Lifting and Rigging

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Safety in lifting is IMPORTANT

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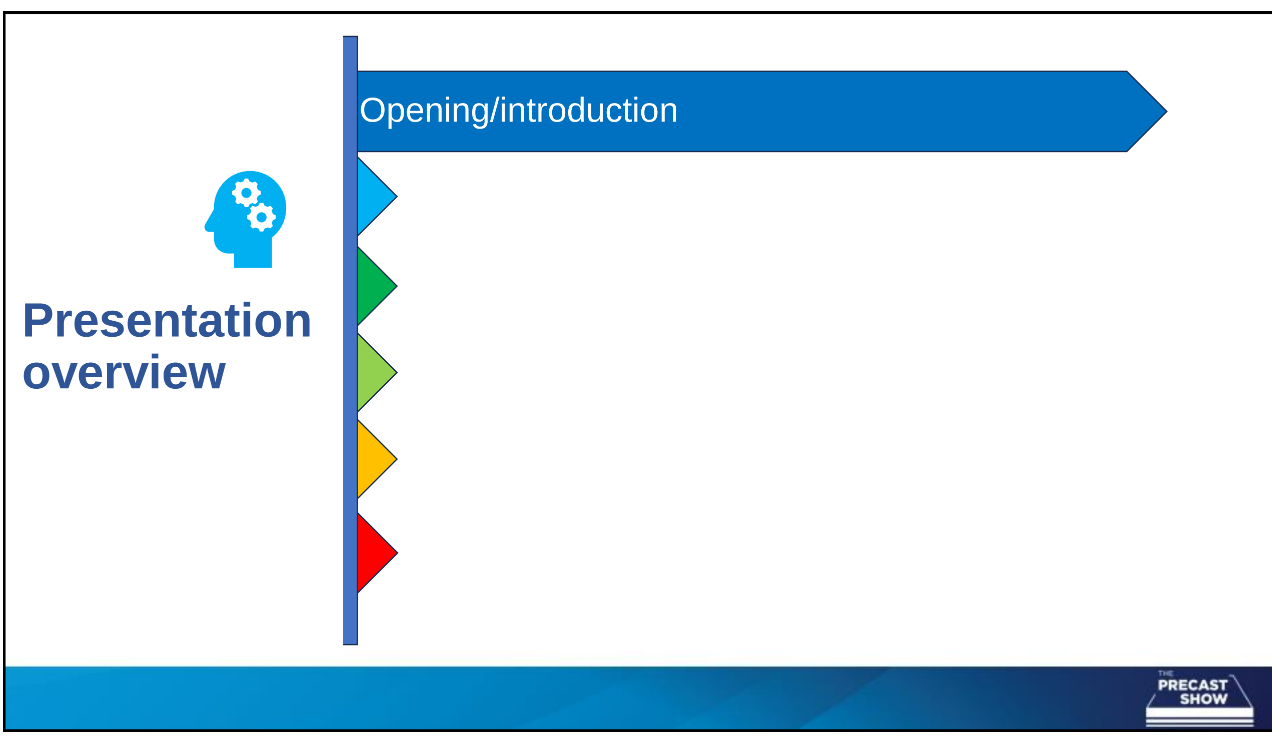
Opening/introduction
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- Opening/introduction
- Types of Lifting Systems and Hardware

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- Determining of Safe Working Load

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- Stripping strength and its effects on insert capacity

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- Physics of lifting

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- Stripping strength and its effects on insert capacity
- Physics of lifting
- SAFETY

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Safety Minute: there is no good reason to make a bad decision!

- Lifting and erecting are critical operations that need to be properly planned to minimize risks

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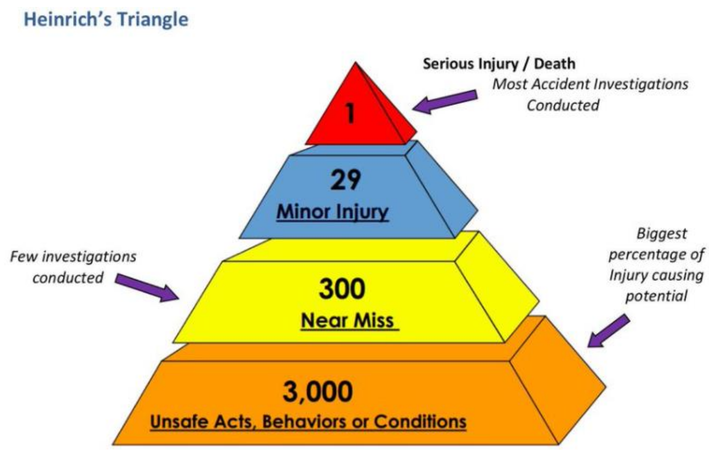
Heinrich's Accident Triangle

Theory on behavior based safety.



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- Types of Lifting Systems and Hardware

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Engineered Vs Non-Engineered Lifting Systems

- Both systems are being sold and provided by a manufacturer or distributor.
- Tested and proven to work.
- Difference:
  - Engineered lifting devices are designed to work with an engineered lifting attachment from the same company.
  - Non-Engineered Lifting systems can be used with a hook and do not require a clutch.

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Engineered Lifting System

Flat Bar Anchor
i.e. Fleet Lift, Quick Lift, Rapid Lift

Uses:

Panels, beams and double tees

Description:

High strength

Engineered to achieve SWL with anchor, recess member and clutch

Increase capacity with reinforcing

Spherical Head Anchors
i.e. Uni Lift, DogBone, Swift Lift, DR Anchor

Uses:

Panels and beams

Description:

Capacity due to foot of anchor

Concrete pullout strength increases with embedment

Engineered to achieve SWL with anchor, recess member and clutch

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Non-Engineered Lifting System

Bent bars (square or round) i.e. Hook Lift, V-Anchor A-Anchor, Easy Lift

Lift Pin

Cable Loops i.e. Lift Loop

Uses: Infrastructure precast

Description:

High strength

Engineered with Recess member

Lifted with Utility Hook

Description:

Rebar with threaded or smooth over mold or Forged Steel

Low capacity

Low price

Description:

Depend on cable capacity and embedment

Low capacity

Low price

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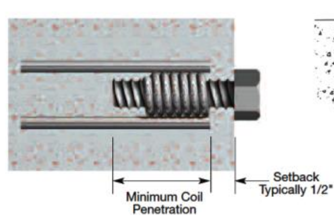
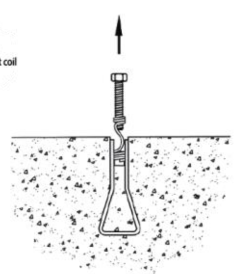
Coil Insert Lifting Systems

MINIMUM COIL BOLT PENETRATION FAILURES

The most common type of insert failure is caused by the lack of sufficient bolt penetration through the coil of the insert. Under applied load, inadequate bolt penetration of the insert coil will cause the upper part of the coil to unwind and pull out of the insert.
This is commonly referred to as the "corkscrew" effect.





