MODULE 4 - LIFTING AND MOVING – Part a

INTRODUCTION

A fire officer on a pumper was once asked why he ordered the pumper engineer to drive the 30,000 pound fire apparatus on a road that had a bridge with a 10,000 load limit. The officer responded to the question by saying that "it was an emergency". Rescue personnel often think that the physical laws of the universe do not apply when there is "an emergency". Gravity is one of the laws of the universe that applies to all earthly (rescue) environments. Rescuers deal with gravity every time they lift a patient, every time they move an object and every time they lower themselves on a rope.

Rescuers need to understand the relationship of gravity to basic tactical evolutions such as lifting, lowering, moving and stabilizing loads. Today even with the availability of powerful cranes, strong hydraulic winches and high pressure air bags there is a need for a knowledge of the basic concepts of leverage and gravity. It is the ability of the rescuer to make effective size ups in confined areas of collapsed buildings that often means the difference between life and death.

The rescuer also has a critical role to play when using the heavy lifting equipment such as cranes. All loads to be lifted or moved must be assessed for weight, stability and rigging points. The rescuer's knowledge of rigging equipment and its basic application will enhance the ability of the heavy equipment to perform.

This training module for the US&R Sructural Collapse Technician will look at levers, gravity, lifting and rescue rigging equipment.

TERMINAL OBJECTIVE

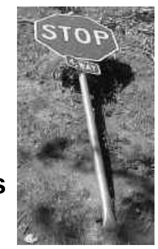
- Size-up objects that have entrapped people and efficiently apply a variety of machines and power to safely move these objects
- To understand the basic physics, material behavior and mechanics necessary to accomplish the above

Class Introduction

- Introduction of instructors
- Schedule of events
  - Classroom lecture
  - Practical evolutions
    - simple and compound machines
    - airbags
    - cranes, bolting, rigging & lifting
  - Rotation schedule/site location
- Personal Protective Equipment

CLASS INTRODUCTION

- Safety considerations
- Feedback
- Student responsibilities



Terminal Objective

- Size up objects that have entrapped people and efficiently apply a variety of machines and power to safely move objects.
- Understand basic physics, material behavior and mechanics necessary to accomplish the above.

MODULE 4 - LIFTING AND MOVING – Part a

ENABLING OBJECTIVES

At the conclusion of module the student should be able to:

For Part a

- Understand the basic physics as they relate to Weight, Gravity, and Center of Gravity.
- Explain the concepts of Energy, Work, and Power
- Describe what determines the efficiency of mechanical advantages.
- Explain the three classes of levers.
- Describe the efficiency of inclined planes.
- Describe the two types of pulley configurations.

For Part b

- Explain the effective use of high pressure air bags.
- Calculate the weights of common materials.

For Part c

- Explain use of proper sling angles to efficiently lift a load
- Explain the use of anchor systems, anchor failure considerations, and proper anchor spacing.
- Describe the proper use of swivel hoist ring, steel angle brackets, and concrete screws.
- Understand the proper use of wire ropes, wire rope fittings, end terminations, and tighteners.
- Explain the use of slings and sling arrangements.
- Describe the use of chains for rigging and lifting.
- Determine the effects of critical angles as the relate to lifting and moving objects.
- Identify and describe the advantages and disadvantages of the different types of cranes.
- Explain considerations for crane use, and demonstrate basic crane signals for rescue operations

PRIME RULE OF L&M

One should only Lift & Move an Object if there is no other viable alternative. Once in Motion, It is more Dangerous

Enabling Objectives

At the completion of this lesson the student shall understand:

- Basic Laws of Physics
- Gravity
- Center of Gravity
- Mass & Equilibrium
- Friction
- Leverage
- Mechanics, energy, work and power
- Mechanical Advantage
- Simple-complex machines

Enabling Objectives

At the completion of this lesson the student shall have a working knowledge of:

- **Inclined Planes**
- **Pulleys**
- **A-Frames**
- **Air bags**
- **Wedges & Cribbing**
- **Calculating weights**
- **Slings: wire, rope, chain & synthetic**
- **Consideration for crane use.**
- **Slings and sling attachments with cranes**
- **Crane hand signals**
- **Anchor systems & lifting devices**

Prime Rules of L&M

- **If you can leave it, leave it.**
- **If you can't leave it, go around it.**
- **If you can't go around it, drag it.**
- **If you can't drag, roll it.**
- **If you can't roll it, lift it.**
- **If you have to lift it, STAY AWAY FROM IT…**
- **IF IT FALLS DON'T BE UNDER IT!**

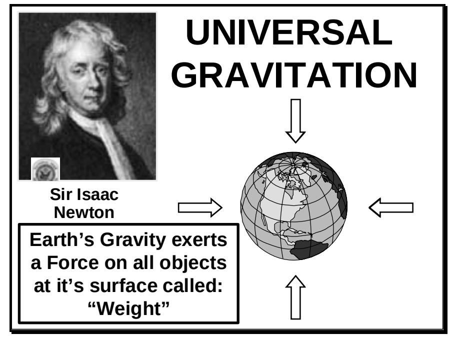
MODULE 4 - LIFTING AND MOVING – Part a

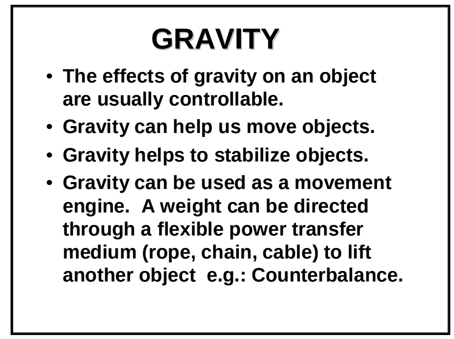
UNIVERSAL GRAVITATION and CENTER of GRAVITY

PRINCIPLE

- The Earth's Gravity exerts a Force on all objects on its surface called "Weight"

  - Gravity can help us move and/or stabilize objects
  - Gravity can be used as a movement engine
  - There is no exception to gravity.
  - All objects seek a state of equilibrium.
  - Gravity effects such evolutions as:
    - Lifting
    - Lowering
    - Moving
    - Stabilizing





CENTER OF GRAVITY (CG) AND POSITION CHANGES

- <u>Center of gravity</u>: Point at which the whole weight of object is acting vertically downward = Balance Point.

- Load's weight is perfectly balanced or distributed around the center of gravity.

- If a load is suspended at its CG, it can be turned in any direction with little effort.

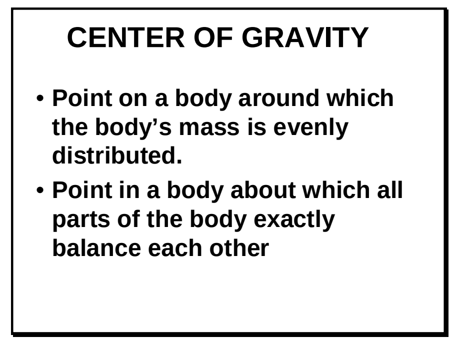
- If load is lifted to the right/left of CG, it will tilt at an angle.

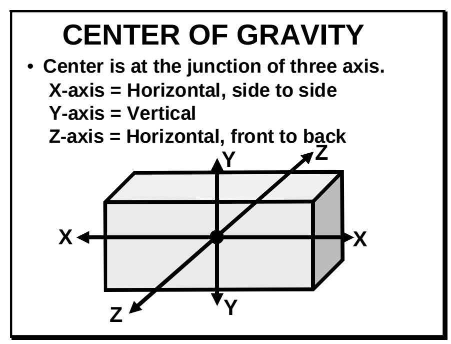
- If a load is lifted below its center of gravity, the weight of the load will be above the lifting point, and the load will tip over.

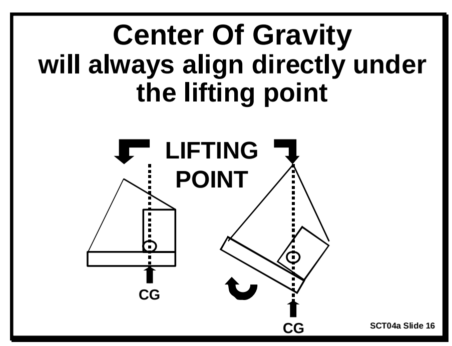
- Important that loads be hoisted above the load's CG.

- CG of a solid object is located in three planes or directions:

  - X axis = Horizontal, side to side
  - Y axis = Vertical axis
  - Z axis = Horizontal, front to back







EXAMPLE OF CG:
A solid piece of concrete that is 10ft long x 4ft wide x 6ft high has it's CG at a point that is 5ft from the end, 2ft from the front, and 3ft from the bottom

MODULE 4 - LIFTING AND MOVING – Part a

WEIGHT

- Force of the Earth's Gravity on a Mass sitting on its surface is called its "Weight"
  - The "Weight of the same Mass on the Moon would be 1/6 as much

Weight

- The force of gravity on an object

EQUILIBRIUM

PRINCIPLE:

- Every object resting on earth is said to be "at rest" and in a state of Static Equilibrium. All objects seek a state of equilibrium.

CHANGING EQUILIBRIUM

- Small outside force/effort at the highest point on the object can change it's condition from static to unstable equilibrium:
  - Wind or a gentle push can move the object out this "balance point" of static equilibrium.
  - With applied force changes into a state of unstable equilibrium.
  - Object will move (fall over) into another position of static equilibrium.

Static Equilibrium

- **An "at rest" object is in a state of static equilibrium.**
- **To move an object, you must overcome static equilibrium.**
- **Static equilibrium is effected by:**
  - **–the object's weight**
  - **–the object's frictional interface with other objects**

FRICTION and RESISTANCE FORCE

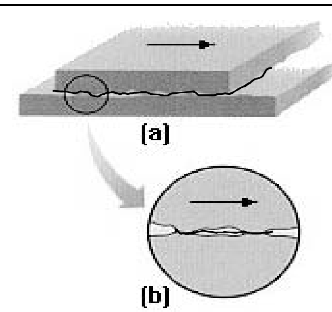
PRINCIPLE:

- Force found in the location of the contact between two surfaces.
- Force acts parallel to those surfaces in a direction opposing the relative motion between them.

The greater the weight (force of gravity) of an object, the greater the friction force

FRICTION

- **A force tangential to the common boundary of two bodies in contact that resists motion of one relative to the other.**
- **The greater the weight, the greater the friction force**
- **A byproduct of friction is HEAT.**



MODULE 4 - LIFTING AND MOVING – Part a

BASIC CONCEPTS RELATED TO FRICTION

- The smoother the two contact surfaces, the less the friction between those surfaces
- Liquids can reduce the friction between two surfaces (unless too much surfacetension is developed)
- Materials with rounded surfaces that break the contact between objects will generally reduce friction
- Reducing the size of the surface area between two objects may reduces the amount of friction present, especially if the contact surfaces are rough:
- Lifting operations often involve lifting only one side of the object which reduces the weight on the contact surface and consequently decreases the friction force.

FRICTION

- **Friction is usually controllable.**
- **Friction can be used to control the rate at which an object moves.**
- **Increase friction to slow movement.**
- **Decrease friction to increase movement.**

FRICTION AND EQUILIBRIUM

- Friction may be the outside force acting on a object creating equilibrium.
- The rescuer can change the amount of friction holding a object in place and allow the force of gravity to overcome the forces of friction:
  - Rocking motion
  - Making surface smaller (tilt lift)
  - Reducing the weight on the contact surface
- Friction holding an object in place can be overcome by the force of gravity when a object is on an inclined plane.

METHODS TO CONTROL FRICTION

- **Liquids**
- **Rollers/pipes/wheels**

- **Lift one side of object to reduce load on contact surface**
- **Reduce the size of a rough contact surface**

APPLICATION OF MECHANICS TO COLLAPSE RESCUE

Inappropriate or ineffective use of rescue tools is often a result of a lack of understanding of mechanical advantage. The following is an overview of mechanics of rescue:

- **Mechanics** is the branch of physics dealing with Force, Energy, Work, and Power in relation to physical bodies.
- **Leverage** is the practical application of the moment of force principle.

Mechanics

- **Mechanics is the act of applying a machine to an object to make it move.**
- **Once gravity and friction have been sized up, machine selection (tool) is next.**
- **Select the machine that most closely corresponds with the PRIME RULES of L&M:**

If you can leave it, leave it.
If you can't leave it, go around it.
If you can't go around it, drag it.
If you can't drag, roll it.
If you can't roll it, lift it.
If you have to lift it, STAY AWAY FROM IT…
IF IT FALLS DON'T BE UNDER IT!

MODULE 4 - LIFTING AND MOVING – Part a

ENERGY

- Energy is the Work that a physical system is doing in changing from it's current configuration to another one.
- Both Energy and Work are measured in Foot-Pounds, but Energy and Work are different
- There are two types of physical Energy systems, Stored Energy and Kinetic (moving) Energy
  - An example of Stored Energy is the condition when a heave object is positioned or suspended above a place where it can move to a lower level.
  - If a Crane suspends a 100lb weight 100ft above the ground, the Stored Energy is 10,000 ft-lbs. Any tall building has millions of ft-lbs of Stored Energy that can be liberated during a collapse
  - A swiftly moving Train is an example of Kinetic Energy
- The basic principles of the Conservation of Energy are stated in the adjacent slide

WORK

- In a general dictionary definition, Work is the Physical or Mental effort directed toward the production or accomplisment of something.
  - Transfer of Energy from one physical state to another
- In our case Work is the physical effort in moving an object from one position to another. The application of a Force in moving an object some distance against a Resistance (Friction and Gravity)
- In the case of Work an object (pounds) will be moved a distance (feet)
- In the case of Energy an object (pounds) is elevated a distance (feet) above where it can eventually be moved

POWER

- Power is the Rate at which Work is done. Objects (pounds are moved Distance (feet) within a specific Time (minutes)
  - One Hoursepower is 33,000 ft-lbs per minute
- We need Work to produce the Power that will overcome Friction, Gravity, Wind Resistance over a specific Time period

ENERGY AND WORK CONCEPTS

The effective use of rescue tools is often determined by a complete understanding of mechanical advantages systems and their application in a given situation.

Energy

- **The work a physical system is capable of doing in changing from its current state to another state:**
  - **burning wood to heat**
  - **rappelling heat from DCD**
  - **compressed SCBA bottled air to pneumatic tools**
  - **internal combustion engine**

Potential Energy: energy, by virtue of its position, stored (contained) energy.

Kinetic Energy: energy that a body possesses by virtue of being in motion.

SCT04a Slide 34

Conservation of Energy

- **Energy is neither created or destroyed, it only changes forms.**
- **A falling body's energy may be changed to heat via a friction control device.**
- **A mechanical advantage system only exchanges the load into extended time and distance.**
- **The amount of energy required to do the job is EXACTLY (minus the friction) the same.**

Work & Power

- **Work is the result of a force moving an object some distance.**
- **Power is the rate at which work is done**

The Human Machine

- **All machines require some type of energy source to make them work.**
- **Humans are an excellent source of readily available energy.**
- **Food is burned as fuel by the body to create an extremely versatile bio-machine.**

MODULE 4 - LIFTING AND MOVING – Part a

MOVEMENT

- Moment of force about a point (always a point) is weight (or force) multiplied by the distance away from the turning point of that weight or force.
- **Foot-pound** means of describing a Moment of Force
  - foot = distance
  - pound= force
  - force = influence that can change an object's velocity.
- When a force is applied that will cause rotation around a fulcrum (pivot point) = moment of force = foot-pounds.

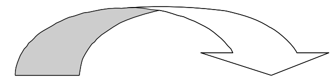
THE HUMAN MACHINE

- All machines require some energy source to apply the forces that will make them produce Work
- Humans can provide at Energy in the form of push and pull forces as well as applying their own weight in the downward direction
- Food is burned as the fuel in the body to create this bio-machine
- As noted in the adjacent slides The Rescue Squad can deliver a lot of Force that does the Work to produce Power

OVERVIEW OF MECHANICAL ADVANTAGE (MA)

- Ratio between the output force a machine exerts to the input force that is furnished to that machine to do work.
- Defines how efficient and effective a machine is.
- Mechanical advantage greater than one (1) means that the output force delivered by the machine exceeds the input force supplied to the machine.
- Mechanical advantage less than one (1) means that the output force delivered by the machine is smaller than the input force supplied to the machine.
- Applied to the relationship between the weight of a load being lifted and the power of the force required to lift/push/hold that load.

Movement



To obtain movement, these factors must come together:

- size-up of object being moved (weight, shape, obstructions, connection methods)
- mechanics (system to apply to the load)
- available energy (fuel, human machines)
- work, power, time

SCT04a Slide 39

The Human Machine

- **The average human rescuer can apply (long term) approximately a 50 pound force (lbf) pushing or pulling an object at the rescue scene.**
- **A force equal to the rescuer's weight may be applied vertically.**
- **The human machine combined with the simple machine can move extremely heavy objects.**
- **A five person team applying force to a 5:1 mechanical advantage simple machine can deliver a 1250lb Force to an object:**
  5 (people) X 50 (lbf each) = 250 X 5 = 1250lbf

The Human Machine + The Simple Machine

- **If an object weighs 5000 pounds, and your team has 10 people on it, what level MA (force multiplier) is required to move the object?**

a) 5:1, b) 7:1, c) 10:1, d) 15:1

Mechanical Advantage (MA) Definition

- **Mechanical advantage is a force multiplier.**
- **The ratio between the output force a machine exerts to the input force that is furnished to that machine to do work, i.e.: 5:1 pulley system, the human machine puts in one part and the anchor holds 4 parts (4 + 1 = 5).**

Mechanical Advantage & Conservation of Energy

Mechanical (apply force to an object)

Advantage (force multiplier) uses the same amount of energy to move an object as would moving the object with zero MA. MA simply allows us to use less force to move an object by spreading the work out over time and distance.

Example: a 5:1 pulley system takes 5 times as much rope to move the load as a 1:1 system would take.

