Visual Stress Grading

Logs and Timbers Used in Log Structures

By Edwin J. Burke, PhD.

Solid Timber Construction – A Long History in America

Log construction has been a part of North American building since the earliest inhabitants arrived centuries ago. Following the Second World War, individual home construction enjoyed a dramatic increase of vitality compared to the depressed pre-war activity in this vital industry. At the same time, the rising standard of living allowed for second homes and vacation cabins in areas where the "rustic charm" of a log home was a natural fit. It was at this time that the then-small log home business was truly rebirthed to become the 500+ company industry known today. During that 50-year process, methods and technology have combined to aid the development of both the hand-crafted and machine-profiled segments of the industry.

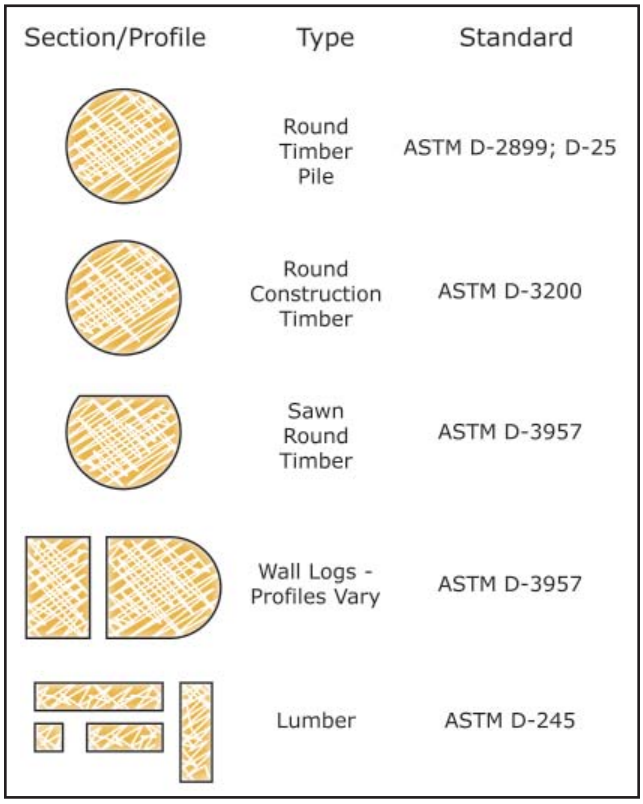

Figure 1: Building log and timber profiles and the standards governing their grading

Structural Integrity of Log Construction

In the beginning days of this recent log construction, primarily the 1950' and 60's, package manufacturers, engineers, log builders, contractors, homeowners and code officials were all struggling to comply with building codes written for conventionally-framed construction. In addition to the lack of any grading or design standards for log structures, reports of a number of serious structural problems with log buildings were circulating. Defective and inappropriately-sized and chosen logs were often the cause of these problems, while the methods and rules that would be required to establish grading standards were not in place. Even less-dramatic and life-threatening problems such as air and water leakage, decay, uneven settling, insect infestations, and finished appearance were also seen as arising from the use of poor materials, including logs.

In the late 1970's, the lack of standardized, wood engineering-based grading rules, as well as a general ignorance of the impact of log quality on structural performance by design and code professionals, rallied the log home industry to take action. Working in unison as the newly-formed Log Homes Council, a member of the council of the Building Systems Council of the National Association of Homebuilders, the effort began with development of ASTM Standard D 3957, *Standard Methods for Establishing Stress Grades for Structural Members Used in Log Buildings*. With this standard as a guide to forming visual stress grades for wall logs and sawn round timber beams and other large timbers, the first accredited log grading agency was formed. Shortly after this breakthrough effort, Timber Products Inspection, long known for its grading services in the lumber and plywood industries, also began providing third-party inspection services to the industry. Both programs are accredited by the International Accreditation Service (IAS), and conform to US and ISO standards for rules writing and third-party inspection agencies.

