Introduction

Donald Ritchie

- Over 30 Experience in Management, HSE, and Machine Operator Training ranging from:
- Director (2014)
- Ritchies Training Centre
- Regional Training Manager Stirling Group (Kurdistan) 2014
- HSE Manager (Dubai) Stirling Group (Nov 2015)
- Director / Team Leader High Access Rescue Team
Class Introduction
Tell us a little about Yourself….
Job Role / Experience / Knowledge....

Mutual Respect and Confidentiality......

Why do we need to train?
To teach necessary skills and relevant job safety required for safe operations
To encourage future good practice in order to maintain and promote skills
To create a safe working environment and procedures within the work place
To conform with all Company Procedures
To provide greater productivity and cost saving as a direct result of training
How?

- Theory Lessons
- Discussion
- Practical Demonstrations
- Assessments

Your input is vital to a successful course

Aims of Course

- Know the importance of lifting operations and procedures
- Be aware of the consequences of misusing lifting operations
- Implement and control lifting operations in a safe manner
- Understanding the needs for safe lifting operations
- Responsibilities of a slinger signaller

Legal Concerns

You and Your Employer can be subject to criminal fines and prosecution
Moral Concerns

Organisations – have moral obligations to ensure that its activities are not harmful to employees and others

Individually - we have a duty to ourselves, our families and work colleagues to work in a safe manner

PPE

- Look after your PPE (It is very expensive and it will not be replaced easily)
- Only wear company issued PPE
- Replace any damaged PPE (Last Line of Defence)

Company Policies / Procedures

Management of Operations

As with all other operation on site, Effective Management of operations should ensure Safety and Efficiency.

Management Principles

- Plan
- Resources
- Communicate
- Monitor

(Fit for Purpose)
Management of Operations
Assess the operation and provide such planning, Equipment and Personnel as necessary to complete any task safely. (Planning)
Provide Instruction and Supervision as is necessary for the task to be undertaken safely. (Supervising)
Taking responsibility for the organisation and control of all operations. (Organisation)
Ensuring that everyone is fully briefed on the content of the method statement/risk assessment and permits to work.
Every one has the **Authority** to stop the operation if they consider any operation is dangerous.

What Factors lead to Injuries?
- Inadequate supervision
- Insufficient training for the task being carried out
- Incorrect protection or equipment choices
- Incorrect use or set-up of equipment including personal protective equipment
- Unwillingness to change the way a task is carried out when a safer alternative is identified
- Suitable equipment being unavailable
Safe Systems of Work (Fit for Purpose)

All operations large or small must be controlled by establishing a Safe Systems of Work (Legal Requirement)

- Planning the operation
- Selection of correct crew and equipment
- Maintenance of equipment
- Selection of trained competent personnel
- Provision of competent supervision
- Safety of those involved or other affected by the operation
- Effective communication between all parties
- Ensure all necessary test certificates / documentation is in order
- Preventing unauthorised movement / use of equipment

Method Statement / Risk Assessment (Fit for Purpose)

The production of a written method statements is one of the most important duties of the Company

- It will highlight any risks and how they are to be addressed
- It explains the method of operations and ensures that suitable equipment is used
- It provides a basis for the communication (Tool Box Talk) to other members of the team

Employers Must:

- Provide and maintain plant and systems of work that are safe and without risk to health.
- Provide a safe working environment that is without risks to health.

They also must:

- Provide any necessary information, including information on legal requirements, to ensure the health and safety of his employees.
- Provide adequate supervision, instruction and training as necessary to ensure the health and safety of his employees.
Reporting of defects and incidents

The appointed person should ensure that there is an effective procedure for reporting defects and incidents.

This procedure should include the notification of the following:

a) any defects found during daily or weekly checks;
b) defects found at any other time;
c) incidents or accidents, however slight;
d) shock loads, however they occur;
e) dangerous occurrences or reportable accidents.

Lifting Appliances (Machines)

Equipment performing the lift

“A mechanical device capable of raising or lowering a load, e.g. cranes, forklift trucks, powered hoists, manual hoists, lever hoists, etc.”

Lifting Accessories

- Slings
- Shackles
- Eye-bolts
- Plate Clamps

CE Marking on a product is a manufacturer’s declaration that the product complies with the relevant European health and safety legislation.
In Service Inspection
A more in-depth inspection than daily or weekly checks and are carried out by a competent Pearson (normally on an annual basis).

Thorough Examination: In Depth and Detailed Inspection
It involves a comprehensive inspection into the mechanical workings or components of the equipment.

Exceptional Circumstances
- Any Concerns Regarding the Safety of Equipment
- Equipment Has Been Shock Loaded
- Long Periods Without Use
- Get Equipment Retested / Certified Before Use

Daily Pre-use or Post Use Inspections
Visual and functional check of all equipment to check for any obvious signs of damage.
A pre-use must be carried out every time before a piece of equipment is used and a post use every time, before it is returned.

