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From the Author of ***Rigging Engineering Basics***

RIGGING ENGINEERING CALCULATIONS



J. Keith Anderson

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Mr. Anderson is the Chief Rigging Engineering for the Bechtel Corporation and the Program Manager of Industrial Training International's Fundamentals of Rigging Engineering, the only Rigging Engineering Training Program currently in existence. He is also a member of the ASME P30 Committee (Lift Planning Standard), and a Bechtel Distinguished Engineer & Scientist (only 53 individuals have received this honor in Bechtel's 120+ year history).

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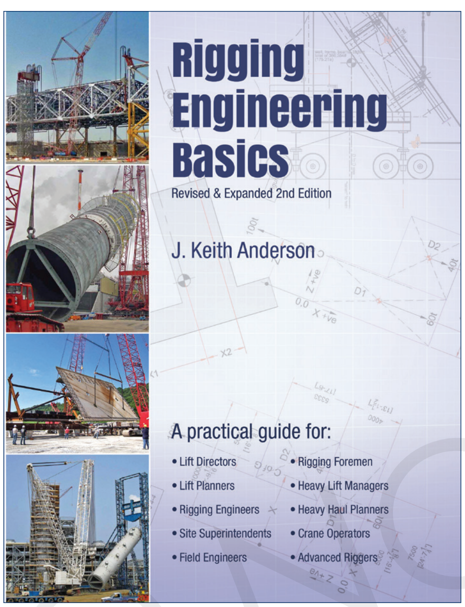

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By J. Keith Anderson

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A practical guide for Lift Directors, Lift Planners, Rigging Engineers, Site Superintendents, Field Engineers, Rigging Foremen, Heavy Lift Managers, Heavy Haul Planners, Crane Operators, and Advanced Riggers. This book is intended to inform people planning rigging operations and point them in the direction of best practice, to alert them to pitfalls and how to avoid them, and to instruct on how to do certain basic rigging engineering tasks.

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A practical guide for rigging engineers and lift planners

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J. Keith Anderson

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2 Weight and C of G

2.1 Weight

2.1.1 Densities of selected materials

Approximate densities of common substances.

	Density			
Substance	**(kg/m³)**		**(lbf/ft³)**	
Alumina	961		60	
Aluminum	2712		169	
Brass - rolled and drawn	8430	8730	526	545
Brick, common red	1922		120	
Clay, wet excavated	1826		114	
Coal, Anthracite, broken	1105		69	
Coal, Anthracite, solid	1506		94	
Concrete, Gravel	2403		150	
Copper	8930		557	
Copper ore	1940	2591	121	162
Crude oil	973		61	
Diesel fuel oil	820	950	51	59
Douglas Fir	530		33	
Earth, dense	2002		125	
Earth, wet, excavated	1602		100	
Gas oil	890		56	
Gravel, wet 1/4 to 2 inches	2002		125	
Hematite (iron ore)	5095	5205	318	325
Ice, solid	919		57	
Iron	7850		490	
Iron ore - crushed	2100	2900	131	181
Limestone, solid	2611		163	
Magnetite, broken	3284		205	
Magnetite, solid (iron ore)	5046		315	
Mahogany	545		34	
Malachite (copper ore)	3750	3960	234	247
Mortar, wet	2403		150	
Mud, packed	1906		119	
Oak	590	930	37	58
Oak, red	705		44	
Pine	560		35	
Rip-Rap	1602		100	
Rock - soft - excavated	1600	1781	100	111
Sand with Gravel, dry	1650		103	
Sand with Gravel, wet	2020		126	
Sand, dry	1602		100	
Sand, wet, packed	2082		130	
Sandstone, solid	2323		145	
Spruce	450		28	
Steel - rolled	7850		490	
Stone (common, generic)	2515		157	
Stone, crushed	1602		100	
Teak	630	720	39	45
Water, pure	1000		62	
Water, sea	1026		64	

1 kg/m³ = 0.001 g/cm3, equivalent to 0.0624 lbf/ft³ = 0.000036127 lbf/in³

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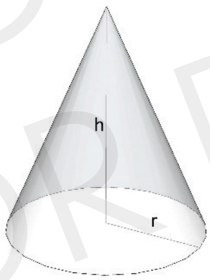
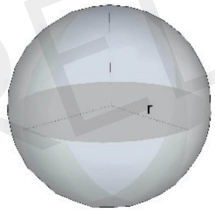
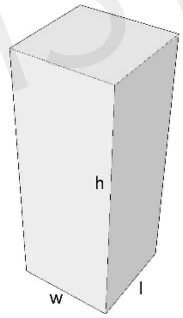
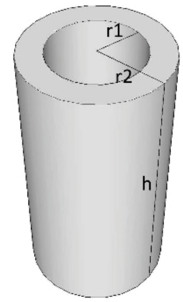
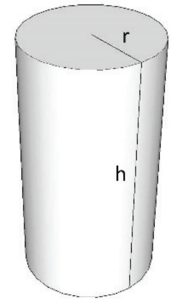
2.1.2 Volumes of common shapes

Volumes of common shapes can be calculated using one or more of the below formulae. Find more on line.

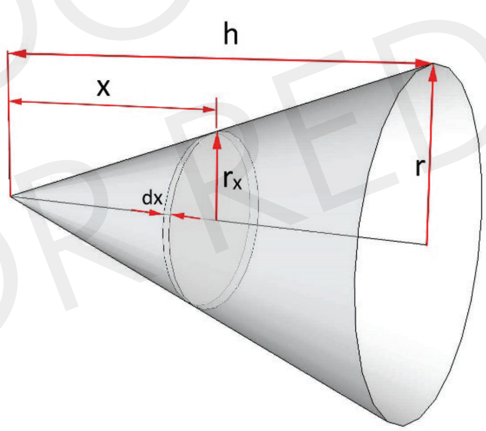
				
$V = \pi r^2 h/3$	$V = 4\pi r^3/3$	$V = l.w.h$ if a cube, l=w=h $V = side^3$	$V = \pi h(r_2^2 - r_1^2)$ If thin walled, $V = 2\pi rht$, where t is the wall thickness	$V = \pi r^2 h$

- Volumes of hollow objects can be determined by calculating the volume as though solid then deducting the volume of the void.
- Volumes of thin objects of uniform thickness can be calculated to a close approximation by multiplying the surface area by the thickness.
- Volumes of complex objects can be calculated by breaking them down into "standard" shapes and summing the volumes of the constituent parts.
- Knowing the volume and the density of the material, the weight can be calculated,

  Weight = volume x density

- The weight per unit length of standard steel sections are published in various manuals and the weights of standard steel plates can be similarly found in manuals or on line.

<ins>Sample Proof</ins>



To determine the volume of a solid with symmetry about one axis, follow this methodology.

Consider a line representing the profile, then rotate it about the axis of symmetry to form the solid.