- Minimum Coil Bolt Penetration Is Two Coil Threads Past The Insert

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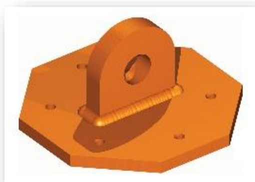
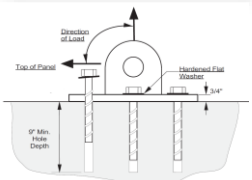
Plate Lifting Systems





Uses:

Post installed, if lifter is missing or misplaced

Description:

Can be used with post installed anchors

Works in tension and shear for rotation

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Bent Rebar Used for Lifting????

- **Can I use rebar as a lifting loop?**

Big question is can I or should I ???

In general, the use of rebar as a lifting loop is not covered by any specification. The precaster is in a precarious situation when using rebar as a lifting loop because many believe they can use them since specifications do not specifically disapprove them. However, in the event of a failure that causes injury, the precaster can be liable since specifications also do not specifically approve them.

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- Engineers use yield to calculate the allowable load/strength of a structural member.
- Lifting devices use the ultimate load and divide it by the safety factor of 4.
- Here is the BIG RISK for you!!!!!!!!
- Did you know that the minimum ultimate strength of rebar was reduced 5 years ago????

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ASTM A-615 Rebar Tensile Requirements

TABLE 2 Tensile Requirements

	Grade 40 [280][A]	Grade 60 [420]	Grade 80 [550]	Grade 100 [690]
Tensile strength, min, psi [MPa]	60 000 [420]	90 000 [620]	105 000 [725]	115 000 [790]
Yield strength, min, psi [MPa]	40 000 [280]	60 000 [420]	80 000 [550]	100 000 [690]
Elongation in 8 in. [200 mm], min, %				
Bar Designation No.				
3 [10]				
4, 5 [13, 16]				
6 [19]				
7, 8 [22, 25]				
9, 10, 11 [29, 32, 3				
14, 18, 20 [43, 57,				

[A] Grade 40 [280] bars a

2018

Reduction in ultimate strength of 11.11%

Tensile strength, min, ps				
Yield strength, min, psi [MPa]	40 000 [280]	60 000 [420]	80 000 [550]	100 000 [690]
Ratio of actual tensile strength to actual yield strength, min	1.10	1.10	1.10	1.10
Elongation in 8 in. [200 mm], min, %				
Bar Designation No.				
3 [10]	11	9	7	7
4, 5 [13, 16]	12	9	7	7
6 [19]	12	9	7	7
7, 8 [22, 25]	...	8	7	7
9, 10, 11 [29, 32, 36]	...	7	6	6
14, 18, 20 [43, 57, 64]	...	7	6	6

[A] Grade 40 [280] bars are furnished only in sizes 3 through 6 [10 through 19].

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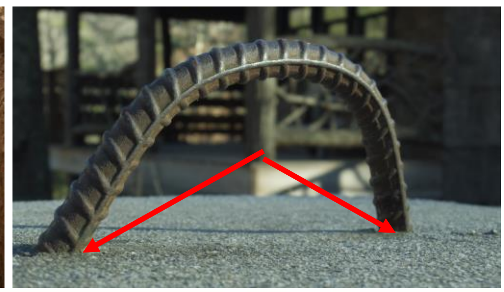
- Engineered and non engineered lifting systems rely on a combination of factors to work.
- “Bendability” for lift loops and rigidness for recessed inserts.
- Rebar, when “sticking” out of concrete, will go into bending around a very sharp and small diameter when a sling angle is applied to it, which may cause it to fail.



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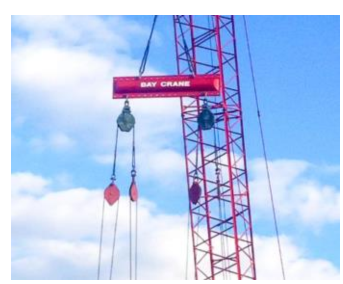
Additional Hardware

Spreader Bar:

- Stiff steel beam to transfer multiple pick points to one location.
- Allows for greater sling angles.

Rolling Blocks:

- Equalize load on slings



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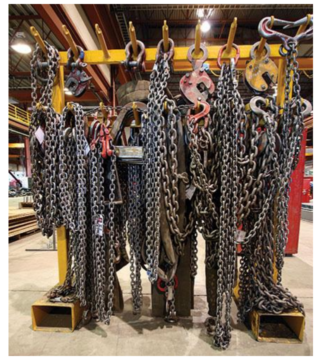
Additional Hardware

Chains and Slings:

Connect from the lifting anchor to spreader bar or crane



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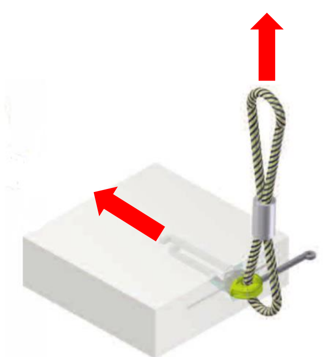
Applied Loads

Shear : A force acting in a direction perpendicular to the anchor length.



Tension : A force acting in a direction parallel to the direction of the anchor length.

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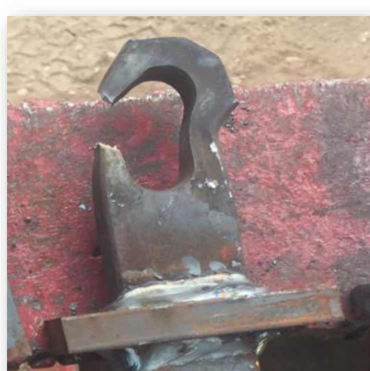
Anchor Capacity: Ultimate Mechanical Load

Ultimate Mechanical Load (UML):

- Load at which an anchor will fail, due to the anchor material rupture
- Not considering concrete capacity



Anchor tonnage:

- Matches equivalent clutch tonnage (in most cases)

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Anchor Capacity

- The Load Imprinted or advertised for the Lifter is not necessarily the actual SWL the Lifter will achieve in concrete

Factors like

- Embedment depth
- Edge distance
- Anchor spacing
- Concrete strength
- Direction of lift

<u>will</u> influence the SWL of the Lifter in Concrete

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Safe Working Load in Concrete

A '4 Ton' Anchor is not always an anchor with 4 Ton SWL in concrete		
Anchor Type		**Tension Rating at 3500 PSI**
4 Ton Spread Anchor 4"		**2,670 lbs. = (1.34Ton)** **Not 4 Ton!**