Requirements (Pre Use Checks)
Before removing any equipment from a rigging loft Slingers:
- Must carry out Pre Use Checks
- Sign Rigging Loft Register for equipment used (In and Out)
- As part of company policy / Procedures
Responsible Person

**Appointed Person:** Plans the whole lifting operation from conception to completion (Crew, Equipment, Lift Plans, JHA's)

**Supervisor:** person who controls the lifting operation and ensures that it is carried out safely

**Operator:** Movement of all items in a safe and controlled manner

**Banksman:** Relays instructions to the operator during lifting activities.

Lifting Operation

**Lifting Operations Must Consider**

- The Foundations
- The Crane
- The Load
- The Rigging

For the Lift Plan to Work Safely
Factor of Safety

The Minimum Breaking Load (M.B.L)

The minimum breaking load is the calculated load at which a sample of the item will break or fail.

Safety Factor (SF)

It is a factor which is applied to the MBL to determine the WLL Constant number according to standard

Safety Factor  7:1

Safety Factor should be applied 7:1
**Dynamo Eyebolt**

Have a large eye and a small collar diameter. Normally fitted by the manufacture to the item. They need not be marked with a S.W.L., are not registered, and are not examined six monthly.

Eyebolts are used for lifting loads, which are usually heavy and concentrated. They are used for general lifting and for permanent attachment to loads, which are to be moved occasionally. They are screwed into tapped location holes provided, and usually will not accept a hook, but must be used with a shackle.

This type of eyebolt should *only* be used for vertical lift.

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**Collard Eyebolts**

This has a smaller eye, a larger collar diameter. Registered as a piece of lifting tackle, and examined six monthly. May be used, in pairs, / Taking an angular pull.
**Collard Eyebolts with Link**

Used for taking an angular pull

**NOTE:** The S.W.L marked on any eyebolt is only applicable to a vertical lift. Whenever an angular pull is used, the rated S.W.L decreases as the Angle of pull from the vertical increase.

**Collar & Dynamo**

Eyebolt threads include Whitworth, BSF, UNC, UNF, or Metric

Extreme care must be taken to ensure that metric threaded eyebolts are not inserted in imperial threaded holes

Although these might appear to match, it is an interference fit only. The mechanical strength may be almost nothing.

**Flowchart:**

- Is the load applied vertically only?
  - Yes → Use Dynamo Eyebolt
  - No → Is load in plane of eye?
    - Yes → Use collar Eyebolt
    - No → Use Eyebolt With link
Eyebolts are made to screw into or through a load and may be Plain (Dynamo) or have collars (Collared Eyebolt)

Dynamo or plain eyebolt  Collar eyebolt

The plain eyebolt is good only for vertical loading
Even when a collared eyebolt is used, the safe working load is reduced with angular loading

When installed, the collar must be at right angles to the hole and Must be in full contact with the surface of the load and be properly tightened.

Collared eyebolts with link may be used providing angle of the load to axis of eyebolt thread does not exceed 15°
Over 15° safe working loads must be de-rated in accordance with BS 4278

Maximum washer thickness not to exceed ½ the pitch of the thread
Maximum angle allowed out of plain is 5°
No more than ½ turn to align to correct plain of eye

Hand tight only do not over tighten
### ISO METRIC COURSE THREAD (ALL DIMENSIONS IN mm’s)

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<td>42.00</td>
<td>4.50</td>
</tr>
<tr>
<td>48.00</td>
<td>5.00</td>
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</tbody>
</table>

**NOTE:**

All pitch sizes must be halved to give correct shim thickness.

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### Weight Reductions

- **90°** REDUCE BY 75%
- **60°** REDUCE BY 60%
- **30°** REDUCE BY 40%

Maximum working angle 90°

Eyebolts with links maximum angle of 15° from vertical when over 15° reduce with table above.

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### Trunnion Lifting

Eyebolts screwed into the side of the load must be de-rated by 75% on each eyebolt.
The flatter angle of pull, the greater the strain and leverage on the eyebolt.

Reeving through connections to load increases load on connection fitting by as much as twice.

