COMPOSITE PANEL ASSOCIATION ℠

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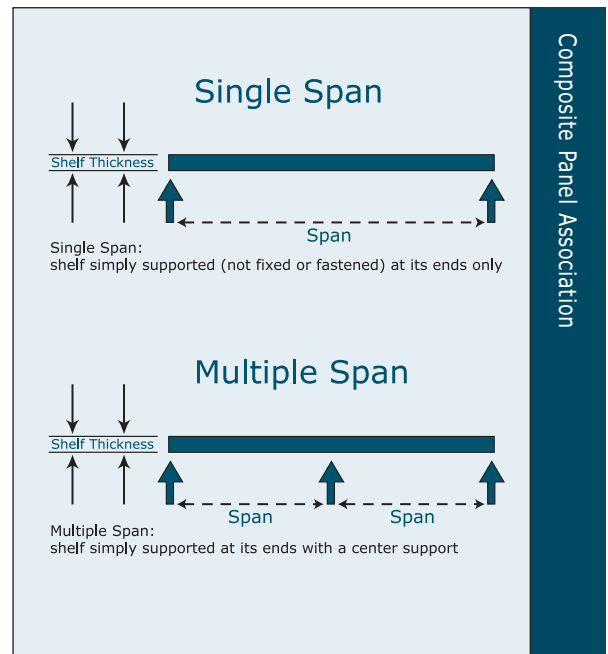## Particleboard and MDF For Shelving

technical
BULLETIN

Introduction

Particleboard (PB) and medium density fiberboard (MDF) are widely used in shelving applications. PB and MDF shelves are uniform and economical, can be painted, laminated or veneered, and have good dimensional stability and load-bearing capacity when properly designed. Today's PB and MDF provide consumers, industrial users, and engineers with a consistent product for a broad range of applications.

This bulletin discusses two approaches to shelving design. The first section, **Consumer Design Guide**, is for do-it-yourselfers and homeowners. It includes basic shelving applications using the board grades typically available at home centers or lumber yards. This section assumes particleboard meets underlayment (grade PBU) or grade M-1 strength specifications, and MDF meets grade MD specifications. The second section, **Engineering Design Guide**, is for industrial specifiers and engineers. It explains in detail how shelving spans are calculated, and includes the wider range of industrial grades available through wholesale distributors or directly from panel producers.

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 panel density, physical and mechanical properties, dimensional tolerances, and formaldehyde emission limits.

Composite Panel Association

Single Span

Shelf Thickness

Span

Single Span:
shelf simply supported (not fixed or fastened) at its ends only

Multiple Span

Shelf Thickness

Span   Span

Multiple Span:
shelf simply supported at its ends with a center support

Consumers Design Guide

Consumers Design Guide:

For Homeowners

For many common shelving applications, use the table provided below. It is designed to quickly determine the amount of load that can be carried on either a PB or MDF shelving system. It is important to understand that the loads shown in the table are in units of pound 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 this table, 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. Spans are limited to a maximum of 36 inches.

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. A simple bathroom scale may be used to estimate the anticipated load.

When concentrated (heavy) loads are anticipated, it is important to note that the load acts only on the area where the object makes contact with the shelf. Concentrated loads can produce severe stress on shelves and must be considered carefully. Use the maximum concentrated load as the shelf loading value, rather than the average of all objects to be loaded on the shelf.

The amount a shelf deflects (or bends) depends upon the load, shelf span, and panel thickness. Table 1 was designed to limit deflections to a percentage of the shelf span. 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").