Establish a formula defining r_x at any point from x=0 to x=h. e.g. a cone; the profile is a straight line:

$$r_x = \left(\frac{r}{h}\right) x$$

Consider a disc at x of very small thickness dx; the area of the disc is given by:

$$A_x = \pi {r_x}^2 = \pi \left(\frac{r^2}{h^2}\right) x^2$$

The volume of that disc dV is the area x thickness and is given by:

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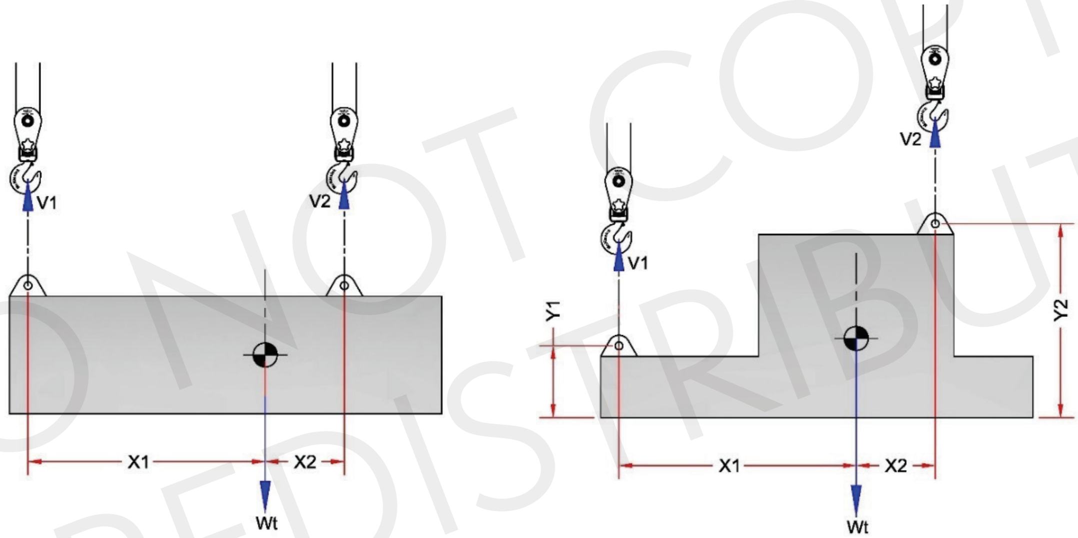
3 Load sharing – 2 lines of support

3.1 Vertical suspension – 2 lifting devices

When an object is suspended from two lifting devices <u>and the lines of suspension are vertical</u>, the lifting device that is closest horizontally to the center of gravity takes the greater proportion of the weight. There are no horizontal components, so the tensions in the slings equal V_1 and V_2.



To paraphrase Newtons Laws, for an object to be in static equilibrium, there must be no nett force or rotational effect acting on the load, i.e. the vertical and horizontal forces have to balance each other out, as do any rotational effects.

Looking at Figure 1, the only forces are vertical, so V_1+V_2 = Wt; & for moment (rotational) balance $V_1X_1 = V_2X_2$.

Think of a see-saw, the heavy kid should sit closer to the pivot for balance. Re-arranging the formula

$$\frac{\mathbf{V_1}}{\mathbf{V_2}} = \frac{\mathbf{X_2}}{\mathbf{X_1}}$$

<u>i.e. the weight of the object is shared between the two lifting devices in the inverse proportion of the horizontal distances they act from the C of G.</u>

Knowing that V_2 = Wt – V_1, substituting into the above and rearranging, we can say that

$$\mathbf{V_1} = \mathbf{Wt}\left(\frac{\mathbf{X_2}}{\mathbf{X_1}+\mathbf{X_2}}\right);\ \text{similarly}, \mathbf{V_2} = \mathbf{Wt}\left(\frac{\mathbf{X_1}}{\mathbf{X_1}+\mathbf{X_2}}\right)$$

<u>Example</u>

If X_1 = 1800 mm and X_2 = 600 mm, weight = 10t

$$V_1 = 10\left(\frac{600}{1800+600}\right) = 2.5\text{t} \qquad V_2 = 10\left(\frac{1800}{1800+600}\right) = 7.5\text{t}$$

What happens if the lugs are not at the same height <u>but the suspensions are still vertical</u>? Consider Figure 2. Equilibrium is unchanged, there are still no horizontal forces, V_1+V_2 = Wt and $V_1X_1=V_2X_2$

The above formulae still apply, the "Y" distances are irrelevant; distances X_1 and X_2 are all you need to calculate the load share.

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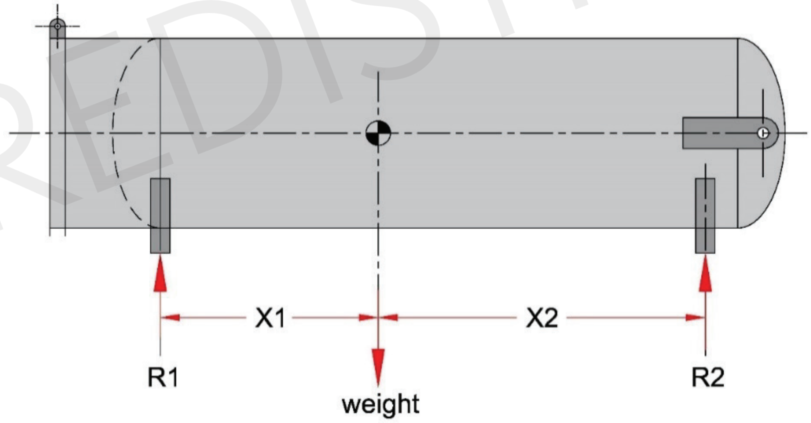
3.2 Load sharing – 2 support saddles

The Load is supported from beneath on two saddles or beams providing two vertical lines of support.



Consider say a vessel supported (statically) on two transport saddles. The weight is a vertical force acting directly downwards, the support reactions R1 and R2 are vertical forces acting directly upwards.

R1+R2 = Wt

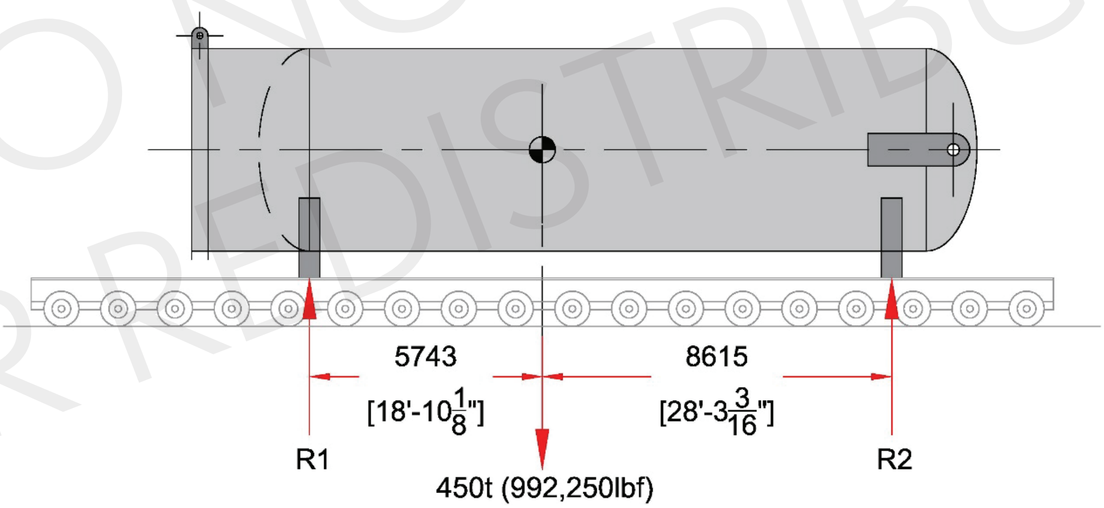
The analysis is the same as if the load were suspended rather than being supported from beneath.

