

Building Bookshelves to Last

How to support loads of any size and weight for years to come

BY JEFF MILLER



Everyone can use a few more shelves. Indeed, in many homes, an available shelf can be as difficult to find as the TV remote. So if you build a set of bookshelves, they'll probably be filled as soon as the finish dries.

Bookshelves can work in any room. You can make them free-standing or built-in. They can be big or small. And they can take any form, from simple screwed-together and painted plywood for use in a utility room, to sophisticated formal library shelves made from beautiful hardwoods.

A shelf should look good

A successful bookshelf design must achieve a balance between appearance and function. A shelf with the perfect look might not be adequately strong. That often means making changes as you work out the design.

A good approach is to start by writing out a wish list that summarizes your ideal shelf design. The list should include the shelf depth, a factor determined by the width of the books going on the shelf. Next, choose a shelf length (bookcase width). Then, choose a shelf thickness— $\frac{3}{4}$ -in. stock is readily available, but let your eye make the final determination. After that, decide if you want the shelves to be fixed, adjustable, or some of each. Finally, choose a joint or mounting system that offers the look you want.

The design process is just beginning once you've worked out your bookshelf

design “brief.” Now you must determine if your initial choices will be strong enough. If not, you’ll have to make some design changes. But before we get to that, it helps to understand how a shelf reacts to load.

Sag is the main enemy

As the load on a shelf increases, the weight eventually reaches a point where the shelf bends, or sags. The same factors that affect appearance also affect shelf sag: the thickness, width, and length of the shelf; the wood species used; and the method used to mount the shelf.

As a general rule, our eyes won’t notice sag if it’s less than $\frac{1}{32}$ in. (0.031 in.) per foot. With time, even if the contents don’t change, a shelf’s initial sag could increase by 50% or more as the wood fibers “tire.” Wood engineers call this “creep.” To be on the safe side, design shelves to limit any initial sag to no more than 0.02 in. per foot under a load of full-size books.

In extreme cases (loading a bookcase with your anvil collection, for example), shelves can deflect so much that the wood actually fails. This is not a common worry. More common, especially on long shelves, is that sag causes the effective length of the shelf to become shorter, causing it to slip off the shelf supports. Or, too much weight on a long shelf can cause some adjustable shelf supports to crush the wood fibers in the case sides. As a result, the supports tilt downward.

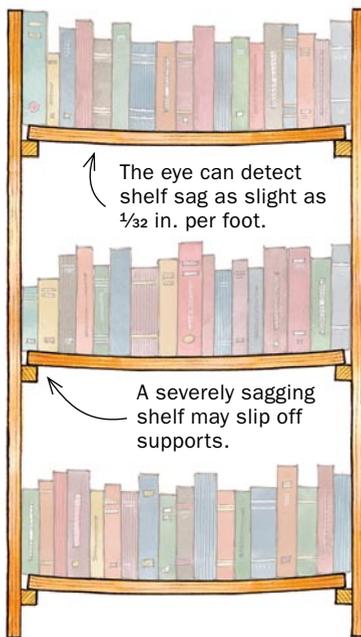
Fixed or adjustable

The method used to mount a shelf affects how much it will bend under a load. All else equal, a fixed shelf will bend less than an adjustable shelf. That’s because on a well-secured fixed shelf, the ends resist both tilting and being pulled inward by the sag (see pp. 40-43 for fixed- and adjustable-shelf options).

Be aware that fixed shelves aren’t immune to failure. With enough weight (perhaps adding your spouse’s anvil collection to your own on the same shelf) and its consequential sag, even fixed shelves can fail at the ends. When that happens, the shelf curves and effectively shortens, the ends pull free, and everything can head south in a hurry.

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Design shelves for maximum load



You don’t need to guess at how much a shelf is going to sag. The chart below provides a quick way to determine if your shelf will be sag-free. If the chart doesn’t work for your shelf, you can use the Sagulator, an online program that makes it easy to determine sag. Both the chart and the Sagulator assume unfixed shelf ends. Fixed ends sag less.

The chart is easy to use. It provides the maximum shelf-weight limits (in pounds per foot) and works for most designs. You need to know the thickness of the shelf ($\frac{3}{4}$ in. or 1 in.) and its length (24 in., 30 in., 36 in., or 42 in.).

If the expected load exceeds the weight limit shown in the chart, you’ll have to make compromises. To do that, use the Sagulator

(www.finewoodworking.com/sagulator).

An answer of more than 0.02 in. per foot of shelf means you need to put less load on the shelf; use a stronger wood; make the shelf thicker, wider, or shorter; or add wide edging. With the Sagulator, you can adjust those values and calculate a new sag number.

Approximate shelf loads:

Hardcover books (9 in. by 11 in.), 20 lb. per ft.
Magazines (9 in. by 11 in.), 42 lb. per ft.