TABLE 1

Shelf Load psf.[5]	Maximum Shelf Span (in.) [1,2]											
	Single Span [3]						Multiple Span [4]					
	Particleboard			Medium Density Fiberboard (MDF)			Particleboard			Medium Density Fiberboard (MDF)		
	Shelf Thickness			Shelf Thickness			Shelf Thickness			Shelf Thickness		
	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"
50	13"	17"	20"	15"	19"	22"	13"	17"	20"	20"	25"	29"
45	14"	18"	21"	16"	19"	23"	14"	18"	22"	21"	25"	30"
40	15"	18"	21"	16"	20"	24"	15"	19"	23"	21"	26"	31"
35	15"	19"	22"	17"	21"	25"	16"	20"	24"	22"	28"	33"
30	16"	20"	23"	18"	22"	26"	18"	22"	27"	23"	29"	34"
25	17"	21"	25"	19"	23"	28"	19"	24"	29"	25"	31"	36"
20	18"	22"	27"	20"	25"	30"	22"	27"	33"	27"	33"	36"
15	20"	25"	29"	22"	27"	33"	25"	32"	36"	29"	36"	36"
10	23"	28"	34"	25"	31"	36"	30"	36"	36"	34"	36"	36"

[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] Multiple Span: 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)

[5] psf. = pounds per square foot

Composite Panel Association

Engineering Design Guide

Engineering Design Guide:
For Specifiers and Engineers

This section contains additional detail to provide the shelf designer with an understanding of the engineering basis used in common designs. It also allows for more refined calculations and flexibility in the design process for those familiar with structural design equations.

Span Tables

For most applications the spans shown in Tables 2 and 3 will suffice. As with any span table there are assumptions built into the calculations. These assumptions are described below.

- Based on the variability associated with industrial production, the published ANSI standard strength and stiffness values (MOR and MOE) for PB and MDF were reduced by 20 percent.

- To minimize long term deflection, an allowable shelf deflection limit of span/240 was used. This minimizes the stress in the shelf. For example, a 32-inch shelf span would be designed for a total instantaneous deflection of 0.13 inches when a load distributed uniformly over the entire surface, is applied. Long term deflection is often considered to be twice the short term deflection for design purposes.

- Due to the wide variety of techniques to fasten the shelf into the frame of a shelf system, all supports were considered pinned (simple) in these analyses. No increase in span was considered for semi-rigid end fixed conditions.

- Spans were limited to a maximum of 48 inches.

Design equations for other loading and support conditions are discussed later.

TABLE 2

Shelf Load psf.[4]	Particleboard Underlayment or M-1			Particleboard M-2			Particleboard M-3			Medium Density Fiberboard, LD			Medium Density Fiberboard, MD			Medium Density Fiberboard, HD		
	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"
50	13"	17"	20"	15"	18"	21"	16"	19"	23"	13"	16"	19"	15"	19"	22"	17"	21"	25"
45	14"	18"	21"	15"	19"	22"	16"	20"	24"	13"	16"	19"	16"	19"	23"	17"	21"	26"
40	15"	18"	21"	16"	19"	23"	17"	21"	25"	14"	17"	20"	16"	20"	24"	18"	22"	27"
35	15"	19"	22"	16"	20"	24"	18"	22"	26"	14"	17"	21"	17"	21"	25"	19"	23"	28"
30	16"	20"	23"	17"	21"	25"	18"	23"	27"	15"	18"	22"	18"	22"	26"	20"	24"	29"
25	17"	21"	25"	18"	23"	27"	20"	24"	29"	16"	19"	23"	19"	23"	28"	21"	26"	31"
20	18"	22"	27"	20"	24"	29"	21"	26"	31"	17"	21"	25"	20"	25"	30"	23"	28"	33"
15	20"	25"	29"	22"	27"	32"	23"	29"	34"	19"	23"	27"	22"	27"	33"	25"	31"	37"
10	23"	28"	34"	25"	31"	36"	26"	33"	39"	21"	26"	31"	25"	31"	37"	28"	35"	42"
5	29"	36"	42"	30"	38"	45"	32"	40"	45"	26"	32"	38"	31"	38"	46"	35"	43"	48"

Maximum Shelf Span (in.)[1,2] - Single Span[3]

