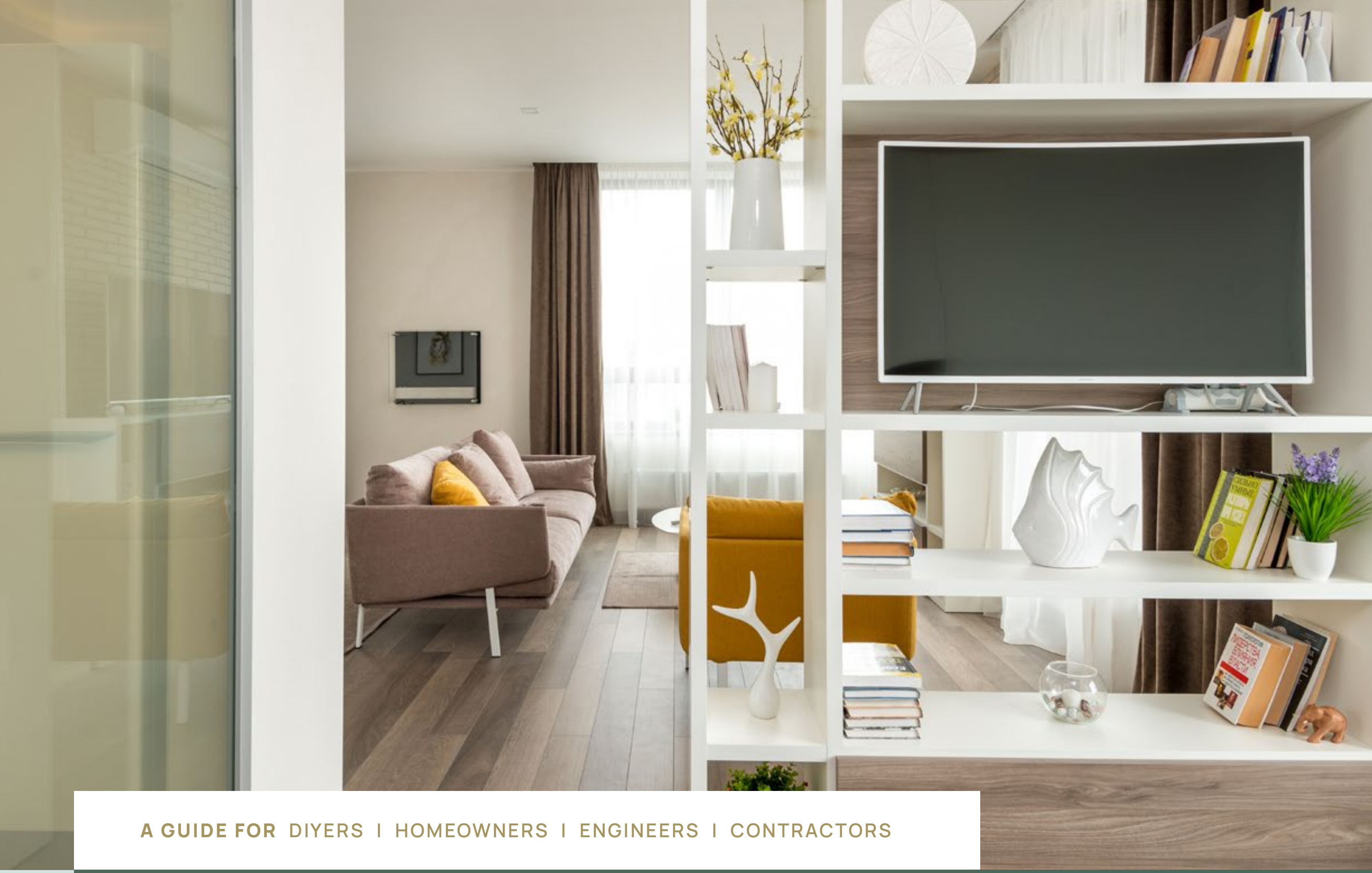


A GUIDE FOR DIYERS | HOMEOWNERS | ENGINEERS | CONTRACTORS

Technical Bulletin

Particleboard & MDF for Shelving

COMPOSITE PANEL ASSOCIATION

Introduction

Particleboard (PB) and medium density fiberboard (MDF) are widely used in shelving, providing consumers, industrial users, and engineers with a reliable product for a broad range of shelving projects.