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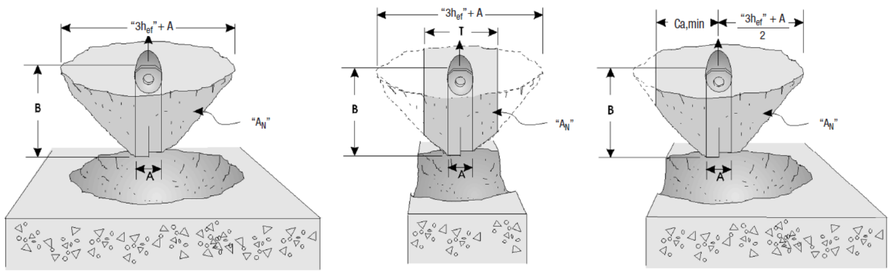
Concrete Shear Cone



Full Shear Cone Condition (face lift)

Partial Shear Cone (edge lift)

Partial Shear Cone (face or edge lift near corner)

- Concrete shear cone assumes a radius of 1.5x embedment depth (h_{ef})
- A partial shear cone will reduce the safe working load (SWL) from manufacturer specifications.
- In partial shear cone conditions the anchor size or amount of reinforcing around the anchor will change to achieve the capacity required to safely lift the concrete product.

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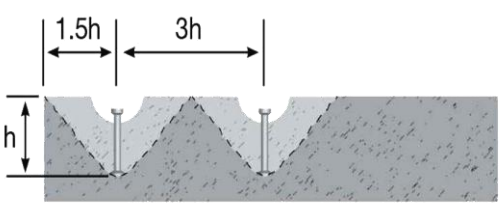
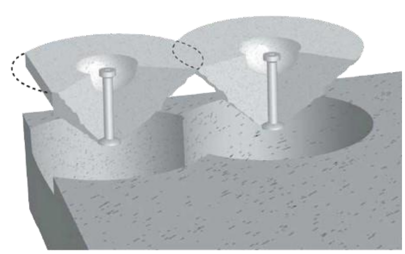
Concrete Shear Cone

Shear Cone Conditions: This applies to the way in which an anchor fails the concrete from the bottom of the anchor to the top surface of the concrete.





Partial Shear Cone : This applies to the way in which an anchor fails the concrete from the bottom of the anchor to the top surface of the concrete. Partial shear cone will reduce the safe working load of the concrete capacity and occurs where edge distance is less than 1.5x anchor depth.

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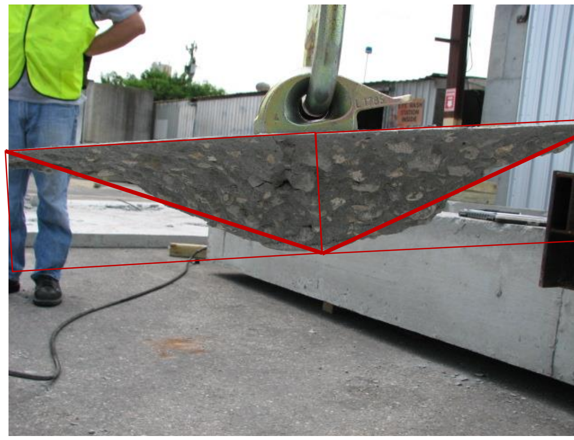
Concrete Shear Cone



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Concrete Shear Cone

This is what happens when a lifter's edge distance is inadequate for shear lifting applications:

This would have been prevented if shear bars were added to this lifter, or the lifter were placed lower in the walls at 3 times the lifter depth.

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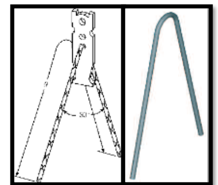
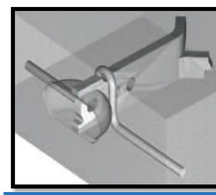
Anchor Capacity: Tension and Shear Bars

- The anchor reinforcement should consist of stirrups, ties, or hairpins placed as close as practicable to the anchor.
- Ear of tech anchor prevents spalling.
- Shear bar used to achieve shear strength.
- Shear bar helps transfer loads deeper into concrete to increase h_{ef} for shear.



Tension Bar



Shear Bar

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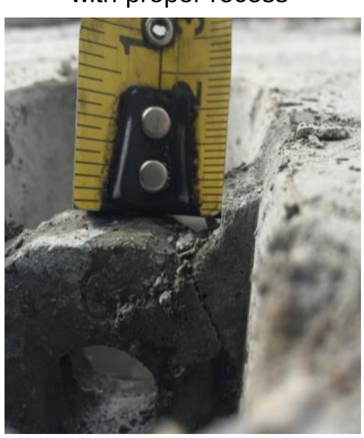
Partial Shear Cone: Example

Correct
Standard depth of anchor with proper recess



VS

Incorrect
Anchor flush with concrete placed too high

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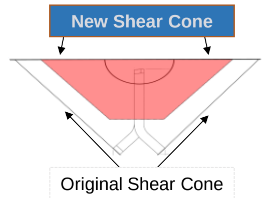
Partial Shear Cone: Example

SPREAD ANCHOR DATA	
Length of Anchor	Allowable Unreinforced Tension Load 4:1 SF (lbs..)
4”	2,670
4 ¾”	3,590
*Table based on dead load only, 150 PCF, concrete compressive strength of 3,500 psi.	



- 4T Anchor was set flush with concrete.
- Anchor mis-installed and flush with concrete.
- Typical set is 3/8” to ½” below surface of concrete.

What was original SWL? **3,590 lbs**

What is current SWL? If we interpolate the values in the chart, it will appear that the new SWL is **2,977** lbs., a reduction of **613** lbs. in SWL. However, this does not include the bending moment on the anchor material, Reduction may be greater once these factors are calculated making the product potentially unsafe to lift.

What is the solution? Contact supervisor, plant engineer or anchor supplier engineering for fixing solutions. If you see something, say something.

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Factors That Increase the Load Transferred to the Lifter

- The Load applied to the anchor is not necessarily the calculated weight of the element divided by number of anchor used.
- Factors like
  - Form suction
  - Shock loads
  - Sling angle
  - Load equalization (rolling block or spreader bar)
  - Center of Gravity
- Will influence the actual load transferred to the anchor.