SCT04a Slide 45

MODULE 4 - LIFTING AND MOVING – Part a

OVERVIEW OF MECHANICAL ADVANTAGE (MA) (cont)

- Since all machines, including lifting devices, the efficiency of a machine is determined by calculating the Theoretical MA and subtracting Friction
  - In pulley systems the Friction Factor may be around 10%. That requires a 110lb force to lift a 100lb object

SIMPLE MACHINES

- Consist of inclined planes, levers, pulley wheels, gears, ropes, belts, and/ or cams.
- Rigid or resistant bodies that have pre-defined motions.
- Capable of performing work.
- Energy applied to these mechanisms by a source that causes these mechanisms to perform useful motion.
- More efficient to perform work with machines than with muscle force only.
- We will now discuss Inclined Planes, Levers, Pulleys, and an advanced leverage application, the A-Frame

Theoretical vs. Actual Mechanical Advantage

- Theoretical MA (TMA) is the system with a complete lack of efficiency robbing friction.
- Actual MA (AMA) is the TMA minus the friction coefficient of the friction surface.
- If TMA = 5:1 and the Friction Coefficient (FC) of the system is 10%
  AMA = 5.0-.5 = 4.5 to1

SCT04a Slide 47

Secondary MA Efficiency Factors

There are inherent secondary inefficiencies in any mechanical system. Myriad factors influence efficiency:

- Equipment condition
- Environmental conditions
- Material elongation
- Beam deflection
- Wood compression
- Torque in a shaft
- Interpersonal relationships

Point Of Diminishing Returns

Every machine has a point of diminishing returns:

- Too big.
- Too complex.
- Too heavy.
- Material weakness.
- Too much fuel required.

SCT04a Slide 49

SIMPLE MACHINE

- A simple machine accomplishes its task in a single movement.
- A COMPOUND machine combines two or more simple machines.
- Machines allow us to *APPLY* mechanical advantage to an object.

Simple & Compound Machines

- Trade off of time and distance by placing the force required to move an object into our available power window.
- Nothing is free, the amount of energy expended is equal. (Conservation of Energy)

SCT04a Slide 51

MODULE 4 - LIFTING AND MOVING – Part a

INCLINED PLANES

- Examples: Ramps, wooden wedge, screw thread
- Gains effectiveness of energy used based on distance traveled = mechanical advantage.
- Use of a gradual slope = less force to move an object a certain distance.
- **Percentage of load based on slope and grade**
  - When an object comes to rest on a slope, the rescuer must determine the percentage of the loads weight that needs to be managed during the stabilization process.
  - To estimate the load percentage first determine the amount of resistance the load surface has in relation to the object.
  - Discounting friction refer to the table below for approximate weight based on slope.

Slope/Grade	% of Load's Weight
45 degrees	71%
30 degrees	50%
20 degrees	34%
10 degrees	17%

- However the friction force associated with sliding objects up ramps may be as high as 35%
  - In this case the Force that is requires to move the object up the ramp is greater as shown above and in adjacent slides
  - The Friction MAY be uses as a Break to keep the object from sliding back down the ramp when the slope is less than about 20 degrees

Inclined Planes

- The least complicated of all simple machines.
- The least efficient of all simple machines because the large surface area of contact generates efficiency robbing friction.

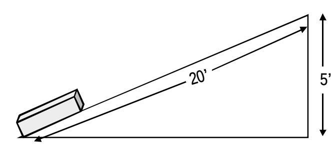
Inclined Planes

- Gain efficiency by reducing required force to raise object.
- Less force and more distance = same work, (Conservation of Energy)
- Efficiency depends on the slope of the incline and the friction on it's surface.

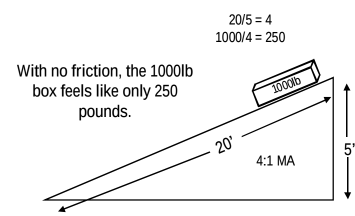
Inclined Planes

Travel length divided by height = MA

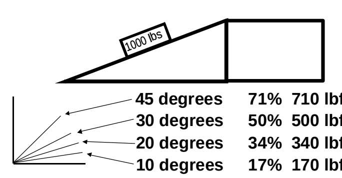
20/5 = 4.0 = 4:1 MA



Inclined Planes



Percentage Of Load Based on Slope w/o Friction



This is the force required to push object up the ramp as a percent of its weight.

MODULE 4 - LIFTING AND MOVING – Part a

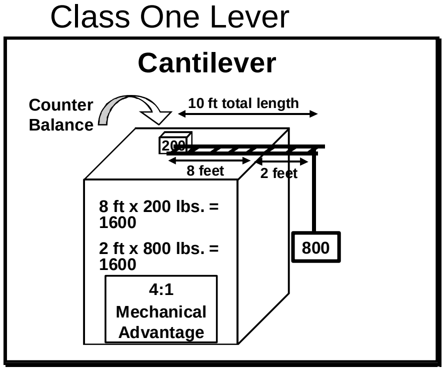
LEVERS

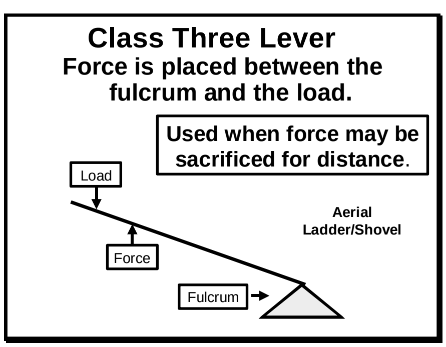
"Give me a place to stand and I will move the World"
Archimedes

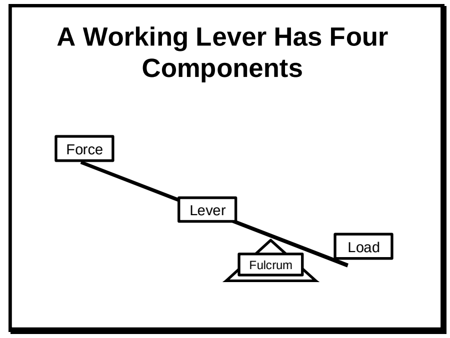
- Application of levers:
  - Move a load that is heavier than can be moved by manpower alone.
  - Pulling/hauling.
  - Raising.
- Leverage is the means of accomplishing work with levers:
  - Transfers force from one place to another.
  - Changes the force's direction.

CLASSES OF LEVERS

- **Class One Lever**
  - Fulcrum is placed between the force applied and weight (load).
  - MA: Used when a decided advantage is desired.
  - Examples: Crowbars, wrecking bars, pliers, scissors
- **Class Two Lever:**
  - Weight (load) is placed between the force and the fulcrum.
  - MA: Used for advantage in moving heavy materials on a horizontal/near horizontal surface.
  - Examples: Wheelbarrows, furniture dollies
- **Class Three Lever:**
  - Force placed between the fulcrum and the load.
  - MA: used when force may be sacrificed for distance.
  - Examples: Brooms, shovels, baseball bat, tweezers
- The cantilever in the slide below is a special case of a Class One Lever

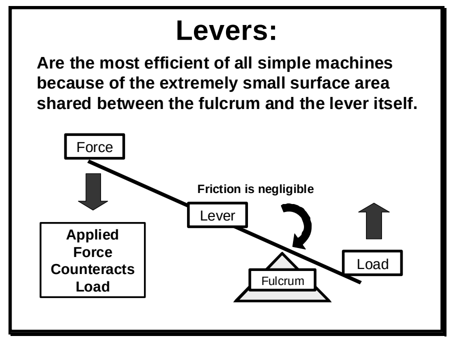


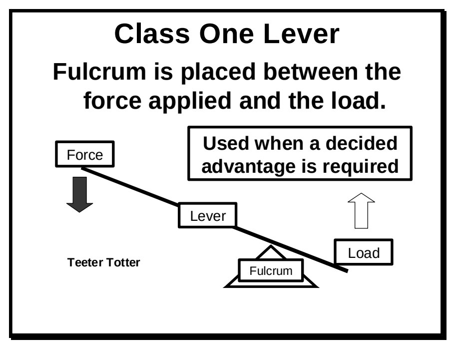


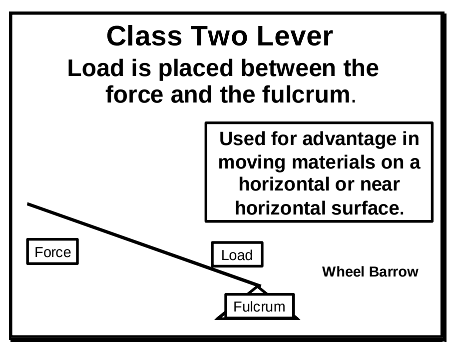


Levers Can:

- **Move a load.**
- **Haul or pull a load.**
- **Raise a load.**
- **Leverage transfers force and/or changes the forces direction.**
- **Levers allow us to perform work by moving heavy objects.**







MODULE 4 - LIFTING AND MOVING – Part a

SCREW-TYPE MACHINES

- Examples of screw-type machines: Worm gears, screw jacks and valves in fire hydrants.

- Characteristics of these machines are:
  - Combination of a lever and an inclined plane.
  - Thread of a screw is an inclined plan encircling the stem of the screw.
  - Handle is the lever.
  - Thread works in a corresponding groove in the base.
  - Thread is forced to move under the load.
  - One rotation of the handle moves the thread through a distance equal to the distance between it and the thread below it.
  - Distance moved is call the pitch of the screw.

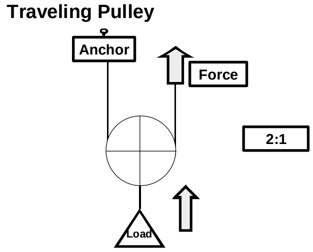
PULLEYS

- Application related to loads:
  - Lifting
  - Pulling
  - Moving
  - Change direction
  - Mechanical advantage
  - Reduce friction

- Fixed Pulley - Change direction of effort:
  - Pulley is stationary: Does not change theoretical mechanical advantage

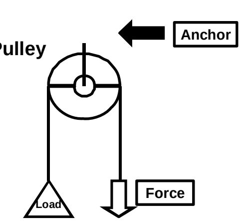
- Traveling Pulley - Gain mechanical advantage:
  - Pulley is moving: Changes mechanical advantage depending on use
  - Bitter end at the load — the simple system is odd
  - Bitter end at the anchor — the simple system is even

TRAVELING PULLEYS



Fixed Pulleys

- COD Pulley



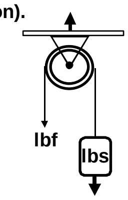
FLEXIBLE POWER TRANSFER METHODS

- Allow us to apply force at one location and move or stabilize an object at another location
- Ropes
- Chains
- Belts
- Cables

Configuration of Pulleys - Fixed

- Fixed pulleys called COD's that provide no mechanical advantage (only Change Of Direction).

Sometimes pulleys change the direction of a force but do not make the load feel lighter.

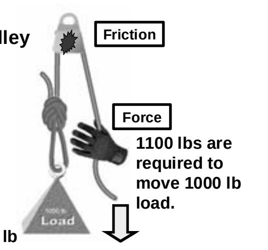


FIXED PULLEYS

All Pulley Bearings make FRICTION.

- COD Pulley

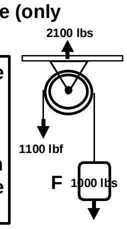
Most ball bearing pulleys lose about 10% efficiency when loaded to 10% or less or their capacity.



Configuration of Pulleys - Fixed

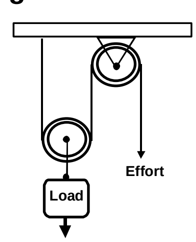
- Fixed pulleys called COD's provide no mechanical advantage (only Change Of Direction).

BUT! All pulleys are force multipliers and even when anchored can increase the load on the anchor…to more than double!



Configuration of Pulleys - Moving

- Moving pulleys that are rigged to the load and move when load is pulled, hauled, or raised (Mechanical Advantage).



MODULE 4 - LIFTING AND MOVING – Part a

PULLEYS (continued)

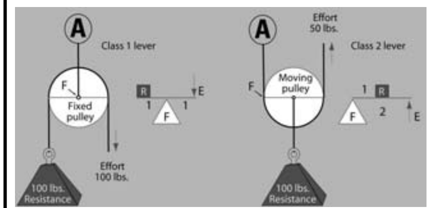
- Calculating Pulley Mechanical Advantage (MA)
  - In general the system needs to have a Traveling pulley in order for there to be a MA
  - The number of rope lines (Parts of Line) coming from the Traveling Pulley determines the MA
  - The Load will travel the distance Traveled by the Pulled end of the line divided by the MA
  - As MA becomes greater the Anchor shares more Parts of Line

- In Simple pulley systems there is one set of Fixed pulleys and one set of Moving pulleys (Sheaves)
  - Add sheaves side by side to increase MA
  - On ODD numbered systems the Terminal end of the rope begins on the Load side of the system
  - For EVEN numbered systems the Terminal end of the rope begins at the Anchor End of the system

- In Compound pulley systems the pulleys are "**Stacked**" to gain MA, as shown in the adjacent slide
  - These systems have less Friction, use less rope and have a shorted Stroke

The difference between theoretical and actual mechanical advantage is "friction

How Pulleys Work



SCT04a Slide 90

Sharing the Load with our Hero the Anchor

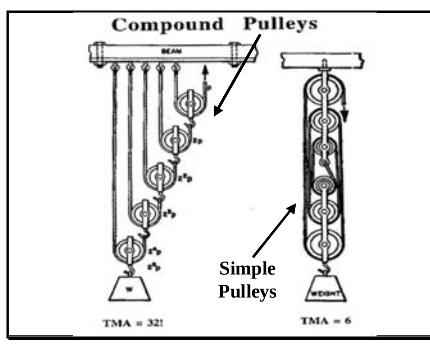
- **The anchor shares progressively more "parts" of the load.**
- **On a 5:1 MA, the anchor carries 4 parts, and the force necessary to move the load only carries one part.**

Simple Pulley Systems

- **Add sheaves (side by side) to gain advantage.**
- **On ODD numbered systems the terminal end of the rope begins on the LOAD side of the system.**
- **On EVEN numbered systems the terminal end of the rope begins on the ANCHOR side of the system.**

Compound Pulley Systems

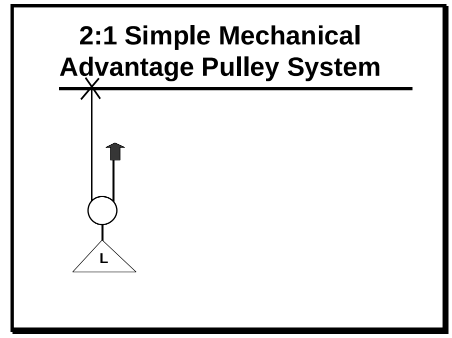
- **Multiply sheaves (stacked pulleys) to gain advantage.**
- **2 to the 2^{nd} power = 4:1 C.**
- **2 to the 4^{th} power = 16:1 C.**
- **Less friction, less rope,**
- **LESS STROKE!**

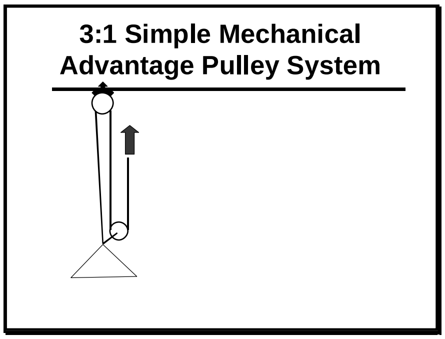


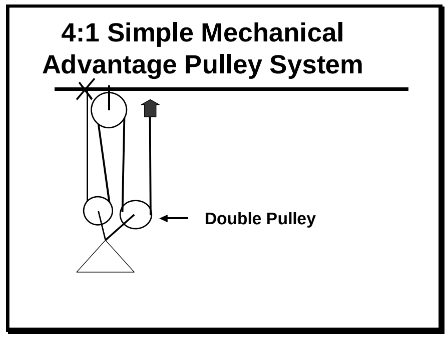
MODULE 4 - LIFTING AND MOVING – Part a

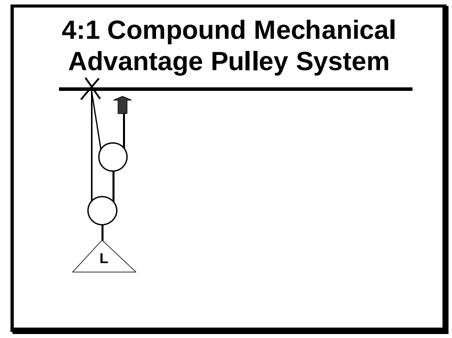
PULLEYS (continued)

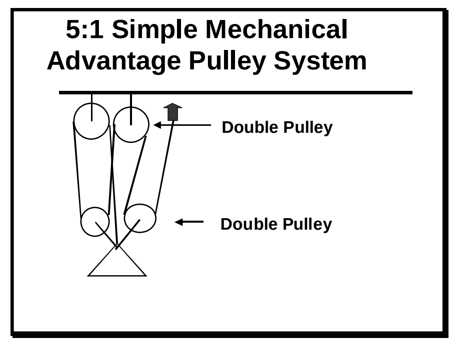
- **The adjacent slides provide examples of various pulley systems with different Mechanical Advantage**



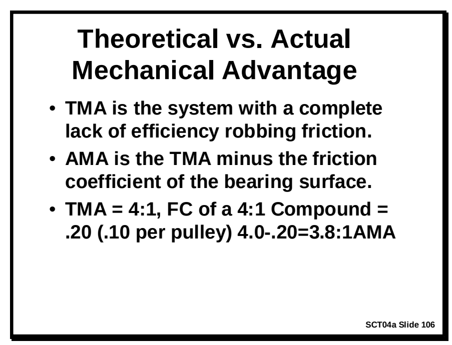








- **The difference between theoretical and actual mechanical advantage is "friction".**
  - **This is illustrated in adjacent slide**
  - **The pull required to move the load that is attached to the rope that runs over the pulley is the Load + Friction**



MODULE 4 - LIFTING AND MOVING – Part a

ADVANCED LEVERAGE APPLICATIONS A-Frame

- The A-Frame is a fairly complex application of leverage that involves floating an object in air between two horizontal points.

- The application for the A-Frame is most practical during collapse situations involving the movement of objects where there are no suitable overhead anchor points and crane access is not practical.

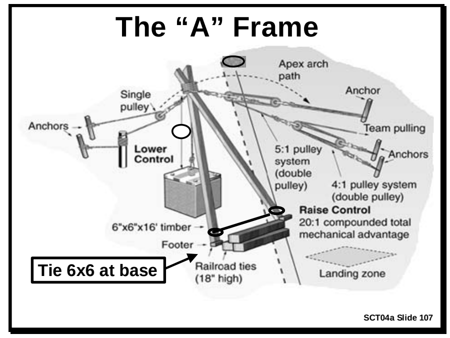
- The A- Frame may be made from two 6x6x14'-0" timbers that are lashed together at the top, or by using a pair of 12 ft long, aluminum rescue struts connected using special apex and foot connections.
  - The two lower ends of the A-Frame must be connected together, just above the ground, using a stout rope, webbing or chain.
  - The legs should be spaced from 10 to 12 feet apart at the ground.

