An INTERTEC® /K-III Publication

S&VC

Dec. 20, 1996

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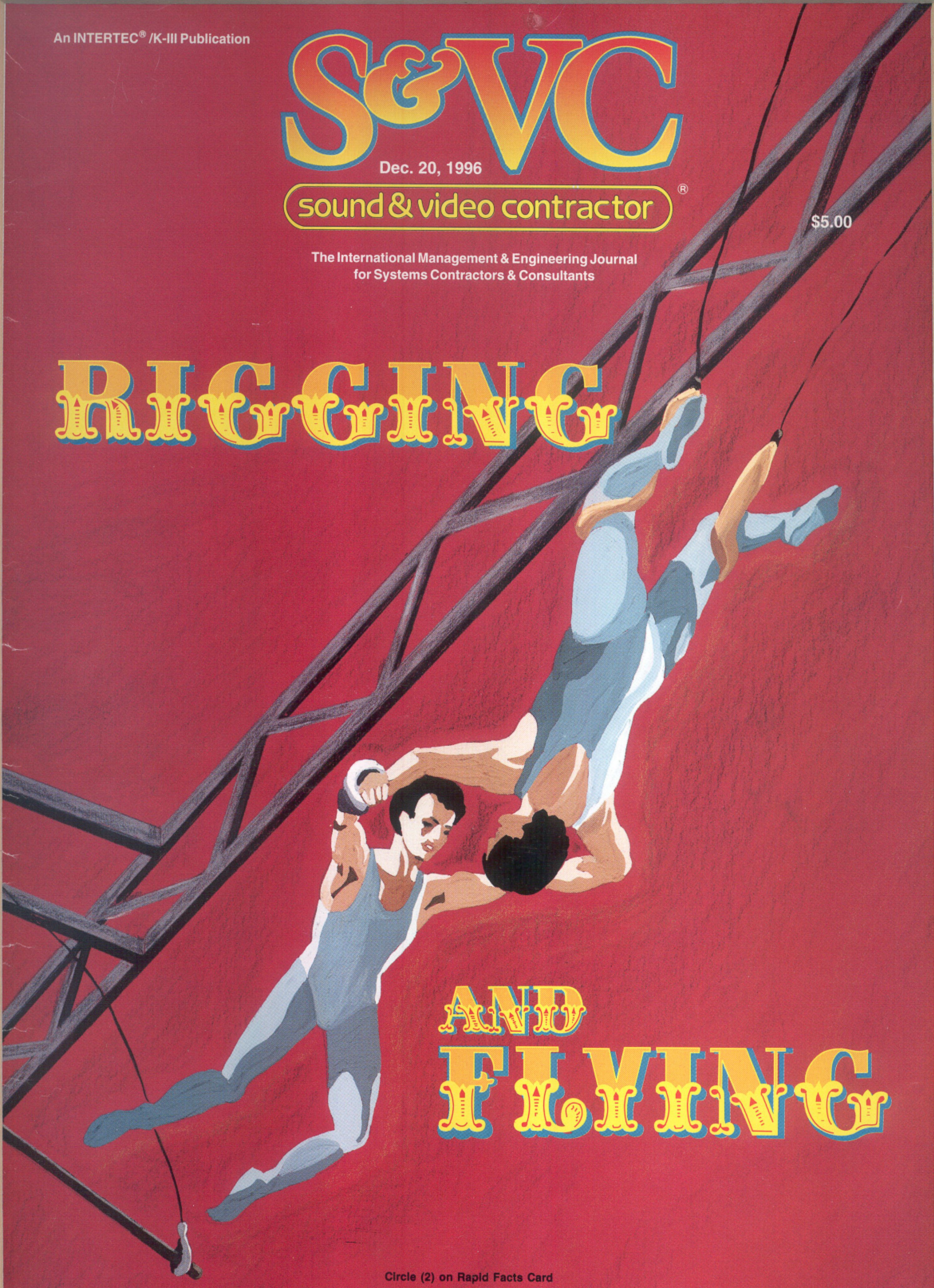
$5.00

The International Management & Engineering Journal for Systems Contractors & Consultants

RIGGING AND FLYING



Rigging formulas & charts

A contractor must understand basic rigging principles and be able to apply them to the situation at hand.

Rigging any load can be complicated and challenging; rigging heavy loads is often more difficult. A contractor must understand basic rigging principals, be able to apply them to the situation at hand and have the ability to decipher load tensions and balances. Here are the formulas and charts that will make it easier to decide how to proceed.

