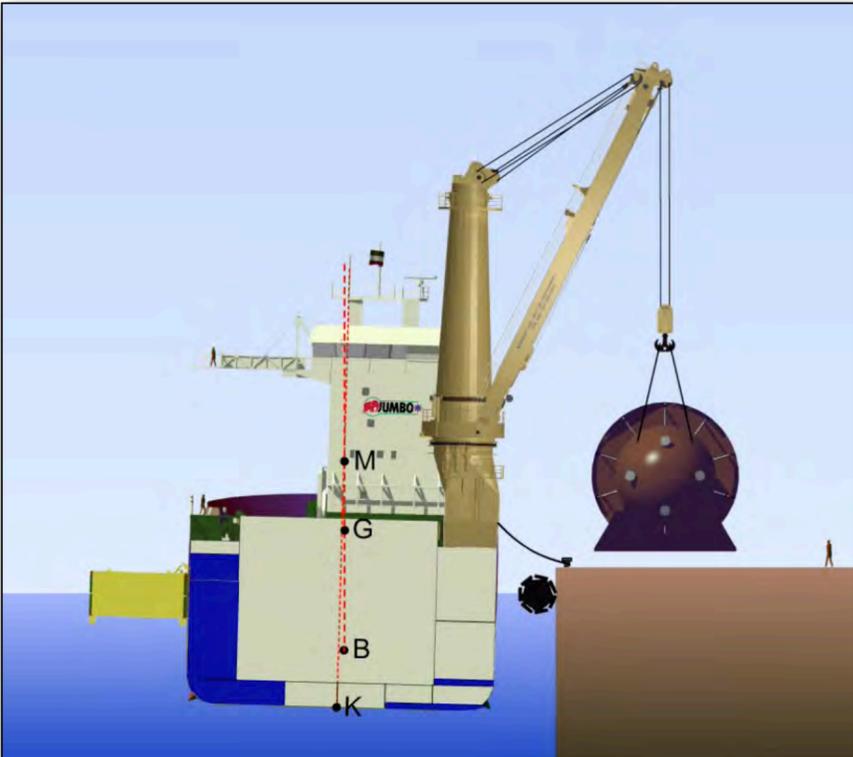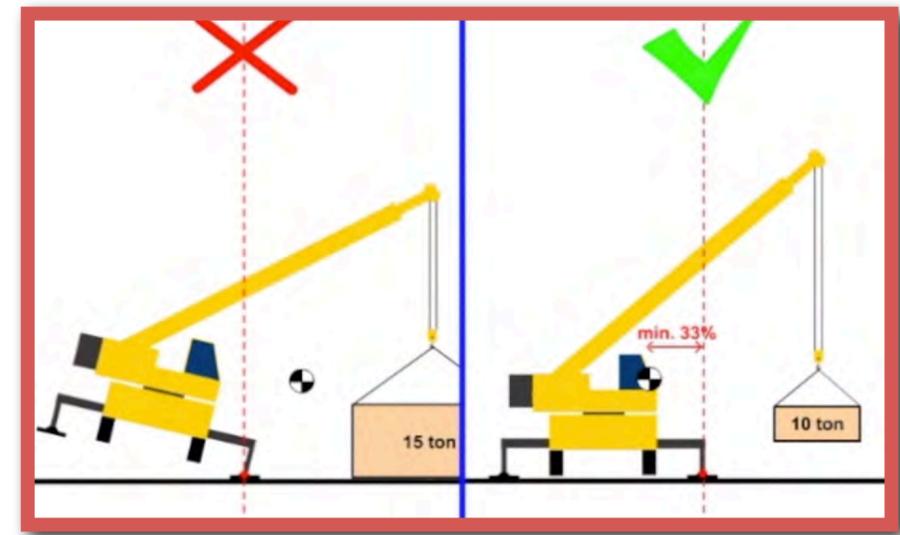# Basic principles of Handling Heavy Lifts

PROJECT CARGO SUMMIT | 11,12 SEPT. 2019 ONDERZEEBOOT-LOODS ROTTERDAM

www.projectcargosummit.com
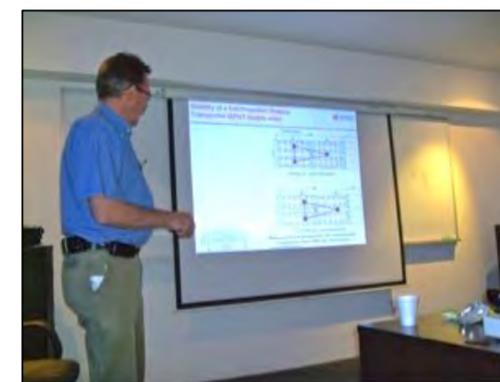
Presented by: Richard L.Krabbendam
Heavy Lift Specialist

Background Richard L. Krabbendam

1945 Born

1966-1972 TU-Delft

1973-1979 Big Lift

1979-1980 Mammoet

1980-1987 ITREC

1982 Married

1987-1989 Van Seumeren

1989-2010 Jumbo Shipping / Offshore

2010- Present Retired FreeLance Consultant/Trainer

2019

Various Transport Modes

Breakbulk movements involve:

1.Transportation

Hydraulic Platform Trailers → Conventional Hydr. Platform Trailers (up to 1000 t)
SPMT's and PST's (up to 17000 t)

Flatbed trailers, Semi-Trailers, Low beds etc. → General cargo transport (up to 100 t)

2.Lifting

Telescopic Cranes → Day to Day work (up to 1200 t)

Lattice type Cranes → Crawler Cranes (Long Term jobs) (up to 4000 t)
Truck Cranes (Long Term jobs) up to 1200 t)
Ringer Cranes (up to 5000 t)

Ships Cranes → Heavy Lift Mast Cranes (up to 1500 t)
Pedestal Cranes (up to 1000 t)

3.Shipping

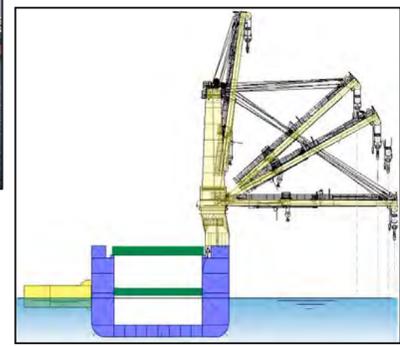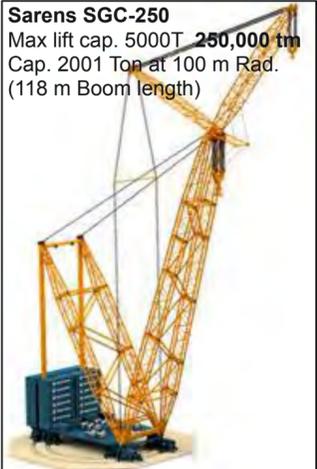**Lift-On/Lift-Off Vessels (Lo-Lo)** → 3 Levels for Cargo stowage (up to 3000 t)

Float-On/Float-Off (Flo-Flo) → Only Floating equipment or Ro-Ro (up to 117000 t)

Roll-On/Roll-Off (Ro-Ro) → 1 level for Cargo i.e large modules (up to 17000 t)

SPMT's

Conventional Platform Trailers in dolly configuration

Semi-Trailer

4000 Tons XCMG88000 +90,000 tm
Here lifting a 1,680 tons tower of 118 m height with 108 m main boom +33 m Fly-jib at 33 m radius

Sarens SGC-250
Max lift cap. 5000T, 250,000 tm
Cap. 2001 Ton at 100 m Rad. (118 m Boom length)

Demag CC8800-1 with Superlift Attachment

Why am I addressing this subject?

- The Airline Industry is the **Safest Transport Industry,** if you compare the number of Fatalities to the number of people transported

- How can we Improve **Safety in Our Industry?**

- **By Sharing Experience, Training & Education** of Staff and Operational Crew members

- **Transport, Lifting and Shipping Companies still lack experienced and trained staff**

- **We can all contribute to SAFETY if we want to**

- **Publish Incident reports in order to learn from the mistakes we made, so others will not make the same mistakes again**

- **Remember the seven P's:**
  Proper Planning & Preparation, Prevents Poor Piss Performance

Accelerations and Decelerations (Stability): Laws of Newton

Mass = 1 Kg

Force = 9,81 N
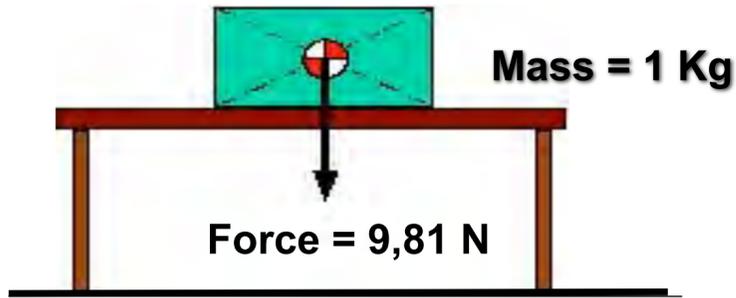
1. In the **Heavy Transport and Lifting business** we are continuously dealing with forces, as we are **always in motion**.