- A 15:1 or 20:1 compounded mechanical advantage pulley system used for swinging the A-Frame is attached to the apex of the gantry and anchored to an appropriate bombproof anchors.

- The object (Load) is attached to the apex of the A-Frame using a short rigging strap, and a lowering control rope is connected opposite the mechanical advantage pulley system.

- As the A-Frame is tensioned and elevated, the load starts to rise. A hoist or come-along may also be used to initially suspend the load.

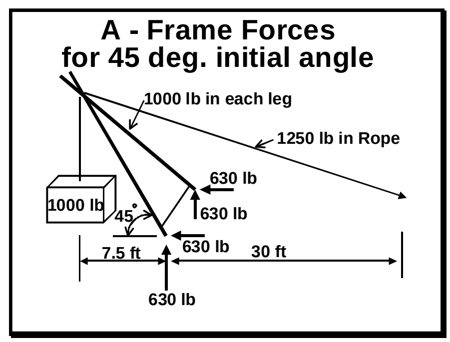
- The A-Frame apex must be rotated to be centered over the load, but the angle between the ground and the A-frame should not be less than 45 degrees.
  - At this angle the initial force on the hauling rope system is about 25% greater than the load, assuming that the hauling anchors are placed at least 30 feet from the base of the A-frame legs.
  - The force in each of the A-Frame legs will be about equal to the load as the lifting begins.

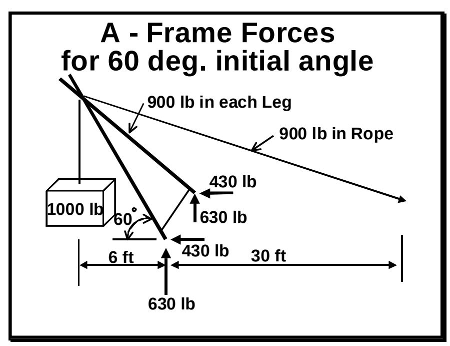


The "A" Frame

- The A-frame provides method for lifting and/or stabilizing heavy loads using simple and readily available materials.
- The A-frame crosses many technical rescue disciplines by allowing rescuers to establish elevated anchor attachments for rope rescue systems, or for use in confined space rescue.
- The simple addition of a third leg makes a stand along tripod. The A-frame reinforces the cognitive ability of being able to improvise when more common rescue tools are not available.

SCT04a Slide 108



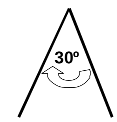


MODULE 4 - LIFTING AND MOVING – Part a

ADVANCED LEVERAGE APPLICATIONS A-Frame (cont.)

- As lifting begins, forces are generated in the A-Frame legs
  - The horizontal force tending to move the base of each of the A frame legs away from the load will be about 2/3 of the load.
  - There will also be a vertical load acting into the ground at the frame base that is about equal to this horizontal force.
  - These forces need to be resisted by the ground, and/or some type of restraint system.
- The dimensions and forces for two A-Frame systems, using 45 and 60 degree initial angles are shown in the adjacent slides and on the following page.

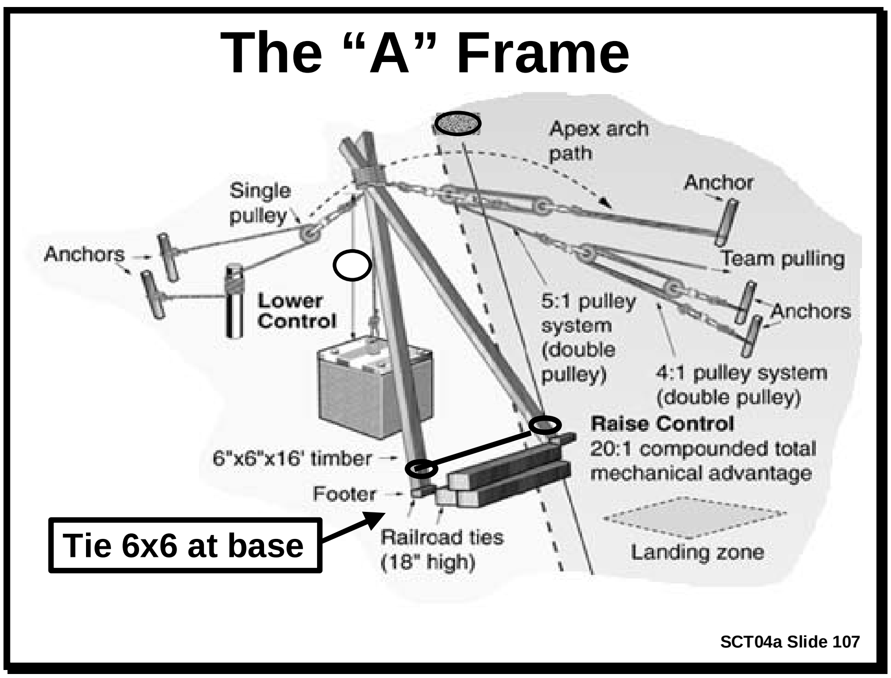
The "A" Frame can be made with 6" X 6" X 16' Timbers Rated at 5,000lb with an Apex Angle of 30º.



SCT04a Slide 112

Lashing 6"X6"X16' Timbers to make the "A" Frame

- Use 60' ½" static rescue rope.
- Clove Hitch with (4) side safety.
- (8) figure eight wraps.
- (4) fraps.
- Clove Hitch with (4) side safety.
- 2"X 6" scabs (5) nail pattern.



SCT04a Slide 107

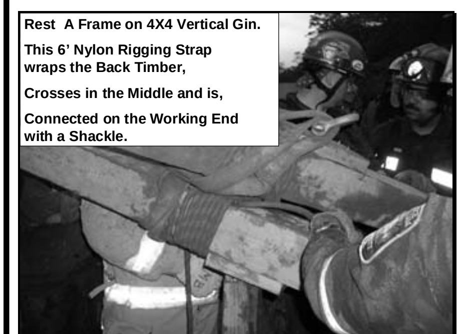
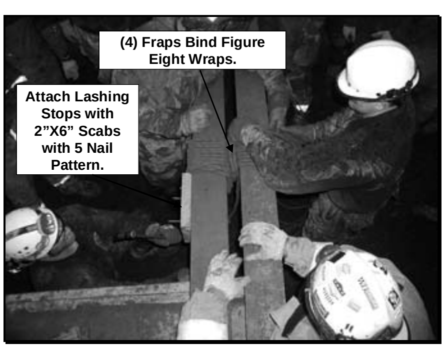
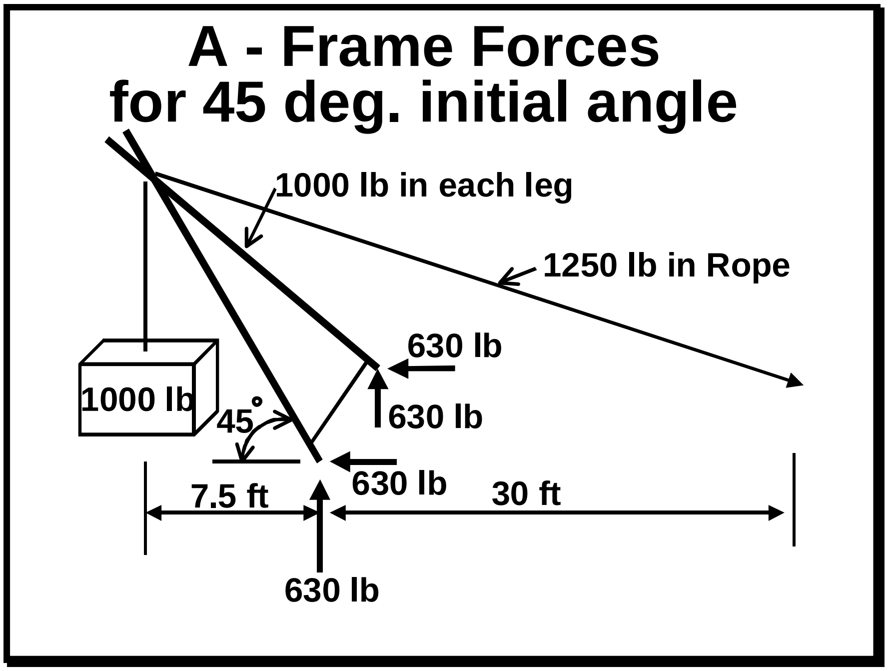


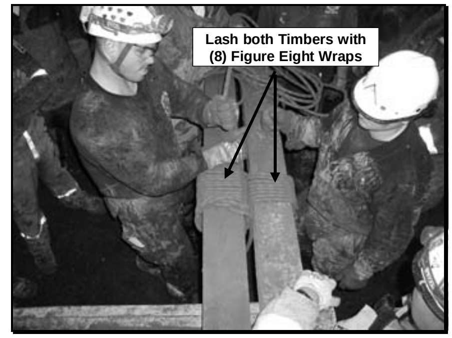
DIAGRAM OF TIMBER A-FRAME

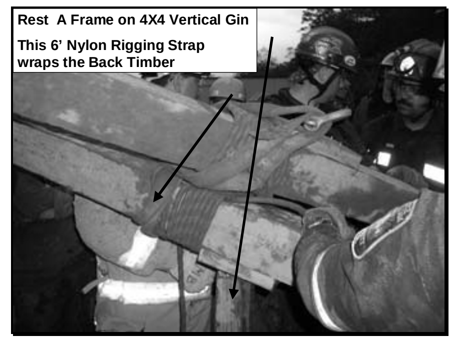


MODULE 4 - LIFTING AND MOVING – Part a

DIAGRAM OF A-FRAME FORCES at 45 degree angle
(per 1000lb load. Suggested maximum Load = 4000lb







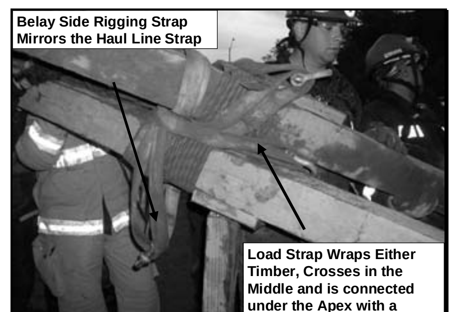
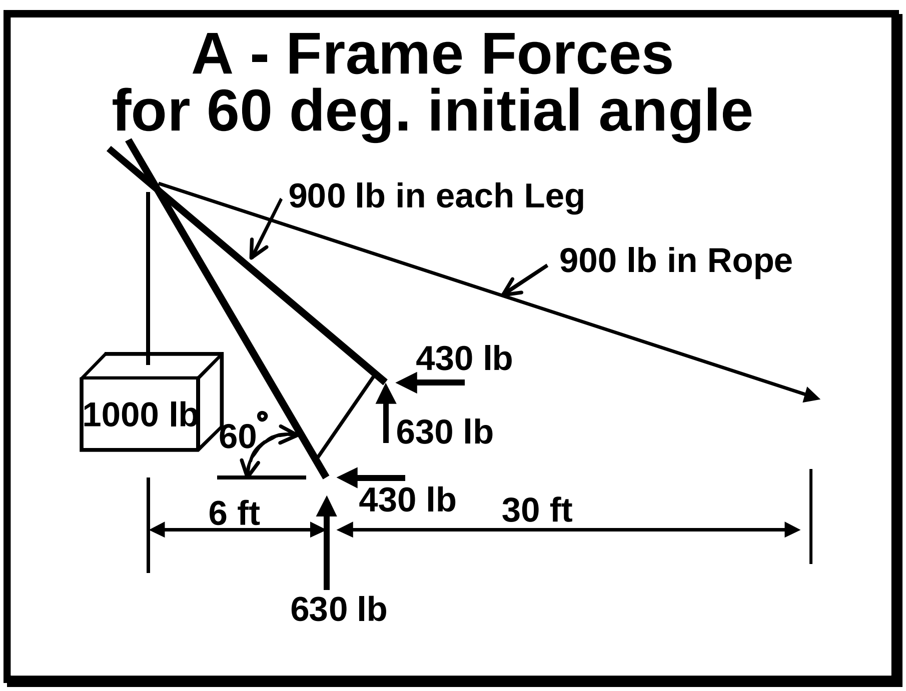
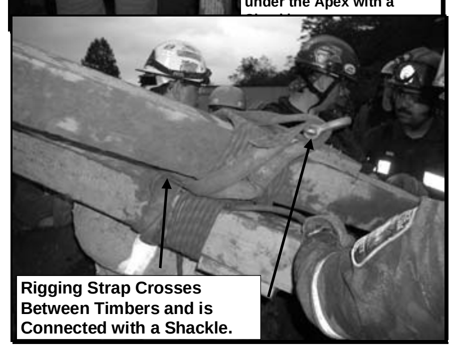


DIAGRAM OF A-FRAME FORCES at 60 degree angle
(per 1000lb load. Suggested maximum Load = 4000lb)

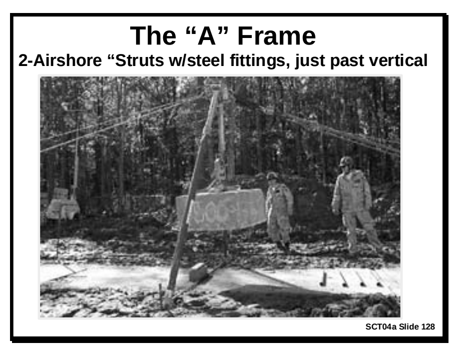




MODULE 4 - LIFTING AND MOVING – Part a

A-FRAME (continued)

- In most cases it is necessary to provide a footing/baseplate for each leg of the A-Frame.
    - In very firm ground, a shallow hole may provide enough resistance to the compression forces that are exerted when the A -Frame legs rotate.
        - The forces at the edges of the 6x6 will dig into the ground and create their own bearing surfaces.
    - In softer ground, it may be necessary to use a pair of 12" square plywood gussets to spread the load, and neoprene pads will be helpful in providing shaped bearings for the edges of the 6x6 as it rotates.
    - On concrete paving surfaces, it will be necessary to carefully restrain the 6x6 from slipping, and provide for the rotating bearing.
    - In the Airshore Rescue Strut A-Frame system, a 12" square base plate that provides for the bearing and rotating leg.
        - This base plate must be properly restrained using rope, chain, or other mechanical anchors.
- As the A-Frame is arched over, the load elevates until the gantry is straight up and the object being lifted is directly beneath apex.
    - As the load moves past 90 degrees, the pulley system becomes useless, and the lowering ropes take over the controlled lowering of the load.



MODULE 4 - LIFTING AND MOVING – Part b

TOPICS to be COVERED in PART b

- **Airbags**
- **Lifting Considerations & Stabilization**
- **Calculating Weights**

HIGH PRESSURE AIR BAGS

- Characteristics are:
  - Neoprene/butyl rubber — outer
  - Steel/Kevlar — reinforcement
  - Variety of sizes
  - Outer layer textured to reduce slippage
  - Capacity is calculated at 1" of lift
  - At maximum height, usable capacity typically is reduced to 50% of the rated capacity.
- Application:
  - Maximum stack of two high (**bag centers must align)**
  - Lift capacity is that of the smaller bag
  - Lift height is increased
  - Ensure that the smallest bag has capacity for the lift
  - Place the large bag on the bottom
- Bags in tandem:
  - Bags side-by-side or at two points on a load
  - Maximum working capacities added together
  - Consider lift height as well as load weight
- Working area:
  - Flat surface
  - Solid cribbing bed under bag
  - Establish safe zones
  - Pressurize bags slowly and watch for load shift
  - If load is uncontrolled, stop the lift and reevaluate
  - Use solid cribbing or wedges under the load to stabilize
  - See manufacturer's manual for additional information
- Calculating lifting capabilities:
  - Maximum working pressure of individual bag
  - Surface area contact (is smaller than bag dimensions)
  - Working pressure of bag under load when in use
  - Maximum working capacity is the maximum contact surface area of the bag (**always smaller than bag dimensions**) times the maximum working pressure.
  - As the air bag lifts and "pillows," surface contact is reduced and the lift capacity is decreased

High Pressure Air Bags

- Characteristics
  - Neoprene/butyl rubber
  - Steel kevlar reinforced
  - Variety of sizes
  - Maximum capacity is calculated at 1 inch of lift
  - Capacity reduced at max height

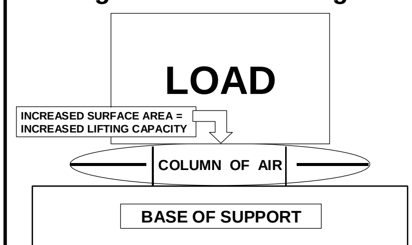
SCT04b Slide 3

High Pressure Air Bags

- Application
  - Maximum stack of two high
  - Lift is limited to capacity of small bag
  - Larger bag on bottom
  - Centers of bags MUST be aligned

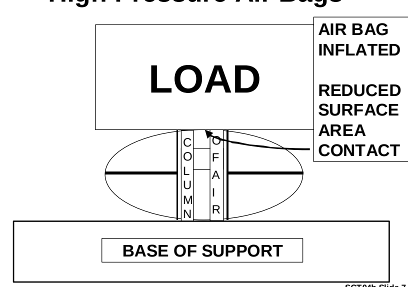
SCT04b Slide 4

High Pressure Air Bags



SCT04b Slide 6

High Pressure Air Bags



SCT04b Slide 7

High Pressure Air Bags

Dimension	Capacity	Lift Ht.	Weight
6”x 6”	1.5 Tons	3”	2 lbs
6”x 12”	3.2	3.5	3
10”x 10”	4.8	5	4
15”x 15”	12.0	8	10
15”x 21”	17.0	9	13
20”x 20”	21.8	11	16
24”x 24”	31.8	13	22
28”x 28”	43.8	16	30
36”x 36”	73.4	20	48

SCT04b Slide 8

MODULE 4 - LIFTING AND MOVING – Part b

HIGH PRESSURE AIR BAGS (continued)

EXAMPLE

- 10" x 10" air bag is 100 sq.in. in total area. The maximum working pressure is 118 PSI, and 100 sq.in. times 118 PSI = 11,800 lbs. of lift (5.9 tons) if full bag area was in surface contact. **From chart, actual capacity is 4.8 tons**.