This guide is intended to help determine maximum shelf spans for two types of shelf loading for particleboard (PB) and MDF shelves, using the board grades typically available at home centers or lumber yards.

COMMON TERMS YOU'LL SEE

Single Span Shelf
A shelf that is supported only at its ends.

Multiple Span Shelf
A shelf that is supported both at its ends and with a center support.

Maximum Shelf Span
The maximum length between supports.

Modulus of Elasticity
Measurement of stiffness of the shelf.

Modulus of Rupture
The point at which a shelf will break.

Concentrated Load
Loads in which the weight is much heavier on some areas of the shelf than others.

Uniformly Distributed Load
Loads in which the weight is spread out evenly over the shelf.

Deflection
The degree to which a shelf changes shape (i.e. sags), which is influenced by a variety of factors, including the material and thickness of the shelf, and the weight and concentration of a given load.

Design Guide
Single Span Vs. Multiple Span Shelving

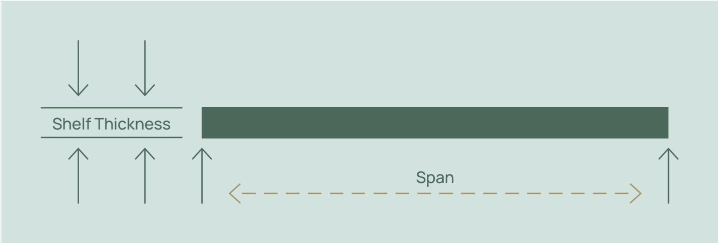
Common sense is the best guide when designing shelf systems.

In addition to the load you expect to place on a shelf, the most important factors in designing a shelf are shelf thickness and the distance between supports. **The thicker the shelf and the closer the supports, the stronger the shelf will be and the less it will exhibit deflection.**

The most common type of shelf loading is the uniformly distributed load, usually expressed in pounds per square foot (psf). Calculations in this bulletin are limited to the two common types of shelf loading—single span (supported at its ends only) and multiple span (supported both at its ends with a center support)—with the load uniformly distributed over the shelf.

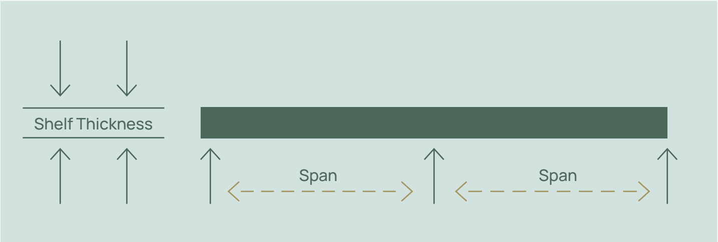
The most efficient use of load-bearing capacity of a shelf involves using end support with continuous support all along the rear edge of the shelf, fastened at six inch intervals. For continuous supported shelves up to 12 inches wide, you may double the span listed in the tables below. If deflection of the front edge is a concern, a strip of lumber can be attached under the front edge to give it more stability, and provide additional resistance to deflection.

FIGURE 1



Single Span

Shelf simply supported (not fixed or fastened) at its ends only.



Multiple Span

Shelf simply supported both at its ends with a center support.

Span Tables

Use the tables provided on the following pages to determine the maximum shelf span for specific uniformly distributed loads on various thicknesses and grades of PB and MDF.

The loads shown in the tables are in units of pounds per square foot (psf). This means that the load is evenly distributed over a one (1) square foot (144 square inches) area of shelf. The distribution area can be in any shape. For example, it can be 12 inches square, 8 by 18 inches, or any combination of dimensions that equals 144 square inches. Figure 1 gives common shelf nomenclature and displays some possible support situations.

To use Tables 1,2,3, and 4, first determine your estimated shelf loading, then select the desired combination of shelf span, product type and shelf thickness for your shelf design. The allowable spans are found directly across from the shelf load values.