Material makes a difference. Some shelf materials resist sag better than others. Red oak is one of the better ones, eastern white pine less so. MDF makes a weaker shelf.

SHELF WEIGHT LIMITS (pounds per foot*)

TYPE		LENGTH			
Species	Thickness	24 in.	30 in.	36 in.	42 in.
RED OAK	$\frac{3}{4}$ in.	49	21	9	5
	1 in.	116	47	23	12
	$\frac{3}{4}$ in. with 2-in. edging	112	47	21	12
POPLAR	$\frac{3}{4}$ in.	42	17	8	4
	1 in.	101	41	20	10
	$\frac{3}{4}$ in. with 2-in. edging	97	39	20	10
EASTERN WHITE PINE	$\frac{3}{4}$ in.	33	14	6	3
	1 in.	74	32	15	8
	$\frac{3}{4}$ in. with 2-in. edging	76	32	14	8
FIR PLYWOOD	$\frac{3}{4}$ in.	32	13	6	3
	$\frac{3}{4}$ in. with 2-in. edging**	96	39	18	9
MDF	$\frac{3}{4}$ in.	9	4	2	1
	$\frac{3}{4}$ in. with 2-in. edging**	73	30	14	7

*Based on 11-in.-wide shelves **Edging is red oak; other edgings are the same wood as the shelf.

Fixed shelves sag less and strengthen the case

Fixed shelves attach to the sides of a case with either wood joinery, hardware, or a combination of both. Unlike adjustable shelves, fixed shelves help strengthen the entire case. And because they are attached to the case sides, fixed shelves sag less.



DADO

Strength: Good

Appearance: Good (excellent if using a stopped dado or if covered by a face frame)

A dado joint effectively houses the ends of the shelf in a long notch, providing some mechanical strength. Because a dado joint produces mostly end-grain surfaces, adding glue increases the strength only nominally. The attachment strength of a shelf can be improved further by combining Confirmat screws (see sidebar, right) with either a dado joint or a rabbeted dado joint. The screws keep the ends of the shelves in the dado, and the dado adds extra shear strength.



RABBETED DADO

Strength: Good

Appearance: Good (excellent if using a stopped dado or if covered by a face frame)

A minor variation on the dado joint is to rabbet the ends of the shelf to fit into a narrower dado. The main advantage is the ability to fit the joint more easily, especially if the shelf thicknesses are inconsistent. This joint is useful when working with hardwood plywood, a material that typically measures less than 3/4 in. thick. In this case, a dado cut by making a single pass with a 3/4-in.-dia. straight router bit ends up too wide. However, with a rabbeted dado, you cut a narrow dado first, then the rabbet for a perfect fit.

CONFIRMAT SCREWS ADD STRENGTH

I'm not a fan of screwing shelves in place with the typical tapered woodscrew. They rarely hold up long-term. That said, I have found a specialized screw that works much better. Called a Confirmat screw, it has a thick body with sharp, deep threads. It's mainly used with particleboard, melamine, and MDF, but it also holds well in solid wood. When used in a dado or a rabbeted dado, the joint strength is excellent. Confirmat screws require a pilot hole and a shank hole. A special bit is available that does the drilling in one step (see "Sources," p. 43).



Rabbeted dado starts with a dado. A T-square jig helps cut a dado across the side. The slot in the jig is just wide enough to accept the bearing of a top-mounted bearing-guided straight bit.



Mark and cut the rabbet. First, mark the rabbet location on the end of the shelf (left), then use a bearing-guided rabbeting bit to cut the rabbet (above).



BISCUITS

Strength: Fair

Appearance: Excellent

It's easy to fix a shelf in place using a biscuit joiner. And, because the biscuits are hidden when assembled, there is no joinery, support parts, or hardware to distract the eye. Use at least two biscuits on each end of the shelf. Add a third biscuit if there's room. The jig shown at right is a good one to use here. Invest a few minutes making it and you'll be rewarded many times over by the time saved.



JIG SPEEDS BISCUITING

A jig for cutting slots in the sides makes it easy to locate shelves accurately. The jig has just two parts: a cleat and a fence. The cleat keeps the end of the fence square to the side. Centerlines for the slots are marked on the end of the fence. With each new set of shelf slots, the fence is crosscut to a shorter length. Toss the jig when done.



SLIDING DOVETAIL

Strength: Excellent

Appearance: Very good (excellent if stopped, or covered by a face frame)

A sliding dovetail adds considerable mechanical strength, but sliding a 10-in.-long dovetail into a tight-fitting slot before the glue sets up is a challenge. Using a fairly slow-setting epoxy glue will help considerably. Epoxy is a slippery glue that helps get this type of joint together without excessive expansion and stress. See p. 74 to learn how to cut a sliding dovetail.