The following formulas and charts are excerpted from the ATM Fly-Ware *Riggermeister Production Rigging Guide.*

Choker hitch capacity

Choker hitch capacity = (sling capacity)(choker factor)(choker angle adjustment)

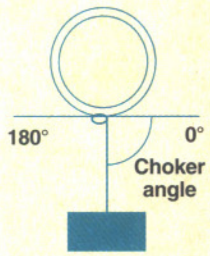


Table 1.
Choker factors

Sling type	Choker factor
Wire rope	70% to 75%
Fiber strap	75% to 80%
Fiber rope	50%
Chain	75%

Table 2.
Choker angle adjustment

Choker angle	Adjustment
120°-180°	100%
90°-119°	87%
60°-89°	74%
30°-59°	62%
0°-29°	49%

Example

For a $^1/_2$ inch, 7 × 19 galvanized aircraft cable with a choker angle of 90°:

Choker hitch capacity = (*4,300)(.70)(.87)
Choker hitch capacity = 2,618.7 pounds

*WLL of $^1/_2$ inch, 7 × 19 GAC = 4,300 pounds

By Andrew T. Martin

Approximate wire rope strength when bent over a pin

(Formulas taken from MACWHITE catalog G-18 p. 174.)
For 6×19 independent wire rope core (6×19 IWRC):

$$D = \frac{\text{diameter of pin}}{\text{nominal diameter of wire rope}}$$

When D≤6, wire rope efficiency = $100 - \frac{50}{\sqrt{D}}$

When D>6, wire rope efficiency = $100-(76/D^{0.73})$

Example

For a $^1/_2$ inch, 6×19 IWRC wire rope wrapped over a $^1/_2$ inch pin, D=0.5/0.5=1. When D ≤6, wire rope efficiency is:

$$100 - \frac{50}{\sqrt{1}} = 50$$

($^1/_2$ inch, 6×19 IWRC) WLL = 4,400 pounds
Wire rope adjusted WLL = 4,400 pounds × 50% (or 0.5)
WLL=2,200 pounds

Resultant turning force

Resultant turning force= (tension)(turning factor)

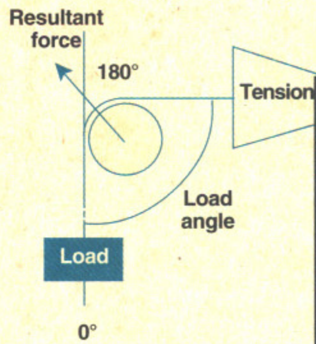


Table 3
Turning factors

Load angle	Turning factor
180°	0%
150°	52%
120°	100%
90°	141%
60°	173%
30°	193%
0°	200%

Example

For a wire rope with 1,000 pounds of tension and a load angle of 90°:

Resultant turning force=1,000(141% or 1.41)
Resultant turning force=1,410 pounds

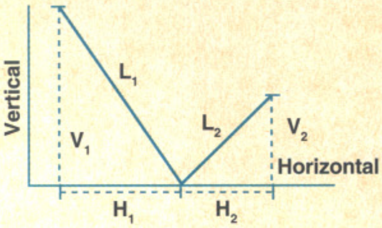
Bridle leg length for horizontal control

Length of bridle leg number one:

$$L_1 = \sqrt{V_1^2 + H_1^2}$$

Length of bridle leg number two:

$$L_2 = \sqrt{V_2^2 + H_2^2}$$



Example

For a two leg bridle, bridle leg #1 originates at 40 foot vertical (V_1) and terminates at 30 foot horizontal (H_1). The bridle leg #2 originates at 25.5 feet vertical (V_2) and terminates at 15.75 feet horizontal (H_2). Therefore:

Length of bridle leg #1:

$$L_1 = \sqrt{40^2 + 30^2} = 50 \text{ feet}$$

Length of bridle leg #2:

$$L_2 = \sqrt{25.5^2 + 15.75^2} = 29.97 \approx 30 \text{ feet}$$

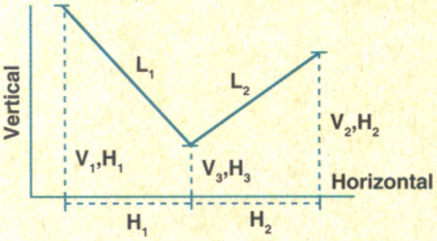
Bridle leg length for horizontal and vertical control