Shelf loads can vary greatly. For example, kitchen cabinet loads can reach up to 25 or 30 psf, while bookshelf loads can easily reach 50 psf. It is necessary to know how much weight the shelf will be expected to carry. You can use a simple bathroom scale to estimate the anticipated load. Whereas a uniform load is spread evenly across the shelf, concentrated (heavy) loads put stress on one particular area of a shelf. Concentrated loads can produce severe stress on shelves and must therefore be considered carefully. We recommend consulting a professional engineer in these cases. The equations in this bulletin are based on uniform, non-concentrated loads. Equations for deflections of shelves with concentrated loads are beyond the scope of this Technical Bulletin.

Maximum shelf spans are shown in the following tables for various thicknesses and grades of particleboard and MDF for single span and multiple span shelves, as depicted in Figure 1. The calculations were based on shelves simply supported at the ends only (not fixed or fastened) over a range of uniformly distributed loads. Calculations for the maximum shelf span for a given thickness is governed by three variables: the load, the elastic property known as modulus of elasticity (E), and the visually accepted deflection.

For most applications, the spans shown in the tables below will be sufficient. For additional information on how these tables were calculated, see the Methodology section.

Span Tables

TABLE 1

Particleboard Single Span[3]

Maximum shelf span for single span particleboard with uniformly distributed load.

Calculations based on the current standards for three grades and thicknesses of PB (ANSI A208.1-2016)

Maximum Shelf Span (in.)[1,2]

Shelf Load psf[4]	PBU			M-2			M-3i		
	Shelf Thickness			Shelf Thickness			Shelf Thickness		
	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"
50	13.4	16.7	20.1	14.1	17.6	21.1	15.2	18.9	22.7
45	13.9	17.3	20.9	14.6	18.2	21.9	15.7	19.6	23.5
40	14.4	18.0	21.6	15.2	18.9	22.7	16.3	20.4	24.5
35	15.1	18.9	22.6	15.8	19.8	23.8	17.1	21.3	25.6
30	15.9	19.8	23.8	16.7	20.8	25.0	18.0	22.5	27.0
25	16.9	21.1	25.3	17.7	22.2	26.6	19.1	23.9	28.6
20	18.2	22.7	27.3	19.1	23.9	28.6	20.6	25.7	30.9
15	20.0	25.0	30.0	21.0	26.3	31.5	22.6	28.3	34.0
10	22.9	28.6	34.4	24.1	30.1	36.1	25.9	32.4	38.9
5	28.8	36.1	43.3	30.3	37.9	45.5	32.7	40.8	49.0

[1] For shelves 12 inches or less in depth with continuous support along the back edge of the shelf, the allowable span can be doubled
[2] A maximum overhang beyond bracket or support not to exceed 6 inches may be added to these spans
[3] Single span: shelf simply supported (not fixed or fastened) at its ends only (see Figure 1)
[4] psf = pounds per square foot

TABLE 2

MDF Single Span[3]

Maximum shelf span for single span MDF with uniformly distributed load.

Calculations based on the current standards for three grades and thicknesses of MDF (ANSI A208.2-2016)

Maximum Shelf Span (in.)[1,2]

Shelf Load psf[4]	115			130			155		
	Shelf Thickness			Shelf Thickness			Shelf Thickness		
	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"
50	12.0	15.0	18.0	14.4	18.0	21.6	15.7	19.7	23.6
45	12.4	15.5	18.6	14.9	18.7	22.4	16.3	20.4	24.4
40	12.9	16.2	19.4	15.5	19.4	23.3	16.9	21.2	25.4
35	13.5	16.9	20.3	16.3	20.3	24.4	17.7	22.1	26.6
30	14.2	17.8	21.3	17.1	21.4	25.7	18.6	23.3	28.0
25	15.1	18.9	22.7	18.2	22.7	27.3	19.8	24.8	29.7
20	16.3	20.4	24.4	19.6	24.5	29.4	21.3	26.7	32.0
15	17.9	22.4	26.9	21.6	26.9	32.3	23.5	29.4	35.2
10	20.5	25.6	30.8	24.7	30.8	37.0	26.9	33.6	40.3
5	25.9	32.3	38.8	31.1	38.9	46.6	33.9	42.3	50.8

[1] For shelves 12 inches or less in depth with continuous support along the back edge of the shelf, the allowable span can be doubled
[2] A maximum overhang beyond bracket or support not to exceed 6 inches may be added to these spans
[3] Single span: shelf simply supported (not fixed or fastened) at its ends only (see Figure 1)
[4] psf = pounds per square foot

Span Tables

TABLE 3

Particle Board Multiple Span[3]

Maximum shelf spans for multiple span particleboard with uniformly distributed load.

