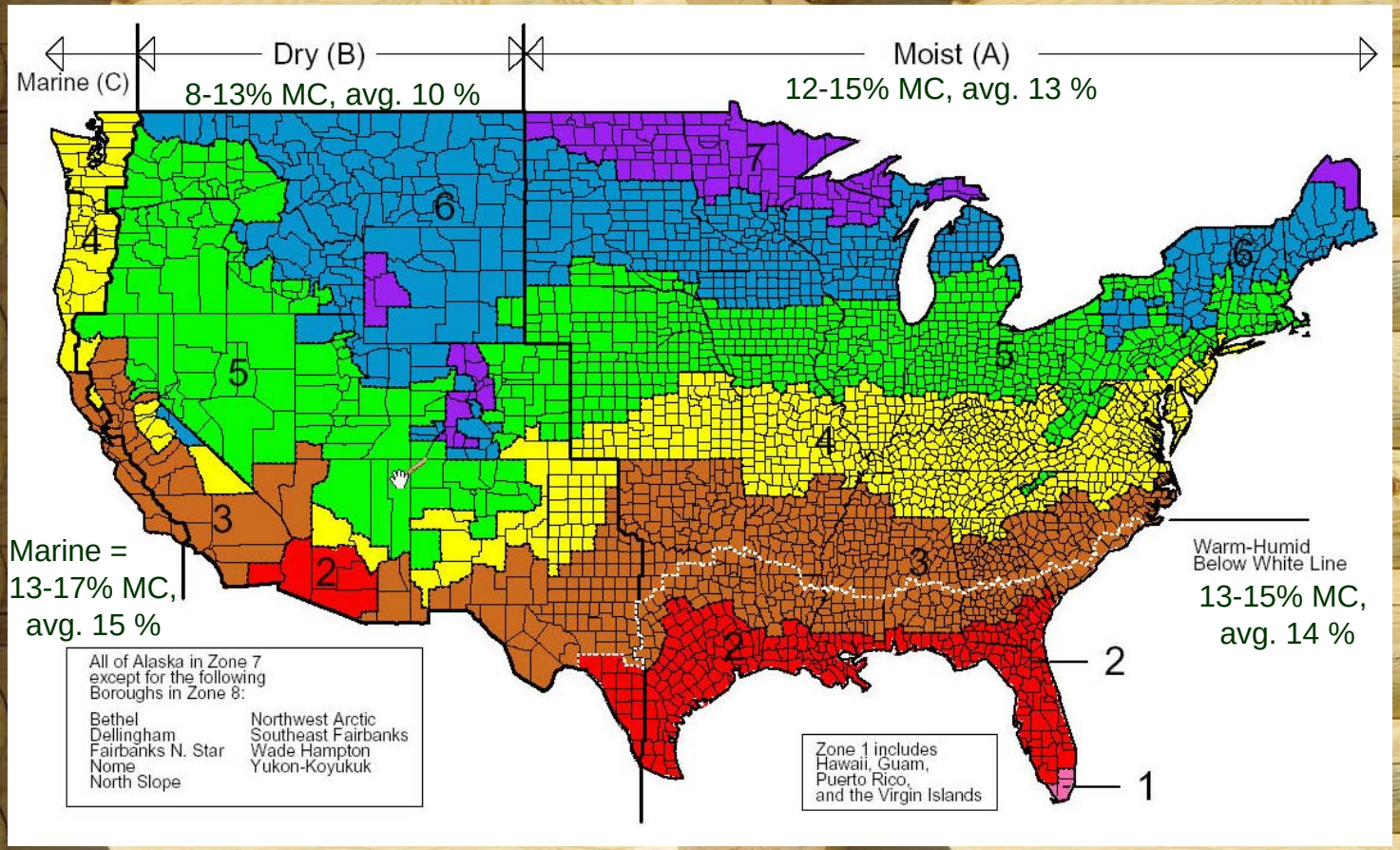
2002: ICC-400 Standard for the Design & Construction of Log Structures

- Response to ICC and industry request for a standard

ICC-400 Log Properties

- Log grading & moisture content
- Design values and section properties
- Fire-resistance ratings
- Settling provisions