i.e. the weight of the object is shared between the two support saddles in the inverse proportion of the horizontal distances they are from the C of G.

$$\frac{\mathbf{R1}}{\mathbf{R2}} = \frac{\mathbf{X2}}{\mathbf{X1}} \qquad \mathbf{R1} = \mathbf{Wt} \times \left(\frac{\mathbf{X2}}{\mathbf{X1} + \mathbf{X2}}\right) \qquad \mathbf{R2} = \mathbf{Wt} \times \left(\frac{\mathbf{X1}}{\mathbf{X1} + \mathbf{X2}}\right)$$

Example

(i) What are the transport saddle reactions in this case?



If X1 = 17000 mm and X2 = 25500 mm, weight = 450t

$$R1 = 450 \times \left(\frac{8615}{5743 + 8615}\right) = 270t$$

$$R2 = 450 \times \left(\frac{5743}{5743 + 8615}\right) = 180t$$

If X1 = 18.844’ and X2 = 28.266’, weight = 992,250lbf

$$R1 = 992250 \times \left(\frac{28.266}{18.844 + 28.266}\right) = 595350lbf$$

$$R2 = 992250 \times \left(\frac{18.844}{18.844 + 28.266}\right) = 396900lbf$$

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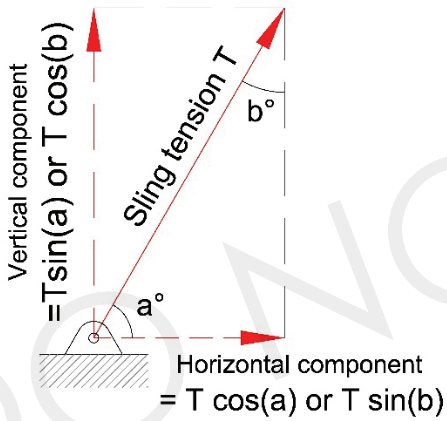
4 Forces in bridle slings

4.1 Effect of sling inclination

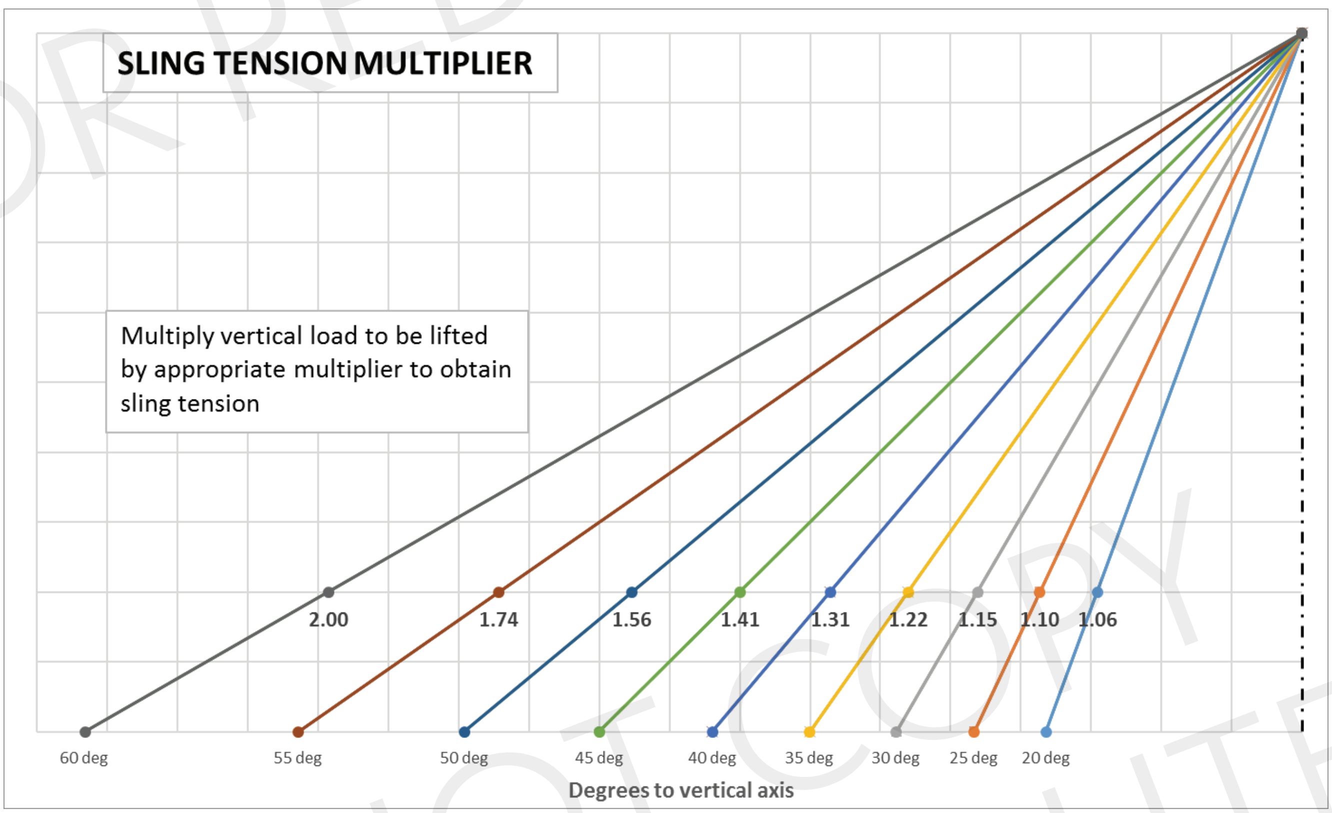
When an inclined sling (or rope, link plate or similar) is used in a rigging arrangement, its tension can be conveniently analyzed by considering its (equivalent) vertical and horizontal components. See Sect. 1.8.



The sling angle is usually referenced to the horizontal in the USA, whereas in Europe it is common to reference the angle to the vertical.

In lifting applications, it is the vertical component of the tension that is generally useful; V = T sin(a) or T cos(b). (Yields the same answer whichever reference is used). The less vertical the sling is, the less effective it is in the vertical sense; another way of looking at it is to say that the less vertical the sling, the higher the tension has to be to obtain a required vertical uplift.

The horizontal component H = T cos(a) or T sin(b). This is the force that gives rise to compression in a spreader system. The flatter the angle to the horizontal, the greater the horizontal force.



Note: in this case the angle is measured to the vertical; to obtain angle to the horizontal subtract from 90°.