Calculations based on the current standards for three grades and thicknesses of PB (ANSI A208.1-2016)

Maximum Shelf Span (in.)[1,2]

Shelf Load psf[4]	PBU			M-2			M-3i		
	Shelf Thickness			Shelf Thickness			Shelf Thickness		
	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"
50	17.9	22.4	26.9	18.9	23.6	28.3	20.3	25.4	30.5
45	18.6	23.2	27.9	19.5	24.4	29.3	21.0	26.3	31.6
40	19.3	24.2	29.0	20.3	25.4	30.5	21.9	27.3	32.8
35	20.2	25.3	30.3	21.2	26.5	31.9	22.9	28.6	34.3
30	21.3	26.6	31.9	22.4	27.9	33.5	24.1	30.1	36.1
25	22.6	28.3	33.9	23.8	29.7	35.6	25.6	32.0	38.4
20	24.4	30.4	36.5	25.6	32.0	38.4	27.6	34.4	41.3
15	26.8	33.5	40.2	28.2	35.2	42.2	30.3	37.9	45.5
10	30.7	38.4	46.0	32.2	40.3	48.4	34.7	43.4	52.1
5	38.7	48.3	58.0	40.6	50.8	60.9	43.8	54.7	65.6

[1] For shelves 12 inches or less in depth with continuous support along the back edge of the shelf, the allowable span can be doubled
[2] A maximum overhang beyond bracket or support not to exceed 6 inches may be added to these spans
[3] Multiple Span: shelf simply supported (not fixed or fastened) at its ends with a center support. Span lengths refer to the distance from support to support, not the total shelf length (see Figure 1).
[4] psf = pounds per square foot

TABLE 4

MDF Multiple Span[3]

Maximum shelf spans for multiple span MDF with uniformly distributed load.

Calculations based on the current standards for three grades and thicknesses of MDF (ANSI A208.2-2016)

Maximum Shelf Span (in.)[1,2]

Shelf Load psf[4]	115			130			155		
	Shelf Thickness			Shelf Thickness			Shelf Thickness		
	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"
50	16.1	20.1	24.1	19.3	24.2	29.0	21.1	26.3	31.6
45	16.7	20.8	25.0	20.0	25.0	30.0	21.8	27.3	32.7
40	17.3	21.6	26.0	20.8	26.0	31.2	22.7	28.4	34.1
35	18.1	22.6	27.2	21.8	27.2	32.7	23.7	30.0	35.6
30	19.1	23.8	28.6	22.9	28.7	34.4	25.0	31.2	37.5
25	20.3	25.3	30.4	24.4	30.4	36.5	26.5	33.2	39.8
20	21.8	27.3	32.7	26.2	32.8	39.4	28.6	35.7	42.9
15	24.0	30.0	36.0	28.9	36.1	43.3	31.5	39.3	47.2
10	27.5	34.4	41.2	33.1	41.3	49.6	36.0	45.0	54.1
5	34.6	43.3	52.0	41.7	52.1	62.5	45.4	56.7	68.1

[1] For shelves 12 inches or less in depth with continuous support along the back edge of the shelf, the allowable span can be doubled
[2] A maximum overhang beyond bracket or support not to exceed 6 inches may be added to these spans
[3] Multiple span (2 equal spans): shelf simply supported at its ends with a center support. Span lengths refer to the distance from support to support, not the total shelf length (see Figure 1).
[4] psf = pounds per square foot

Bending Properties Table

TABLE 5

Particleboard (PB) & Medium Density Fiberboard (MDF)

Table 5 contains mechanical properties specified in the current standards for PB (ANSI A208.1-2016) and MDF (ANSI A208.2-2016) for modulus of rupture (MOR) and modulus of elasticity (MOE).