Length of bridle leg #1:

$$L_1 = \sqrt{(V_1 - V_3)^2 + (H_1 - H_3)^2}$$

Length of bridle leg #2:

$$L_2 = \sqrt{(V_2 - V_3)^2 + (H_2 - H_3)^2}$$



Example

A two-legged bridle has both wire ropes junction (H_3=0) at 20 foot (V_3) from the floor. Bridle leg #1 originates at 69 foot vertical (V_1) and terminates at 29 foot horizontal (H_1). Bridle leg #2 originates at 58 foot vertical (V_2) and terminates at 40 foot horizontal (H_2). Therefore:

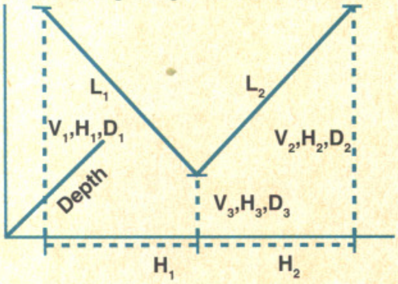
Length of bridle leg #1:

$$L_1 = \sqrt{(69-20)^2 + (29-0)^2} = 56.94 \approx 57 \text{ feet}$$

Length of bridle leg #2:

$$L_2 = \sqrt{(58-20)^2 + (40-0)^2} = 55.17 \approx 55 \text{ feet}$$

Bridle leg length for 3-D control



Length of bridle leg #1:

$$L_1 = \sqrt{(V_1 - V_3)^2 + (H_1 - H_3)^2 + (D_1 - D_3)^2}$$

Length of bridle leg #2:

$$L_2 = \sqrt{(V_2 - V_3)^2 + (H_2 - H_3)^2 + (D_2 - D_3)^2}$$

Example

A two-legged bridle has both wire rope junctions (H_3=0) at 20 foot (V_3) off the floor and 10 foot (D_3) from the downstage edge. Bridle leg #1 originates at 60 foot vertical (V_1) and terminates at 40 foot horizontal (H_1) by 0 foot deep (D_1). Bridle leg #2 originates at 60 foot vertical (V_2) and terminates at 40 foot horizontal (H_2) by 20 foot deep (D_2).

Length of bridle leg # 1:

$$L_1 = \sqrt{(60-20)^2 + (40-0)^2 + (0-10)^2} = 57.45 \approx 57.5 \text{ feet}$$

Length of bridle leg #2:

$$L_2 = \sqrt{(60-20)^2 + (40-0)^2 + (20-10)^2} = 57.45 \approx 57.5 \text{ feet}$$

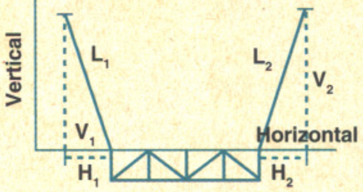
Deadhang leg length

Length of deadhang leg #1:

$$L_1 = \sqrt{V_1^2 + H_1^2}$$

Length of deadhang leg #2:

$$L_2 = \sqrt{V_2^2 + H_2^2}$$



Example

For a two-legged deadhang of a truss, bridle leg #1 originates at 40 foot vertical (V_1) and terminates at 10 foot horizontal (H_1). Bridle leg #2 originates at 42.5 foot vertical (V_2) and terminates at 12 foot horizontal (H_2).Therefore:

Length of bridle leg #1:

$$L_1 = \sqrt{40^2 + 10^2} = \sqrt{1{,}700} \approx 41.2 \text{ feet}$$

Length of bridle leg #2:

$$L_2 = \sqrt{42.5^2 + 12^2} = \sqrt{1{,}950.25} \approx 44.2 \text{ feet}$$

Estimated bridle leg length table

(All lengths are rounded to the nearest foot.)

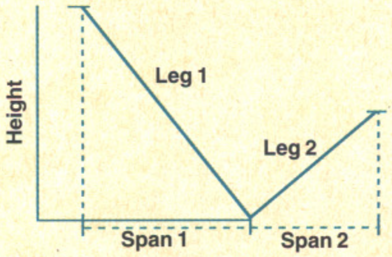


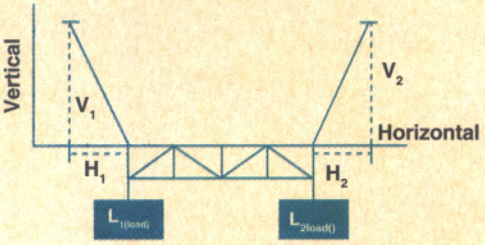
Table 4.

