Production Process Panel

(Planning Production Process & Facilities Panel)

SHIPYARD RIGGING COMMON COMPONENT CATALOG

National Steel and Shipbuilding Company

Initial Design & Naval Architecture

Originally Issued: JULY 2009

Update May 2011 – Revision (A)

NASSCO ENGINEERING

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Authors Note

This document may at times repeats information that is in different sections and also with information the other accompanying documents. Such repetition is by design to present the reviewer of any particular section with relevant information. It is seen as preferable to repeat information rather than have that information overlooked.

This document has information for many of the rigging components commonly used in a shipyard and is intended to provide relevant information for the design of critical lifts using these components. It should be noted that no catalog can be complete and cover all information needed, all manufacturers, or any set circumstance, and thorough Engineering review should be undertaken whenever the well being of personnel or property is endangered.

Proper analysis of stresses within ships blocks during rigging lifting arrangements requires significant experience and detailed knowledge to approximate solutions. Although these documents provide a small foundation for the information needed for the design of critical lifts, it is no substitute for the application of sound Engineering judgment accompanied with analytical thought.

This document is part of a packet which includes:

LIFT CHECK SHEET

LIFT APPROACH GUIDANCE

RIGGING LIFT COMMON COMPONENT CATALOG

For the final analysis and design of any lift, ultimate responsibility and application of guidance referenced rests with the user.

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OVERVIEW

A qualified Rigging Engineer at a shipyard needs to know information about ship structure, yard practices, procedures, and capabilities in addition to having a solid grasp of Rigging Engineering fundamentals. The goal of this catalog is to give an Engineer a list of common parts, regulations and restrictions regarding these practices, general engineering data useful for using rigging components, and descriptions as to how these parts are used and interface with each other. This is intended to complement the Lift Check Sheet and the Lift Approach Guidance document with additional manufacturer and item specific information. The following items are included:

PADEYES
SHACKLES, MASTER-LINK RINGS
SLINGS (wire rope, synthetic, & chain)
CHAIN-FALLS, AIR HOISTS
FLOUNDER PLATES AND EQUALIZERS
SPREADER BEAMS
HOOKS
CRANES

Ideally every shipyard should have a catalog of its own equipment integrated into an extensive library of acceptable arrangements and loads. This will reduce the time spent on the non-value added work of figuring out lift arrangements, and what are acceptable limits for individual components in such an arrangement. This is beneficial for training new employees, or used as a collaborating reference for seasoned ones, all of which will allow the work load to be better distributed during times of high demand. These catalogs of relevant information should be geared towards increasing the learning curve and improving the efficiency of employees.

A catalog of common shipyards components that are used for lifts can quickly become quite extensive as significant amounts of information can be generated and accumulated. It is important to keep a specific focus on items added to this catalog with a regard to what is relevant information. It is suggested that the item specific information in a catalog of critical components includes the following:

- ❑ Manufacturers of such components should be cataloged such that one can always contact the source directly if a question prompts the need for more detailed or current information. Also, comparisons can quickly be made with similar parts that may provide a better solution for a particular arrangement.

- ❑ Size and dimensions of components should be available for parts used such that critical dimensions can be checked against mating surfaces and overall sizes may give indications of possible interferences.

- ❑ Capacity of lift components should be available so the proper one can be selected without significant probability of failure.

- ❑ Properties of components are important for they may degrade under certain conditions or have limitations based on environmental, fatigue, wear, or other operations factors.

- ❑ End connections of items should be documented so it is known what items can be linked to other and where limitations exist.

- ❑ Regulations and standards that affect the use of an item should be that when checking physical limitations, regulatory requirements can be reviewed.

1. PADEYE

Design Philosophy

A Padeye, is type of pin connection used for connecting structure to a shackle. Typically, on a ships block under construction, they will be welded to the hull over or onto a structurally significant part of the block. This is usually a sturdy frame or bulkhead. As the type, strength, and orientation of the structure and lift can vary substantially, many different shapes and geometries of padeyes have been created.

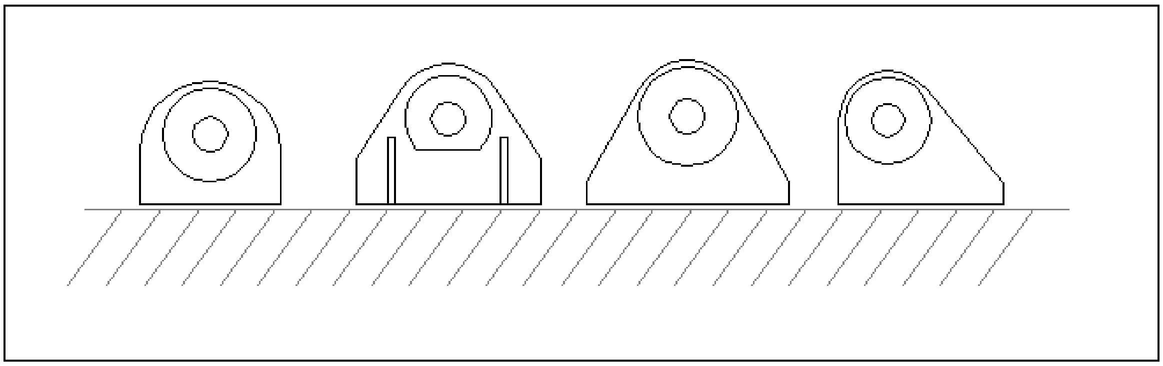


Figure 1: Examples of Padeyes

Padeyes are typically shipyard specific as many shipyards have there own designs that have been designed and built in house. This familiarity helps guide the rigging engineering design process as the potential limits are better understood. There are, however, consultant engineering firms that can design and engineer padeye.

A typical padeye will have circular boss plates on both sides surrounding the shackle pin hole. These plates perform several critical functions. Many documented steel single plate padeye failures are due to shear in this highly stressed region, and there are well documented standards and guidelines for stresses due to bearing forces, tensile forces near the shackle hole, splitting and fracture of the surface beyond the hole, and shearing or tearing near the edges of the hole. These well documented modes of failure result in well defined requirements and a similarity among most padeyes surrounding the pin connection hole. The exception being aluminum padeyes that may or may not have brass or bronze inserts pressed inside of the shackle hole to provide a harder bearing surface.

There is significant variance in the lower half of many padeye that reflects individual designer choices as well as load requirements based on particular design criteria. Some padeyes are designed with ample space beneath the shackle hole such that the padeye can be trimmed off and reused multiple times. Also, some padeyes have chocks or gusset plates to help stabilize the weak axis of the padeye if out of plane loads are anticipated. The types of structures the padeye will be welded will also influence the geometry of the padeye. If the structure is relatively thin in comparison to the padeyes thickness, the padeye may need to be lengthened to spread the load over a greater length of the thin block structure. Also, whether the padeye is just used with only vertical loads, or if the padeye is intended for turning operations with horizontal loads, will greatly affect the shape at the attachment to the structure.

Turning operations may require a padeye to be loaded through 180 degrees during a single lift. This often requires a padeye to have its shackle hole extended over the end of the structure that it is attached. Two approaches to this problem are to lap the padeye onto the structure, and to cantilever the padeye out over the edge. From the designs reviewed there seems to be no clear consensus as to the best way to do this or what the best geometry might be.

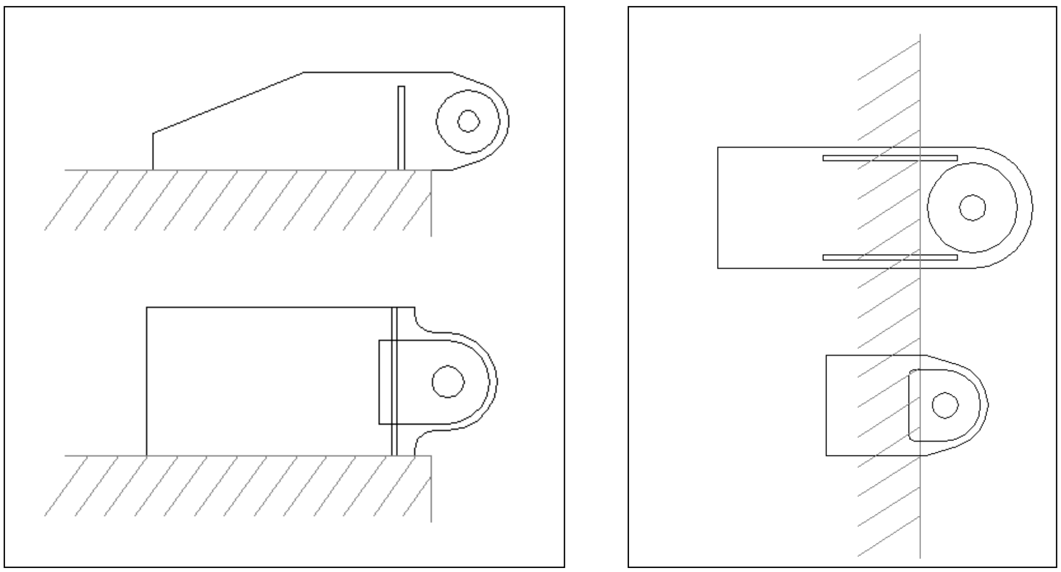


Figure 2: Blade and Lap-On Padeyes Used For Turning

One approach to lifting and turning operations is with the use of trunions. Typically these are cylindrical posts sticking proud that a sling or line can be wrapped around. This arrangement can allow loads to be applied in any direction in the radial plane. Often two trunions are used on either side of the center of gravity to facilitate easy rotation of an object. They have limited use in large block shipbuilding lifting as multiple lifting points are usually required, and in order to structurally integrate trunion into most structure they must be effectively buried making removal difficult.

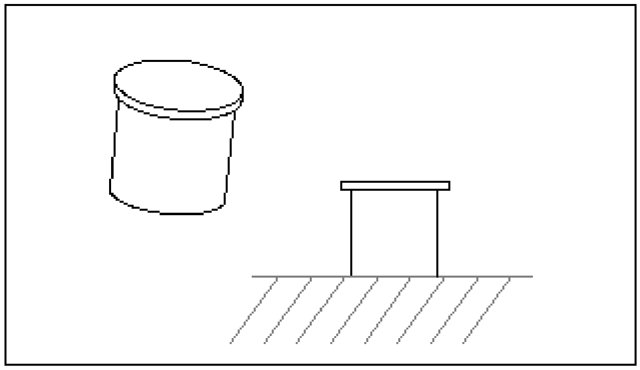


Figure 3: Trunion

Standards and Regulations

There are no published standards specifically applicable to padeyes used for ship construction. NAVSEA however has a guidance drawing, (No. 5184133) pertaining to permanently installed padeye for machinery lifting. The best document to govern lifting padeye design would be the American Society of Mechanical Engineers Design of Below the Hook Lifting Devices. (ASME BTH-1-2005) This design standard gives very detailed advice as to the design of single plate pin connections which is the heart of many padeyes. The structural design section of this document also gives clear advice as to how to apply recommended design factors to either calculated Von Mises stresses or classically calculated shear or moment forces on different sections. Many of the formula prescribed are based on AISC allowable stress design formula with slight modification resulting in increased design factors. These have been added to allow for the increased failure consequences rigging items face.

2. SHACKLES, MASTER LINK RINGS

The most common types of rigging hardware are shackles and rings which allow different components to be attached together. As key links in any rigging arrangement, it is important to understand how they should be loaded and what their limitations are. Different manufactures have slightly different recommendations, so specific requirements for a given shackle should be confirmed with the manufacturer.

Manufacturers

The main shackle provider for rigging equipment for large lifts is Crosby. Skookum is another major US shackle provider. NASSCO primarily uses these manufacturers as a source for shackles. Other manufactures of shackle certainly do exist and can provide shackle functionally similar to them. These manufactures include: Chicago Hardware and Fixture, Van Beest, Yoke, Suncore, Sea-Fit, LGH-Lifting Gear Hire, BLB Superstorre, Bishop Lifting products, Taylor Chain, KWS Thiele, and Hale Iron.

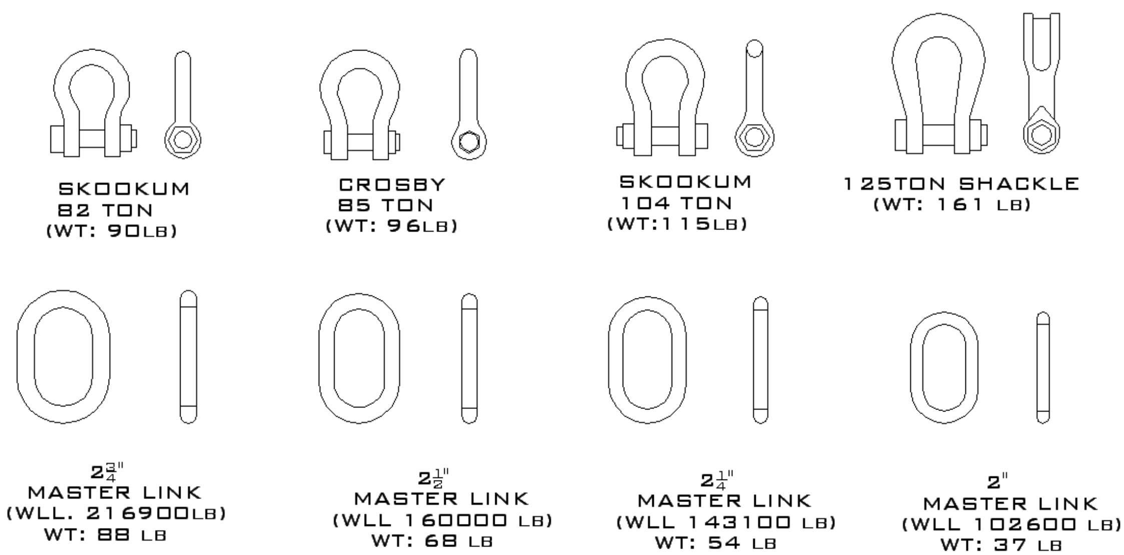


Figure 4: Selection of Typical Shackles and Rings

Loading Restrictions and Recommendations

The most ideal way to load the pins of shackles is with a uniform section that is 80% as wide as the opening of the shackle. This loading method will reduce the bending moment on the pin.

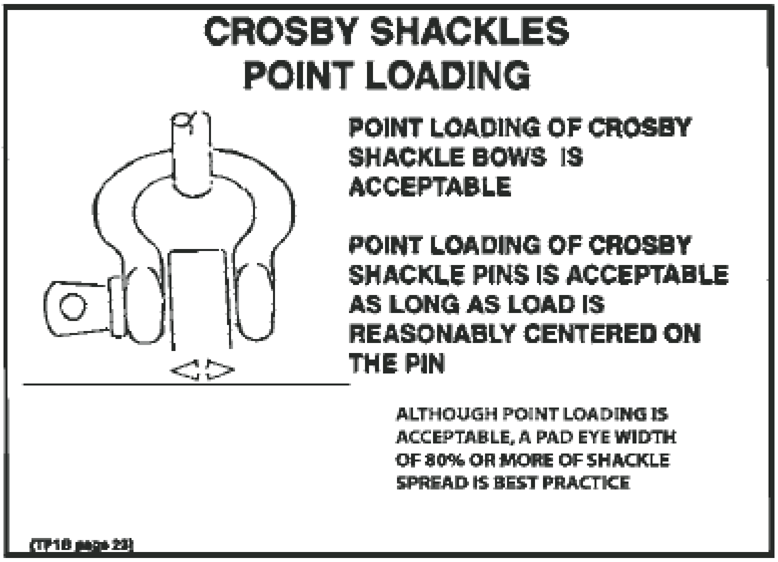
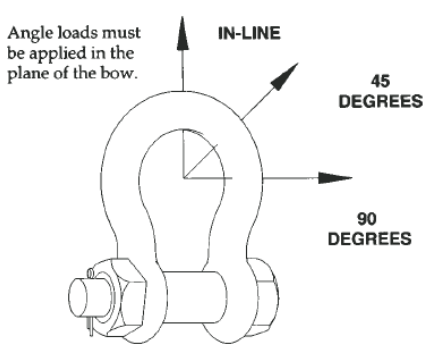


Figure 5: Recommended Distributed Loading of Shackle Pins

Figure reprinted with permission from the

CROSBY GROUP

Shackles will have their greatest strength when loaded in-line such that the load will be evenly divided on both halves with minimal bending when transferred back to the pin connection. When multiple lines are connected to the same shackle there will inevitably be some angle between the loads and thus they will not be in-line with the ideal loading condition. If the angle the loads are applied to the shackle is taken to an extreme, with the angle between them being almost 180 degrees and the lines themselves being at almost 90 degrees from in-line, it can easily be seen how this load orientation could reduce the strength of the shackle. With this extreme loading condition significant bending forces will be placed in the shackle and the pin will be under tension. Crobsy has recommendations to derate the shackle under these conditions as shown in Table 1. It should also be noted that it is never acceptable to put these extreme loading condition on a shackle with the pin held in place with a cotter pin as this configuration will not handle tension.



Side Loading Reduction Chart For Screw Pin and Bolt Type Shackles Only †	
Angle of Side Load from Vertical In-Line of shackle	Adjusted Working Load Limit
0° In-Line *	100% of Rated Working Load Limit
45° from In-Line *	70% of Rated Working Load Limit
90° from In-Line *	50% of Rated Working Load Limit

* In-Line load is applied perpendicular to pin.
† DO NOT SIDE LOAD ROUND PIN SHACKLES

Table 1: Side Loading Load Reduction

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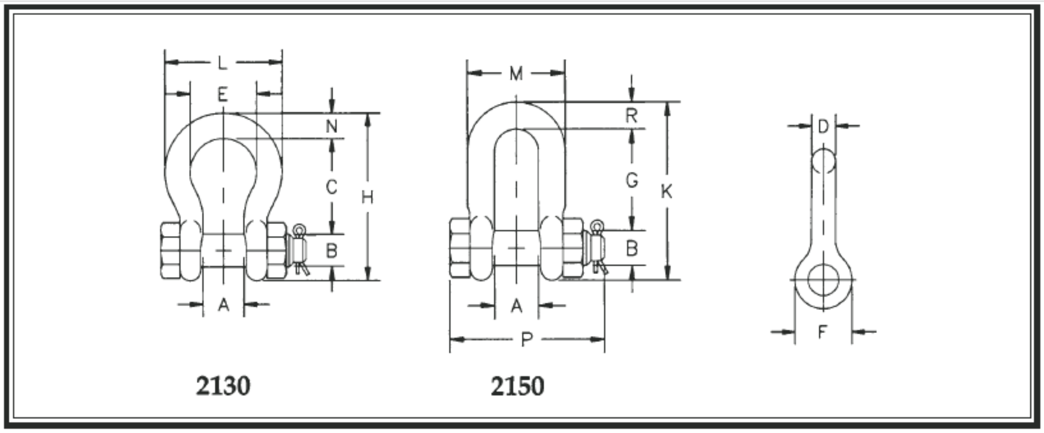
CROSBY GROUP

Typical sizes and strengths of Crosby G-shackles and Chain shackles can be seen in Table 2



Nominal Size (in.)	Working Load Limit * t	Weight Each (lbs.)		Dimensions (in.)														Tolerance + / -	
		G-2130 S-2130	G-2150 S-2150	A	B	C	D	E	F	G	H	K	L	M	N	P	R	C&G	A
3/16	1/3	.06	—	.38	.25	.88	.19	.60	.56	—	1.47	—	.98	—	.19	—	—	.06	.06
1/4	1/2	.11	.13	.47	.31	1.13	.25	.78	.61	.75	1.84	1.59	1.28	.97	.25	1.56	.25	.06	.06
5/16	3/4	.22	.23	.53	.38	1.22	.31	.84	.75	1.00	2.09	1.91	1.47	1.16	.31	1.82	.31	.06	.06
3/8	1	.33	.33	.66	.44	1.44	.38	1.03	.91	1.22	2.49	2.30	1.78	1.41	.38	2.17	.38	.13	.06
7/16	1 1/2	.49	.49	.75	.50	1.69	.44	1.16	1.06	1.42	2.91	2.66	2.03	1.62	.44	2.51	.44	.13	.06
1/2	2	.79	.75	.81	.63	1.88	.50	1.31	1.19	1.63	3.28	3.03	2.31	1.81	.50	2.80	.50	.13	.06
5/8	3 1/4	1.68	1.47	1.06	.75	2.38	.63	1.69	1.50	2.00	4.19	3.75	2.94	2.31	.69	3.53	.63	.13	.06
3/4	4 3/4	2.72	2.52	1.25	.88	2.81	.75	2.00	1.81	2.38	4.97	4.53	3.50	2.75	.81	4.07	.81	.25	.06
7/8	6 1/2	3.95	3.85	1.44	1.00	3.31	.88	2.28	2.09	2.81	5.83	5.33	4.03	3.19	.97	4.71	.97	.25	.06
1	8 1/2	5.66	5.55	1.69	1.13	3.75	1.00	2.69	2.38	3.19	6.56	5.94	4.69	3.69	1.06	5.31	1.00	.25	.06
1 1/8	9 1/2	8.27	7.60	1.81	1.25	4.25	1.13	2.91	2.69	3.58	7.47	6.78	5.16	4.06	1.25	5.90	1.25	.25	.06
1 1/4	12	11.71	10.81	2.03	1.38	4.69	1.25	3.25	3.00	3.94	8.25	7.50	5.75	4.53	1.38	6.51	1.38	.25	.06
1 3/8	13 1/2	15.83	13.75	2.25	1.50	5.25	1.38	3.63	3.31	4.38	9.16	8.28	6.38	5.00	1.50	7.21	1.50	.25	.13
1 1/2	17	20.80	18.50	2.38	1.63	5.75	1.50	3.88	3.63	4.81	10.00	9.06	6.88	5.38	1.62	7.73	1.62	.25	.13
1 3/4	25	33.91	31.40	2.88	2.00	7.00	1.75	5.00	4.19	5.75	12.34	10.97	8.86	6.38	2.25	9.05	2.12	.25	.13
2	35	52.25	46.75	3.25	2.25	7.75	2.00	5.75	4.81	6.75	13.68	12.28	9.97	7.25	2.40	10.41	2.00	.25	.13
2 1/2	55	98.25	85.00	4.13	2.75	10.50	2.62	7.25	5.69	8.00	17.84	14.84	12.87	9.38	3.13	13.56	2.62	.25	.25
3	† 85	154.00	124.25	5.00	3.25	13.00	3.00	7.88	6.50	8.50	21.50	16.88	14.36	11.00	3.62	16.50	3.50	.25	.25
3 1/2	†120 ‡	265.00	—	5.25	3.75	14.63	3.62	9.00	8.00	—	24.63	—	16.50	—	4.12	19.00	—	.25	.25
4	†150 ‡	338.00	—	5.50	4.25	14.50	4.10	10.00	9.00	—	25.69	—	18.42	—	4.56	19.75	—	.25	.25

* NOTE: Maximum Proof Load is 2.0 times the Working Load Limit. Minimum Ultimate Strength is 6 times the Working Load Limit. For Working Load Limit reduction due to side loading applications, see page 20.
† Individually Proof Tested with certification.
‡ Furnished in Anchor style only. Furnished with Round Head Bolts with welded handles.

Table 2: Typical Crosby Shackles
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CROSBY GROUP

The Oregon Department of Occupational Safety and Health Division has created a table that matches wire rope sling size to required shackle size which can be found in their rigging and rigging processes handbook part 437-007-0635. This table roughly matches wire rope allowable load based on a factor of safety to minimum breaking strength of 5 and shackle working load and can be referenced in Table 3: Recommended Shackle Size for Wire Rope Sizes (OROSHA).

This table provides useful information given certain assumptions that may not always be listed or easily identifiable. This particular table should be used with caution as wire ropes and shackles can vary in strength depending on the specific manufacture and construction. Furthermore this table makes no allowance for termination type of the wire rope which will reduce its strength unless a socket connection is used. This is a good example that one should exhibit caution when referencing tables and always apply good Engineering judgment over all references and components in a given rigging arrangement.

G	SHACKLES / METAL SPAR GUYLINE SAFETY STRAPS	Oregon Administrative Rules Oregon Occupational Safety and Health Division

(22) The minimum size of shackles required for joining or attaching lines are shown in Table 7-5.

Table 7-5
Bell Shaped and Sleeve Shackles Used to Join or Attach Lines

Wire Rope Size In Inches	Shackle Size In Inches	Wire Rope Size In Inches	Shackle Size In Inches
1/2	5/8	1	1 1/4
9/16	3/4	1 1/8	1 3/8
5/8	7/8	1 1/4	1 1/2
3/4	1	1 3/8	1 5/8
7/8	1 1/8	1 1/2	2

(23) The minimum size of flush pin straight-sided shackles for joining or attaching skyline extensions are shown in Table 7-6.

Table 7-6
Flush Pin Straight-Sided Shackles Used for Attaching Skyline Extensions

Wire Rope Size In Inches	Shackle Size In Inches	Wire Rope Size In Inches	Shackle Size In Inches
1/2	5/8	1	1 1/8
9/16	3/4	1 1/8	1 1/4
5/8	3/4	1 1/4	1 3/8
3/4	7/8	1 3/8	1 1/2
7/8	1	1 1/2	1 5/8

Table 3: Recommended Shackle Size for Wire Rope Sizes (OROSHA)

Standards and Regulations

There are well defined requirements and safe working loads for common rigging items such as shackles and rings, that can be found in OSHA federal standards under safety and health regulations for general construction Part 1926. These requirements are followed by US manufacturers and it is common rigging practice to use ratings developed by US manufacturers. The OSHA Part 1915 specifically pertaining to shipyards has significantly less information on rigging hardware and their requirements, but most shackles for rigging will exceed or conform to Part 1926 and the requirements there in.

The code of federal regulations title 29 part 1926.251 deals with rigging equipment for material handling and subpart (f) deals specifically with shackles. It states as follows:

> (1) Table H–19 shall be used to determine the safe working loads of various sizes of shackles, except that higher safe working loads are permissible when recommended by the manufacturer for specific, identifiable products, provided that a safety factor of not less than 5 is maintained.

TABLE H–19—SAFE WORKING LOADS FOR SHACKLES

[In tons of 2,000 pounds]

Material size (inches	Pin diameter (inches)	Safe working load
1/2	5/8	1.4
5/8	3/4	2.2
3/4	7/8	3.2
7/8	1	4.3
1	1 1/8	5.6
1 1/8	1 1/4	6.7
1 1/4	1 3/8	8.2
1 3/8	1 1/2	10.0
1 1/2	1 5/8	11.9
1 3/4	2	16.2
2	2 1/4	21.2

Table 4: Shackle Safe Working Loads (OSHA)

Modern manufacturers shackles will typically exceed these load ratings of Table 4: Shackle Safe Working Loads (OSHA) based on pin size as there have been much advancement in material technology since the table was formulated. The new materials in use still provide a safety factor of 5 as required by the OSHA standards but do so with reduced weight and size.

3. SLINGS

Slings are an important part of rigging as almost all lifts require a flexible temporary link to transmit the loads from the object being lifted to the lifting device or crane. Shipyards typically use slings made from chain, wire rope, or synthetic materials. Of these materials, wire rope and synthetic slings are the most common for the large lifts in shipyards, with high performance synthetics increasingly becoming the dominantly used material.

Chain slings are perhaps the original high capacity sling material as historically speaking they are much stronger than natural fiber rope. Although very resilient with the ability to work in extreme and punishing environments, chain slings are generally no longer used as they are the heaviest sling material available, imposing significant handling costs. Chain slings are however still used as part of chainfalls, which allow the sling to be varied in length while under load. This significant advantage can provide the small adjustments needed when erecting units requiring a high degree of control of angle and positional tolerance. Large chainfalls as are readily available with working loads of 100 tons, but these require considerable time to set up, and are generally avoided if possible. For small lifts and material handling in restrictive environments these devices still rein supreme, as the ability to maneuver loads through sling adjustments is crucial.

Wire rope has been the material of choice for almost two centuries and replaced chain in almost all rigging applications. This material was much stronger and more resilient than fiber rope, and cheaper and much lighter than chain slings. The development of wire rope stems from the discovery that drawing a wire creates very high tensile strength as this process purifies the steel. A wire rope consists of bundles of strands, each consisting of several drawn wires, which are all wrapped around themselves, and therefore transfing load to each other though friction. Wire rope remains very popular with riggers since the load bearing components are not only tough, but visible, allowing quick visual inspections for indications of wear or damage on all external surfaces. This toughness along with ease of inspection generates the confidence required for lifting and handling gear.

Synthetic slings are gaining dominance for high capacity lifts because wire rope and especially chain slings often are heavy or bulky and there are many benefits of keeping the rigging hardware as light and small as possible. One significant desire for lighter rigging equipment is safety, as manipulating dense and heavy slings and hardware requires significant effort, may be done in awkward or overhead positions, all of which results in a greater risk of injury to rigging personnel. Furthermore, with the desire to minimize equipment handling costs through a reduction of the rigging efforts required, significant savings can be realized through the use of these lighter high performance slings. A typical high performance Twin-Path Extra sling will have only 10-15% of the weight of a comparable wire rope, which can be directly correlated to the handling efficiencies that can be gained. Although there are many reasons for the adoption of high performance slings the relative lack of detailed standards, use guidance, and historical anecdotes, can create apprehension to their adoption, along with their delicate nature, and the concealment of the main strength members.

Wire Rope

Modern wire rope is perhaps the most widely used rigging sling material and has been in use for over one hundred and seventy years. This long history of use has allowed an evolution of improvements and significant knowledge being accumulated with regards to its properties and performance. This long working history gives it reliability unmatched by other materials and makes it ideal for reducing risk for critical lifts. The one main drawback is its size and weight which can make it time consuming to install and fraction of full strength when subject to bending.

Manufacturers

There are many manufactures of wire rope for use as rigging slings such as Bridon, Crosby, Contental Cabel, Diepa, Landmann, Premier, Loosco, Peway, Python, Galin, Strand Core, Yarbrough and many others.

Strength and Selection

The strength of wire rope varies considerably as the wires themselves can be made of many different types of steel. Common wire types are Traction Steel (TS), Extra High Strength traction (EHS), Improved Plow Steel (IPS), Extra Improved Plow Steel (EIPS), and Extra Extra Improved Plow Steel (EEIPS). Wire rope intended for service in the marine environment may even be of stainless or monel. The core of a wire rope also affects its strength as it may be fiber or of steel wire. Furthermore the number and rotation of the wires themselves also affects the strength and general properties. This results in significant combinations of wire ropes to be obtained with countless desired properties. Unfortunately, this results in many things one needs to consider when selecting a specific wire rope. An abbreviated list of considerations one should be familiar with when selecting a wire rope includes:

- Classification
- Strength of individual strand
- Fiber core or internal wire rope core
- Lay of wire in rope
- Rotation resistance
- Fatigue resistance
- Bearing strength
- Design factor required
- Sheave or shackle diameter intended
- Compacted wire rope
- Plastic filled or coated
- Corrosion resistance

As significant data has been compiled about wire rope libraries of failed wire ropes have been photographed, compiled, and tables produced cataloging the resulting failure modes that one should be familiar with. Typical modes of failure for wire rope are well documented and include:

- Ropes of incorrect size, construction or grade
- Ropes allowed to drag over obstacles.
- Ropes operating over sheaves or drums of to small a diameter.
- Ropes overwinding or crosswinding on drums.
- Ropes operating on sheaves or drums that are out of alignment, or improver fitting grooves and broken flanges.
- Ropes permitted to jump sheaves.
- Ropes subject to moisture or acid fumes.
- Ropes permitted to untwist.
- Ropes subjected to excessive heat.
- Ropes kinked.
- Ropes allowed to accumulate grit producing internal wear.