2. The earths gravity is symbolised by the symbol g_n, in which g is the gravity, and n the normal force perpendicular on the plane. On earth g_n = 9.81 m/s^2. (this is an average value, as it is higher at the poles (9.83) and less at the equator (9.78). The earth is a bit flattened off at the poles. For ease of calculation we count with 10.
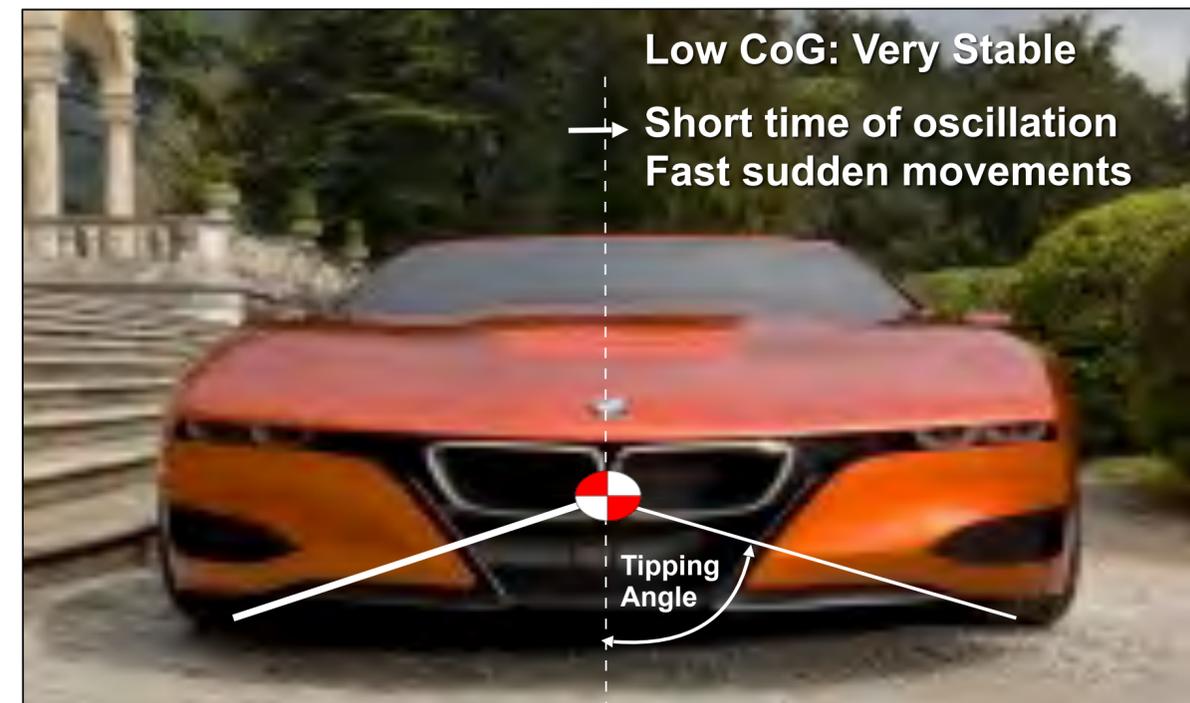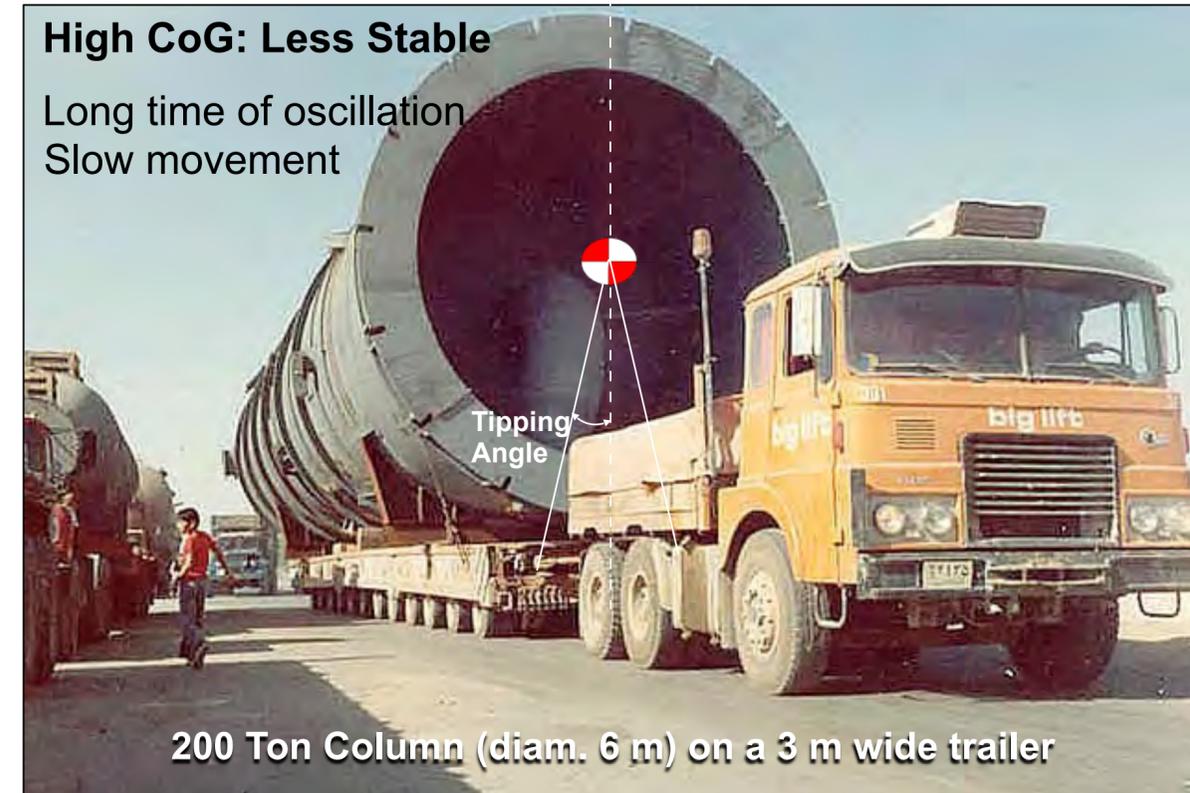
3. Control of Forces, acting on the Load

4. In general speech we talk about **kilograms and tonnes (Lbs and tons)** (Physically this is not correct and it should be Newtons (N) or KiloNewtons (KN)):

   Second Law of Newton ⟶ Force= Mass x Acceleration (F = m * a)

5. Change of movement (deceleration and acceleration) creates an increase of forces

6. Make sure that when moving a load it is always done **gently and gradually.**

6.Do not cause sudden movements!