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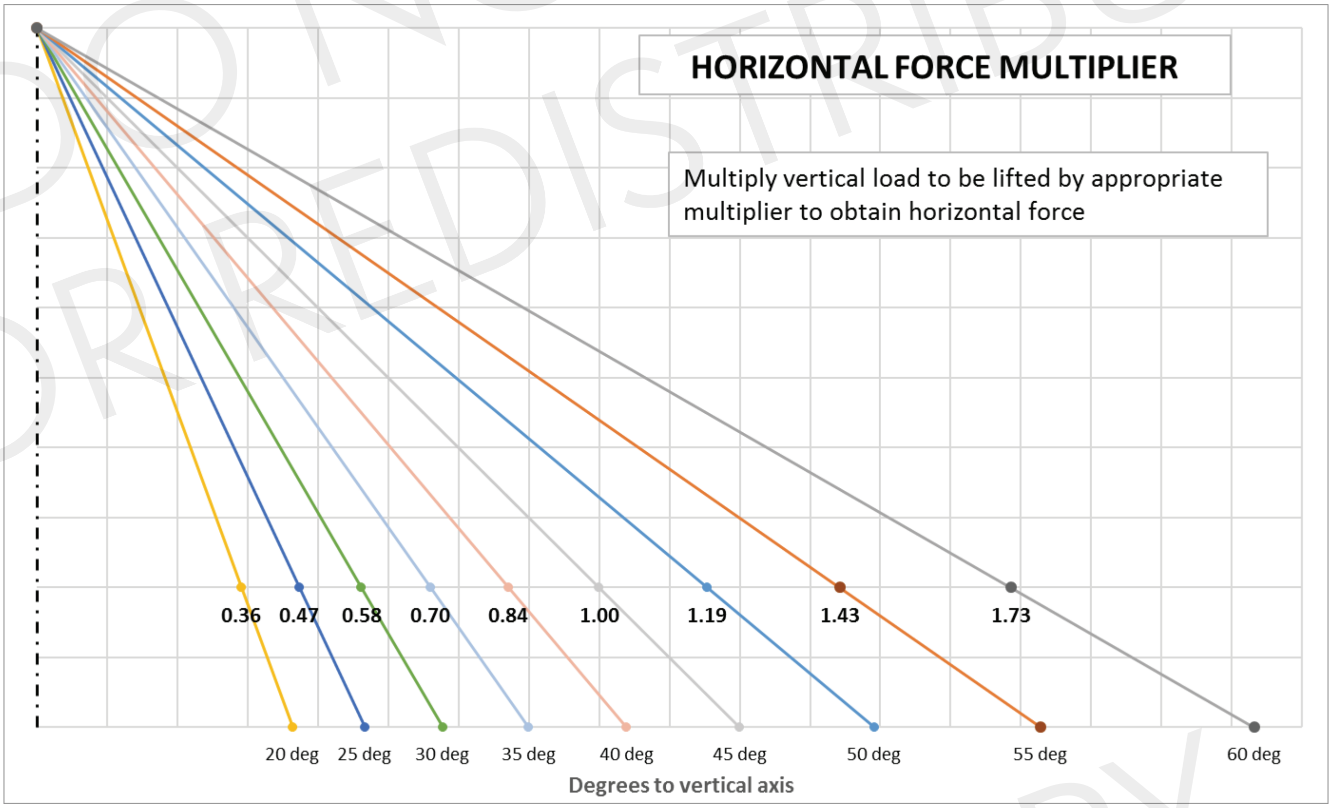
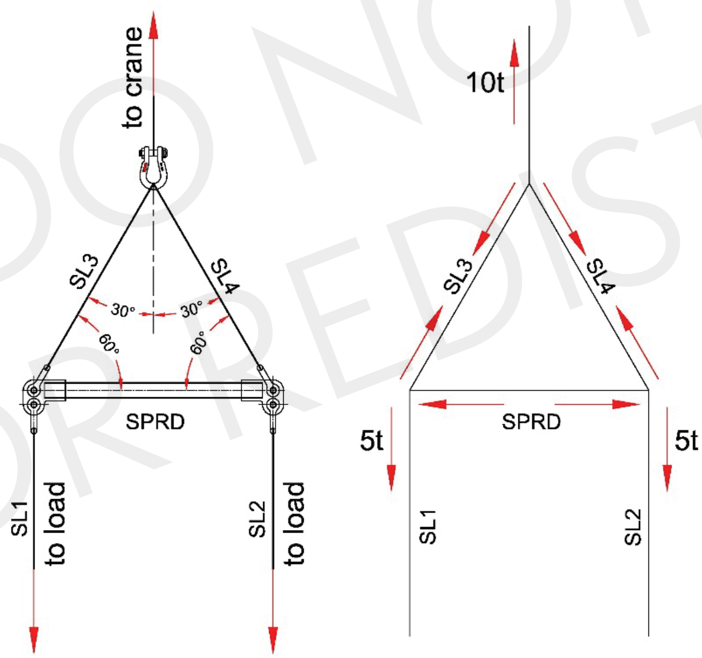


The above two tables can be used to determine the sling tensions and horizontal forces if you know the required vertical forces and the sling angles (to the vertical).

<u>Example</u>

How to use the preceding tables? For example, consider a simple spreader arrangement such as this.



It is a symmetrical arrangement with the slings inclined at 60° to the horizontal (equivalent to 30° to the vertical). A 10t load is to be lifted.

Ignore the self-weight of the spreader for this exercise.

The vertical sling tensions SL1 and SL2 are each 50% of the weight = 5t each.

The inclined sling tension multiplier for 30° to the vertical is 1.15x, so the tensions SL3 and SL4 are both 1.15 x 5t = 5.75t.

The horizontal multiplier = 0.58x the vertical force, so the compressive force SPRD = 0.58 x 5 = 2.9t.

This force is applied equally and oppositely to the compression member at either end through the shackles located on the Neutral Axis (N.A.).

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7 Assessed capacities of slings

7.1 General

7.1.1 Basic principles - all types of slings

Manufacturers determine a rated capacity for every type of sling they manufacture based on factors such as:

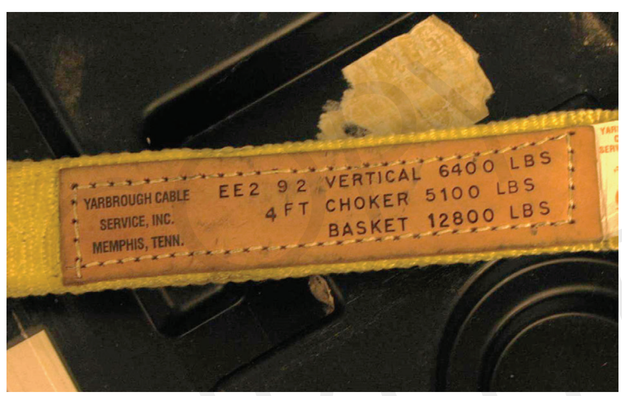
- The grade of the material used
- The size (diameter, width, thickness etc.) of the sling
- The construction of the sling
- The type of eye or other end terminations used
- The intended mode of use
- The environment in which it is to be used
- The design code that applies *(note for example that in Europe, synthetic slings are required to have a 7:1 safety factor as against 5:1 in the US)*.