Measured Length

As the length of slings can be critical to keeping a lift level or having each sling share the load equally it should be known how to measure them. When specifying the length of wire ropes they should be measured by the distance between the two pull locations, or the center of the pin to be pulled in the socket. An example of measure lengths are shown in Figure 6

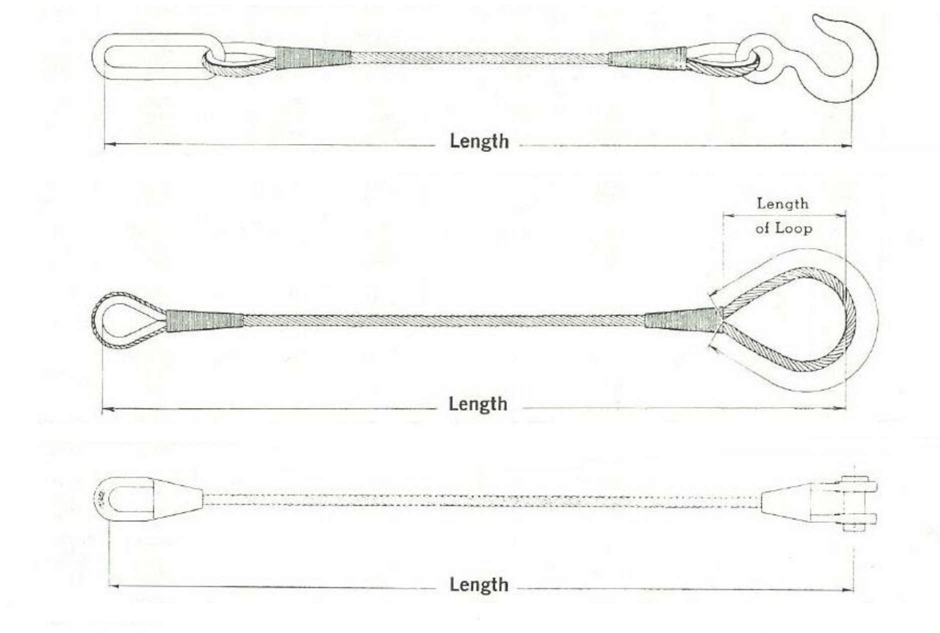

Figure 6: Wire Rope Length Measurements
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WIRE ROPE TECHNICAL BOARD

Strain and Modulus

The stretch of a wire rope is dependant on two factors. First there is the elastic stretch of the steel elements that elongate in proportion to the modulus of elasticity of the metal. An equally important component for wire rope is the structural stretch cause by the compression of the rope core and adjustments of the wires in the rope. This component can vary due to many factors such as the type of core, the length of the lays, the amount of bending the rope is subjected or has seen, vibration, and the complete load history of that particular wire rope. Older wire ropes that have seen heavy duty cycles will see less elongation than new ropes during loading. The structural stretch of the wire rope will also cause the wire rope to twist as it unlays. For very long lengths of wire rope a swivel block can be considered if it is critical that no torsion be transmitted to the attachments, however, for most critical lifts this is not a concern. One must be careful when adding a swivel because some wire ropes cannot be allowed to twist as they are loaded.

Due to the factors mentioned above the modulus of elasticity of a wire rope will vary considerably during its life generally increasing throughout. The greatest portion of the structural stretch occurs during the initial period of its life. Below is a table of commonly used approximate values for modulus of elasticity for various constructions. It can be seen that an Internal Wire Rope Core (IWRC) increases the stiffness of the rope. The values shown below are for wire ropes that are broken in and constructional stretch removed.

Rope Classification	Zero through 20% Loading	21% to 65% Loading
6 x 7 with fiber core	11,700,000	13,000,000
6 x 19 with fiber core	10,800,000	12,000,000
6 x 36 with fiber core	9,900,000	11,000,000
8 x 19 with fiber core	8,100,000	9,000,000
6 x 19 with IWRC	13,500,000	15,000,000
6 x 36 with IWRC	12,600,000	14,000,000
8 x 19 with IWRC	12,000,000	13,500,000
8 x 36 with IWRC	11,500,000	13,000,000

*Applicable to new rope with constructional stretch removed.

Table 5: Approximate Modulus of Elasticity for Wire Rope in psi
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End Connections

There is a large variation in the types of end connection possible with wire rope. The two main types are splices and sockets. Splices are typically used with a thimble and are not as strong as sockets because of the bend radius that the line is subjected. They will also be subject to a shortened life due to fatigue. Wire rope sockets contain the end of the wire typically with a poured zinc or resin plug. Other plug material can be used however they vary with strength and validation of their strength should be confirmed.

Typically for critical lifts sockets are used that allow the rope to provide its full strength. Closed spelter sockets which are ideal for connecting to the round of a G-shackle and can be obtained with safe working loads of hundreds of tons.

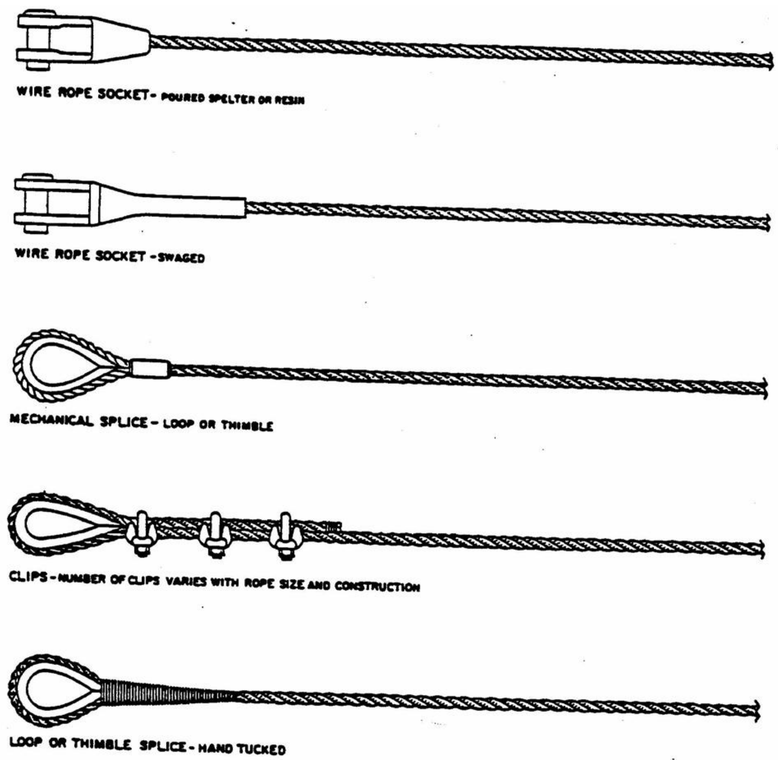

Figure 7: Types of Wire Rope Ends
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Type of Termination	Efficiency Rope with IWRC*	 Rope with FC**
Wire Rope Socket (Spelter or Resin)	100%	100%
Swaged Socket (Regular Lay Ropes Only)	100%	(Not Recommended)
Mechanical Spliced Sleeve (Flemish Eye)		
1" dia. and smaller	95%	92-1/2%
Greater than 1" dia. through 2"	92-1/2%	90%
Greater than 2" dia. through 3-1/2"	90%	(Not established)
Loop or Thimble Splice-Hand Spliced (Tucked) (Carbon Steel Rope)		
1/4"	90%	90%
5/16"	89%	89%
3/8"	88%	88%
7/16"	87%	87%
1/2"	86%	86%
5/8"	84%	84%
3/4"	82%	82%
7/8" thru 2-1/2"	80%	80%
Loop or Thimble Splice-Hand Spliced (Tucked) (Stainless Steel Rope)		
1/4"	80%	
5/16"	79%	
3/8"	78%	
7/16"	77%	
1/2"	76%	
5/8"	74%	
3/4"	72%	
7/8"	70%	
Wedge Sockets*** (Depending on Design)	75% to 80%	75% to 80%
Clips*** (Number of clips varies with size of rope)	80%	80%

*IWRC=Independent Wire Rope Core **FC=Fiber Core
*** Typical values when terminations are correctly designed, applied and maintained. Refer to fittings manufacturers for exact values and method.

Table 6: Terminal Efficiencies (Approximate)
Efficiencies are applicable to the rope's minimum breaking force
WIRE ROPE TECHNICAL BOARD

Bend Radius

Wire rope is often wrapped under a load and at the corners subject to being wrapped at a given bend radius. The size of this bend radius is critical with regards to the strength of the rope. The reduction of strength associated with these bending restrictions has been tabulated and can be referenced below. A small bend radius will also reduce the life of a wire rope as fatigue onset will be more prone to occur.

Wire ropes are typically bent over the sheaves in the winch and crane, through shackles, or wrapped under items being lifted. Sometimes wire rope is bent about itself as is done during a choker lift in which the sling is terminated to itself. When a wire rope is wrapped all the way around itself as shown in Figure 1 the D/d ration is one. Figure 8 shows that at this ratio the capacity of the wire rope is approximately half its straight pull value. Different angles of choker hitches produce different bend radiuses and have different reductions of efficiency which can be referenced in Figure 9, which is in addition to the standard reduction amount for chocker lifts.

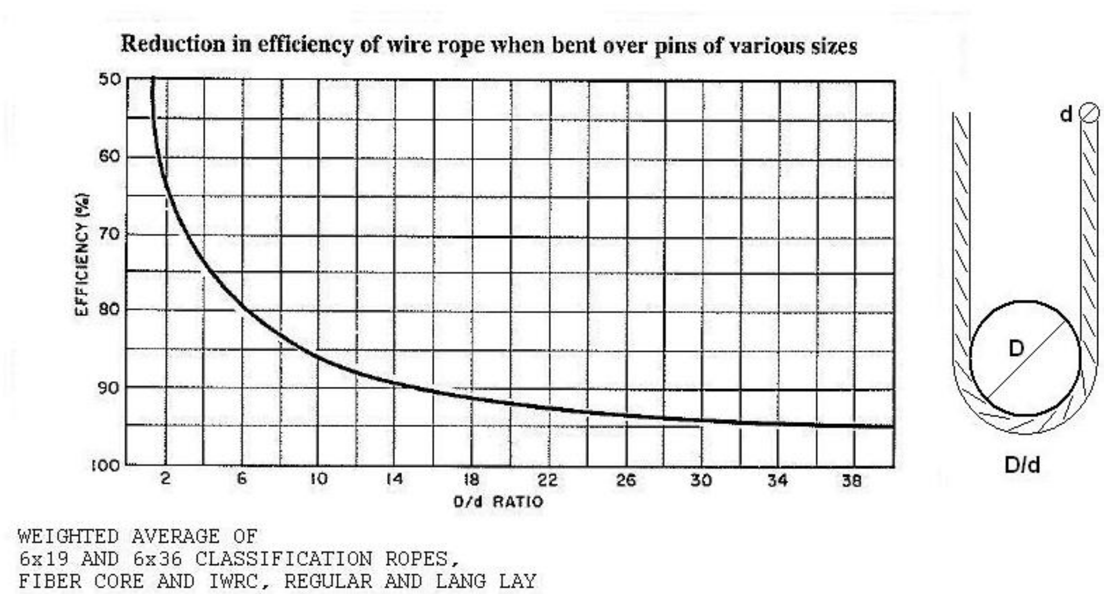

Figure 8: Wire Rope Efficiencies for Various D/d Ratios
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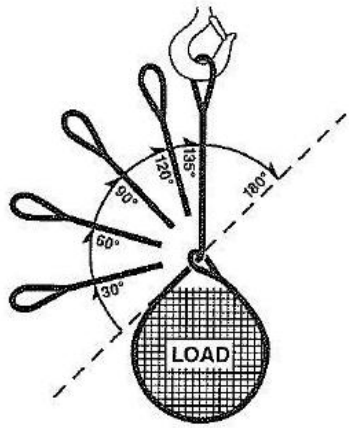

Choker Hitch Capacity Adjustment	
Angle of Choke (degrees)	Rated Capacity (Percent)
120 to 135	100
90 to 120	87
60 to 89	74
30 to 59	62
1 to 29	49

Figure 9: Choker Hitch Efficiency

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The termination efficiency of an eye at the end of a wire rope can be compromised if the diameter of the attachment piece is either to large or too small. If the pin passing through the eye is too large the eye will be subject to splitting where the two sides of the eye reconnect, and failure will occur. Conversely if the pin if too small the strength will also be reduced. A pin of equal diameter to the rope size will effectively create a D/d ratio of one reducing the efficiency of each part by 50%. The fatigue life of a wire rope is also greatly dependant on the bend radius that it is subjected. A wire rope subject to this type of loading with a D/d ratio approaching unity will have very minimal fatigue life somewhat depending on the type of rope. Ropes subjected to this severe loading condition should be thoroughly inspected after every use.

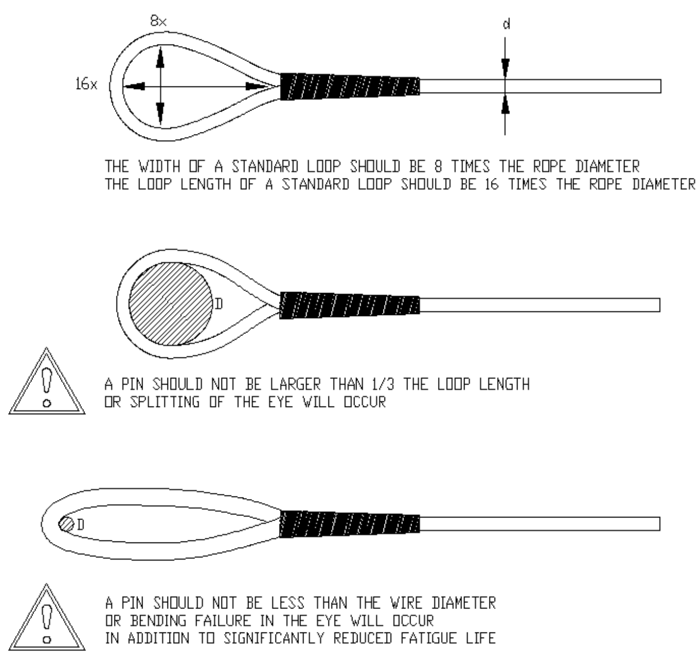


Figure 10: Relationship Between Pin Size and Wire Rope Loop

Standards and Regulations

The Code of Federal Regulations (CFR) sets criteria for different uses of wire rope. OSHA provides tables H-3 to H-14 in 29 CFR 1926.251 with ratings for wire rope capacity for a few selected different types and configurations. These are the same tables, or almost identical, to tables which can be found in ASME B30.9 standards for slings. Wire ropes may have working loads higher than those provided in the tables, provided the breaking strength is five times higher than the intended load. If one knows the straight pull or vertical rated capacity of the cable, the bend radius that it may be subjected to, as well as the efficiency of the termination, basic trigonometry can be used to find the exact rated strength for any angle. Figure 11 below shows the configurations of the five different arrangements which are used in the OSHA tables.

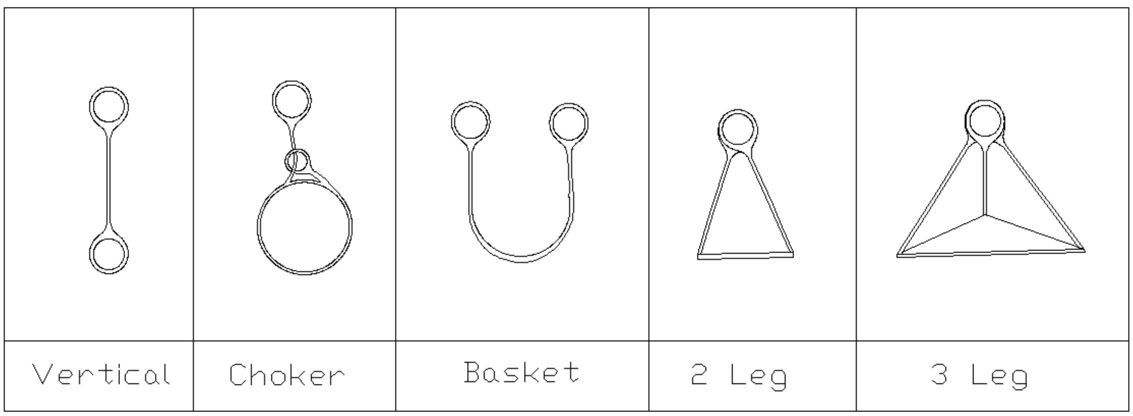


Figure 11: Statically Determinant Lift Arrangements Covered by OSHA Regulations

The rated capacities given by OSHA are of limited use by shipyards rigging personnel designing critical lifts since most of the lifting arrangements used do not confirm to the basic configurations shown in Figure 11. Furthermore it should be understood that many manufactures have wire ropes that exceed the strength characteristics that are assumed from these tables based on the five times breaking strength requirement.

OSHA Table H-3 and Table H-4 gives capacity ratings in short tons for two classification types of steel rope one with fiber core and the other one with independent wire rope core. Three different arrangements are calculated: vertical leg, looped as a basket, and choker. The tables give the capacities based on minimum bend radius requirements, specific termination types and their rated efficiencies.

TABLE H–3—RATED CAPACITIES FOR SINGLE LEG SLINGS

6×19 and 6×37 Classification Improved Plow Steel Grade Rope with Fiber Core (FC)

Rope		Rated capacities, tons (2,000 lb.)								
Dia. (inches)	Constr.	Vertical			Choker			Vertical basket [1]		
		HT	MS	S	HT	MS	S	HT	MS	S
1/4	6×19	0.49	0.51	0.55	0.37	0.38	0.41	0.99	1.0	1.1
5/16	6×19	0.76	0.79	0.85	0.57	0.59	0.64	1.5	1.6	1.7
3/8	6×19	1.1	1.1	1.2	0.80	0.85	0.91	2.1	2.2	2.4
7/16	6×19	1.4	1.5	1.6	1.1	1.1	1.2	2.9	3.0	3.3
1/2	6×19	1.8	2.0	2.1	1.4	1.5	1.6	3.7	3.9	4.3
9/16	6×19	2.3	2.5	2.7	1.7	1.9	2.0	4.6	5.0	5.4
5/8	6×19	2.8	3.1	3.3	2.1	2.3	2.5	5.6	6.2	6.7
3/4	6×19	3.9	4.4	4.8	2.9	3.3	3.6	7.8	8.8	9.5
7/8	6×19	5.1	5.9	6.4	3.9	4.5	4.8	10.0	12.0	13.0
1	6×19	6.7	7.7	8.4	5.0	5.8	6.3	13.0	15.0	17.0
1 1/8	6×19	8.4	9.5	10.0	6.3	7.1	7.9	17.0	19.0	21.0
1 1/4	6×37	9.8	11.0	12.0	7.4	8.3	9.2	20.0	22.0	25.0
1 3/8	6×37	12.0	13.0	15.0	8.9	10.0	11.0	24.0	27.0	30.0
1 1/2	6×37	14.0	16.0	17.0	10.0	12.0	13.0	28.0	32.0	35.0
1 5/8	6×37	16.0	18.0	21.0	12.0	14.0	15.0	33.0	37.0	41.0
1 3/4	6×37	19.0	21.0	24.0	14.0	16.0	18.0	38.0	43.0	48.0
2	6×37	25.0	28.0	31.0	18.0	21.0	23.0	49.0	55.0	62.0

[1] These values only apply when the D/d ratio for HT slings is 10 or greater, and for MS and S Slings is 20 or greater where:
D=Diameter of curvature around which the body of the sling is bent. d=Diameter of rope.
HT=Hand Tucked Splice and Hidden Tuck Splice. For hidden tuck splice (IWRC) use values in HT columns.
MS=Mechanical Splice.
S=Swaged or Zinc Poured Socket.

TABLE H–4—RATED CAPACITIES FOR SINGLE LEG SLINGS

6×19 AND 6×37 CLASSIFICATION IMPROVED PLOW STEEL GRADE ROPE WITH INDEPENDENT WIRE ROPE CORE (IWRC)

Rope		Rated capacities, tons (2,000 lb.)								
Dia. (inches)	Constr.	Vertical			Choker			Vertical basket [1]		
		HT	MS	S	HT	MS	S	HT	MS	S
1/4	6×19	0.53	0.56	0.59	0.40	0.42	0.44	1.0	1.1	1.2
5/16	6×19	0.81	0.87	0.92	0.61	0.65	0.69	1.6	1.7	1.8
3/8	6×19	1.1	1.2	1.3	0.86	0.93	0.98	2.3	2.5	2.6
7/16	6×19	1.5	1.7	1.8	1.2	1.3	1.3	3.1	3.4	3.5
1/2	6×19	2.0	2.2	2.3	1.5	1.6	1.7	3.9	4.4	4.6
9/16	6×19	2.5	2.7	2.9	1.8	2.1	2.2	4.9	5.5	5.8
5/8	6×19	3.0	3.4	3.6	2.2	2.5	2.7	6.0	6.8	7.2
3/4	6×19	4.2	4.9	5.1	3.1	3.6	3.8	8.4	9.7	10.0
7/8	6×19	5.5	6.6	6.9	4.1	4.9	5.2	11.0	13.0	14.0
1	6×19	7.2	8.5	9.0	5.4	6.4	6.7	14.0	17.0	18.0
1 1/8	6×19	9.0	10.0	11.0	6.8	7.8	8.5	18.0	21.0	23.0
1 1/4	6×37	10.0	12.0	13.0	7.9	9.2	9.9	21.0	24.0	26.0
1 3/8	6×37	13.0	15.0	16.0	9.6	11.0	12.0	25.0	29.0	32.0
1 1/2	6×37	15.0	17.0	19.0	11.0	13.0	14.0	30.0	35.0	38.0
1 5/8	6×37	18.0	20.0	22.0	13.0	15.0	17.0	35.0	41.0	44.0
1 3/4	6×37	20.0	24.0	26.0	15.0	18.0	19.0	41.0	47.0	51.0
2	6×37	26.0	30.0	33.0	20.0	23.0	25.0	53.0	61.0	66.0

[1] These values only apply when the D/d ratio for HT slings is 10 or greater, and for MS and S Slings is 20 or greater where:
D=Diameter of curvature around which the body of the sling is bent. d=Diameter of rope.
HT=Hand Tucked Splice: For hidden tuck splice (IWRC) use Table H–3 values in HT column.
MS=Mechanical Splice.

Table 7: OSHA 1926.251 Tables H-3 to H-4

OSHA Table H-5 and Table H-6 give the give the capacity ratings for single leg sling for construction galvanized aircraft grade rope and IWRC construction improved plow steel grade rope. Three different arrangements are calculated: vertical leg, looped as a basket, and a choker. The tables give the capacities based on minimum bend radius requirements, and an assumed termination of a mechanical splice.

S=Swaged or Zinc Poured Socket.

TABLE H–5—RATED CAPACITIES FOR SINGLE LEG SLINGS

Cable Laid Rope—Mechanical Splice Only

7×7×7 and 7×7×19 Construction Galvanized Aircraft Grade Rope

7×6×19 IWRC Construction Improved Plow Steel Grade Rope

Rope		Rated capacities, tons (2,000 lb.)		
Dia. (inches)	Constr.	Vertical	Choker	Vertical basket[1]
1/4	7×7×7	0.50	0.38	1.0
3/8	7×7×7	1.1	0.81	2.2
1/2	7×7×7	1.8	1.4	3.7
5/8	7×7×7	2.8	2.1	5.5
3/4	7×7×7	3.8	2.9	7.6
5/8	7×7×19	2.9	2.2	5.8
3/4	7×7×19	4.1	3.0	8.1
7/8	7×7×19	5.4	4.0	11.0
1	7×7×19	6.9	5.1	14.0
1 1/8	7×7×19	8.2	6.2	16.0
1 1/4	7×7×19	9.9	7.4	20.0
3/4	[2] 7×6×19	3.8	2.8	7.6

TABLE H–5—RATED CAPACITIES FOR SINGLE LEG SLINGS—Continued

Cable Laid Rope—Mechanical Splice Only

7×7×7 and 7×7×19 Construction Galvanized Aircraft Grade Rope

7×6×19 IWRC Construction Improved Plow Steel Grade Rope

Rope		Rated capacities, tons (2,000 lb.)		
Dia. (inches)	Constr.	Vertical	Choker	Vertical basket[1]
7/8	[2] 7×6×19	5.0	3.8	10.0
1	[2] 7×6×19	6.4	4.8	13.0
1 1/8	[2] 7×6×19	7.7	5.8	15.0
1 1/4	[2] 7×6×19	9.2	6.9	18.0
1 5/16	[2] 7×6×19	10.0	7.5	20.0
1 3/8	[2] 7×6×19	11.0	8.2	22.0
1 1/2	[2] 7×6×19	13.0	9.6	26.0

[1] These values only apply when the D/d ratio in 10 or greater where: D=Diameter of curvature around which the body of the sling is bent. d=Diameter of rope.

[2] IWRC.

TABLE H–6—RATED CAPACITIES FOR SINGLE LEG SLINGS

8-Part and 6-Part Braided Rope

6×7 and 6×19 Construction Improved Plow Steel Grade Rope

7×7 Construction Galvanized Aircraft Grade Rope

Component ropes		Rated capacities, tons (2,000 lb.)					
Diameter (inches)	Constr.	Vertical		Choker		Basket vertical to 30°[1]	
		8-Part	6-Part	8-Part	6-Part	8-Part	6-Part
3/32	6×7	0.42	0.32	0.32	0.24	0.74	0.55
1/8	6×7	0.76	0.57	0.57	0.42	1.3	0.98
3/16	6×7	1.7	1.3	1.3	0.94	2.9	2.2
3/32	7×7	0.51	0.39	0.38	0.29	0.89	0.67
1/8	7×7	0.95	0.71	0.71	0.53	1.6	1.2
3/16	7×7	2.1	1.5	1.5	1.2	3.6	2.7
3/16	6×19	1.7	1.3	1.3	0.98	3.0	2.2
1/4	6×19	3.1	2.3	2.3	1.7	5.3	4.0
5/16	6×19	4.8	3.6	3.6	2.7	8.3	6.2
3/8	6×19	6.8	5.1	5.1	3.8	12.0	8.9
7/16	6×19	9.3	6.9	6.9	5.2	16.0	12.0
1/2	6×19	12.0	9.0	9.0	6.7	21.0	15.0
9/16	6×19	15.0	11.0	11.0	8.5	26.0	20.0
5/8	6×19	19.0	14.0	14.0	10.0	32.0	24.0
3/4	6×19	27.0	20.0	20.0	15.0	46.0	35.0
7/8	6×19	36.0	27.0	27.0	20.0	62.0	47.0
1	6×19	47.0	35.0	35.0	26.0	81.0	61.0

[1] These values only apply when the D/d ratio is 20 or greater where: D=Diameter of curvature around which the body of the sling is bent. d=Diameter of component rope.

Table 8: OSHA 1926.251 Tables H-5 and H-6

OSHA Table H-7 and Table H-8 gives the rated load capacities for 2 and 3 leg bridle slings arrangements for improved plow grade rope with fiber core or wire core based on the ropes classification. The tables give the capacities based on a termination of a mechanical splice or hand tucked splice.

TABLE H–7—RATED CAPACITIES FOR 2-LEG AND 3-LEG BRIDLE SLINGS—Continued

6×19 and 6×37 Classification Improved Plow Steel Grade Rope With Fiber Core (FC)

Rope		Rated capacities, tons (2,000 lb.)											
		2-leg bridle slings						3-leg bridle slings					
Dia. (inches)	Constr.	30° [1] (60°) [2]		45° angle		60° [1] (30°) [2]		30° [1] (60°) [2]		45° angle		60° [1] (30°) [2]	
		HT	MS	HT	MS	HT	MS	HT	MS	HT	MS	HT	MS
5/8	6×19	4.8	5.3	4.0	4.4	2.8	3.1	7.3	8.0	5.9	6.5	4.2	4.6
3/4	6×19	6.8	7.6	5.5	6.2	3.9	4.4	10.0	11.0	8.3	9.3	5.8	6.6
7/8	6×19	8.9	10.0	7.3	8.4	5.1	5.9	13.0	15.0	11.0	13.0	7.7	8.9
1	6×19	11.0	13.0	9.4	11.0	6.7	7.7	17.0	20.0	14.0	16.0	10.0	11.0
1 1/8	6×19	14.0	16.0	12.0	13.0	8.4	9.5	22.0	24.0	18.0	20.0	13.0	14.0
1 1/4	6×37	17.0	19.0	14.0	16.0	9.8	11.0	25.0	29.0	21.0	23.0	15.0	17.0
1 3/8	6×37	20.0	23.0	17.0	19.0	12.0	13.0	31.0	35.0	25.0	28.0	18.0	20.0
1 1/2	6×37	24.0	27.0	20.0	22.0	14.0	16.0	36.0	41.0	30.0	33.0	21.0	24.0
1 5/8	6×37	28.0	32.0	23.0	26.0	16.0	18.0	43.0	48.0	35.0	39.0	25.0	28.0
1 3/4	6×37	33.0	37.0	27.0	30.0	19.0	21.0	49.0	56.0	40.0	45.0	28.0	32.0
2	6×37	43.0	48.0	35.0	39.0	25.0	28.0	64.0	72.0	52.0	59.0	37.0	41.0

HT=Hand Tucked Splice.
MS=Mechanical Splice.
[1] Vertical angles.
[2] Horizontal angles.

TABLE H–8—RATED CAPACITIES FOR 2-LEG AND 3-LEG BRIDLE SLINGS

6×19 and 6×37 Classification Improved Plow Steel Grade Rope With Independent Wire Rope Core (IWRC)

Rope		Rated capacities, tons (2,000 lb.)											
		2-leg bridle slings						3-leg bridle slings					
Dia. (inches)	Constr.	30° [1] (60°) [2]		45° angle		60° [1] (30°) [2]		30° [1] (60°) [2]		45° angle		60° [1] (30°) [2]	
		HT	MS	HT	MS	HT	MS	HT	MS	HT	MS	HT	MS
1/4	6×19	0.92	0.97	0.75	0.79	0.53	0.56	1.4	1.4	1.1	1.2	0.79	0.84
5/16	6×19	1.4	1.5	1.1	1.2	1.81	0.87	2.1	2.3	1.7	1.8	1.2	1.3
3/8	6×19	2.0	2.1	1.6	1.8	1.1	1.2	3.0	3.2	2.4	2.6	1.7	1.9
7/16	6×19	2.7	2.9	2.2	2.4	1.5	1.7	4.0	4.4	3.3	3.6	2.3	2.5
1/2	6×19	3.4	3.8	2.8	3.1	2.0	2.2	5.1	5.7	4.2	4.6	3.0	3.3
9/16	6×19	4.3	4.8	3.5	3.9	2.5	2.7	6.4	7.1	5.2	5.8	3.7	4.1
5/8	6×19	5.2	5.9	4.2	4.8	3.0	3.4	7.8	8.8	6.4	7.2	4.5	5.1
3/4	6×19	7.3	8.4	5.9	6.9	4.2	4.9	11.0	13.0	8.9	10.0	6.3	7.3
7/8	6×19	9.6	11.0	7.8	9.3	5.5	6.6	14.0	17.0	12.0	14.0	8.3	9.9
1	6×19	12.0	15.0	10.0	12.0	7.2	8.5	19.0	22.0	15.0	18.0	11.0	13.0
1 1/8	6×19	16.0	18.0	13.0	15.0	9.0	10.0	23.0	27.0	19.0	22.0	13.0	16.0
1 1/4	6×37	18.0	21.0	15.0	17.0	10.0	12.0	27.0	32.0	22.0	26.0	16.0	18.0
1 3/8	6×37	22.0	25.0	18.0	21.0	13.0	15.0	33.0	38.0	27.0	31.0	19.0	22.0
1 1/2	6×37	26.0	30.0	21.0	25.0	15.0	17.0	39.0	45.0	32.0	37.0	23.0	26.0
1 5/8	6×37	31.0	35.0	25.0	29.0	18.0	20.0	46.0	53.0	38.0	43.0	27.0	31.0
1 3/4	6×37	35.0	41.0	29.0	33.0	20.0	24.0	53.0	61.0	43.0	50.0	31.0	35.0
2	6×37	46.0	53.0	37.0	43.0	26.0	30.0	68.0	79.0	56.0	65.0	40.0	46.0

HT=Hand Tucked Splice.
MS=Mechanical Splice.
[1] Vertical angles.
[2] Horizontal angles.

Table 9: OSHA 1926.251 Tables H-7 and H-8

OSHA Table H-9 and Table H-10 gives the rated load capacities for 2 and 3 leg bridle slings arrangements for improved plow grade rope and aircraft grade rope. The tables give the capacities based on an assumed termination of a mechanical splice.