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Double Tee Form Adhesion Research

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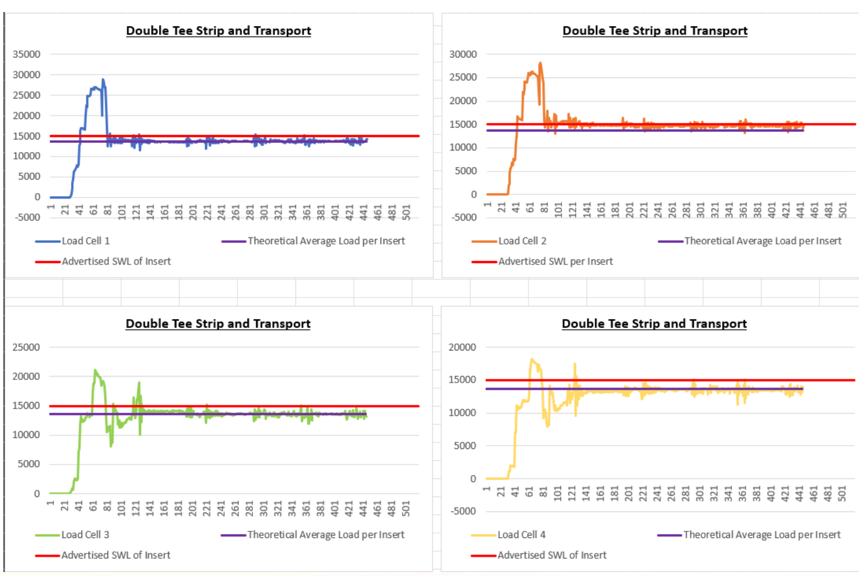
Form Adhesion



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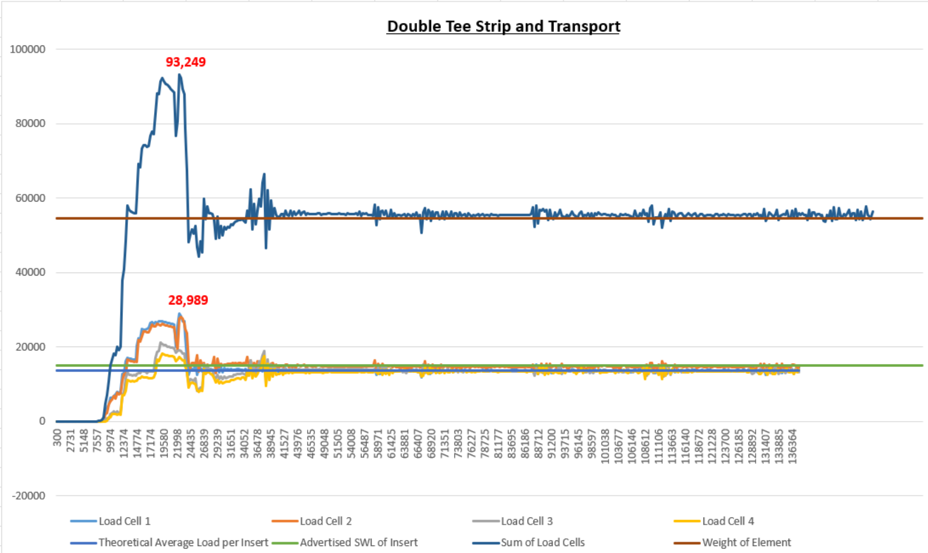
Form Adhesion



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Applied Loads

- Equivalent static loads can be considered for stripping and dynamic forces

Table 8.3.1. Equivalent static load multipliers to account for stripping and dynamic forces[a,b]

Product type	Finish	
	Exposed aggregate with retarder	Smooth form (release agent only)
Flat, with removable side forms, no false joints or reveals	1.2	1.3
Flat, with false joints and/or reveals	1.3	1.4
Fluted, with proper draft[c]	1.4	1.6
Sculptured and other conditions	1.5	1.7
Yard handling[d] and erection[b]		
All products	1.2	1.2
Transportation[d]		
All products	1.5	1.5

Notes:
[a] These factors are used in flexural design of panels and are not to be applied to required safety factors on lifting devices. At stripping, suction between product and form introduces forces, which are treated here by introducing a multiplier on product weight. It would be more accurate to establish these multipliers based on the actual contact area and a suction factor independent of product weight.
[b] May be higher under certain circumstances.
[c] For example, tees, channels, and fluted panels.
[d] Certain unfavorable conditions in road surface, equipment, etc. may require use of higher values.

PCI Handbook

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Safety Factors

- Consider:
  - Failure mode (ductile)
  - Predictability of loads
  - Quality of products
  - Human error
  - Economics
  - Reuse factor
  - Concrete strength
  - Sling angles
  - Rigging

Precast Products	Safety Factor
Reusable hardware (clutch)	5:1
Inserts and anchors	4:1
Permanent connections	3:1

- Example: An insert or anchor with SWL of 4,000lbs at 4:1 safety factor will ultimately fail at 16,000lbs of force.

- Safety Factors are Determined by the degree of risk involved in the use of the product established by:
  - Occupational Safety and Health Administration (OSHA)
    OSHA 1926.704 (c) for lifter and (d) for clutch

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Concrete Age and Compressive Strength

- Concrete compressive strength increases over time as concrete continues curing.
- Safe working loads are typically advertised for concrete:
  - 150 pcf
  - 3,500 psi compressive strength
- If the concrete failure is the limiting condition, safe working load can be adjusted if different concrete strengths are used compared to manufacturer values
- Table shows the conversion factor from a reference strength of 3500 psi to other strength values

Convert from 3500 psi to	Multiply by
2000 psi	0.75
2500 psi	0.84
3000 psi	0.92
4000 psi	1.07
4500 psi	1.13
5000 psi	1.19

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Anchor Capacity and Concrete Strength

Lifter Capacity at Stripping

Rated Lifter Capacity	Concrete Strength			
	1500PSI*	**2000PSI**	**3000PSI**	**3500PSI**
1 TON	0.65TON	0.76TON	0.93TON	1TON
2 TON	1.31TON	1.51TON	1.85TON	2TON
4 TON	2.62TON	3.02TON	3.70TON	4TON
8 TON	5.24TON	6.05TON	7.41TON	8TON

* Minimum recommended PSI for handling

- At 1500 PSI the lifter is only able to lift 65% of its rated capacity
- At 2000 PSI it can lift 75% of its capacity
- At 3000 PSI it can lift 92% of its capacity
- At 3500 PSI the lifter has full capacity
- Higher Capacity lifters are needed for lower concrete strength at stripping.