High CoG: Less Stable

Long time of oscillation
Slow movement

Tipping Angle

200 Ton Column (diam. 6 m) on a 3 m wide trailer

Low CoG: Very Stable

Short time of oscillation
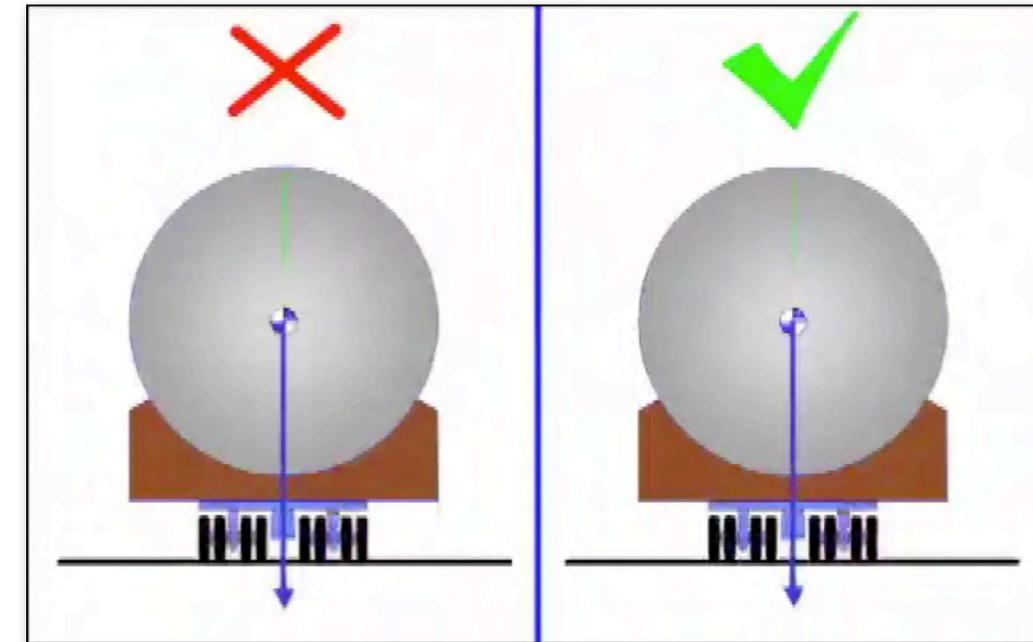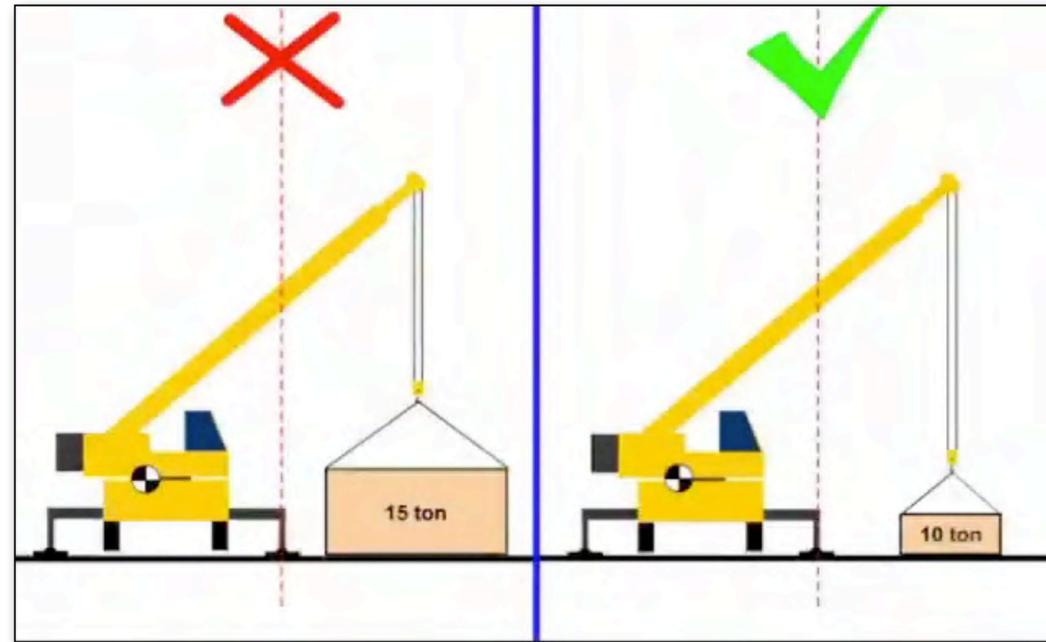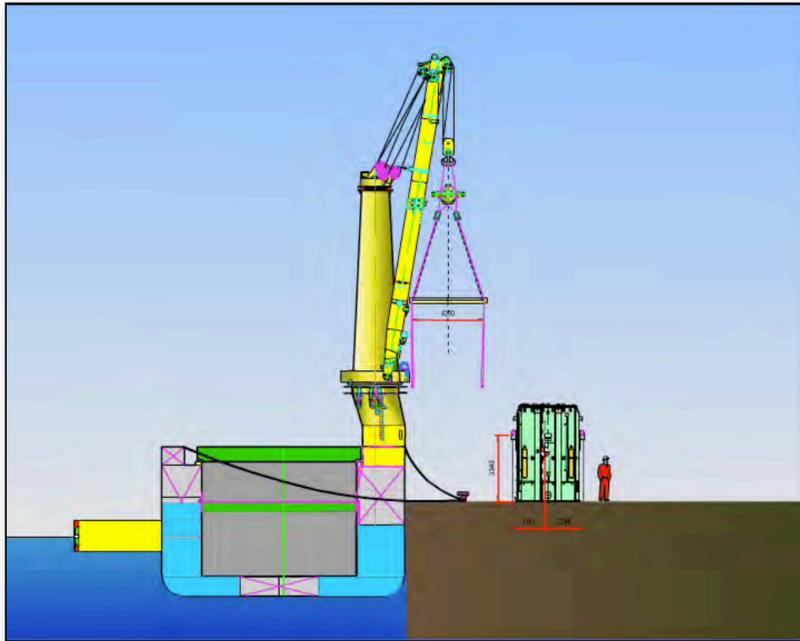**Fast sudden movements**

Tipping Angle

Some preventable incidents

Stability of Equipment and Cargo is Crucial

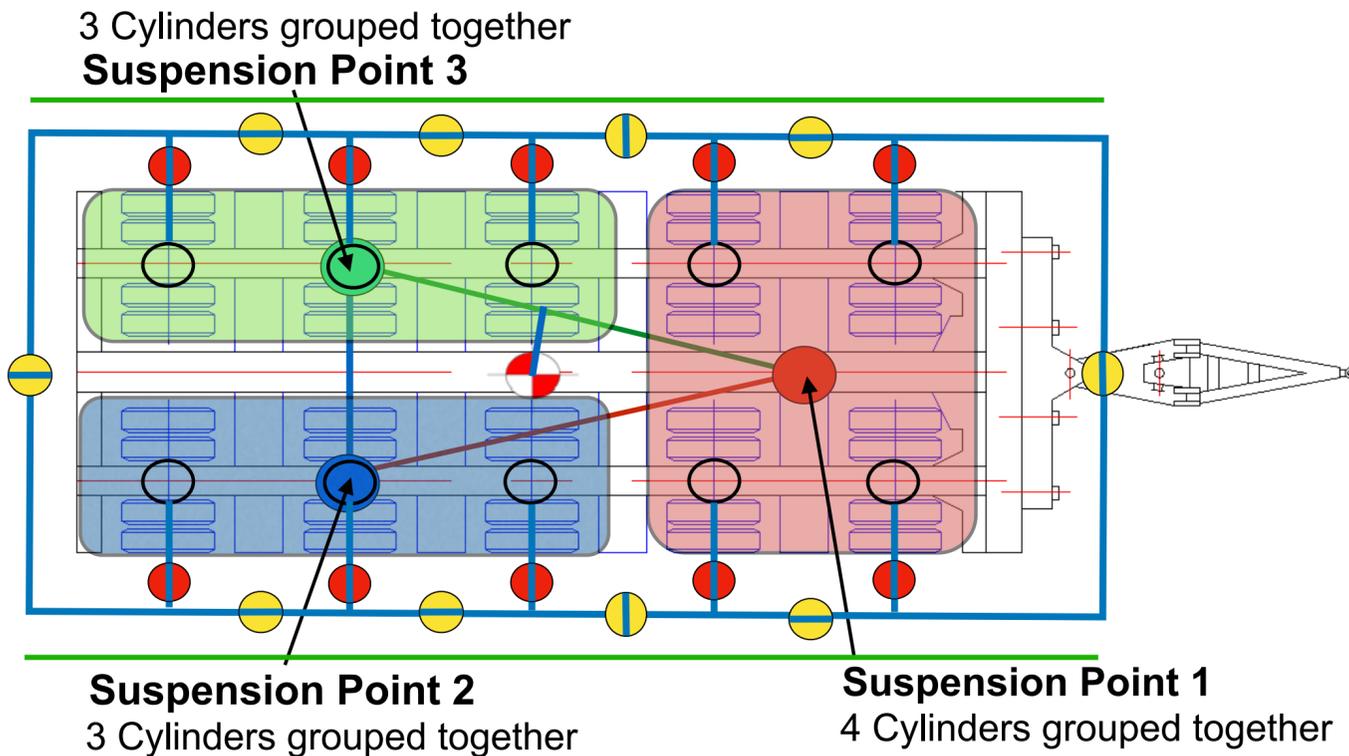- There are stability rules for Ships (IMO)

- There are stability rules for Cranes (75% of Tipping)
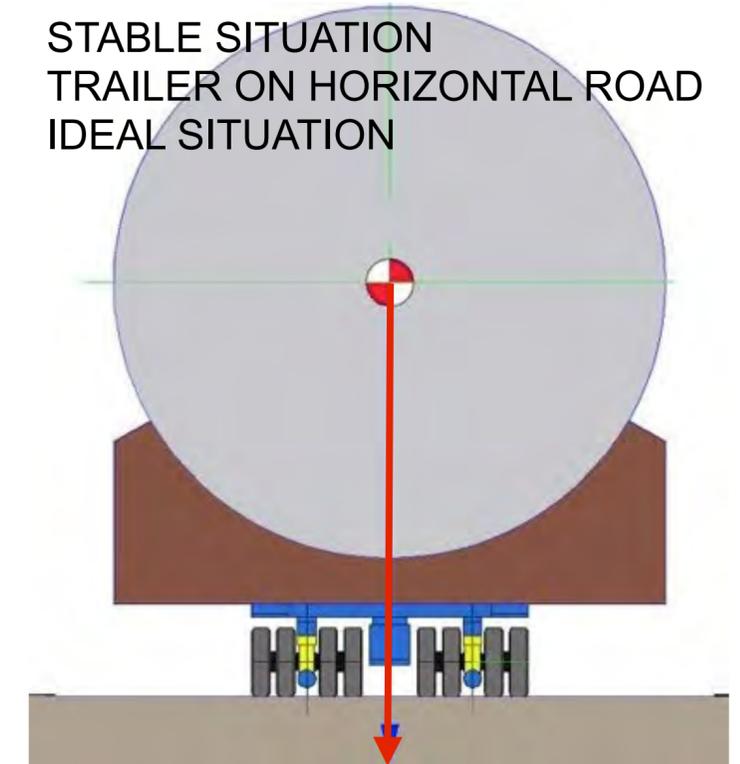
- There are NO stability Rules for Trailers