DO NOT REEVE

The above table is derived from AS2317-1984 and BS4278-1984.
**RUD Star Point Swivel Eyebolt**

- Self aligns to direction of force
- Higher WLL capacity than standard eyebolts
- Load rated for side pull
- Rotates 360 degrees
- Integrated key for quick and easy installation and removal

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**Crosby Swivel Hoist Ring**

- Rated at 100% at 90° 360° Swivel and 180° Pivot Action
- No need for washers or shims
- Red UNC thread
- Silver Metric thread
- Used with webbing slings
- Used with chains slings

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<table>
<thead>
<tr>
<th>Size</th>
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<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
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<td>1.6</td>
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<td>M48</td>
<td>32</td>
<td>64</td>
<td>12</td>
<td>24</td>
<td>25.5</td>
</tr>
</tbody>
</table>
Eyebolts

Care and maintenance

- Do not store in situ return to tackle store
- Protect threads from damage
- Slightly oil or grease to prevent corrosion
- Clean threads of debris with wire brush

Weaknesses & Reasons for Failure

- Eyebolts have severe limitations of use
- Corrosive damage / non use of shims
- Eyebolts not screwed home properly
- Using wrong eyebolts / Incorrect thread size
- Using eyebolts in acidic environments
- Lifting loads out of plain & Using bent or damaged eyebolts

Lifting & Spreader Beams

Spreaders are used to support long or wide loads during lifts

They eliminate the hazard of load tipping, as well as wide sling angles and any tendency of the sling to crush the load
Care must be taken not to exceed the S.W.L at the various slinging points.

Equaliser beams are used to equalise the load in the sling legs and to keep equal loads when making multiple leg lifts.

**Equaliser Beam**

**Multiple attachments**

How much do you reduce S.W.L of eyebolts when using a spreader beam with a 2tonne load?

**Areas of Low headroom**
- Avoids wide sling angles that would crush a load
- Lifting unbalanced loads
- Tandem lifts on loads

**Spreader Beams**
- Weaknesses & Reasons for Failure
  - Unstable with loads with a low centre of gravity
  - Corrosive damage
  - Damage to bolted or welded areas / attachments
  - Lifting loads outside design spec
  - Overloading attachment points
Spreader Beams
Care and maintenance

Store beams in dry conditions
Store beams on stands or adequate packing
If beams are dismantled store all parts together
& Reassemble correct components

Shackles

Bow shackles should be used when one or more attachment is made,
or to allow movement on the plain of the shackle

Bow shackles
Dee shackles

Dey shackles are usually joining shackles
Only use shackles that are marked with their safe working load.

Never use bolts instead of proper shackle pins.

In line 100% of rated capacity

45° from in line 70% of rated capacity

90° from in line 50% of rated capacity

Shackles symmetrically loaded with two leg slings having a maximum included angle of 120° can be utilized to full working load.

This applies to Crosby shackles only unless stated by your supplier.

Point loading of Crosby shackle pins is acceptable as long as the load is reasonably centred on the pin.

Although point loading is acceptable a pad eye width of 80% or more of shackle spread is best practice.

Inspect before use.
Shackles should be fitted in a manner that allows the shackle body to take the load in a true line along its centre line.

Shackle pin cannot turn
Shackle pin can work loose
Shackles are used in the main for attaching
- Lifting gear to the crane hook / Lifting gear to the load
- Bow shackles for more than one attachment
- Dee shackles for joining

Weaknesses & Reasons for Failure

- Shackles have no apparent weaknesses under normal use as long as they are looked after properly.
- The main reason for failure is overloading, eccentric loads and misuse.
- Check for distortion and damage to the pin.
- Check that it is the correct pin for the shackle.
- Check that the pin is seated correctly.
Shackles
Care and maintenance

Maintenance of shackles are minimal
Keep clean protect from corrosion and ensure that threads are protected from damage

Web Slings

There are usually lines of black stitching on webbing slings
the amount of lines denotes SWL
i.e. two lines of stitching = 2 tonne SWL

Due to the materials used in webbing slings they would be unsuitable for proof testing
Various attachments available for webbing slings

- Blue label: 100% Polyester
- Polyester: Damaged by Weak Alkalies
- Polyester: Resists Weak Acids
- Polypropylene: Resists Both (Stretches easy)
- Nylon: When Wet Must Reduce SWL by 50%

NOTE: No natural fibre slings will be used on a construction site
Any damage to webbing slings disregard

Protect from sharp edges of load
Keep away from Acids or Alkalis
Keep away from heat
Keep away from frost/extreme cold
Keep away from any U.V. Light
Do not toe or drag any loads
Keep away from mildew
Always store in dry clean place