That rated capacity or Working Load Limit (WLL), formerly referred to as Safe Working Load (SWL), is required to be tagged on the sling. The WLL is the maximum load (force) that the sling is rated to carry; the actual capacity of a sling however is affected by the way you are using it. A primary consideration is the hitch being used, the three basic hitches are:

- Vertical (straight line pull) – *100% of WLL*
- Choke hitch – *75% of WLL (at natural choke angle 120°-135°) for wire rope slings in the US, 70% for cable laid slings, 80% for chain and synthetic slings in the US; 80% for all types of slings in Europe*
- Basket hitch – *200% of WLL (with legs near parallel); see later re de-rating for tightness of bend*

Normally you would not have to calculate the choke and basket hitch capacities; this information should be on the tag. The choke capacity will be at the natural angle of choke and the basket capacity will be with vertical legs. Note that in Europe, the basket capacities are based on the conservative assumption that the legs are inclined at 45° and capacities are therefore less (1.4x rather than 2x the basic WLL).

Your mode of use may require you to de-rate these capacities – see following!



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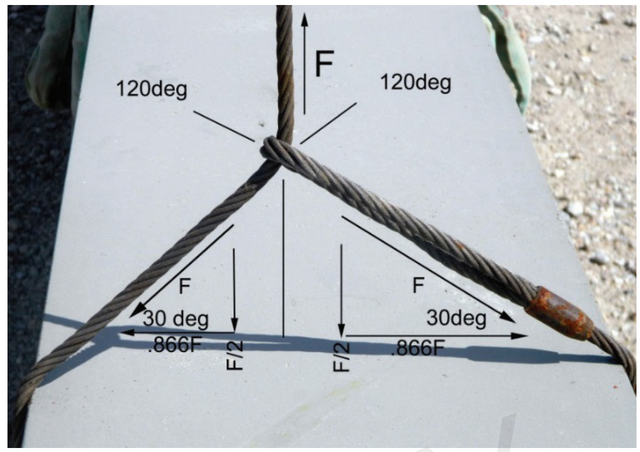
Other factors that may require the user to de-rate a sling or multi-leg bridle include:

- Rendering a choke hitch (choke angle <120°) – refer to section 7.2.4 on page 71.
- Inclining the legs of a basket hitch to say a crane hook.
- Bending a sling in a basket hitch more tightly than about 25:1 (D/d).
- The angle of inclination of a sling; this does not weaken the sling, but increases the tension in it. i.e. it is less effective in supporting a vertical load, the flatter its angle to the horizontal.

7.2 Wire rope slings

7.2.1 Forces in a choke hitch



Assuming the choke to be frictionless, the tension in the vertical leg of the sling is constant throughout its length. Equilibrium is found when the three angles formed are equal (120° each). The two inclined legs at 30° are each 50% effective vertically (see later) together they balance the force in the vertical leg. The load is being compressed by the horizontal components of the force. The reduced efficiency of the choke hitch is due to the bending of the wire at the point of choke. *Comment: note the lack of the recommended shackle at the choke and softeners where the sling is being bent around the load.*

7.2.2 Wrapped choke

Wrapped choke hitch

Taking an additional wrap around the load before "choking" grips loose bundled loads better but does not change the choke capacity for better or worse (for wire rope slings or any other sort).

7.2.3 Bending of rope within a choke hitch

When a wire rope sling is bent around a load, the relationship of the strands to each other adjusts to accommodate the bend; this locally disturbs the equality of load-sharing between the strands. The tighter the bend the more the construction is disturbed. To maintain the required factors of safety, it is necessary to de-rate the sling.

Many years ago, McWhyte conducted a series of static tests to destruction on a variety of types of wire ropes to determine the reduction of strength when bent around pins. From these test, McWhyte's efficiency curve was derived; by convention, this curve is used to determine a derating for wire rope slings when bent. *See later re bending of wire rope slings in basket hitches.*

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9 Drifting a load

9.1 What is "drifting" a load?

"Bull rigging" is the moving and manipulation of loads (pipe, valves, mechanical etc.) by (primarily) manual means using tools such as chain falls, come-alongs, skates, jacks, rollers, hand winches and small powered equipment such as tuggers. Load drifting is a technique much used in bull rigging to handle loads into or out of restricted locations. It is basically the process of moving a suspended load horizontally using two or more hoists, pulling up on some and slackening off others. Drifting techniques can be used to pass a load from one line of support to another to say move the load through a building. The process can be repeated bay after bay if required

9.1.1 Typical case – Hoists attached at the same height

In most cases, the hoists are attached at the same height in which case, the situation is simplified.

As you remember, the weight is split (vertically) between the hoists in the inverse ratio of the tangents of the angles they make to the vertical.

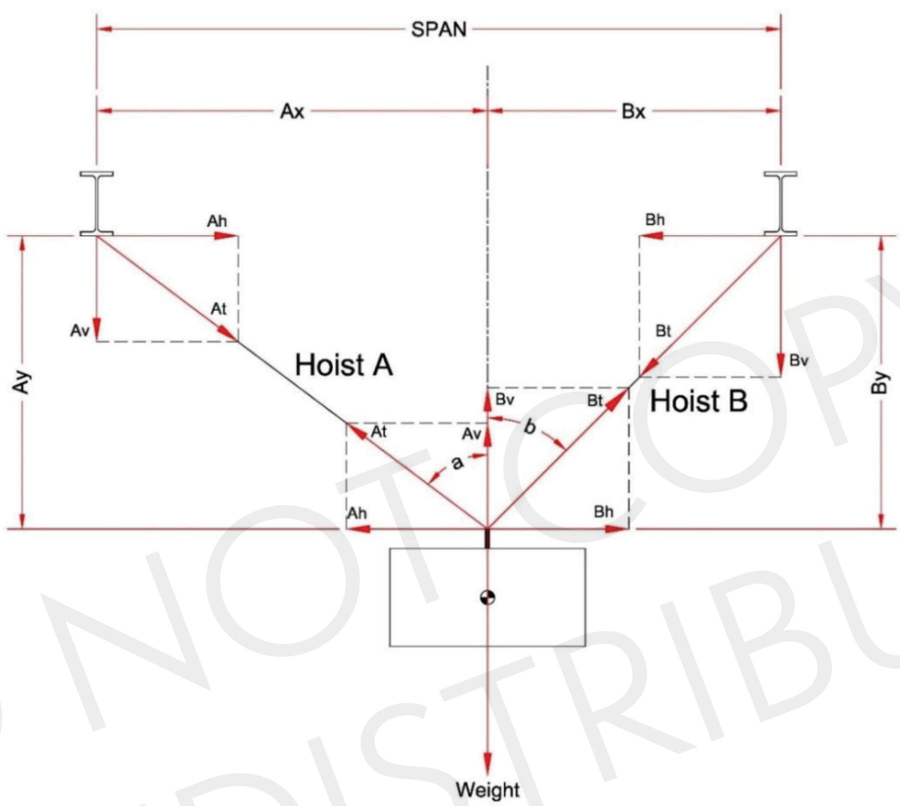
$$\tan A = \frac{A_x}{A_y}; \qquad \tan B = \frac{B_x}{B_y}$$