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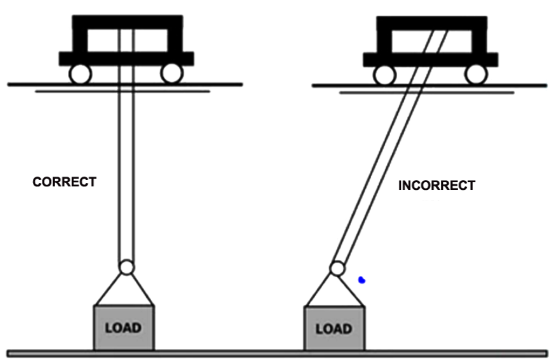
Rigging

Always Center Your Loads



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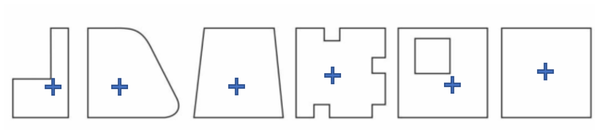
Center of Gravity

The quantity of inserts is dependant upon many factors including but not limited to

- Center of gravity
- Piece weight
- Piece shape
- Opening sizes
- Opening locations
- Stripping strength
- Lifter type
- Sling angle
- Plant hardware



Center of gravity

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Rigging: Sling Angle

Beer Facts

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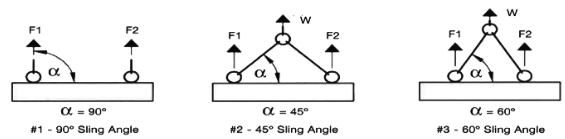
Rigging: Sling Angle (α)

- Sling angles should be limited to **minimum 60º** from horizontal, to limit loads introduced to element and total load in sling
- **Spreader beams** can be used to increase sling angle
- **Rolling blocks** can be used to balance uneven load distribution



θ	90º	75º	60º	45º	30º
F	1.00	1.04	1.16	1.42	2.00
10,000 lbs	10,000 lbs	10,400 lbs	11,600 lbs	14,200 lbs	20,000 lbs

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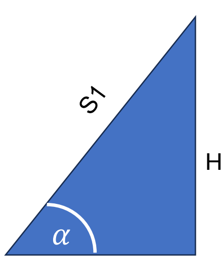
Rigging: Sling Angle (α)

- How do we get these numbers????
- TRIGONOMETRY



$$\sin(\alpha) = \frac{H}{S1} \qquad \frac{1}{\sin(\alpha)} = \frac{S1}{H}$$

$$Sling\ Factor = \frac{1}{\sin(\alpha)} \quad or \quad Sling\ Factor = \frac{S1}{H}$$

Example

$$\alpha = 60 \quad \sin(60) = 0.86 \qquad Sling\ Factor = \frac{1}{0.866} = 1.16$$

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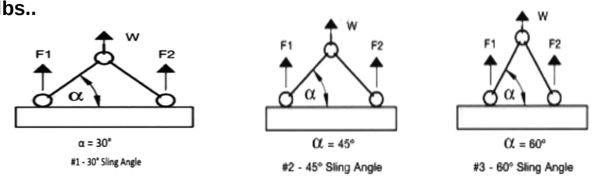
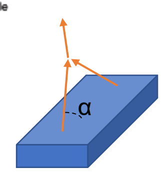
Example: Sling Angle

Concrete dead weight = 12' x 10' x 16"/12" x 150 pcf = **24,000** lbs..
Form adhesion (concrete form) = 12' x 10' x 20 lbs = **2,400 lbs**… Combined load (CL) = **26,400 lbs..**





Example 2: New Sling/Incline Angle Used = 45°
F1 = 26,400/2 (two anchors working) x 1.42 (sling angle factor)
F1 = **18,744 lbs. per anchor**

Example 3: New Sling/Incline Angle Used = 30°
F1 = 26,400/2 (two anchors working) x 2 (sling angle factor) per anchor
F1 = **26,400 lbs. per anchor**

Rigging must comply with specification from Engineering

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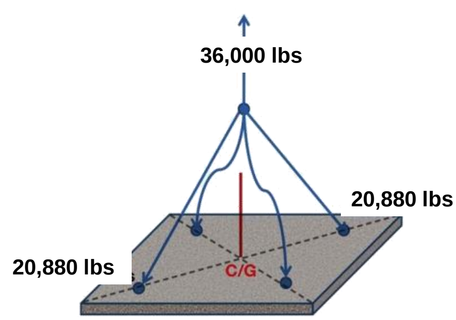
Example: 4 Inclined Slings

- Concrete compressive strength = 1,500 psi
- Stripping and dynamic force multiplier = 1.5 (travel effects and smooth mold)
- Slab = 12' x 10' x 16"
- Sling angle = 60° → F=1.16 (multiplication factor)
- Concrete volumetric weight = 150 pcf

Dead weight = 12' x 10' x 16"/12" x 150 pcf = 24,000 lbs
Stripping and dynamic force multiplier x 1.5
Combined load (CL) **36,000 lbs**

F1 = 1.16 x 36,000 / 2 (only two anchors working) = **20,880 lbs per anchor**



Each anchor must have a Safe Working Load greater than 20,880 lbs in 1,500 PSI concrete

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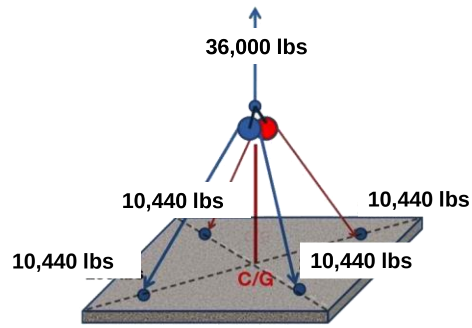
Example: 4 Inclined Slings with Rolling Blocks

- Concrete compressive strength = 1,500 psi
- Stripping and dynamic force multiplier = 1.5 (travel effects and smooth mold)
- Slab = 12' x 10' x 16"
- Sling angle = 60° → F=1.16 (multiplication factor)
- Concrete volumetric weight = 150 pcf

Dead weight = 12' x 10' x 16"/12" x 150 pcf = 24,000 lbs	
Stripping and dynamic force multiplier	x 1.5
Combined load (CL)	**36,000 lbs**

F1 = 1.16 x 36,000 / 4 (all anchors working) = **10,440 lbs per anchor**



<u>Each</u> anchor must now only have a Safe Working Load greater than 10,440 lbs in 1,500 PSI concrete

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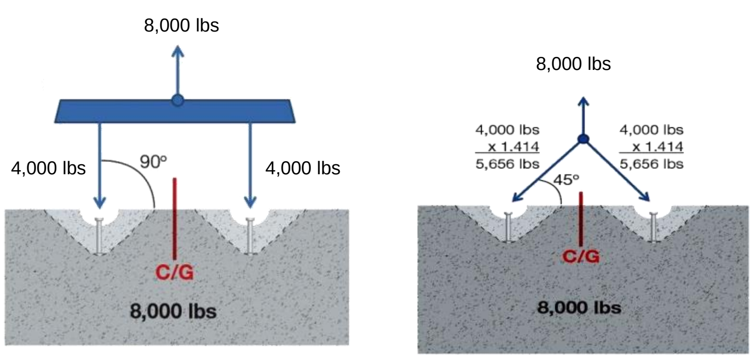
Rigging: Spreader Bar



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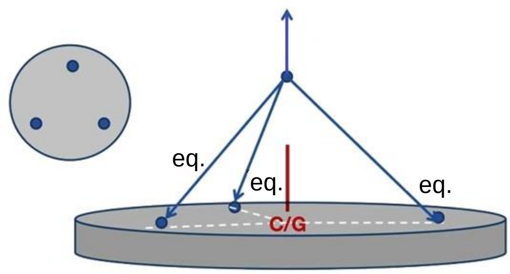
Rigging: Sling Angle

3-Point Picks on small slabs can ensure an even disbursement of the load to the anchors at 120 degree spacing around the center of gravity.