Moisture Content by Climate Zone



ICC-400 Log Properties

- Log grading & moisture content
- Design values and section properties
- Fire-resistance ratings
- Settling provisions
- Thermal envelope

FPL-RN-0268, Equilibrium Moisture Content of Wood in Outdoor Locations in the United States and Worldwide

by IECC Thermal Zones

Zone	1	2	3	4	5	6	7	8	9
Average by Zone:	13.2	12.6	12.3	13	12.8	12.6	14.3	14.6	No data

by IECC Climate Zones

	Dry	Moist	Warm-Humid	Marine
Minimum by Zone:	8	12	13	13
Average by Zone:	10	13	14	15
Maximum by Zone:	13	15	15	17

Specific Gravity (G) at Exterior EMC

		Average EMC by Zone*:			
		Dry	Moist	Warm-Humid	Marine
SG, unconditioned wood (ASTM D2555)		**10**	**13**	**14**	**15**
Cedar: Northern white	0.29	0.306	0.303	0.302	0.302
Cedar, White (WC), Cedar: Eastern white-Canadian, balsam poplar (North), black cottonwood (North)	0.3	0.317	0.314	0.313	0.312
Cedar: Atlantic white, Cedar, Red (Western, RC), Cedar: Western red (WRC), Cedar: Western red-Canadian (WRC-N), Black Cottonwood, subalpine fir	0.31	0.328	0.325	0.324	0.323
Aspen: Largetooth-Canadian, Cedar: Port Orford, Fir: Pacific silver, Hem-Fir (HF), Hemlock: Eastern, Pine: Lodgepole, Pine: Ponderosa (PP), Pine: Red-Canadian (RP-N), redwood (Old Growth)	0.39	0.419	0.414	0.413	0.411
Ash: Black, Douglas fir: Coast, Douglas fir: Interior North, Douglas fir-Canadian, Douglas Fir-Larch (DFL)	0.45	0.489	0.483	0.481	0.479
Birch: Paper, Larch, western, Southern Pine (SP), Mixed Southern Pine (MSP), Tamarack-Canadian	0.48	0.524	0.517	0.515	0.513
Ash: White, Pine: Longleaf (LLP), Pine: Slash (SHP)	0.54	0.597	0.588	0.585	0.582
Hickory: Bitternut, Oak, White (WO)	0.62	0.696	0.684	0.68	0.675
Oak, Live	0.81	0.671	0.659	0.656	0.652

*Assuming wood is at 30% MC at fiber saturation. Wood species groups per Log Homes Council Grading Program.

Equations per Wood Handbook, FPL,	Calculation of Specific Gravity at Varying EMC: Eq. 3-5: $Gm=Gb/(1-.(0.265*a*Gb))$ $a= (MC_{PSP}-EMC)/MC_{PSP}$ Gb = specific gravity based on green volume (ASTM D2555)

Integral Insulation & Thermal Mass: Solid wood walls having a mass greater than or equal to 20 psf

	Weight (psf) per Inch of Log Thickness Average EMC by Zone*:				R-Value per Inch of Log Thickness Average EMC by Zone*:			
	Dry	Moist	Warm-Humid	Marine	Dry	Moist	Warm-Humid	Marine
SG, Grn	10	13	14	15	10	13	14	15
0.29	1.75	1.8	1.81	1.83	1.6	1.55	1.53	1.51
0.3	1.81	1.86	1.88	1.9	1.56	1.51	1.49	1.47
0.31	1.88	1.93	1.94	1.96	1.51	1.46	1.45	1.43
0.39	2.4	2.46	2.48	2.51	1.24	1.2	1.18	1.17
0.45	2.8	2.87	2.9	2.92	1.09	1.05	1.04	1.03
0.48	3	3.08	3.11	3.13	1.02	0.99	0.98	0.97
0.54	3.41	3.51	3.54	3.57	0.91	0.88	0.88	0.87
0.62	3.98	4.09	4.13	4.16	0.8	0.77	0.77	0.76
0.81	3.84	3.94	3.98	4.01	0.82	0.8	0.79	0.78