TABLE H–9—RATED CAPACITIES FOR 2-LEG AND 3-LEG BRIDLE SLINGS

Cable Laid Rope—Mechanical Splice Only

7×7×7 and 7×7×19 Construction Galvanized Aircraft Grade Rope

7×6×19 IWRC Construction Improved Plow Steel Grade Rope

Rope		Rated capacities, tons (2,000 lb.)					
		2-leg bridle sling			3-leg bridle sling		
Dia. (inches)	Constr.	30° [1] (60°) [2]	45° angle	60° [1] (30°) [2]	30° [1] (60°) [2]	45° angle	60° [1] (30°) [2]
1/4	7×7×7	0.87	0.71	0.50	1.3	1.1	0.75
3/8	7×7×7	1.9	1.5	1.1	2.8	2.3	1.6
1/2	7×7×7	3.2	2.6	1.8	4.8	3.9	2.8
5/8	7×7×7	4.8	3.9	2.8	7.2	5.9	4.2
3/4	7×7×7	6.6	5.4	3.8	9.9	8.1	5.7

Table 10: OSHA 1926.251 Tables H-9

TABLE H–9—RATED CAPACITIES FOR 2-LEG AND 3-LEG BRIDLE SLINGS—Continued

Cable Laid Rope—Mechanical Splice Only

7×7×7 and 7×7×19 Construction Galvanized Aircraft Grade Rope

7×6×19 IWRC Construction Improved Plow Steel Grade Rope

Rope		Rated capacities, tons (2,000 lb.)					
		2-leg bridle sling			3-leg bridle sling		
Dia. (inches)	Constr.	30° [1] (60°) [2]	45° angle	60° [1] (30°) [2]	30° [1] (60°) [2]	45° angle	60° [1] (30°) [2]
5/8	7×7×19	5.0	4.1	2.9	7.5	6.1	4.3
3/4	7×7×19	7.0	5.7	4.1	10.0	8.6	6.1
7/8	7×7×19	9.3	7.6	5.4	14.0	11.0	8.1
1	7×7×19	12.0	9.7	6.9	18.0	14.0	10.0
1 1/8	7×7×19	14.0	12.0	8.2	21.0	17.0	12.0
1 1/4	7×7×19	17.0	14.0	9.9	26.0	21.0	15.0
3/4	7×6×19 IWRC	6.6	5.4	3.8	9.9	8.0	5.7
7/8	7×6×19 IWRC	8.7	7.1	5.0	13.0	11.0	7.5
1	7×6×19 IWRC	11.0	9.0	6.4	17.0	13.0	9.6
1 1/8	7×6×19 IWRC	13.0	11.0	7.7	20.0	16.0	11.0
1 1/4	7×6×19 IWRC	16.0	13.0	9.2	24.0	20.0	14.0
1 5/16	7×6×19 IWRC	17.0	14.0	10.0	26.0	21.0	15.0
1 3/8	7×6×19 IWRC	19.0	15.0	11.0	28.0	23.0	16.0
1 1/2	7×6×19 IWRC	22.0	18.0	13.0	33.0	27.0	19.0

[1] Vertical angles.
[2] Horizontal angles.

TABLE H–10—RATED CAPACITIES FOR 2-LEG AND 3-LEG BRIDLE SLINGS

8-Part and 6-Part Braided Rope

6×7 and 6×19 Construction Improved Plow Steel Grade Rope

7×7 Construction Galvanized Aircraft Grade Rope

Rope		Rated capacities, tons (2,000 lb.)											
		2-leg bridle slings						3-leg bridle slings					
		30° [1] (60°) [2]		45° angle		60° [1] (30°) [2]		30° [1] (60°) [2]		45° angle		60° [1] (30°) [2]	
Dia. (inches)	Constr.	8-Part	6-Part	8-Part	6-Part	8-Part	6-Part	8-Part	6-Part	8-Part	6-Part	8-Part	6-Part
3/32	6×7	0.74	0.55	0.60	0.45	0.42	0.32	1.1	0.83	0.90	0.68	0.64	0.48
1/8	6×7	1.3	0.98	1.1	0.80	0.76	0.57	2.0	1.5	1.6	1.2	1.1	0.85
3/16	6×7	2.9	2.2	2.4	1.8	1.7	1.3	4.4	3.3	3.6	2.7	2.5	1.9
3/32	7×7	0.89	0.67	0.72	0.55	0.51	0.39	1.3	1.0	1.1	0.82	0.77	0.58
1/8	7×7	1.6	1.2	1.3	1.0	0.95	0.71	2.5	1.8	2.0	1.5	1.4	1.1
3/16	7×7	3.6	2.7	2.9	2.2	2.1	1.5	5.4	4.0	4.4	3.3	3.1	2.3
3/16	6×19	3.0	2.2	2.4	1.8	1.7	1.3	4.5	3.4	3.7	2.8	2.6	1.9
1/4	6×19	5.3	4.0	4.3	3.2	3.1	2.3	8.0	6.0	6.5	4.9	4.6	3.4
5/16	6×19	8.3	6.2	6.7	5.0	4.8	3.6	12.0	9.3	10.0	7.6	7.1	5.4
3/8	6×19	12.0	8.9	9.7	7.2	6.8	5.1	18.0	13.0	14.0	11.0	10.0	7.7
7/16	6×19	16.0	12.0	13.0	9.8	9.3	6.9	24.0	18.0	20.0	15.0	14.0	10.0
1/2	6×19	21.0	15.0	17.0	13.0	12.0	9.0	31.0	23.0	25.0	19.0	18.0	13.0
9/16	6×19	26.0	20.0	21.0	16.0	15.0	11.0	39.0	29.0	32.0	24.0	23.0	17.0
5/8	6×19	32.0	24.0	26.0	20.0	19.0	14.0	48.0	36.0	40.0	30.0	28.0	21.0
3/4	6×19	46.0	35.0	38.0	28.0	27.0	20.0	69.0	52.0	56.0	42.0	40.0	30.0
7/8	6×19	62.0	47.0	51.0	38.0	36.0	27.0	94.0	70.0	76.0	57.0	54.0	40.0
1	6×19	81.0	61.0	66.0	50.0	47.0	35.0	22.0	91.0	99.0	74.0	70.0	53.0

[1] Vertical angles.
[2] Horizontal angles.

Table 11: OSHA 1926.251 Tables H-9 to H-10

OSHA Table H-11 through Table H-14 gives the rated capabilities for continuous loops of wire rope in various configurations, for various classifications, with hand tucked or mechanical spliced joints for improved plow steel grade rope, construction improved steel plow rope and aircraft grade rope. Three different arrangements are calculated being a vertical leg, looped as a basket, and used as a choker. The tables give the capacities based on minimum bend radius requirements where applicable.

TABLE H–11—RATED CAPACITIES FOR STRAND LAID GROMMET—HAND TUCKED

Improved Plow Steel Grade Rope

Rope body		Rated capacities, tons (2,000 lb.)		
Dia. (inches)	Constr.	Vertical	Choker	Vertical basket[1]
1/4	7×19	0.85	0.64	1.7
5/16	7×19	1.3	1.0	2.6
3/8	7×19	1.9	1.4	3.8
7/16	7×19	2.6	1.9	5.2
1/2	7×19	3.3	2.5	6.7
9/16	7×19	4.2	3.1	8.4
5/8	7×19	5.2	3.9	10.00
3/4	7×19	7.4	5.6	15.0
7/8	7×19	10.0	7.5	20.0
1	7×19	13.0	9.7	26.0
1 1/8	7×19	16.0	12.0	32.0
1 1/4	7×37	18.0	14.0	37.0
1 3/8	7×37	22.0	16.0	44.0
1 1/2	7×37	26.0	19.0	52.0

[1] These values only apply when the D/d ratio is 5 or greater where: D=Diameter of curvature around which rope is bent. d=Diameter of rope body.

TABLE H–12—RATED CAPACITIES FOR CABLE LAID GROMMET—HAND TUCKED

7×6×7 and 7×6×19 Construction Improved Plow Steel Grade Rope

7×7×7 Construction Galvanized Aircraft Grade Rope

Cable body		Rated capacities, tons (2,000 lb.)		
Dia. (inches)	Constr.	Vertical	Choker	Vertical basket[1]
3/8	7×6×7	1.3	0.95	2.5
9/16	7×6×7	2.8	2.1	5.6
5/8	7×6×7	3.8	2.8	7.6
3/8	7×7×7	1.6	1.2	3.2
9/16	7×7×7	3.5	2.6	6.9
5/8	7×7×7	4.5	3.4	9.0
5/8	7×6×19	3.9	3.0	7.9
3/4	7×6×19	5.1	3.8	10.0
15/16	7×6×19	7.9	5.9	16.0
1 1/8	7×6×19	11.0	8.4	22.0
1 5/16	7×6×19	15.0	11.0	30.0
1 1/2	7×6×19	19.0	14.0	39.0
1 11/16	7×6×19	24.0	18.0	49.0
1 7/8	7×6×19	30.0	22.0	60.0
2 1/4	7×6×19	42.0	31.0	84.0
2 5/8	7×6×19	56.0	42.0	112.0

[1] These values only apply when the D/d ratio is 5 or greater where: D=Diameter of curvature around which cable body is bent. d=Diameter of cable body.

TABLE H–13—RATED CAPACITIES FOR STRAND LAID ENDLESS SLINGS-MECHANICAL JOINT

Improved Plow Steel Grade Rope

Rope body		Rated capacities, tons (2,000 lb.)		
Dia. (inches)	Constr.	Vertical	Choker	Vertical basket[1]
1/4	[2]6×19	0.92	0.69	1.8
3/8	[2]6×19	2.0	1.5	4.1
1/2	[2]6×19	3.6	2.7	7.2
5/8	[2]6×19	5.6	4.2	11.0
3/4	[2]6×19	8.0	6.0	16.0
7/8	[2]6×19	11.0	8.1	21.0
1	[2]6×19	14.0	10.0	28.0
1 1/8	[2]6×19	18.0	13.0	35.0
1 1/4	[2]6×37	21.0	15.0	41.0
1 3/8	[2]6×37	25.0	19.0	50.0
1 1/2	[2]6×37	29.0	22.0	59.0

[1] These values only apply when the D/d ratio is 5 or greater where: D=Diameter of curvature around which rope is bent. d=Diameter of rope body.

[2] IWRC.

TABLE H–14—RATED CAPACITIES FOR CABLE LAID ENDLESS SLINGS-MECHANICAL JOINT

7×7×7 and 7×7×19 Construction Galvanized Aircraft Grade Rope 7×6×19 IWRC Construction Improved Plow Steel Grade Rope

Cable body		Rated capacities, tons (2,000 lb.)		
Dia. (inches)	Constr.	Vertical	Choker	Vertical basket[1]
1/4	7×7×7	0.83	0.62	1.6
3/8	7×7×7	1.8	1.3	3.5
1/2	7×7×7	3.0	2.3	6.1
5/8	7×7×7	4.5	3.4	9.1
3/4	7×7×7	6.3	4.7	12.0
5/8	7×7×19	4.7	3.5	9.5
3/4	7×7×19	6.7	5.0	13.0
7/8	7×7×19	8.9	6.6	18.0
1	7×7×19	11.0	8.5	22.0
1 1/8	7×7×19	14.0	10.0	28.0
1 1/4	7×7×19	17.0	12.0	33.0
3/4	[2]7×6×19	6.2	4.7	12.0
7/8	[2]7×6×19	8.3	6.2	16.0
1	[2]7×6×19	10.0	7.9	21.0
1 1/8	[2]7×6×19	13.0	9.7	26.0
1 1/4	[2]7×6×19	16.0	12.0	31.0
1 3/8	[2]7×6×19	18.0	14.0	37.0
1 1/2	[2]7×6×19	22.0	16.0	43.0

[1] These values only apply when the D/d value is 5 or greater where: D=Diameter of curvature around which cable body is bent. d=Diameter of cable body.

[2] IWRC.

Table 12: OSHA 1926.251 Tables H-11 to H-14

Synthetic Slings

Modern polymer and composite materials are rapidly replacing steel for countless tasks and engineered objects. High strength synthetic slings are becoming an alternative to wire rope slings as they are lighter, generally require less maintenance, and are easier to handle. This results in a cost savings through the reduction of production rigging time with an increase crane efficiency, but this is not the only reason for their wide spread adaptation. Synthetic slings are also relatively soft and wide which enables then to be wrapped around cylindrical objects such as rocket boosters or generator turbines that either have delicate and easily damaged surfaces, or polished surface finishes that cannot be marred, which might happen from a wire rope lift.

There are two main types of synthetic slings, web slings and roundslings. Web slings can be characterized as being relatively flat typically being an order of magnitude wider than they are thick. These slings are perhaps the most common sling being used by the industry and are available in sizes up to about 50 tons. Multiple layers or plys can be added to a sling in order to strengthen it, but this can sacrifice flexibility and there is a definite limit as to how many plys a sling can have. When a critical lift requires a large capacity synthetic sling, typically a round sling is used.

Roundslings can be characterized by having a protective cover around the strength yarns, which are not woven together but loose inside, and transfer the load evenly between them through friction and rendering. There are two main materials for the strength elements of roundslings, polyester and K-Spec, with the latter being the highest capacity synthetic sling commercially available. This K-Spec round sling is commonly referred to as a Twin-Path Extra with Covermax (TPXC) and have proven themselves to be reliable and forgiving, and become one of the most prominently used roundslings at shipyards. The WSTDA has a standard for polyester roundslings which is fairly comprehensive, but the TPXC slings currently do not have and extensive standard covering their use. The follow section aims to fulfill this need for more guidance on their safe use and included the prospective of and end user.

Twin-Path® Extra Synthetic Slings

Twin-Path, Slingmax, Sparkeaters, K-Spec, Covermax, are registered trademarks of Slingmax

One drawback with the shift to newer high capacity synthetic slings is that the reference documents and standards that sound engineering requires, is relatively sparse when compared to wire rope, which has a century's worth of collective use history and data available. For the K-Spec multiple cored slings, no standard organization had produced documentation with regard to their proper use, although different individual manufacturers of the product have created information to meet this need. This catalog attempts to compile the information of different manufactures of these various slings in an organized format combined with the use perspective of an end user. This shipyard rigging equipment catalog, attempts to present much of the information that is known or suspected, with the goal of helping to increase the safe adoption of this cost saving gear. As this technology is still in its infancy much of the documentation on these slings does not have significant data recorded through scientific experiments, conducted by multiple third parties and standard organizations. Where information is suspected but cannot be confirmed or necessarily proven, this guide uses terminology such as "it is suspected' or "it is believed". The promotion of information that cannot be proven as fact is seen as beneficial as it is intended to promote collective thought with regards to the use and failures observed with these slings to increase the collective knowledge available. This document is intended to provide a foundation of information available for proper Twin-Path sling use, but it is no substitute for the application of sound Engineering or rigging judgment accompanied with analytical thought. Furthermore, a manufacturers should always be contacted to determine what the most current advice is, and whether an intended application is within what is considered acceptable practice.

Twin-Path synthetic slings do have disadvantages which are not always highlighted in the manufacturing sales and use literature, although to the manufacturers credit, the product continues to undergo modifications to improve its safety and reliability. Many of these disadvantages relate directly to the soft nature of the material which they are composed of, and the fact that the core of these fibers cannot be seen. These load carrying fibers are susceptible to being damaged from high bearing pressures or being cut by edges protruding from an object, regardless of how sharp the edge is. Some roundslings have documented bearing considerations that are generally not encountered with synthetic web slings, since web slings by their nature are significantly wider than they are thick, which results in lower bearing pressures. Since roundslings have a lower cross sectional aspect ratio, this generally leads to higher bearing pressures that may need to be considered, along with cutting considerations. If a wire rope is subjected to large bearing pressures, flat spots and subsequently broken wires will usually be readily visible, alerting the rigger to the need to replace or repair the sling. As a roundslings strength core is hidden behind a protective cover, there may be little indication that damage has occurred unless the protective cover is also damaged. The use of duel protective covers with different colors helps a rigger see if the outer cover is damaged, but the outer cover can be damaged without damage done to the internal core fibers. Also is it suspected that it is possible that damage can be done to the internal core elements without any visible damage done to the outside cover. Until recently the primary inspection technique for roundslings was feeling the core, through the outer protective cover, a relatively subjective skill that requires significant training to understand what to feel for, and how the different components of the core should feel.

In addition to abrasion problems one must also be award that synthetic slings will be damaged by chemicals and have their strength reduced after exposure to UV or sunlight. Both of these forms of damage may or may not be readily apparent as the damage occurs on a molecular level. Temperature is also a problem as plastics have a much lower melting temperature as opposed to steel. Synthetic slings are relatively new and do not yet have copious amounts of historic data documenting failures and problems as compared to wire ropes. This means engineers and riggers must be even more aware of potential, and unexpected problems, that these new materials may bring.

Manufactures

The entry barrier into high performance synthetic sling manufacturing is significantly higher than other sling materials, which has resulted in fewer manufactures making them, and fewer different high performance fiber products available. The development of new fibers is a significantly research intensive and expensive endeavor which prevents most from undertaking this activity. The primary maker of high performance synthetic slings fibers is Slingmax, which in turn licenses manufacturing rights to assemble Twin-Path slings worldwide to approximately 22 manufactures in North America. Some of these include: American rigging, Bairstow, Bishops lifting, Carpenter group, I-and-I sling, J.Henry Holland, Lift-it, Rasmussenco, Slingset, Safety Sling, Yarbrough, and many others. The umbrella of Slingmax originally stems from an agreement with DuPont to be the sole distributer of the K-Spec fiber used in Twin-Path slings, although this is no longer the case. Slingmax ensures that all K-Spec fiber slings are made under the same standards, meeting the same specifications and being of identical quality. All manufacturers of the Twin-Path slings submit samples on a yearly basis to ensure that the process is being followed and all slings meets the quality standards.

General Construction

Twin-Path roundslings with K-Spec load bearing fibers follow the same construction methodology as other roundslings. The initial step of roundsling constructions starts with a toroidal protective cover that the load bearing fibers are wound within. The protective cover may be composed of multiple layers of different materials and is intended to prevent physical containments and Ultra Violet (UV) light from interacting with the core fibers where they will have detrimental effects. Single path roundslings have a single toroidal cover in which the load bearing fibers are wound, multiple path roundslings are either composed of multiple toroidal covers sewn together, or a single large toroidal cover sewn down the middle to partition the cover into two sections. Making a cover with two toroids sewn together has traditionally resulted in a tighter cover with less bagginess and wrinkles which sometimes snag on terminations. However, the manufacturing processes for this arrangement may allow the core to be perforated with a needle and thread, so this has resulted in more recent configuration of having a single cover separated into two paths with sewing down the middle. For Twin-Path slings this outside cover is typically made of green bulked Nylon with a layer of red underneath to help ease the inspection for sling tears, and is referred to as Covermax. Dyneema sleeve pads can also be added the outside of the sling to help increase bearing strength, abrasion resistance, and strengthen terminations.

Depending on the capacity and length of the sling required, the winding of the core fibers will vary slightly. The K-Spec yarns are woven into cords with an unloaded diameter of roughly five millimeters and in spool lengths of hundreds of yards long. There are some slight variations on roundsling manufacturing processes, but these cords are essentially wound between two sheaves or driver rollers that are set at the required distance apart to result in the finished sling having the specified length. For high capacity slings of long length, a very significant number of wraps are often required, which results in a total core length greater than a typical spool of K-Spec fiber. After the first cord spool is wrapped to its entirety the ends are tied together and wrapped with tape similar as shown on the left of Figure 12 and another cord spool is started. This process is continued until the total number of loops of the core fibers is greater than the calculated number to meet the strength requirements. The exact process Slingmax uses has added a slight twist such that the there is a helical winding of the individual core fibers, similar to wire rope, which should allow for a better transfer and distribution of load among the core fibers. For slings with multiple paths, such as Twin-Path slings this winding process in completed in parallel in both of the path sections.

Figure 12: Component Construction of a Single Path Roundsling

Strength

Twin path Extra slings are readily available in sizes ranging from 5 to 250 short ton vertical rated capacity. These standard sizes are usually more than sufficient for almost all shipyard applications as the relative local strength of ship modules often dictates the amount of load that can be placed at any one specific spot without the addition of significant temporary structure. The vast majority of lifts at shipyards have loading of less than 100 tons per attachment point and often slings capacities are selected based on these requirements. The construction and offshore industries do occasionally have the need to have larger capacities and K-Spec roundslings have been made with ratings of 660 short tons, although in this specific configuration as Tri-path slings. All standard slings sold are rated to ensure a five to one design factor between rated capacity and estimated failure load. Although ASME does not require the proof testing of new slings, that do not have previously used or welded fittings, all Twin-Path roundslings are loaded to twice the rating after manufacture.

Length and Strain

Twin-Path slings have been made 150 feet long and as short as 18 inches. In the past length tolerances were considered to be about plus or minus one half of one inch as described in slingmax's technical bulletin number four. Recently this fixed amount has been updated to take into account different manufacturing facilities and the fact that the horizontal manufacturing process must deal with a certain catenary effect that has a greater effect on tolerances of longer slings. The current quoted tolerance of a slings loaded length is roughly (+/-) 1 inch for slings less than 40 foot long, (+/-) 2 inches for 40 to 80 foot lengths, and (+/-) 3 inches for over 80 foot lengths. For most sling lengths typically ordered this works out to be less than 0.5% of the overall sling length. Slings made at the same time, on the same machine, by the same operator will usually be much closer in tolerance than the values indicated above. If matched length slings are ordered, tolerances can usually be created of only (+/-) 1/ 4 inch for nearly any length sling.

Measuring the length of a Twin-Path sling can be difficult as how it is taken can significantly affect the stated length. The proper measurement of a roundsling must be made of the slings core, which resists the loads and not the cover which may be of slightly different and somewhat variable length. A nylon cover will be especially likely to affect the measured length, and is the most common cover material. There are two main reasons for the variation in length of a Nylon cover, water absorption and re-crystallization. Water absorption will make nylon fibers swell and elongate, as well as make them weaker in strength. Although this can make the cover baggier and more susceptible to abrasion damage it will not affect the overall length. Nylons are semi-crystalline polymers, meaning that they have regions of densely packed high order crystalline structures, and amorphous regions of lower order. The process of creating a drawing a nylon fiber to create rope or webbing results in a high degree of chain extensions of the crystalline material to create a high strength and higher modulus material. However, over time the fiber material can have a tendency to shrink through a process of re-crystallization. This results in a reduction of length of the nylon cover webbing. This effect is most commonly noticeable on older slings that have been patched or repaired frequently during their life and the affect is estimated to be up to the order of five percent of total length. To overcome this cover phenomenon, any accurate measurement of the slings length should be taken when it is loaded to 10% of its rated load. In this way one can be assured that the length measurement taken is of the core bundle. A slight variation of the measured length of the sling will also result if different size pins are used for preloading the sling for measurement. To standardize sling measurements, it is suggested that the pins size used should be 2" diameter.

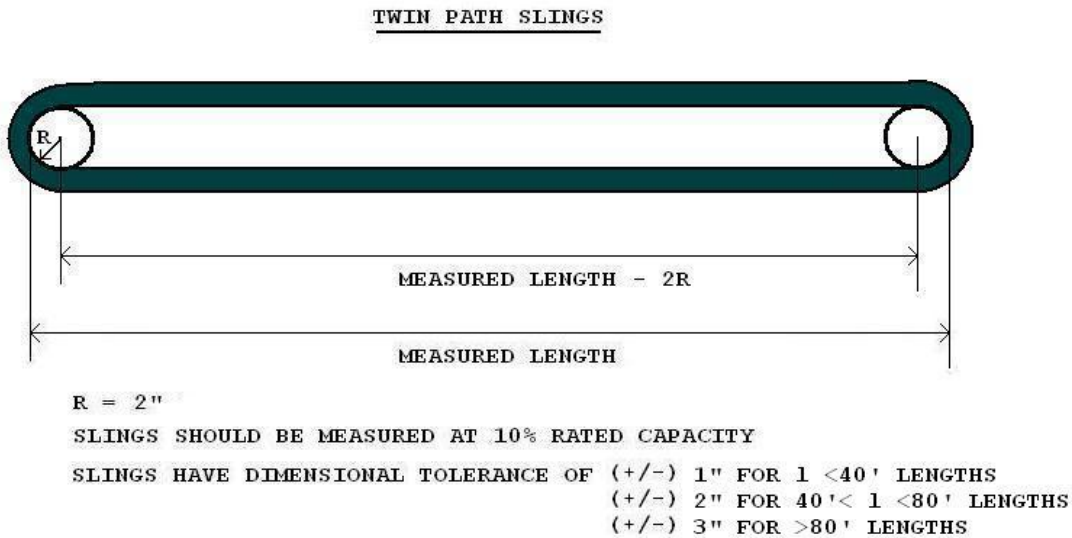


Figure 13: Twin-Path sling length and Measurement

It is very important to note that a shrunken cover will reduce the apparent length of the sling under no or minimal load. For lifts with multiple slings, riggers will correctly try to equalize or balance the load taken by each sling, and the apparent shorter sling length may result in adjustments made to balance the initial sharing of the loads. However, as the load gets drawn up the nylon cover will stretch until the K-Spec fibers engage, near the original manufactured length. Depending on the flexibility of the entire rigging arrangement, this lengthening can result in the arrangement relieving that sling of load, which is then transferred to accompanying members. This has important implications for operations where the length or modulus of the sling is critical under load such as some flounder plate arrangements and other load sharing equalizers. An depiction of this elongation versus load effect can be seen in Figure 14.

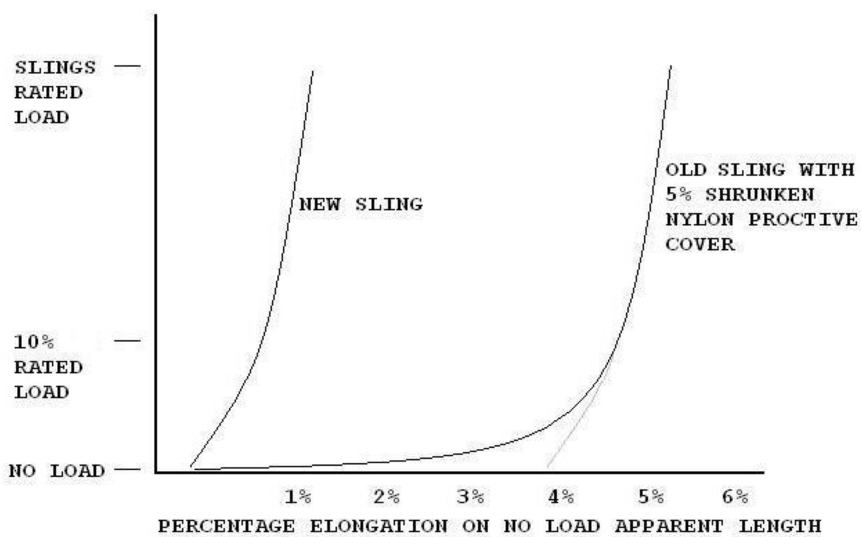


Figure 14: Approximate Elongation of New Sling vs. Old with Shrunken Cover

The elastic elongation of Twin-Path slings under rated load is similar to wire rope with regards to expected stretch, which is quoted as one percent of length, at rated load. Most other synthetic slings have much greater elongations such as nylon or polyester which typically have elongations of seven percent and four percent respectively. The relative rigidity of Twin-Path slings can provide some benefit over other synthetic slings as stiffer slings are less likely to cause load control problems. Slings that significantly elongate as the load is taken up can cause the initial rigging arrangement to be altered and result in a destabilization of the lifted load. A double basket hitch lifting arrangement as shown in Figure 15 is especially vulnerable to destabilization due to sling elongation. In this arrangement, if an error is made as to the location of the center of gravity, one of the lifting slings would take more load, causing more elongation and the load to shift in that direction, which could lead to a possible run away destabilization resulting in failure. These non-linear load shifting effects due to sling elongation are also very difficult to fully account for during the engineering design of lifts, and having a relatively rigid sling makes this complication less critical. It should be noted that for most synthetic slings the elongation with load is not linear, as slings will get stiffer with increasing load. No specific plot of load against elongation has been published for Twin-Path slings.

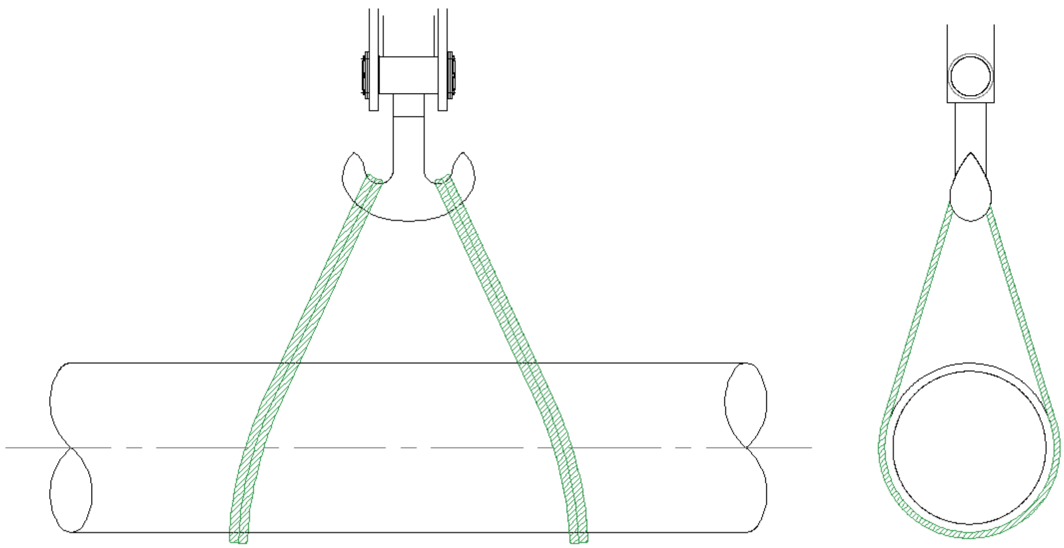


Figure 15: Basket Hitch With Spread Slings for Better Load Control

Construction stretch

The manufacturers of Twin-Path slings currently state that these slings do not have construction stretch, or a slight elongation of the slings shortly after leaving the factory and after being broken in with moderate use. When manufactured, the slings are constructed to have a 5 to 1 ratio between breaking strength and rated load. However, after some use, slings have often been quoted to have increased strength with ratios observed approaching 6 to 1. The explanation of this is that the manufacturing process has some inevitable variance included which does not guarantee that the load is evenly distributed among all yarns, and inevitably some cords in the core are slightly longer and thus take less load. As the sling is used, the cords in the core adjusted themselves into a more perfect alignment, in which they share the load better and more evenly, thus increasing the breaking strength of the sling. Some of this core adjustment most certainly occurs with the proof load to twice the rated load, which occurs before a sling leaves the manufacturing plant. If additional adjustment is in fact taking place it must be accompanied with some elongation of the total length of the sling, whether this is measureable or not is up for debate.

During Crosby's extremely severe cyclic testing of Twin-Path slings documented in technical bulletin 9a, they state that the slings appeared to get between 2.5% and 4% longer after the test. Riggers at some American shipyards also insist on observed elongations of Twin-Path slings after they have been broken in, of a much smaller percentage in length, but measurable none the less due to the significant lengths often in use. Furthermore, the longer and higher capacity the sling is, the more difficult it is during the manufacturing process to ensure that all yarns are the same length. Partially for these reasons, it is advisable that slings of similar age and work history be paired together as much as possible, especially in applications where equal length parts is an essential ingredient of the rigging design.

Twisting over Length

Most standards explicitly expresses that roundslings should not be twisted, or as in the specific wording of ASME, the twisting of slings shall be avoided. Sometimes when fittings at either end of the sling are at 90 degree angles to each other, it is required that the sling be twisted through this arc over the course of its length. This practice is believed to be completely acceptable. Slingmax did experiments which are documented in their technical bulletin 30, which shows that some twisting of the slings actually increased their strength up to a certain point. The tests were performed on six 5 ton slings five feet in length and this limited data sample suggested that twisting up to perhaps one twist per every 5 widths in length, increased the slings strength. This increase in strength is believed to be due to the internal adjustments that twisting allows, such that a better more even load distribution is facilitated among all core fibers in the bundle. Importantly, it should be noted that these tests were done on slings of relatively small width and that larger higher capacity slings that are wider may not have the exact same relationship between twisting and strength. These experiments do show however that slight twisting of slings, as shown in Figure 16, is most probably not harmful.