How Log Grades are Developed and Used

The ASTM Standard D3957-90 defines and distinguishes between two types of sawn or machined timbers, with different grading procedures and rules for each. Solid wood components termed "Sawn Round Timbers" and "Wall Logs" are defined in terms of cross-section and use as follows:

A **Sawn Round Timber Beam** (SRTB) is a structural log that meets both of the following criteria

- Shaved or sawn on one side only within the limits set forth in D3957-90, and
- Normally loaded on the flat side as a beam, primarily stressed in bending and shear

A **Wall Log** (WL) is a structural log that meets one or more of the following criteria

- Sawn or unsawn, stacked horizontally or vertically to form a load-bearing wall, or
- Sawn on one side only, but does not meet the definition of a sawn round timber, or
- Sawn and machined on more than one side

Figure 1 compares the requirements of sawn round timbers and wall logs to other structural elements and their governing standards.

In order to relate round log grading and design to existing lumber grading techniques and current methods of determining allowable properties, the inscribed method, as outlined in ASTM D3957-90, approximates the shape of rectangular lumber (*Figure 2*). This shape is assumed for design purposes, and the grading rules use it for establishing maximum allowable knot sizes for each grade. As an example of the inherently conservative approach taken in grading structural logs, any weakening character outside the rectangle reduces the log's design value, but any additional strength contributed by the wood outside the rectangle is ignored.

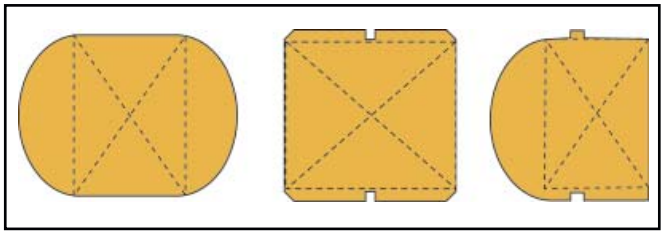

Figure 2: The inscribed rectangle for several wall-log profiles

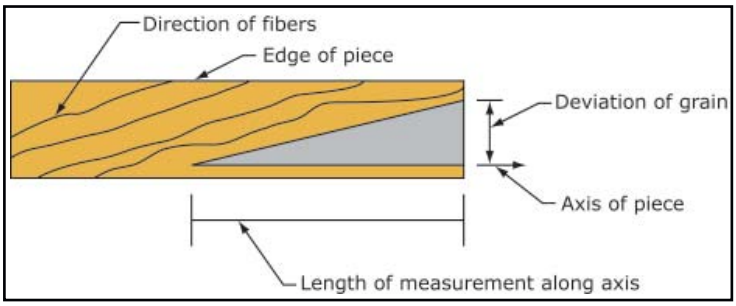

Figure 3: Slope of grain deviation and its measurement

Each grade is developed by setting a ratio of the desired design strength to published data for clear unseasoned wood strength of any species of interest (ASTM Standard D 2555-98). For example, a strength ratio for members used as floor joists is determined and the slope of grain (*Figure 3*) that corresponds to that ratio serves as the basis for setting allowable knot size as well as the size and location of splits, checks and ring shake (*Figure 4*).

Engineers and architects use design values and a listing of limiting characteristics for different log grades in choosing the appropriate material for the application. Like lumber, the Allowable Unit Stress (AUS) value for the species of wood and the grade is based on clear wood values adjusted for duration of load, natural variability, and a factor of safety which reduces the lower 5% level of the mean of that species' clear wood strength. With this adjusted clear wood strength, the Allowable Design Stress Value (ADSV) is determined using adjustment in AUS caused by seasoning, slope of grain, knots, checks, splits, ring shake, and other strength-reducing characteristics.

For example, the Log Homes Council Grading Program's design values for logs and sawn round timber beams account for species, grade, size and conditions of use and are tabulated in a limiting characteristics sheet as shown in *Figure 5*.

Every size and profile of log requires a separate computation of the inscribed rectangle and the ADSV, and therefore requires a separate Limiting Characteristics Sheet. The grading company should be able to provide the designer with this information, including design values, for all of its profiles.