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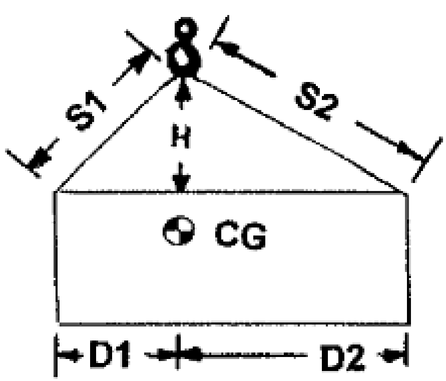
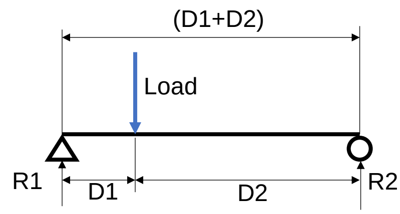
Sling Angle – Unequal Legs

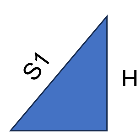


LOAD ON SLING CALCULATED
TENSION 1 = LOAD X D2 X S1/(H(D1+D2))
TENSION 2 = LOAD X D1 X S2/(H(D1+D2))



$$R1 = \frac{Load \times D2}{(D1 + D2)}$$

$$R2 = \frac{Load \times D1}{(D1 + D2)}$$



$$Sling\ Factor = \frac{S1}{H}$$

$$R1 = \frac{Load \times D2}{(D1 + D2)} \times \frac{S1}{H}$$

$$R1 = \frac{Load \times D2 \times S1}{(D1 + D2) \times H}$$

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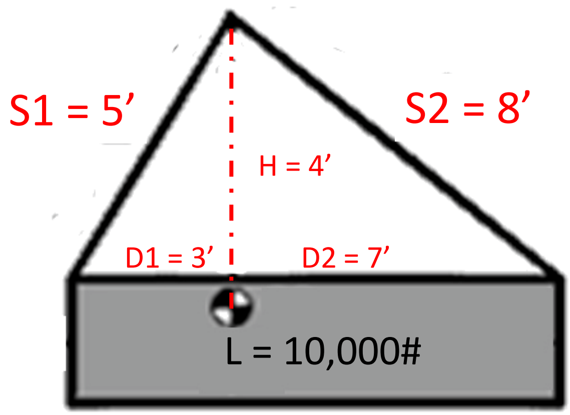

How will SLING ANGLES affect lifting capacity?

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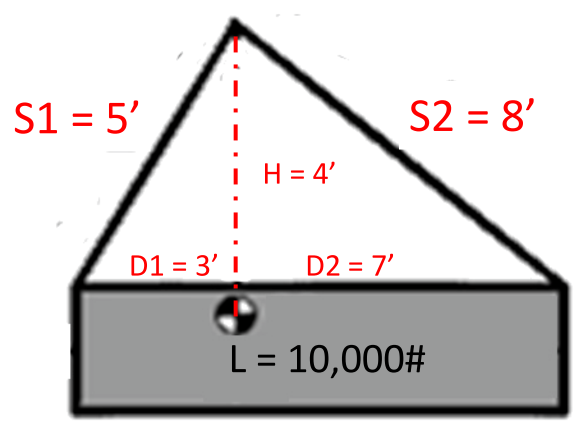
Sling 1

- $Tension\ S1 = \frac{10{,}000 \times 7 \times 5}{4 \times (3+7)}$
- $Tension\ S1 = \frac{350{,}000}{40}$
- $Tension\ S1 = 8{,}750\#$



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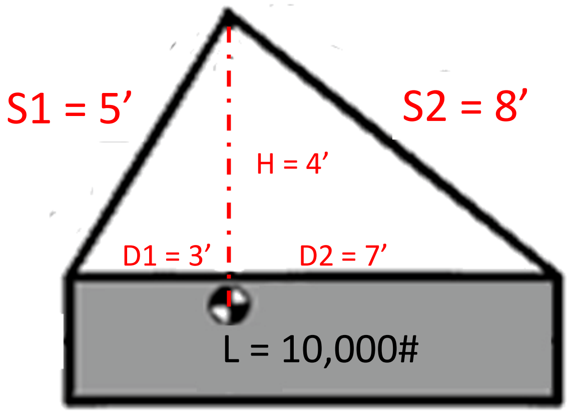

Sling 2

- $Tension\ S2 = \frac{Load \times D1 \times S2}{H \times (D1 + D2)}$
- $Tension\ S2 = \frac{10{,}000 \times 3 \times 8}{4 \times (3 + 7)}$
- $Tension\ S2 = \frac{240{,}000}{40}$
- $Tension\ S2 = 6000\#$

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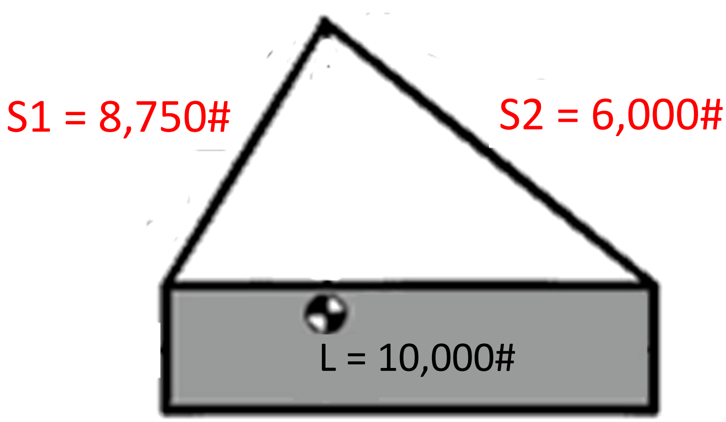
Sling Angle – Unequal Legs



How will SLING ANGLES affect lifting capacity?