- Check bag for **Identification Tag** that lists maximum pressure, load and lift height data.

High Pressure Air Bags
I.D. Tag is right on Bag

MAXIFORCE KPI 12
AIR LIFTING BAG SERIAL# 940492
MAXIMUM LIFTING CAPACITY 12TONS 10845 KG
MAXIMUM WORKING PRESSURE 118 PSI 8 BARS
MAXIMUM LIFTING HEIGHT 8 IN. 208 MM
MAXIMUM AIR CAPACITY 2.3 CU FT 65 LITERS
PARATECK INCORPORATED FRANKFORT, IL. U.S.A.
READ INSTRUCTIONS BEFORE OPERATING THIS EQUIPMENT

MECHANICS OF LOAD STABILIZATION AND MOVEMENT

- Four functions that need to be addresses before any load is stabilized, lifted, or moved:
  - Center of gravity
  - Load Stability including Shims, Wedges & Cribbing
  - Estimating Load Weight
  - Lifting Functions including Critical Angle Considerations

Lifting Or Moving A Load
- FUNCTIONS TO BE ADDRESSED
  - –Center of Gravity
  - –Load Stability
    - wedges & cribbing
  - –Estimating Load Weight
  - –Lifting Functions
    - critical angle

SCT04b Slide 22

CENTER OF GRAVITY

- **Center of gravity** is where any load's entire weight is concentrated.

- Loads will seek to have their center of gravity below the point of support.

- Moment of force (distance times weight) is created when the center of gravity moves around a fulcrum.

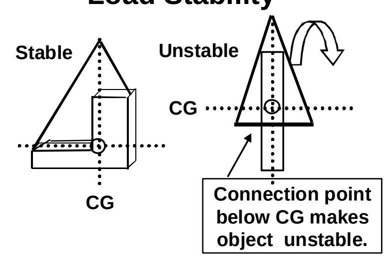
- Narrow base of support can rapidly become fulcrum (pivot point) for the load.

- The higher the center of gravity is located in the load, the wider and more stable the base of support needed to maintain the static equilibrium.

- A load with a relatively high estimated center of gravity and narrow base of support must be considered to be in a state of unstable equilibrium = moment of force of load's own weight (or external force) can cause the load to move into a state of equilibrium (i.e., fall over).

- Load rotation when the lifting point of the rigging is not directly above the center of gravity.

Center of Gravity and Load Stability



SCT04b Slide 23

MODULE 4 - LIFTING AND MOVING – Part b

LOAD STABILIZATION

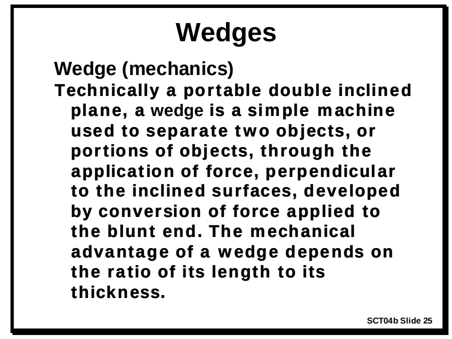
- Make load attachments above center of gravity when possible.
- Place attachments above and on either side of the estimated position of center of gravity to control load.
  - Wind or shaking from an earthquake (external force) can move a load with high estimated center of gravity and narrow base of support.
- Widen and extend the load base of support when:
  - Distance from base of support to estimated center of gravity is greater than the width of base of the support. Loads showing any signs of rocking or swaying = unstable equilibrium state. Consider that center of gravity may change:
  - Ground shaking changing position of internal load such as machinery in structure
  - Base of support shifting

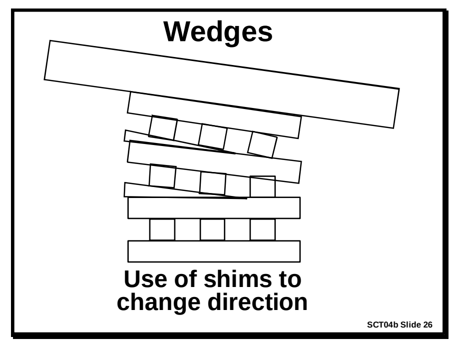
WEDGES / SHIMS / CRIBBING

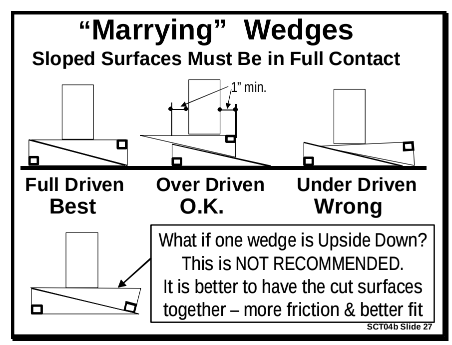
- Wedge Sets (always use Married Pairs)*
  - Snug up or tighten load.
  - Change of direction.
  - 2x wedges are more stable than 4x
  - For Shoring, Wedges will start to Cup when the Load reaches about 1.5 times the Allowable Load. This converts to a pressure of about 1000psi. This provides an Overload Indicator (Structure Fuse) for shoring.
  - If Cupping of Wedges occurs when Moving Objects, the process must be stopped Immediately, since it is too dangerous

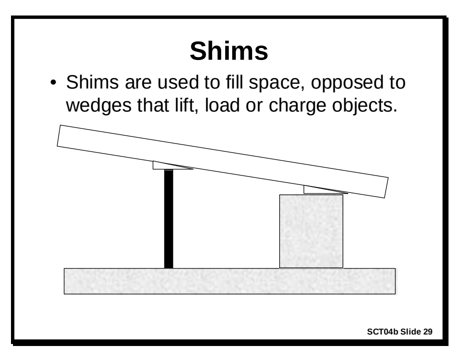
  * = It is always best to place the Wedge Pairs so their Cut Surfaces are in Full contact with each other when moving objects. There will be more Friction and more complete contact . The Ends will also be Square for better Driving

- Shims (single wedge):
  - Stabilizing tools.
  - Incline plane (MA).
  - Take up void space.





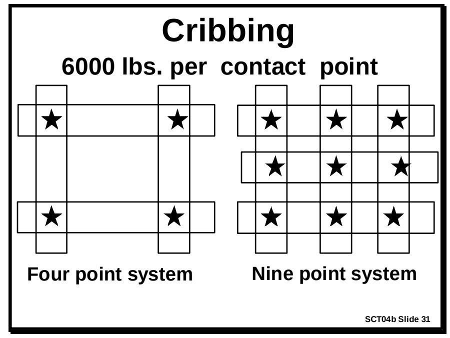


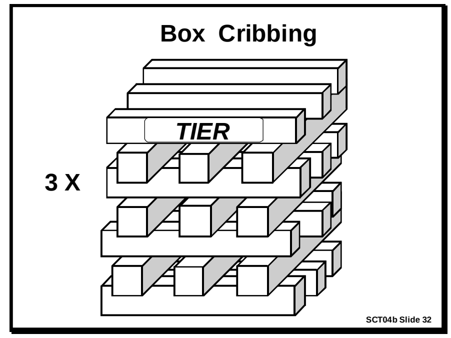


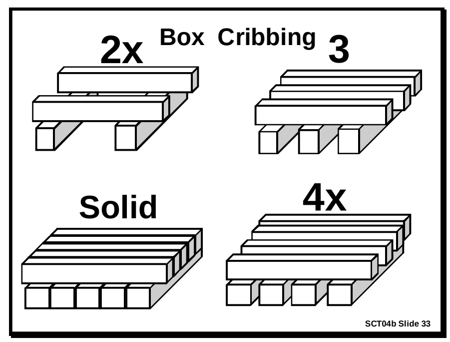
MODULE 4 - LIFTING AND MOVING – Part b

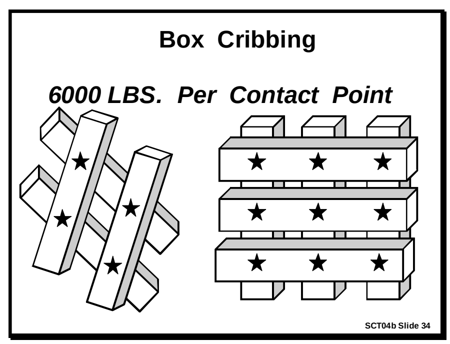
CRIBBING

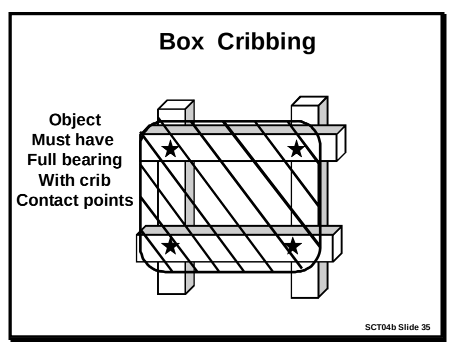
- Characteristics of Cribbing
  - Douglas Fir or Southern Pine
  - Tends to crush slowly
  - Provides advance warning of failure
  - 500 pounds per sq. inch (psi) maximum load capacity
- Cribbing Types:
  - Box (2 x 2 Crib) : four points of contact
  - Crosstie (3 x 3 Crib) : 9 points of contact
  - Solid : entire surface area contact
- Cribbing strength is determined by figuring the surface area at each point of contact and multiplying by the wood strength
  - 500 psi for Douglas Fir, but as low as 250 psi for softer wood..
- Example:
  - 4x4 box cribbing is really 3.5" X 3.5" = 12.25 X 500psi. = 6,125 lbs. per contact point. Call it 6000 lbs
    - Total for Box Crib = 4 x 6000 = 24,000
    - Total for 3 x 3 Crib = 9 x 6000 = 54000
  - 6x6 box cribbing is really 5.5" X 5.5" = 30.25 X 500 lbs. = 15,125 lbs. per contact point. Call it 15,000 lbs
    - Total for Box Crib = 60,000 lbs
    - Total for Crib 3 x 3 = 135,000 lbs
- Height of cribbing when used to stabilize loads to be moved should be limited to two times the width.
  - Support the load on the contact points (load to ground) as uniformly as possible.
  - When using cribbing to support collapsed structures the height may be increased to three times the width.
- See Adjacent Slides for information on limiting height to only 1 to 1, etc. when Load is not supported uniformly.

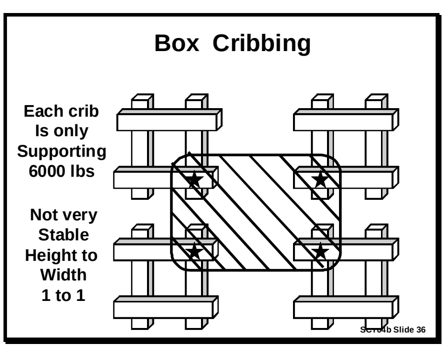


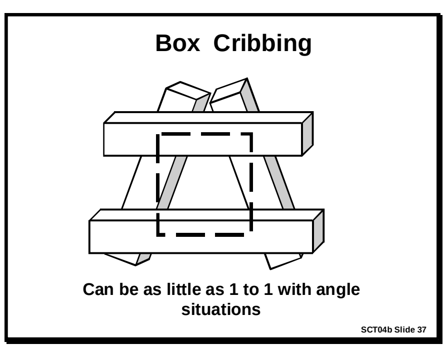












MODULE 4 - LIFTING AND MOVING – Part b

CRIBBING (continued)

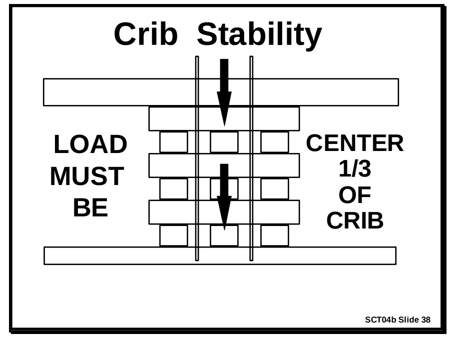
- When used for Moving Objects, the Center (or C.G.) of the Supported Load must be within the middle 1/3 of the Crib as shown in the Adjacent 3 Slides
  - The third of these Slides shows a Sloped Slab being supported by Cribbing.
  - The angle of the Slope to be allowed when Moving Loads needs to be limited to 10%
    (1 ft in 10 ft, same as 6 deg)
  - When using Cribbing as Shoring to support Sloped Slabs of Structures the angle is limited to 30%
    (3 ft in 10 ft, same as 15 deg)

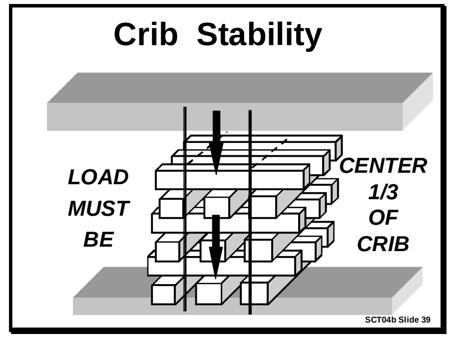
ESTIMATING LOAD WEIGHTS

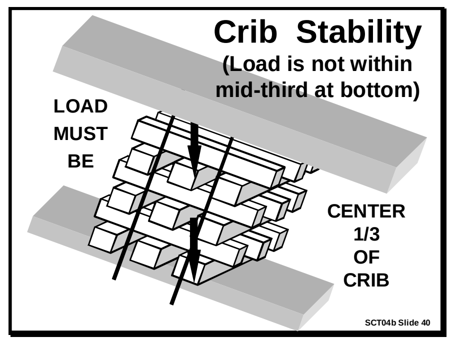
- Weight for material in pounds per cubic foot (pcf)
  - Reinforced concrete = 150 pcf **
  - Steel use 490 pcf (use 500)
  - Earth use 100 pcf
  - Wood use 40 pcf

** = This assumes that the concrete weighs 145 pcf and the reinforcing steel adds 5 pcf. However, Concrete Beams and Columns are often more heavily reinforced and may weigh as much as 175 pcf. This can be very important to know when lifting with a Crane

- Size formula for solid objects = W x H x L x weight
- For Cylinder = 0.8 Diameter^2 x L x weight
- For Pipe = (Volume of Solid – Volume of Hole) x weight





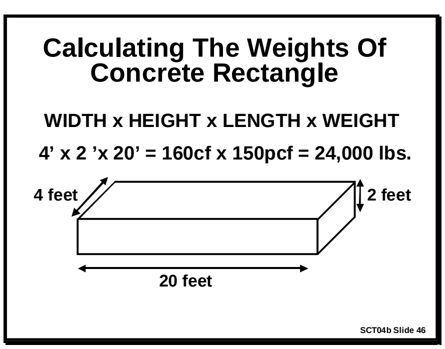


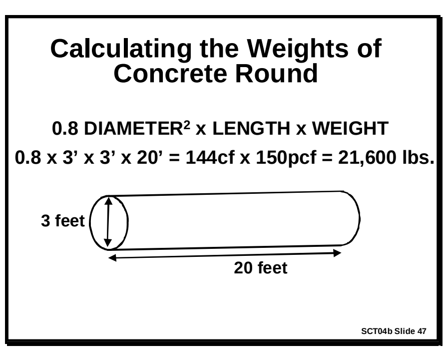
Weights Of Common Materials

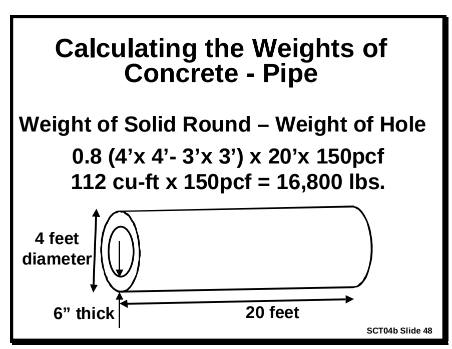
WIDTH X HEIGHT X LENGTH = CUBIC FT

- Steel 490 lbs. per cubic foot (pcf)
  - See following slides for 3.4lbs per Sq in per ft Method
- Concrete 150 pcf (Columns & Beams may be Heavier)
- Earth 100 pcf (approximate)
- Wood 40 pcf

SCT04b Slide 45







MODULE 4 - LIFTING AND MOVING – Part b

ESTIMATING THE WEIGHT OF STEEL

- Often rescue operations are needed when large steel beams and columns are present in a collapsed structure.
- Since these heavy objects will need to be moved, some of the first things to consider are the lifting capability of the available equipment, based on the distance to the objects initial and final positions.
  - The information regarding maximum lifting capacity will determine where to mark and cut the heavy steel members so that the weight requirements are met.
  - Most metal suppliers offer booklets that give information about the weight of steel by thickness, shape and dimension, usually on a per foot basis.
- There is a very simple way to calculate the weight per foot of any steel cross section when one realizes that a one square inch bar of steel that is one foot long weighs 3.4 lbs

Calculating the Weight of Steel
- Steel weighs 3.4 lbs per sq inch, per foot of length
  - 1” square steel bar weighs 3.4 lbs per ft
- Example 1:
  1” x 12” steel plate x one foot long weighs?
  12 sq in x 3.4 = 40.8 lbs per linear foot (plf)
  (same as 12 - 1” square bars x one foot long)
- Example 2:
  1 ½” dia. round steel bar x 20 ft weighs
  1.5” x 1.5” x .78 (for round shape) x 20’ x 3.4
  = 1.77 sq in x 20’ x 3.4 = 120 lbs
  (Wire Rope weighs abt 2/3 of same size Round Bar)

SCT04b Slide 49

Therefore the **General Rule** to remember is:
<u>Steel weighs 3.4 lbs per square inch, per foot of length</u>
(A 1” x 1” square steel bar, 12” long weighs 3.4 lbs)

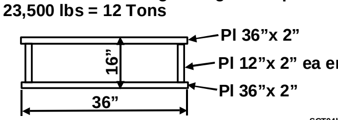
Example 1:
The weight of a 1 inch thick x 12 inch steel plate is ?
1” x 12” x 3.4 lbs per sq inch per ft of length = 12 sq in x 3.4
= **40.8 lbs per ft.** (same as 12 one inch sq bars x 1’ long)

Example 2:
What does a 1 ½” diameter X 20 ft long round steel bar or steel cable weigh?