Chemical Resistance Chart

<table>
<thead>
<tr>
<th>Damage</th>
<th>Polyester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkalis</td>
<td>OK</td>
</tr>
<tr>
<td>Water and Seawater</td>
<td>OK</td>
</tr>
<tr>
<td>Soap and Detergents</td>
<td>OK</td>
</tr>
<tr>
<td>Oils, Lubricating</td>
<td>OK</td>
</tr>
<tr>
<td>Oils, Crude</td>
<td>OK</td>
</tr>
<tr>
<td>Ketones</td>
<td>OK</td>
</tr>
<tr>
<td>Hydrocarbons</td>
<td>OK</td>
</tr>
<tr>
<td>Halogenated Hydrocarbons</td>
<td>NO</td>
</tr>
<tr>
<td>Ethers</td>
<td>OK</td>
</tr>
<tr>
<td>Dry cleaning Solvents</td>
<td>OK</td>
</tr>
<tr>
<td>Bleaching Agents</td>
<td>**</td>
</tr>
<tr>
<td>Strong Alkalis</td>
<td>NO</td>
</tr>
<tr>
<td>Aldehydes</td>
<td>OK</td>
</tr>
<tr>
<td>Alcohols</td>
<td>*</td>
</tr>
<tr>
<td>Acid</td>
<td>Polypropylene</td>
</tr>
</tbody>
</table>

THIS IS A GENERAL GUIDELINE ONLY
*Chemicals that were not tested are marked as "OK".
**Chemicals that were not tested are marked as "NO".

Disintegrated by concentrated sulphuric acid.
Degraded by strong alkalis at elevated temperatures.
Ritchies Offshore Services Ltd

**Webbing Slings**

- Light in weight for given capacity
- Easier to handle than Wire or Chain
- Can be pushed through narrow gaps
- Unaffected by Grease or Rust

**Weaknesses & Reasons for Failure**

- Durability and storage deterioration is poor
- Prone to abrasion damage
- Can be contaminated by alkalis and acids
- Affected by heat
- Web slings are inclined to stretch and may not be suitable for precise positioning

**Care and Maintenance**

- Webbing slings char or decompose over a range of temperatures, *NEVER!*
- Dry slings near a fire or heating pipes, as overheating will cause embrittlement
- Can be cut by loads if unprotected

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**Wire Rope**
Available in a wide range of capacities and sizes

Danger do not use if
Stretched or damage to thimble
Any wire broken at collar area

Type identified by a number 6/7, 6/12, 6/24 the first figure refers to the number of strands in the rope and the second figure to the number of wires in the strands.
Wire ropes may be fibre cores or steel cores. Fibre cores are more flexible steel cores are stronger.

The Regulations State:
A wire rope shall not be used when more than 5% or one in twenty of the wires, can be seen to be damaged in any ten diameter length.

Types of lay:
The two most common types of lay are:
LANGS LAY: Where the wires in the strands are twisted in the same direction as the strand in the rope. (Running Rope)
ORDINARY LAY: Where the wires in the strand are twisted in the opposite direction to the strands in the rope. (Pendant Rope)
Safety Factor

Mobile Crane Hoist Rope 4.5 - 6 to 1
Overhead Crane (Gen. Duties) 6 to 1
Wire Rope Slings 6 to 1
Multi Leg Slings 8 to 1
Lifts and Hoists (Goods) 6 to 1
Lifts and Hoists (Passenger) 12 to 1

Note: Steel cored rope must be used in hot works condition only

Wire Rope Sling to this standard are not calculated with the uniform method used in BS 1290 / BS 7072 a different more complex system is used.

BF = Breaking Force
R = Gross Mass ( Gross Weight )
G = Acceleration ( 9.81 )
N = Number of Sling Legs
V = Angle from Vertical ( 30° = 0.866 45° = 0.707 )
SF = Safety Factor ( Reference Load Chart )

Note when carrying out calculations for slings you should calculate 4 legs slings as 3 legs ( Normally only 3 legs would support the load ) and calculate 2 leg slings as single legs ( so 1 not 0.707 or 0.866 ) this is because of the angles involved
Gross weight of 6 tonne and we require a sling angle of 45° calculations are as follows.

\[ R = 6 \text{ (Gross Mass) } \times 9.81 \text{ (Acceleration)} \]
\[ \text{Then ÷ by the number of legs } (3 \times 0.707 = 2.1) \]
\[ \text{Then } \times 10 \text{ (the safety factor given on load chart)} \]
\[ \text{Then } = 9.81 \text{ (to convert from KN to Tonnes)} \]
\[ \text{Then } = 5 \text{ (the wire rope safety factor)} \]

\[ BF_{min} = \frac{R \times G}{N(3) \times V} \times SF \]

\[ = 58.86 \]
\[ = 28.03 \]
\[ = 280.30 \]
\[ = 28.57 \]
\[ = 5.1 \text{ Per Leg} \]

If we require a single leg for a unit gross weight of 6 tonne the calculations are as follows.