Mechanical Property Values

Panel Type	Grade	Modulus of Rupture (MOR)		Modulus of Elasticity (MOE)	
		psi	N/mm²	psi	N/mm²
PB*	PBU	1,595	11	250,200	1,725
	M-2	1,885	13	290,100	2,000
	M-3i	2,176	15	362,600	2,500
MDF**	115	1,800	12.4	180,000	1,241
	130	3,130	21.6	313,000	2,160
	155	4,050	27.9	405,000	2,792

*ANSI A208.1-2016
**ANSI A208.2-2016

Mechanical property values shown in Table 5 represent lower 5th percentile specification limits with the exception that particleboard underlayment (PBU) values reflect 5-panel averages. They do not include safety factors, and it is the responsibility of the designer to determine safety factors or other reduction factors commensurate with their particular application.

Lacking published working stresses for particleboard and MDF, calculations for safe bending strength require that the calculation includes a reduction in the modulus of rupture for the material used for the shelf. In the past, calculations have used a value equivalent to 25% of the modulus of rupture as the value.

If it is desired to determine whether strength (assuming the stress at 25 % of the MOR is acceptable) or deflection is the limiting factor, the solution is illustrated in Appendix B.

The tabulations contained in this bulletin for maximum shelf spans are applicable to unfinished (raw) PB and MDF. Appendix C provides information about the impact laminates have on a shelf's bending modulus of elasticity and maximum shelf span.

Solutions for non-uniform, concentrated, or impact loads are beyond the scope of this document. For information on design of shelving for support conditions and loading applications other than uniformly loaded single and multiple span shelving, please consult a professional engineer or engineering textbooks.

Metric Conversion Values

1ft	=	0.3048 m
1m	=	3.281 ft
1ft²	=	0.0929 m²
1m²	=	10.76 ft²
1lb/ft²	=	4.882 kg/m²
1kg/m²	=	0.2048 lb/ft²

Additional Considerations

The previous information may not be adequate for some residential or industrial applications.

Where other deflection limits, load, or span conditions are desired, a trained professional should be consulted. An understanding of basic engineering design principles is assumed.

Whenever possible, specify products with the CPA Grademark or other certification mark. Products so marked are strictly manufactured to the American National Standards Institute Standards for PB and MDF, A208.1 and A208.2 respectively.

These Standards classify the products into grades based on physical and mechanical properties, dimensional tolerances, and other considerations such as moisture resistance and formaldehyde emissions.

The information in this document is believed to be reliable and is intended to assist users of composite panel products. However, the determination of suitability of this information for a particular application remains the sole responsibility of the user.

No guarantees, representations or express or implied warranties are made regarding the accuracy and completeness of this information, and the Composite Panel Association (CPA) assumes no responsibility or liability for any loss or damage through reliance upon it.

Methodology

For shelf design, the span, design load, fiber stress in bending, and modulus of elasticity of the material are either given or can be determined by measurements. Finding the required dimensions of the shelving section needed to support the design load with a minimum deflection generally involves two steps: First, it must be determined what section will safely carry the load then, what section will limit deflection to a specified level. The larger section of the two is the correct solution to the problem.

This bulletin contains calculations for deflection limitations, so the most important property is the modulus of elasticity of the material. **In most cases of shelving design, deflection rather than strength is the limiting factor.** The calculations in the span tables (Tables 1, 2, 3, and 4) have determined the maximum shelf span that will provide deflection less than the limitation of span/240.

Like most span tables, there are assumptions built into the calculations, which are described below:

- The values represent calculations for unfinished (raw) PB and MDF.
- The calculations do not include the weight of the particleboard or MDF:
  - → To minimize long term deflection, spans in this bulletin were generated using an allowable shelf deflection of span/240. For example, a shelf with a 24 inch span can be expected to deflect a maximum of 0.10 inches, while a 36 inch shelf span will deflect 0.15 inches (slightly more than 1/8 -inch).

Examples of the equations to determine maximum deflection and maximum shelf spans for single and multiple span shelf designs are provided in Appendix A.

References

ANSI A208.1 -2016 Particleboard, American National Standard, Composite Panel Association, Leesburg, VA.

ANSI A208.2 -2016 Medium Density Fiberboard (MDF) For Interior Applications, Composite Panel Association, Leesburg, VA.