If the hoists are at the same height, $A_y = B_y$

$$\frac{A_v}{B_v} = \frac{\tan B}{\tan A} = \frac{B_x}{A_x}$$

i.e. In the "typical" case where the hoist attachment points are at the same height, the weight is simply shared (vertically) in inverse proportion to the horizontal distances from the C of G to the two hoist attachment points:

$$\frac{A_v}{B_v} = \frac{B_x}{A_x}$$



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Therefore, the vertical load carried by Hoist A,

$$A_V = \frac{B_x}{span} \times Weight$$

Vertical load carried by Hoist B,

$$B_V = \frac{A_x}{span} \times Weight$$

Horizontal load carried by each chain fall is equal

$A_h = A_V \times \frac{A_x}{A_y}$ or $B_h = B_V \times \frac{B_x}{B_y}$

The tension in Hoist A, $A_t = \sqrt{{A_v}^2 + {A_h}^2}$

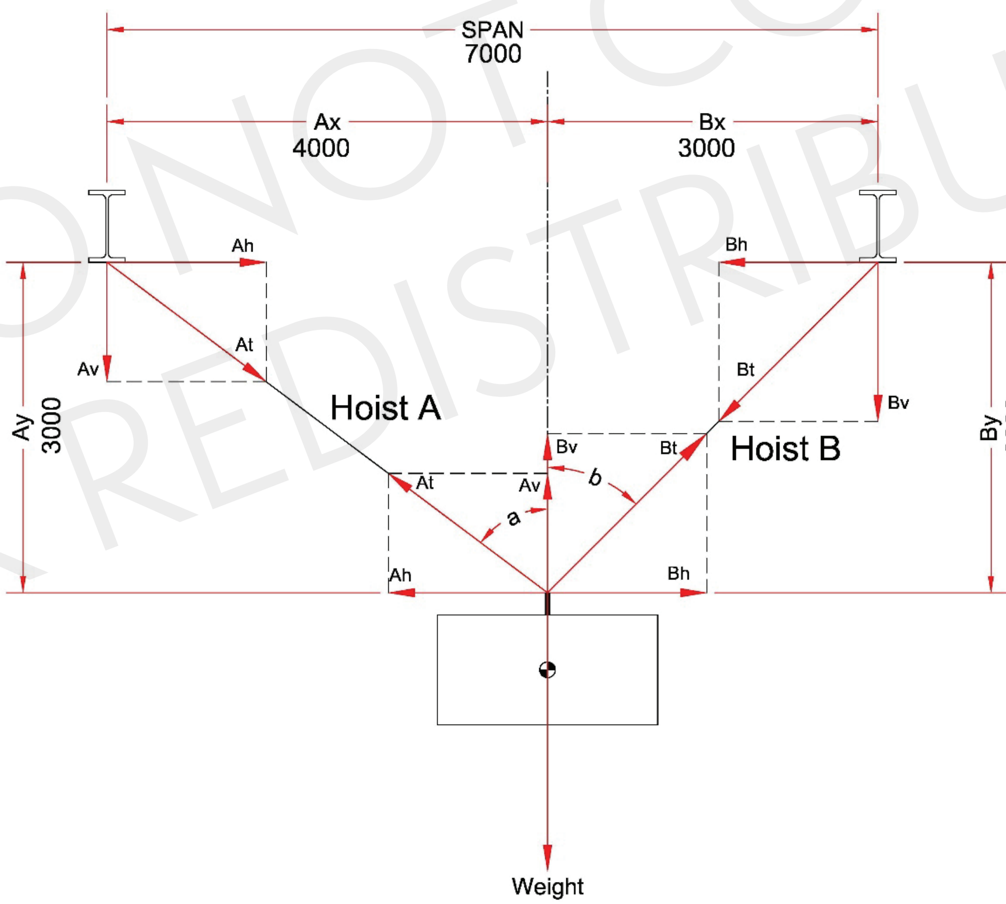
The tension in Hoist B, $B_t = \sqrt{{B_v}^2 + {B_h}^2}$

If you know the inclined lengths L_A and L_B (which are not usually as easily measured as the horizontal and vertical distances), you can dispense with Pythagoras and use:

The tension in Hoist A, $A_t = A_V \times \frac{L_A}{A_y}$

The tension in Hoist B, $B_t = B_V \times \frac{L_B}{B_y}$

<u>Example</u>



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11 Design of lift beams and spreader bars

11.1 Design standards

11.1.1 Background

Historically, lift beams and spreaders were designed to structural steel design codes.

Traditionally design codes were based on allowable stress design (ASD) whereas more recent structural steel design codes are based on Limit State Design (LSD).

- Allowable Stress design codes (ASD) sum the various force combinations that may apply and derive the resulting stresses; these service stresses are compared to code allowable stresses based on the nominal strength of the structure divided by a factor of safety. The result is so many percent of "allowable". This applies to all the stress conditions (bending, shear, combined, deflection etc.).
- Limit State Design (LSD) codes (a.k.a. Load and Resistance Factor Design (LRFD) applies a specified load factor to each of the loads in the load combination, then sums the load effects to give the required strength. The required strength must be less than the design strength which is the nominal strength of the structure multiplied by a specified resistance factor. This applies to all the limit states (bending, shear, deflection etc.).

LRFD is considered to produce a more efficient design and be a more reliable method of determining the performance of a structure.

Recognizing the type of duty, for lift beams and spreaders, an arbitrary design factor would typically be applied (up front) to the required rated load to obtain a design load to which the relevant code would be applied. i.e. for a beam to be rated for 100 tons, the design load to which the structural codes were applied might typically be 125 tons. The inverse approach would be to use the required rating and reduce the allowables to say 80% of that allowed for structures.

ASD will yield a perfectly serviceable design for a simple lift beam or spreader; it may not be the most efficient design but that approach is generally much easier.

11.1.2 Current standards

In 1999, ASME published ASME BTH-1 as a self-contained design standard for below-the-hook lifting devices in support of the safety standard ASME B30.20 - Below-the-Hook Lifting Devices.

The current issue is ASME BTH-1-2017 - *Design of Below-the-Hook Lifting Devices*.

BTH-1 recognizing the service conditions when lifting, uses more conservative design factors than are used for regular structural design of structures.

See also EN 13155, *Cranes - Safety - Non-fixed load lifting attachments*. This is not a design code but it does stipulate some design requirements that apply to lifting beams and spreaders.

11.1.3 Design to BTH-1

BTH-1 requires the designer to select a Design Category (based on static strength criteria) and a Service Class (based on fatigue life criteria) for the lifter considering its intended application. Design Category A applies only to controlled applications when the magnitude and variation of the loads are predictable, where the loading and environmental conditions are accurately defined or not severe. There is the presumption of rare and only minor unintended overloading and only mild impact loads during routine use (max multiplier 50%). The load cycles are <20,000. All other applications should be treated as Design Category B.