★ *What about Stability of the Load???*

Transport Stability (3-Point Suspension System)

1. As long as **the force of the combined CoG stays within the tipping lines**, there is no danger of Tipping

3 Cylinders grouped together
Suspension Point 3

Suspension Point 2
3 Cylinders grouped together

Suspension Point 1
4 Cylinders grouped together

STABLE SITUATION
TRAILER ON HORIZONTAL ROAD
IDEAL SITUATION

2. At a certain road camber the **force will get closer and closer to the tipping line.** Because of the **list of the load**, the left tires will get more load and the tires will be pushed in, hereby creating even **more list of the combination.**

3. **Make sure you do not reach this situation**, as at a certain moment the pressure in the suspension is already so high that you cannot level the trailer anymore. (The power pack can not develop more pressure then 250 Bar)

MORE LOAD ON LEFT AXLES
DUE TO CAMBER IN ROAD
TRAILER MUST BE LEVELLED
CoG STILL WITHIN TIPPING LINES

Transport Stability (4-Point Suspension System)

1. At a certain moment **the force will go over the tipping line** and the transport combination will tip over.

   PAY ATTENTION:
   This can happen earlier then one thinks, due to **dynamic effects**, inaccuracy of the CoG and deflection of the tires

2. With the **hydraulic suspension** system the trailer can at all times **easily be adjusted to horizontal level.**
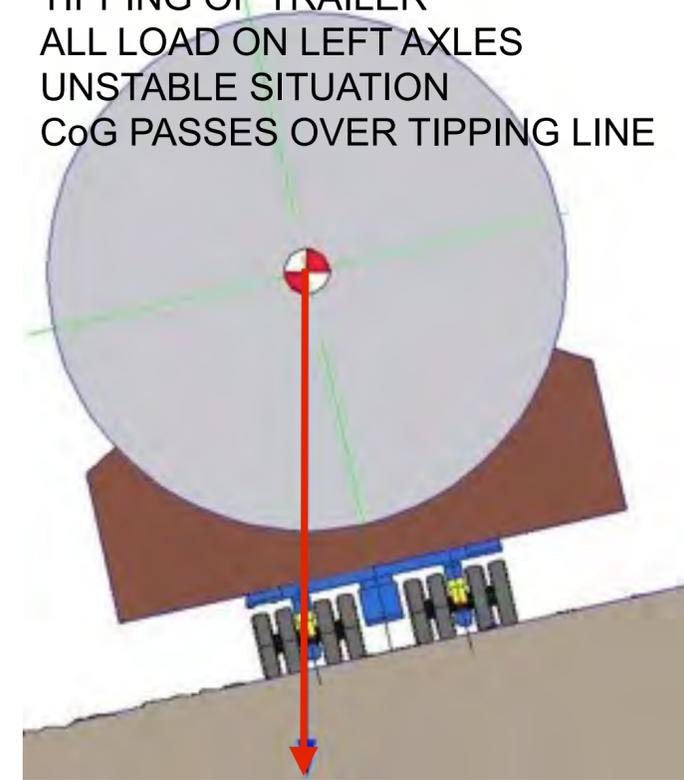
3. **Use a spirit level to check this frequently!!**

NOTE:
A 4 point suspension system has the best stability, compare it with a table on 3 or 4 legs, but from a structural point of view a 3 point suspension avoids possible overloading

Tipping Angle must be >8°

TIPPING OF TRAILER
ALL LOAD ON LEFT AXLES
UNSTABLE SITUATION
CoG PASSES OVER TIPPING LINE

CAMBER OF ROAD CAN BE NEGOTIATED SAFELY PROVIDED TRAILER BED IS LEVELLED WITH HYDRAULIC SUSPENSION SYSTEM
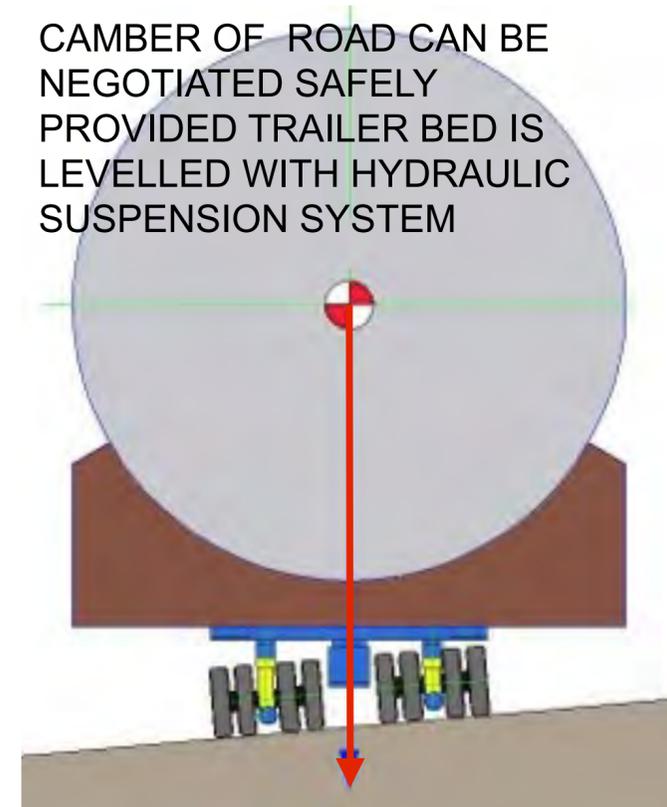
Or as a 4 point Suspension with RED Tipping Lines