[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 3

Shelf Load psf.[4]	Particleboard Underlayment or M-1			Particleboard M-2			Particleboard M-3			Medium Density Fiberboard, LD			Medium Density Fiberboard, MD			Medium Density Fiberboard, HD		
	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"	1/2"	5/8"	3/4"
50	13"	17"	20"	15"	19"	23"	17"	21"	25"	15"	19"	23"	20"	25"	29"	22"	27"	33"
45	14"	18"	22"	16"	21"	25"	17"	22"	26"	16"	20"	24"	21"	25"	30"	23"	28"	34"
40	15"	19"	23"	17"	22"	26"	19"	23"	28"	17"	21"	26"	21"	26"	31"	24"	30"	35"
35	16"	20"	24"	19"	23"	28"	20"	25"	30"	18"	23"	27"	22"	28"	33"	25"	31"	37"
30	18"	22"	27"	20"	25"	31"	22"	27"	33"	20"	24"	29"	23"	29"	34"	26"	32"	39"
25	19"	24"	29"	22"	28"	34"	24"	30"	36"	21"	26"	31"	25"	31"	37"	28"	34"	41"
20	22"	27"	33"	25"	31"	38"	27"	33"	40"	22"	28"	33"	27"	33"	39"	30"	37"	44"
15	25"	32"	38"	29"	35"	42"	31"	38"	45"	25"	30"	36"	29"	36"	43"	33"	41"	48"
10	30"	37"	44"	33"	40"	48"	35"	43"	48"	28"	35"	41"	34"	41"	48"	37"	46"	48"
5	37"	46"	48"	41"	48"	48"	43"	48"	48"	34"	43"	48"	41"	48"	48"	46"	48"	48"

Maximum Shelf Span (in.)[1,2] - Multiple Span[3]

[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 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.

Engineering Design Guide

Engineering Design Equations

The previous information may not be adequate for some residential or industrial applications. Where other deflection limits, load, or span conditions are desired, the following equations are applicable. Actual design should be left to a trained professional. An understanding of basic engineering design principles is assumed, and the determination of suitability of this information is the sole responsibility of the user.

Physical/mechanical property values published in the ANSI standards are shown in Table 4 and represent average properties. 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. The following equations use loading values expressed in pounds per square inch (psi), while the span tables on the proceeding pages use loading values expressed in pounds per square foot (psf). These equations are from the Timber Construction Manual, 4th Edition, 1994, courtesy of the American Institute of Timber Construction.

TABLE 4

Physical/Mechanical Property Values for Particleboard and Medium Density Fiberboard

Panel Type	Grade	Modulus of Rupture (MOR)		Modulus of Elasticity (MOE)	
		psi.	N/mm^2	psi.	N/mm^2
PB *	PBU, M-1 M-2 M-3	1595 2100 2390	11 14.5 16.5	250000 326000 399000	1725 2250 2750
MDF	LD MD HD	2000 3500 5000	14 24 34.5	200000 350000 500000	1400 2400 3450

* *ANSI A208.1-1993*

** *ANSI A208.2-1994*

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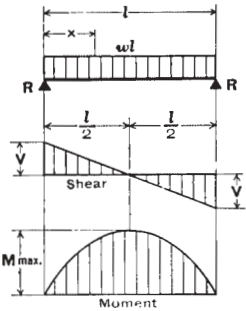
"Loading that is not symmetrically positioned on a shelf can cause exaggerated moments in a shelf panel, particularly when several loads are placed on the same shelf."
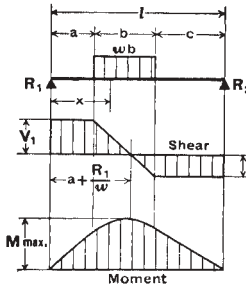
Engineering Design Guide
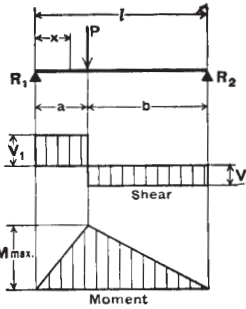
Single Span (Simple Support) Condition

