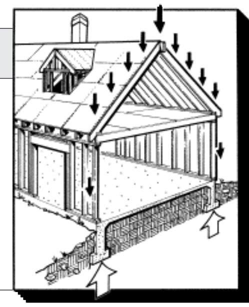


Hanging Kitchen Cabinets

by Harris Hyman, P.E.

Think that engineering is just for major structures? Not necessarily. Kitchen cabinets are often subjected to some serious loading. This usually leads not to disaster and lawsuits, but occasionally to a lot of embarrassment on the part of the builder if a cabinet sags or slips off the wall.

Gravity vs. Wood Screws

Take a basic wall cabinet: It's 36 inches wide and 12 inches deep, with three shelves and an accessible top surface. Now let's fill it up and see what it weighs (see illustration, next page).

Weights and measures. A can of soup measures 4 inches high, $2\frac{1}{2}$ inches in diameter, and weighs 13 ounces. Some quick arithmetic shows that you can pack about 14 of these cans, 4 deep, across the first shelf. Now stack them 3 high and you have a total load of 136.5 pounds on the first shelf. Fill the second shelf with 5-pound bags of flour; you can get 7 across, 3 deep, for a total of 105 pounds.

On the third shelf, put three stacks of plates. My stoneware plates are 11 inches across and weigh 2 pounds 11.5 ounces. Stack them 10 high, 3 stacks across, for a total load of 81.5 pounds on the third shelf. Load the top of the cabinet lightly, say 30 pounds, and allow 50 pounds for the cabinet itself. This brings the total weight of the cabinet to 403 pounds. (This may sound like a worst-case cabinet scenario; it is. But at least one of the cabinets — maybe more — is sure to be packed to the brim. And the owner probably won't tell you which one — so you'd better make sure that all the cabinets are adequate for the job.)

In addition to food and dishes, kitchens often have curious kids who use the bottom shelf as a support in climbing up onto the counter. A good weight for a curious kid is about 40 to 60 pounds; smaller and they are not as active and bigger they are more reasonable and humanlike. Add in a 50-pound child hanging from the cabinet and you've got a 453-pound package. Think you should be worried about all those cabinets you've hung over the years using just a couple of drywall screws?

Lateral loading. There are two types of loading failure that can apply to cabinet fasteners. The first is *lateral failure*. Here the load is at right angles to the fastener. The tendency is for the fastener — a screw in a wood stud, for instance — to bend and rip out of the wood.

The lateral load on the fastenings in this case is the total load of the cabinet — 453 pounds in my example. (Include the kid: You should always plan for the worst case.) According to charts published in reference books, a 7-gauge wood screw will handle a lateral load of about 90 pounds in Doug fir or about 74 pounds in eastern spruce. This assumes 7 diameters of penetration into solid wood — or about 1 inch for a 7-gauge screw (see chart, above). The load on a kitchen cabinet is of long duration — it continues for years without letup as cans are pulled and replaced. Whenever wood is loaded in a long-duration situation, it tends to fail with a lighter force. To be on the safe side, the design capacity of the screws should be reduced by about 10% (per the *Uniform Building Code*). A quick calculation says that it will take about 7 screws to hold the loaded cabinet when screwing into spruce studs and about 6 screws when screwing into Doug fir.

Withdrawal. Lateral failure isn't the only type of failure. There is also direct withdrawal to be concerned with. Withdrawal is the tendency for a straight-on force to pull the screw out of the stud.

Look at the diagram below. Engineers use this type of sketch to figure leverages called *moments*, which are the *product of a force times a distance*. These moments act about a pivot point. The distance is called the *lever arm*, measured in inches. Since the force is measured in pounds, the moment of the force is given in inch-pounds.

You have direct experience with moments every time you pry a nail out of a board with a hammer. The force you exert with your arm multiplied by the length of the hammer handle is the moment that overcomes the withdrawal resistance of the nail. If your hammer handle breaks, you get a crowbar and try again — this time multiplying your force times a greater distance — and out pops the nail.

In our example, the bottom back corner of the cabinet is the pivot point. There are two forces at work: the total weight of the cabinet and the child. The weight of the cabinet and contents — 403 pounds — is just about centered along a vertical line running through the middle of the cabinet, 6 inches out from the wall. The leverage, or moment (M), exerted by this weight is:

