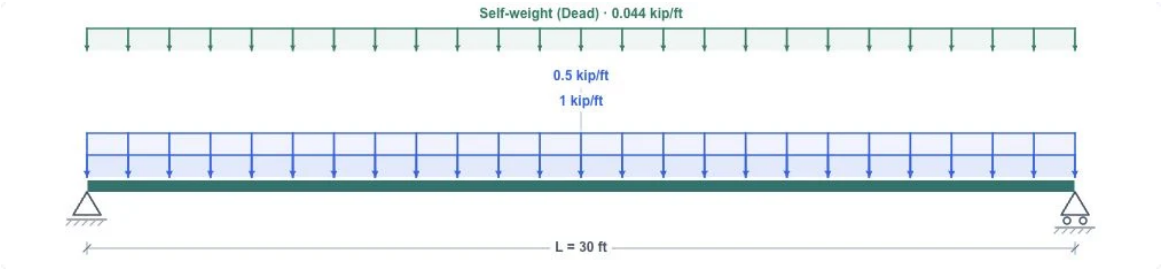
OPTIMAL BEAM / WORKED EXAMPLE 01

Steel beam design. Every calculation connected.

AISC 360-22 LRFD | 30 ft W21X44 | ASTM A992

Full bending, shear and deflection calculations, three-section comparison and an editable beam model.

Prepared and reviewed by Tamer Hijjawi, P.Eng. | Last technical review November 15, 2026



Actual model. Continuous compression-flange bracing assumed; no composite action.

Design brief

Input	Value	Input	Value
Span / supports	30 ft / pin + roller	Steel grade	A992, Fy = 50 ksi
Dead load, excluding beam	0.500 kip/ft	Live load	1.000 kip/ft
Self-weight	44 lb/ft = 0.044 kip/ft	Elastic modulus	29,000 ksi
Total deflection limit	L/240 = 1.500 in	Live deflection limit	L/360 = 1.000 in

Result summary

Check	Demand	Available / limit	Utilization
Bending	253.440 kip-ft	357.750 kip-ft	70.8%
Shear	33.792 kip	217.350 kip	15.5%
Total deflection	1.151 in	1.500 in	76.7%
Live deflection	0.745 in	1.000 in	74.5%

Total deflection governs at 76.7%. All four selected checks pass for the stated inputs. A member pass is not a complete project design.

Prepared November 15, 2026. Original educational example by Optimal Beam; not an independent engineering approval.

02-03 / LOADS AND ANALYSIS

Build the loads and combinations

Keep member self-weight in the dead load case. The entered 0.500 kip/ft dead load excludes the beam itself, so add the W21X44 weight once.

Self-weight = 44 / 1,000 = 0.044 kip/ft
D = 0.500 + 0.044 = 0.544 kip/ft
L = 1.000 kip/ft
1.4D = 1.4(0.544) = 0.7616 kip/ft
1.2D + 1.6L = 1.2(0.544) + 1.6(1.000) = 2.2528 kip/ft
Service D + L = 0.544 + 1.000 = 1.544 kip/ft

Selected gravity-only combinations. Establish all required loads, combinations and patterns under the applicable building code and load standard for an actual project.

Calculate reactions, shear and moment

RA = RB = wu L / 2 = 2.2528(30) / 2 = 33.792 kip
|Vu|max = 33.792 kip, at the supports
V(x) = 33.792 - 2.2528x [kip; x in ft]
M(x) = 33.792x - 1.1264x^2 [kip-ft; x in ft]
V(x) = 0 at x = 15 ft
Mu = wu L^2 / 8 = 2.2528(30^2) / 8 = 253.44 kip-ft

Sagging moment is positive. For unfactored service D + L: reactions = 23.160 kip each, peak moment = 173.700 kip-ft. For 1.4D alone: 11.424 kip and 85.680 kip-ft. For live load alone: 15.000 kip and 112.500 kip-ft.

04 / MAJOR-AXIS FLEXURE

Check steel beam bending strength

First establish that the flange and web are compact. This rolled, doubly symmetric W shape is checked about its major axis, with continuous restraint of the compression flange and the required torsional restraint assumed.

Flange: bf / (2tf) = 6.50 / (2 x 0.450) = 7.222
Flange compact limit = 0.38 sqrt(E/Fy) = 0.38 sqrt(29,000/50) = 9.152 > 7.222
Clear web height h = d - 2kdes = 20.70 - 2(0.95) = 18.8 in
Web: h / tw = 18.80 / 0.350 = 53.714
Web compact limit = 3.76 sqrt(E/Fy) = 90.553 > 53.714
Mn = Mp = Fy Zx = 50(95.4) = 4,770 kip-in = 397.5 kip-ft
phi-b Mn = 0.90(397.50) = 357.75 kip-ft
Bending utilization = 253.44 / 357.75 = 70.8% < 100%

AISC Table B4.1b (Cases 10 and 15), Sections F1 and F2, Eq. F2-1. Compactness permits plastic strength. Continuous bracing removes a finite unbraced segment from this example; LTB does not govern. For context, Lp = 1.76 ry sqrt(E/Fy) = 53.41 in. If restraint changes, evaluate the actual unbraced lengths and the applicable F2 lateral-torsional buckling provisions. Do not use the 30 ft span as proof of adequate bracing.