Uniform load

$$R = V \quad \ldots \ldots \ldots \quad = \frac{wl}{2}$$

$$V_x \quad \ldots \ldots \ldots \quad = w\left(\frac{l}{2} - x\right)$$

$$M \text{ max.} \left(\text{at center}\right) \quad \ldots \quad = \frac{wl^2}{8}$$

$$M_x \quad \ldots \ldots \ldots \quad = \frac{wx}{2}(l - x)$$

$$\Delta\text{max.} \left(\text{at center}\right) \quad \ldots \quad = \frac{5\,wl^4}{384\,EI}$$

$$\Delta_x \quad \ldots \ldots \ldots \quad = \frac{wx}{24EI}(l^3 - 2lx^2 + x^3)$$

Uniform load partially distributed

$$R_1 = V_1 \left(\text{max. when } a < c\right) \quad \ldots \quad = \frac{wb}{2l}(2c + b)$$

$$R_2 = V_2 \left(\text{max. when } a > c\right) \quad \ldots \quad = \frac{wb}{2l}(2a + b)$$

$$V_x \left(\text{when } x > a \text{ and } < (a+b)\right) \quad . \quad = R_1 - w(x - a)$$

$$M \text{ max.}\left(\text{at } x = a + \frac{R_1}{w}\right) \quad \ldots \quad = R_1\left(a + \frac{R_1}{2w}\right)$$

$$M_x \left(\text{when } x < a\right) \quad \ldots \ldots \quad = R_1 x$$

$$M_x \left(\text{when } x > a \text{ and } < (a+b)\right) . \quad = R_1 x - \frac{w}{2}(x - a)^2$$

$$M_x \left(\text{when } x > (a+b)\right) \quad \ldots \quad = R_2(l - x)$$

Concentrated load at any point

$$R_1 = V_1\left(\text{max. when } a < b\right) \quad \ldots \quad = \frac{Pb}{l}$$

$$R_2 = V_2\left(\text{max. when } a > b\right) \quad \ldots \quad = \frac{Pa}{l}$$

$$M \text{ max.}\left(\text{at point of load}\right) \quad \ldots \quad = \frac{Pab}{l}$$

$$M_x \left(\text{when } x < a\right) \quad \ldots \quad = \frac{Pbx}{l}$$

$$\Delta\text{max.} \left(\text{at } x = \sqrt{\frac{a(a+2b)}{3}} \text{ when } a > b\right) = \frac{Pab(a+2b)\,\sqrt{3a(a+2b)}}{27\,EI\,l}$$

$$\Delta a \left(\text{at point of load}\right) \quad \ldots \quad = \frac{Pa^2b^2}{3EI\,l}$$

$$\Delta_x \left(\text{when } x < a\right) \quad \ldots \quad = \frac{Pbx}{6EI\,l}(l^2 - b^2 - x^2)$$

Engineering Design Guide

Two unequal concentrated loads unsymmetrically placed

$$R_1 = V_1 \quad \ldots \ldots \ldots \ldots \ldots \quad = \frac{P_1 (l - a) + P_2 b}{l}$$

$$R_2 = V_2 \quad \ldots \ldots \ldots \ldots \ldots \quad = \frac{P_1 a + P_2 (l - b)}{l}$$

$$V_x \quad \left(\text{when } x > a \text{ and } < (l - b) \right) \ldots \quad = R_1 - P_1$$

$$M_1 \quad \left(\text{max. when } R_1 < P_1 \right) \quad \ldots \quad = R_1 a$$

$$M_2 \quad \left(\text{max. when } R_2 < P_2 \right) \quad \ldots \quad = R_2 b$$

$$M_x \quad \left(\text{when } x < a \right) \ldots \ldots \quad = R_1 x$$

$$M_x \quad \left(\text{when } x > a \text{ and } < (l - b) \right) \ldots \quad = R_1 x - P_1 (x - a)$$
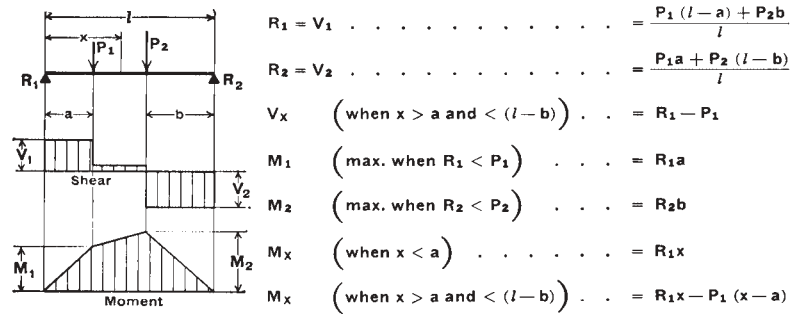
Multiple Span (Multi-Support) Condition