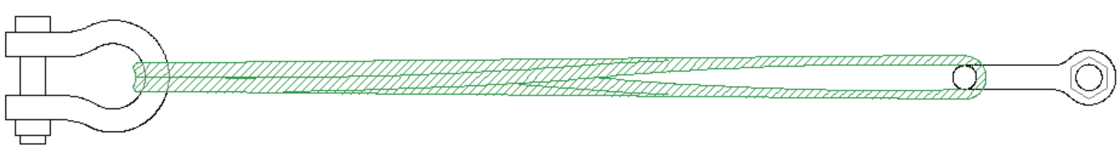


Figure 16: 90 Degree Twisting of Twin-Path Sling

End Connections

Synthetic sling connections are different than traditional wire rope or chain in that they result in a connection between metallic and non-metallic parts. This is noteworthy since to date, nearly 100% of all synthetic sling failures have been caused by the inadvertent cutting of the strength fibers. For synthetic roundslings there are fewer types of connections or terminations than wire rope, and most are based on the loop of sling, especially for high capacity usage. The three common types of hitches usually listed by manufacturers can be seen in Figure 17. The basket hitch shown on the left of Figure 17 is the most efficient use of an endless sling as it is essentially like having two slings with the load divided between them. The two main drawbacks to this type of hitch is the very long length of sling typically required, and that special care must be taken when setting the load down, as the sling must not be pinched under the load. This effectively eliminates this hitch for many ship unit erections. Additionally, careful attention must be paid to the bearing points at all corners of the object being lifted, as each location will have an associated bearing pressure which may cut or damage the sling.

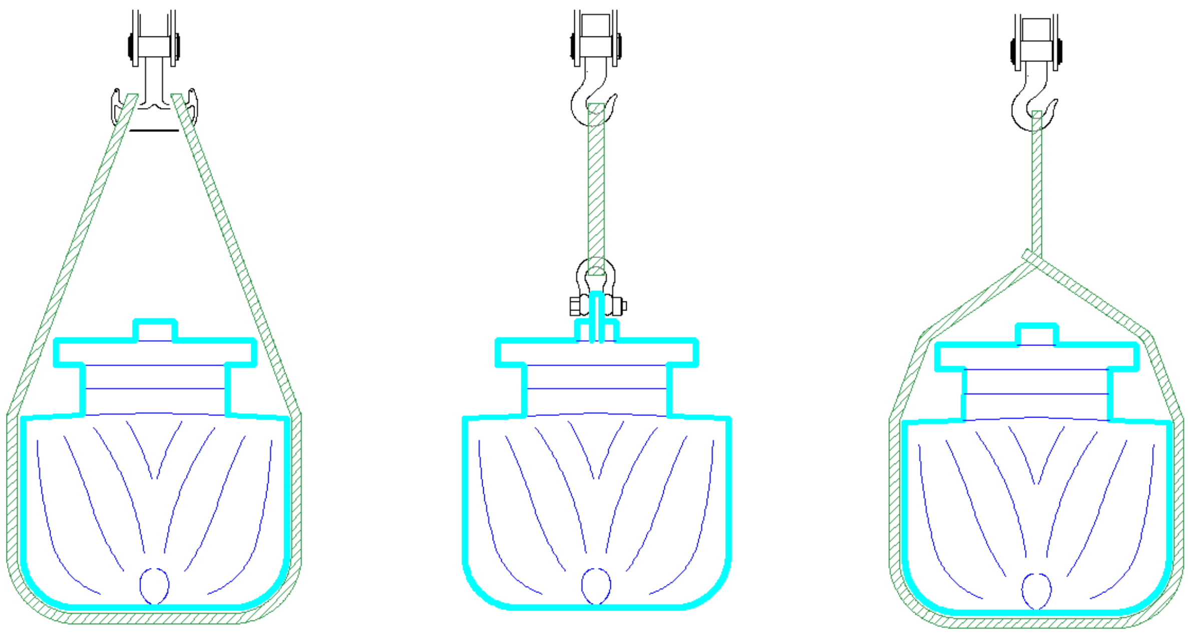
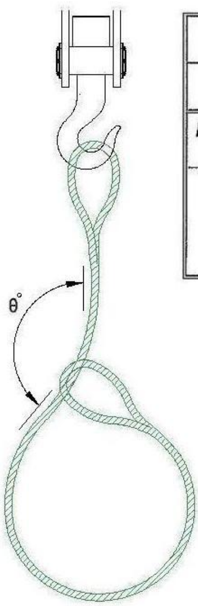


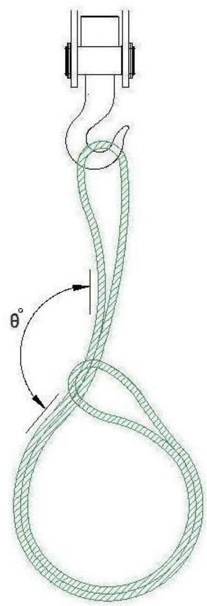
Figure 17: Three Main Sling Hitches, Basket, Vertical, and Choker

A choker hitch is similar to the basket hitch but is actually the least efficient lifting methodology as the strength of the sling is reduced both geometrically and due to the choking action of the sling bearing into itself. It is very important to note that the capacity of a choker hitch with an endless sling could be less than typically quoted for slings with spliced eye terminations. Spliced eye slings have two paths for the load to transfer through in the choking eye, effectively halving the sling loading at the termination. The WSTDA standard for synthetic roundslings suggests that since an endless sling does not have an extra path at the choking termination the capacity should be further reduced. This is different than ASME guidelines which use a standardized linear deduction. A table showing the difference between an endless sling and spliced eye sling reduction factors can be seen in Figure 18. The WSTDA table for choking hitch reduction of endless roundslings is based solely on theoretical calculations based on geometric angles and the author is aware of no documented and published testing which may confirm this reduction. However Slingmax has stated that this standard reduction is conservative for Twin-Path slings. It should also be noted that other organizations have slightly different deductions for choking hitches. Most of these reduction factors typically reduce the hitch capacity further from the already lower standard choker rating, with the exception being NAVFAC P-307 which also reduces the standard deduction. The use of the choking hitch also suffers from the long length of sling needed, and bearing pressures which will usually be higher than a normal basket hitch. This is because the choking nature of the lift causes an additional squeezing pressure which increases the bearing pressure seen at all contact points. Also, additional planning must be used for choking hitches to ensure the choking action is not on a spliced, or tagged area of the sling, which may cause local abrasion.



ASME

Standard Eye Sling	
Choker Hitch Capacity Adjustment	
Angle of Choke (degrees)	Rated Capacity (Percent)
120to 135	100
90 to 120	87
60 to 89	74
30 to 59	62
1 to 29	49



WSTDA

Endless Round Sling	
Choker Hitch Capacity Adjustment	
Angle of Choke (degrees)	Rated Capacity (Percent)
120to 135	100
90 to 120	71
60 to 89	58
30 to 59	52
1 to 29	50
or	
Angle of Choke (degrees)	Rated Capacity (Percent)
120to 135	100
113to 120	90
103to 113	80
90 to 103	70
66 to 90	60
0 to 66	50

Figure 18: Comparison of Reduction Factors for Eye Sling and Endless Roundsling

The most common large shipyard rig of endless slings is a vertical hitch, which may or may not be vertical in orientation, and for large lifts may be arranged with multiple spreader beams, cranes, hooks, and a dozen individual slings. The primary reason for the use of so many slings is to spread the load out over the lifted unit such that the forces are not concentrated in just a few areas. This method requires padeyes or special lifting points to be installed onto the structure, to which a shackle is attached.

The attachment of the sling to the shackle or any metal connection must be chosen with consideration for bunching, and bearing pressure. Bunching of the sling is a problem resulting from the use of an undersized shackle or connection without enough width for the sling to spread out on, and results in uneven loading and reduction of contact surface between the shackle and the sling. An example of bunching can be seen in Figure 19. Severe bunching of a sling can result in reduced capacity and permanent damage to a sling. The use of a sling without significant room may also result in the pinching of the fibers at the edges, which can cause cutting and permanent damage. Slingmax sells shackle pin pads which protect the sling form the sharp corners near the shackle pins edge, or threads of the pin. These are intended to be used with high performance Twin-Path slings and help provide a softer and larger bearing area.

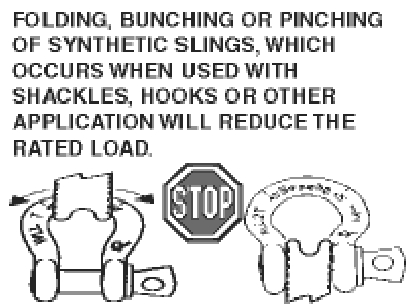


Figure 19: Bunching of a Sling in a Shackle
Figure reprinted with permission from the
CROSBY GROUP

Most slings break at transitions or contact points, and this is not different for synthetic slings. This is why special attention must be paid to the connection and bearing points of an endless roundsling. Some manufacturers of Twin-Path slings recommend that only wide body shackles be used with Twin-Path Extra slings and that they should be polished to a fine surface finish. Shackles previously subjected to large bearing pressures, which commonly happens when two shackles are linked together, often have indentations which can be seen on the surface, and this may reduce the capacity of the attached sling. It is thought that the bearing surface needs to be smooth with no abrupt hard transitions which may locally increase bearing pressures and other stress rising effects, which may shorten sling life or cause failure. Similarly many shackles have manufacturing rating information forged directly into the side of the shackle bow. Shackles with these imprints should be avoided as they may similarly act as stress risers. The concept of having a smooth bearing surface is not limited just to the steel surface of the shackle. Some Twin-Path manufacturers have recommended “Milking” the Covermax cover, before all lifts. The construction of the slings protective cover is bulky and baggy with excess material that can form large wrinkles on the outside of the sling. Milking is the process of removing these wrinkles from the bearing area, helping to create a smooth uniform bearing surface.

High shear and bearing pressures are typically associated with sharp corners, although will be present on any edge if the sling tension is large enough and the radius small. The resultant forces and pressures can abrade or cut into a roundsling cover, as well as damage or sever the core strength fibers. Bearing pressures may also be related to useful life expectancy, but the exact mechanisms which causes this are still in question, and no known test have been done specifically design to test this theory. All standard organizations indicate that synthetic slings absolutely must be protected from these high bearing or shearing pressures, but most do not suggest what the safe limit is, with the exception of the Web Sling and Tie Down Association (WSTDA), which has a comprehensive standard for polyester roundslings. Lift-it, a Los Angeles manufacturer of Twin-Path slings has recommended applying the WSTDA standards for polyester roundslings, to those made of high performance fibers, such as Twin-Path slings with K-Spec cores. The WSTDA has perhaps done the most research into bearing pressures on roundslings, and they recommend a maximum bearing pressure of 7,000 psi in their standard for roundslings with a polyester core. This recommendation is based on an unreleased data set stemming from destructive tests conducted on 375 single path polyester roundslings. According to WSTDA these slings consistently broke at approximately 28 ksi of bearing pressure with failure modes being a combination of shear and tension. The 7,000 psi bearing limit was then set with the desire to maintain approximately a design factor of 4, between a fully tensioned brand new sling, and the perceived bearing failure limit. These results may be applicable to low denier fibers similar to polyester, but any extrapolation of these results to higher capacity yarns is yet uncorrelated. Also, failure modes of roundslings may be affected by the amount of elongation that the core yarns undergo, elastic slings with polyester cores may behave very differently than relatively rigid slings with K-Spec cores. Slingmax states that the maximum safe bearing pressure for K-Spec Twin-Path Extra slings is 25,000 pound per inch of width, or 25 ksi on the projected bearing area.

Slingmax conducted a cutting and bearing pressure test in early 2010, where a 300,000# rated sling was loaded to capacity around a sharpened steel plate. The intent of this test was to prove the suitability of TPXC slings that have Dyneema bearing sleeves on the cover. This cover is intended to increase safety and life expectancy of a sling, through minimizing the chance that bearing pressures will cause cutting of the core fibers. During this test an estimated bearing pressure of over 37,500 (psi) was achieved and an inspection afterward revealed no indications of any damage or abrasion being present on the Dyneema sleeve or the bulked Nylon Cornermax cover. This bearing pressure exceeded the official rated pressure for the Dyneema sleeves by 150%, which is rated at 25,000 (psi). Full details of this test can be seen in the Slingmax report entitled “Testing of 10-inch Cornermax /Dyneema Sleeve”. Since the bearing pressure on the core fibers is also a direct function of the bending radius, and the Dyneema sleeve only marginal added extra area, it would be logical to conclude that the bearing pressure on the core fibers during this test was almost equally as large. This shows that excessive bearing pressure on Twin-Path slings, does not necessarily result in an instantaneous failure of the sling. Large bearing pressures may however, reduce the lifespan of a sling, but the exact function or rate of which this degradation happens, is unknown.

To maximize sling life it is sometimes recommended that the bearing points be rotated along the slings length to avoid continuously loading the same area. It is believed that continuous bearing pressures in the same area can harden the core fibers, as evidenced by cyclic tests conducted in August of 2006. The Crosby Group Laboratories conducted cyclic testing of four foot long Twin-Path slings to 150% of their rated load using a bolt shackle that had a rating similar to the sling. The bow of the shackle was polished to a smooth finish to promote a uniform bearing pressure, of approximately 4,500 pounds per square inch. The test was conducted on three different slings, at different cyclic frequencies, one at two Hz, and two at four Hz. Each of the three samples was tested for over 50,000 loading cycles. No sling failed during the test, however all slings showed "hardening" of the cover and core fibers around the bearing area. One of the tested slings was destructively tested afterwards, and failed at four times its rated capacity, showing it maintained a significant strength reserve above its original rated capacity. Additional details about these tests can be seen in Slingmax technical bulletin number 9A.

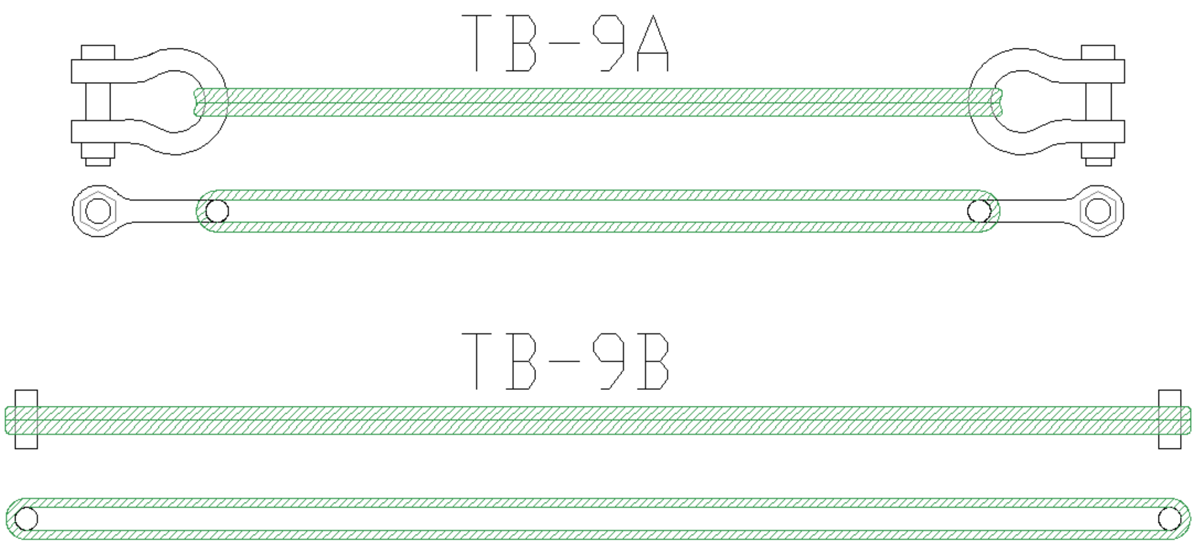


Figure 20: Cyclically Tested Twin-Path Test Slings

A similar fatigue test was conducted on a six foot long TPXC sling in October of 1997 by Tension Member Technology. This test had one key difference in that instead of the curved bow of an anchor shackle, a straight pin was used. The calculated bearing pressure during the test was approximately the same, and after 50,000 cycles of 150% of the rated load being applied, the sling was pulled to failure. The sling maintained over five times its original rated capacity and it is believed that this difference is mainly a function of the single degree of curvature of the bearing surface. A roundsling bearing onto a cylindrical surface is more likely to have a uniform bearing pressure than a sling on a segment of a torodial surface. On a segment of a torodial surface there is also additional pressure since less of the bearing pressures normal force is directly opposite the direction of the pull. Furthermore, since the maximum strength of a sling requires the full engagement of all filaments in the core, and since the filaments on the edge of the sling near the shackles increased curvature are more likely to be under higher load, the Crosby test was a more severe test. This shows that bunching, or any termination that does not promote the even loading of all filaments in the core, can degrade the slings strength over time. Additional details about this test can be seen in Slingmax technical bulletin number 9B.

If a typical sling is used 15 times a day, fifty thousand cycles represents nine years of service, and given the extreme 150% duty cycle loading of the TB9a and TB9b tests done, long life expectancy of slings seems plausible, especially since synthetic slings are not subject to corrosion like wire rope. However, it needs to be noted that these performance tests are done under laboratory conditions, and will never perfectly reflect real world circumstances.

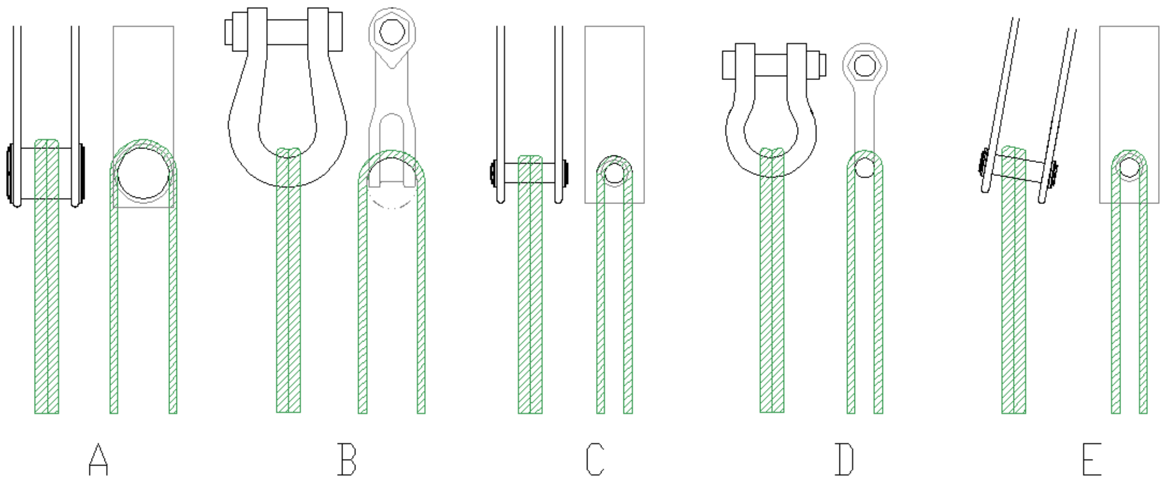


Figure 21: End Connections for Vertical Hitches

Figure 21 shows end connections common to vertical hitches with endless roundslings. The best type of termination is a right angle connection with the sling normal to the axis of curvature of the attachment, where the bearing pressures are low, such as when a sling is wrapped around a large diameter pin as shown in case A of Figure 21. The surface finish of the pin that the synthetic roundsling is bearing on should be smooth, with no gouges that can damage the sling during rendering, or potentially tear the sling. Case C and D of Figure 21 are very similar to the cyclic tests conducted in Slingmax technical bulletin nine. Although both terminations are considered safe if the rating of the pin or shackle is above that of the sling, after tens of thousands of loading cycles, the sling in case D may be more likely to show signs of wear and age. This is mainly due to the two degree of curvature of the surface that the sling is attached in case D, which does not promote uniform bearing pressure. Theoretically, if the bearing surface is large enough, the effects of bearing on a two degree of curvature surface will be negligible, as expressed with case B. If the curvature of the surface is too severe, or the shackle not wide enough, the result is bunching, which will significantly reduce the strength and useful life of a sling. Finally, side loading as seen in case E can be detrimental if the bearing forces are high enough, as with a small diameter pin. This is because it is possible that in this condition, only one path of a Twin-Path roundsling will be taking most of the load. It must be remembered that rigging is a dynamic event that is often pictured and analyzed as quasi-static, but in reality an angle between a sling and an attachment point will vary by a few degrees as the load is moved, so to some extent, side loading is inevitable. A sling that is side loaded will most likely have a lower breaking strength, but the exact limit or maximum safe angle for side loading is unknown.

It should be noted that side loading is sometimes designed into a sling arrangement with a common example being basket hitches from a duplex hook being spread to either side for better load control, as seen in Figure 15. With a basket hitch however, the side loading is usually on an object of considerable diameter or size, so the overall bearing pressure is low and the core fibers have space to adjust themselves and promote more uniform loading.

Rendering

When a roundsling is configured for a lift a rigger will try to ensure that the sling is snug and properly attached, such that a minimal amount of adjustment will occur as the load is drawn up. The adjustment that occurs is often referred to as rendering. One side of the endless roundsling will inevitably have extra length that will not fully take load until the sling has equalized itself with both sides being of equal length. When this adjustment takes place the cover can often be seen to slide around the pin connection, and due to the load in the sling, friction abrasion and wear will occur on the bearing surface, which can sometimes even produce tears on the bulked nylon Covermax cover. It is believed that the incorporation of Cornermax sleeves onto designated bearing points on a Twin-Path sling will substantially toughen up these surfaces and significantly reduce the chance for rendering related damage to occur. Furthermore, rigging practices can be optimized to minimize this effect by attaching the roundsling to the hook first, and then pulling the sling down to the load. If the bow of a shackle is allowed to hang from the sling during this process there is a better chance that both sides will be of equal length, minimizing the chance of tears in the cover from rendering.

Additionally, although not visually apparent, there should be some tendency for rendering of the internal core fibers of a roundsling as they naturally adjust themselves into a position that uniformly shares the load between them. Internal rendering will occur immediately after manufacture as the slings internal core fibers adjust themselves to a more optimal position. This process may also occur to some extent when the diameter of a slings bearing point is changed, such that the ratio of the circumferences for the inside path core fibers and outside path is slightly altered. During any rendering of internal core fibers, some of the loaded core fibers may bear into the others preventing them from freely adjusting and considerable frictional and abrasive stresses may develop. For these reasons it is may be advisable that relatively consistent connection hardware be maintained to minimize any internal rendering effects, and thus maximize life expectancy of a sling.

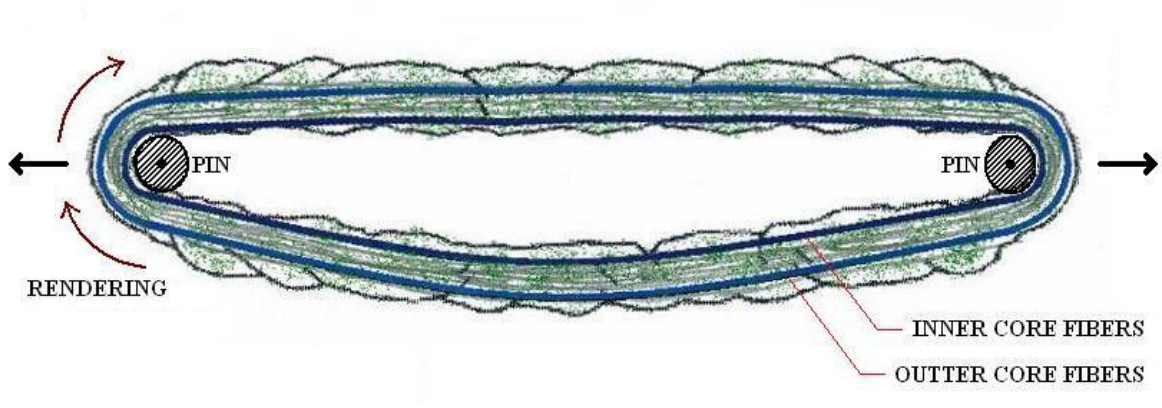


Figure 22: Cover, Inner and Outer Core Fibers of a Roundsling

Wear Protection

ASME considers cut protection mandatory where synthetic slings make contact with edges, as cutting is the number one cause of synthetic sling failure. Wear and abrasion protection can also help prolong a slings life. Many products are sold for synthetic slings with the specific intent to minimize bearing pressures, and reduce the chance of cutting or abrasion. Most of the edge protectors sold are based around the concept of softening the surface on which the sling bears, and increasing the bearing area to reduce the pressures present. Some wear protection is sling oriented being sewn or attached onto the sling at a designated bearing area, and other protection is intended for the areas of contact. Load oriented protection is typically intended to be used for basket and choker lifts, when the corners of the load may need specific softening. Consideration for the specific protection chosen for a given application is necessary since different protectors have different temperature and strength ratings.

There are several products available that attach to the sling or load and protects against failure due to abrasive surfaces, cutting, or bearing problems.

- Dyneema bearing sleeves are typically sewn into designated bearing spots on a Twin-Path sling and are intended to provide protection from abrasion and cut resistance.
- Mesh Guard protectors which have a unique combination of wire mesh and felt cloth designed to protect a sling from a sharp corner.
- Magnetic corner protectors are made which are effectively three quarters of a cylinder plastic castings which are designed to create a radius to soften the edge of a load. These devices do however have their own maximum allowable bearing pressure along with temperature considerations.
- Shackle Pin Pads are designed to be inserted onto a shackle pin to prevent the cutting or binding that may occur on threads that are not fully engaged or the sharp interior corner.
- CornerMax cut protection pads are made of multiple plastic rods enclosed in tough padding which is designed to fully enclose the edge load and minimize cutting potential. These pads are typically attached to the sling with Velcro to minimize the chance they will slip out, or shift during the rigging operation.

All of these devices have maximum rated loads, and maximum widths which can be safely accommodated.

Figure 23: Dyneema bearing sleeve

Inspection and Safety Features

The manufactures of Twin-Path s slings are always striving to improve their product, increase its safety, and add features which will allow better inspection to increase reliability and user confidence in their slings. These features are especially relevant since unlike many other slings, the strength elements are not visible. Where slings made of wire ropes can be quickly visually inspected for broken strands, the core strength fibers of roundslings are hidden inside the protective cover and cannot be visually inspected in the field. The original inspection technique to confirm the soundness of the core fibers is to feel them, which takes more time than a visual inspection and requires some knowledge and training as to what the core should feel like. The task of feeling the core is especially complicated and subjective since a bulked nylon cover prevents one from directly accessing the core bundles. If a core cord were to part during use it would recoil in either direction and most likely end up bunched up near the bearing surface at the time of use. This tactile inspection of roundslings is specifically oriented towards looking for tumors, knots, or hard spots that can result from a parted cord, which if present indicate a sling has been severely damaged and should be immediately removed from service. Several unique safety an inspection systems have been created to help ensure the strength core of Twin-Path sings are fit for use.

To provide a quicker visual inspection technique Twin-Path slings now come with and External Warning Indicator (EWI) that is designed to notify the user if the sling has been over loaded and may be in danger of failure. This indicator is a completely separate cord wrapped in each core of the sling which is designed to break when the sling is significantly overloaded, on the order of two to four times the slings rated capacity. As load and elongation are directly related, the EWI will break when the sling is stretched to an amount slightly greater than occurs during the sling's proof load, recoiling inside the cover. The recoil of the EWI breaking will cause its somewhat arbitrary length external tell-tails to disappear completely into the roundsling, providing sufficient notification to users that the sling has seen excessive load and should be removed from service for factory inspection and repair. During normal operation the rendering of a sling can sometimes cause the EWI tell-tails to shift location slightly, and therefore the length that protrudes from the cover, but so long as it has not disappeared entirely the sling can be consider safe. One of the features of the check fast system is the check fast tag, which indicated to the rigger that a tell-tail should be present. This is an important feature as it allows a rigger to distinguish between a sling that has potentially been overloaded, and an older sling that does not have the check fast system incorporated into it.

An additional inspection method for Twin-Path slings can also be acquired thought the use of a fiber optics strand laid within the core bundle. The use of fiber optics provides an additional and somewhat different protection than the External Warning Indicator. Where the EWI's protection is mainly a function of total sling elongation, a fiber optic tail provides a better indication of crushing, cutting, or environmental damage. A fiber optic strand acts as a channel or conductor of light, which will bounce down its length and through its curves to appear with minimal loss out the other side. The transition of light through the core filament of the fiber optics depends on the refraction properties of the coatings on the surface of fiber optic filament. If the surface of the fiber optic cable is damaged the amount of light being transmitted though the fiber optic cable will be greatly diminished and if the cable were to part, no light will be transmitted at all. The fiber optic cable used in Twin-Path slings have a polyethylene refractive jacket, which aids the detection of chemical exposure or other environmental damage such as temperature on the core bundles. This is because many of the temperate and chemicals that effect K-Spec fibers will also degrade the polyethylene fiber optic jacket. If crushing damage occurs to the core yarns of the Twin-Path sling, there is a good chance that the fiber optic cable laid within will also be damaged, and will no longer transmit light. Similarly the wear and abrasion of the core fibers that occurs over time will similarly abrade the fiber optics polyethylene jacket, providing a user with an indication that the slings useful life may be coming to an end.

Figure 24: Check-Fast Tell-tail

Temperature Considerations

Synthetic sling fibers are plastics, which are more effected by temperature than metals, over an even narrower temperature range. Typically plastics are harder and stronger at colder temperatures; and more elastic and weaker at elevated temperatures. The brittle properties at cold temperatures that some plastics possess is of special concern for rigging equipment, as the sudden quick failure that results, may be unexpected, and occur with little warning. Slingmax tested the core fibers of Twin-Path slings, the K-Spec filaments, at different low temperatures to estimate these environmental effects. These results show that the fibers got approximately 25% stiffer and over 30% stronger at extremely low temperatures, and no brittle failure occurred. The results and a description of this test can be seen in Technical Bulletin 34, and a plot of the results in Figure 25. This figure is shows a plot of break strength against temperature, with the design factored strength normalized against the 70°F control sample. The extrapolation of a best fit curve of this data also shows an estimation of reduction of strength with temperature, and indicates that a healthy margin of retained strength is maintained through all expected ambient temperatures that are encountered at US shipyards. Although there is not complete consensus among the different manufacturers, the current safe exposure temperature range as quoted by Slingmax, is -40°F to 180°F. This safe working temperature range is being refined and updated as experience and testing prove the applicability of these slings over various temperatures. Anecdotally, there are many Twin-Path slings operating in the deserts of middle-east, and there have been no reports of problems. Since Slingmax is the manufacturer closest aligned with development of these slings, their website should be considered the most current guidance on this subject.

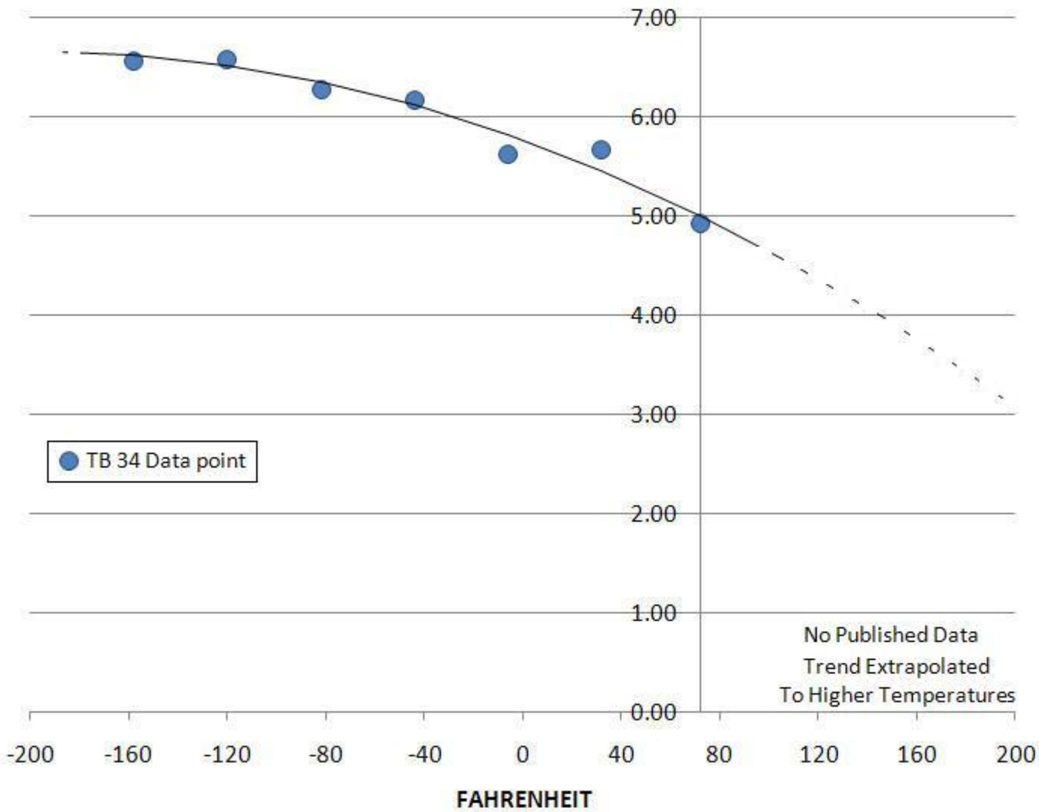


Figure 25: Effects of Cold Temperature on K-Spec Fiber

If slings with a higher temperature rating are required, a modification of the TPXC slings is made with a different blend of core fibers is available. Sparkeater slings are Twin-Path slings similar to the TPXC available up to 50 short ton capacity and are rated up to 300°F.