Suspension Point 3
3 Cylinders grouped together

Suspension Point 4
2 Cylinders grouped together

Suspension Point 2
3 Cylinders grouped together

Suspension Point 1
2 Cylinders grouped together
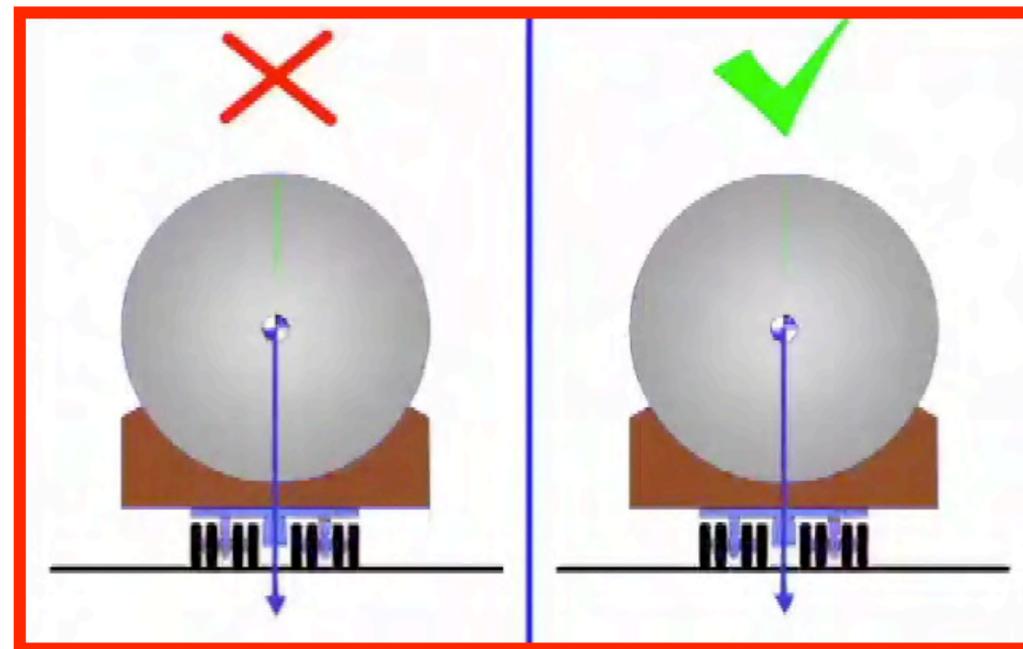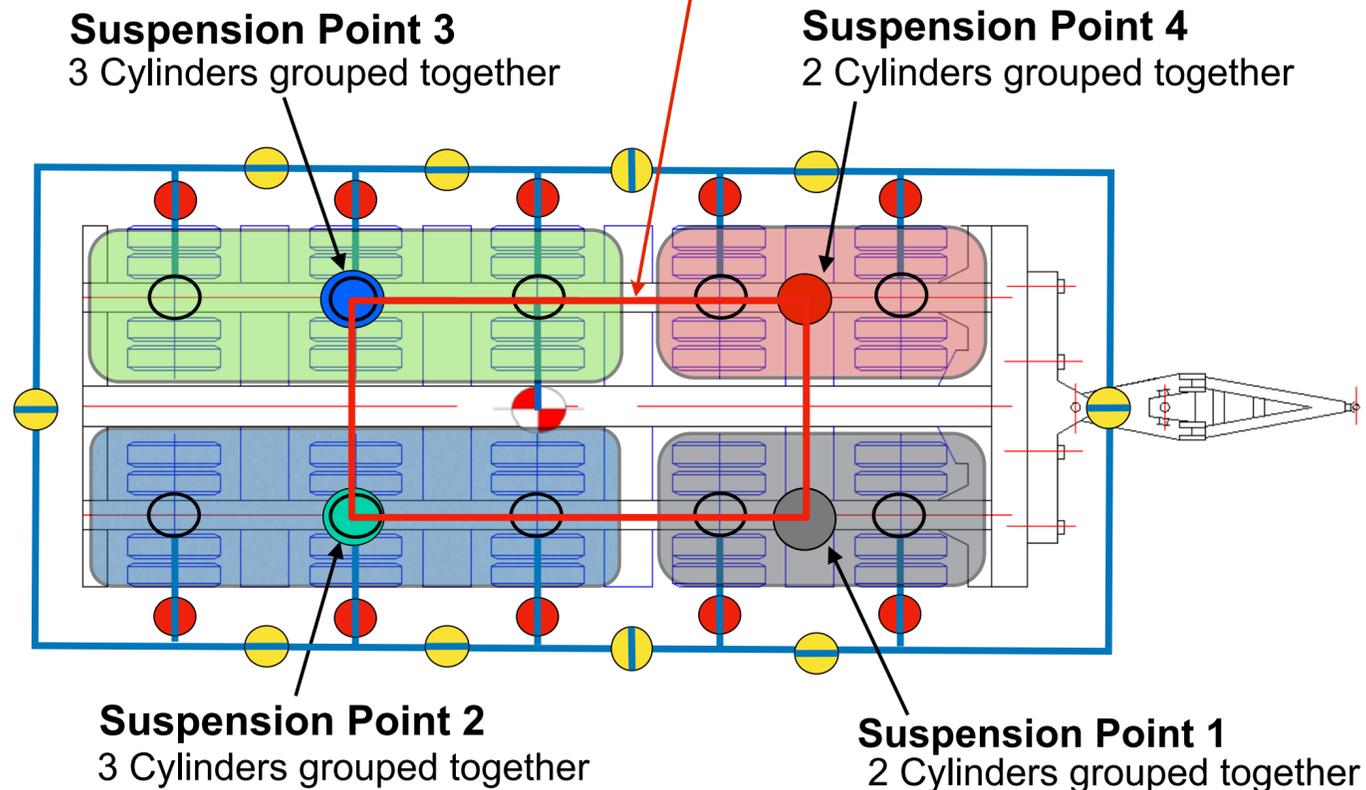
Trailer tipped

Trailer set at a **3-Point** Suspension System

Lower part of road
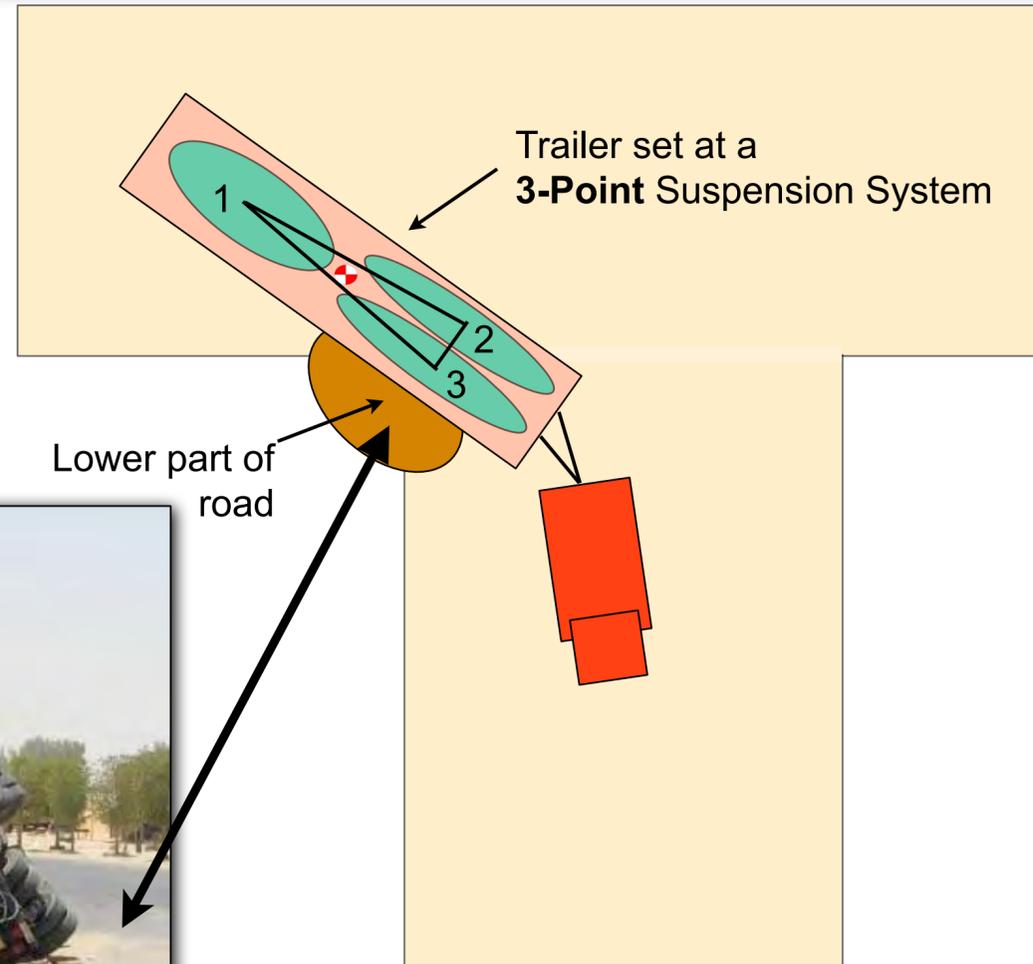
- Trailer was about to **enter the corner**
- 3-point suspension with the **single point (1) at the rear (Wrong? or Correct?)**
- When entering the corner, suspension point 3 will **tilt** the **trailer immediately** without warning
- With the tractor unit **pulling it around the corner** this will help tilting the transport combination
- If the **single point suspension** was at the front we would have noticed that the front axle went down due to the **lower part of the road** and the trailer **could have been levelled in time**

1. **Monitor trailer level** at all times during transport **(Spirit level, Electronic device etc.)**

2. **A rule of thumb is:** A load which is **2 x as high as the width of the trailer** on which it will be transported: **WATCH OUT FOR STABILITY OF THE TRANSPORT COMBINATION!**

3. **Check the theoretical Tipping Angle. If it is between 8º and 15º, be careful as stability becomes critical**

4. **Preference** for a **3 point suspension** system due to equal axle loads

4. At **high** loads a **4 point suspension** system gives **a better stability**

5. **Watch the pressure** in each hydraulic suspension point, and adjust if necessary

6. **Always avoid sudden movement** (braking, fast change of direction, bumps etc.)

670 Ton

90 Ton

7170

4894

2394±350

4400

750

1450

5330

18.23º

Theoretical Tipping angle = INV Tan (1450/4400) = 18.23º

1. The **load moment** of a crane is load (ton) x radius (m) measured to the center of the crane and is defined in **Ton meter**.