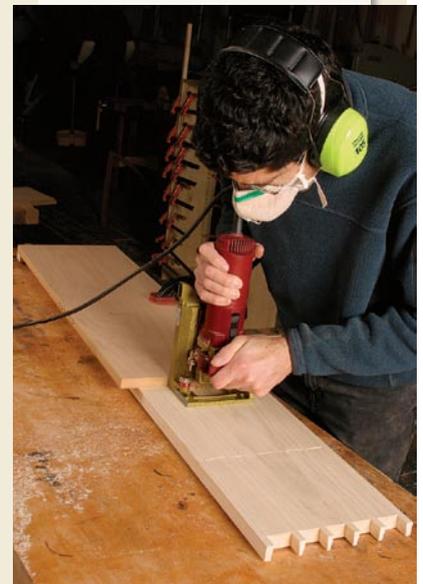


SCREWED CLEATS

Strength: Very good

Appearance: Fair

Screwed cleats let you add shelves without too much fuss, but they come up a little short in the appearance department. With the exception of the hole closest to the front, all of the holes in the shelf should be slotted to accommodate wood expansion. For the same reason, if you wish to glue this joint, bear in mind that you should glue only the front inch or so.



Clamp and cut. Clamp the jig to the case. Cut one set of slots, then use the jig to cut the same slots on the other side. Crosscut the fence to the next shelf position, and repeat until all slots are cut.

Adjustable shelves add versatility

Adjustable shelves make it easy to change the spacing as needs change. But there is a structural cost: These shelves do nothing to hold the cabinet sides together. So, on taller bookcases it's a good idea to have one fixed shelf to help anchor the case sides.



SHELF PINS

Strength: Good (very good with sleeves)

Appearance: Good

Shelf pins come in a wide variety of shapes, sizes, materials, and finishes. My favorites are the machined solid brass ones from Lee Valley. I also like the very small round pins by Häfele for smaller cases. Shelf pins also come with special clips for securing the shelves or for holding glass shelves. Sleeves are a great way to recover from poorly drilled holes. Stamped sleeves (short tubes with a flared and rounded-over end) tend to look like shoelace eyelets when installed in a cabinet. Solid brass machined sleeves look better, even though they accentuate the row of holes in the case sides somewhat. Some sleeves are threaded for specially threaded shelf pins.



Sleeve adds refinement and strength. You can improve both the appearance and strength of a shelf pin simply by slipping a brass sleeve into the pin hole.

A JIG FOR PIN HOLES



Shelf-pin holes in a jiffy. Thanks to this shop-made jig, Miller quickly drills shelf-pin holes that are the same depth and perfectly spaced.



HIDDEN WIRES

Strength: Good

Appearance: Very good

These bent-wire supports fit into holes drilled in the case sides. A stopped kerf cut in the ends of the shelf slips over the support, hiding the hardware. Structurally, this means the end of the shelf is thinner. This affects the shelf's shear strength, but will have little effect on sag.



WOODEN STANDARDS

Strength: Very good

Appearance: Very good

Wooden shelf standards have been around in various styles for generations. They are easy to make and add an interesting look to almost any bookcase. The style shown in the top-left photo (I call it zig-zag) is one of the more common forms.

Another style (I call it half-moon) is shown in the lower left photo. To make a pair, you'll need a piece of stock that's at least double the width of each standard. Scribe a lengthwise centerline along the stock, then lay out the shelf spacing by making a series of evenly spaced marks along the centerline. Use a spade bit or a Forstner bit to drill a through-hole at each marked centerpoint. Finally, using a tablesaw, rip the stock down the middle. The net result is a pair of standards, each with a series of half-moon shapes.

Make the cleats just loose enough to slip in and out with ease.



METAL STANDARDS

Strength: Very good

Appearance: Fair

It's hard to beat metal shelf standards for ease of installation. Just run a pair of dados down each side of the case, and nail, staple, or screw the shelf standards into place. Shelf supports usually just hook into place, although one new version has brass support pins that screw into threaded holes in the brass standards. In general, shelf standards seem out of place on finer furniture. But they are great for utilitarian pieces, and even in larger bookcases, where any support system will be pretty much invisible once the shelf is full of books.

ZIG-ZAG SUPPORT IN THREE STEPS



Start with stock wide enough to make four standards. Using the tablesaw, make a vertical cut at each shelf location (1). An auxiliary miter-gauge fence with a location pin in front (much like a finger-joint jig) makes it easy to position the stock for subsequent cuts. Follow with 45° cuts (2) after relocating the location pin. Remove the triangular waste piece, then clean the resulting flat with a chisel. Rip the stock to create four standards (3).

SOURCES OF SUPPLY

HÄFELE

www.hafele.com; 800-423-3531

LEE VALLEY/VERITAS

www.leevalley.com; 800-871-8158

McFEELY'S

www.mcfeelys.com; 800-443-7937

ROCKLER

www.rockler.com; 800-279-4441