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NAIL-WITHDRAWAL RESISTANCE OF AMERICAN WOODS

Resistance of a nail to direct withdrawal from a piece of wood is intimately related to the density or specific gravity of the wood, the diameter of the nail, and the depth it has penetrated. The surface condition of the nail and the type of shank and point it has will also influence the withdrawal resistance.

For bright common wire nails driven into the side grain of wood, the withdrawal resistance immediately after the nail is driven is given by the formula, $p = 6900\, G^{5/2} D$, in which $\underline{p}$ represents the ultimate load per lineal inch of penetration in the member holding the nail point; $\underline{G}$ the specific gravity of the wood based on weight and volume when ovendry; and $\underline{D}$ the diameter of the nail in inches.

Relationships expressed by this equation are general and provide information on the relative withdrawal resistance of different species of wood. Certain species of wood, however, give test values that are somewhat higher or lower than the equation values. Usually common knowledge of the characteristics of the nail, and of the species with particular reference to tendency to split, will aid in deciding whether the withdrawal resistance will fall above or below the equation values.

The general equation indicates that the dense, heavy woods offer greater nail-withdrawal resistance than the ones of lighter weight. This does not mean that the lighter species are not qualified for uses requiring high withdrawal resistance. As a rule, the lighter species do not split as readily as the dense ones; thus lighter woods offer an opportunity for increasing the diameter, length, and number of the nails to compensate for the wood's lower nail-holding properties.

In practically all species, nails driven into green wood and pulled before any seasoning takes place will offer about the same withdrawal resistance as nails driven into seasoned wood and pulled soon after driving. However, if common smooth-shank nails are driven into green wood that is allowed to season or into seasoned wood that is subjected to cycles of wetting and drying before the nails are pulled, they lose a major part of their withdrawal resistance. In seasoned wood that is subjected only to

Table 1. --NAIL-WITHDRAWAL RESISTANCE

Hardwoods

	Specific gravity[1]	Relative nail load[2]
Ash, black	0.53	1380 D
Ash, commercial white	.61	2900 D
Aspen, bigtooth	.41	740 D
Aspen, quaking	.40	690 D
Basswood, American	.40	690 D
Beech, American	.67	2550 D
Birch, sweet	.71	2900 D
Birch, yellow	.66	2410 D
Chestnut, American	.45	970 D
Cottonwood, black	.37	550 D
Cottonwood, eastern	.43	830 D
Elm, American	.55	1520 D
Elm, rock	.66	2410 D
Elm, slippery	.57	1720 D
Hackberry	.56	1590 D
Hickory, pecan	.65	2350 D
Hickory, true	.74	3240 D
Magnolia, southern	.53	1380 D
Maple, black	.62	2140 D
Maple, red	.55	1520 D
Maple, silver	.51	1310 D
Maple, sugar	.68	2620 D
Oak, commercial red	.66	2410 D
Oak, commercial white	.71	2900 D
Sweetgum	.53	1380 D
Sycamore, American	.54	1450 D
Tupelo, black	.55	1520 D
Tupelo, water	.52	1310 D
Yellow-poplar	.43	830 D

Softwoods

	Specific gravity[1]	Relative nail load[2]
Alaska-cedar	0.46	970 D
Baldcypress	.48	1100 D
Douglas-fir, Coast-type	.51	1310 D
Douglas-fir, Rocky Mountain-type	.45	970 D
Fir, balsam	.41	740 D
Fir, commercial white	.41	740 D
Hemlock, eastern	.43	830 D
Hemlock, western	.44	900 D
Larch, western	.59	1860 D
Pine, eastern white	.37	550 D
Pine, lodgepole	.43	830 D
Pine, ponderosa	.42	790 D
Pine, red	.51	1310 D
Pine, southern yellow	.59	1860 D
Pine, sugar	.38	620 D
Pine, western white	.42	790 D
Port-Orford-cedar	.44	900 D
Redcedar, western	.34	470 D
Redwood (old-growth)	.42	790 D
Spruce, Engelmann	.35	500 D
Spruce, red	.41	740 D
Spruce, Sitka	.42	790 D
Spruce, white	.45	970 D
White-cedar, Atlantic	.35	500 D
White-cedar, northern	.32	410 D

[1] Based on weight and volume when ovendry.

[2] Load in pounds. D = nail diameter in inches.