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Sling Angle – Spreader Beam

- Distributes load evenly without excessive sling angles
- Requires greater headroom clearance

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Sling Angles

- Sling tension
  - Loads tend to hang vertically
  - Forcing load points away from vertical requires force
  - Reaction to the force increases sling tension
- Remember
  - Sling angle will **<u>not</u>** reduce the SWL of our insert but increase the applied load to it!

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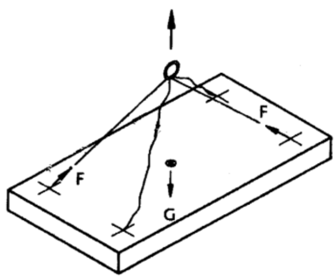
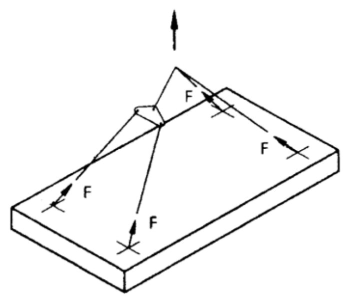
Flat Panel Lifting



Two Load Bearing Anchors



With a load compensating rig the load is distributed evenly to all four anchors

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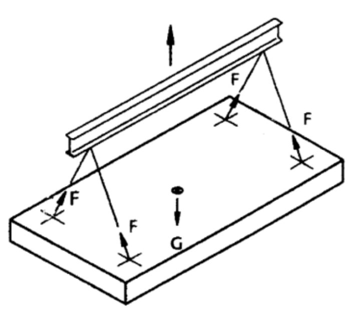
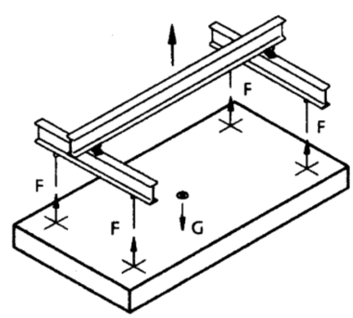
Use of Spreader Bars



Spreader bar and two pairs of anchors set symmetrically.



Use of crossed spreader beam to avoid angle pull.

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Rigging Misconceptions

- All Slings have the Same Length.
  - Believe me we measured them!!! ☺
- All Inserts are installed they way the plan shows them!
  - Yeah right! ☺
- I like it better when you have multiple inserts to chose from, so I can decide which ones to engage!
- 4 Inserts were slightly overloaded, so we added 2 inserts and made it a 6-point pick!

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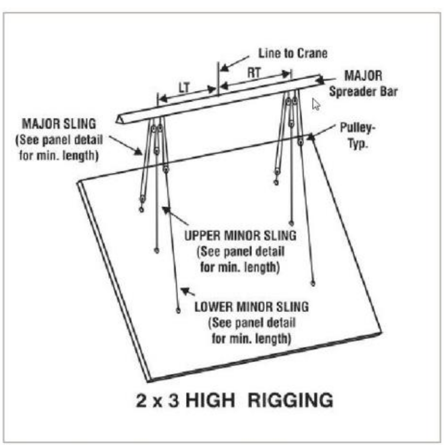
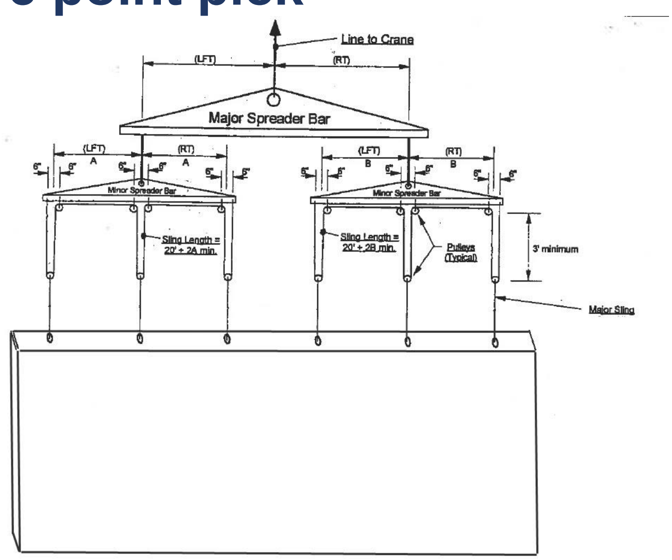
Rigging for 6 point pick



Warning: Pulleys can bind at spreader bar due to insufficient clearance unless sling lengths are sized correctly. To provide adequate clearance between pulleys, the Major Sling must be at least 3.7 times longer than the Minor Slings. Minor Slings should be equal in length. See panel details for correct sling lengths.



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When good intensions go wrong/improper Rigging

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Rigging Importance

- Rigging is one of the most neglected details in the precast industry.
- If you see something that does not look correct, say something.
- When in doubt call your engineering department.
- Most failures during lifting can be contributed to improper rigging.

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Presentation overview

- Opening/introduction
- Types of Lifting Systems and Hardware
- Determining of Safe Working Load
- Stripping strength and its effects on insert capacity
- Physics of lifting
- SAFETY

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Safety Considerations

- Inspection Procedures
- Insert care and maintenance
- Sling angle
- Bail position

A failure happens when the safety guidelines are not followed.
Safety is not an option!

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Eliminate Hazards while Lifting

General considerations that every precaster has top of mind when lifting elements:

- Lift the product a few inches and inspect the rigging.
- Protect slings from sharp edges.
- Plan the lift, know ahead of time where to deposit the load.
- Plan an escape route, do not stand in front of stationary objects.
- If you are placing the load on dunnage, have it ready.
- Treat the rigging as though your life depends on it; it does if it fails!

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Safety: Inspection Procedure

Anchor

Look for cracks or physical defects or missing pieces. Bent or deformed shapes.

Recess Member

Rips, tears or excessive cracking. Missing magnets or plugged holes. DO NOT USE homemade recess members

Finish

Verify the proper finish as specified.