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To paraphrase, engineered and closely controlled applications <u>might</u> be Category A whereas all other general use "lifters" are Category B.

BTH-1 stipulates that design factors for Design Category A lifting devices shall be not less than 2.00 for limit states of yielding or buckling and 2.40 for limit states of fracture and for connection design; for Category B lifting devices, they shall be not less than 3.00 for limit states of yielding or buckling and 3.60 for limit states of fracture and for connection design.

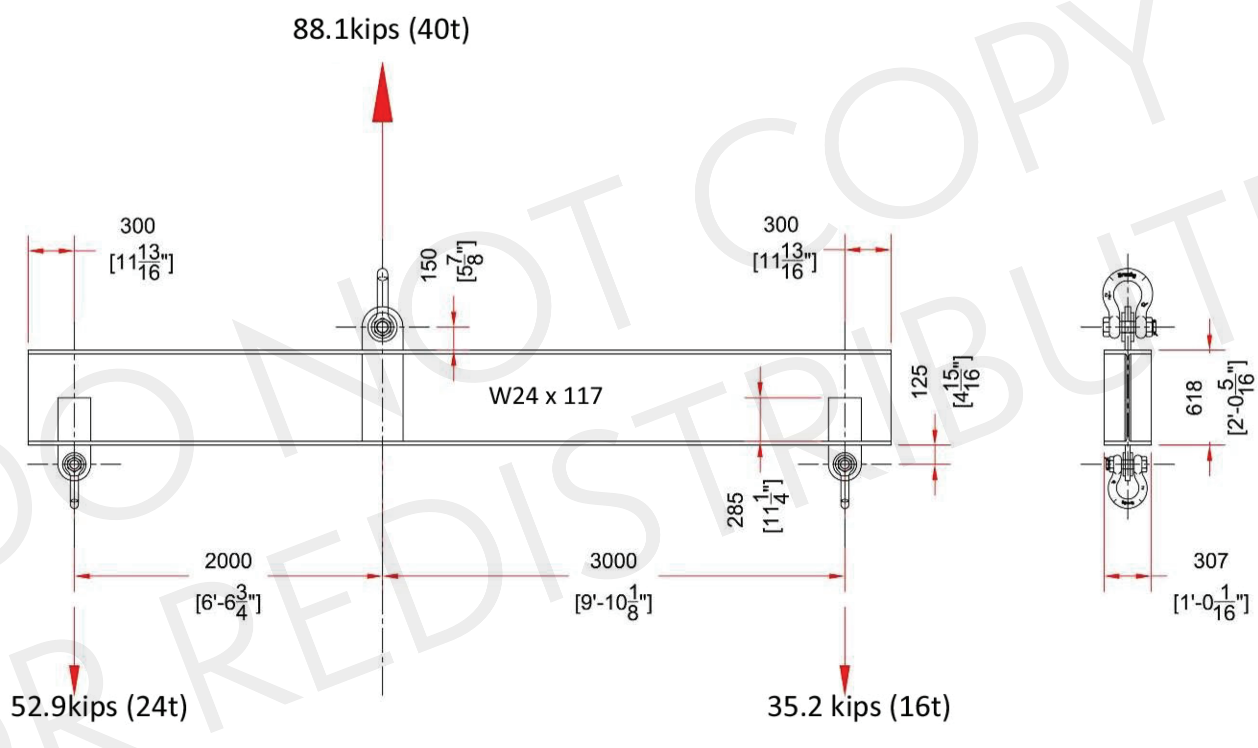
Comment: These factors compare with AISC specifying (for structural steel design), nominal design factors of 1.67 for yielding and buckling and 2.00 for fracture and connections.

11.1.4 Example beam design to ASME B30.20 BTH-1-2017

<u>Worked example using U.S. Customary Units (USCU).</u>

Consider the below custom lifting beam. It is to be used to lift a small Turbine weighing 77.175 kips (35t). The locations of the lugs are determined by the Turbine dimensions. To give some reserve over the Turbine weight, to account for factors such as the weight "growing" as the project develops, the beam will be rated for a WLL of 88.2 kips (40t). The material specified is A36, which has a yield strength of 36 ksi.

Per BTH-1 2017 criteria for Design Category and Service Life, (predictable loads, conditions not severe, low number of load cycles) this beam is to be rated as a Category A lifter.



The beam is to be rated at 88,200# (88.2 kips)

Load at LH lug = 88.2x118.125 / (78.75+118.125) = 52.92 kips

The RH lug sees the remainder = 88.2 - 52.92 = 35.28 kips

Max shear force = 52.92 kips

Max moment = 52.92 x 78.75 = 4167.45 kip-in.

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14 Assessing wind forces

14.1 Wind speed, wind pressure and forces induced

14.1.1 Wind speed

Wind speed may be quoted in conventional units of speed or as a number from 0 to 12 on the Beaufort scale. The below tabulates Beaufort scale number to force rating (description) and observable land effects and shows the equivalent wind speed in mph, km/hr and m/s. e.g. Beaufort 6 is a strong breeze that would sway large branches and equates to 25-31mph or 40-50km/hr or 11-14m/s. Note that these wind speeds are quoted at a standard 10m (33') above grade.

Beaufort Scale	Force Rating	Observable Land Effects	Speed (mph)	Speed (km/hr)	Speed (m/s)
0	Calm	Vertical Smoke	1	1.6	0.4
1	Light Air	Slight smoke drift	1-3	1.6 - 4.8	0.4 - 1.3
2	Light Breeze	Leaves gently rustle	4-7	6.4 - 11.3	1.8 - 3.1
3	Gentle Breeze	Leaves and twigs move	8-12	12.9 - 19.3	3.6 - 5.4
4	Moderate Breeze	Raises paper moves small branches	13-18	20.9 - 29.0	5.8 - 8.0
5	Fresh Breeze	Sways small leafy trees	19-24	30.6 - 38.6	8.5 - 10.7
6	Strong Breeze	Sways large branches	25-31	40.2 - 49.9	11.2 - 13.9
7	Moderate Gale	Trees sway	32-38	51.5 - 61.2	14.3 - 17.0
8	Fresh Gale	Broken twigs, walking impeded	39-46	62.8 - 74.0	17.4 - 20.6
9	Strong Gale	Chimneys, slates, hoardings damaged	47-54	75.6 - 86.9	21.0 - 24.1
10	Whole Gale	Trees Blown Down and Considerable damage	55-63	88.5 - 101.4	24.6 - 28.2
11	Storm	Major Damage	64-76	103.0 - 122.3	28.6 - 34.0
12	Hurricane	Very dangerous tropical whirling winds	76+	122.3 +	34 +

Note: Wind speeds are usually measured at 10m above grade in an unobstructed area.
Actual wind speed at height will likely be greater.

NOTE: Speed Conversions

1mph = 1.61km/hr = 0.45m/s

1km/hr = 0.62mph = 0.28m/s

1m/s = 2.24mph = 3.60km/hr

14.1.2 Wind speed versus height

By convention, wind speeds are measured and quoted (by say a weather station) at 10m (33') above grade.

