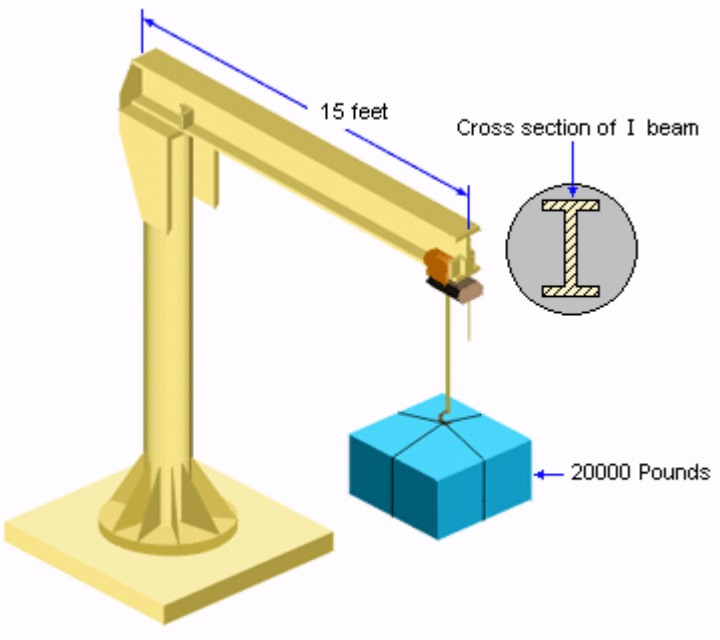
Interactive Roark's Formulas: Design of an I beam used in a crane



We assume that the I beam can be modeled as a cantilever beam fixed at the left end with a concentrated load at the end.

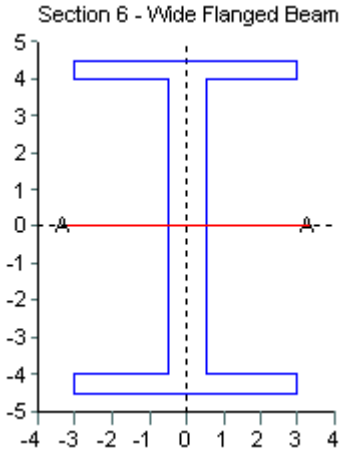
Using the 7th edition of Roark's Formulas for Stress and Strain we will make use of two tables:
The I beam cross section can be located in Appendix 1, Table A.1.
Table 8.1, case 1a provides the shear, stress, and deflection formulas for our load and support condition.

Both cases get loaded into TK Solver using the on-line menuing system.
We then enter the data for the cross section and the beam. After solving we get the following results.

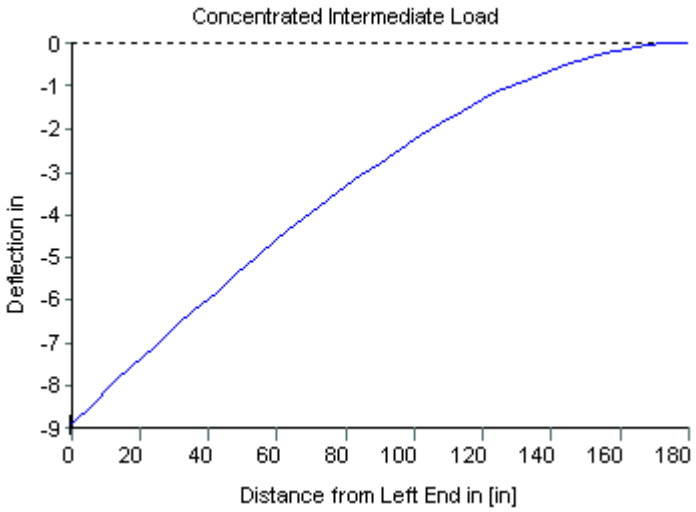
St	Input	Name	Output	Unit	Comment
	1	axis			Neutral Axis (1,2)
	6	t1b		in	Length of Flanges, b
	0.5	t1t		in	Thickness of Flanges, t
	8	t1d		in	Length of Center, d
	1	t1tw		in	Thickness of Center, tw
		A	14	in^2	Area, A
		t1y	4.5	in	Centroid to Extremity, y
		I	151.1667	in^4	Area moment of inertia
		I%c	33.5926	in^3	Elastic Section Modulus, I/c
		t1r	3.286	in	Radius of Gyration, r
		Z	41.5	in^3	Plastic Section Modulus, Z
		SF	1.2354		Shape Factor, SF
		t	9	in	Depth