Chemical and Environmental Considerations

K-Spec

The core fiber of Twin-Path extra with Covermax slings are made of the K-Spec fiber of which the exact blend is a trade secret. The primary fibers include aramid, such as Technora; and high molecular polyethylene, such as Spectra, and chemical considerations are similar to the component fibers. The K-Spec core yarn strength retention is based on tests results of components at 150°F (or less) for 6-months.

100% Strength Retention when exposed to

Age, 10% detergent solution, rot and mildew, sunlight and Toluene

99% Strength Retention

Acitic acid, gasoline, one molar solution of hydrochloric acid, hydraulic fluid, Kerosene, seawater,

98% Strength Retention

25% ammonium hydroxide, 10% hypophosphate solution, 40% phosphoric acid

97% Strength Retention

5 molar solution of sodium hydroxide,

95% Strength Retention

Portland cement and sulfuric acid

88% Strength Retention

Clorox and nitric acid.

Nylon

The most common cover used with Twin-Path slings is the green and red bulked nylon cover referred to as Covermax. Nylon is a common material for rigging slings with a long history of use and significant data available. A brief overview of chemical and environmental considerations for nylon is as follows.

Nylon is affected by most acids and bleaching agents. Hydrochloric acids and Sulfuric acids even in deluded form even can cause a significant loss of strength. A 10% concentration of hydrochloric acid and sulfuric acid at room temperature will cause a noticeable loss in strength Some of the chemicals which act as solvents for nylon are formic acid, phenolic compounds, calcium chloride, zinc chloride, benzyl alcohol, and methanol. Nylon looses 15 % strength when wet.

Nylon is not significantly affected by greases, oil, hydrocarbons, aldehydes, alkalis

Over time nylon webbing will shrink, when not used the webbing will shrink 5% of its length. When webbing is knitted tightly it will shrink less compared to when it is loosely knitted. Humidity and temperature has an effect on the shrinking rate. At working load limit nylon will stretch 6-8 %, however when new elongation will be larger until broken in.

Polyester

Some rigging operations request Twin-Path slings with polyester covers. The cover should be chosen based on what is considered to be the best material for the job. Polyester is a common material for rigging slings with a long history of use and significant data available. A brief overview of chemical and environmental considerations for Polyester is as follows.

Polyester will disintegrate when in contact with concentrated sulfuric acid. Polyester is resistant to aqueous solutions and strong alkalis at room temperatures, however when brought to boil these substances will destroy the material. Polyester's strength is not affected by moisture.

Aramid

Aramids are affected by strong acids, bases, and sodium hypo-chlorite bleach, especially at high concentrations and temperatures.

Standards and Regulations

OSHA

The Occupational Safety and Health Act (OSHA) is the main federal law intended to promote safe working conditions for employees in U.S. Territories. Part 1910 of Title 29 of the Code of Federal Regulations (CFR) carries out the directive of the Occupational Safety and Health Act. In addition the act included a general duty clause was included requiring employers to provide a work place free of recognized hazards. These standards incorporated into the different parts are intended to make any national consensus standards, law, such that widely adopted and agreed upon safe practices are promoted.

For the most part, OSHA has not updated its standards that pertain to slings, which were originally heavily based on ASME's standard for slings B30.9 at the time of execution. This means that any newly developed materials or equipment, such as high performance synthetic roundslings, for which a specific national consensus has not matured, is not included in the original standard. As the ASME sling standard has evolved and been modified with time, OSHA has taken the standpoint that full compliance with the current ASME standard is acceptable in lieu of the older guidance incorporated directly into the CFR. This policy is quoted as "de minimis violations" which literally means of minimal violations, and basically assumed that there is no indication that newer standards are less safe than what was promulgated in the early nineteen seventies, and that most changes are minor. An example of this deferment can be seen in a letter on interpretation from 1994, the director of the office of construction suggests that high capacity synthetic slings made from materials like Spectra, should have a factor of safety of 6, as this is similar to OSHA's rigging standards for other synthetic fibers. This letter also suggest that polyester rope slings maintain a factor of safety of nine. However, currently OSHA's website seems to indicate that polyester roundslings, which are composed of polyester cords, should comply with tables identical to those listed in ASME's B30.9 sling standard, which is based on a design factor of five. This seems to suggests that as standard organizations, specifically ASME, update their standards, OSHA will default to their new recommendations. Similarly, the OSHA standards repeatedly refers an employer to the guidelines set by the manufacturer of any product in question, as any standard cannot always be kept abreast of manufacturing updates, and thus may be incomplete.

The Code of Federal Regulations (CFR), Title 29, Section 1910 is the main regulatory law for which compliance must be in accordance with. This section also sets part 1926 to be additional standards pertaining to construction work, and sets part 1915 to be additional standards pertaining to shipyard work. Within this main part, section 1910.184 covers slings with topic (h) dealing specifically with Synthetic slings. Although this standard has no guidance for roundsling use of any type, a rigging engineer, or lift designer, may be interested in certain comments in this part defining some of the limits of natural and synthetic rope slings. A brief synopses of some of these interesting points are:

- Depending on the type of rigging operation, sets a minimum diameter of curvature (related to bearing area), for fiber rope slings of either double or eight times the rope diameter in Figures N-184-3 and 4.
- Allows angles of 5° or less to be considered to be vertical for natural or synthetic fiber slings.
- Defines a safe operating temperature of -20°F to 180°F for natural and synthetic fiber rope slings, inside of which no decrease in the rated load is required.

The Code of Federal Regulations (CFR), Title 29, Section 1915 is the mandatory regulatory law covering shipyard employment which all compliance must be in accordance with. Within this main section, Subpart G, sections 1915.111 through 1915.120 covers rigging equipment and material handling. No paragraph of this section refers to synthetic slings or has any provisions which can be applied to assist the design of a lift

The Code of Federal Regulations (CFR), Title 29, Section 1926 is the mandatory regulatory law covering construction for which compliance for those industries must be in accordance with. Since the construction industry is much larger than the shipbuilding industry in the United States, most rigging equipment manufacturers comply with and reference this section. Also Subpart 1926.30 of the act states that shipbuilding or ship repair, that is done under government contract is subject to the construction act (1926), with the exception naval ship construction. Within the construction act, several Subparts deal with rigging equipment, but Subpart H is most applicable as it deals with material handling. The main sections within this for slings is 1926.251 which has over twenty tables of rated capacities for slings. However, no paragraph of this section refers to synthetic slings or has any provisions which can be applied to assist the design of a lift with this material. The synthetic sling section of these standards primarily reference rope or web slings. In terms of use guidance it provides the standard tables for type of hitch, and angle of sling. These standards also have use guidance based on environmental considerations and safe operating temperatures. However there is no information on Synthetic roundslings. This is probably because they do not consider there to be enough industry consensus yet developed.

ASME

The American Society of Mechanical Engineers (ASME) standards for rigging related equipment is one of the most quoted rigging equipment standards. The specific ASME standards covering synthetic slings is "B30.9 -2010 Slings, *Safety Standards for Cableways, Cranes, Derricks, Hoists, Hooks, Jacks, and Slings*", which was recently updated in March of 2011. This standard has three chapters on synthetic slings including one, chapter 9-6.10, that specifically deals with roundslings, their selection, use, and maintenance. This section has several sections including, training, materials and components, fabrication and configurations, design factor, rated load, proof test requirements, sling identification, environmental effects, inspection removal and repair, and operating practices. This standard references and appears to rely on some of the testing done by the Web Sling and Tie Down Associations (WSTDA). A rigging engineer, or lift designer, reviewing this standard might be most interested in specific comments in this chapter on specific limits for roundsling use. A brief synopses of some of these important points in the standard are:

- Sets a minimum roundsling design factor of five, which is the ratio of minimum breaking strength to rated load.
- The chapter on roundslings is mainly oriented towards polyester yarns, and indicates that for roundslings of other yarns, one should check recommendations of the manufacturer.
- Indicates that polyester roundslings have a temperature range of -40°F to 194°F and that some other synthetic roundsling materials do not retain its published breaking strength above 140°F. Suggests that users of roundslings made from other materials should consult the manufacturer for safe temperature ranges.
- This chapter indicates that synthetic roundslings should not be used to support personnel platforms.
- The section on choker hitches uses the standard reduction typically associated with spliced eyes and does not include any extra reduction due to the fact that the choking portion of the sling may be under greater load, as seen in the WSTDA standard.
- This chapter sais nothing of maximum allowable bearing pressures, except that slings must be protected against cutting.
- It states that many of the rated loads to be referenced, are based on pin diameters, are from the WSTDA standard for synthetic polyester roundslings. This seems to suggest that to some degree allowable bearing loads from WSTDA have been incorporated by ASME.
- From an rigging engineering perspective, very little changed in the 2010 ASME B30.9 update to this chapter. One specific comment that was added to the reference table of nominal rated loads, (Table 25), is that the rated loads shown are based on specific pin diameters, and smaller pin diameters will reduce the allowed load. This implies a continued movement towards indicating an allowable maximum bearing pressure for roundslings.
- States that twisting of roundslings should be avoided.

Cordage Institute

The Cordage Institute is a organization primarily dedicated to standards for fiber rope and related industries. As ropes with synthetic material have developed with increasing capacity, standards have been produced to define recommended practices for these products. Since roundslings are essentially large bundles of high capacity rope, the cordage institute developed a roundsling standard. This is standard CI 1905-07 and most recently published in 2007, and is intended to cover roundslings of any synthetic fiber construction, of single or multiple path. Topics included relate to the materials for roundslings, finishes, hitches, proof loading, break testing, identification, responsibility, environmental, temperature, fittings, inspection, removal, repairs, and operating practices. A rigging engineer, or lift designer, reviewing this standard might be most interested in specific comments in this chapter on specific limits for roundsling use. A brief synopses of some of these important points in the standard are:

- Sets a minimum synthetic roundsling design factor of five, which is the ratio of minimum breaking strength to rated load.
- Defines two main groups of roundslings, those made of high capacity fiber and standards capacity fiber. This definition effectively rates the strength of the fiber, with high capacity fiber defined as those above 15 grams per denier, and standard core material being less than that.
- Indicates that the load bearing yarns of polyester roundslings be used at temperatures between -40°F to 194°F.
- This standard covers the three standard rigging hitches, but does not present a table for the reduction of rating for a choker hitch due to choking angle.
- States that roundslings in general should not used at temperatures above 180°F, and that High Molecular Poly-Ethylene (HMPE) cores, such as Spectra or Dyneema, should not be exposed to temperatures over 158°F.
- This standards does not specifically address bearing pressures of roundslings, but does indicate edges and abrasive surfaces should be kept from contact with sling.
- The section on fittings states that fittings must be smooth and be wide enough to prevent crushing, bunching, or restricting the roundslings attachment. This section also indicates that the shape of the bearing surface can affect the strength of the roundsling, but does not define a maximum recommended pressure.
- Indicates that unprotected shackle pins may damage a roundsling and should be avoided, with protection added to protect the sling
- The standard indicated that both the static and dynamic loads expected must be below the rated load.
- The standard indicates that slings and their fittings shall be compatible with regards to load rating, such that the rating of the union is the lesser of the two.
- States that slings should not be twisted, and that twisting of slings should be avoided.

WSTDA

The Web Sling and Tie Down Association (WSTDA) is an organization of sling manufacturers and industry that is intended to promote quality and safety through the creation of voluntary standards and reference material. The standards it creates are almost entirely related to the manufacturing process and use of synthetic slings. This organization has a standard for polyester roundslings, WSTDA-RS-1, which covers basic definitions and manufacturing requirements for these slings, and also has guidance for the proper use of these slings. This standard has several revisions and was most recently revised in 2010. There are four main chapters in this standard, and they are more extensive and detailed than other standards, and include specific numbers for many of the recommendations. These chapters cover material construction, procedures for testing, and recommended operating practices. Some manufacturers of the Twin-Path slings suggest that many of the operating practices laid out in this standard be followed, even though this is written for polyester, and not K-Spec core fibers. A rigging engineer, or lift designer, reviewing this standard might be most interested in specific comments in this chapter on specific limits for roundsling use. A brief synopses of some of these important points in the standard are:

- Sets a minimum roundsling design factor of five, which is the ratio of minimum breaking strength to rated load. A warning is included in this paragraph noting to the user that depending on the bearing pressure present, the actual failure load of a sling may be less than the nominal breaking strength of the sling. A note in the bearing section suggests that a capacity reduction of 20% may be appropriate depending on the specific requirements desired. Furthermore this standard cautions the user that this design factor is the design factor present when the sling is tested in laboratory conditions, which are never exactly duplicated in the real world.
- This standard indicates that roundslings should not be used to support personnel platforms, or have personnel ride loads lifted by roundslings.
- This standard covers the three standard rigging hitches, and also covers a approved methods of adjusting the length of the sling.
- For choking hitches this standards has a reduction table that is different than others as the WSTDA believes that endless slings will be subject to additional stresses at the choking point which will further reduce capacity. These reductions are in addition to the reduction to 80% of vertical capacity.
- This standard has one of the most comprehensive sections on bearing pressures and requirements for connections. It sets a maximum bearing strength of 7,000 (psi) which should be applied to all pins and edges of loads. Worked examples are included for the calculations of bearing strength.
- States that all bearing surfaces should be clean and adequately radiuses to prevent cutting or other forms of damage to the slings.
- A section on effective width of bearing surfaces is included which reduces the bearing area of bowed bearing surfaces such as anchor shackles to 75% the diameter of the bow to account for the localized compression of the sling. This value however should not exceed the actual width of the sling.
- States that roundslings shall not be twisted, and twisting of the legs should be avoided.

NAVFAC P307

This extensive Naval Facilities Engineering Command document relates to the management of weight handling equipment for the US NAVY. This publication covers a variety of rigging activities from cranes to miscellaneous rigging equipment. Section 14 provides recommendations for rigging gear such as slings, hardware, scales and load cells; and subpart 14.7.4.3 specifically covers roundslings. Specific topics in this short subpart relate to the inspection, rejection, repairs, and use criteria of synthetic roundslings. The guidance pertaining to slings mainly references ASME B30.9 criteria with some exceptions. A rigging engineer, or lift designer, reviewing this standard might be most interested in specific comments in this chapter on specific limits for roundsling use. A brief synopses of some of these important points in the standard are:

- States that roundslings shall only be used in the lifting applications for which they were designed by the original equipment manufacturer. Strict compliance with OEM’s instructions are required.
- Recommends split pipe or other rounded shoes hard material to protect synthetic slings from sharp corners or edges.
- Warns users of arrangements that bunch slings in the bowl of shackles as they can cause uneven loading on the fibers of the sling.
- Table 14-4 indicates reductions for choker hitches for synthetic web and roundslings which is slightly more conservative than most tables. This table has a much lower allowed rating than often found in other tables. This table includes the standard deduction in with the angle deduction and essentially used the standard deduction of 80% vertical rated load for choking angles larger than 120° and an increased deduction of 75% vertical rated load for choking angles smaller than 120°, in addition to the standard deduction which is a sine function of the choking angle.

  This requires that roundslings with core yarns other than nylon or polyester shall have the pin diameter used for the proof test indicated on the slings certificate and furthermore that this sling never be used on a pin of smaller diameter than used for the proof test

Chain Slings

Manufactures

Rigging chain is required by regulation to be of a higher grade of material. This limits the availability of suitable chain to certain manufactures. Some of the common manufactures of rigging grade chain are Crosby, KWS Thiele, Pewag, and Laclede.

Strength and Strain

As with many rigging products toughness or ability to be overloaded without sudden brittle failure is required. For this reason only alloy steel chain of grade 80 and 100 should be used. Alloy chain or suitable grade 80 or 100 will be marked and sold as 8, 80, or 800; or 10, 100, or 1000 respectively. Chain used as a sling should have a design factor of 4 and manufactures load ratings should be ensured to conform to these requirements if specifying for a lift requirement.

Table 13 below gives the allowable chain loading based on chain size straight pull for grade 80 and 100 alloy steel chain manufactured by Cosby. The tables give the working limits in pounds of the chain with a design factor of 4 to 1. Working limits of chain should be further reduced if chain is used as a choker to account for the angular choke, similar to wire or synthetic slings a minimum angle of choke of 120 degrees is recommended.

Spectrum 8® Alloy Chain Size		90°
(in.)	(mm)	Single Leg
7/32	6	2500
1/4 (9/32)	7	3500
5/16	8	4500
3/8	10	7100
1/2	13	12000
5/8	16	18100
3/4	20	28300
7/8	22	34200
1	26	47700
1-1/4	32	72300

Spectrum 10® Alloy Chain Size		90°
(in.)	(mm)	Single Leg
—	6	3200
1/4 (9/32)	7	4300
5/16	8	5700
3/8	10	8800
1/2	13	15000
5/8	16	22600
3/4	20	35300
7/8	22	42700
1	26	59700
1-1/4	32	90400

Table 13: Load Ratings based on Chain Dimensions

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CROSBY GROUP

Chain experiences a reduction in strength when exposed to high temperatures although is much more suitable for high temperature than synthetics or wire rope. Table 14 below give the percentage reductions based on the temperatures. Normal operating temperatures for slings are from -40 to 400 degree Fahrenheit. For the most part these temperature extremes are outside of any probable expectations for a typical shipyard unless casting of specific parts is actively performed. Chemical interaction should also be considered when working in chemically active environments.

Table 1

Use of Crosby Grade 80 Chain At Elevated Temperatures

Temperature of Chain		Temporary Reduction of Rated Load at Elevated Temperature*	Permanent Reduction of Rated Load after exposure to Temperature**
(F°)	(C°)		
Below 400	Below 204	None	None
400	204	10%	None
500	260	15%	None
600	316	20%	5%
700	371	30%	10%
800	427	40%	15%
900	482	50%	20%
1000	538	60%	25%
Over 1000	Over 538	OSHA 1910.184 requires all slings exposed to temperatures over 1000° F to be removed from service.	

* Crosby does not recommend the use of Alloy Chain at temperatures above 800° F.
** When chain is used at room temperature after being heated to temperatures shown in the first column.

Table 2

Use of Crosby Grade 100 Chain At Elevated Tempertures

Temperature		Temporary Reduction of Rated Load at Elevated Temperature*	Permanent Reduction of Rated Load after exposure to Temperature**
(F°)	(C°)		
Below 400	Below 204	None	None
400	204	15%	None
500	260	25%	5%
600	316	30%	15%
700	371	40%	20%
800	427	50%	25%
900	482	60%	30%
1000	538	70%	35%
Over 1000	Over 538	OSHA 1910.184 requires all slings exposed to temperatures over 1000 F to be removed from service.	

* Crosby does not recommend the use of Alloy Chain at temperatures above 800° F.
** When chain is used at room temperature after being heated to temperatures shown in the first column.

Table 14: Temperature based Chain Rating
Figure reprinted with permission from the
CROSBY GROUP

When designing lifts attention has to be paid to how the chain wraps around the corners and pads should be used when chain is in contact with sharp corners. This is shown in Figure 19 below.

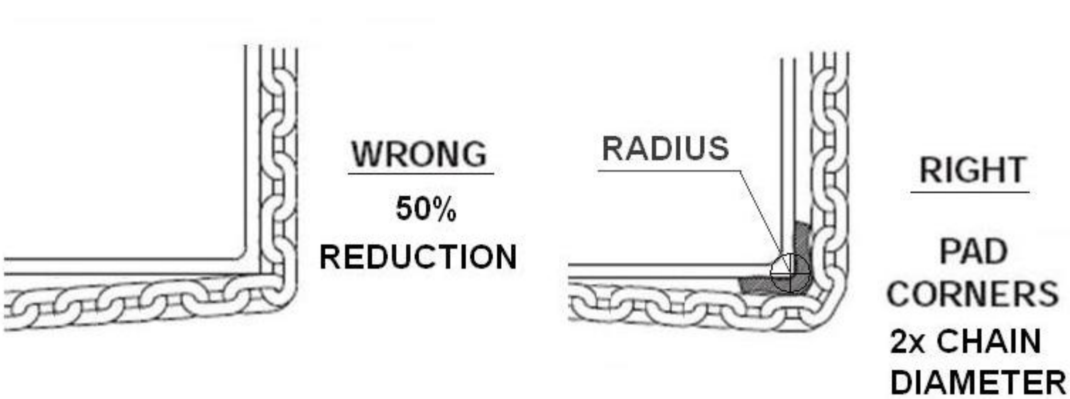


Figure 26: Corners and Chain

Chain is one of the stiffest sling materials when used in the vertical direction. At angles other than vertical the weight of the chain becomes an important factor as catenary factors allow the chain to apparently lengthen as the load increases. As these translations and deflection are significantly larger that the ductility of steel, they will therefore govern the elongation and can be relatively tricky to figure out as the effects are non linear.

End Connections

Chain has the benefit that one can easily vary the length of the sling by moving the attachment one link down the chain. Several companies make attachments that a link can be dropped trough securing a connection. Usually chain slings are manufactured with hooks, and master links permanently fixed on either end of the chain.

Standards and Regulations

OSHA Standards for Chain, Table 15 gives rated capacity in pounds for alloy steel chain slings based on chain diameter, number of sling branches and sling angles. Alloy steel has to have permanently affixed durable identification including size, grade, rated capacity and sling manufacturer. Hooks, rings and other attachments used with alloy steel chain need to have rated capacity of greater then the alloy chain steel. In OSHA's H-2 table they provide allowable wear of the chains job hooks and links.

TABLE H–1—RATED CAPACITY (WORKING LOAD LIMIT), FOR ALLOY STEEL CHAIN SLINGS [1]

Rated Capacity (Working Load Limit), Pounds

[Horizontal angles shown in parentheses] (2)

Chain size (inches)	Single branch sling—90° loading	Double sling vertical angle (1)			Triple and quadruple sling vertical angle (1)		
		30° (60°)	45° (45°)	60° (30°)	30° (60°)	45° (45°)	60° (30°)
¼	3,250	5,560	4,550	3,250	8,400	6,800	4,900
⅜	6,600	11,400	9,300	6,600	17,000	14,000	9,900
½	11,250	19,500	15,900	11,250	29,000	24,000	17,000
⅝	16,500	28,500	23,300	16,500	43,000	35,000	24,500
¾	23,000	39,800	32,500	23,000	59,500	48,500	34,500
⅞	28,750	49,800	40,600	28,750	74,500	61,000	43,000
1	38,750	67,100	54,800	38,750	101,000	82,000	58,000
1⅛	44,500	77,000	63,000	44,500	115,500	94,500	66,500
1¼	57,500	99,500	81,000	57,500	149,000	121,500	86,000
1⅜	67,000	116,000	94,000	67,000	174,000	141,000	100,500
1½	80,000	138,000	112,500	80,000	207,000	169,000	119,500
1¾	100,000	172,000	140,000	100,000	258,000	210,000	150,000

[1] Other grades of proof tested steel chain include Proof Coil, BBB Coil and Hi-Test Chain. These grades are not recommended for overhead lifting and therefore are not covered by this code.

(1) Rating of multileg slings adjusted for angle of loading measured as the included angle between the inclined leg and the vertical.

(2) Rating of multileg slings adjusted for angle of loading between the inclined leg and the horizontal plane of the load.

TABLE H–2—MAXIMUM ALLOWABLE WEAR AT ANY POINT OF LINK

Chain size (inches)	Maximum allowable wear (inch)
1/4	3/64
3/8	5/64
1/2	7/64
5/8	9/64
3/4	5/32
7/8	11/64

TABLE H–2—MAXIMUM ALLOWABLE WEAR AT ANY POINT OF LINK—Continued

Chain size (inches)	Maximum allowable wear (inch)
1	3/16
1 1/8	7/32
1 1/4	1/4
1 3/8	9/32
1 1/2	5/16
1 3/4	11/32

Table 15: 1926.251 OSHA 1926.251 Table H-1 and H-2 Chain Slings

Additional references for regulations and standards which cover chain are OSHA 1910.184 for Slings, and ASME B30.9-“Slings”.

4. CHAIN-FALLS AND AIR-HOISTS

Chain falls and air hoist offer infinite precision with regards to adjusting the length of a sling and therefore the load in it and the angle of the block being lifted. This allows erected blocks to be aligned precisely in their final ships position before being released by the crane. Also tolerance critical items such as shafting or propellers can be leveled and installed precisely. These rigging tools are used extensively in shipyards for block and equipment lifting arrangements.

Manufactures

There are many manufactures of chain falls and air hoists. Some popular makers are Ingersoll-Rand, J. D. Neuhaus, Harrington Hoist and Cranes, Budgit, Coffing, and Yale.

Most typical sizes are less than ten tones but larger models are made for large lifts such that take place in shipyards.

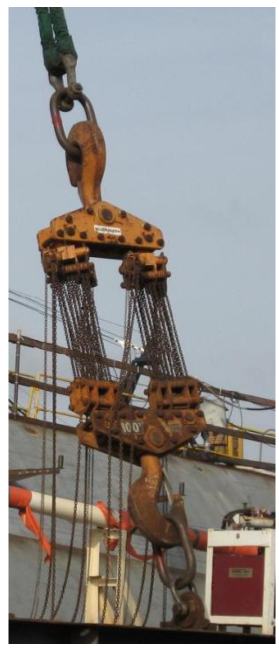


Figure 27: 100 Short Ton Manual Chain fall

Size

Chain falls and air hoist can be obtained from multiple manufactures in sizes up to 100 tons. Typically these hoists are not made for material handling but for precision lifting as the speeds that they reel in and out are quite slow at only a few feet per minute. The weight of the chain fall itself can be considerable and the weight per length of the chain must not be forgotten as the amount of chain can be varied to accommodate different lift length. Air hoists require air pressure to operate and without suitable air pressure will not engage for lifting or lowering. Popular heavy lift air hoists made by J. D. Neuhaus require at least 80 psi of air pressure with flow rates of up to 425 cubit feet per minute for a 100 ton hoist. These require considerable hose sizes that must be available at both locations of the lift and erection. For this reason manually operated chain hoists have benefit.

End Connections

Typically large chain falls used in a rigging arrangements used for large lifts have standard hooks at the top and bottom. These hooks can be used for both connecting to slings or shackles and allow that particular sling leg to be varied in length.

Standards and Regulations

The Occupational Safety and Health Administration has a specific section for the use of chain fall at shipyards which can be found in 29 CFR 1915.114. This section covers regulations for properly labeling chain falls, regular inspection, and required the mounting structure to be adequate to load and secure the hook from coming loose.

Other standards that relate to the design of chain falls and airhosts include ASME B30.16 which covers air powered and manual overhead hoists. ASME also has performance standards for hoists for evaluating the performance of particular hoists.

HST-5M Performance Standard for Air Chain Hoists,
HST-4M Performance Standard for Overhead Electric Wire Rope Hoists and
HST-6M Performance Standard for Air Wire Rope Hoists

5. FLOUNDER PLATES AND EQUALIZERS

Load Sharing Rigging Device Overview

Large blocks of ship structure lifted during construction often need to be picked up from multiple locations. This is due to the desire to spread the rigging forces over a larger area to avoid concentrating the loads imposed in just a few locations. This is often achieved through the use of rigging devices such as spreader bars, equalizer beams, and flounder plates to transfer the loads from one sling to two or more. The main geometric distinction between these devices is that flounder plates are smaller with an aspect ratio near unity and equalizer beams are typically much larger with higher aspect ratios. The proper function of these devices is dependent on several factors such as sling length, sling elasticity, block flexibility, aspect ratio of the flounder or equalizer plate, size of the flounder or equalizer plate, and other geometric relations of a given arrangement.

Figure 1. Load Sharing Device Near the End of Spreader Beam

As flounder plates and equalizers beams are often used in statically indeterminate arrangements, a solid understanding of critical factors relating to how they share or balance the load is necessary. Some of the main factors for how the load is shared is the location of the center of gravity, sling length, and angular arrangement of the slings. Overall sling leg length can vary from several factors such as manufacturing tolerance of the sling, height variation in the location of the attachment point, and differences in the size of shackles used. The load in a given sling can be a variable that is impossible to calculate, and often can only be estimated once the lift has occurred through inferred measurement. This is especially important when both legs of the sling are near vertical as seen in Figure 1 and Figure 2 where a rotation and load shift will result from one sling being longer than another. Experienced riggers will usually visually note the rotation when load is first taken up, and then add different size shackles as required to both slings to attempt to even out the load. Typically a correctly rated shackle will be added to the longer side, and a larger overrated shackle will be added to the shorter side, which will tend to even out the load distribution by bringing the overall lengths of the slings closer to uniformity.

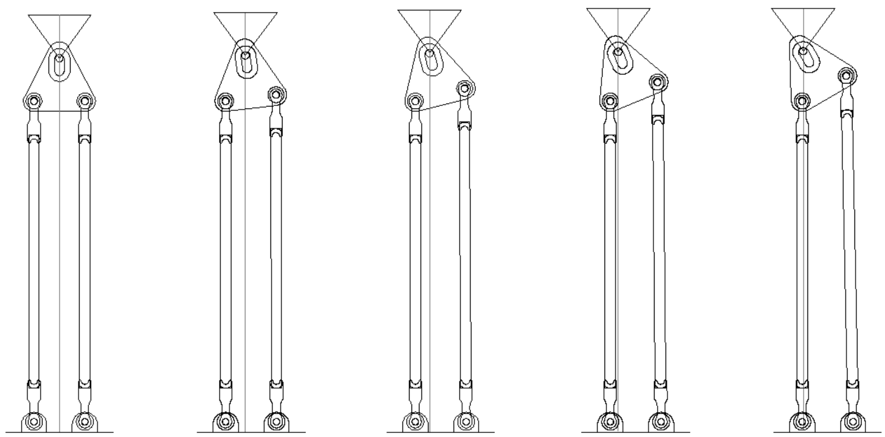


Figure 2. Depiction of Flounder Rotation Resulting From Sling Length Variance

When designing a rigging arrangement with flounder plates care must be taken to ensure the arrangement is balanced. Initially the line of action of the two resultant sling forces is inevitably offset some amount from the combined loading point and a moment is then placed on the flounder plate as load is applied. The two slings forces must counteract each other so that equilibrium is obtained with the sling tension as a direct function of how close their line of action is to the top loading point as seen in Figure 3. This trigonometric function that results can be relatively complex to solve because the translation and rotation of all members will result when not in equilibrium.

