CHAPTER 8 – Defects and Quality Control

Wood as a biological material is susceptible to attack by many biological organisms that may cause discoloration or degradation to the wood. In addition, because it is a hygroscopic material that changes dimension as it naturally picks up and loses water in its environment it is also susceptible to stress-related degradation influenced by the dimensional change. When the degradation negatively affects the appearance, strength, or workability of the wood it is considered a defect.

Defects that are related to biological organisms include degradation caused by insects, decay fungi, bacteria, and marine boring animals. Defects that appear during the drying of wood can be grouped into three categories defined by the origin of the defect and the mechanism by which it is formed. These four categories of defects can be classified as follows:

- Biological degradation
    - Insect – most damage is related to galleries and tunnels produced by wood boring insects. The exception is termites; they consume wood as a food source. Four categories of wood damaging insects are:
        - Termites
        - Carpenter ants and bees – wood boring
        - Dry wood beetles – wood boring, prefer wood below 25% MC
        - Wet wood beetles – wood boring, prefer living or recently dead trees or wood with a MC greater than 30%MC
    - Fungus – degradation of cell wall substance by wood destroying fungi, requires MC greater than 25%
    - Stain – discoloration caused by mold fungi, decay fungi, bacteria, etc. Species susceptible to attack from blue stain fungi need to be processed within a few days of harvest or kept saturated with water until they are sawn. Once sawn the lumber needs to be kiln dried within a few days.
    - Bacteria – degradation of materials stored in cells and also cell wall substance. Bacterial degradation is very slow acting and requires MC greater than 25%
    - Marine – surface degradation by exposure to salt water or degradation by marine boring animals
- Growth related
    - Shake – a separation along the growth rings
    - Warp – deviation in straightness related to grain angle, sawing pattern, and the presence of reaction wood
- Stress related
    - Surface checks and end checks
    - Honeycomb – internal checks perpendicular to growth rings

    - Collapse – cell collapse causing uneven thickness and wavy surfaces
    - Casehardening – internal stresses causing distortion when wood is resawn
- Chemical discoloration
    - Sticker stain, mineral streak, kiln brown stain – chemical oxidation of enzymes and extractives
    - iron stain – oxidation of iron minerals in wood or iron in contact with the surface of wood

The biological degradation and the growth related defects will likely occur if the conditions are favorable. However, controlling the wood moisture content or how wood is dried can minimize the potential for damage and defect. Controlling wood moisture content is very effective in minimizing most of the biological organisms (except termites, carpenter ants and bees, and marine organisms). The other defects (except shake) can be controlled by the method in which wood is initially dried from the green moisture content (i.e. the wood moisture content in the living tree). The drying defects (warp, stress-related, and chemical discoloration) are discussed in more detail below.

Drying Stresses

Warp – This condition is defined as the distortion of the original rectangular shape of a piece of lumber as it dries. Warp is directly related to how the growth rings (grain) of a tree are positioned in a sawn piece of lumber. This is because wood exhibits differential shrinkage. Wood shrinks twice as much in the direction tangential to the grain (direction tangent to the concentric rings of a tree) as it does in the direction radial to the grain (following the rays, along a radius from the bark to the center of the tree). Figure 2 illustrates how grain angle influences warp.

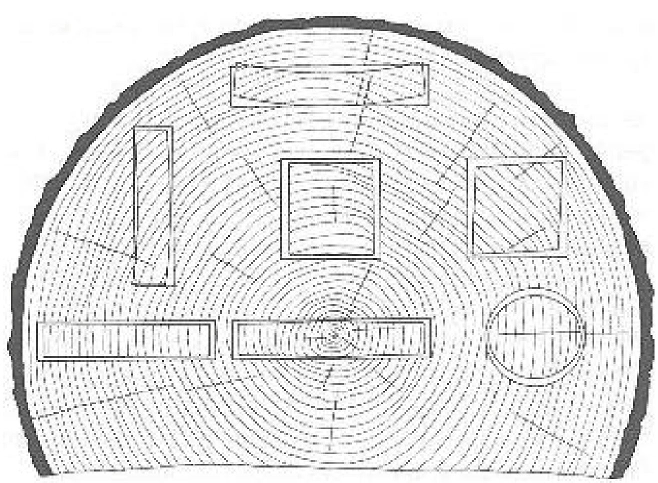
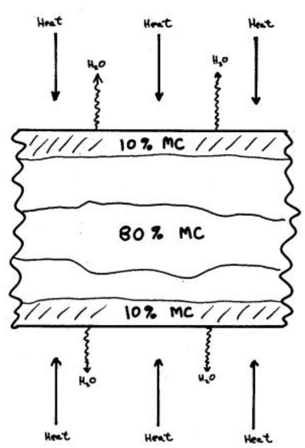


Figure 1. Differential shrinkage related to grain direction cause warp.