\[ R = 6 \text{ (Gross Mass) } \times 9.81 \text{ (Acceleration)} \]
\[ \text{Then ÷ by the number of legs } (1 \times 1) \]
\[ \text{Then } \times 10 \text{ (the safety factor given on load chart)} \]
\[ \text{Then } = 9.81 \text{ (to convert from KN to Tonnes)} \]
\[ \text{Then } = 5 \text{ (the wire rope safety factor)} \]

\[ BF_{min} = \frac{R \times G}{N(3) \times V} \times SF \]

\[ = 58.86 \]
\[ = 11.84 \]
**Inspection Points**

- The wire rope sling shall not be used and shall be disposed if they are:
  - Broken wires
  - Bird cages
  - Kinks
  - Surface wires are worn by 1/3 or more

**Weaknesses & Reasons for Failure**

- Wire rope
- Slings may be
- Damaged when
- Kinked sharply
- Or put under
- Stress when
- Twisted

**Wire rope Slings**

- Care and maintenance
  - Steel wire may be damaged by corrosion through poor care and storage
  - As with all lifting gear do not leave ropes laying around on floor

- Lighter than chain for given capacity
- Can be applied where no lifting points are on the load
- Can be hooked into lifting points i.e. Lugs, Shackles

- Flexible
Chain Slings

Master link

Auxiliary Link

C hook

Reach

Hook

Safety catch

Maximum sling angle

Identification No.

Capacity of sling

Stretch – all chains of equal length

Legible markings

Worn, Stretched or twisted links

Cuts, Nicks, Gouges, Cracks, Corrosion

Heat discoloration

Or any other defect apparent to the fittings

Maximum wear on a link 10%
When slings are used in choke hitch the working load limit should be reduced by 20%.

<table>
<thead>
<tr>
<th>Sling Temperature</th>
<th>Reduction in Working Load Limit</th>
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<tbody>
<tr>
<td>-40°C to 200°C</td>
<td>GRADE II</td>
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<tr>
<td>200°C to 399°C</td>
<td>GRADE I</td>
</tr>
<tr>
<td>400°C to 499°C</td>
<td>10%</td>
</tr>
<tr>
<td>ABOVE 400°C</td>
<td>DO NOT USE</td>
</tr>
</tbody>
</table>

- Load bearing legs must go through bottom of clutch
- Chains should be kept the same length
- Dead ends of chain must be kept together
- Remember the shorter the chain slings are the wider sling angle, therefore causing more stress.

Maximum sling angle 90°
- Avoid sling angles less than 15° this could cause load instability
- Do not use multi leg slings at angles within the shaded area

Chains can be used up to a 120° angle if tested for such a use.
UNIFORMED LOAD method of rating

10t 0° - 90 °  UK TRIGONOMETRIC method of rating

10t 0° - 45 ° CE
10t AT 90 °
10t 90° - 120 °
10t 45° - 60 ° CE

WORKING LOAD LIMITS
Grade ‘T’ (8) Chain Sling
Calculated by UNIFORMED LOAD method of rating

<table>
<thead>
<tr>
<th>CHAIN SIZE (mm)</th>
<th>SINGLE LEG (Tonnes)</th>
<th>ENDLESS (Tonnes)</th>
<th>TWO LEG (At 90°) (Tonnes)</th>
<th>THREE LEG (At 90°) (Tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
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<td>9.0</td>
<td>9.0</td>
<td>9.75</td>
<td>11.00</td>
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</table>

Ritchies Offshore Services Ltd
Grades of Chain Slings

**Wrought Iron:** Very little mechanical strength unless heat-treated periodically.

**Mild Steel Grade 30:** Low carbon content producing a soft chain with high ductility. Not to be used for lifting purposes.

**High Tensile Steel Grade 40:** Medium carbon steel has good wear and shock absorbing properties and is also used for shackles, eyebolts & other lifting gear.

**Alloy Steel Grade 60:**
Alloy steel of this grade produces a chain 50% stronger than high tensile steel and does not suffer from brittleness in extreme cold.

**Alloy Steel Grade 80:**
Harder than lower grades and more resistant to wear, allowing for a lighter sling for given load.

**Alloy Steel Grade 100 (8 + 10):** 25% better lifting properties than a grade 80 chain sling.

Due to the risk of embrittlement, alloy steel grade (8 + 10) chain slings must not be used in acid or acid laden atmospheres.
The column headed ‘40’ refers to Higher Tensile steel chain Grade 40 to BS 1663. Column ‘M’ refers to Grade M chain to BS 4942 part ii and column ‘T’ refers to high Alloy steel Grade T

Grade T chains are not recommended for working with acids As they can be affected adversely by acids and acidic fumes
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Load Chart

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Load vs Sling Angle

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**Load vs Sling Angle**

- **5.8t @ 60°**: 10 ton
- **7.1t @ 90°**: 10 ton

---

**Magic Sevens**

- One leg sling = Mode factor 1
- Two leg sling = Mode factor 1.4
- Three or four leg sling = Mode factor 2.1

**BS 1290 Working Load Limits Of Slings**

- **16 ton**: 90°

To calculate what SWL is needed for both slings:
- Divide 16 by mode factor 1.4
- So each sling leg must be capable of lifting 11.4 tonnes each.
To calculate what SWL is needed for sling to be used:
Divide 35 by load factor 2.1
35 ÷ 2.1 = 16 tonne slings for lift
So each sling leg must be capable of lifting 16 tons each.