Distance of span 1 or span 2

Height	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46
5	5	6	8	9	11	13	15																
10	10	11	12	13	14	16	17	19	21	22	24	26	28	30	32								
15	15	16	16	17	18	19	21	22	23	25	27	28	30	32	34	35	37	39	41	43	45	48	
20	20	20	21	22	22	23	24	26	27	28	30	31	33	34	36	38	39	41	43	45	47	48	50
25	25	25	26	26	27	28	29	30	31	32	33	35	36	38	39	41	42	44	45	47	49	51	52
30	30	30	31	31	32	32	33	34	35	36	37	38	40	41	42	44	45	47	48	50	52	53	55
35	35	35	36	36	36	37	38	38	39	40	41	42	44	45	46	47	49	50	52	53	55	56	58
40	40	40	40	41	41	42	42	43	44	45	46	47	48	49	50	51	52	54	55	57	58	59	61

Deadhang object location

$(H_1/V_1)L_{1(load)} = (H_2/V_2)L_{2(load)}$



Example

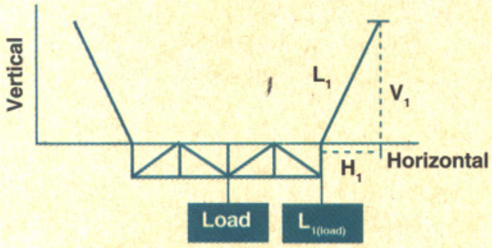
For a two-legged deadhang of a truss with two loads, bridle leg #1 originates at 20 foot vertical (V_1) and terminates at 20 foot horizontal (H_1). Bridle leg #2 originates at 20 foot vertical (V_2) and terminates at 22 foot horizontal (H_2). Therefore:

$$(20/20)500=(22/20)454.5$$

For the truss to hang flat, if $L_{1(load)}$=500 pounds, then $L_{2(load)}$=454.5 pounds.

Deadhang leg tension

Deadhang leg tension = $(L_1/V_1)L_{1(load)}$



Example

A two-legged deadhang of a truss has a 1,000 pound load, which means $L_{1(load)}$=500 pounds. Bridle leg #1 originates at 30 foot vertical (V_1) and terminates at 20 foot horizontal (H_1). To find the deadhand leg tension:

$$\text{Deadhang leg tension}=(36.06/30)500\approx 600 \text{ pounds}$$

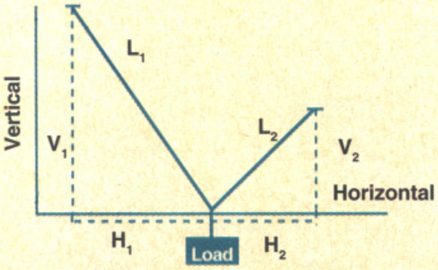
Bridle leg tension for a vertical load

Tension in bridle leg #1:

$$T_1 = \frac{(L_{load})(L_1)(H_2)}{[(V_1)(H_2)]+[(V_2)(H_1)]}$$

Tension in bridle leg #2:

$$T_2 = \frac{(L_{load})(L_2)(H_1)}{[(V_1)(H_2)]+[(V_2)(H_1)]}$$



Example

For a two-legged bridle with a vertical load weighing 1,000 pounds (L_{load}), bridle leg #1 originates at 40 foot vertical (V_1) and terminates at 30 foot horizontal (H_1). Bridle leg #2 originates at 25.5 foot vertical (V_2) and terminates at 15.75 foot horizontal (H_2).

Tension in bridle leg #1:

$$T_1 = \frac{(1{,}000)(50)(15.75)}{[(40)(15.75)]+[(25.5)(30)]} \approx 564.52 \text{ pounds}$$

Tension in bridle leg #2:

$$T_2 = \frac{(1{,}000)(30)(30)}{[(40)(15.75)]+[(25.5)(30)]} \approx 645.16 \text{ pounds}$$

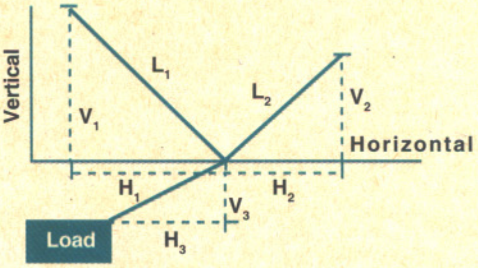
Bridle tension for an off-vertical load

Tension in bridle leg #1:

$$T_1 = F_{load}\left[\frac{L_1}{L_3}\right]\left[\frac{(V_3)(H_2)-(V_2)(H_3)}{(V_1)(H_2)-(V_2)(H_1)}\right]$$