NOTE: If obtaining wind data from a local weather station or airport, or reading historical data for the purposes of lift planning, it will be quoted at that height; the wind speed at the height you are interested in will likely be different. e.g. if you want to estimate the wind force on an object you are lifting, you will want to know the likely wind speed at the height of the object.

The best solution is to measure the wind speed at the height and locale of interest, say at the crane boom head for crane operations, at the top of a structure to which you are lifting an object if estimating the force on the suspended object. Predictively you may be able to look at recorded data over a period measured at the top of tallest structures or boom/jibs heads at the jobsite or close to it.

If designing say a guying arrangement for a temporary structure (say a lifting system), you may be able to refer to building codes to get a basic wind speed for the location. This will probably be a maximum 3-second gust speed with a return period of maybe 10, 25, 50 or 100 years. To derive a design wind speed, that figure will possibly have to be modified using height, topography and statistical (for short duration) factors. There is a lot of help available free on line to assist you in this.

In practice, wind speed increases logarithmically with height according to a curve similar to the following.

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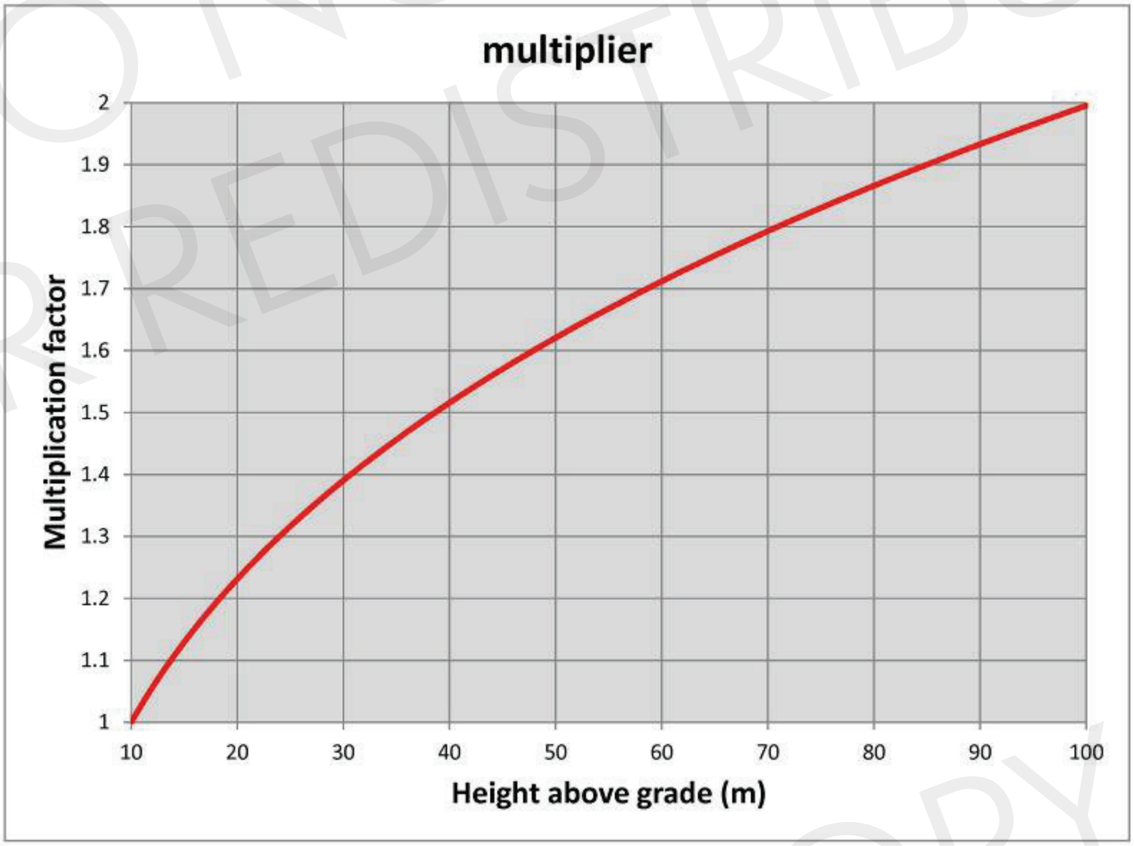

The actual shape of the curve depends on whether the air is stable, neutral or unstable, whether over water or land, whether the site is disturbed by human habitation and so on. In this instance, the wind speed at 100m (330') is twice that at 10m (33'). This results in a pressure four times higher at 100m that at 10m; you need to be aware of this!

14.1.3 Wind speed topography considerations

As alluded to above, topography can play a large part in modifying the basic wind speed up or down at a specific location. Be aware that on construction sites, nearby structures may be providing shielding from the wind giving you a false sense of security at ground level. Once a load is lifted above those structures and the shielding disappears, the wind speed may be a lot higher. Similarly, there may get funneling of the wind around cooling towers and the like, once you move a suspended load into those areas, the wind may suddenly "catch" it.

As noted, where possible, measure the wind speed at the actual location of interest.

14.1.4 Wind pressure

When a static object is subjected to a flowing stream of air, pressure is created acting on that object.

Pressure is given by the formulae (you pick your units of choice):

$P=0.00256Vs^2$ lbf/ft^2 or approximately **$Vs^2/400$ lbf/ft^2**, where Vs is in mph

or **$P=0.613Vs^2$ N/m^2** (or Pa); equivalent to **$P=0.0625Vs^2$ kg/m^2**, where Vs is in m/s

or **$P=0.0473Vs^2$ N/m^2** (or Pa); equivalent to **$P=0.00482Vs^2$ kg/m^2**, where Vs is in km/hr

NOTE: wind pressure is directly proportional to the square of the wind speed e.g. twice the wind speed, four times the pressure.

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About the Author

Keith Anderson is a native of Newcastle U.K., a Chartered Engineer and Fellow of the Institution of Mechanical Engineers. After graduating in 1975 with a BSc in Mechanical Engineering, he was engaged in designing high pressure vehicle braking systems. In 1979, he joined the world of heavy lifting at Kramo Montage, engineering and overseeing specialist lifting applications using hydraulic gripper type climbing jack systems.

Over the next 12 years, he rose to Chief Engineer and was responsible for many complex, heavy and innovative lifting operations and for the further expansion and development of the heavy lift systems used. In 1991, Keith was appointed Chief Engineer for Van Seumeren UK (now Mammoet UK), responsible for engineering and proposal preparation for heavy lift and specialist transport operations.

For 2 years from 1996, Keith managed Sarens heavy road haulage company in the UK, after which he rejoined Van Seumeren as Contracts Manager in Utrecht, Netherlands. In 2000, Keith joined Bechtel as Senior Rigging Engineer based in London, transitioning to the US in 2001 as Rigging Manager / Chief Rigging Engineer, the position he currently holds. Keith is a Bechtel Distinguished Engineer and an ASME P30 Lift Planning Standard Committee Member. He lives in Louisville Kentucky.

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