Wood Handbook, Wood as an Engineering Material, USDA, FS , Forest Products Lab, FPL-GTR-113.

McNatt, D. 1992, Laminate Properties, Unpublished Manuscript, Forest Products Lab.

The Composite Panel Association (CPA), founded in 1960, represents the North American wood-based composite panel and decorative surfacing industries on technical, public policy, quality assurance and product acceptance issues. CPA General Members include the leading manufacturers of particleboard, medium density fiberboard (MDF), engineered wood siding and trim and hardboard in North America, representing more than 90% of industry manufacturing capacity. CPA Associate Members include manufacturers of decorative surfaces, furniture, cabinets, mouldings, doors and equipment, along with laminators, distributors, industry media and adhesive suppliers committed to product advancement and industry competitiveness. CPA is a vital resource for specifiers, manufacturers and users of industry products. The association provides leadership on federal, state and provincial regulatory and legislative matters of interest to industry. As an internationally recognized and accredited standards developer, CPA writes, publishes and maintains the industry's definitive ANSI product standards. CPA also operates the International Testing Center (ITC) and manages the Grademark Certification Program, the largest and most stringent testing and certification program of its kind for North American composite panel products. CPA developed the Eco-Certified Composite (ECC) Sustainability Standard and Certification Program, a voluntary industry standard for composite wood panels and finished products made with particleboard, MDF, hardboard and engineered wood siding and trim.

Appendix A

Single Span Uniformly Distributed Load

Examples of the equations to determine maximum deflection and maximum shelf spans for the common shelf designs shown in Figure 1.
The equation for maximum deflection of a shelf simply supported with a uniformly distributed load of w pounds per unit of length (pli) over the entire length is:

Equation Terms =

w	=	pounds per linear inch (pli)
L	=	length of span, in.
E	=	modulus of elasticity, psi
I	=	moment of inertia of the cross section with respect to the neutral axis, inches.[4]

EQUATION 1

Maximum deflection = 5w L^4/384 EI

Using Equation 1, the procedure to determine maximum span (L) for the single span uniformly distributed load is as follows:

- Assume that maximum deflection = L /x
- Therefore, $L/x = 5wL^4/384\ EI$ and $384L\ EI = 5wxL^4$
- The equation becomes $5wxL^3 = 384\ EI$
- Solving for maximum length (L) we get :

Maximum length of span (L) = $\sqrt[3]{(384\ EI/5wx)}$

If deflection is limited to span/240:

EQUATION 2

The equation for maximum length of span = $\sqrt[3]{(384\ EI/\ 5w\ (240))}$

Assume we want to calculate the maximum span for a shelf 12 inches wide made from ¾-inch grade 130 MDF and loaded with a uniform load of 50 psf.

- If the shelf is 12 inches wide, the load per inch of length = 50/12 = 4.17 pounds/in.
- MDF grade 130 has modulus of elasticity (MOE) of 313,000 psi.
- Moment of inertia (I) for a rectangular shelf 12 inches wide = $(\text{width})(\text{thickness})^3/12$
- Therefore, $I = (12)(0.75)^3/12 = (0.75)^3 = 0.422$ in.^{4}
- Substituting in Equation 2 the maximum length of span = $\sqrt[3]{[(384)(313{,}000)(0.422)/(5)(4.17)(240)]}$

Therefore, maximum length of span = $\sqrt[3]{10{,}136}$ = 21.6 in.

Appendix A

Multiple Spans (2 Equal Spans) Uniformly Distributed Load

Likewise, the equation for a shelf with multiple spans (i.e. 2 equal spans simply supported at its ends with a center support is):

EQUATION 3

Maximum deflection = $wL^4/185\ EI$

Using Equation 3, the procedure to determine maximum span (L) for a shelf with multiple spans (2 equal spans) uniformly distributed load is as follows:

- Assume that maximum deflection = L/x
- Therefore, $L/x = wL^4/185\ EI$
- And $185LEI = wL^4x$
- The equation becomes $L^3wx = 185\ EI$
- Solving for maximum length (L) we get :

Maximum length of span (L) = $\sqrt[3]{(185\ EI/wx)}$

Equation Terms =		
w	=	pounds per linear inch (pli)
L	=	length, in.
E	=	modulus of elasticity, psi
I	=	moment of inertia of the cross section with respect to the neutral axis, $inches^4$

If deflection is limited to span/240:

EQUATION 4

The equation for maximum length of span = $\sqrt[3]{(185\ EI/\ w\ (240))}$

Assume we want to calculate the maximum span for a shelf 12 inches wide made from ¾-inch grade 130 MDF and loaded with a uniform load of 50 psf.