Tension in bridle leg #2:

$$T_2 = F_{load}\left[\frac{L_2}{L_3}\right]\left[\frac{(V_3)(H_1)-(V_1)(H_3)}{(V_1)(H_2)-(V_2)(H_1)}\right]$$



Example

A two-legged bridle has an off-vertical load of 1,000 pounds. Therefore, F_{load}=1,398. (To get F_{load}, use either formula for the bridle leg tension for a vertical load). Bridle leg #1 originates at 40 foot vertical (V_1) and terminates at 25 foot horizontal (H_1). Bridle leg #2 originates at 30 foot vertical (V_2) and terminates at 20 foot horizontal (H_2). Down leg of bridle terminates at 16 foot vertical (V_3) and 10 foot horizontal (H_3). Therefore:

Tension in bridle leg #1:

$$T_1 = 1{,}398\left[\frac{47.2}{22.4}\right]\left[\frac{[(16)(20)]-[(30)(10)]}{[(40)(20)]+[(30)(25)]}\right] \approx 37.75 \text{ pounds}$$

Tension in bridle leg #2:

$$T_2 = 1{,}398\left[\frac{36.1}{22.4}\right]\left[\frac{[(16)(25)]+[(40)(10)]}{[(40)(20)]+[(30)(25)]}\right] \approx 1{,}160 \text{ pounds}$$

Bridle leg tension for a vertical load with a downward leg

Tension in bridle leg #1:

$$T_1 = \frac{(L_{load})(L_1)(H_2)}{[(V_1)(H_2)]-[(V_2)(H_1)]}$$

Tension in bridle leg #2:

$$T_2 = \frac{(L_{load})(L_2)(H_1)}{[(V_1)(H_2)]-[(V_2)(H_1)]}$$

Example

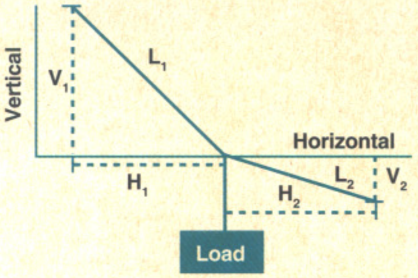
A two-legged bridle has a vertical load weighing 1,000 pounds (L_{load}). Bridle leg #1 originates at 30 foot vertical (V_1) and terminates at 20 foot horizontal (H_1). Bridle leg #2 originates at 10 foot vertical (V_2) and terminates at 21 foot horizontal (H_2). Therefore:

Tension in bridle leg #1:

$$T_1 = \frac{(1{,}000)(36.1)(21)}{[(30)(21)]-[(10)(20)]} \approx 1{,}763 \text{ pounds}$$

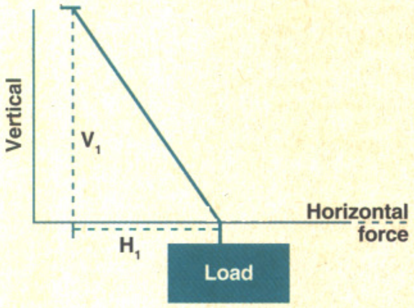
Tension in bridle leg #2:

$$T_2 = \frac{(1{,}000)(23.3)(20)}{[(30)(21)]-[(10)(20)]} \approx 1{,}083.7 \text{ pounds}$$



Horizontal force

Horizontal force= $(H_1/V_1)L_{load}$



Example

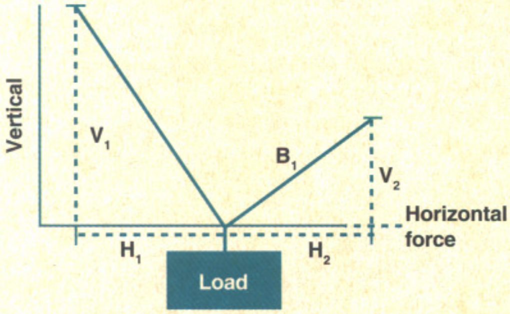
Find the horizontal force necessary to move a 1,000 pound load (L_{load}=1,000 pounds) off-vertical by 10 foot. Leg #1 originates at 50 foot vertical (V_1) and terminates at 10 foot horizontal (H_1).