Answer 2: 1 ½” x 1 ½” x .78 (for round shape) x 20’ X 3.4
= 1.77 sq in x 20’ x 3.4 = **120 lbs**

Example 3:
What is per ft weight of a fabricated, square steel tube column that is made from a pair of 36” x 2” plates and a pair of 12” x 2” plates? (See adjacent slide for configuration)

Calculating the Weight of Steel
- Example 3:
  What is weight of the fabricated steel column that is shown below?
  (2 x 36” x 2” + 2 x 12” x 2”) x 3.4
  (144 sq in + 48 sq in) x 3.4
  192 sq in x 3.4 = 653 lbs per ft (plf)
  If Column is 36’ long it weighs 653 plf x 36’ = 23,500 lbs = 12 Tons



SCT04b Slide 51

Answer 3: (2 X 36” x 2” + 2 x 12” x 2”) x 3.4 =
(144 sq in + 48 sq in) x 3.4 =
192 sq in x 3.4 = 653 lbs per foot (plf)

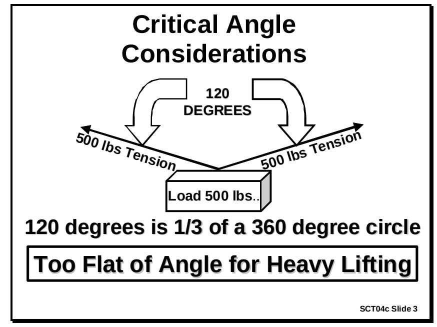
If this column was 36 ft long it would weigh
653 plf x 36 ft = **23,500 lbs = 12 Tons**

MODULE 4c - LIFTING & MOVING – Part c

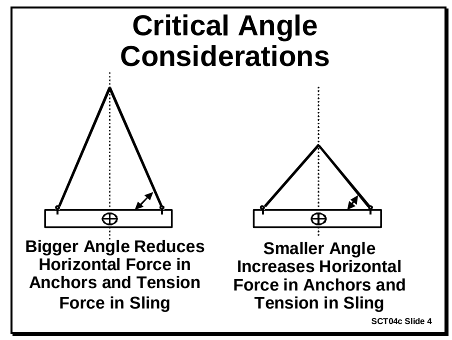
TOPICS to be DISCUSSED

- **Critical Angles**
- **Concrete Anchor Systems**
- **Lifting Equipment & Techniques**
- **Cranes & Rigging**

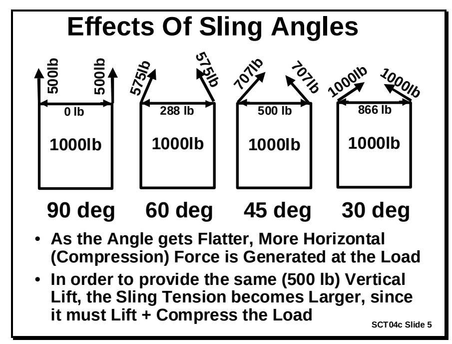
CRITICAL ANGLE CONSIDERATIONS



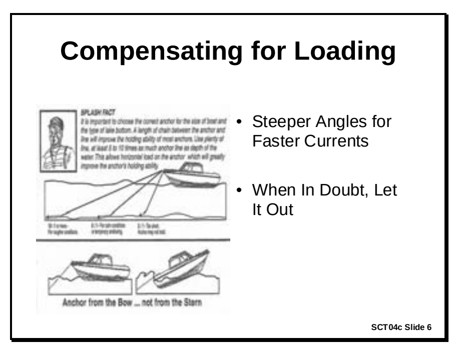
- The angle of a rigging strap/ cable attachment in relation to the lifting point greatly effects the vertical and horizontal forces placed on the anchor attachments as well as the forces in the strap/cable.
  - These forces are easily calculated, based on the properties of the triangle that is created.



- A circle can be divided into three 120 degree sections.
  - If the included angle of the rope system is equal to 120 degrees, the force in the rope and it's attachment is equal to the supported load.
  - If the angle becomes greater by pulling the load line tighter, a greater force is placed on the rope and the anchors.
  - If the included angle is less, the force in the rope is less.
  - In lifting systems the angle should be as small as possible, but a 120 deg angle, which translates to a 30 deg angle, measured up from the horizon, is the Largest Included Angle that is Allowed



- Applying this concept to rigging can be done by inverting the triangle.
  - The higher the point of attachment is over the objects CG the lesser the forces on the sling and it's attachments.
  - The flatter the angle, the greater the forces, as shown in the adjacent slide.
    - As the angle gets flatter and flatter, there is a greater and greater Compression that is applied to the top of the Load, due to the Angle of the Force in the Sling
  - Keep this in mind when you begin any lifting operation.
    - In some cases lifting a fairly light object with a flat lifting angle will create forces substatial enough to break the sling and/or blow-out the anchor points.

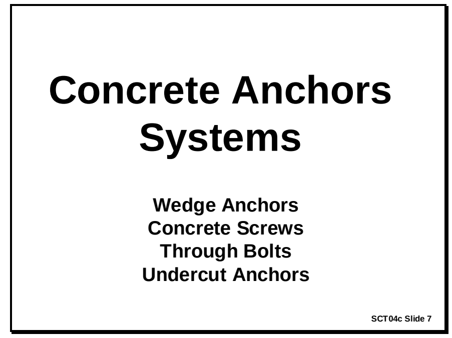


- The adjacent slide illustrates "If in Doubt, Let It Out". For Slings this means that the Longer the Sling, the Steeper the Horizontal Angle, and the Less Force in the Sling and its Anchors

MODULE 4c - LIFTING & MOVING – Part c

CONCRETE ANCHOR SYSTEMS

INTRODUCTION



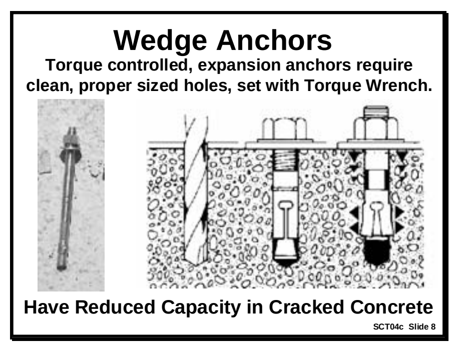
- The purpose of this section is to provide information about safe and practical methods of anchoring to concrete when some other method (such as cable loops or chokers) is not available.
- Not all of the methods discussed may have useful application in US&R work.
  - The special equipment required for undercut anchors and the sensitivity of Adhesive anchors to vibration and heat, make both of little value in critical US&R situations.
- All of the available methods are presented in order to give the student a more complete understanding of anchors

TYPES OF ANCHORS:

Most of these anchors require the drilling and cleaning of holes in concrete of the proper size and depth.

- Available types:
  - Wedge Anchors
  - Concrete Screws
  - Through Bolts
  - Undercut Anchor Bolts

Wedge Anchors (most comenly used in US&R)

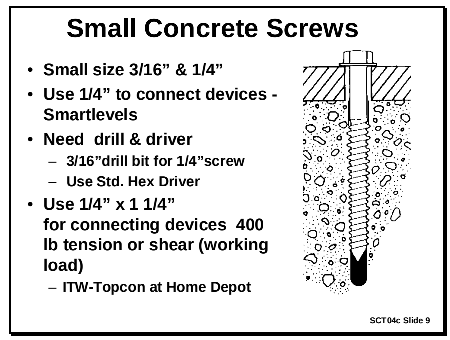


- Are torque controlled anchors that come in two types; Wedge Anchors and Sleeve Anchors. They both have an undercut shaft that is inserted into the hole and the wedge or sleeve device that expands as a cone at the bottom of the shaft is pulled through it when the fastener is tightened.
- Wedge Anchors have higher tension strength than sleeve anchors of the same size. However the sleeve anchor is the only anchor bolt (other than the through bolt) that can be safely be used in hollow concrete block.
- Correct hole size (not too large) is very important since the wedge or sleeve must develop great friction against the sides of the hole.
  - The hole size is the same as the anchor. (½" hole for ½" anchor)
- Most of these anchors will develop more friction as they are loaded in tension, since more expansion occurs as the pull on the shaft causes the cone to spread the wedges or sleeve with greater force against the side of the hole.

MODULE 4c - LIFTING & MOVING – Part c

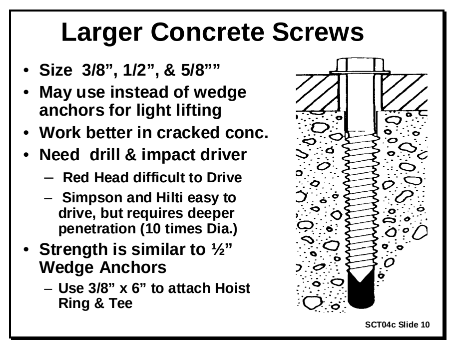
TYPES OF ANCHORS- Wedge Anchors (continued)

- Applying a setting torque with a calibrated wrench is essential to the reliable performance of this type of anchor, since doing so actually tests the installation.
- The proper failure mode for this type of anchor is either pull-through (where the conical part of the shaft pulls through the sleeve or wedge) or pull-out of a concrete cone.
  - The diameter of concrete cone that can be pulled is usually more than two times the depth of the embedment of the anchor, however, this assumes un-cracked concrete.
- Anchors of this type should not be used in badly cracked concrete.
- Expansion anchors may be used to anchor raker shores and in tieback systems, provided that the concrete into which they are set is relatively crack free.



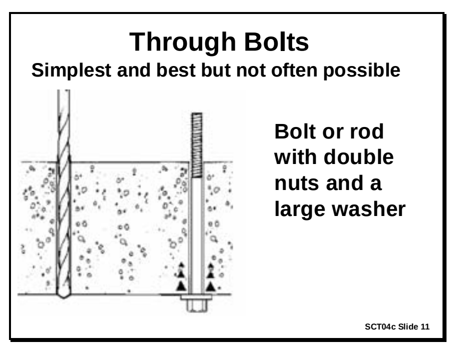
Concrete Screws

- The 1/4” diameters screws are used in US&R to fasten devices like the Electronic Level and other monitoring devices. They have a design strength of 300 lbs
- The 3/8” dia screws are similar in strength to ½” Wedge Anchors. They may be used to fasten the Swivel Hoist Ring
- Screws are driven into a pre-drilled hole and the installation requires the use of the proper sized drill bit.
  - The 3/8” Simpson Titan Screw requires a 3/8” bit.
  - The 3/8 Hilti HUS-H Screw uses 5/16” bit.
- They can be installed in less than one minute and placed as close as one inch from the edge of the concrete, using an impact driver or a torque wrench



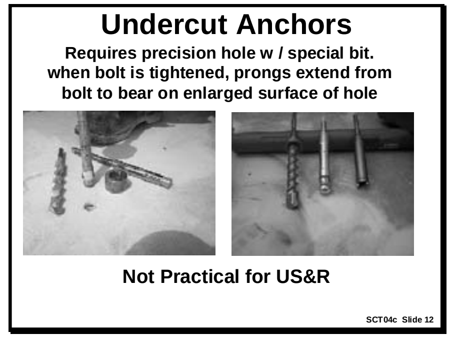
Through Bolts

- When both sides of a concrete slab are accessible, a standard machine bolt or piece of threaded rod can be extended completely through the concrete.
  - If a large washer and bolt head/nut bears against the far side of the slab, a simple, reliable anchor is created.
- The allowable tension value for a through bolt would be the same as for an expansion bolt of the same size with embedment the same as the thickness of the slab.
- Through bolts require access to both sides of the concrete. Not much application in lifting concrete from debris piles.
- Through bolts may be useful when anchoring to URM walls, or in tiebacks where concrete or URM walls are involved



MODULE 4c - LIFTING & MOVING – Part c

TYPES OF ANCHORS (continued)



Undercut Anchor Bolts (not used in US&R)

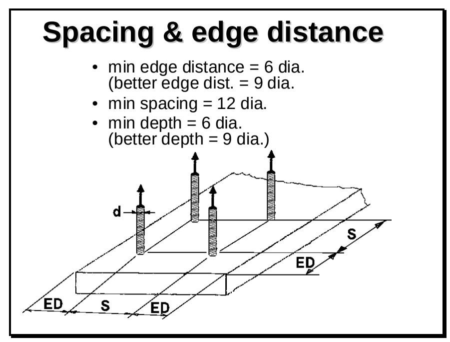
- Relatively complicated devices that require the cutting of a straight hole in the concrete and then inserting a special bit that enlarges the hole near its bottom.

- The undercut anchor bolt is then inserted and during the tightening process, prongs extend out from the body of the bolt that engage and bear on the surface of the enlarged hole.

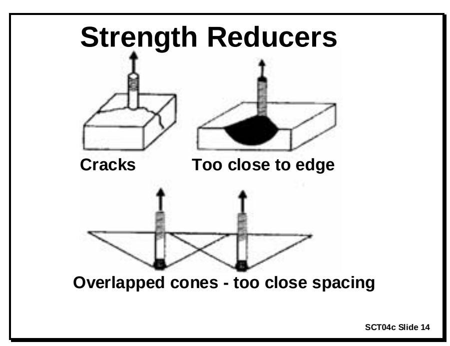
- This produces a very positive anchor, since it does not have to depend on friction between the bolt and the hole as in the case of the other anchors presented here.

- The system requires the use of the special drill bit that undercuts the hole, and, therefore, would not be useful in most emergency situations.

ANCHOR APPLICATIONS



- Anchor Spacing & Edge Distance
  - Minimum spacing between anchors: 12 times the diameter of the anchor
  - Minimum distance to nearest concrete edge: 6 times the diameter of the anchor (9 times if load is acting towards the edge)
  - Minimum anchor depth in concrete: 6 times the diameter of the anchor
  - Anchor depth should be increased to 9 times the diameter of the anchor, since at ultimate load a more gradual failure will occur.



- One can increase tension values especially in lower strength concrete (2000 PSI) by increasing embedment and spacing to as much as double the minium listed strength values.
- Cracks in concrete near expansion bolts or shields can significantly reduce their strength.
  - Cracks do not significantly reduce the strength of Adhesive and Through Bolt anchors.

MODULE 4c - LIFTING & MOVING – Part c

ULTIMATE LOAD VS WORKING LOAD

Ultimate load vs Working load (called different things by different anchor manufactures)

- Working load = Allowable working load
- Working load = Safe working load
- Working load = 1/4 Ultimate load
- Proof load = 2 x Working load

SCT04c Slide 15

- The strength of these anchors has been determined by laboratory testing under “ideal” conditions, and is published as the Ultimate Strength.
  - If only the “strength” is listed without the word “Ultimate” one should assume that the value given is the Ultimate Strength and that the safe working load is about one fourth as much.
- The *Allowable Working Load* (sometimes called Safe Working Load or Working Load Limit) should be listed as not greater than one fourth the *ultimate strength*.
- The values given for most anchors are based on the ultimate crushing strength of the concrete into which they are inserted.
  - F'c=3000 PSI) means that a 6” diameter x 12” high cylinder made from the concrete will crush at 3000psi when tested 28 days after it was cast.
  - Most sound concrete can be assumed to have an *ultimate strength* of 3000 PSI.
  - Test it with a heavy blow from a framing hammer. It should ring and not be noticeably damaged, as long as its not hit on a corner.

INSTALLATION OF ANCHORS

Installation

- Hole size very important
- Use metal detector to avoid rebar
- Need to clean holes, especially for epoxy
  - Blow, brush, blow
- Torque all expansion bolts = Test
- Adhesive anchors require special care, set time, and no vibration
- Concrete screws require drill bit & driver

SCT04c Slide 16

- Drilled holes should be the proper size and depth. Dull bits produce oversized holes which can lead to premature pull-out.
- A metal detector should be used to locate existing rebar, so that it can be avoided.
  - Hitting rebar with the bit will cause oversized holes, and a dull bit which will continue to produce oversized holes.
- Holes need to be cleaned of most all loose material.
  - One method to accomplish this is to drill the hole about one inch deeper than the insertion length, so that some of the loose material will drop to the bottom. (In thin slabs, one may drill completely through.
  - The pile of concrete powder that collects around the drill bit at the top of slab should be carefully swept away.
  - In addition, one should lift-out the loose material by quickly pulling out the drill bit as it is rotating.
  - One may use air to blow out the hole, but do not allow anyone to inhale any concrete dust – it is very damaging to the lungs

MODULE 4c - LIFTING & MOVING – Part c

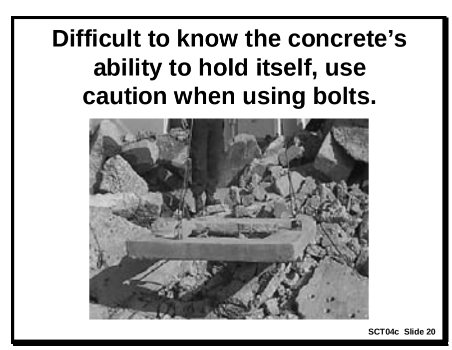
INSTALLATION OF ANCHORS (continued)

- Wedge Anchors need to be tightened with a calibrated torque wrench as previously discussed.
  - This tests and "preloads" the anchor, giving one reasonable confidence in the installation.
  - See table on following page for Anchor strength and required torque values.
  - Hole size is same as anchor size (½" hole for ½"anchor)
- Concrete screws are easily installed, provided the proper size drill bit is used.
  - Use 3/8" bit for 3/8" Simpson Titan Screw and 5/16" bit for 3/8" Hilti HUS-H Screw
  - They can be installed in less than one minute and placed as close as one inch from the edge of the concrete, using a hand, torque, or impact wrench
  - Drill the holes about one inch deeper than the insertion length. Then the holes need only need to be cleaned using the drill-bit to lift out the excess.
  - The screws can be driven (screwed) into the holes only once, since the threads cut their way into the concrete.
- Adhesive anchors are not normally used in US&R. Their installation requires very clean holes. If they are used, the following installation rules should be followed:
  - Adhesive anchors should be inserted into previously cleaned holes after the adhesive has filled the hole about 3/4 full. All dust needs to be removed by brushing and air blowing (Again to breathing of concrete dust is very harmful to the lungs
  - The adhesive should be placed using a coaxial cartridge dispenser with a long tube that reaches to the bottom of the hole.
  - Fill the hole from the bottom up, in order to minimize air pockets.
  - Insert the threaded rod with a twisting motion and work out all the bubbles.
  - Most epoxies require a minimum of 24 hours to fully cure at 60^{o} F (15^{o} C) and above. This time must be increased to about 48 hours at 40 degrees F (5^{o} C).
  - Acrylic adhesives can fully cure in as little as 1 hour at 60^{o} F (15^{o} C) and above
  - Most all adhesives used in Anchor Systems have a "Shelf Life" of one year or so, and, therefore, should not be kept in a US&R Cache for longer periods.