The special fluorescent pink powder coating permanently highlights the maximum temperature at which the VIP chain has been used. The pink colour changes to black when the chain is used at more than 400°C (forbidden).

Less sensitive to notching and hydrogen embrittlement than quality Grade 80.

When using 4 legged chain slings it is important to check the tension on each sling leg each slack leg you must reduce SWL of chain sling by 25%.

When slewing with the load because of the weight transfer on the load, or you are not using 2 of the 4 chain legs you should reduce SWL of chain sling by 50%.

Remember: Any slack legs are not taking a full load bearing weight of the lift they are only acting as stabilisers.
**Sling Level / Beyond Sling Attachment Point = 60° Angle**

**¾ of Sling Attachment Point = 90° Angle**

**2/3 of Sling Attachment Point = 120° Angle**

---

**Shocked Loading**

<table>
<thead>
<tr>
<th>Description</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Load at Rest A</td>
<td>6,612 IBS / 3000Kgs</td>
</tr>
<tr>
<td>Talking up 3&quot; Slack B</td>
<td>12,345 IBS / 5600Kgs</td>
</tr>
<tr>
<td>Talking up 6&quot; Slack C</td>
<td>13,778 IBS / 6250Kgs</td>
</tr>
<tr>
<td>Talking up 12&quot; Slack D</td>
<td>17,277 IBS / 7837Kgs</td>
</tr>
</tbody>
</table>

---

**Can be applied where no lifting points are on load**

**Where more than one lifting point on load is required**

**Can be hooked into lifting points i.e. lugs, shackles.**

**Length adjustable.**

**Flexible.**

**Weaknesses & Reason for Failure**

- Links and hooks may become distorted and fracture if subjected to excessive stress.
- Chain can be subject to stretch.
Chain Slings
Care and Maintenance

Keep clean and protect from corrosion.
Do not leave chains lying around on the floor where they are liable to be damaged.
If left outside slightly oil.
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1 tonne

2 tonne

SWL of sling must be double of load

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1 tonne eyebolt
1 tonne shackle
5 tonne web sling
5 tonne chain sling
12 tonne shackle

What is the maximum weight of lift that can be achieved

1 tonne

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Operations Start

Stop
There are some load considerations affecting the choice of lifting gear for each lifting operation:

- Weight of the load
- Position of centre of gravity (CoG) of the load

Weight of the load can be established in the following ways:

- Weight is marked on the load
- Weight is indicated on documentation (e.g. shipping documents)
- Weight is indicated on drawings
- Weight can be identified using scale/load cell
- Weight can be estimated by a competent person
We will look at how to estimate various types of load configuration and their weight and what kind of information is required.

In order to calculate it properly we need to know the density of materials.

Please note that the density may vary depending on water content (some material may be saturated with water), contamination, decomposition etc.

Therefore we can only estimate it – never assume that it will be precise calculation.

There is a table of Densities of Materials on the next slide recommended by BS 7121-3:2000.

<table>
<thead>
<tr>
<th>Material</th>
<th>Density (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>2700</td>
</tr>
<tr>
<td>Brass</td>
<td>8500</td>
</tr>
<tr>
<td>Brick</td>
<td>2100</td>
</tr>
<tr>
<td>Copper</td>
<td>8800</td>
</tr>
<tr>
<td>Concrete</td>
<td>2400</td>
</tr>
<tr>
<td>Earth</td>
<td>1600</td>
</tr>
<tr>
<td>Iron – Steel</td>
<td>7700</td>
</tr>
<tr>
<td>Lead</td>
<td>11200</td>
</tr>
<tr>
<td>Oil</td>
<td>800</td>
</tr>
<tr>
<td>Water</td>
<td>1000</td>
</tr>
<tr>
<td>Wood</td>
<td>350 to 1000     (soft / hard)</td>
</tr>
</tbody>
</table>

In order to estimate the weight of the load first of all we need to determine its volume.