$$R_1 = V_1 = R_3 = V_3 \ldots \quad = \quad \frac{3}{8} wl$$

$$R_2 = 2V_2 \ldots \ldots \quad = \quad \frac{10}{8} wl$$

$$V_2 \quad \ldots \ldots \ldots \quad = \quad \frac{5}{8} wl$$

$$M_x \quad \ldots \ldots \ldots \quad = \quad R_1 x - \frac{wx^2}{2}$$

$$M_x \left(\text{at } x = \frac{3l}{8} \right) \ldots \quad = \quad \frac{9}{128} wl^2$$

$$M_1 \quad (\text{at support } R_2) \ldots \quad = -\frac{wl^2}{8}$$

$$\Delta \text{ Max. } (0.4215l \text{ from } R_1 \text{ or } R_3) = wl^4/185EI$$

$$\Delta_x = \frac{wx}{48EI} (l^3 - 3lx^2 + 2x^3)$$
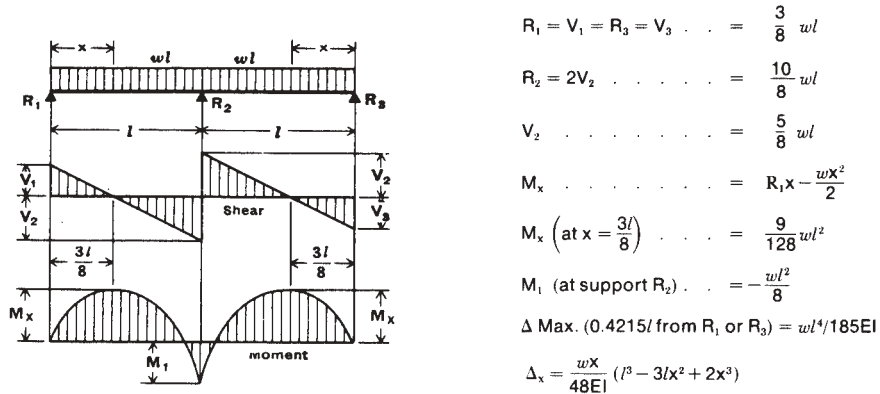
Two equal spans with concentrated loads at any point
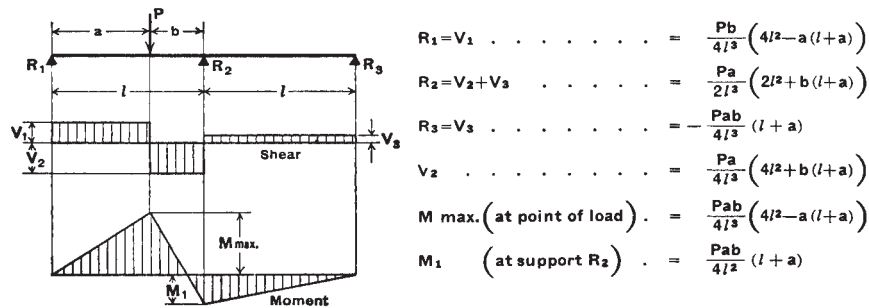
$$R_1 = V_1 \quad \ldots \ldots \ldots \quad = \quad \frac{Pb}{4l^3} \left(4l^2 - a(l+a) \right)$$

$$R_2 = V_2 + V_3 \quad \ldots \ldots \quad = \quad \frac{Pa}{2l^3} \left(2l^2 + b(l+a) \right)$$

$$R_3 = V_3 \quad \ldots \ldots \ldots \quad = -\frac{Pab}{4l^3} (l + a)$$

$$V_2 \quad \ldots \ldots \ldots \ldots \quad = \quad \frac{Pa}{4l^3} \left(4l^2 + b(l+a) \right)$$

$$M \text{ max.} \left(\text{at point of load} \right) . \quad = \quad \frac{Pab}{4l^3} \left(4l^2 - a(l+a) \right)$$

$$M_1 \quad \left(\text{at support } R_2 \right) \quad . \quad = \quad \frac{Pab}{4l^2} (l + a)$$

"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."