Stress Related – The stresses that cause lumber to warp are a direct result of the inherent differential shrinkage that occurs in wood across the grain, that is, between the tangential (tangent to the growth rings) and radial directions (parallel to the rays), or natural or saw-induced grain deviation within a board. Drying lumber in thicker dimensions or placing a uniformly distributed dead weight restraint on the boards to keep them flat during drying can minimize warp. Also, narrow boards will warp less than wider boards.

Stress-related drying defects occur because stresses are created inside wood as the water leaves and the wood shrinks. If these stresses are large enough, they can cause defects such as checks, honeycomb, casehardening, and collapse. Although most of these defects are not apparent until the wood is nearly dry, they actually begin to develop very early in drying when the shrinkage of a dry shell is restrained by a wet core in a swollen state (Figure 1). During the first stage of drying cell collapse begins as the free water inside of saturated cells is removed. Drying stresses begin in stage 2 when the outer shell of the wood begins to dry. The faster the wood dries in stages 1 and 2 the greater the stresses will be, resulting in more drying defects. In stage 3 the inner core dries below the fiber saturation point (about 25% MC) and if the conditions were set up in stage 1 and 2 then the drying defects will begin to appear in this stage (stage 3).



Wood dries from the outside in, creating moisture gradients that lead to drying stresses and potential defects.

Stage 1 – free water removal
- a. stress free
- b. cell collapse

Stage 2 – shell in tension, core in compression
- a. surface checks
- b. collapse

Stage 3 – shell in compression, core in tension
- a. honeycomb
- b. caseharden

Figure 2 – How stresses develop during drying and the defects they cause.

The critical stage is from the initial green MC (when the lumber is first cut from a fresh log) down to about 25%. The difficult to dry species have a tendency to develop collapse and honeycomb if they are dried too fast during the critical stage. It is important to dry them slowly (2% - 3% MC decrease per day) at low temperatures and a high relative humidity (below 110° F and above 85% RH) until a wood MC lower than 25% is reached.

A summary of the stress-related drying defects and recommended drying techniques follows.

- Warp – This distortion in lumber caused by differential shrinkage can be nearly eliminated if the lumber is cut from the log in such a way that the end grain is either perpendicular (quarter-sawn) or parallel (flat-sawn) to the flat surface of the board. For boards that deviate from true quarter-sawn or flat-sawn, warp in the lumber can be minimized by restraining it from movement. For example, if a board is kept flat with a top load (evenly distributed weight across the length of the board) while it dries it will remain flat when it is dry (no warp).
- Surface Checks (cracks) and End Checks – defects created in the first stage of drying when the exposed surfaces of wood are rapidly drying and the shrinkage of the surface zones is restrained by a wetter subsurface. Checks are minimized by slow drying during stages 1 and 2 and protecting the surfaces from hot dry air or direct sun exposure. Coating the ends of lumber with paraffin or lumber end-seal paint is recommended for check-prone species.
- Honeycomb – These internal checks appear during stage 3 drying but the conditions for their development are created in stage when the surface is dried too quickly and a severe MC gradient is established through the piece. Honeycomb is minimized by slow drying during stage 1.
- Collapse – Rapid removal of free water from saturated wood cells causes the weaker cells to collapse. This defect can be minimized by slow drying during stage 1, or by steaming the lumber for a few hours during stage 2. Bacterially infected wood is very prone to cell collapse when it is dried.
- Casehardened lumber – This term describes the condition where the outer shell of a piece of wood is stressed in compression and the inner core is stressed in tension. When casehardened wood is cut with a saw the wood will pinch the saw blade and the wood will be permanently warped. Casehardening can be minimized by slow drying during the stage 2 drying.