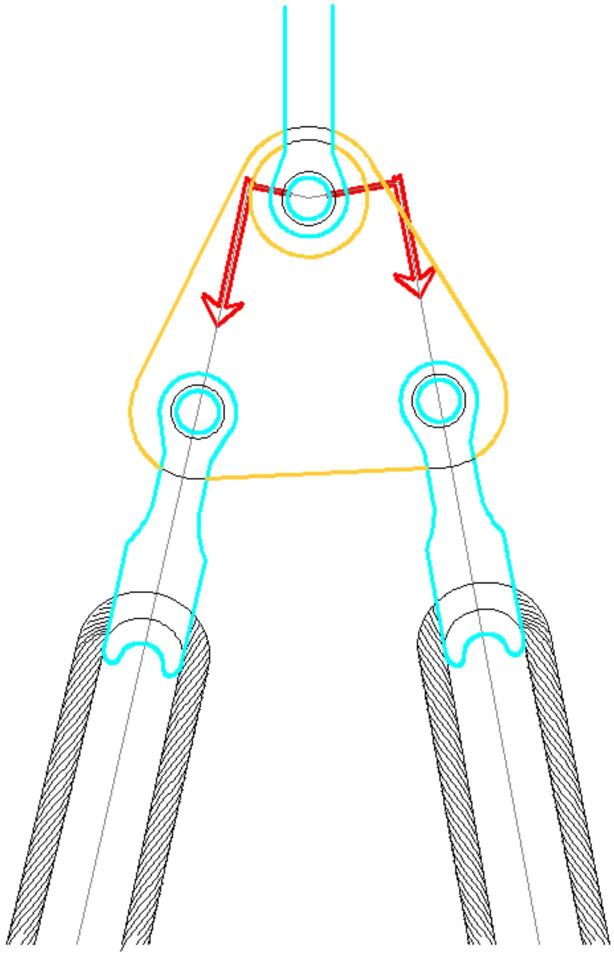


Figure 3. Offset Line of Action of Sling Forces

Calculation and Standardization of Load Sharing Device Geometry

For universally review and analysis of the behavior of flounder plates and equalizer beams a broadly applicable way of categorizing them is necessary. The use of a single length dimension of the distance between the sling attachment points allows these tools to be analyzed in a non-dimensional way. This allows the results to be easily extrapolated across the broad spectrum of plates being used by the shipbuilding industry. Figure 4 shows a flounder plate that is designed to be used with a crane hook, and the method of measuring the size and aspect ratio of the flounder plate. For comparison Figure 5 shows a typical equalizer beam and the typically larger size and aspect ratio associated with it.

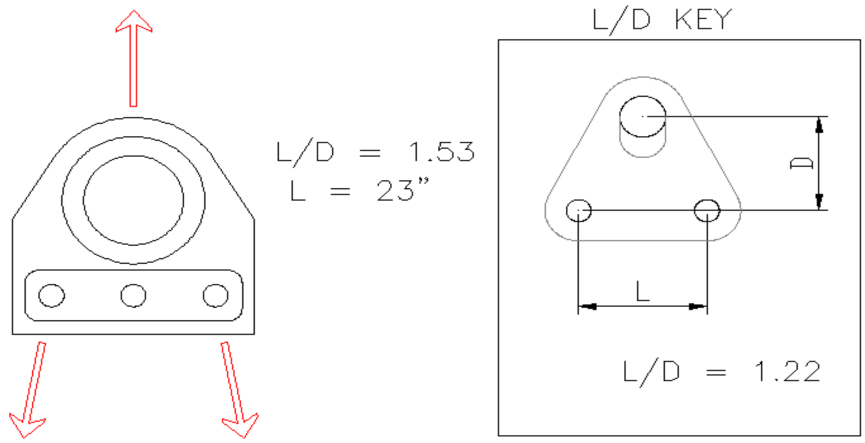


Figure 4. Typical Flounder Plate Made For Crane Hook (left)

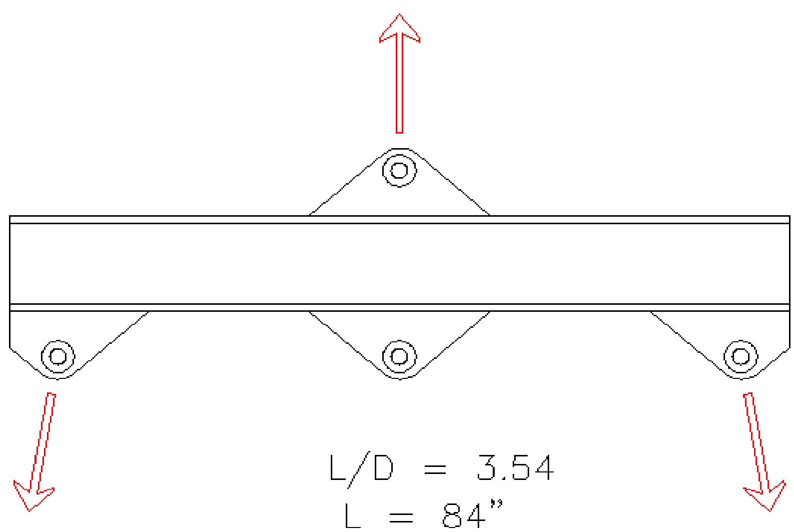


Figure 5. Typical Equalizer Beam

Given the variability of items that require lifting at shipyards, there is a wide range of flounder plates and equalizer beams available. A parametric study of flounder plates and typical equalizer beams found at shipyards combined with commercially available systems was compiled and can be seen in Figure 6. From this presentation of characteristics, the main geometric distinction of the overall size and aspect ratio between flounder plates and equalizer beams is more visible. As it will be explained in further detail, the reason for two relatively distinct groups is directly related to their best use. Flounder plates generally have a low aspect ratio that is ideally suited for single crane lifts attached directly to the hook. As a result, they tend to be smaller with typically no more than 30 inches separating the attachment points and an aspect ratio of less than two. Equalizer beams, which are better suited for complex, multiple-crane rigging operations tend to be much larger in length with sizes greater than 80 inches being common and also have larger aspect ratios that facilitates better load sharing. Some equalizer beams are built with multiple attachment points to maximize their utility. In Figure 6 these show up as lines with square points at the locations of functional usage. An example of a commercially available model of variable attachment load sharing bar which can be used as a flounder plate or equalizer beam is shown in Figure 7.

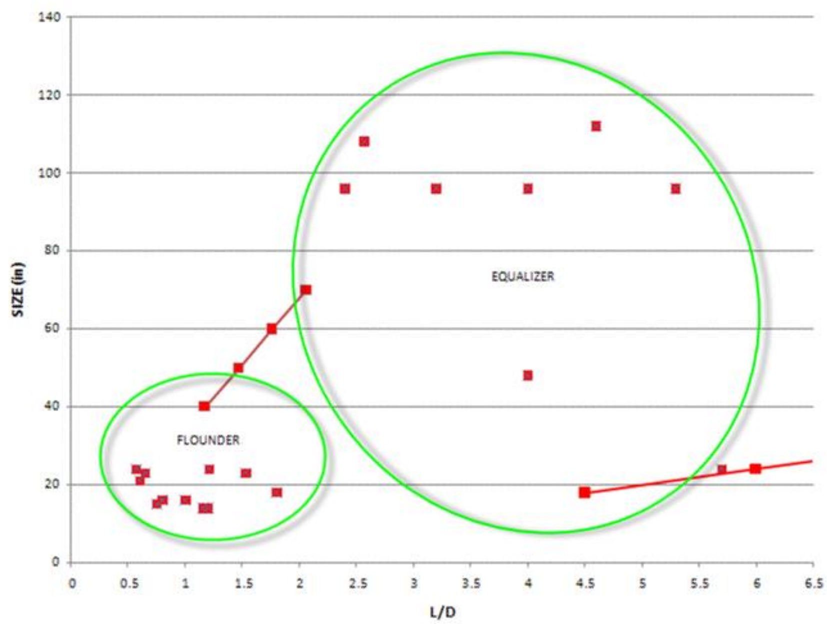


Figure 6. Parametric Review of Flounder and Equalizer Beams

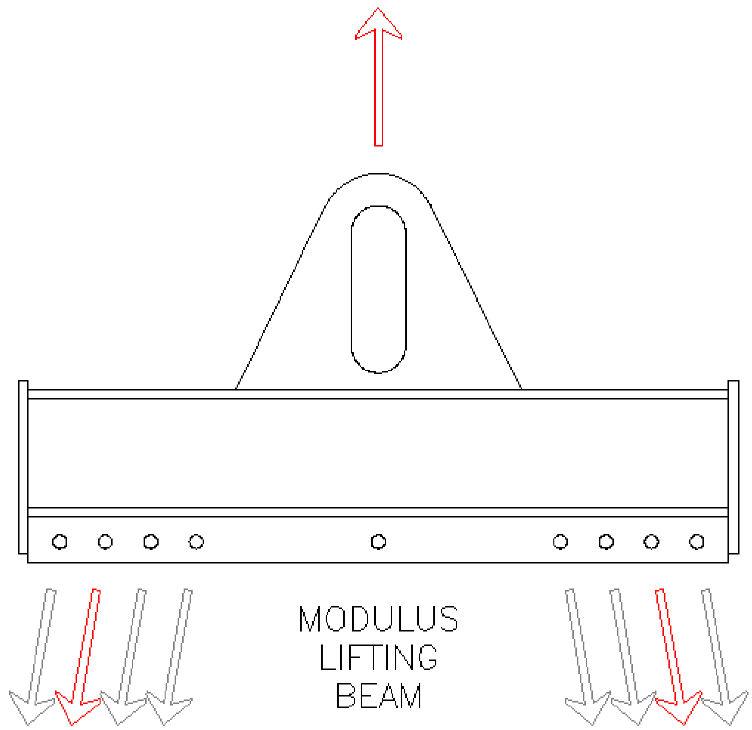


Figure 7. Variable attachment handling system made for a hook.

The analysis of a two sling load sharing system hung from one end of a spreader bar results in a system of five equations and five unknowns when certain assumptions are made. These assumptions relate to what components length or orientation changes the most, and are that the slings do not stretch or elongate significantly under load, there are no significant frictional effects in the various pin connections that would prevent rotation, and that any localized deflection of the block is far less than the translation that the equalizer plate allows. Most importantly it is assumed that the center of gravity of the lifted systems is reasonably known as if this were untrue significant deviations would alter the declivity of the block below, and the assumptions would lose validity. As the block is not expected to deviate from roughly horizontal it can be assumed that the load on the top of the flounder plate is always in the vertical direction, and the sling attachment points at the bottom of the system do not rotate relative to each other. This system shown in Figure 8 can then be readily solved with trigonometric identities or through the use of numerical modeling resulting in curves like that seen in Figure 9 Figure 10 and Figure 11. These curves of load sharing are valid when based on the analysis of two equalizing plates used under a spreader beam as used in some large complex rigging arrangements.

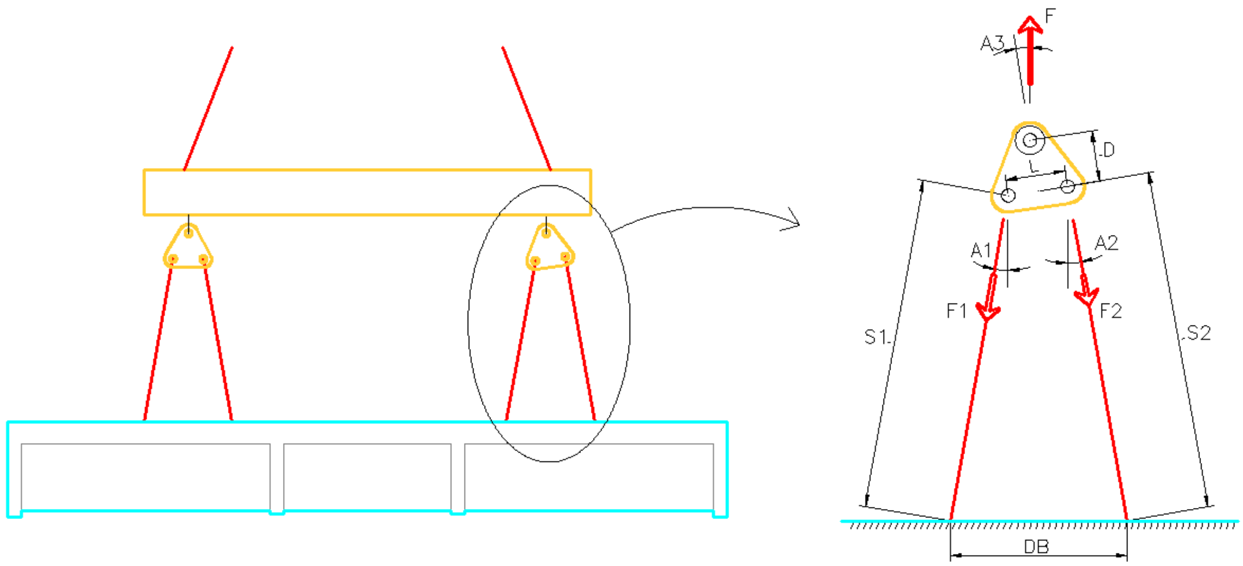


Figure 8. Free Body of Load Share Problem

The equation describing the system shown in Figure 8 are:

$$\sum F_x = 0: \qquad F_1 \cos(A_1) = F_2 \cos(A_2)$$

$$\sum F_y = 0: \qquad F_1 \sin(A_1) = F_2 \sin(A_2)$$

$$\sum M_{TopHole} = 0:$$

$$F_1\left[D\cos(A_3) + (\frac{L}{2})\sin(A_3)\right]\sin(A_1) + F_2\left[L\cos(A_3) - ((\frac{L}{2})\cos(A_3) - D\sin(A_3))\right]\cos(A_1) -$$

$$F_1\left[(\frac{L}{2})\cos(A_3) - D\sin(A_3)\right]\cos(A_1) - F_2\left[D\cos(A_3) - (\frac{L}{2})\sin(A_3)\right]\sin(A_2) = 0$$

$$\sum X_{GeometricHorizontal} = 0: \qquad DB = L\cos(A_3) + S_1\sin(A_1) + S_2\sin(A_2)$$

$$\sum Y_{GeometricVertical} = 0: \qquad S_1\cos(A_1) + L\sin(A_3) = S_2\cos(A_2)$$

From these equations curves were developed and represent the load sharing between the slings when there is a difference in length between them, which is shown on the horizontal axis of the curves. In most of these tabulated graphs this length difference is shown as percentage of sling length to keep the curves in a non-dimensional format. Figure 9 shows these curves in two formats, where on the left is sling deviation as a percentage of sling length and on the right is in inches of deviation. The graphs presented here show increasing sling length down the page depicting 10 foot, 20 foot and 40 foot sling lengths with additional length added to account for 85 ton Crosby shackle on each end. When the slings have exact equal lengths there is a even load share with 50% of the total load in each sling. It can be seen on the right side of this figure that a high aspect ratio equalizer shares the load remarkably well with the more heavily loaded sling having 55% of the total load, resulting from a 4 inch difference in sling length. The left of this figure shows what appears to be less of a load share, but this is slightly deceptive because this information is presented in terms of percentage of sling length and a set percentage of a longer sling represents more deviation from an ideal share.

Figure 10 is a direct comparison of a high aspect ratio short length equalizer with a low aspect ratio flounder plate of the same width. For a ten foot sling length, the curves can be directly compared in the top two graphs. It can be seen that for a given deviation in sling length, the high aspect ratio equalizer shares the load more equally. It can also be seen that high aspect ratio equalizers are less affected by the separation distance where the slings meet the ship unit block. This separation distance, DB, has effects that can clearly be seen for the lower aspect ratio flounder. When the slings are near vertical with a base separation distance of 30 inches, a 2.5% deviation in sling length with ten foot slings causes the more heavily loaded sling to take 87% of the total load. When the separation distance is 90 inches the same deviation causes the more heavily loaded sling to take 65% of the total load, which is a more even load share. However, this does represent a slightly larger average sling load as the increased angle of the slings results in a greater tension in the slings for the same vertical force.

Finally Figure 11 shows curves developed for various aspect ratio load sharing devices of similar size such that one can see the effects that aspect ratio has on load sharing ability. From this it can clearly be seen that in this application, high aspect ratios equalizers are better for sharing the load. The main drawback to a high aspect ratio design is that the internal stresses in such an equalizer are much higher and would thus need to be comparatively heavier, with more consideration given to the structural design.

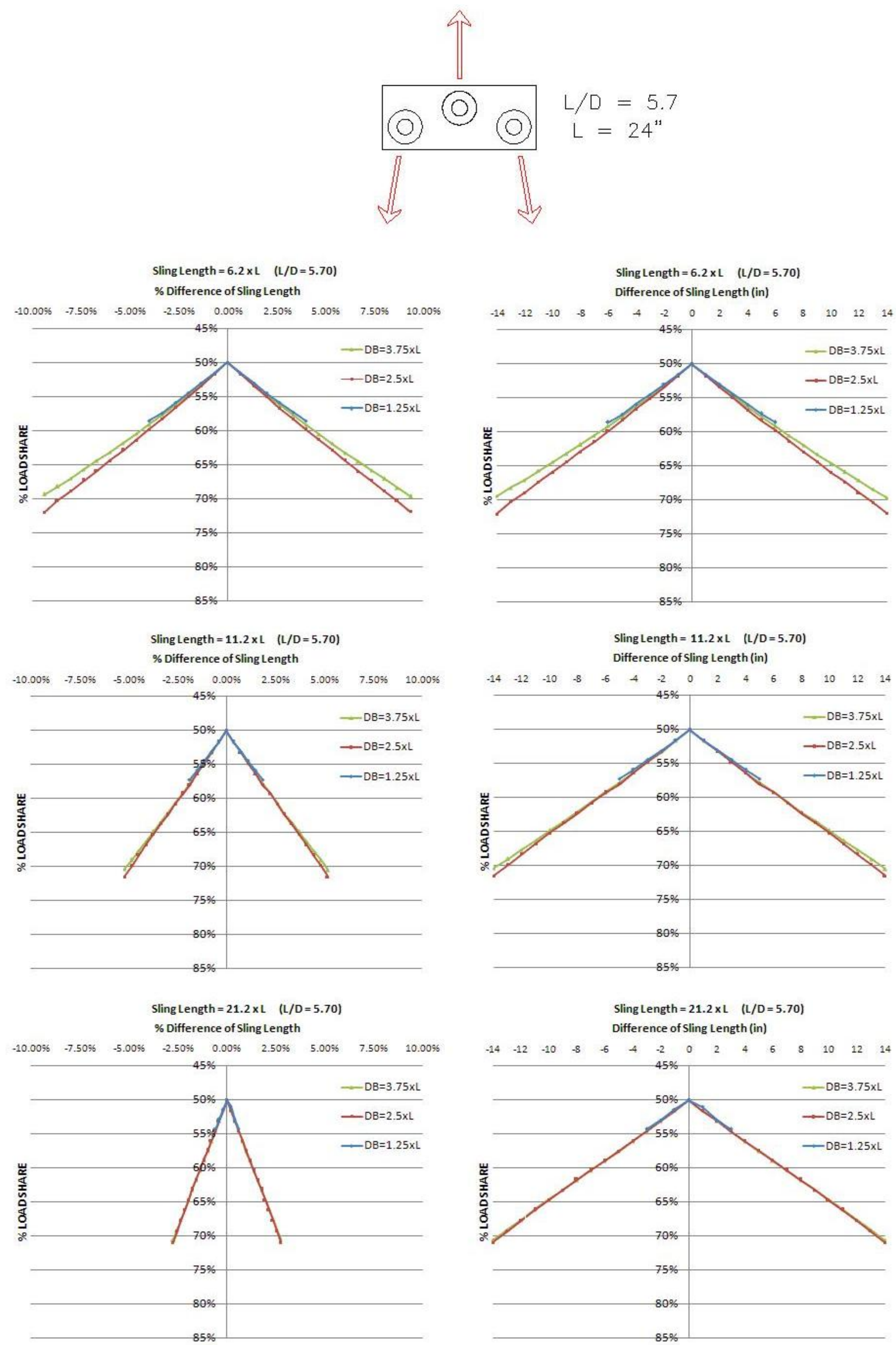


Figure 9. High Aspect Equalizer Plate of Minimal Length

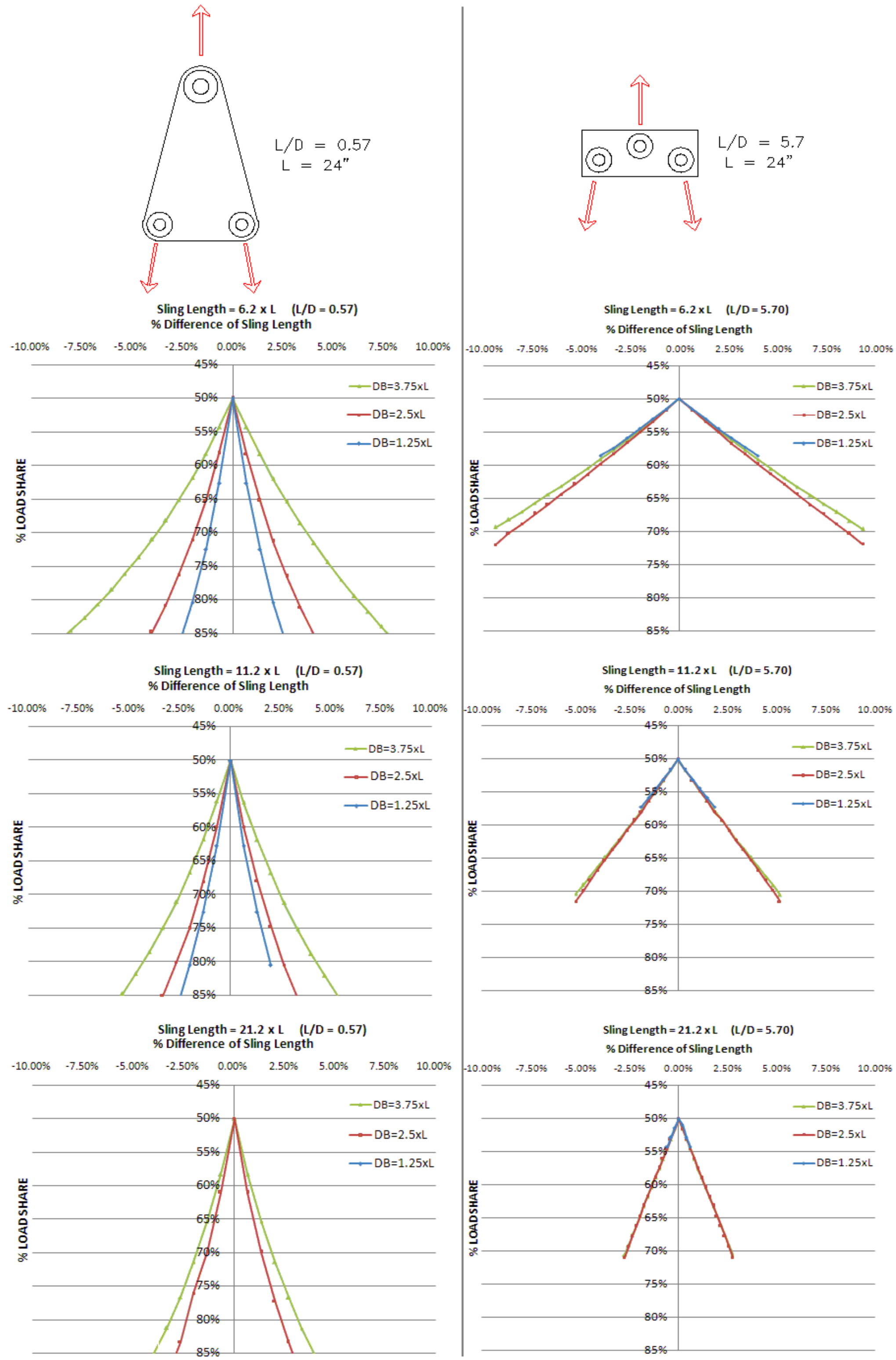


Figure 10. Comparison of Load Share for High and Low Aspect Equalizer Plate of Minimal Length at Different Spread Widths

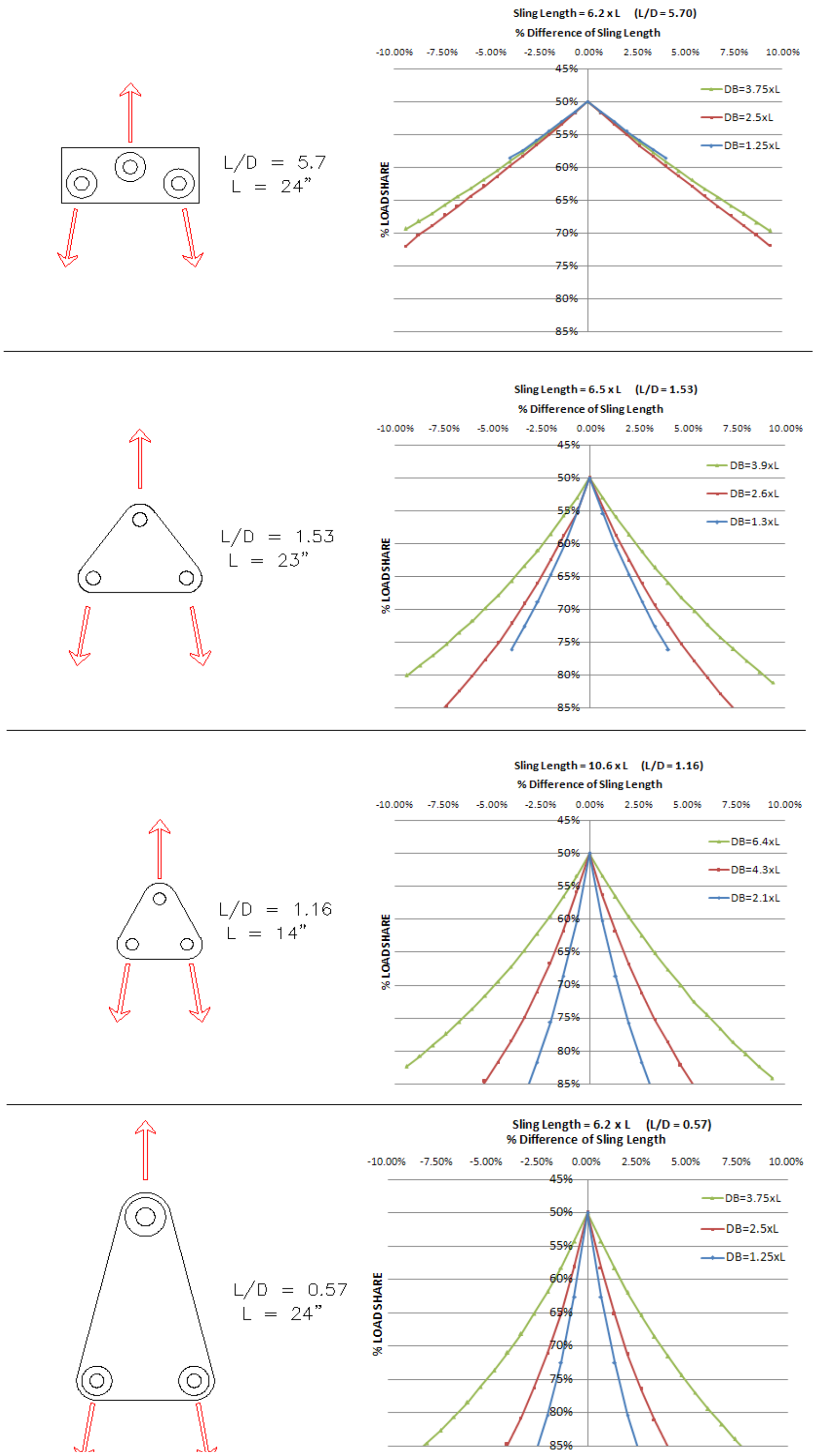


Figure 11. Comparison of Load Share for Various Aspect Ratio Equalizer Plates

Flounders and Equalizers in Complex Rigging Arrangements

Large lifts of typical ship structure often requires the distribution of the sling forces to a large area such as to eliminate concentrated loading that can be detrimental both local structure and the global response of the entire block. Some very flexible, small assemblies also require a complex system of spreader beams, flounder plates and equalizers because they are not capable of supporting themselves from a minimal number of lifting points without excessive deflection or distortion. A typical example of a two crane, four equalizer plate complex rigging arrangement commonly used to distribute loading can be seen in Figure 12.

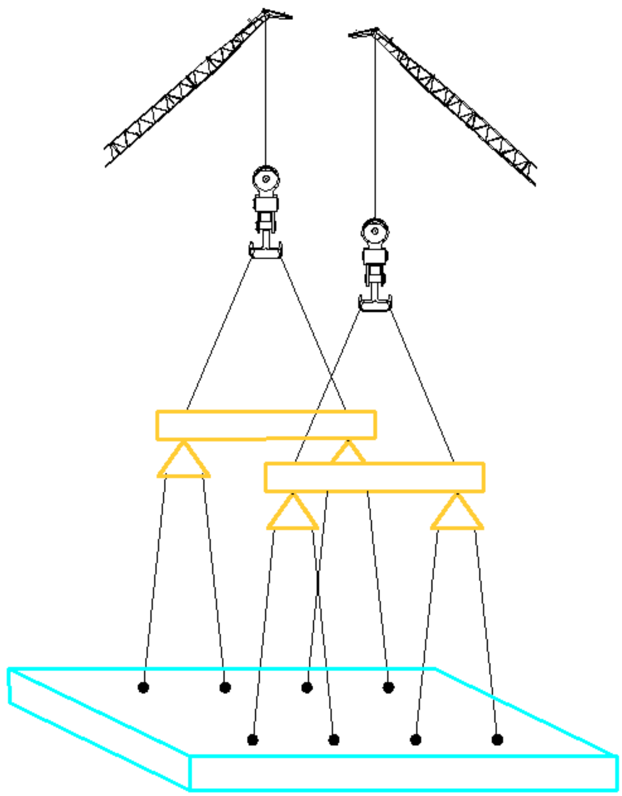


Figure 12.   Two Crane Eight Sling Spread Rigging Arrangement

In this figure we see each crane holding a spreader bar with two equalizer plates underneath and a total of eight slings attached to the block. Although the load for each crane can be calculated with a known block center of gravity, the exact load in a particular sling represents a statically indeterminate problem. Without equalizer plates the specific forces in each sling depends entirely on the exact length and stiffness of the sling along with the blocks rigidity, along with other geometric factors of the global rigging arrangement. Wire rope and high strength synthetic slings are relatively stiff with elongations of about a quarter of one percent and one percent respectively at the full rated load. This means that total elongation for a fully loaded 30 foot long wire rope sling is less than one and a half inches, and the relative difference between two of such slings loaded at 80 and 50 percent of capacity would be expected to be on the order of 3/8 of an inch. As the manufacturing tolerances of wire ropes are on the order of a half a percent the sling length, or almost two inches for the 30 foot sling mention above, the importance of soft connection devices such as equalizer or flounder plates that facilitate the small length adjustments necessary to evenly distribute the loads are clear. Similarly as lifted deflections of bulkheads in large multistory blocks can be shown to be minimal, the importance of soft connection devices for safe operations is necessary. Since the assumption that equalizers or flounders will always distribute the load equally is incorrect, and even with these devices slings could have zero or minimal tension, with the subsequent shifting of load to the others members, an understanding of their operational limits is fundamental for safe rigging.

An example of an improperly designed rigging arrangement can be seen in Figure 13 where it can clearly be shown that the forces acting on the equalizer plates are not depicted in equilibrium on the left. The subsequent lifting would result in the rotation of the equalizer plates and in this particular case, with a low aspect ratio load sharing device, and a non-symmetrical arrangement, the outside two slings will be relieved completely of any load. In the previous section, it is shown that low aspect ratio equalizers as shown below are not the best shape to assist the even sharing of the sling forces. This zero tension scenario is certainly true if the block is rigid and the slings are stiff. However, if the block is extremely flexible it would deform and deflect until the outside slings began to see some load. Similarly if the slings are very flexible the heavily loaded slings would stretch and lengthen, which could also result in the outside slings reengaging themselves and taking some of the load of the block. Although both of these factors can be true to some extent, typical large ship blocks are not flexible enough, and high capacity slings not elastic enough to allow the even distribution of load among them. The result in this extreme case would be that several components from the block, padeye, shackles, and might see as much as twice as much load as the ideal or planned scenario. Furthermore not only will the padeye on the block see much more overall load, but the angle at which the tension is applied will result in a greater amount of side load, which can be very detrimental.