There are various forms of load can be encountered within the lifting industry:

Basic forms – easy to calculate the volume

Complex forms – need to be carefully calculated

Following formulae can be used for volume determining:

**NOTE:** Always ensure that all measuring units are the same, i.e. all dimensions are in meters.
Basic Shapes

- Area

To get a squared area we need to multiply its Length by the Width, i.e.

\[ S = L \times W \]

Rectangular Prism (Cuboid)

To get the volume of a rectangular prism (cuboid) we need to multiply its Length by the Width and by the Height, i.e.

\[ V = L \times W \times H \]

Solid Cylinder

To get the volume of a solid cylinder we need to multiply the number \( \pi (\text{Pi}) \) by cylinder’s squared Radius and by its Length, i.e.

\[ V = \pi \times R^2 \times L \]

Note:
\( \pi \) is a mathematical constant (never changes) and equals to 3.14
Rectangular Base Pyramid

To get the volume of a rectangular base pyramid we need to multiply the area of the base by the Height and divide by 3, i.e.

\[ V = \frac{1}{3} \times L \times W \times H \]

Irregular Cuboid

To get the volume of an irregular cuboid we need to cut this object into rectangular prisms (cuboids) and then calculate the volume of each separately and just add the results at the end.

Angle Beam

The calculation process is the same – cut it into sections and calculate each separately with adding outcomes at the end.
The calculation process is still the same – cut it into sections and calculate each separately with adding outcomes at the end.

V = \pi \times (R_o^2 - R_i^2) \times L
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Rough calculation of motor’s volume can be done as shown on sketch.

Calculation Exercises

Calculate the approximate weight of the steel plate with given dimensions.

\[
V = 3.5 \times 1 \times 0.05 = 0.175 \text{ m}^3
\]

Plate weight = 0.175 x 7700 = 1347.5 kg = 1.35 te

Calculate the approximate weight of the concrete block with given dimensions.

\[
V = 4 \times 1.2 \times 1.8 = 8.64 \text{ m}^3
\]

Block weight = 8.64 m$^3$ x 2400 kg/m$^3$ = 20,736 kg = 20.74 te
Calculate the approximate weight of the **brass** cylinder with given dimensions

- 25cm = 0.25m
- \( V = 3.14 \times 0.0625 \times 10 = 1.9625 \text{ m}^3 \)
- Cylinder weight = \( 1.9625 \text{ m}^3 \times 8500 \text{ kg/m}^3 = 16,681.25 \text{ kg} \)
  
  \( = 16.69 \text{ te} \)

Calculate the approximate weight of the **aluminum** pipe with given dimensions

- 35cm = 0.35m and 30cm = 0.3m
- \( V = 3.14 \times (0.1225 – 0.09) \times 12 = 1.2246 \text{ m}^3 \)
- Pipe weight = \( 1.2246 \text{ m}^3 \times 2700 \text{ kg/m}^3 = 3306.42 \text{ kg} \)
  
  \( = 3,31 \text{ te} \)

Calculate the approximate weight of this irregular cuboid made up of **soft wood** with given dimensions

- This figure is made from two cuboids with dimensions:
  - 4m \times 3.8m \times 3m
  - 5m \times 3.8m \times 6.2m

- Volume of first cuboid = \( 4 \times 3.8 \times 3 = 45.6 \text{ m}^3 \)
- Volume of second cuboid = \( 5 \times 3.8 \times 6.2 = 117.8 \text{ m}^3 \)
- Total volume of both cuboids = \( 45.6 \text{ m}^3 + 117.8 \text{ m}^3 = 163.4 \text{ m}^3 \)
- Wooden cuboid weight = \( 163.4 \text{ m}^3 \times 350 \text{ kg/m}^3 = 57,190 \text{ kg} \)
  
  \( = 57,19 \text{ te} \)
Centre of Gravity (CoG) – is the point about which all parts of the load (body) exactly balanced against each other.

To ensure safety of the lift the hook of lifting appliance should be positioned above the CoG.

Estimation for basic shapes is straightforward, e.g. the CoG of a straight pipe can be found just by measuring a midpoint in each direction.

For complex shapes usually CoG of subdivided parts is estimated and then combined CoG is found.

In any case the determined CoG should be marked in some way, e.g. sticky tape, marker, chalk etc.

On following slides we will have a look on some examples of CoG estimation.

Just measure the midpoint from each end.
Always ensure that the load is equally balanced.

Below is an example:

- Divide the whole figure into separate cuboids
- Define CoG of each separate cuboid and estimate their weight
- Measure the distance from one end of the whole figure to each separate CoG
To determine the unknown CoG – Z use the following formula:

\[ (WA + WB + WC) \times Z = L1 \times WA + L2 \times WB + L3 \times WC \]

or

\[ (2 + 5 + 1) \times Z = 1 \times 2 + 5 \times 2.5 + 1 \times 4 \]

\[ Z = 18.5 \]

Following:

\[ Z = 2.3 \]

Same process should be done for all other planes to find out CoG’s precise position.

There is another method of CoG calculation.

After breaking the whole figure into separate sections determine their CoGs.

After making a triangle by connecting all CoGs the combined CoG will be somewhere within this triangle.