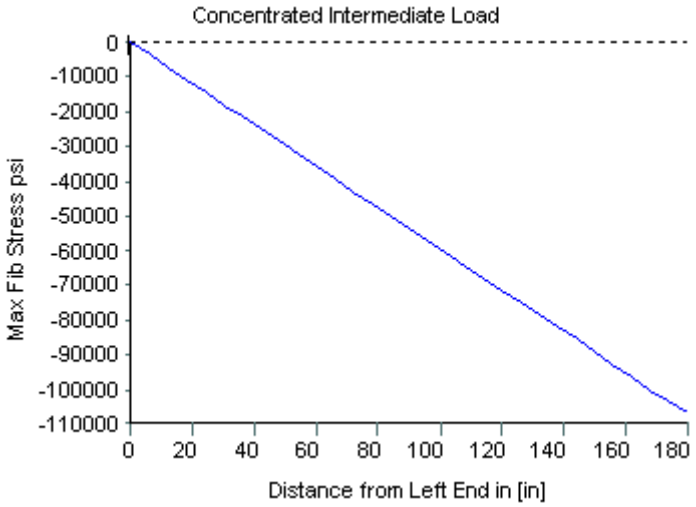
St	Input	Name	Output	Unit	Comment
					Left end free, right end fixed
					Table 8.1: Case 1 - Roark's Formulas
					Concentrated Intermediate Load
		case	'CASE_1a		End Restraints Reference Number
	17	matnum			Material Number (See Material Table)
		matl	"Steel - A		
		plot	'y		Generate plots ? 'n=no (Default=yes)
	180	L		in	Length of beam
	0	a		in	Load distance from left end
	20000	W		lbf	Load
		E	2.9E7	psi	Young's Modulus
		z	'_	in	Neutral axis to stress point
					AT SECTION:
	180	x		in	Distance from left end
		V	-20000	lbf	Transverse shear
		M	-3600000	lbf-in	Bending moment
		theta	0	rad	Slope Angle
		y	-8.882E-16	in	Deflection
		st	_	psi	Fiber stress at stress point
		sty	-107166.48	psi	Max Fiber stress at extremity y
					AT LEFT END:
		RA	0	lbf	Vertical reaction
		MA	0	lbf-in	Bending moment
		thetaA	0.0739079	rad	Slope Angle
		yA	-8.8689503	in	Deflection
					AT RIGHT END:
		RB	20000	lbf	Vertical reaction
		MB	-3600000	lbf-in	Bending moment
		thetaB	0	rad	Slope Angle
		yB	0	in	Deflection

Here is the cross-section plot.



Here are the deflection and stress plots.





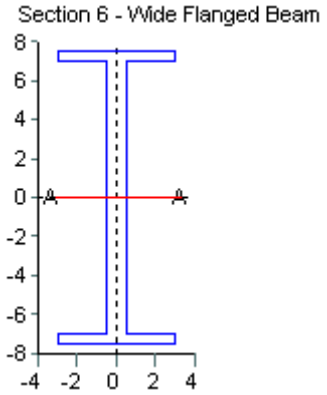
We find that the stress is too high for the type of material we have in mind and the deflection is too great. One way to reduce the stress is to change the cross section. In this case let us assume that we are prepared to change the depth of the beam cross section (variable t1d).

At this point we will change the value of stress (variable sty) from the calculated value of -107166 psi to a new value of –50000 psi by entering it in the input column. We then go to the status column for variable t1d (beam cross section depth) and type a G to assign a guess to that variable. When we solve, new results are immediately available.