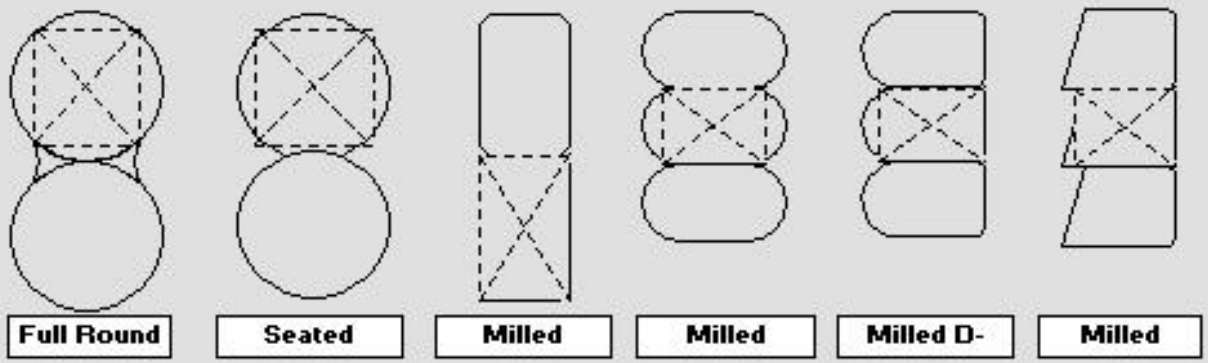
Eq. 3-6b: Density = 62.4 x Gm(1+EMC/100) *Weight = density/12*

Eq.3-7: k = SG[B+ C(MC)] +A MC = EMC

For SG > 0.3, design temperature at 75° F, and MC <25%: ***A*** *= 0.129* ***B*** *= 1.34* ***C*** *= 0.028*

Note the inverse relationship of mass and R-value across a range of specific gravities.

ICC 400 Log Wall Thickness



Short Cut: Average width = Nominal width x

Full Round	Seated	Milled	Milled	Milled D-	Milled
0.785	0.837	1	0.683	0.841	0.969

Better Determination of Average Width =

Nominal width/stack height Width of Inscribed Rectangle

ICC 400 Prescriptive R-values

R-Value of Log Wall by Average Width and Specific Gravity

Specific Gravity (SG)	Average Width 5 in.	6 in.	7 in.	8 in.	9 in.	10 in.	12 in.	14 in.	16 in.
0.29	8.98	10.61	12.23	13.86	15.48	17.11	20.36	23.61	26.86
0.3	8.76	10.35	11.93	13.51	15.1	16.68	19.84	23.01	26.17
0.31	8.56	10.1	11.64	13.19	14.73	16.27	19.35	22.44	25.52
0.32	8.37	9.87	11.37	12.87	14.38	15.88	18.89	21.89	24.9
0.33	8.18	9.65	11.11	12.58	14.04	15.51	18.44	21.38	24.31
0.34	8	9.44	10.87	12.3	13.73	15.16	18.02	20.88	23.75
0.35	7.84	9.23	10.63	12.03	13.43	14.82	17.62	20.41	23.21
0.36	7.68	9.04	10.41	11.77	13.14	14.5	17.24	19.97	22.7
0.38	7.38	8.68	9.99	11.3	12.6	13.91	16.52	19.13	21.74
0.39	7.24	8.52	9.79	11.07	12.35	13.63	16.18	18.74	21.29
0.41	6.98	8.2	9.43	10.65	11.88	13.1	15.55	18	20.45
0.42	6.85	8.05	9.25	10.45	11.66	12.86	15.26	17.66	20.06
0.44	6.62	7.77	8.93	10.08	11.24	12.39	14.7	17.01	19.32
0.47	6.3	7.4	8.49	9.58	10.67	11.76	13.94	16.12	18.3
0.5	6.02	7.05	8.09	9.12	10.16	11.19	13.26	15.33	17.4
0.51	5.93	6.95	7.97	8.98	10	11.02	13.05	15.08	17.11
0.52	5.85	6.85	7.85	8.85	9.85	10.84	12.84	14.84	16.84
0.53	5.77	6.75	7.73	8.71	9.7	10.68	12.65	14.61	16.58
0.54	5.69	6.65	7.62	8.59	9.55	10.52	12.45	14.39	16.32
0.55	5.61	6.56	7.51	8.46	9.41	10.37	12.27	14.17	16.08
0.59	5.32	6.22	7.11	8.01	8.9	9.8	11.58	13.37	15.16
0.6	5.26	6.14	7.02	7.9	8.78	9.66	11.43	13.19	14.95
0.7	4.69	5.46	6.23	6.99	7.76	8.53	10.07	11.6	13.14

Note: Above and left of the bold line, log criteria does not meet IECC requirements for heat capacity for thermal mass credit.