Section properties used

d	bf	tw	tf	kdes
20.70 in	6.50 in	0.350 in	0.450 in	0.95 in
Ix	Sx	Zx	ry	A
843 in^4	81.6 in^3	95.4 in^3	1.26 in	13.0 in^2

Properties: AISC Shapes Database v16.0, US customary values. Lateral bracing and its attachments must supply the required strength and stiffness; this example does not design those components.

05 / SHEAR AND ALTERNATIVE METHOD

Check web shear strength

h / tw = 53.714 <= 2.24 sqrt(29,000/50) = 53.946
Cv1 = 1.0; phi-v = 1.0
Aw = d tw = 20.70(0.350) = 7.245 in^2
Vn = 0.6 Fy Aw Cv1 = 0.6(50)(7.245)(1.0) = 217.35 kip
phi-v Vn = 1.0(217.35) = 217.35 kip
Shear utilization = 33.792 / 217.35 = 15.5% < 100%

AISC G2.1(a), Eqs. G2-1 and G2-2. The shear area is the overall depth d times web thickness tw; the clear height h is used for slenderness. The rolled-section factor criterion is checked with unrounded values. Bearing and web crippling at the supports remain separate checks.

What changes with ASD?

Ma = (D + L) L^2 / 8 = 1.544(30^2) / 8 = 173.7 kip-ft
Mn / Omega-b = 397.50 / 1.67 = 238.024 kip-ft
ASD bending utilization = 173.70 / 238.024 = 73%
Va = 1.544(30) / 2 = 23.16 kip
Vn / Omega-v = 217.35 / 1.50 = 144.9 kip
ASD shear utilization = 23.16 / 144.90 = 16%

AISC F1 and G2.1(a). The total and live deflection checks stay the same. LRFD and ASD are separate design methods; do not mix factored demands with ASD available strengths. The downloadable model includes the D + L ASD assignment.

06-08 / SERVICEABILITY AND SECTION SELECTION

Check total and live-load deflection

Span = 30 x 12 = 360 in; E = 29,000 kip/in^2; Ix = 843 in^4
delta-max = 5w L^4 / (384 E Ix)
Total w = 1.544 / 12 = 0.12866667 kip/in
delta-total = 5(1.544/12)(360^4) / [384(29,000)(843)] = 1.15104 in
Total limit = 360 / 240 = 1.5 in; utilization = 76.7%
delta-live = 5(1.000/12)(360^4) / [384(29,000)(843)] = 0.74549 in
Live limit = 360 / 360 = 1 in; utilization = 74.5%

Both maximum deflections occur at midspan. This is linear-elastic, small-displacement Euler-Bernoulli bending without shear deformation, composite stiffness or camber subtraction. Floor vibration and finishes-sensitive serviceability criteria are outside this example.

Compare passing sections

Same span, loads, A992 steel, continuous bracing and project limits. Each candidate includes its own self-weight. Percentages below are utilization.

Section	lb/ft	Depth in	Bending	Shear	Total defl.	Live defl.
W21X44	44	20.7	70.8%	15.5%	76.7%	74.5%
W18X46	46	18.1	74.6%	17.3%	91.0%	88.3%
W16X50	50	16.3	73.7%	18.2%	98.5%	95.4%

W21X44 is lightest among these three alternatives. W18X46 and W16X50 are shallower but heavier. Total deflection rises from 1.151 in to 1.365 in and 1.478 in. Total dead loads are 0.544, 0.546 and 0.550 kip/ft respectively.

This is not a universal span table. A different bracing arrangement, load, support condition or project limit can change the governing check and the selected section.

09-10 / REPRODUCE, REVIEW AND ADAPT

Open the complete beam model

Load the W21X44 example in Optimal Beam

The model carries the span, supports, catalog section, named dead/live loads, automatic self-weight, strength and service combinations, and the example design assumptions.

1. Review Beam Input. The opening analysis scenario is service D + L. Run it and check 23.16 kip reactions and 173.70 kip-ft moment.

2. Select LRFD 1.2D + 1.6L for the strength demand: 33.792 kip and 253.44 kip-ft. In Design, review LRFD, A992, continuous bracing, L/240 total and L/360 live, then check the section.

3. Compare sections or change the depth constraint. Recheck after changing the model. This educational PDF is free; exporting your own live reports follows your account plan.

Scope and review

This example checks major-axis bending, web shear and project-defined total/live deflection only. It does not establish connections, bearing, web crippling, bracing adequacy, vibration, fatigue, fire resistance, axial interaction, torsion, composite action or construction-stage stability. Loads and serviceability criteria must match the actual project.

Prepared and technically reviewed by Tamer Hijjawi, P.Eng.; last technical review November 15, 2026. These calculations are educational and are not a construction design.

References

1. AISC 360-22 Specification for Structural Steel Buildings
Table B4.1b, F1, F2, G2 and Appendix 6 for restraint design. Consult applicable errata.

2. W21X44 catalog dimensions and properties
AISC Shapes Database v16.0. US customary properties are used throughout; displayed metric values are not mixed into the calculations.

3. University of Illinois Shi Lab: direct F2 worked check
Independent reproduction of AISC Companion F.1-1B; methodological reference for compact, continuously braced W-shape flexure. It uses a different beam.

4. University of Illinois Shi Lab: direct G2 worked check
Independent reproduction of AISC Companion G.1B; methodological reference for rolled-section shear factors. It uses a different beam.

5. Simply supported beam formulas
Full-span UDL equilibrium and elastic deflection equations.

The Illinois examples use different sections; they support the F2 and G2 methods, not the numerical answer for this original W21X44 example.