Surface checks, end checks, and honeycomb are permanent defects that cannot be corrected once they develop. Collapse and casehardening can be partially corrected and sometimes eliminated. Much of the cell collapse can be recovered by steaming the lumber at a high temperature in a closed chamber. Casehardening is relieved by adding moisture back into the kiln at the end of the drying period to re-hydrate the surface zones causing the surface to swell and relieve some of the compression stress. Just the right amount of stress relief will eliminate casehardening but too much re-hydration will cause a condition of reverse casehardening, a permanent defect that cannot be corrected.

Chemical Discoloration

Chemical discoloration sometimes occurs during drying. For these stains to develop moist wood and moderate drying conditions are required. The stains are most likely to develop when temperatures are between 90 – 110^{o} F and the relative humidly is above 80%. These stains often manifest adjacent to or beneath the stickers used to separate courses of lumber during drying, a condition referred to as sticker stain. Some species, such as maple, ash, and tanoak are very susceptible to chemical staining. The recommended method to minimizing chemical stains is too dry the surface of the wood very quickly at low temperatures (to avoid causing other drying defects). Drying stain-prone wood during stage 1 with a temperature of 100^{o}F at a relative humidity less than 60% with very high air velocity produces stain free lumber.

Quality Control

Once lumber is dried with a schedule designed to produce high quality results it is a good idea to evaluate the quality of the lumber produced. A simple table for recording the quality of a sample of boards is a good way to keep track of the results and to monitor the success of an operation. By tracking such quality parameters as final moisture content and the presence of warp and other drying defects it is possible to set up target quality parameters and quickly recognize when a process is operating out of control. Table 1 below shows an example of a quality control record for a sample of 25 boards taking from a kiln run of 5,000 board feet. The drying operation is considered successful if the standard deviation is less than 1.5, the mean MC measurements is within 15% of the target MC, and the mean value for each drying defect is less than 1. In the example used in Table 1 the final target moisture content was 6% MC. The mean dry moisture content of the sample was 5.3% within the 15% range of the target and the standard deviation was 0.95, which is less than 1.5. Also the means for all the defect ratings were less than 1.0. The drying operation was therefore considered successful.

This example is only provided as an example of how to set up a basic quality control process. Each operation needs to develop its own acceptable limits for the process being monitored. The limits will be influenced by product standards and market conditions.

Table 1. A Quality control table for monitoring the kiln drying of 5000 board feet of lumber.

	Moisture Content				Defect (1=moderate, 3=severe)					
Board #	1	2	3	Average Board MC	Cup	Twist	Bow	Crook	Collapse	Stain
1	5.2	4.3	5.1	4.9						2
2	4.5	3.6	4.4	4.2	2				1	
3	4.1	5.5	5.3	5.0			1			
4	3.7	4	3.1	3.6	2					
5	5.6	4.9	5	5.2	1		1			
6	4.9	4.9	5.9	5.2	1	1				
7	6.6	7.9	6.5	7.0	1		3			
8	4.6	5.1	6.3	5.3		1	3			
9	4.6	7.4	5.2	5.7	1		2			
10	6.1	4.3	3.9	4.8					1	
11	7.1	5.9	5.9	6.3						
12	6.5	6	5.6	6.0		1				
13	3.1	4.4	4.1	3.9				2		
14	5.9	5.1	5.3	5.4	1	1				
15	6.4	6.1	6.7	6.4			1			
16	4.9	5	4.5	4.8	0	1				
17	6.6	4.4	7.1	6.0	1	1	2			
18	5.2	5	5.1	5.1		1				
19	3.7	4.8	5.6	4.7					1	
20	7	7.1	9.5	7.9			2		1	
21	5.5	5.5	5.1	5.4	1	1			1	
22	4.3	5	4.3	4.5		1			1	
23	5.5	5.4	4.3	5.1		1	1		1	
24	5.8	5.4	3	4.7	1	1	1		2	
25	5.5	4.2	5	4.9			1		1	
Mean				5.3	0.2	0.4	0.6	0.1	0.4	0.1
Stnd. Dev			.	0.95						

The basic introduction to biological degradation and drying defects is summarized in the following slide presentation.