Engineering Design Guide

Two equal spans with uniform load on both spans

Overhang Condition

For purposes of engineering design, it will be assumed that the overhanging ends of a shelf system induce a moment in the primary span (l). This moment depends upon the size of the overhang and the weight on it.
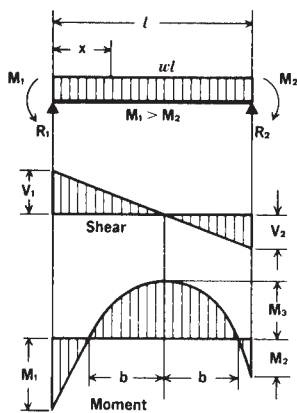
$$R_1 = V_1 = \frac{wl}{2} + \frac{M_1 - M_2}{l}$$

$$R_2 = V_2 = \frac{wl}{2} - \frac{M_1 - M_2}{l}$$

$$V_x = w\left(\frac{l}{2} - x\right) + \frac{M_1 - M_2}{l}$$

$$M_3 \left(\text{at } x = \frac{l}{2} + \frac{M_1 - M_2}{wl}\right)$$

$$= \frac{wl^2}{8} - \frac{M_1 + M_2}{2} + \frac{(M_1 - M_2)^2}{2wl^2}$$

$$M_x = \frac{wx}{2}(l - x) + \left(\frac{M_1 - M_2}{l}\right)x - M_1$$

$$b\binom{\text{To locate}}{\text{inflection points}} = \sqrt{\frac{l^2}{4} - \left(\frac{M_1 + M_2}{w}\right) + \left(\frac{M_1 - M_2}{wl}\right)^2}$$

$$\Delta_x = \frac{wx}{24EI}\left[x^3 - \left(2l + \frac{4M_1}{wl} - \frac{4M_2}{wl}\right)x^2 + \frac{12M_1}{w}x + l^3 - \frac{8M_1 l}{w} - \frac{4M_2 l}{w}\right]$$

Uniformly distributed load with variable end moments
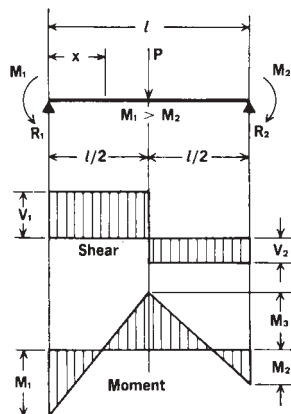
$$R_1 = V_1 = \frac{P}{2} + \frac{M_1 - M_2}{l}$$

$$R_2 = V_2 = \frac{P}{2} - \frac{M_1 - M_2}{l}$$

$$M_3 \text{ (At center)} = \frac{Pl}{4} - \frac{M_1 + M_2}{2}$$

$$M_x \left(\text{When } x < \frac{l}{2}\right) = \left(\frac{P}{2} + \frac{M_1 - M_2}{l}\right)x - M_1$$

$$M_x \left(\text{When } x > \frac{l}{2}\right) = \frac{P}{2}(l - x) + \frac{(M_1 - M_2)x}{l} - M_1$$

$$\Delta_x \left(\text{When } x < \frac{l}{2}\right) = \frac{Px}{48EI}\left(3l^2 - 4x^2 - \frac{8(l - x)}{Pl}[M_1(2l - x) + M_2(l + x)]\right)$$

Concentrated load at center with variable end moments

Other Considerations

Adjustment Factors - Adjustment factors can take the form of reductions in the allowable design values to compensate for potential overload situations or creep deflection. Creep refers to the phenomenon of shelf deflection that accumulates over time under sustained loading. For most wood composites, creep can be exaggerated by high or fluctuating humidity conditions. Often a designer will assume creep deflections to be equal to or greater than the initial elastic deflection and design accordingly.