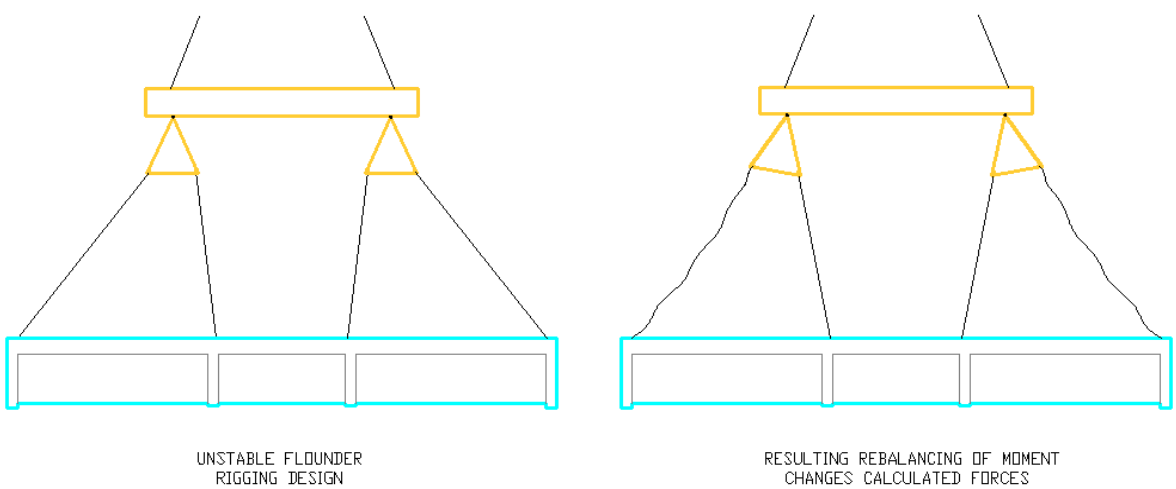


Figure 13. Poorly Configured Equalizer Arrangement Beneath Spreader Beam

The best geometry for a load sharing device below a spreader beam is one with a high aspect ratio as this can be shown to share the load the most equally among all the slings. A depiction of this can be seen in Figure 14 where the top two graphics show an idealized lift of a two dimensional structure and the bottom two graphics show what will happen when the far right sling is made two percent longer. Although in both cases it results in a slight rotation of the block along with rotation of the equalizer it can clearly be seen through review of the line of action of the slings that that the low aspect ratio equalizer on the left produced the most concentration and increase of individual sling tensions. Extrapolation of this concept to a three dimensional lift further complicates rigging analysis as one would now have to account for the torsional resistance and deflection in the block. As any real world situation will have not just one sling longer but multiple tolerances, stiffness's, and variations to deal with, one can imagine the complications for analysis that will result. Inevitably to a significant degree a rigging engineer or lift designer is going to have to strive to implement the best possible arrangement with the best equipment obtainable and then select appropriately increased design factors and margins to account for the range of variability that exists within or because equipment, as well as operational factors and other unknowns. A rigging Engineer can review typical tolerances for slings and installation variances and get a rough approximation of the amount of load sharing that can typically be expected.

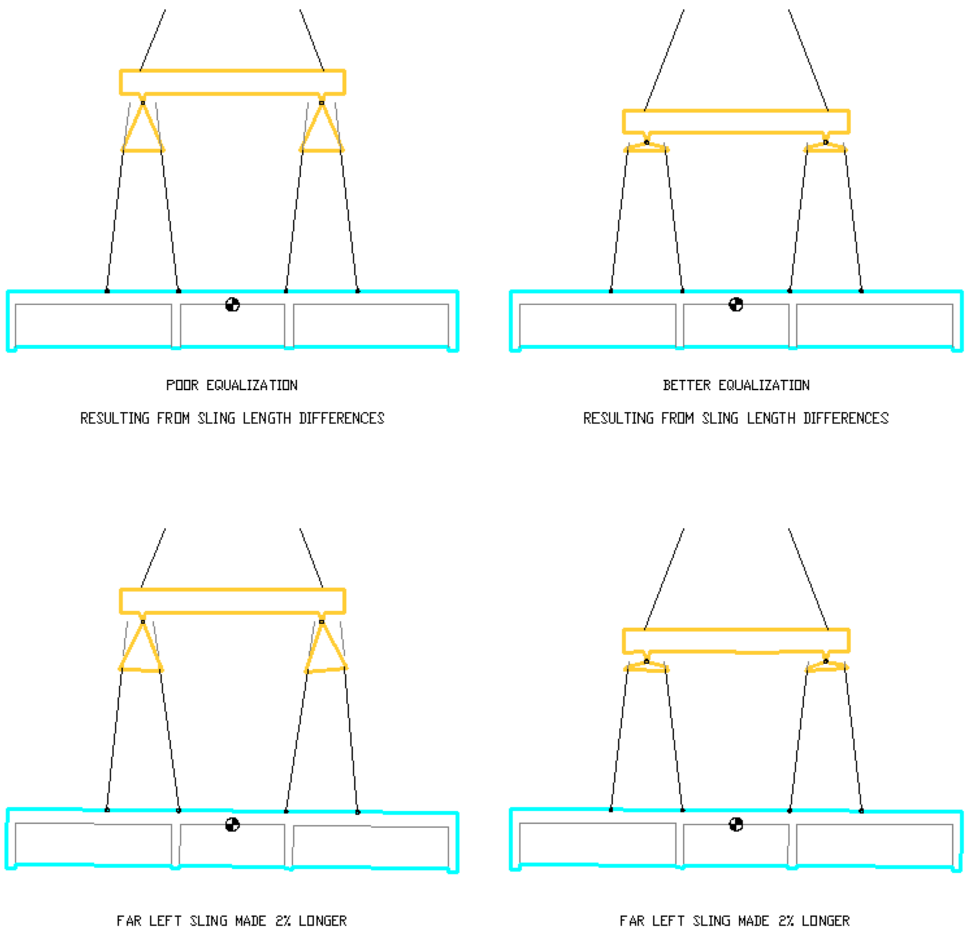


Figure 14. Best Type of Equalizer Under Spreader Beam

Another important aspect of rigging arrangement design is that the designer must account for the fact that during some rigging operations, the arrangement configuration will change through the course of the lift. This is especially true during turning operations as seen in Figure 15, which shows a depiction of a highly cambered deck being flipped. Although the sling lengths are initially set such that they all equally sharing the load, the act of block rotation alters the relative heights of the attachment points. This effectively causes the sling lengths to change, which results in the load no longer being shared the same. In this exaggerated case it can be seen that after the block has been rotated from upside-down to ships position the inside slings are now slack and carry no load. This results in the outer slings taking the entire load which is more than twice the original tension, increased slightly due to the slings vertical angle change. The result in this extreme case would be that several components from the block, padeye, shackles, and might see as much as twice as much load as the ideal or planned scenario. Furthermore, not only will the padeye see an increase of overall load, but the increased angle at which the tension is applied will result in a greater amount of side load, which can be very detrimental. This example is shown with a relatively extreme camber on the deck, which requires the load sharing devices to make up a greater adjustment of sling length. Most vessels will not have such extreme camber, so the effect will be less, but still requires review and consideration.

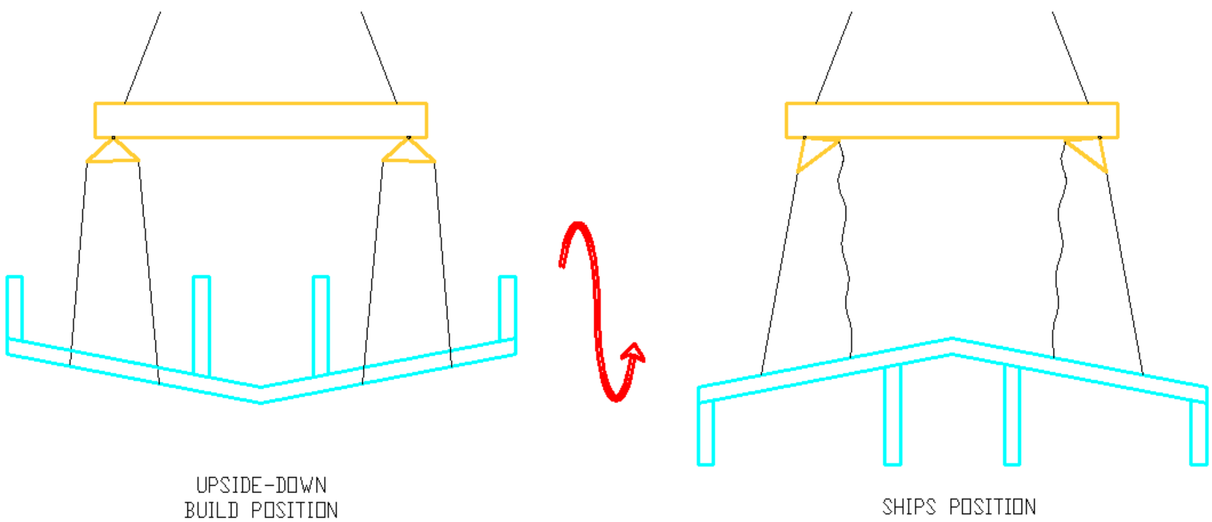


Figure 15. Load Redistribution During Turn as a Result of Attachment Point Height Variance

Whenever possible one should strive for a design that is balanced at all times and will not experience a variance in the required sling length that translates to different and increased sling tensions. These effects can be eliminated if all attachment points occupy the exact same axis, so that the centers of all pin connections that experience rotation during the turn are collinear. Furthermore, this effect will be minimized if the aspect ratio of the equalizer is high because this geometric configuration allows the most forgiveness in this application due to the larger rotation sweep and subsequent equalization range. In cases where significant sling adjustment will occur during the lift, it may be possible to pre-load the side that will experience load relief to minimize loading variation. The concept of this pre-loading can be seen in Error! Reference source not found.Figure 16.

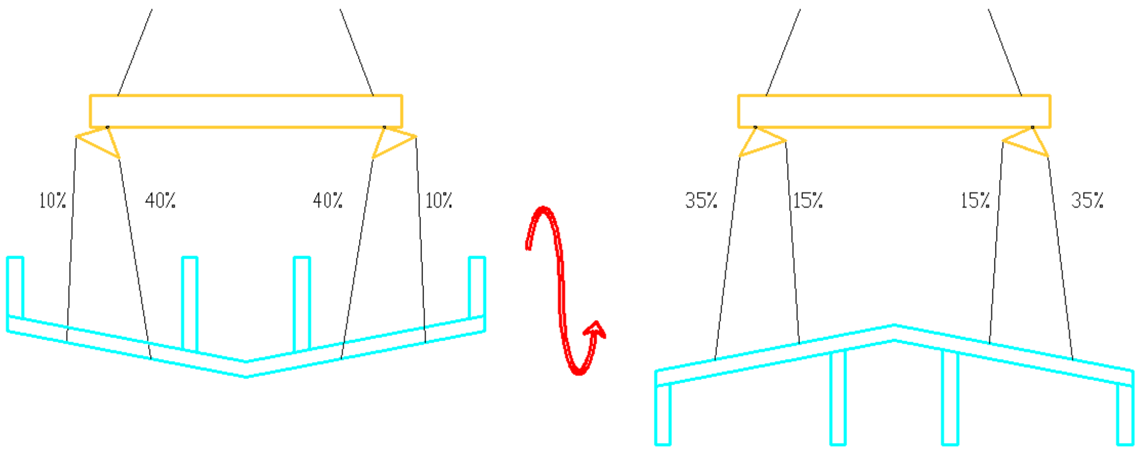


Figure 16. Load Redistribution During Turn as a Result of Attachment Point Height Variance

Equalizer and flounder principles can also be applied to large gantry cranes which can effectively be compared to multiple cranes acting together, in which equalizers with flounders are used upside-down to lift small but heavy objects. Figure 17 shows this analogy by comparing the similarities between a large gantry crane rigging arrangement and a more traditional use of large equalizers with two cranes. In this example both are depicted lifting a small but heavy object that is beyond the capacity of a single crane or winch unit.

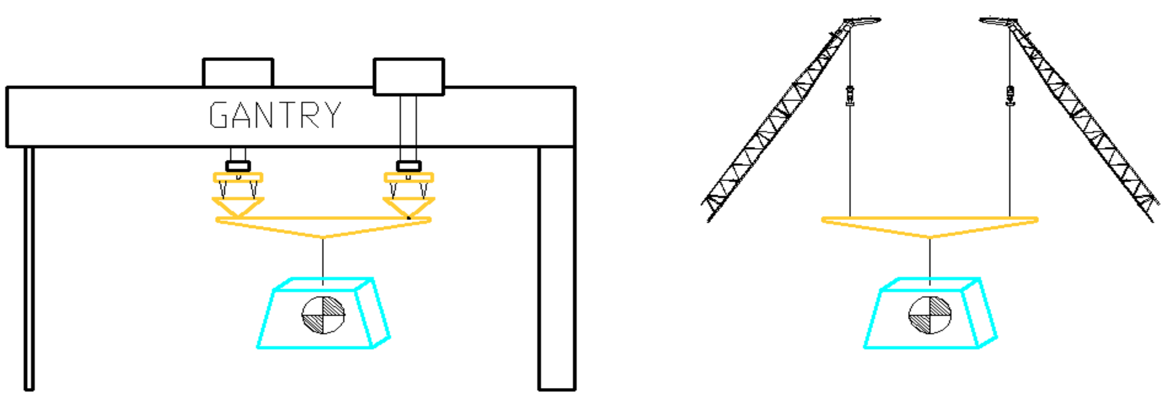


Figure 17. Large Equalizer Beam Between Two Cranes or Gantry

A representation of a nested equalizing bar usually present on large gantry cranes is shown in Figure 18. It can be seen that it acts as a cascading group of equalizers, which helps distribute the load on the various slings. Through independent rotation between the three various members, the loads are more or less evenly distributed on all slings. Each equalizing member has an infinite aspect ratio, which allows an almost completely equal division of the load. Complete equalization can only be obtained through the slings having equal and opposite lines of action, on each side simultaneously, for complete balance to be achieved. Unless all slings are vertical this will most likely never be achieved but the design does create the most uniformly equal distribution of load practically possible.

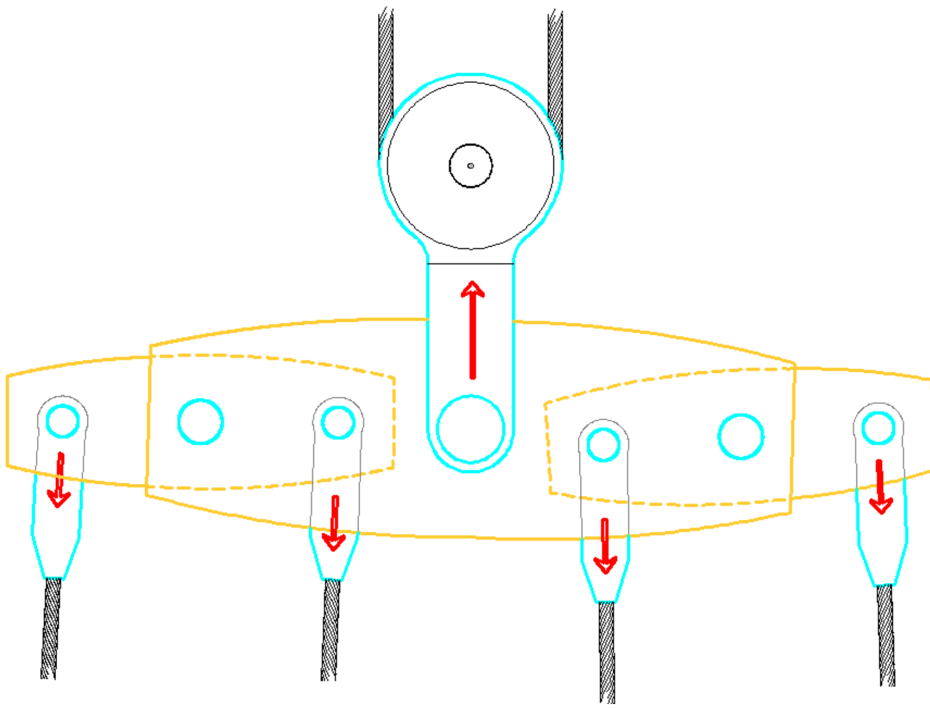


Figure 18. Typical Nested Equalizer Bar Under Large Gantry Winch House

Single Crane Use of Flounders

Lifting an object with a single crane and four slings that are connected rigidly, represents a statically indeterminate problem in which the actual vertical component of force in each sling is unknown, and can vary from nothing to half of the total load. This is because if one sling is slightly longer than the others it will not engage the load and will hang slack. This sling's opposite corner attachment will thus similarly be slack, as all the moments created about the center of gravity must have a equilibrium maintained. This is especially true if the slings are not elastic and do not stretch much under load, which is the case for wire rope or high tensile strength synthetic slings such as Twin-Path with K-Spec. This concept is widely understood as a four legged stool or table with one leg longer or shorter than the others which will forever rock back and forth on two legs at opposite corners, with these opposite leg pairs taking all the weight. This concept as it relates to rigging is shown in Figure 19 where two different possible vertical components of the sling tensions are shown.

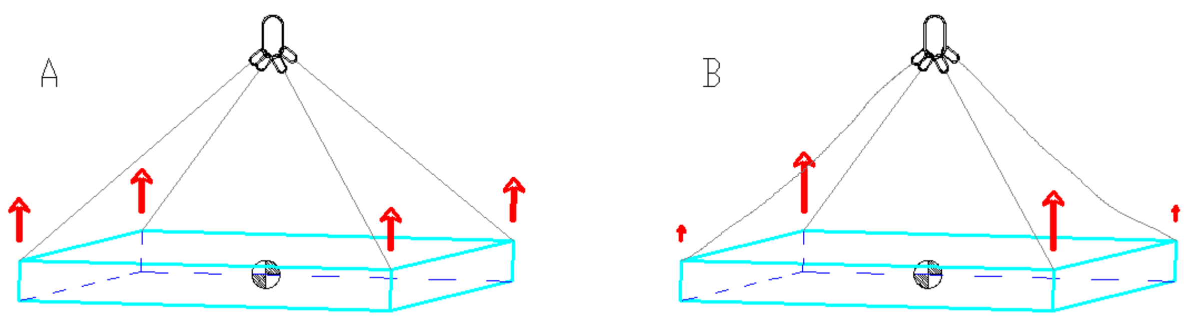


Figure 19. Indeterminate Four Slings Arrangement

In rigging flounder plates have traditionally been used as a form of sling equalizer allowing a more equal tension on all four slings during a single crane lift. These plates work because they create what can be considered a soft connection, in that they allow rotation that effectively varies the length of the slings by the translation of the attachment points through an arc. The use of flounder plates is safer and stronger than other methods of sling equalization such as wrapping the sling over the hook, because it prevents slippage of the slings if the arrangement is unstable, and furthermore does not create a loss of strength as a result of a bend radius created in the slings over the hook. A representation of a typical single crane lift utilizing two flounder plates can be seen in Figure 20.

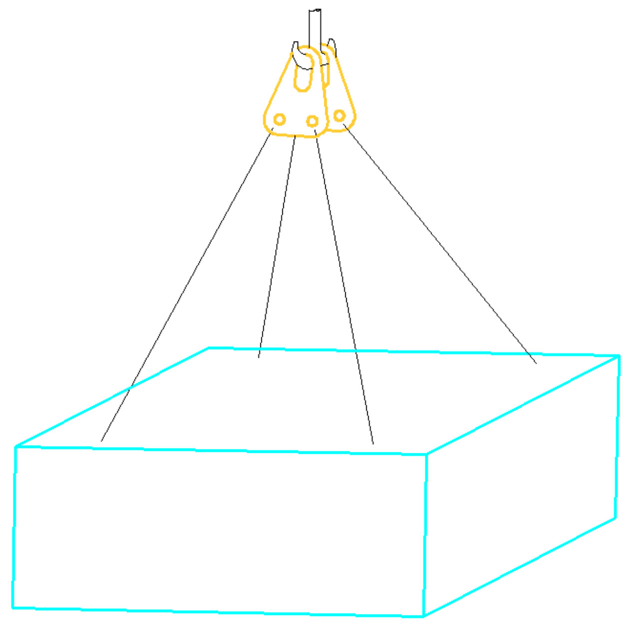


Figure 20. Two Flounder Plates on Either Side of a Sister Hook

Flounder plates have certain strength advantages over other methods of sling equalization but attention must still be paid when configuring a rigging arrangement as there are limitations to their effective range. It should be realized that the loads in the slings are not always distributed in the ideal 50-50 share but are a variable depending on the geometric factors and sling properties. Flounder plates work as the slings attached, impart moments that rotate the plate into a stable arrangement in which there is a balance of forces about them. This is accompanied with sling and block rotation, along with translations of a small but important amount, the main driver of which is the lowering of the blocks center of gravity. These adjustments will have the effect of increasing some sling tensions, so an understanding of the probable result along with the estimate of the final stable arrangement should be made. An example of this re-balancing can be seen in Figure 21 where the initial unstable configuration results in rotations and shifting of the forces carried between members.

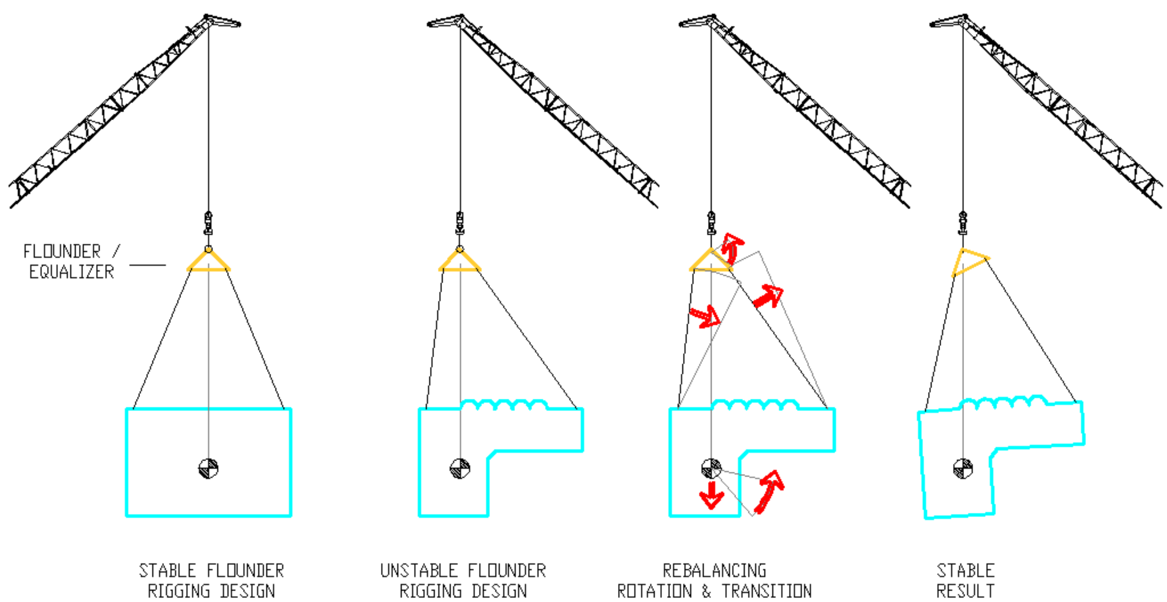


Figure 21. Rebalancing of Load and Flounder Plate

One of the very first concepts of rigging is that for a single crane lift the center of gravity (COG) of what is lifted will always end up directly below the hook. This concept holds true with flounder plate use and although rigging arrangements can be more forgiving with their use, the design of a proper arrangement still requires a reasonable estimation of COG to be made. For any arrangement to be stable, or lift as intended, the center of gravity must be bounded by the attachment locations of the slings as shown in Figure 22, and preferably have the COG equal distance between sling attachment points.

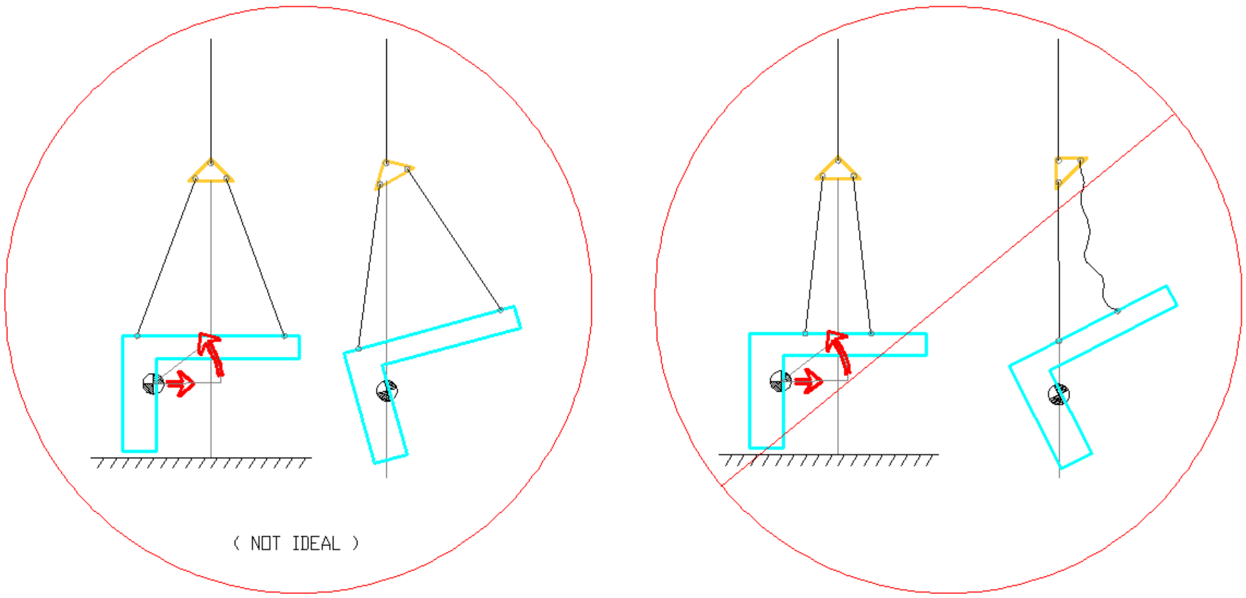


Figure 22. Flounder Plates Use Still Requires Good Estimation of the Center of Gravity

It is inevitable that some inaccuracy results when estimating the center of gravity of an object, which can be considered an offset between its predicted, and actual position. Along with the design of the rigging arrangement the shape of the flounder plates has a significant effect as to how well the slings forces are balanced, and the resultant angle of the lift. Flounder plates that have a low aspect ratio, as shown on the left in Figure 23, will typically result in lower sling tensions and less angular rotation of the object lifted, due to an offset of the estimated center of gravity. It therefore can be readily concluded that flounder plates with low aspect ratios are better for use on single crane lifts.

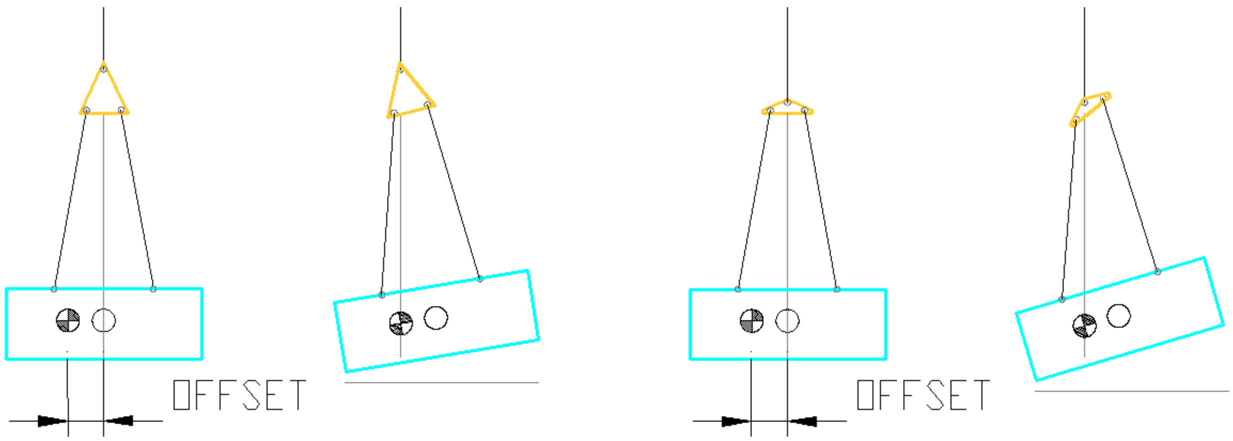


Figure 23. Inaccuracy in COG Estimation Results in Rotations

Some rigging arrangements are more susceptible to lifting adjustments particularly when there are significant differences in the planned angles or lengths of the slings as shown on the right of Figure 24. These complex lifts typically require alteration of slings lengths, possibly due to the asymmetry of the object or obstructions preventing a symmetrical and balanced rigging arrangement. Examples of the block geometry preventing the preferred simple arrangement as can be seen in scenario B and C in which the slings are prevented from being the same or approximate equal length. If the stable arrangement is easy to calculate and the increased length of sling required small, extra shackles can be inserted into the sling to increase it to the required length as shown in scenario B. This can typically be calculated through a numerical or iterative application of the elementary principles of statics. However this calculation for exact sling length can be fairly complex at times and typically requires a highly accurate estimate of the center of gravity, and if an absolutely level lift is required, the easiest engineering fallback is to specify that a chain fall be used as seen in scenario C. With the use of chain falls the sling lengths can be quickly adjusted in situ to the exact lengths required to ensure a level lift. Setting up a chain fall for a large lift can be fairly laborious and typically there is the desire to avoid this especially on large complex lifts. Where possible the slings should be kept the same length, and evenly spaced on either side of the center of gravity, to avoid the complicated multi-degree of freedom calculations that would need to be done to check the resultant re-balancing that occurs. This straight forward case can be seen in scenario A, which represents the best arrangement as it is the most likely to divide the sling forces equally when tolerances of the slings or COG estimate create slight adjustments, and furthermore allows the easiest and most straight forward tabulation of the resulting sling tensions, and ease of rigging.

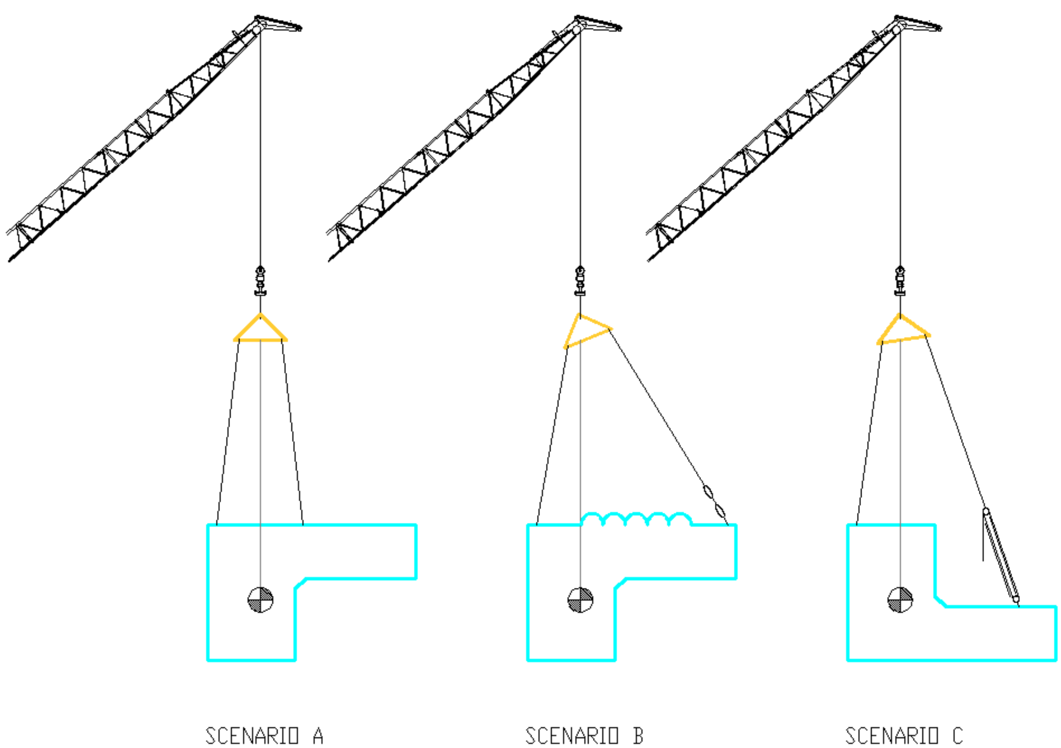


Figure 24. Flounder Plate Applications

Additionally flounder plates are sometimes used directly with a cranes sister hook as a method of attaching a single sling. This is typically needed when the sister hook does not have a central attachment point for a single shackle. As sister hooks have limitations as to the amount of loading that can be placed on only one side, flounders can be used to distribute the load to both sides as shown on the left of Figure 25. Here two large shackles are attached to the flounder plate and looped over each side of the hook. In this way a single sling with a relatively large load can be attached to a sister hook while staying within the capacity limits of the hook.