Installation

- Hole size very important
- Use metal detector to avoid rebar
- Need to clean holes, especially for epoxy
  - Blow, brush, blow
- Torque all expansion bolts = Test
- Adhesive anchors require special care, set time, and no vibration
- Concrete screws require drill bit & driver

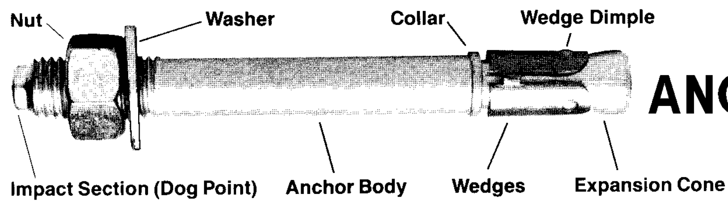
SCT04c Slide 16



MODULE 4c - LIFTING & MOVING – Part c

ALLOWABLE WORKING LOADS for WEDGE ANCHORS

SAFE WORKING LOADS



ANCH-6S

WEDGE ANCHORS • *Kwik Bolt, Wedge-All or Trubolt*

Allowable Tensile Loads (lbs)

Diameter	Embedment	Required Torque (ft-lb)	f'_c = 2000 psi	f'_c = 3000 psi
3/8″	1 5/8″	20	530	605
	2 1/2″	use 25	1130	1210
	4 1/4″	25	1200	1230
1/2″	2 1/4″	40	870	970
	3 1/2″	use 50	1750	2000
	6″	65	1970	2170
5/8″	2 3/4″	85	1430	1690
	4″	use 100	2170	2670
	7″	110	3000	3270
3/4″	3 1/4″	150	1850	2180
	4 3/4″	use 225	2750	3630
	8″	235	3750	4630
1″	4 1/2″	250	2930	3650
	6″	use 350	4000	5310
	9″	450	6070	7070

Allowable Shear Loads (lbs)

Diameter	Embedment	f'_c = 2000 psi	f'_c = 3000 psi
3/8″	1 5/8″	930	970
	≥ 2 1/2″ *	1100	1100
1/2″	2 1/4″	1810	1840
	≥ 3 1/2″ *	1840	1840
5/8″	2 3/4″	2880	2880
	≥ 4″ **	3140	3140
3/4″	3 1/4″	3880	3880
	≥ 4 3/4″ **	4220	4220
1″	4 1/2″	6620	7120
	≥ 6″	8620	8620

INCREASE TENSION & SHEAR VALUES 1.33 x FOR WIND & EARTHQUAKE LOADING

TEN + SHEAR: $(P/P_{allow})^{5/3} + (V/V_{allow})^{5/3} \leq 1$

SLEEVE ANCHORS

Carbon Steel Allowable Working Loads in Concrete (lbs.)

Sleeve Anchor Diameter	Bolt Diameter	Embedment Depth	Required Torque (ft-lb)	2000 PSI		4000 PSI	
				Tension	Shear	Tension	Shear
1/4″	3/16″	1″	5	275	235	275	240
5/16″	1/4″	1″	5	275	410	380	420
3/8″	5/16″	1 1/4″	10	425	680	580	945
1/2″	3/8″	1 1/2″	30	820	960	820	1340
5/8″	1/2″	2″	50	960	1270	960	1410
3/4″	5/8″	2″	90	1270	1900	1270	2350

Carbon Steel Allowable Working Loads in Hollow Concrete Block* (lbs)

Sleeve Anchor Size	Bolt Diameter	Tension (lbs)	Shear (lbs)
1/4″	3/16″	300	490
5/16″	1/4″	330	670
3/8″	5/16″	420	930
1/2″	3/8″	610	930

*ASTM Specification C90, Grade N, Type II.

ANCH-6S 03/02

MODULE 4c - LIFTING & MOVING – Part c

ALLOWABLE WORKING LOADS for EPOXY ANCHORS

EPOXY ANCHORS

Allowable Loads ·Threaded Rod Anchors

Allowable Tensile Loads (lbs)

Stud Dia	Drill Bit Dia	Min Embed Depth	Spa-cing	Edge Dist	Avg ult 2500 psi	Based on Bond Strength fc = 2000	Based on Bond Strength fc=2500
3/8″	1/2″	3 1/2″	4 1/2″	2 5/8″	8888	1985	2220
1/2″	5/8″	4 1/4″	6″	3 1/4″	10384	2320	2595
5/8″	3/4″	5″	7 1/2″	3 3/4″	17512	3915	4375
3/4″	7/8″	6 3/4″	9″	5″	27896	6235	6970
7/8″	1″	7 1/2″	10 1/2″	5 5/8″	32032	7160	8005
1″	1 1/8″	8 1/4″	12″	6 1/4″	41813	9350	10450

Allowable Shear Loads (lbs)

Avg Ult 2500 psi	Based on Bond Strength fc = 2000	Based on Bond Strength fc = 2500	Based on Bond Strength fc = 3000	Based on Steel Strength A 307
4096	910	1020	1750	1040
9664	2160	2415	3375	1870
13952	3115	3485	2965	2940
25920	5795	6480	4380	4250
24970	5580	6240	7275	6000
28746	6425	7185	7275	7820

Allowable tensile loads for ASTM A615 Gr 60 Reinforcing Bar

Rebar Dia.	Drill Bit Dia.	Minimum Embedment Depth	Concrete Compression Strength fc = 2500	Concrete Compression Strength fc = 4500
No. 4	5/8″	4 1/4″	3055	3565
No. 6	7/8″	6 3/4″	7850	9070
No. 8	1 1/8″	8 1/4″	9065	10240

Minimum spacing = 12 bar diameters
Min. edge distance = 6 bar diameters

MODULE 4c - LIFTING & MOVING – Part c

LIFTING DEVICES

Steel Swivel Hoist Rings

- These are devices that can be attached to concrete using, an expansion anchor, concrete screw, or through bolt.
- Since the ring's loop pivots 180 degrees and the ring's base swivels 360 degrees, the load will always be applied directly through the bolt into the concrete.
  - There is also no danger of the swiveling ring applying a de-torquing twist to the properly tightened, expansion anchor.
- These rings are available in sizes from 5/16" to 3". The ½" size is suggested as a minimum size, and it has a 2500 lb allowable working load which is greater than the 2000 lb of a ½" expansion anchor with 6" embedment.
  - The ½" Swivel Hoist Rings and Expansion Anchors are included in the FEMA US&R Cache List
- For larger loads, it is recommended that the 3/4" size be used. It has a 5000 lb allowable working load. A 3/4 expansion bold with 8" embedment has 4500 allowable working load. It is not in the FEMA US&R Cache
- Previous slides in this section illustrate the proper way to install the Hoist Ring using a ½" x 7" wedge anchor.
  - The hole may be cleaned by just lifting out the concrete dust with the bit a few times if the hole is made 1" deeper than the required 4 ½" embedment.
  - A 3/8" x 6 concrete screw (Simpson or Hilti) may also be used to attach the ½" Swivel Hoist Ring. Since the hoist ring is about 1 ¼" high, the screw will be embedded at least 4 ½".

Swivel Hooks

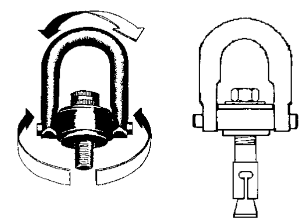
- These devices may be used to attach to a shackle, however most often a sling will be used between the load anchors and the Crane Hook
  - If these are used, the Load must be kept from spinning, and or the sling be kept from twisting.

Lifting Devices

- **Steel Swivel Hoist Rings/Hooks**
- **Eye Nuts**
- **Steel Angles**
  - ***Used when a better way of connecting to concrete is not available. (Sling, strap, or wire rope choker is not practical).***

SCT04c Slide 21

STEEL SWIVEL HOIST RINGS



Steel Swivel Hoist Rings

- **Pivot 180 deg & swivel 360 deg**
- **Usually are proof load tested**
- **Use with wedge anchor**
  - **Remove machine bolt (replace after use)**
  - **Torque required for wedge anchor is greater than torque listed for Hoist Ring but works fine for better quality Hoist Ring.**
  - **Don't buy Hoist Rings w/o Testing Them, (buy only from known manufacturer)**

SCT04c Slide 23

Torque Anchor To 50 Ft-lb

SCT04c Slide 19

Swivel Hooks

- **Use with shackles to create connection points.**
- **Prevents load from spinning, twisting sling legs**

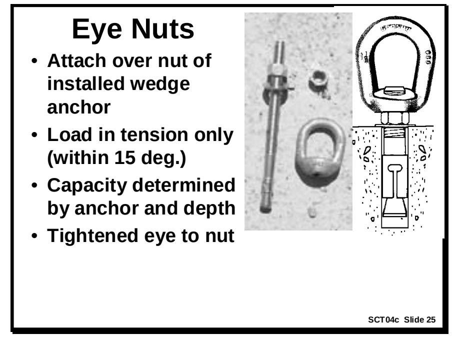
SCT04c Slide 24

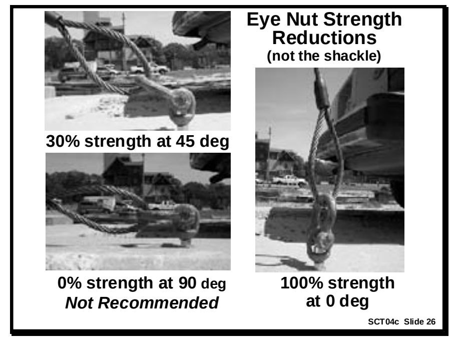
MODULE 4c - LIFTING & MOVING – Part c

LIFTING DEVICES (continued)

Eye Nuts

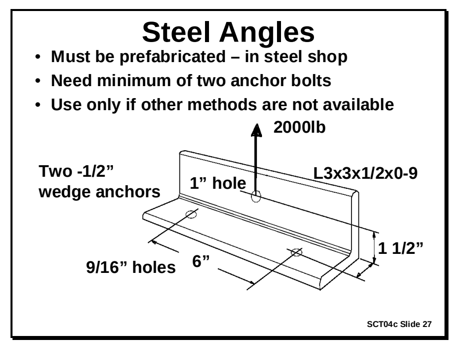
- Eye Nuts are drop forged and galvanized devices that can be attached to the exposed threads of an installed expansion bolt to produce a lifting device. ½" Eye Nuts are in the FEMA US&R Cache
- They have a lifting capacity slightly greater than the tension capacity of a wedge anchor, provided that the direction of the load is vertical, (or within 15 degrees of vertical) thereby, loading the anchor primarily in tension.
  - The adjacent slide shows what the eye nut looks like when attached to a ½" x 5" wedge anchor
  - The wedge anchor needs to be installed first; driven 4 inches into the ½" hole (with double nuts w/ washer just above the top end); then one of the nuts is removed, so the lower nut may be torqued to 50 ft-lb against the concrete: then the eye not is tightened on top of the bolt.
- The ½" Eye Nuts with ½" wedge anchors have an allowable working load of about 2,000lb for a vertical pull.





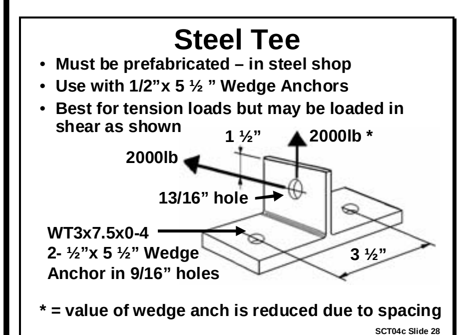
Steel Angles

- May be pre-fabricated to be used with wedge anchors, screws and /or through bolts, however, if not sized properly will cause the failure of the lifting system.
- To be useful an angle must be of sufficient thickness and length. A minimum of two bolts must be used with a single angle in order to assure that it will not spin.
- Due to the prying action of the vertical leg of the angle, it takes two expansion bolts to produce the same allowable working load as one bolt when used with the hoist ring.
- Use this angle only if a hoist ring is not available.



Steel Tees

- May be pre-fabricated to be used with ½" Wedge Anchors or 3/8" Concrete Screws (if Hoist Rings are not available)
  - The 3/8"x 6" concrete screws have better resistance in cracked concrete, and have tested to be as strong as ½" wedge anchors.
- The T must be a sufficient size to allow for the required spacing of the fasteners, and have the thickness necessary to resist the bending stresses. For tension forces, there is no prying action.
- When the T is loaded in shear (parallel to the concrete surface) the T stem needs to be aligned with the direction of the pull. Use a 5/8" (min) shackle to connect to rigging



MODULE 4c - LIFTING & MOVING – Part c

RIGGING TOOLS

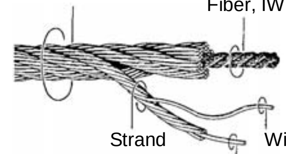
SLINGS

- Commonly used material for the manufacture of slings
  - Wire rope
  - Chain
  - Synthetic Fibers

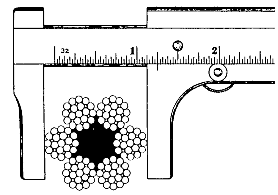
Rigging Definition: A length of rope / chain / webbing attached to a load to and/or an anchor for the purpose of stabilizing, lifting, pulling, or moving objects.

- **Wire Rope**
  - Very strong – suited for US&R enviroment
  - Strenght depends on size, grade,and core
  - Resistant to abrasion and crushing
  - Must keep from bending or kinking
  - Sharp bends and edges can cause damage
- **Wire rope components**
  - Core (Fiber Core or Independent Wire Rope Core)
  - Strand
  - Wire
  - Center
- **Wire rope safety factor**
  - Wire Rope Slings, Etc = 5 to 1
  - Lifts w/ Personnel = 10 to 1
  - Elevators = 20 to 1
  - Mobile Crane = 3 to 1 for standing ropes
  - Slings have greater factor of safety than for wire rope used on cranes due to likelihood of rough usage & wear

Wire Rope Configuration

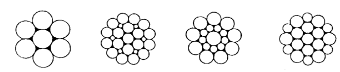


WIRE ROPE SIZE



Measure across crowns not across flats

WIRE STRAND CONFIGURATIONS



Classification	No of Strands	Wires per Strand
6 x 7	6	3 to 14
6 x 19	6	16 to 26
6 x 37	6	27 to 49
8 x 19	6	15 to 26

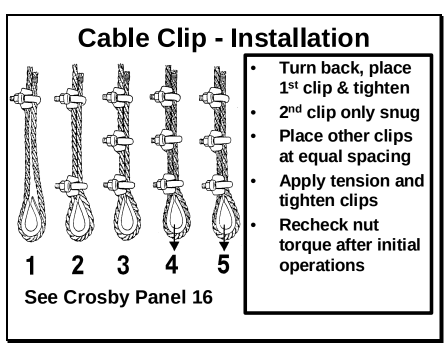
WIRE ROPE SAFETY FACTORS

- **Wire rope slings = 5 to 1**
- **Lifts w/ personnel = 10 to 1**
- **Elevators = 20 to 1**
- **Mobile Crane = 3 to 1 for standing ropes and 3.5 to 1 for running ropes**
- **Slings have greater factor of safety than wire ropes used on cranes due to likelihood of rough usage and wear**

MODULE 4c - LIFTING & MOVING – Part c

SLINGS (continued)

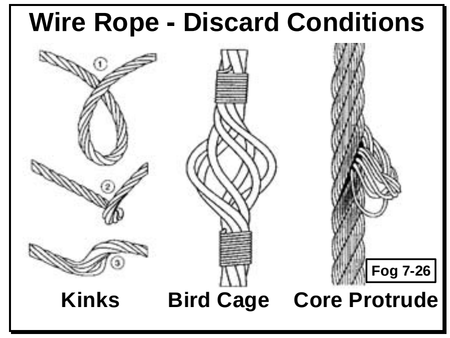
- Wire Rope Inspection should be done on a regular basis
  - Need to check for conditions in adjacent slide
  - The following are wire rope discard conditions
    - Kinks
    - Bird cage
    - Core protrusions
- Wire rope fittings and terminations are available in many designs. There are Socket Terminations and Loop Terminations as shown in adjacent slides
  - Swaged and Spelter Sockets
    - These sockets are normally found connecting the Standing lines (wire rope lines that do not move) on a Crane
  - Wedge socket
    - If properly manufactured and installed, will only reduce capacity by 10%
    - These normally occur at the connection of the Ball to the Whip line of a Crane. (Whip line is a single part line that extends from the Crane boom tip, just beyond the main sheaves)
  - Flemish eye
    - Most reliable and efficient termination. Must be done in a shop, and it does not reduce load capacity.
  - Fold back eye
    - Unreliable, do not use it.
  - Cable clips
    - During past US&R incidents it has been necessary to construct cable terminations using these clips.
    - All rescue personnel should become familiar with how to position and tighten these useful devices.
    - Reduce capacity by 20%

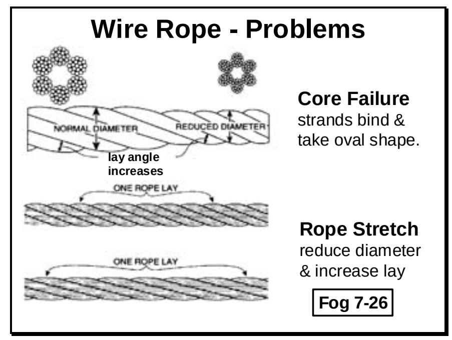


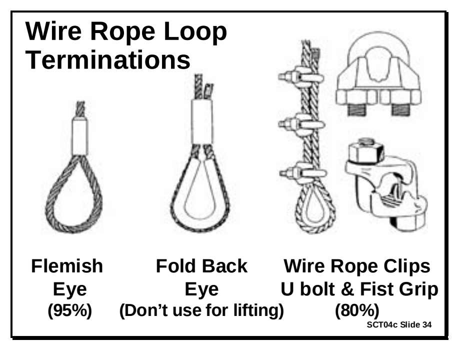
Wire Rope Inspection

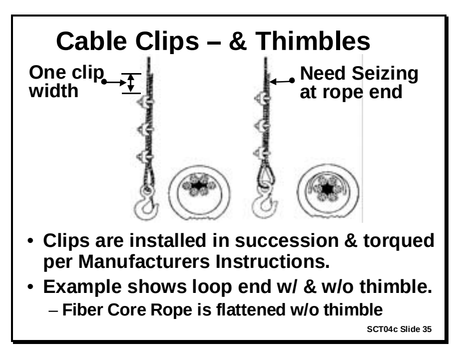
- Should be done on regular basis
- Check for:
  - Broken wires - depends on location
  - Crushed strands
  - Kinks, bird caging, & protruding core
  - Stretch, diameter reduction
  - Abrasion and corrosion
  - Fatigue and electric arc

SCT04c Slide 31









MODULE 4c - LIFTING & MOVING – Part c

SLINGS (continued)

Chain and Chain Slings

- Limited use due to weight.
- Links can break without warning
- Requires padding between chain and load to create better gripping surface.
- Should not be exposed to cold temperatures for long periods of time.
- Avoid kinking and twisting while under stress.
- Load must be seated in the hook.
- Avoid sudden jerks in lifting / lowering the load.
- Use padding (planks, heavy fabric) around sharp corners on the load to protect links from being cut.
- Cannot use for overhead lifting unless tagged by manufacturer.