M = 6 *in.* x 403 *lb.* = 2,418 *in.-lb.*

In addition, the curious kid is hanging onto the cabinet edge, 12 inches out

Strength of Wood Screws

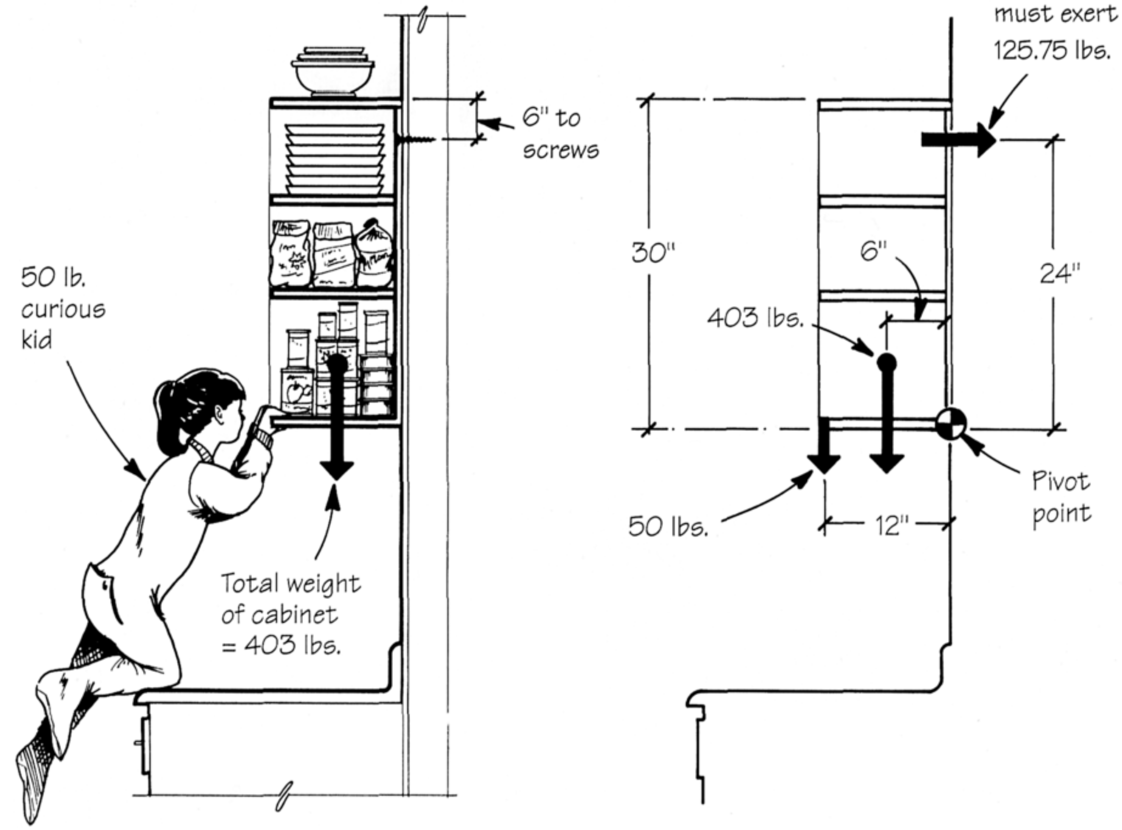
(in pounds in Doug fir and SPF lumber)

	Lateral Strength[1]		Withdrawal Strength[2]	
Screw Size	**Doug fir**	**SPF**	**Doug fir**	**SPF**
#7 wood screw	90	74	112	80
#10 wood screw	143	117	141	100
$\frac{1}{4}$x4" lag screw	170	130	232	180

Note: *Reduce values by 10% for long duration loading.*

[1]*Assumes 7 diameters penetration* [2]*Per inch penetration*

Calculating Withdrawal Forces



The drawing at left represents a worst-case kitchen cabinet — filled to the max, with a 50-pound child hanging from the bottom shelf. At right is a moment diagram of the same cabinet, which shows how the forces act. The weight of the cabinet and contents (403 pounds) is centered along a line 6 inches out from the wall, creating a 6-inch lever arm. Similarly, the weight of the child acts at the end of a 12-inch lever arm. The screws holding the cabinet to the wall must exert a 125.75-pound resistance to withdrawal.

from the wall. The moment exerted here is:

M = *12 in. x 50 lb. = 600 in.-lb.*

So the total moment exerted by the cabinet and its load is 3,018-inch pounds.

The counteracting leverage necessary to resist this moment comes from an upper row of screws, placed 6 inches down from the top of the cabinet (screws placed lower in the cabinet have a shorter lever arm, so resist with much less moment, which we'll ignore). These screws are loaded in withdrawal and are being pulled out of the wall. They are acting at the end of a 24-inch lever arm.

To find the total resistance to withdrawal (P_w) that the screws must exert, we divide the withdrawal force of the cabinet by the 24-inch lever arm of the screws:

P_w = *3,018 in.-lb. ÷ 24 in. = 125.75 lb.*

So the screws must exert a total force against withdrawal of 125.75 lb. to resist the 3,018 inch-pound moment.

Our screws, with 1-inch penetration, have a withdrawal strength of 112 pounds in fir and 80 pounds in spruce. Reducing by 10% for long-duration loading gives 100.8 pounds and 72 pounds. This means that for resisting withdrawal loads, two screws are sufficient in either Doug fir or spruce framing.

By the way, with withdrawal force, the deeper you penetrate the stud, the more resistance you develop. This isn't true with the lateral resistance. At 7 diameters, the screw develops most of the lateral strength it can. So make sure you penetrate deep enough with the screws to resist withdrawal, then use *enough* of them to handle the lateral load.

Recommendations

So chances are, most of those cabinets you've hung with a couple of screws are not going to fail from screw withdrawal. But you may still have that lateral load to worry about.

I've written this assuming 7-gauge wood screws, but almost everyone I know uses drywall screws. Drywall screws are made for hanging wallboard, and are not necessarily approved by code for structural applications, though most building officials will not question their strength. Personally, I feel comfortable with drywall screws as compared with ordinary off-the-shelf wood screws. But in general, I prefer lag screws for installing cabinets. They are stronger and fewer are required.

It's best to evenly distribute fastenings across the back of the cabinets. Also, at the risk of being insultingly obvious, make sure you're putting the screws into studs, not into insulation.

Give the cabinet construction a good look before installation. The back must be strong enough in itself to hold the fastenings. Quarter-inch material is a little on the light side and may need to be stiffened with a brace inside the cabinet; 3/8-inch and 1/2-inch backs are fine. The cabinet back must also be securely attached to the sides so that the load can be transferred from the sides to the fastenings; a bunch of brads around the edge will keep things looking okay when you give the owner the keys to the front door, but you can surely expect a phone call later. ■

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