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Summary of Important Strength Reducing Features of Logs and Sawn Round Timber Beams

Species and Wood Density

Homeowners, contractors and prospective clients all have asked the question, and often have an opinion about, "What is the best species for a log home?" Durable species such as "cedars" are often offered up as the best species for a log home due to their resistance to decay and insect attack. Other species, such as lodgepole pine, lend themselves well to handcrafted log homes, where their small amount of taper makes an attractive, yet affordable, handcrafted structure, as this natural taper is left in the building logs, and the joints are hand fitted. High-density species like Douglas-fir, western larch, southern pine and oak are often cited as the best species due to these woods' inherent strength. Spruce and white pine are often suggested as the top species to use due to their low density and naturally high thermal R value that is important in energy calculations. Cost, climate, architecture, availability, and client preference are the factors that should be fully understood before making the final decision on the "best" species for a project.

Slope of Grain and Knot Type, Size and Distribution

Slope of grain is defined as the orientation of wood fibers relative to the edge or centerline of a log or timber (*Figure 3*), and is expressed as a ratio, like the description of roof pitch. For example, a 1:12 slope of grain would be evidenced by a 1-inch deviation by the wood cells' orientation from the edge or centerline of the piece. Slope of grain is caused by naturally-occurring spiral grain in the tree, diagonal grain in a sawn timber caused by sawing at an angle to the long axis of the tree, or a combination of both.

Slope of grain has a major influence on the compression, tension, shear and general bending strength of logs. Research has shown that while no tree has a grain direction that is truly parallel to the pith and/or outside faces of the stem, bending strength is little affected by deviations less than 1 inch in twenty inches (1:20). With angles greater than that, however, strength suffers and allowances must be made. Log grades use slope of grain as a starting point for developing the numerical limits of the other strength reducing characteristics, such as knot size, type and location. Maximum allowable slope of grain for most lumber and log applications, remembering that this value is for the lowest grade, is generally 1:4. It is not unreasonable to easily find timbers and logs with slopes of grain of 1:8 or straighter.

Knot size is directly related to slope of grain. In fact, the limits on knot size are determined not because the knot itself is weak, but because the angle of the wood cells of the trunk must deviate around the knot, thus making larger, higher-angled deviations with larger knots. It is, therefore, slope of grain that is truly the most important growth-related feature of a particular log that determines its overall strength and suitability for use. Visual log grading always takes slope of grain and knot size, type, and location into consideration when assigning a stress value.

Other Strength Reducing Features

Breaks in the wood, whether natural or caused during tree felling or processing, can cause reductions in strength. Naturally occurring, radially oriented cracks caused by drying stresses are known as checks and are assumed to be present or will be present in all solid wall logs and sawn round beams. These features are assumed to be present in every log, and are accounted for in the grading rules and design values. The same can be said for ring shake, a tangential separation of growth rings, and splits, generally caused by breakage during felling or handling. *Figure 4* illustrates these three characteristics, all of which are accounted for during grading.

Biological pathogens such as bacteria, sapstain fungi, decay fungi, and insects are often looked on as negatively impacting the structural integrity of wood construction materials. As is the case with many things, not all of these supposed threats pose a real danger to a log's strength. Insect holes in a log generally come from boring beetles that invade the log while it is still a standing dead tree. Most of these larvae remain in a log only one to two years before emerging as adults looking to find a new dead tree for their eggs. The adults rarely re-infect wood in service. Carpenter ants and termites truly pose a threat to wood integrity and are always cause for rejecting a log. Most decay fungi that inhabit the wood while the tree is still living are no longer viable following wood drying, and are therefore known as "live tree decays." When present in a log, their impact is evaluated by the grader and the type, amount, and location are limited by grading rules. Decay that is not of the "live tree" type is also very restricted by grade rules, and Certified Graders are trained to recognize and reject logs with any significant amount of service decay.▪

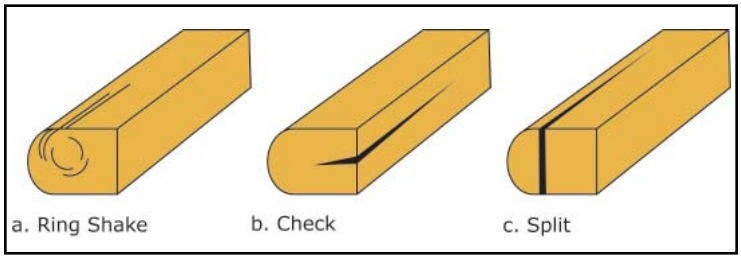


Figure 4: Typical ring shakes, checks, and splits found in structural logs and timbers