Horizontal force = (10/50)1,000=200 pounds

Breastline force

Breastline force=$(B_1/H_1)Force_{horizontal}$

(See previous formula for $Force_{horizontal}$.)



Example

Find the breastline force necessary to move a 1,000 pound load ($L_{1(load)}$=1,000 pounds) off-vertical by 10 foot. Leg #1 originates at 50 foot vertical (V_1) and terminates at 10 foot horizontal (H_1). Breastline #1 originates at 30 foot vertical (V_2) and terminates at 20 foot horizontal (H_2).

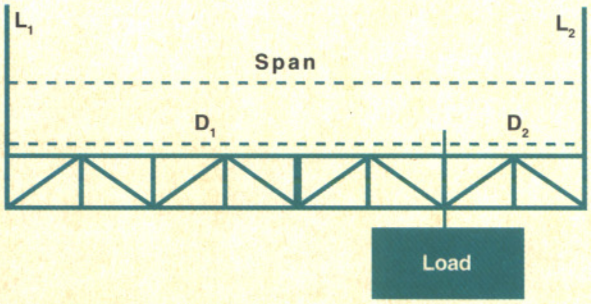
Breastline force=(~36.1/20)200≈362 pounds

This breastline force is perpendicular to the load, making it a horizontal force.

Simple load distribution

$Force_{Leg1}=(D_2/Span)L_{load}$

$Force_{Leg2}=(D_1/Span)L_{load}$



Example

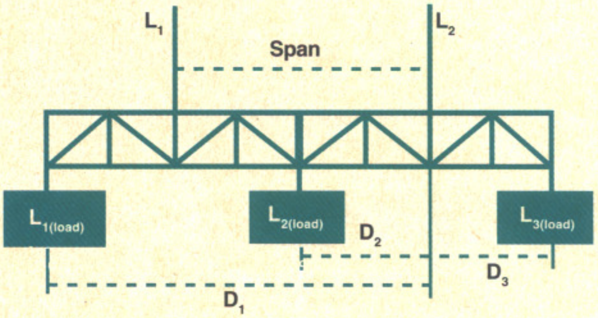
A two-legged vertical deadhang of a truss has a 1,000 pound load (L_{load}=1,000 pounds). The load is located 15 feet (D_1) from the left suspension leg and 5 feet (D_2) from the right suspension leg. The total span between the suspension legs is 20 feet (Span). Therefore:

$Force_{Leg1}$=(5/20)1,000=250 pounds

$Force_{Leg2}$=(15/20)1,000=750 pounds

Complex load distribution

$$Force_{leg1} = \frac{[(L_{1_{load}})(D_1)]+[(L_{2_{load}})(D_2)]-[(L_{3_{load}})(D_3)]}{Span}$$

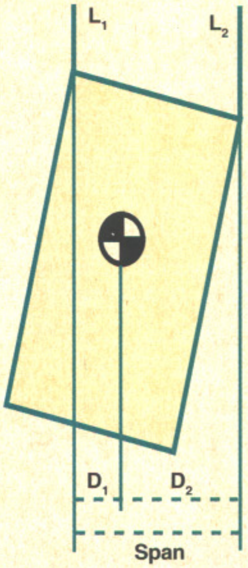


Example

A two-legged vertical deadhang of a truss has three 1,000 pound loads ($L_{x(Load)}$=1,000 pounds). Load #1 is on the left edge; load 2 is in the center; load 3 is 20 feet from the left edge. The total span of the truss is 20 feet; the total span between the suspension legs is 10 feet (Span). Therefore, D_1=15 feet, D_2=5 feet and D_3=5 feet.

$$Force_{leg1} = \frac{[(1{,}000)(15)]+[(1{,}000)(5)]-[(1{,}000)(5)]}{10}$$

$Force_{leg1}$=1,500 pounds



Load stability

$Force_{Leg1}=(D_2/Span)L_{load}$

$Force_{Leg2}=(D_1/Span)L_{load}$

Example

For a two-legged vertical deadhang of a loudspeaker weighing 250 pounds (L_{load}=250 pounds), leg #1 is 6 inches (D_1) behind the center of gravity, and leg #2 is 14 inches (D_2) in front of the center of gravity. Therefore:

$Force_{Leg1}$=(14/20)250

$Force_{Leg1}$=175 pounds

$Force_{Leg2}$=(6/20)250

$Force_{Leg2}$=75 pounds S&VC