Let see how it can be estimated on next slides.

We need to find a combined CoG between two separate sections.

The combined CoG will be closer to heavier part, therefore:

\[ \frac{WB}{WB + WA} = \frac{8000}{(8000 + 2000)} = 0.8 = 80\% \]

The same should be done with another section and already found combined CoG.
The combined CoG will still be closer to heavier part, therefore:

\[
\frac{(WA+WB)}{(WA + WB)+WC} = \frac{10000}{10000 + 2000} = 0.83 = 83\%
\]

When more sections involved the same process should be conducted until all sections covered and main CoG is found.

This can be marked on the load by chalk or marker.

### Tension in each leg:

- At 0º Vertical: 4 Te in each leg
- At 90º Angle: 5.6 Te in each leg
- At 120º Angle: 8 Te in each leg
- At 151º Angle: 16 Te in each leg
- At 171º Angle: 48 Te in each leg

### SWL:

- 0º
  - SWL: SWL of one sling x 2
- 30º
  - SWL: SWL of one sling x 2 x 0.966
- 60º
  - SWL: SWL of one sling x 2 x 0.866
- 90º
  - SWL: SWL of one sling x 2 x 0.707
- 120º
  - SWL: SWL of one sling x 2 x 0.5
- 0º
  - SWL: SWL of one sling only
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**Recommended Maximum Included Angle**

- 45°
- 90°

Max Lift =

S.W.L. of one sling \( \times 0.707 \times 3 \)

\[ = 3t \times 0.707 \times 3 = 6.3t \]

Max Lift =

90° Max between any 2 diagonally opposite legs

90° Max between any 2 adjacent legs

Max Lift =

S.W.L. of one sling \( \times 0.707 \times 3 \)

\[ = 3t \times 0.707 \times 3 = 6.3t \]

When the weight is equally distributed between lifting points, the tension will be the same for each sling if they used at the same angle.
When the weight is not evenly distributed between lifting points, the slings and fittings will not have the same tension. Leg 2 is closer to the COG and therefore has the more tension.

\[
\text{Leg 1} = 5 \times \frac{3}{3 + 7} = 1.5 \text{ te} \\
\text{Leg 2} = 5 \times \frac{7}{3 + 7} = 3.5 \text{ te}
\]

If load should be lifted using two single leg slings under the angle, this method could be used to calculate tension on each leg.

\[
\text{Tension 1} = \frac{\text{Load} \times N2 \times L1}{H \times (N1 + N2)} \\
\text{Tension 2} = \frac{\text{Load} \times N1 \times L2}{H \times (N1 + N2)}
\]

When length (L) and height (H) are known you can calculate the tension on equipment using the angle factor:

<table>
<thead>
<tr>
<th>Vertical Angle</th>
<th>Length Factor</th>
<th>L/H</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 deg</td>
<td>1.15</td>
<td>2</td>
</tr>
<tr>
<td>50 deg</td>
<td>1.31</td>
<td>1.55</td>
</tr>
<tr>
<td>45 deg</td>
<td>1.41</td>
<td>1.4</td>
</tr>
<tr>
<td>40 deg</td>
<td>1.55</td>
<td>1.3</td>
</tr>
<tr>
<td>35 deg</td>
<td>1.74</td>
<td>1.21</td>
</tr>
<tr>
<td>30 deg</td>
<td>2</td>
<td>1.16</td>
</tr>
</tbody>
</table>
The maximum recommended included angle is 90°. This angle can be approximately estimated if sling length and distance between lifting points are known.

Most slinging method calculations are based on triangle principle. Any triangle can be subdivided into separate (smaller) triangles and calculated to find out the side needed.

**Pythagorean Theorem (right triangle)**
- **Cathetus** – are always shorter sides
- **Hypotenuse** – is always the longest side

**Pythagorean Theorem**
If you know two of the lengths of a right triangle you can always find the third one.

\[
\begin{align*}
\text{If } a^2 + b^2 &= c^2 \\
\text{or } c^2 &= a^2 + b^2 \\
\text{or } c^2 &= b^2 + a^2 \\
c &= \sqrt{a^2 + b^2}
\end{align*}
\]
To calculate the length of the sling multiply distance between lifting points to the angle factor.

To calculate the sling length for 4 legged sling, multiply distance between diagonal lifting points to the angle factor.

In order to calculate total slinging height always take into account all equipment used, e.g. Shackles, master link etc.

Some slinging method calculations are based on circumference length (for slinging round loads)

If you know the diameter of your load you can calculate the circumference length using the following formula:

\[ L = 2\pi R \] or \[ L = \pi D \]

What Could Fail?

A lift plan Must Consider

- The Foundations
- The Crane
- The Load
- The Rigging

For the Lift Plan to Work Safely