■ **Synthetic slings:**

- Tends to mold around the load adding additional holding power.
- Do not rust and are non-sparking.
- Are light weight making it easier and safer to rig, and carry on rubble pile
- Have no sharp edges thereby reducing injury potential.
- Are more elastic than chain or wire rope and can absorb shock loading better.
- Are not effected by moisture and are resistant to many chemicals.
- Are very susceptible to abrasion and catastrophic failure, especially in the collapse structure environment.

Synthetic Slings

- Must include manufacturer's sewn on tag
  - Gives fiber type and safe working load
- Provided with protective cover - seamless
- Use corner protection
- Need careful inspection
- Do stretch - up to 10% ; polyethylene = 1%
- Very light weight and easy to use
- Minimize twisting & spinning during lifting

SCT04c Slide 42

ROUND SLINGS

Synthetic sling made from a continuous loops or hank of yarn and covered with a protective sheath.

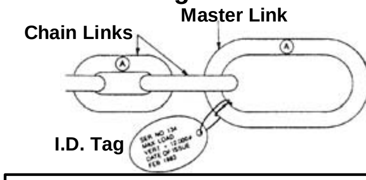
Edge protection is a must!!!!!

Chain Sling Identification

- There are two types of Alloy Lifting Chain
- Grade 8, and Grade 10
- Marking; A, T, 8, 80, or 800, for 10 mark = 10 or 100
- Only use these grades of chains for US&R Lifting

SCT04c Slide 37

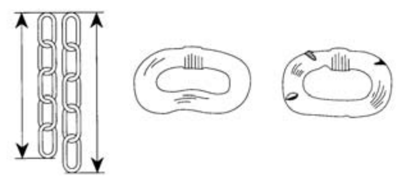
Chain Sling Identification



There are two types of Alloy Lifting Chain
Grade 8: has mark A , T , 8, 80, or 800
Grade 10: has mark 10 or 100

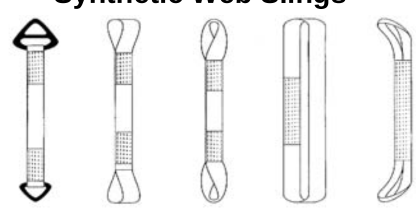
Use only Alloy Lifting Chain for US&R Lifting

Chain Sling Problems



SCT04c Slide 38

Synthetic Web Slings



SCT04c Slide 39

Synthetic Sling Types

- Nylon.
  - General purpose, unaffected by grease & oil, many chemicals except acids.
  - Loose 15% strength when wet.
- Polyester.
  - Unaffected by most chemicals including mild acid and water. Disintegrate in sulfuric acid.
- Aramid, Kevlar, Dacron, Nomex.
  - Resistant to most weak chemicals.
- High density polyethylene.
  - Resistant to most chemicals.

SCT04c Slide 41

MODULE 4c - LIFTING & MOVING – Part c

BASIC SLING ARRANGEMENTS

- **Single vertical / horizontal hitches:**

  - Supports load with single leg of rope / chain / webbing.
  - Full load carried by a single leg (one straight piece of chain / rope / webbing).
  - Should not be used when:
    - Load is hard to balance.
    - Center of gravity hard to establish.
    - Loads are loose.
    - Load extend past the point of attachment.

- **Basket hitches:**

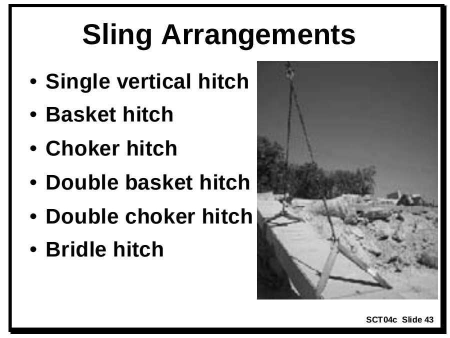
  - Supports load by attaching one end of the sling to a hook.
  - Sling wrapped around the load.
  - Sling returns to the other end to attach to the same hook as the other side of the sling.
  - Presents problems related to keeping the load balanced or stabilized.

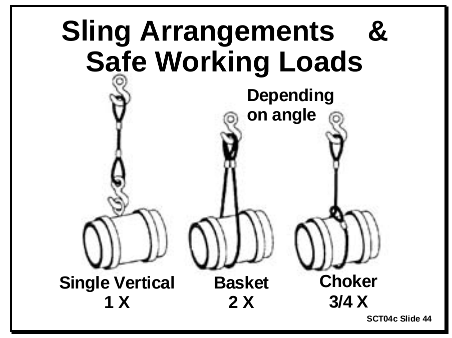
- **Double basket hitches:**

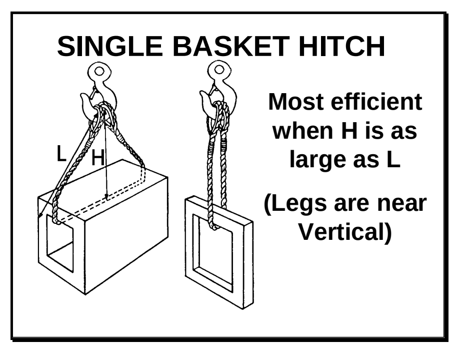
  - More stable than single basket hitch.
  - Uses 2 single slings wrapped at separate locations on the load in the same manner .
  - Allows for the locating of the center attachment hook over the estimated center of gravity.
  - Permits the wrapping of the slings to either side of the center of gravity.
  - Can use a "double wrap" basket hitch which makes contact all the way around the load surface for increased securing of loads (i.e., good for cylindrical loads).

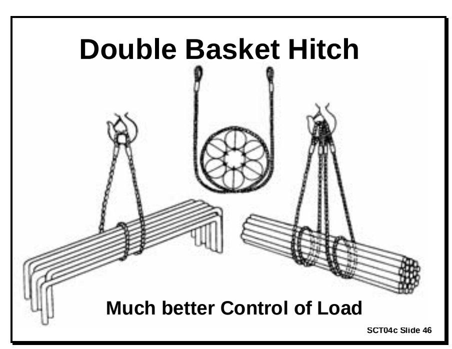
- **Single choker hitches:**

  - Loop a strap / rope around the load.
  - Pass 1 eye through shackle attached to the other eye.
  - Pass the eye over the hook.
  - Sling should be wrapped around the load.
  - Sling is secured back onto itself.
  - Potential of having stability problems.
  - Creates a vise-like grip on load.





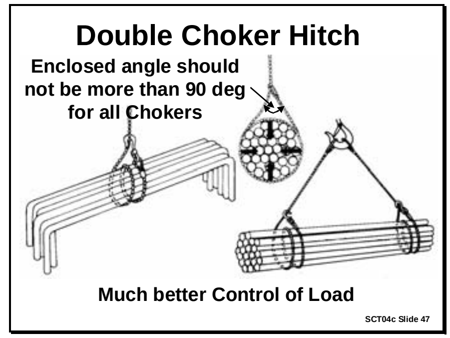


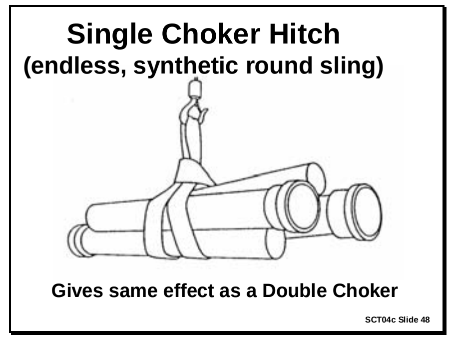


MODULE 4c - LIFTING & MOVING – Part c

BASIC SLING ARRANGEMENTS (continued)

- **Double choker hitches:**
  - Has two single slings spread apart around the load.
  - Does not make full contact with the load surface.
  - Can be double wrapped to help control / hold the load.
  - Double choker with 2-points of wrap around the load provides better lifting / pulling / stabilizing / moving than single choker.
  - When using straps in pairs, hooks should be arranged on the straps so that they will pull from the opposite sides = better gripping action.
  - Creates a vise-like grip on load.

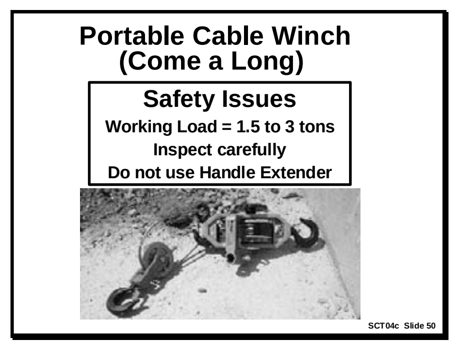




- **Bridle hitches:**
  - Uses 2 / 3 / 4 single slings -- each sling is called a "LEG."
  - Slings secured to a single point this is usually in line between the center of gravity and the anchor (lifting point).
  - Can provide very stable lifting, stabilizing, moving, pulling due to distribution of load onto the multiple slings.
  - Sling lengths must provide for even distribution of the load.
- Basic guideline for sling formations - make sure slings protected at all actual or potential sharp corners in contact with loads.

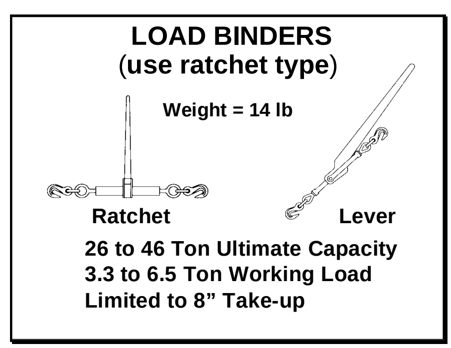
TIGHTENERS

- **Wire rope tighteners** have been required during many US&R incidents.
  - They may be used for lifting light loads as well as tightening cable tiebacks and other rigging.
  - Care needs to be taken to not overload them. **DO NOT ADD CHEATER BARS TO THE HANDLES**
  - They are available in several configurations, and are included in the FEMA US&R Cache.



- **Cable winch**
  - The length of the handle and the strength of one person provides the Overload Limit. **DO NOT ADD TO LENGTH OF HANDLE.**
  - Take care in re-winding the cable, it can foul.
  - These devices are 2 to 3 feet long, therefore their use may be limited in confined spaces.

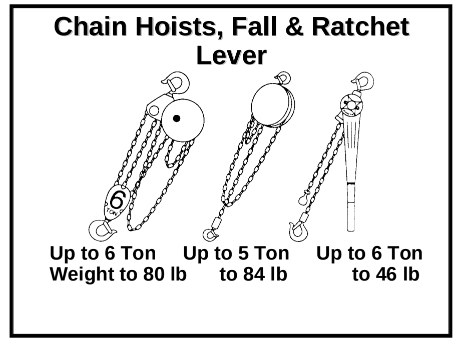
- **Load binder (most common with chain use)**
  - Use ratchet type for reliability, and must wire tie handle for safety.
  - Have 50 to 1 ratchet action, but only 8 inch take-up.



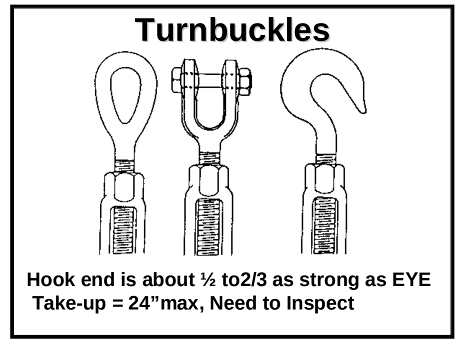
MODULE 4c - LIFTING & MOVING – Part c

TIGHTENERS (continued)

- **Chain hoist**
  - Can lift up to 6 tons with 100lb pull. **DO NOT EXTEND HANDLES OR OVERPULL USING MORE THAN ONE PERSON.**
  - These tighteners have large take-up (up to 10 feet), and some only require only 12 inch clearance.

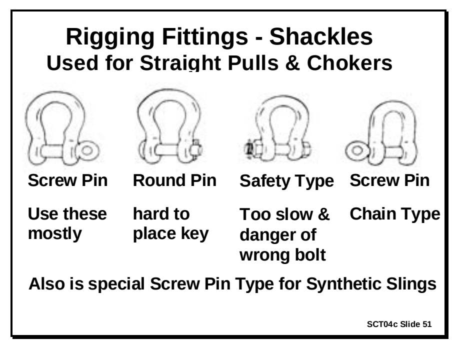


- **Turnbuckles**
  - Commonly used tightening device, and are in the US&R Cache
  - Can be used to do final tightening of tiebacks, and liberate Cable Winch to do other jobs.
  - The maximum take-up can vary from 8” to 24”, depending on what type is purchased.
  - They may be difficult to tighten at high loads, so keep the WD-40 handy.
  - HOOK ends are only 2/3 as strong as EYE or JAW ends

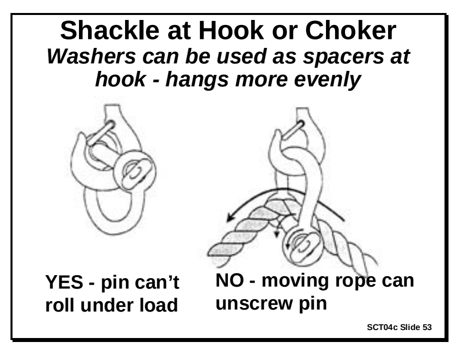


RIGGING FITTINGS

- Ring, hook, and shackle components of slings should be made from forged alloy steel.
- Basic components:
  - Hooks
  - Shackles
  - Eyes
- Provide means of hauling (lifting) loads without directly tying to the load.
  - Can be attached to wire or fiber rope, blocks, or chains.
  - Used when loads too heavy for hooks to handle.
  - Hooks need latch or mouse closing/securing device.



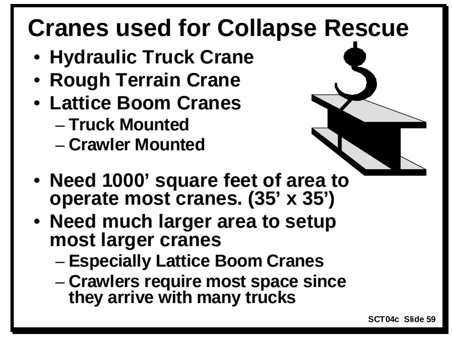
- **Mousing**
  - Process of closing the open section of a hook to keep slings / straps from slipping off the hook.
  - Can mouse hooks using rope yarn, seizing wire or shackle.
- **Shackles**
  - Check rating stamp and Working Load rating.
  - Pins not interchangeable with other shackles.
  - Screw pin in all the way and back off ¼ turn before loading.



MODULE 4c - LIFTING & MOVING – Part c

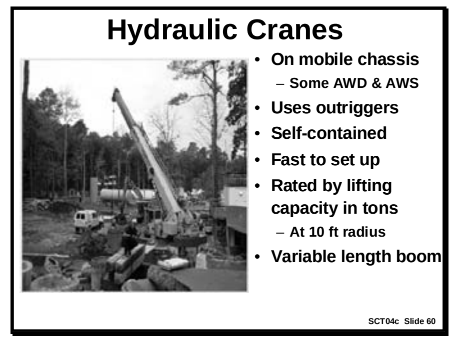
OVERVIEW OF CRANES USED FOR COLLAPSE RESCUE

- Pre-incident information:
  - Develop and maintain listing of businesses with crane resources including crane equipment, crane operators and crane rigging equipment.
  - Develop telephone call-up list for crane resources listed.
  - Develop an identification and vendor call-back system for verification of incident needs and projected response time to the incident scene and confirming on scene contact person and their location.

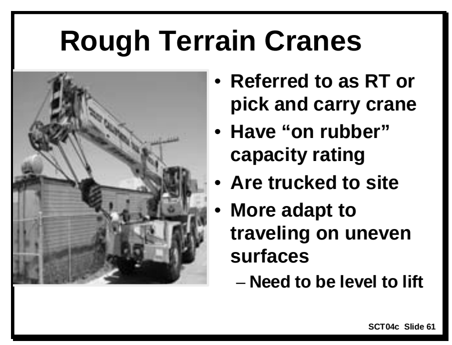


TYPES OF MOBILE CRANES

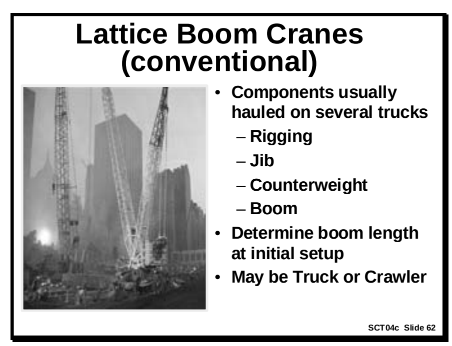
- **Hydraulic Cranes**
  - Mounted on mobile chassis. (some have AWD & AWS)
  - Have outriggers, which need to be set on firm bearings, and some have "on rubber" lifting capacities.
  - Self-contained. (except for 120 Tons and greater)
  - Relatively fast to set up.
  - Rated by lifting capacity, in tons, at a distance of about 10 ft from the center of the crane .
  - The variable length boom makes them very useful in a US&R incident.



- **Rough Terrain (RT) Cranes**
  - Normally would be trucked to the site
  - "Pick and carry" capabilities – driving with loads
  - Rated for "on rubber"
  - More adaptable to rough terrain, but must be leveled to lift.