Nail diameter varies for different types of nails. Here are diameters of bright common wire nails:

Penny	Gage	Diameter	Penny	Gage	Diameter
4	12-1/2	0.098	12	9	0.148
6	11-1/2	.113	16	8	.162
8	10-1/4	.131	20	6	.192
10	9	.148			

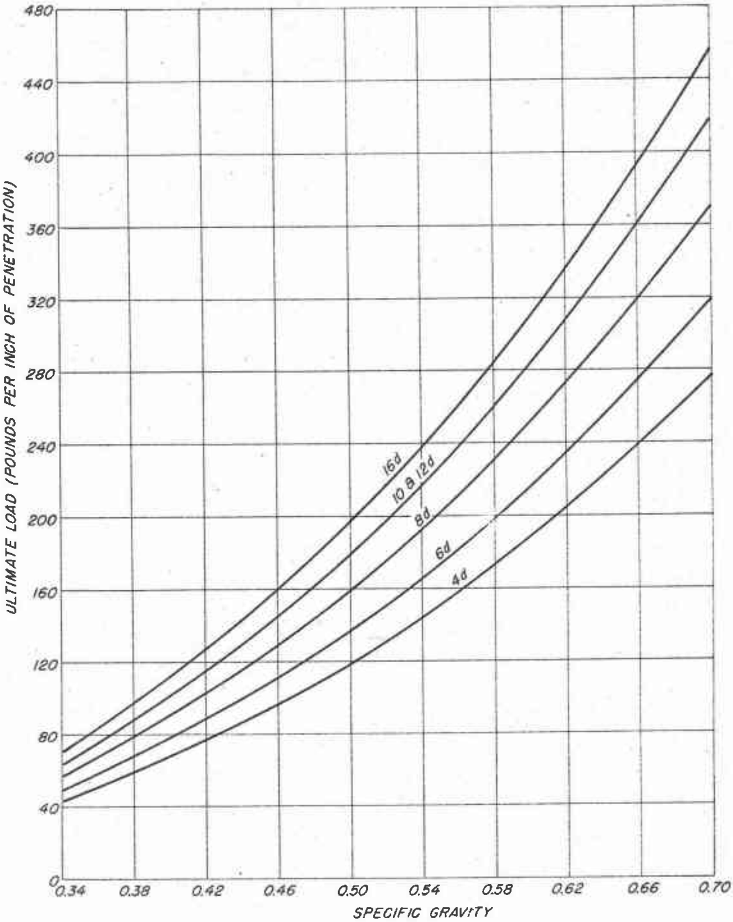

Figure 1. --Load required to withdraw common nails from wood of different specific gravities immediately after nails were driven. Specific gravity is based on weight and volume of ovendry wood.

moisture changes from normal atmospheric variations, the withdrawal resistance of smooth-shank nails also diminishes in time. On the other hand, tests indicate that, when moisture conditions cause nails to rust, withdrawal resistance is verv erratic; it may be regained or even increased over the immediate withdrawal resistance. Under all conditions of use, the withdrawal resistance of nails varies so widely that it is difficult to evaluate their behavior. The withdrawal loads for plain nails driven into wood that is subjected to wide alternating changes in moisture content may be as much as 75 percent below the values given by the general formula.

The specific gravity of various species of wood and their relative resistance to the withdrawal of smooth-shank nails are given in table 1. There the numerical value of 6900 $G^{5/2}$ has been calculated for each species. The load per inch of penetration immediately after driving may be obtained by multiplying this nail-withdrawal factor by the diameter, D. For example, table 1 shows a value of 790 D for an eightpenny common nail (0.131-inch diameter) in ponderosa pine. Multiplying 790 times 0.131 gives a value of 103 pounds per inch of penetration.

The curves in figure 1 show the relationship between load for common wire nails and the specific gravity of the wood. By using the specific gravity from table 1, the withdrawal resistance of a given size nail may be obtained directly from the curves. For example, to obtain the withdrawal resistance of an eightpenny (0.131-inch diameter) common nail in ponderosa pine, follow the specific gravity line at 0.42 upward to the 8 D curve. A horizontal line from that point of intersection to the load scale shows a load of 103 pounds.

The values given herein are for nails driven perpendicular to the grain of the wood. When the nail is driven parallel to the wood fibers -- into the end of the piece -- withdrawal resistance in the softer woods drops to 75 or even 50 percent of the resistance obtained when the nail is driven perpendicular to the grain. The direction at which the nail is driven has less effect on the withdrawal resistance in dense woods than in softer woods. Slant driving of nails is usually superior to straight driving.

Many other types of nails have been developed for ordinary or special uses. These include annular grooved, spirally grooved, and coated or etched nails. In general, they have been developed to provide higher resistance to withdrawal than furnished by the common nail. Under conditions involving changes in the moisture content of the wood, annular grooved and spirally grooved nails provide considerably greater withdrawal resistance than the common wire nail. This is especially true of nails driven into green wood that subsequently seasons.