2. The **tipping moment** of a crane is the (moment of the load + the moment of the boom weight) around the tipping line A

3. The **stabilising moment** is the moment of the weight of the fixed parts of the crane around tipping line A

4. The Capacity of a lift crane is based on **75%** of the **tipping moment**

5. In other words, the tipping moment must be at least: 1/0,75 = **1,33 x as big** as the **stabilising load moment**

6. With an **unloaded crane** the angle between the vertical line through the tipping line and the line through the CoG must be **at least 5°**

5°

Radius

A

Traglasten / Lifting capacities
Forces de levage / Portate
Tablas de carga / Грузоподъемность

Basic Load chart of Liebherr LTM1130-5.1 Telescopic crane

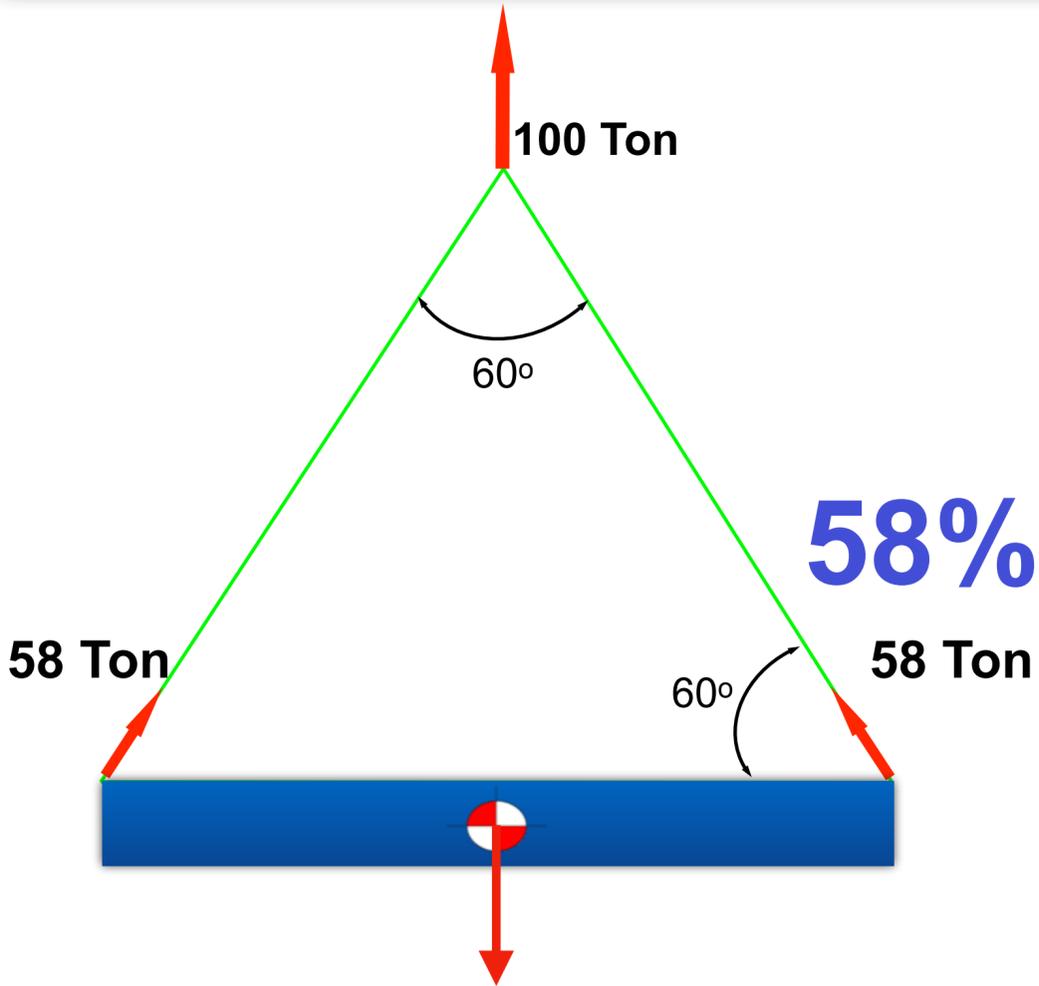|	12,7 m	17 m	21,4 m	25,7 m	30,1 m	34,4 m	38,8 m	43,1 m	47,5 m	50,5 m	51,9 m	54,9 m	56,2 m	60 m	
3	130	82,6	82,6												3
3,5	92,4	82,6	82,6	82,4	67,3										3,5
4	86	82,6	82,3	79,5	66,3	56,1									4
4,5	80,4	79,9	76,7	73,9	65,3	55,4									4,5
5	75,5	74,5	71,9	69,1	64,3	54,7	43,7								5
6	67,2	64,7	63,9	61,3	60,1	52,2	42,5	32,9							6
7	60,1	56,9	57,6	55,9	53,9	49,3	41	32	25,2						7
8	53,5	50,2	50,9	50,7	48,9	47	39,4	31,1	24,7	19,8					8
9	46,8	44,6	45,3	45,5	44,7	43,9	37,9	30,2	24,1	19,5	14,5	16			9
10	37,7	37,7	40,4	40,6	40,4	40,5	36,5	28,9	23,5	19,1	14,5	16	12,8		10
11			36,3	36,4	36,3	36,8	35,1	27,3	22,9	18,7	14,2	15,9	12,8	13	11
12			32,8	33	32,8	33,4	33	25,7	21,9	18,3	13,7	15,7	12,7	13	10,5	12
14		27	27,5	27,9	27,7	27,2	23	19,8	17,1	12,7	14,9	12,2	12,6	10,5	14
16			23,6	23,6	23,3	22,9	20,6	17,9	15,7	11,7	13,9	11,5	12	10,3	16
18			20,2	19,9	19,5	18,5	16,2	14,3	10,8	12,9	10,7	11,2	9,9		18
20				17,5	17,2	16,7	16,9	14,7	13	9,9	11,9	9,9	10,5	9,2	20
22				15,3	15	14,7	15	13,5	12	9,1	10,9	9,2	9,8	8,6	22
24					13,1	13,5	13,1	12,2	11	8,4	10,1	8,5	9,2	8,1	24
26					11,7	12,1	11,6	11	10,2	7,7	9,3	8	8,6	7,5	26
28						10,8	10,3	10	9,3	7,1	8,6	7,4	8	7	28
30						9,7	9,2	9,3	8,3	6,6	8	6,9	7,5	6,6	30
32						7,5	8,2	8,5	7,8	6,1	7,4	6,5	7	6,1	32
34							7,8	7,6	7,2	5,6	6,8	6	6,5	5,7	34
36							7,1	6,9	6,8	5,3	6,2	5,7	6,1	5,3	36
38								6,2	6,2	4,9	5,9	5,3	5,6	4,9	38
40								5,8	5,6	4,6	5,4	5	5	4,6	40
42									5,1	4,3	4,9	4,7	4,5	4,2	42
44									4,6	4,1	4,4	4,4	3,9	4,4	44
46										3,8	4	4,4	3,5	3,5	46
48										3,3	3,6	3,6	3,1	3,1	48
50											3,2	2,8	2,8	50
52											2,8	2,4	2,4	52
54													2,1	54
56													1,8	56

Take following precautions to reduce the risk of a crane accident:

1. Properly **train crane operators** and other personnel
2. Conduct complete **crane inspections**
3. Having an effective **preventive maintenance** program
4. **Not exceeding the maximum lift load capacity** of the crane
5. **Properly rigging of** the loads to the crane
6. **Proper communication** between the crane operator and workers in the vicinity
7. Proper communication when **assembling or disassembling** the crane
8. **Supervision of all aspects of crane operation**, from assembly to disassembly
9. Make a **Lift Plan**

How do we quickly estimate forces in lifting slings?