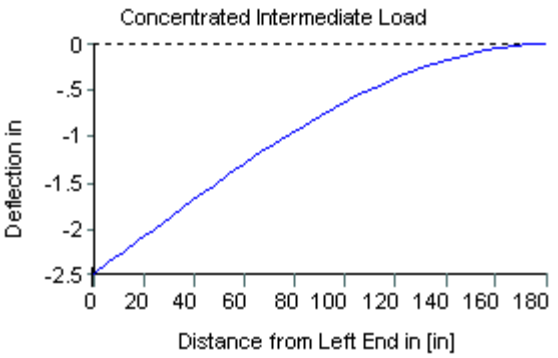
Here is the updated Variable Sheet.

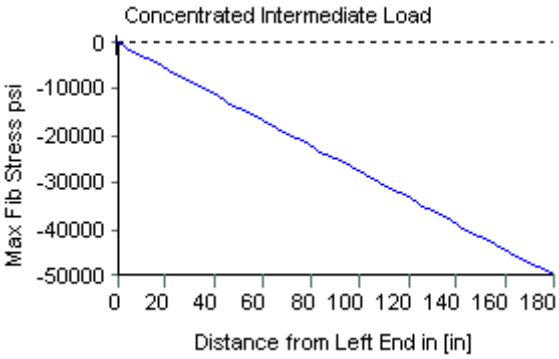
St	Input	Name	Output	Unit	Comment
	1	axis			Neutral Axis (1,2)
	6	t1b		in	Length of Flanges, b
	0.5	t1t		in	Thickness of Flanges, t
		t1d	13.9258	in	Length of Center, d
	1	t1tw		in	Thickness of Center, tw
		A	19.9258	in^2	Area, A
		t1y	7.4629	in	Centroid to Extremity, y
		I	537.3276	in^4	Area moment of inertia
		I%c	72	in^3	Elastic Section Modulus, I/c
		t1r	5.1929	in	Radius of Gyration, r
		Z	91.759	in^3	Plastic Section Modulus, Z
		SF	1.2744		Shape Factor, SF
		t	14.9257666	in	Depth
					Left end free, right end fixed
					Table 8.1: Case 1 - Roark's Formulas
					Concentrated Intermediate Load
		case	'CASE_1a		End Restraints Reference Number
	17	matnum			Material Number (See Material Table)
		matl	"Steel - A		
		plot	'y		Generate plots ? 'n=no (Default=yes)
	180	L		in	Length of beam
	0	a		in	Load distance from left end
	20000	W		lbf	Load
		E	2.9E7	psi	Young's Modulus
		z	'_	in	Neutral axis to stress point
					AT SECTION:
	180	x		in	Distance from left end
		V	-20000	lbf	Transverse shear
		M	-3600000	lbf-in	Bending moment
		theta	0	rad	Slope Angle
		y	-6.661E-16	in	Deflection
		st	_	psi	Fiber stress at stress point
	-50000	sty		psi	Max Fiber stress at extremity y
					AT LEFT END:
		RA	0	lbf	Vertical reaction
		MA	0	lbf-in	Bending moment
		thetaA	0.0207926	rad	Slope Angle
		yA	-2.4951066	in	Deflection
					AT RIGHT END:
		RB	20000	lbf	Vertical reaction
		MB	-3600000	lbf-in	Bending moment
		thetaB	0	rad	Slope Angle
		yB	0	in	Deflection

Here is the new cross-section plot.



Here are the new stress and deflection plots.


Concentrated Intermediate Load
Deflection in
0
-.5
-1
-1.5
-2
-2.5
0 20 40 60 80 100 120 140 160 180
Distance from Left End in [in]


Concentrated Intermediate Load
Max Fib Stress psi
0
-10000
-20000
-30000
-40000
-50000
0 20 40 60 80 100 120 140 160 180
Distance from Left End in [in]