- **Lattice Boom Cranes (sometimes called conventional**
  - Lattice Boom Cranes may be **Truck Mounted** or **Crawler Mounted**
  - Normally requires more than one truck to haul the boom components, counter weights, and rigging.
  - **Crawler Cranes** usually require several trucks, since the crawlers may be trucked separately
  - Have a longer set-up time than the hydraulic crane
  - Rated by lifting capacity, in tons, at a distance of about 10 ft from the center of the crane .
  - Require more set-up area than the hydraulic crane.
  - Need to find a place to park all the trucks



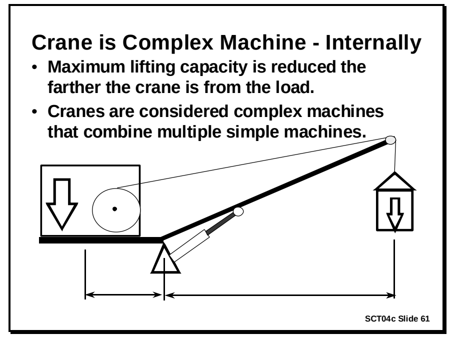
MODULE 4c - LIFTING & MOVING – Part c

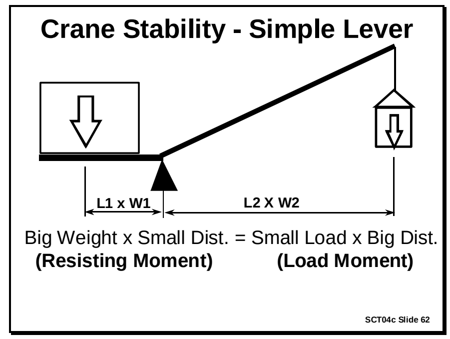
CRANES USED FOR COLLAPSE RESCUE (continued)

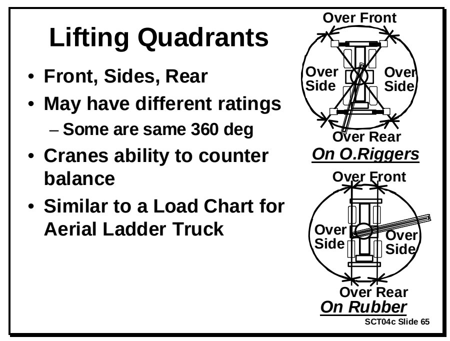
- Lifting capacity of all cranes is reduced the farther away the center of the cranes is from the load.
  - The ‘Rated Load” is what can be lifted at 10 to 12 ft from the Crane “Pin” (the Center of Rotation)
  - They are, essentially a very complicated 1st class lever

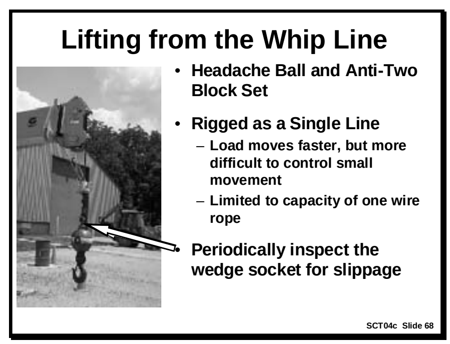
- **Areas of Operation**
  - All Cranes are required to carry Load Charts on board
  - Cranes may have different capacities for different Quadrants of Operation, as shown in adjacent slide
  - Some Cranes may Lift “on Rubber”, but most require their Out Riggers to be Fully Extended in order to operate safely.
  - Crawler Cranes are, of course an exception to the statement above, but some crawlers do have extendable tracks for greater lifting capacity

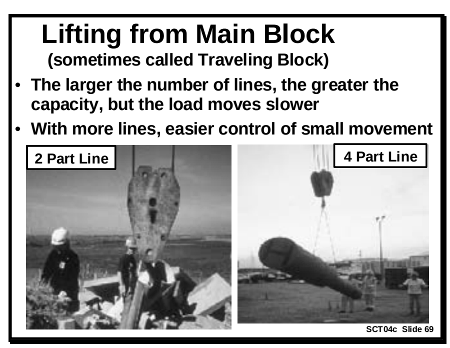
- **Crane Rigging**
  - Most Cranes have two separate Hook/Systems that they can lift from.
  - The Main Block will have more than one sheive so that its hook has the greatest capacity.
    - It may have several “Parts of Line”, which multiplies the strength of the wire rope that is connected to the Drum for lifting.
    - Often the capacity of each Part of Line is determined by the strength of the Brakes on the Drum. However the capacity of the wire rope, also must not be exceeded
  - The Ball (Headache Ball) and Hook normally drops over a single shieve at the tip of the Crane Boom
    - It most always has one “Part of Line”, but the Load moves much faster on this “Whip Line”.
    - Again the capacity of this line is often determined by the strength of the Brake at the Drum











MODULE 4c - LIFTING & MOVING – Part c

CRANES USED FOR COLLAPSE RESCUE (continued)

- **Moving the Load & Moving Tatics**

  - **Securing the Load**
    - As stated in the adjacent slide, the type of Load and its weight + center of gravity must be known**.**
    - When Cranes are lifting near their maximum reach, have a very small Safety Factor for Tipping. A load the is underestimated by 20% can tip a Crane.
    - As previously discussed the Sling Angle should be made as steep as possible, although 45 deg is a reasonable place to start

  - **Adjusting the Rigging**
    - **Check all slings, hooks & connectors**
    - **All should be aligned and without twists, etc**
    - Load should be slowly lifted a short distance off the ground
    - Check balance and that all slings appear to be tight (one should note that for four leg slings it is very difficult to have more that three be tight. This is not a problem, since the Strength Rating of a Four Leg Sling is based on only 3 Legs

  - **Checking Center of Gravity (C.G.)**
    - If Load does not come up level, it means that the Rigging has not been correctly placed (Not Centered on the C.G.)
    - The Load will rotate until its C.G. is directly under the Lifting Hook
    - The Load, then, needs to be set down, and the rigging needs to be shifted towards the side of the Load that came up Last

Many Cranes have both Main Block & Whip Line

- Main/Traveling Block is Rigged as a 4:1 = 4 Part Line
- Whip Line = Single Line
- Operator must take care so Single Line does not get tangled around Main Lines
  – Can be caused by Rapid Swing of Boom

SCT04c Slide 70

Moving the Load / Rigging Tactics

- Securing the Load
- Adjusting the Rigging
- Placement of the Load
- Removing the Equipment

SCT04c Slide 71

Adjusting the Rigging

- Check that all slings/hooks/connector are free of twists and are aligned in direction of pull
- Any unused sling legs must be secured
- Load should not jump from ground, slow controlled moves

SCT04c Slide 73

Checking the Balance

- As the load leaves the ground it will shift and locate itself directly below the hook
- As tension is applied stand clear of the load keep hands and feet clear

SCT04c Slide 74

Checking Center of Gravity

- If load did not come up level, sit it down and relocate more directly over CG
- The part of the load that comes up last indicates the direction the hook should be moved toward
- After moving hook, recheck sling legs

SCT04c Slide 75

MODULE 4c - LIFTING & MOVING – Part c

CRANES USED FOR COLLAPSE RESCUE (continued)

- **Sling Leg Adjustment**
  - One may need to change position of the Slings, or type of Hitch, in order to properly center the load
  - In some cases a pair of Slings may not be able to be positioned so the Load can be lifted without tilt
  - In such a case, another connection devise may need to be added, such as a Chain Hoist that is connected to the Load using an anchored Hoist Ring or Eye Nut
  - **Note that Edge Softeners are needed to preserve the integrety of Synthetic Slings, especially when lifting Broken Concrete**

Sling Leg Adjustment

- May need to change the type of hitch used to shorten or lengthen
- Use softeners as needed
- Change attachment points, by moving closer in or farther apart

SCT04c Slide 76

Rules of Thumb

- Leg of Sling 30 deg to flat, double the load
- Leg of Sling 45 deg to flat, 1 ½ time the load
- Choker de-rates sling 25%
- Lose 50% rating of rigging when bending rope around of equal or less than diameter
- Figure Multi-leg bridles to lift on no more than 2 legs
- Chains too brittle below 32 deg F
- Work from top to bottom, trace out Load Paths
- ***Crib around the victim***
- 20 Feet from Electric wires

SCT04c Slide 77

Common Considerations

- Double "T"
- Wood Trusses
- No Rapid Swinging
- Using Rigging as Shoring
- Obtaining a gap for slings
- Don't Move a disaster from one spot to another, block load when landed

SCT04c Slide 78

Summary
Lifting or Moving a Load

- Center of gravity
- Load stability
  - Wedges & cribbing & ropes
- Estimating Load weight
- Rating of Rigging
- Place to land load
- Load Clear to be lifted
- Load de-energized
- Shifting centers of gravity (fluids)
- Can the mass being lifted hold it's own weight?
- Can you stabilize load where you land it?
- Hands & Feet

SCT04c Slide 79

MODULE 4c - LIFTING & MOVING – Part c

REQUESTING THE APPROPRIATE CRANE

- Prepare for crane request by using standard US&R forms.
  - 20 questions and Form are on final pages of this module

- Be sure to describe potential load weights and load materials so that the right size crane, the right rigging equipment, and the right personnel can be matched and sent to the incident.

- Reach distance should be calculated from suitable crane lifting location or locations.
  - This assessment should be completed by identifying suitable location(s) that would accommodate aerial ladder operations
    - Distance is measured from the center pin on crane turntable to the center of gravity of the load.

  - Generally, the larger (either load capacity or reach) the , the longer the response time and a larger area is required for effective operation.
  - Conventional cranes may require an area as large as 35ft x 200ft for boom assembly, adjacent to lifting area

- Ensure sufficient access to the area before crane's arrival:

  - Access road condition and width.
  - Overhead clearance. (including power lines near site)
  - Room and conditions to maneuver around the site

- Rescue personnel must be assigned to facilitate crane operations:

  - Communicate with the crane operator
  - Assist the crane operator and riggers

- Rescuers should prepare for crane operations:

  - Anticipate the best location for crane operation & setup.
  - Initiate clearing activities prior to the arrival of the crane.
  - Is surface sloped or level?
  - Is surface hard or soft?
  - Obstacles and hazards:
    - Buildings
    - Walls
    - Wires

Requesting the Appropriate Crane

- Estimate the potential load.
  - Find the heaviest thing to lift and measure the distance to it from the center of where you will spot the crane.
  - The greater the distance, the larger the crane.
- Provide access to the scene.
- The bigger the crane the longer the response, set-up time, and setup area needed.
- Answer 20 questions and use US&R Crane Forms.
  - CU-1 to help when ordering a crane
  - RAP as planning tool and to hand-off info at shift change

SCT04c Slide 78

Basic Requirements
Related to on-scene Crane Operations

- Assign Heavy Equip & Rigging Spec (HERS) + Rescue Leader as Crane Liaison.
- Prepare for Crane Operations.
  - Pick best location to locate & to setup.
  - Clear debris from set-up area.
  - Determine weights of critical pieces to be moved
    - Get help from Structures Spec
- Must have knowledge of hand signals.

SCT04c Slide 79

Safety Rules

- Know Weight
- Know C.G.
- Know Rigging Ratings
- Inspect Before Use
- Use Softeners
- Allow for increased Tension when loaded
- Once a Choker is loaded do not force hitch down
- Allow low D/d for wire rope
- Reduce ratings for chokers
- Only use Grade 8 or equal chain
- Use Tag Lines as needed
- Stay Clear of Lift
- Lift a couple of inches and re-check
- Start & Stop Slowly

SCT04c Slide 82

More Rules

- Watch for Obstacles
- Only One Person Signals
- Use known Hand Signals
- Know Swing Radius of Crane
- Keep Lift Line Vertical
- Allow for Wind Loading, No Lifts if Wind greater than 35mph (Special Care over 25mph)
- Respect your Gut Feeling
- Keep Alert

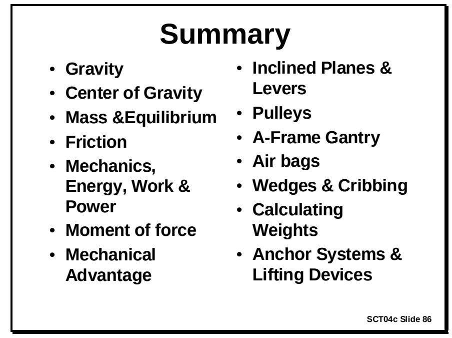
SCT04c Slide 83

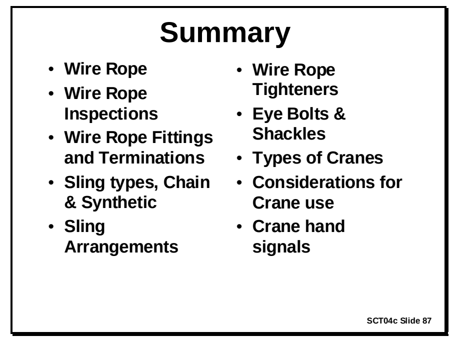
MODULE 4c - LIFTING & MOVING – Part c

20 QUESTIONS to ANSWER WHEN ORDERING A CRANE

When you contact a rental source of heavy lift equipment, they will start asking questions to permit them to give you what you need. If you can have answers to their questions ready beforehand, you will speed the process considerably. If you have answers to the following questions, you will be well prepared for the rental agent's questions.

1. Who are you and what are you doing?
2. How quickly do you want a machine?
3. What do you intend for this machine to do?
   Pick and swing
   Pick and carry
   Lift large objects at small distance
   Lift small objects at large distance
4. Will multiple machines be needed? (Second machine to set up primary machine).
5. What are the capabilities of the onsite crew? (Are they qualified to assist with set up?)
6. If this machine is for a single task, what is the load weight and what is the load radius?
7. If this is for multiple tasks, what are several combinations of load and distance? Max load / min distance, max distance / min load, possible mid load/mid distance?
8. Will this task require pick and carry capability?
9. What are the limits of room available for operation of the machine? Overhead clearance, tail swing clearance, underground obstructions?
10. Is there a place to assemble boom (if lattice) and crane (counterweights)? Including room for assisting crane?
11. Are there limitations on delivery of crane or parts? Posted bridges, low clearances, underground utilities?
12. What areas of operation are anticipated? Over rear, Over side, Over front, On rubber?
13. Are two crane (simultaneous) picks anticipated?
14. Will work be performed on a continuous (24 hr) basis? Is auxiliary lighting available?
15. Will radio communication be required to control load? Are dedicated radios available?
16. How much boom is required? Are special boom features (offset, open-throat) needed?
17. What size hook block is needed? Are shackles to fit hook available?
18. Will jib be needed? Jib length? Offset? Load?
19. Are additional rigging components needed? Load cell, lift beams, slings, shackles?
20. Who is the contact person and who is the person directing the rigging operations?





MODULE 4c - LIFTING & MOVING – Part c

US&R Crane Use Form CU-1

This form is intended to act as a check-list when ordering or planning for the use of a Crane. One form may be used for each Crane

The Sketch should show the approx position of crane and setup area, as well as where trucks for removal of debris should be staged. Also need to show locations of overhead and underground hazards **Get form on Disasterengineer.org**

US&R Crane Use/Order Form CU-1 By: Date: Page of

Situation Name:	**Date and Time of Lift:**
Rigging Task:	**Task Force Name:**
Weather Conditions:	**Task Force Leader:**
Load Description:	Crane Operator:
Load Weight:	Crane Make & Model:
Block Weight:	Crane Serial No:
Rigging Weight:	Boom Length:
Jib Weight:	Jib Length:
Jib Ball Weight:	Jib Position: ☐ Stowed ☐ Retracted ☐ Offset at
Hoist Line Weight:	Size of Counterweights Installed:
Other Weight:	Front Outrigger Installed: Yes No
Total Weight:	**Setup On:** ☐ Crawlers ☐ Outriggers ☐ Tires
Lift will be On: ☐ On Main Block ☐ On Jib	☐ Extended ☐ Retracted ☐ Other

Max. Intended Working Radius	Boom Angle:	Rated Capacity:	Percent of Capacity : (Total Load / Rated Capacity)
Over Rear:	Over Rear:	Over Rear:	Over Rear:
Over Side:	Over Side:	Over Side:	Over Side:
Over Front:	Over Front:	Over Front:	Over Front:

Hazards: ☐ Electrical ☐ Fire ☐ Underground ☐ Other   Are Crane Mats, Blocking Reqd:

SKETCH

MODULE 4c - LIFTING & MOVING – Part c

US&R Rigging Action Plan - RAP

It is intended to be the planning tool and record of rigging ops during one operational period. It can then serve to hand-off the info to the on-coming shift. A copy should also get pack the the TF and/or IST Plans Unit

The HERS should number all significant loads, give dimensions & weight, indicate load Radius, indicate where the load is intended to go, and check-off if moved by end of shift

One page will work for 12 loads. Use as many pages as necessary. This form works best if a copy machine is located at the forward BoO. **Get form on Disasterengineer.org**

US&R Rigging Action Plan - RAP Task Force: ________ Date: ________ Op Period ______ Page ____ of ____

Situation Name:	**Crane Size & Type:**
HERS Name:	**Crane Supplier:**
RTM Name:	**Operator Name:**
StS Name:	**Oiler/Rigger Name:**
Squads Assigned:	**Boom Langth:**
Radio Frequency:	**Net Lift Cap @ 50ft:**
Operation Mode (circle one) **Rescue** **Recovery**	**Foot Print Dimen.:**

LOAD PATH HAZARDS

Overhead

Below Grade

Contanimation ☐ Biological ☐ Chemical ☐ Radiation ☐ Other

Debris Removal Effects

Chain of Evidence Needs:

Load No.	Weight & Size	Load Radius	Landing Zone	Completed Yes	Completed No

SKETCH:

MODULE 4c - LIFTING & MOVING – Part c

CRANE HAND SIGNALS

Rescue personnel must have a basic knowledge of hand signals normally used to communicate with the crane operator.

Use Hand Signals to Guide Movements

- Use of these hand signals in the positioning a Ladder Co's Aerial Ladder
- Raising & Lowering Loads with Rope
- Raising & Lowering Loads with Levers/air Bags
- Use Tag Lines as needed to Control the Load
- Raise Load, Lower Load, Stop, Lock off,
- Extend Boom, Retract Boom

SCT04c Slide 85