The Structural Log Grading Process

Companies wishing to participate in one of the two accredited log grading programs have committed themselves to providing the materials and work environment conducive to the manufacturing quality control concept. Certified grader candidates study grading rules methods and attend a course in log grading, culminating in written and practical grading examinations. Once a company has Certified Graders, it must maintain a Quality Control program that includes grading and certifying all structural log and timber components of each package they produce. In addition to scrutinizing and grade-marking each log or round timber beam, the Certified Grader is also responsible for providing each package with a Certificate of Inspection that will serve as evidence of grading during all phases of construction, even after construction has covered, or otherwise made grade marks unviewable. The grader also ensures that records of all grading activities are kept current and available for inspection by the Agency during third party inspections. Substandard performance in any of these several areas requires heightened monitoring and retraining, or even loss of the company's grading privileges.

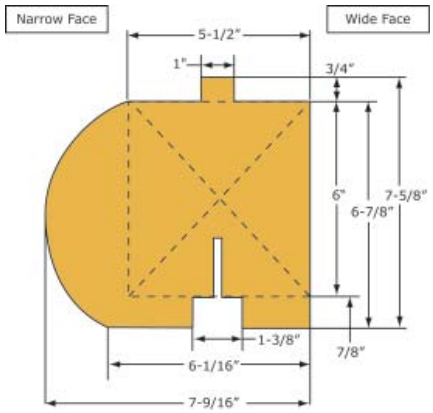
The Design Professional's Role

The engineer/architect should always require use of graded logs in log and timber structures, as required by Code and the upcoming *Standard for Design and Construction of Log Structures* (ICC-400). Architects and engineers must ensure that species, size and grade of logs are all specified in the plans, and that all who read the plans will be aware of how the grade of individual logs will be designated. In their communication with code officials, design professionals should make certain that the official knows that the package will contain graded logs, and should indicate how the log grade will be identified, whether by grade marks on individual logs, certificates of inspection or a combination of both. The inspection agency grading program coordinator is an excellent resource for any information the designer or code official may need.

Summary

Logs and heavy timbers and the structures they produce, have served generations of rural, urban and industrial users, and remain an integrated part of the Nation's continuing construction heritage. Building codes require the use of graded wood structural components. The International Codes Council's pending *Standard for Design and Construction of Log Structures* requires that structural wood timber and log components be stress-graded using rules promulgated by an accredited third party inspection agency. With many of a project's graded structural logs exhibiting defects much smaller than maximum allowable size, and with the contribution of wood lying outside the inscribed rectangle being ignored, the designer can be confident that logs graded through one of the two accredited agencies are significantly stronger than the design values assigned to their grades. A solid timber/log project that begins with good design and engineering and utilizes materials graded by certified graders is well on the way toward success. Proper construction techniques by qualified contractors using well-established techniques and equipment

LOG HOMES COUNCIL MEMBER COMPANY
7″ X 8″ (NOMINAL WALL LOG INSCRIBED RECTANGLE: 5½" x 6″)



LIMITING CHARACTERISTICS				
General	**Beam**	**Header**	**Wall**	**Utility**
Slope of Grain	1:14	1:10	1:6	1:4
Max. narrow face knot	1½″	2¼″	3¼″	4[2]
Max. wide face knot	1½″	2½″	3½″	4¼″
Max. kerfed face knot	1⅛″	2⅛″	3⅛″	3⅞″
Lodgepole pine	**Design Values in P.S.I.**			
F_{D}' lateral load	1300	1100	725	475
F_{D}' vertical load	1300	1100	725	475
F_{1}	775	650	425	275
F_{V}	65	65	65	65
F_{C} (perp. to grain)	170	170	170	170
F_{D} (para. to grain)	850	725	550	475
E	1.1 x 10^{6}	1.1 x 10^{6}	.9 x 10^{5}	.9 x 10^{5}

Figure 5: Sample Limiting Characteristics Sheet for a hypothetical machine-profiled log showing the inscribed rectangle as well as allowable slope of grain and knot size for the various grades

are also a critical part of any successful project. Finally, a long-term maintenance plan using high quality methods and materials will keep the logs, and that dream structure, in the high-quality condition that accredited log grading assured.▪

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