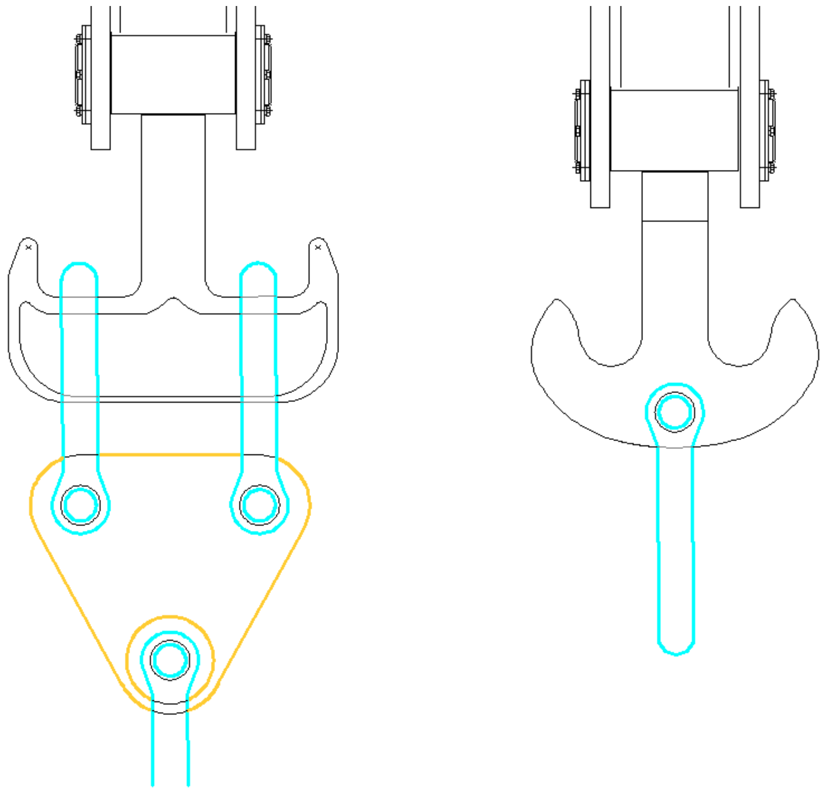


Figure 25. Flounder Plate Use on a Sister Hook

The concepts addressed when reviewing flounder plates are also directly applicable to lifts with spreader beams. Spreader beams can be thought of as very large flounder plates as shown on the right of Figure 26. As rigging slings are relatively rigid the top half of a spreader beam arrangement will have very similar behavior that a large flounder plate made from steel plate. In this regard a lower aspect ratio arrangement will result in less angular deflection of the load, for a given of center of gravity offset.

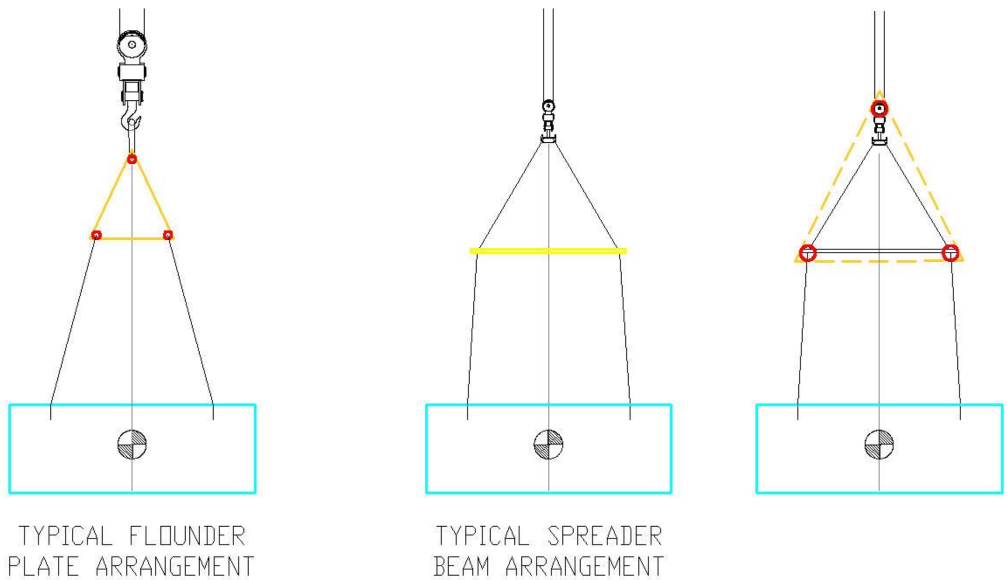


Figure 26. Comparison of Flounder Plate and Spreader Beam

6. SPREADER BEAMS

Manufactures

Typical shipyards will require spread lifting capabilities matching the lifting capacity of their largest crane, or a rough average of about 300 tons. This capacity is larger than most commercially available bar manufactures produce and can require a custom order or design.

Readily, available commercial spreader bars have primarily smaller lifting capabilities than but larger working loads can be obtained. Spreader beam manufactures include, Bushman Cadwell, Modulift, Tandemloc Inc, and Vestil.

NASSCO has roughly 24 spreader bars in regular use, ranging form 2.5 to 295 short tons lifting capability and form 4 ft to 42 ft in spreadable length. The largest spreader bar matches the lifting capability of the largest crane . Many of the spreader bars have a unique geometry and lifting attachments to accommodate a large range of lifts. All spreader beams have been custom designed in house.

End Connections

Spreader beams are used to spread the load of an object being lifted and they achieve this by different forms of attachments. Typical attachments points are hooks, permanently secured master links, or pin connections for shackles or endless slings. Most critical lifts are secured with either padeyes and shackles or pins and endless synthetic slings .

Standards and Regulations

The best standards for spreader beams are the American Society for Mechanical Engineers Below the Hook Lifting Devices Design Guide and associated standard B30.2. Special considerations need to be made during the design of spreader beams as the long life cycle can have significant effect on the design. It is possible that during this life cycle they will perform tens of thousands of lifts potentially of unknown loads and variable conditions. A respectable design factor should be chosen as bearing wear, fatigue, corrosion, and other effects of ageing that will set in.

Allowable Loads

As large spreader beams are typically unique they will have specific allowable loads associated with them. It is recommended that for any given spreader beam documentation be created that explains what these allowable loads are. An abbreviated example of such a guide is shown in Figure 28 where allowable loads at specific location can be referenced.

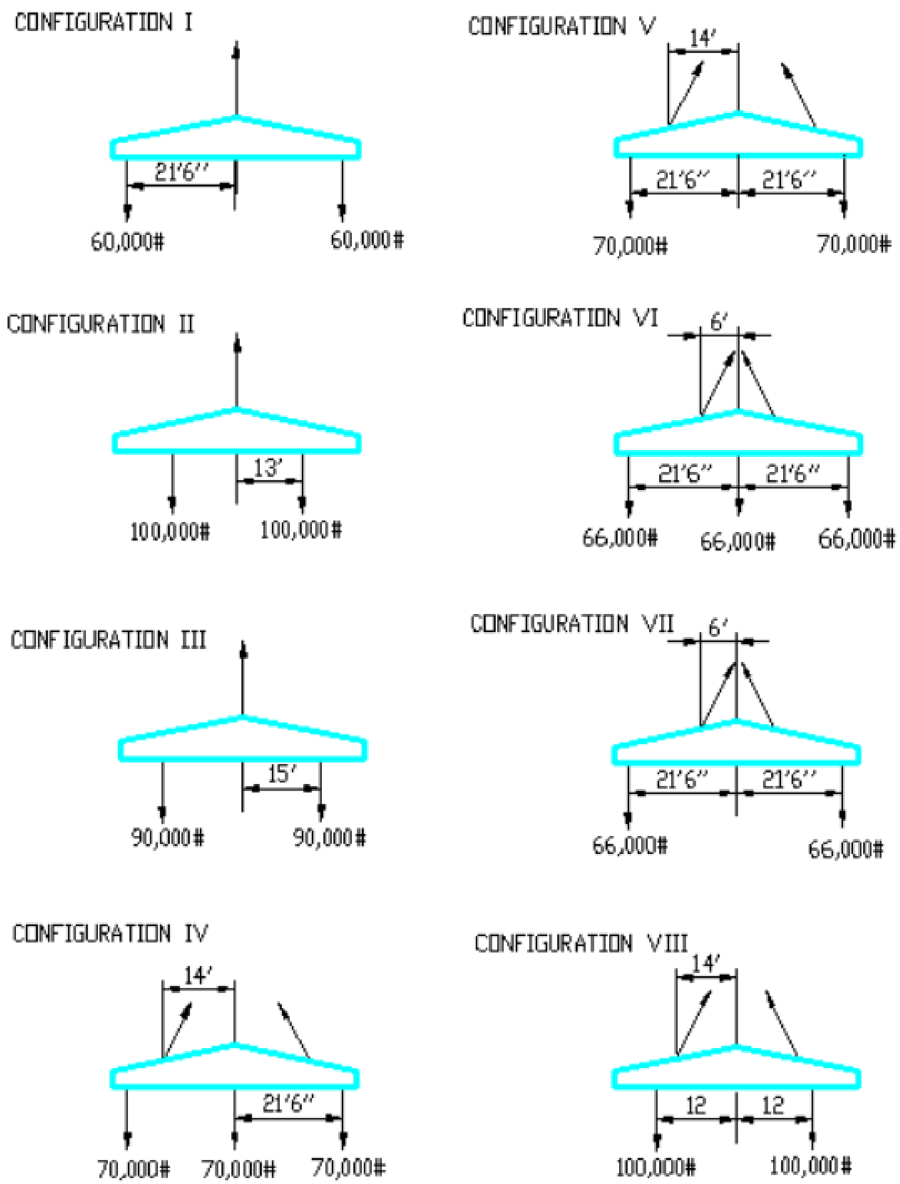


Figure 28: Typical Spreader Beam Allowable Load Guidance

Sizes and Standard Types

Box Spreader Beam

NASSCO spreader bars include, four adjustable box beams, two with 295 ton lift capability and two with 170 ton capability. The 295 ton spreader bars have top and bottom lifting attachment which always travel together and span 14 feet to 50 feet with 5 configurations in between. These beams, however, cannot be used as equalizers and are not deigned to withstand much internal moment.

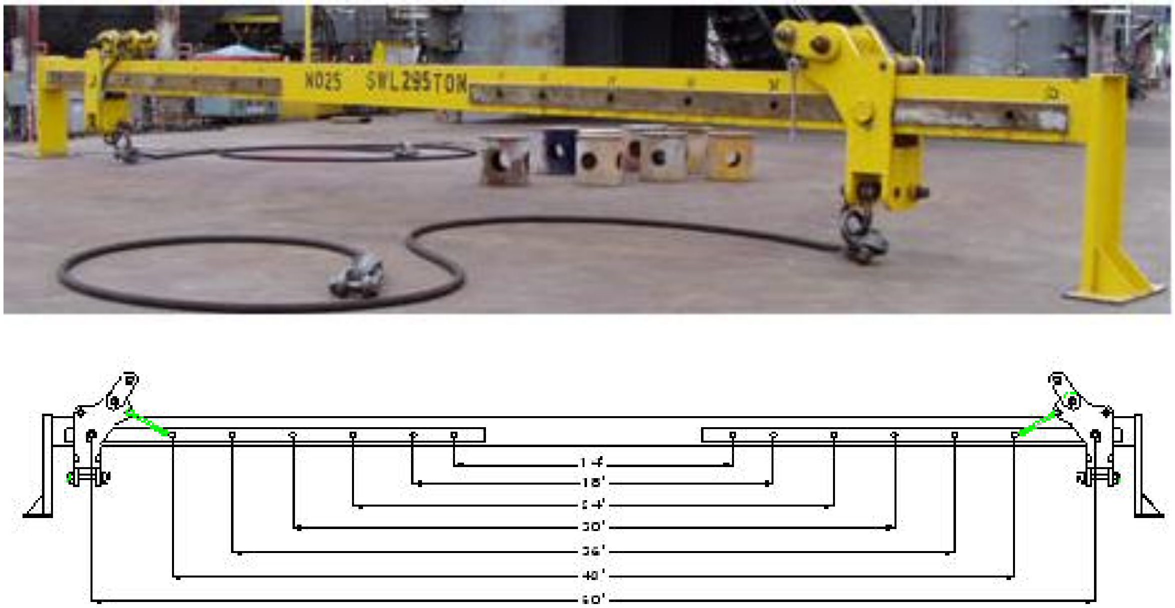


Figure 29: Adjustable Box Bar Spreader Beam

Round Spreader Beam

Round bar has a lift capability of 210 tons and span of 14 ft, with effectively two padeyes on top and two on bottom, located on each end. This spreader is similar to the adjustable box beam spreader for use but cannot be adjusted with regards to spread distance.

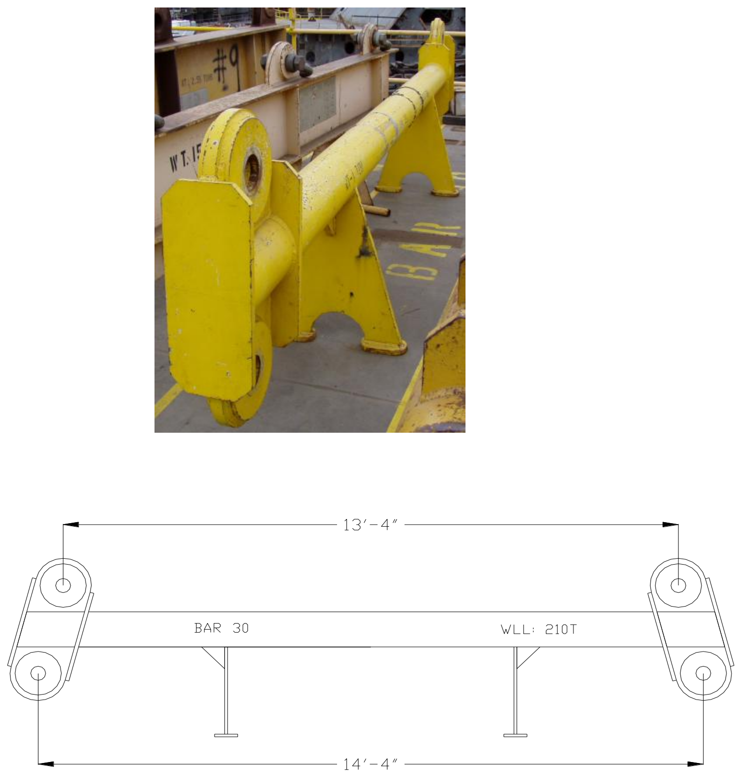


Figure 30: Round Bar Spreader Beam

Telescoping Spreader Beam

Other spreader bars in existence include modular, and telescoping spreader bars. These have the advantage of relatively easily breaking down or reducing in size such that can be transported or stored easily.

An example of a telescopic bar can be seen in Figure 31Figure 31: Telescoping Spreader Beam which has a 50 ton lifting capability, up to 65 ft in length with 6 in adjustment increments. With significant adjustment possible vertical slings can be used minimizing internal moments and compressive forces will be imparted into the ships block during the lift. These spreader beams typically cannot be used as an equalizer because they are not designed for internal moment.

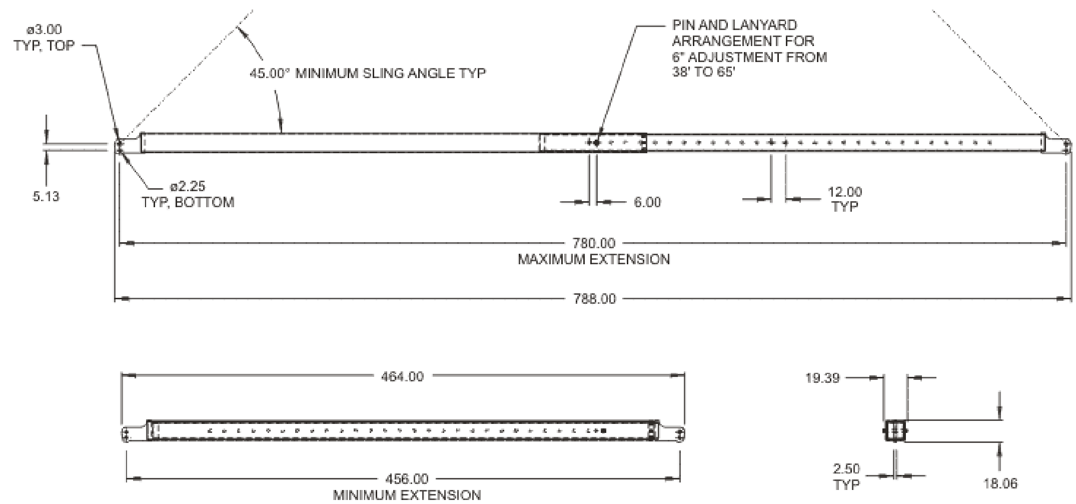


Figure 31: Telescoping Spreader Beam
Figure reprinted with permission from
Tandemloc Inc

A similar concept to the telescoping spreader beam is modular spreader beams which have bolt together sections that can be added or removed to vary the length of the beam.

Equalizer Plate Clamp Spreader Beam

Three Equalizer Type bars with 30, 35 and 64 ton ratings, spreading 17, 35 and 42 ft. These bars have two top attachments and permanent chain attachments with plate clamps underneath located on average every 3 ft. The ones at NASSCO are designed to be used with plate clamps to equally spread the load out over a large area. This is particularly useful if lifting large plates that are not well stiffened and required multiple pick points.

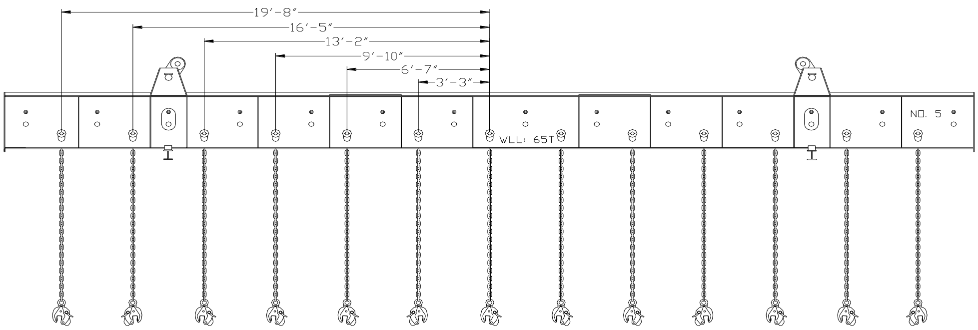


Figure 32: Plate Clamp Equalizer Spreader Beam

Roller Spreader Beams

NASSCO has four beams that are referred to as roller beam bars, with lifting capabilities of 99,124,141,173 short tons and respectively 12ft, 8ft, 20ft and 12 feet in length. These beams are essentially an I-beam with padeyes attached on both top and bottom, located on roughly every 5 ft.

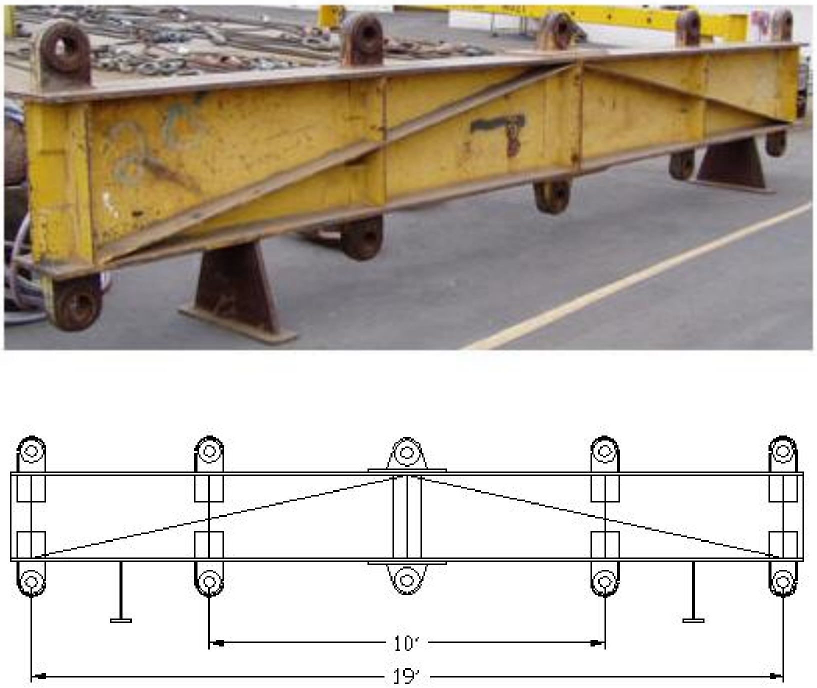


Figure 33: Roller Spreader Beam

Single Web Girder Spreader Beams

NASSCO has three Single Web Girder Bars with lift capabilities of 40, 70 and 80 ton and lengths of 45 feet. These spreader bars are capable of many different lift arrangements and can be used as equalizers. Figure 28 shows a load rating for many different typical lifting arrangements.

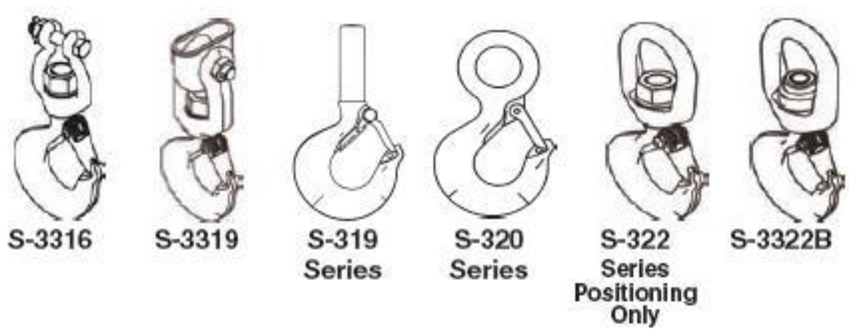
Figure 34: Single Web Girder Spreader Beam

7. HOOKS

In almost all lifting arrangements a hook is used somewhere. Typically for most critical lifts the hook that is used in on the crane and has a rating greater than that of the crane. It is however important to know some of the loading restrictions that hooks have. Hooks used in rigging have been used as long as lifts have been needed and standard shapes and sizes have been established.

Size and Strength

Table 16 below gives the working load limits for Crosby Hooks as well as the chain and wire rope dimensions typically used with these smaller hooks.



Crosby Hook Identification & Working Load Limit Chart+

S-1316A & S-1317A Only Grade 100 Chain			S-316A, S-317A, S-318A, S-326A					S-318A Only	
Chain Size		Working Load Limit (lbs.)** 4:1	Grade 80 Chain			Wire Rope XIP Mechanical Splice		Maximum Shank Diameter (in.)	Minimum Thread Size (in.)
			Chain Size		Working Load Limit (lbs.)** 4:1	Wire Rope Size (in.)	Working Load Limit (lbs.)* 5:1		
(in.)	(mm)		(in.)	(mm)					
—	6	3200	—	6	2500	5/16	2000	.72	1/2" - 13 UNC
1/4	7	4300	1/4 - 5/16	7 - 8	4500	7/16	3800	.94	5/8" - 11 UNC
5/16	8	5700	—	—	—	—	—	—	—
3/8	10	8800	3/8	10	7100	1/2	5000	1.06	3/4" - 10 UNC
1/2	13	15000	1/2	13	12000	5/8	7800	1.19	1" - 8 UNC
5/8	16	22600	5/8	16	18100	7/8	15200	1.38	1-1/4" - 7 UNC
3/4	18/20	35300	3/4	18/20	28300	1	19700	—	—
7/8	22	42700	7/8	22	—	—	—	—	—
1	26	59700	1	26	—	—	—	—	—

* Ultimate Load is 5 times the Working Load Limit based on XIP Wire Rope.
** Ultimate Load is 4 times the Working Load Limit based on Grade 80 or Grade 100 Chain.
+ Working Load Limit - The maximum mass of force which the product is authorized to support in general service when the pull is applied in-line, unless noted otherwise, with respect to the centerline of the product. This term is used interchangeably with the following terms: 1. WLL, 2. Rated Load Value, 3. SWL, 4. Safe Working Load, 5. Resultant Safe Working Load.

Table 16: Hook Working Limits
Table reprinted with permission from the
CROSBY GROUP

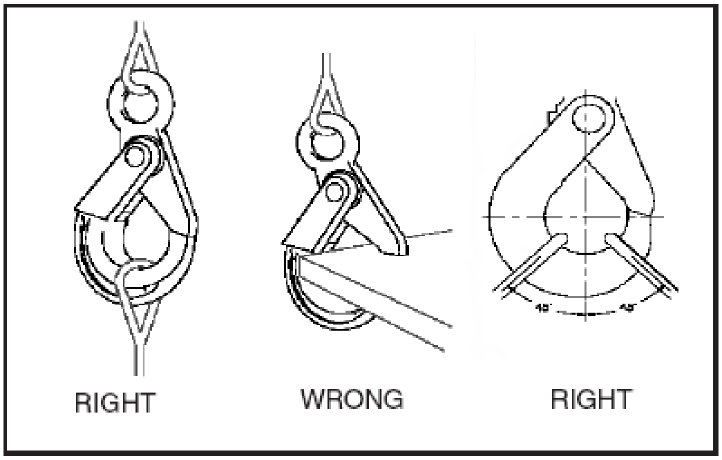


Figure 35: Use of Hooks
Figure reprinted with permission from the
CROSBY GROUP

Despite the apparent simplicity of hooks there are many ways in which hooks can be improperly loaded, Figure 35 and Figure 36 gives some examples of proper and improper loading of some hooks.

Some hooks are designed with an additional safety latch. When using these hooks caution needs to be used to never allow the load to be supported by the latch. The latches are not designed to with stand the rated loading of the hooks. When using more then one sling on the hook the angle between the hook legs should be less then 90 degrees. When threading in the hooks, the amount of thread engaged should be no less then 1 thread diameter, caution needs to be used as the thread may corrode over time causing the hook weaken and to eventually pull out. Side loads, back load and tip loads should be avoided when rigging with hooks as many are not designed for these loading conditions.

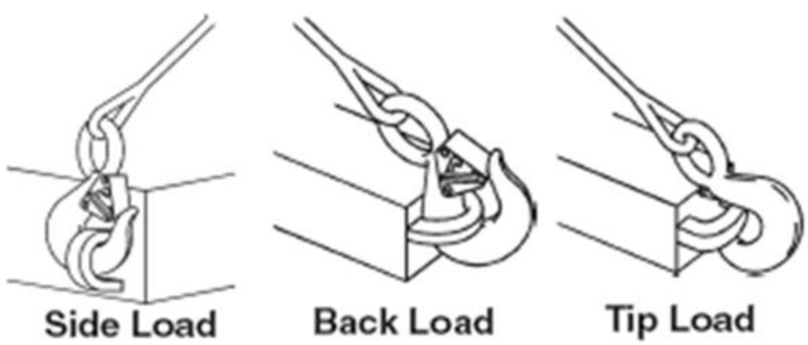


Figure 36: Ways of Loading Hooks
Figure reprinted with permission from the
COSBY GROUP

Standards and Regulations

The code of federal regulations title 29 part 1926.251 deals with rigging equipment for material handling and subpart (f) deals specifically hooks. Safety factor for hooks is listed as the following:

> .
>
> (2) The manufacturer's recommendations shall be followed in determining the safe working loads of the various sizes and types of specific and identifiable hooks. All hooks for which no applicable manufacturer's recommendations are available shall be tested to twice the intended safe working load before they are initially put into use. The employer shall maintain a record of the dates and results of such tests.

Additional standards for hooks can be referenced in ASME B30.10- 2005 Hooks.

8. CRANES

Cranes are required for lifting items in a shipyard. Typically for most large critical lifts the cranes used are relatively unique and not mass produced off the shelf items. Shipyards should have thorough documentation created with regards to the extent of the cranes capabilities.

Standard types

Cranes are mechanical devices which are used to lower, lift and move horizontally material. Cranes come in different varieties: mobile, crawler, wheel-mounted, gantry and overhead cranes.

Gantry

Gantry Cranes consist of a hoist in a trolley which runs horizontally along a rail or a pair of rails fitted under a beam. The crane can move along the rails and typically has a hook or set of hooks. These cranes can also be mounted to the side of the buildings using one wall of the building for support.

Whirly / Mobile

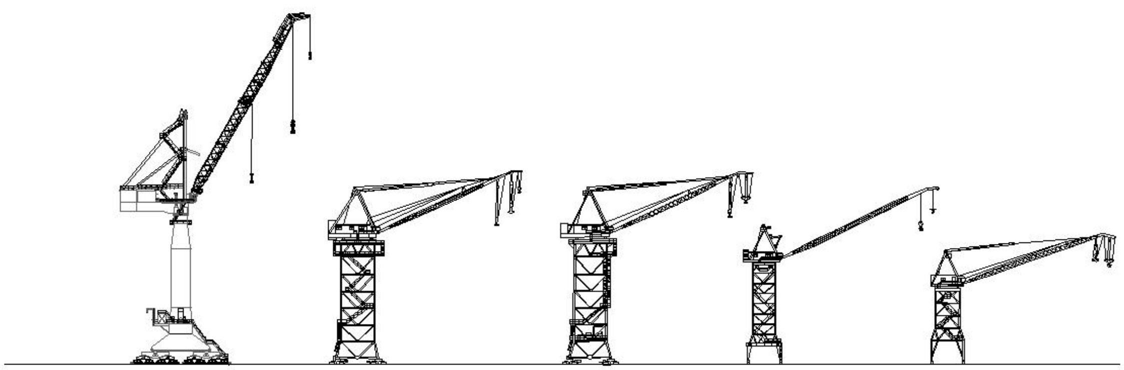


Figure 37: Whirly / Mobile Cranes at NASSCO

Mobile crane is made up of a truss, latticed or telescopic boom which moves around on rails, wheels or caterpillar tracks. The boom which is hinged at the bottom is raised and lowered by cables or hydraulic cylinders. Hooks are suspended from the boom by wire ropes which are operated through a variety of transmissions. Mobile crane with caterpillar tracks are typically referred to as crawlers and have hydraulic extendable supports which can increase stability but eliminate mobility.

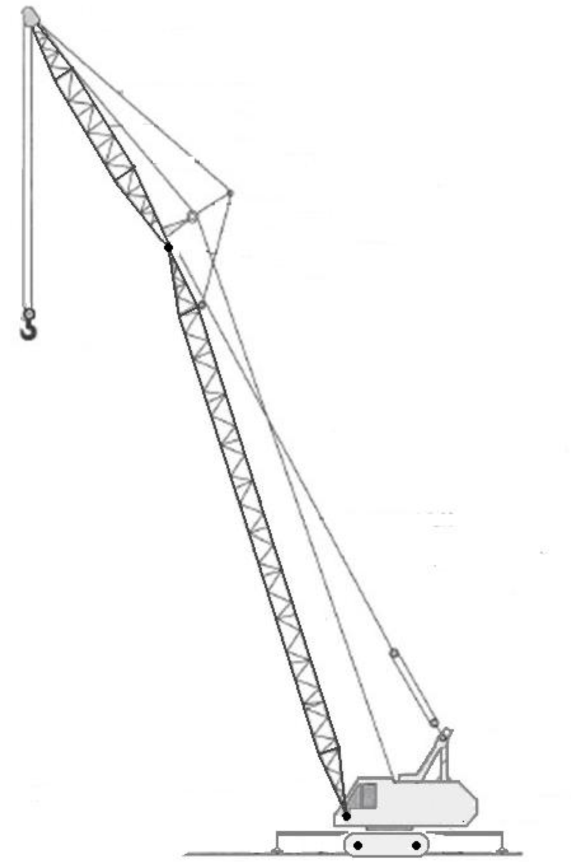


Figure 38: Typical Crawler Crane

Standards and Regulations

OSHA 1926 Subpart N- Cranes, Derricks, Hoists, Elevators AND Conveyors
 1926.550 Cranes and Derricks
ASME B30.2 1990 Overhead and Gantry Cranes
Crane Certification Association of America
Crane Manufacturers Association of America

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