- If the shelf is 12 inches wide, the load per inch of length = 50/12 = 4.17 pounds/in.
- MDF grade 130 has modulus of elasticity (MOE) of 313,000 psi.
- Moment of inertia (I) for a rectangular shelf 12 inches wide = $(\text{width})(\text{thickness})^3/12$
- Therefore, $I = (12)(0.75)^3/12 = (0.75)^3 = 0.422\ in.^4$
- Substituting in Equation 4 the maximum length of span = $\sqrt[3]{[(185)(313{,}000)(0.422)/(4.17)(240)]}$

Therefore, maximum length of span = $\sqrt[3]{24{,}416}$ = 29.0 in.

Appendix B

Example to determine whether strength or deflection governs in a given shelf design.
Assume MDF grade 115 is used as a shelf resting on supports spaced 22 inches apart.
The shelf is 12 inches wide and has a uniformly distributed load of 20 psf. The deflection of the shelf, limited to L/240, equals 0.092 inches. What thickness is required to support the design load?

STEP 1

- Assume the working stress is 25% of the MOR. The MOR for grade 115 MDF is 1800 psi.
- Therefore, 25% of 1800 = 450 psi. The modulus of elasticity (MOE) is 180,000 psi.
- The bending moment (M) = $wL^2/8$
- Where : w = load per linear inch (pli) and L = span in inches

For a uniformly distributed load of 20 pounds per square foot, the load on the shelf per inch of length is 20/12= 1.67 pounds per linear inch.

- $M = (1.67)(22)^2/8 = 101$ in-pounds

The flexure formula expresses the relation between the external forces (M), the unit stress (σ), and the properties of the cross section, I/c. The expression I/c is called the section modulus (S) where I= moment of inertia and c = distance from the neutral axis to the point at which the stress is desired. We are interested in the stress at the surface of a shelf so c= thickness/2.

The flexure formula is:

- $\sigma = Mc/I = M/S$
- Solving for S, it can be seen that $S = M/\sigma$

Section modulus(S) to carry the load safely is:

- $S = M/450 = 101/450 = 0.224$ in.^{3}
- The section modulus (S) for a rectangular cross-section is $S= bd^2/6$
- Where b = shelf width and d = shelf thickness
- $S = 0.224 = (12)d^2/6$
- Therefore, $d^2 = (0.224)(6)/12 = 0.112$ and $d = \sqrt{0.112} = 0.335$ in.
- Shelf thickness to safely carry the load is 0.335 in.

STEP 2

Shelf thickness required to limit deflection to 0.092 in. (i.e. 22/240) now must be determined as follows:

- Using Equation 1, max deflection = $5wL^4/384\ EI$
- Solving for $I = (5)(1.67)(22)^4/(384)(180{,}000)(0.092) = 0.3076$

For a rectangular shelf

- $I = bd^3/12 = 0.3076$
- And $d^3 = 12\ (0.3076)/12$
- Therefore, $d = \sqrt[3]{0.3076} = 0.675$ in.

Since thickness based on the deflection requirement of L/240 is greater than the thickness determined for the safe load, deflection thickness governs and a thickness of 0.675 in. would be used. Any thickness less than 0.675 in. would result in deflection greater than the specified limit for L/240.

Appendix C

Example to illustrate how laminates and veneer affect the modulus of elasticity. The tabulations for maximum shelf spans contained in this bulletin are applicable to unfinished (raw) PB and MDF. The values do not apply to shelves that have laminates or overlays that exhibit different properties from the substrate (PB or MDF). The following examples will illustrate the impact on effective or apparent modulus of elasticity of a composite containing PB or MDF as a substrate (core) laminated with melamine paper on face and back or black walnut veneer on face and back. To maintain a balanced construction, the examples include identical material on the face and back.