100 Ton

60°

60°

58 Ton   **58 Ton**

58%

100 Ton

120°   30°

100 Ton   **100 Ton**

100%

100 Ton

90°

45°

71 Ton   **71 Ton**

71%

1000N
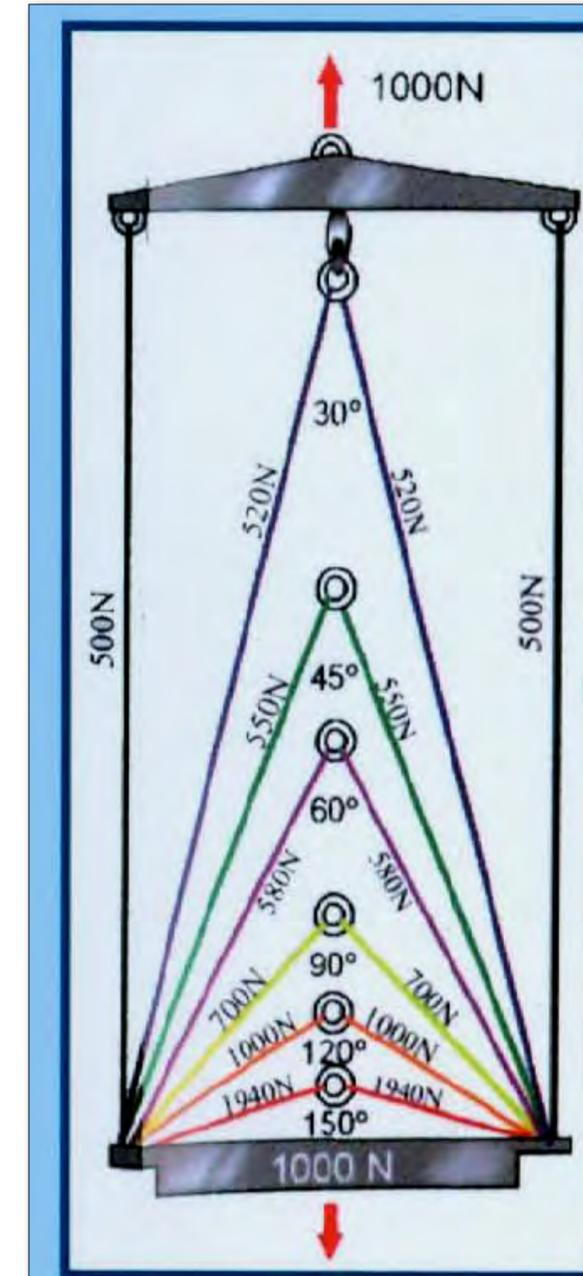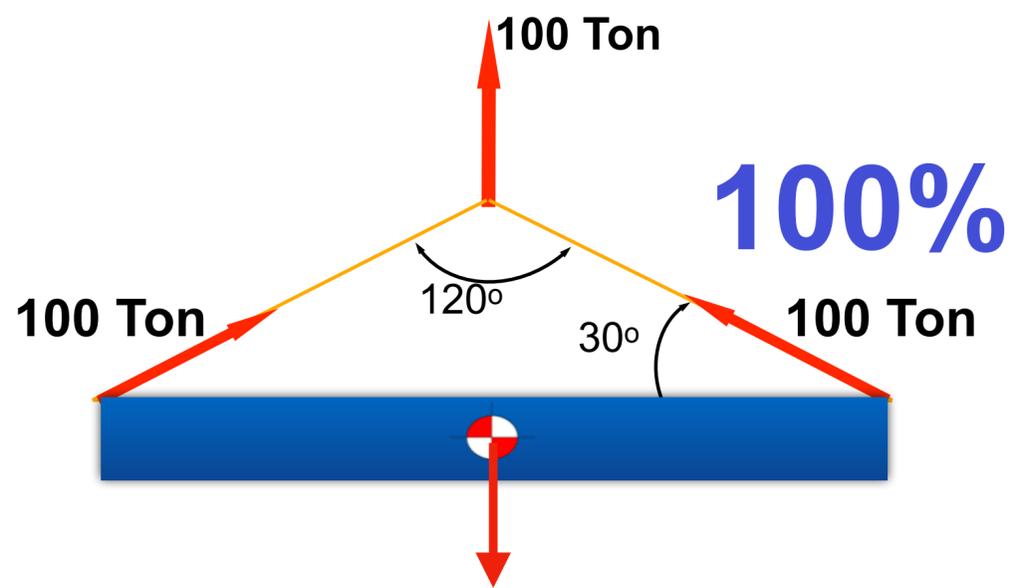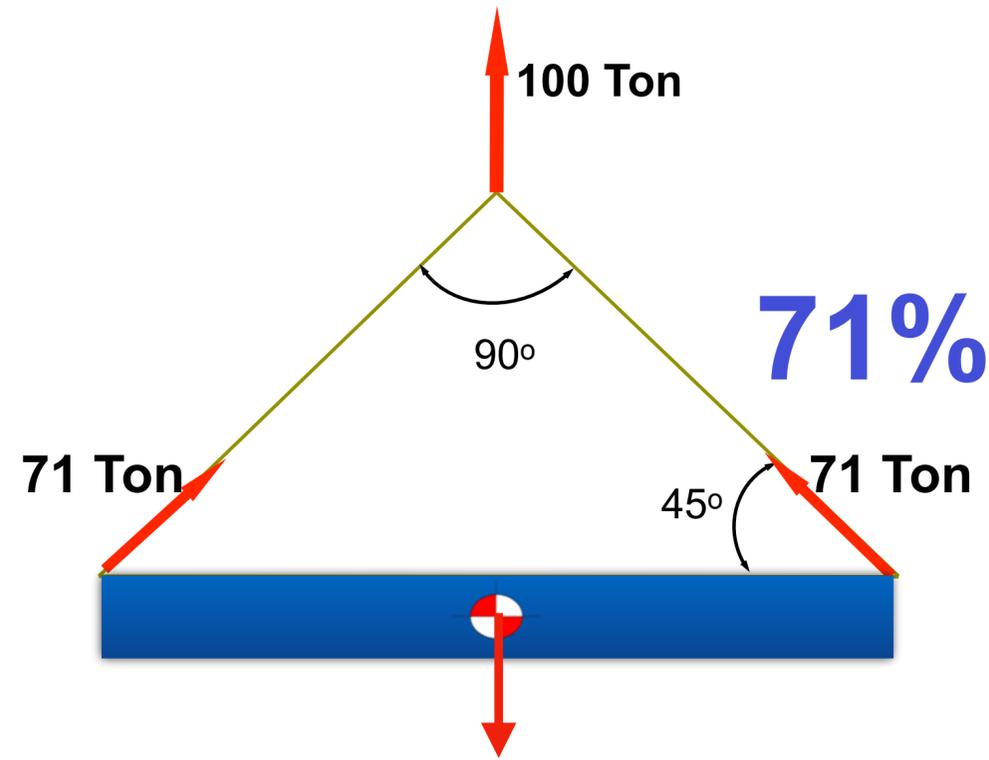
Load per sling at different top angles