Unsymmetric Loading - Loading that is not symmetrically positioned on a shelf can cause exaggerated moments in a shelf panel, particularly when several loads are placed on the same shelf. The effect can be compounded when shelf overhangs are part of the design. The designer is cautioned to use the appropriate design equation when considering such load applications. When overhangs are considered, the equations shown above are useful to calculate the maximum bending moment.

Concentrated Load Considerations - Concentrated loads typically cause stresses in excess of uniform loads of equal magnitude. However, most loads are neither concentrated at a point or uniformly distributed across the shelf area. Therefore, when designing shelving systems it is usually more prudent to design for concentrated loads than uniform loads. For complicated concentrated load situations, the law of superposition can be applied.

Actual Loads - Shelf loads 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. A simple bathroom scale may be used to estimate the anticipated load levels.

Metric Conversion Values

$1 ft = 0.3048$ m
$1 m = 3.281$ ft.
$1 ft^2 = 0.0929$ m^2
$1 m^2 = 10.76$ ft^2
$1 lb/ft^2 = 4.882$ kg/m^2
$1 kg/m^2 = 0.2048$ lb/ft^2

What is the Composite Panel Association?

The Composite Panel Association (CPA) is the North American trade association for the particleboard (PB) and the medium density fiberboard (MDF) industries, and for other compatible products. The CPA is dedicated to increasing the acceptance and use of industry products and educating users about the benefits of these products.

Membership in the CPA currently includes 34 of the leading U.S. and Canadian manufacturers of industry products. Together, they represent more than 85 percent of total North American manufacturing capacity of these products.

The Composite Panel Association was formed in 1997 as a consolidation of the National Particleboard Association and the Canadian Particleboard Association. The CPA represents industry on technical, regulatory, quality assurance and product acceptance issues.

An affiliated organization, the Composite Wood Council, was formed in 1989 to broaden participation in industry educational and promotional programs. Membership in the Composite Wood Council is highly diverse and includes more than 175 companies worldwide, including all members of the Composite Panel Association. Programs and activities of the CPA and the Council complement each other.

References

1997-1998 Buyers and Specifiers Guide to North American Particleboard and MDF Manufacturers and Products, Composite Panel Association, Gaithersburg, MD.

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ANSI A208.2-1994 Medium Density Fiberboard, American National Standard, Composite Panel Association, Gaithersburg, MD.

Medium Density Fiberboard From Start to Finish, Composite Panel Association, Gaithersburg, MD, 1998.

Particleboard From Start to Finish, Composite Panel Association, Gaithersburg, MD, 1996.

Timber Construction Manual, 4th Edition, 1994, American Institute of Timber Construction, Englewood, Colorado.

CPA Member Companies

Allegheny MDF LP
Allegheny Particleboard LP
Boise Cascade Corporation
CanPar Industries
Collins Products, LLC
Columbia Forest Products
Del-Tin Fiber, LLC
Flakeboard Company Ltd.
Florida Plywoods, Inc
Georgia-Pacific Corporation
Hambro Forest Products, Inc.
Isobord Enterprises, Inc.

Langboard, Inc.
Louisiana-Pacific Corporation
MacMillan Bloedel Ltd.
Merillat Industries, Inc.
Norbord Industries, Inc.
Northern Engineered Wood Products, Inc.
Panolam Industries
Pan Pacific Products, Inc.
Plum Creek Timber Company LP
Potlatch Corporation
Proboard Ltd.

Rexwood Products (1996) Ltd.
SierraPine Ltd.
Tafisa Canada and Company Ltd.
Temple
Timber Products Company
Uniboard Canada, Inc.
Union Camp Corporation
Webb Furniture Enterprises, Inc.
West Fraser Mills
Weyerhaeuser Company
Willamette Industries, Inc.

Composite Panel AssociationSM
Association des fabricants de panneaux de composites