Calculated at 12% EMC, including air films

ICC 400 Structural

Building Systems Magazine's 2002 Excellence in Model Home Design –

Heritage Log Homes, Inc.

- Prescriptive vs. Engineered
- WFCM as model
- Lateral loading on log walls
- Diaphragm and shear wall analysis

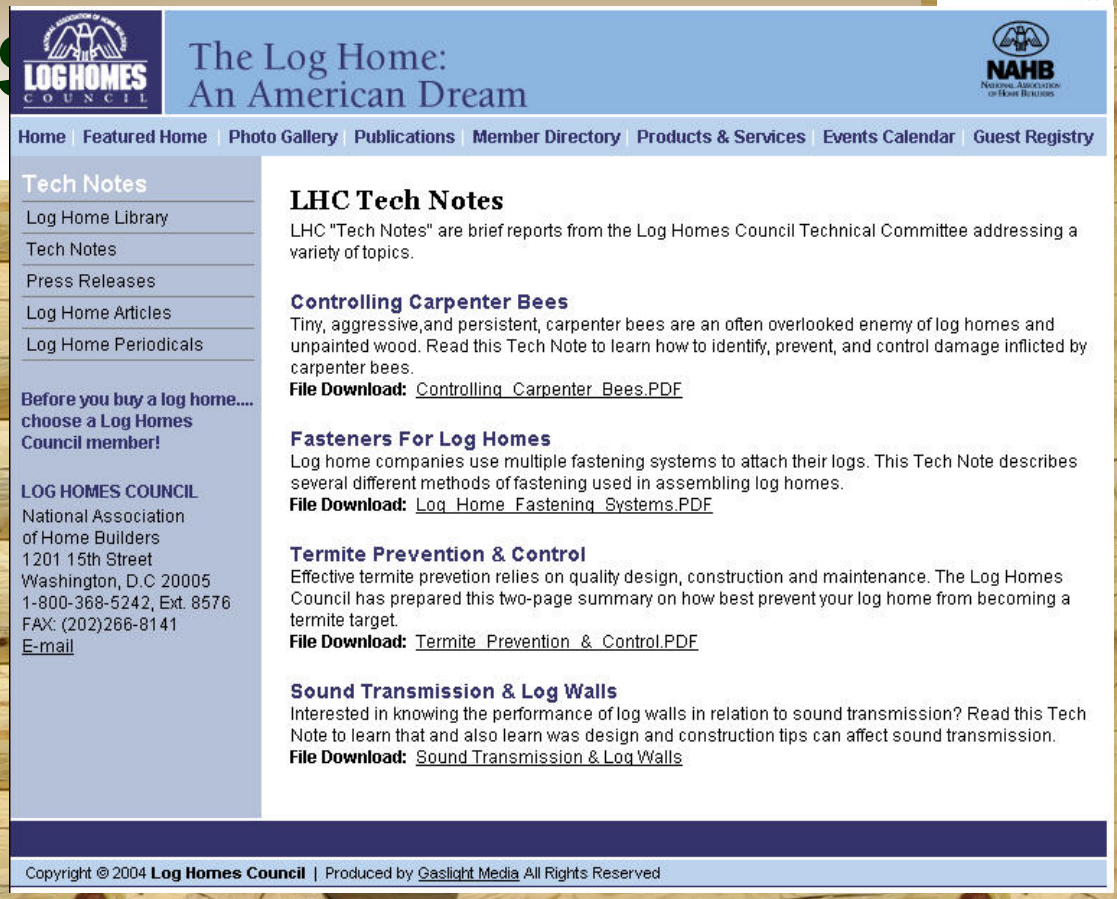
Questions

For more information:

Log Homes Council

1-800-368-5242 x8577

www.loghomes.org



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