EXAMPLE 1

Laminators of wood veneer typically purchase 11/16-inch PB or MDF to make a composite product ¾-inch thick when laminated with veneer 1/32-inch thick. The following example shows the procedure for determining the effective or apparent modulus of elasticity for a composite with black walnut veneer on face and back and grade M-3i PB in the core.

- Grade M-3i (11/16 –inch)
- Black walnut veneer (1/32 –inch) face and back
- Black walnut at 12% moisture content has modulus of elasticity of 1,680,000 psi. (Wood Handbook)
- Modulus of elasticity of grade M-3i PB from Table 5 is 362,600 psi.

If it is desired to determine the maximum shelf span for this composite, the deflection depends on the determination of an apparent modulus of elasticity which is , in turn, dependent on the modulus of elasticity values for the materials in the core and the outer layers (face and back).

The basic equation for this example is :

EQUATION 5

$$E_a = (E_f I_f + E_c I_c)/I$$

For a shelf 12 inches wide, the moment of inertia of the composite with total thickness of 0.750 inches is (0.750)3= 0.422. Let d_t = total thickness of the composite and d_c = thickness of the core. Substituting into Equation 5:

- $E_a = [1{,}680{,}000\,(d_t^3 - d_c^3) + 362{,}600\,(d_c^3)]/d_t^3$
- $E_a = [1{,}680{,}000(0.422\text{-}0.325) + 362{,}600(0.325)]/0.422$
- $E_a = [1{,}680{,}000(0.097) + 362{,}600(0.325)]/0.422$
- $E_a = [162{,}900 + 117{,}845]/0.422$
- $E_a = 280{,}805/0.422 = 665{,}415$ psi

Equation Terms =

I = moment of inertia of the entire cross section about the neutral axis, inches⁴

E_a = apparent modulus of elasticity of the composite, psi

E_f = modulus of elasticity of the face and back laminates, psi

E_c = modulus of elasticity of the core, psi

I_f = moment of inertia of the face and back laminates about the neutral axis of the section, inches⁴

I_c = moment of inertia of the core about the neutral axis of the section, inches⁴

Appendix C

Using the apparent E of the composite, the maximum shelf span for a single span with simple supports and uniformly distributed load can be determined by using Equation 2.

Assuming maximum deflection is limited to span /240 as before and uniform load of 50 psf on the shelf, the maximum span is:

- $L = \sqrt[3]{[(384)(665{,}415)(0.422)/(5)(4.17)(240)]}$
- $L = \sqrt[3]{21548.6} = 27.8$ in.

EXAMPLE 2

Assume a shelf has a uniformly distributed load of 50 psf. The shelf is made from (3/4 –inch) MDF grade 130 overlaid on face and back with melamine paper (0.006 in. thick). The laminate has E = 1,280,000 psi. (McNatt,1992)

Using Equation 5 as before where $d_t = 0.762$ and $d_c = 0.750$, the solution for apparent E becomes:

- $E_a = [1{,}280{,}000(d_t^3 - d_c^3) + 313{,}000\ (d_c^3)]/d_t^3$
- $E_a = [1{,}280{,}000\ (0.762^3 - 0.750^3) + 313{,}000\ (0.750)^3]/\ (0.762)^3$
- $E_a = [1{,}280{,}000\ (0.4425 - 0.4219) + 313{,}000\ (0.4219)]/0.4425$
- $E_a = [1{,}280{,}000\ (0.0206) + 313{,}000\ (0.4219)]/0.4425$
- $E_a = (26{,}368 + 132{,}055)/0.4425$
- $E_a = 158{,}423/0.4425 = 358{,}017$ psi

Using Equation 2, the maximum shelf span (L) = $\sqrt[3]{[(384)358{,}017)(0.4425)/(5)(4.17)(240)]}$
Maximum shelf span = 22.99 in.

Note: If the laminate material has E equal to or greater than the E of the particleboard or MDF used as a substrate in a composite, a conservative estimate can be made by simply assuming the entire composite has the E of the substrate and avoid the calculation for effective E. If this approach is used in the above example, the composite would have total thickness of 0.762 and E of 313,000 psi. Using equation 2, the maximum shelf span would then be 21.99 instead of 22.99 inches.