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Safety: Inspection Procedure

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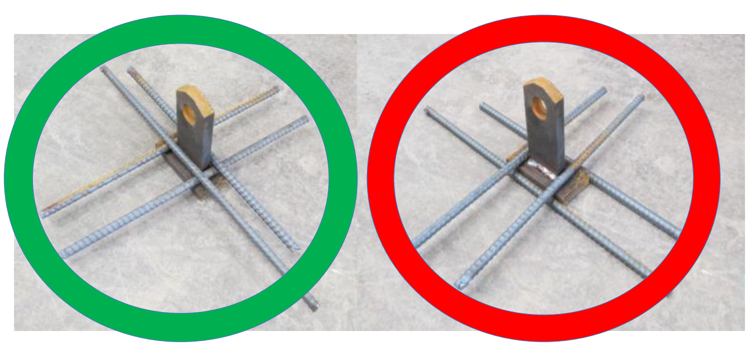
Safety: Inspection Procedure

Precaster QA/QC verifies reinforcing placement to
meet manufacturers recommendation



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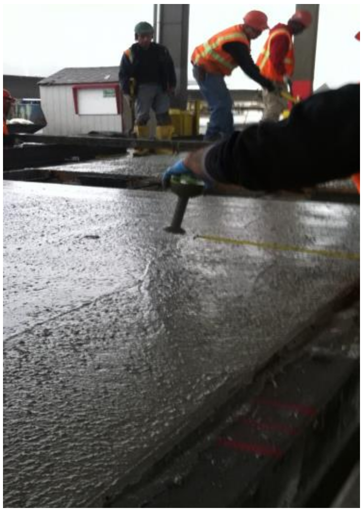
Safety: Insert Care and Maintenance


Safety: Insert Care and Maintenance



- Any modifications to lifters is not permitted at any time.
- This includes but not limited to welding, cutting , grinding or introduced to chemicals.
- Please use caution when using form oil around the lifters and recess members not to get any on the lifter because it will act as a bond breaker between the lifter and the concrete which gives the lifter its strength.

Safety: Wet Setting



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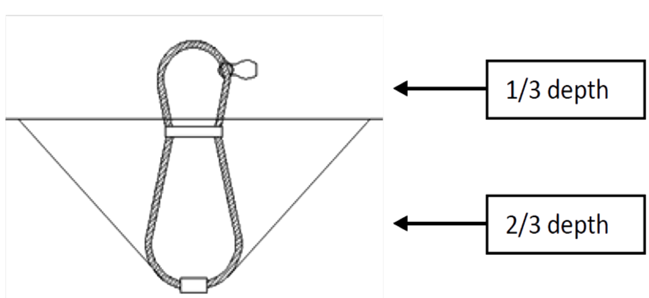
Safety: Inspection Procedure

Precaster QA/QC verifies proper embedment in concrete ahead of concrete pour



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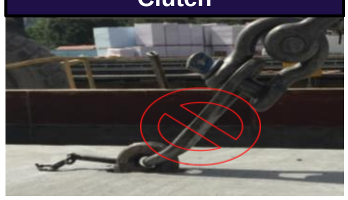
Safety: Inspection Procedure

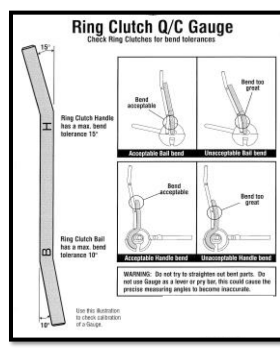
Safety: Inspection Procedure

- Clutch inspection and proper usage must be done at all times.
- Failure to do so may result in damage to the anchor which could result in the anchor failure, injury or death.
- Defective clutches must be removed from production floor and destroyed.

Clutch



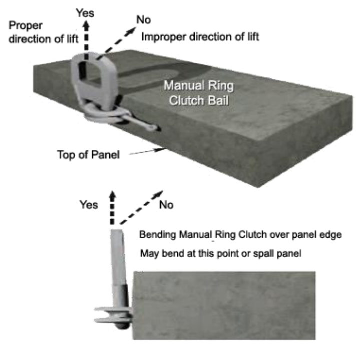
This example shows a clutch bail that is bent beyond the manufacturers' allowable tolerance



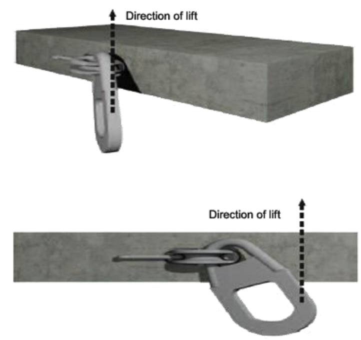
- Q/C gauge can be used to evaluate maximum ring clutch bend tolerances
- If tolerances are not met, there should be no attempts to straighten and clutches should be replaced

Safety: Bail Position

Correct
Lift directly over the Ring Clutch and a load is applied in a direction towards the bottom of the panel.



Wrong
The Clutch, if positioned below the ring clutch, may lock
in a position preventing free movement of the unit.
Do not bend clutch over panel edge.



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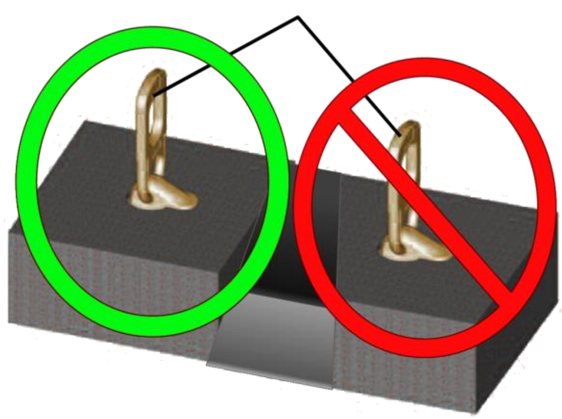
Safety: Bail Position

LIFTING CLUTCH INSTALLATION

Anchor attachment – Turn the lifting clutch upside down, positioned and centered over the head of the anchor. Drop the lifting clutch down into the void formed by the recess former. Rotate the lifting unit around the head of the anchor until the unit contacts the surface of the concrete. The "ear" of the clutch must be facing center lift point. Installation is complete, ready to lift.



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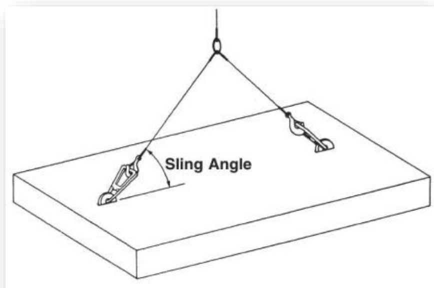
Safety: Sling Angle

- Sling angles should be limited to **minimum 60º** from horizontal, to limit loads introduced to element and total load in sling
- Load from low sling angles may cause instability of element



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Safety: Coring

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Safety: One to One Rule

A life and limb saving rule to follow is when around a piece being lifted is "For every 1' in height up you should keep at least 1' away from the piece".

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Key Takeaways

At the conclusion of this presentation, you should be able to:

- Identify different styles of lifting hardware and equipment and their applications.
- Identify the impact of concrete strength on lifting hardware and their capacities.
- Differentiate between a safe working load and an ultimate load.
- Identify the basic physics of lifting, sling angles, the number of lift points and center of gravity.
- Identify signs of wear and damage on hardware and equipment.
- Outline safety best practices for lifting and handling.

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THANK YOU!

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