500N   500N
520N   520N
30°
550N   550N
45°
580N   580N
60°
700N   700N
90°
1000N   1000N
120°
1940N   1940N
150°
1000 N

The bigger the spread the more pain!
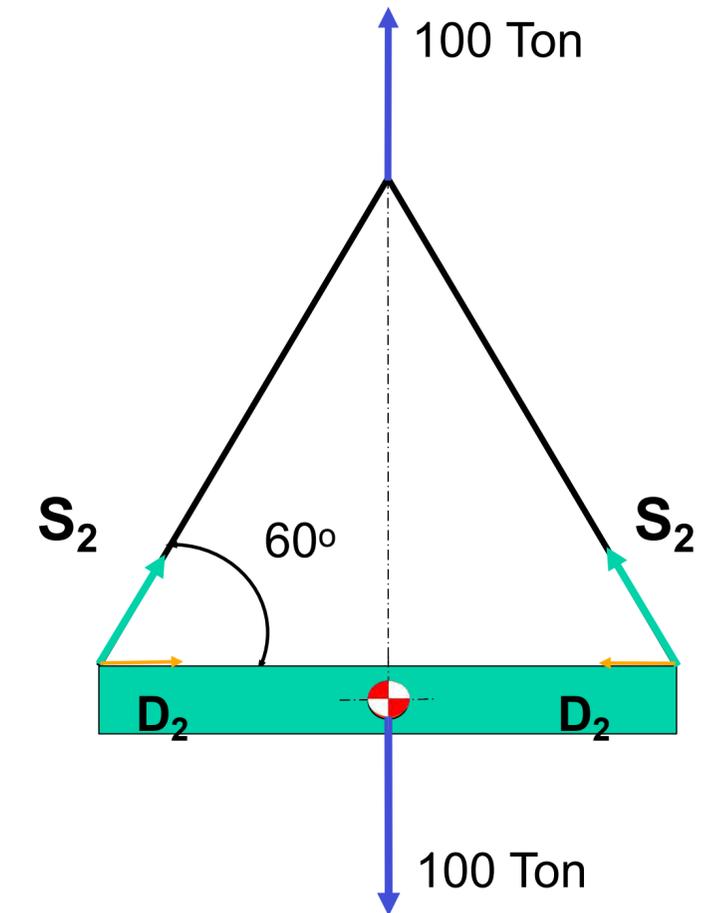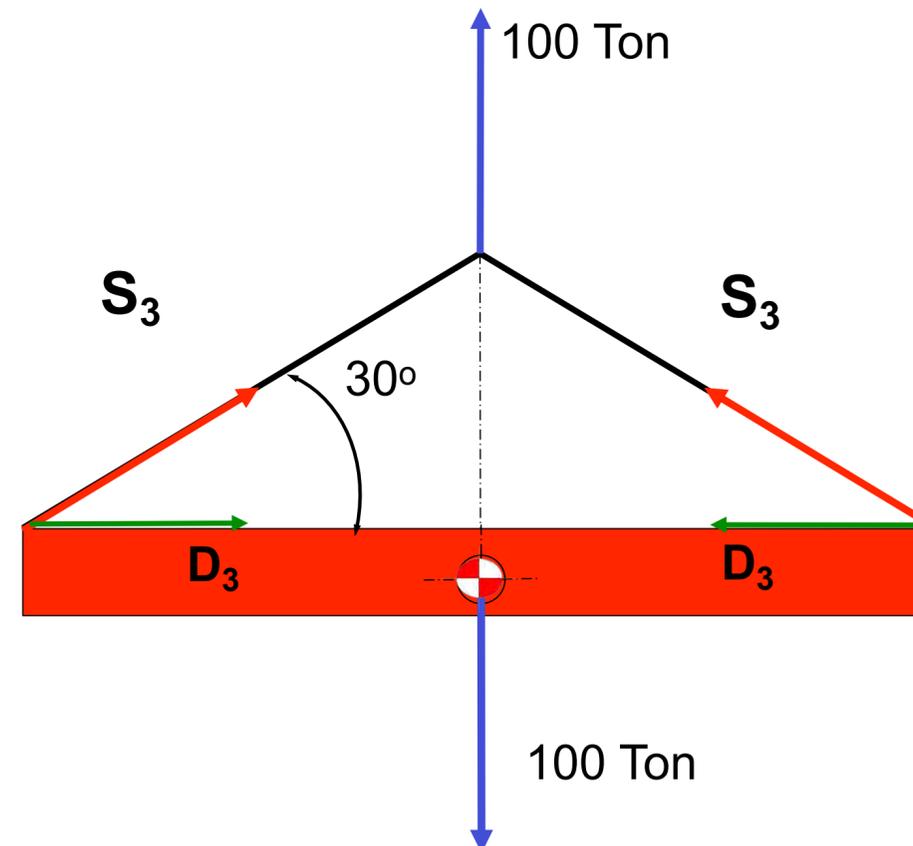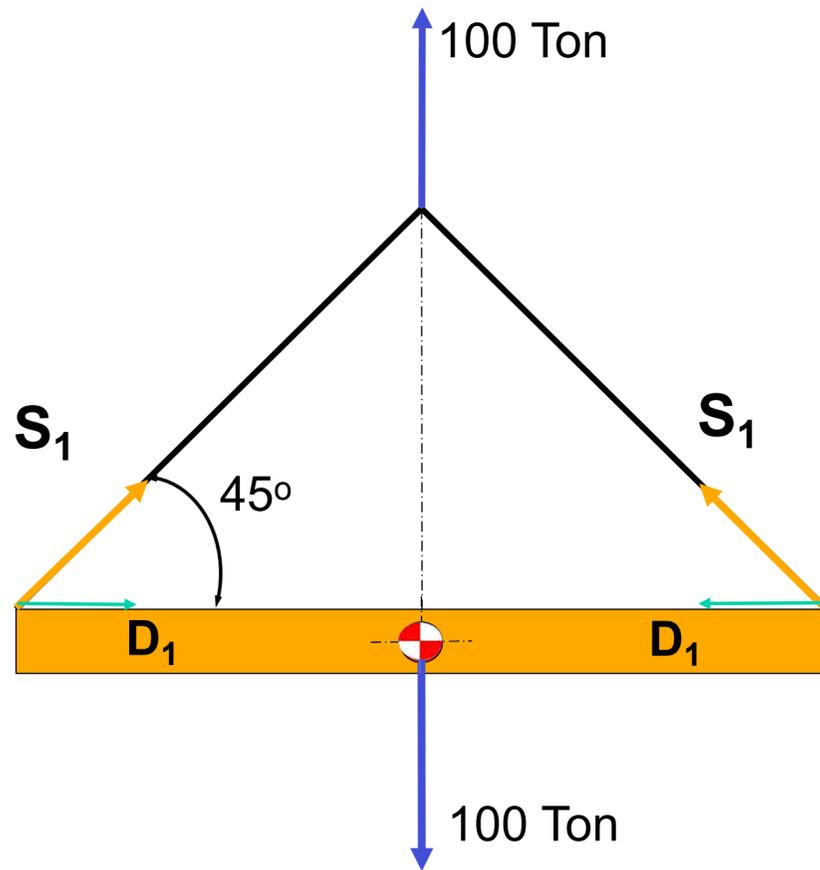
Lifting a 120 Tons Rotor into a river vessel went wrong
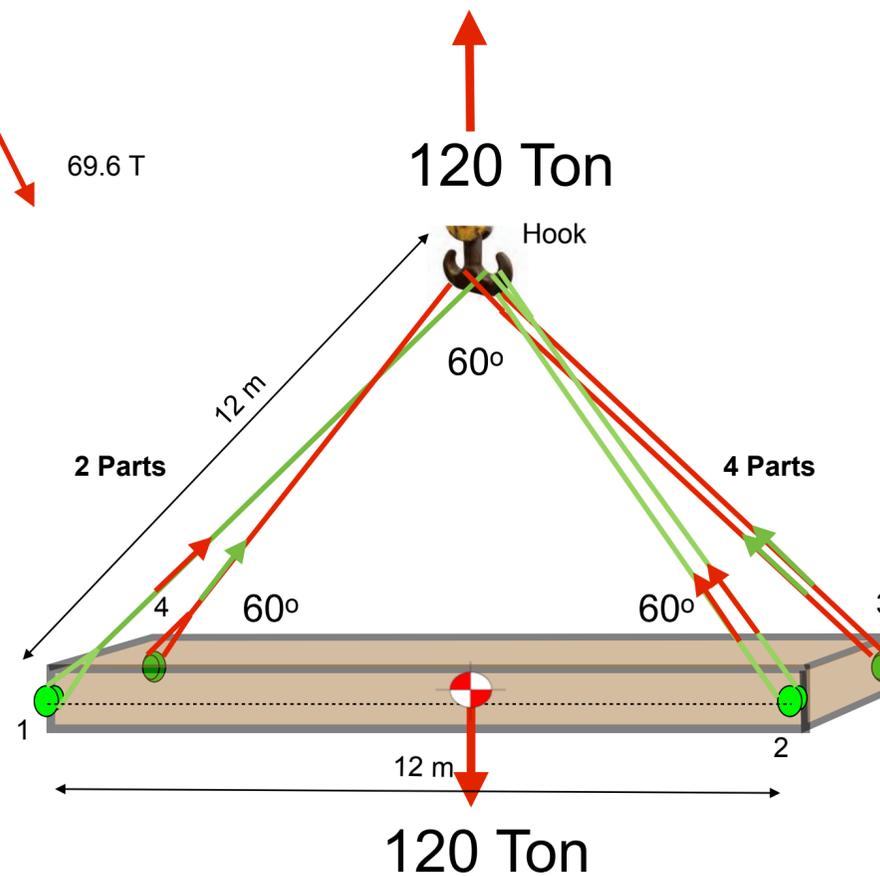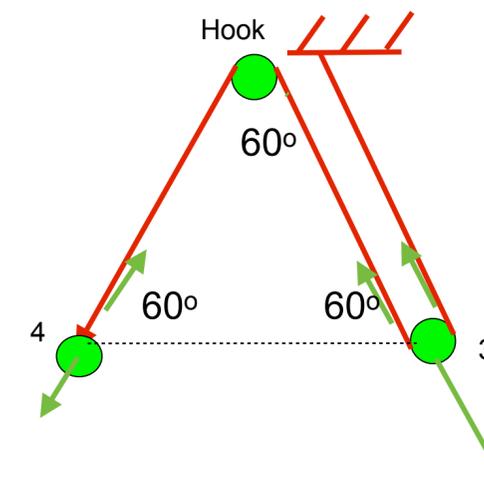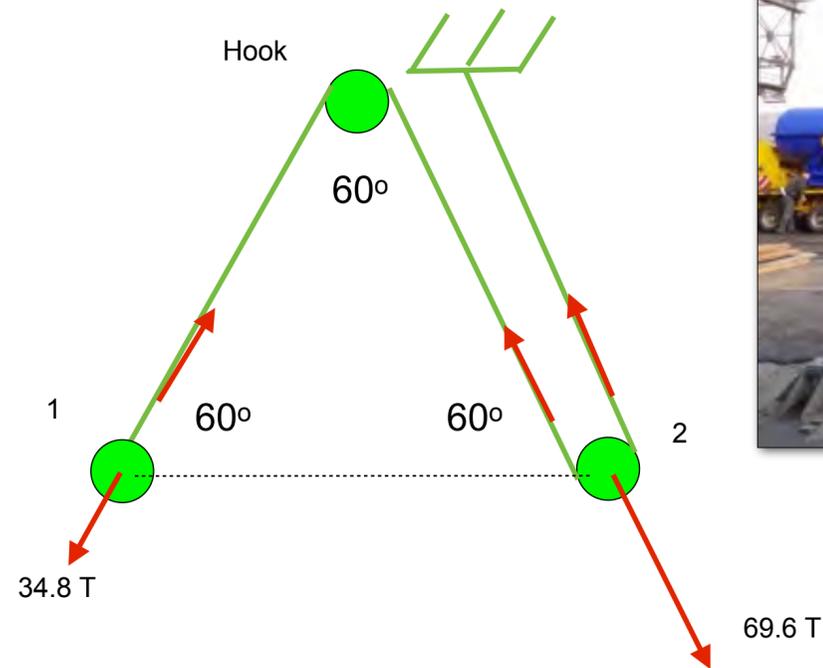
1. Two slings were used, each with a length of 36 m.

2. The green sling goes from pt.1 over the ramshorn hook around lifting bollard 2 back to the hook

3. The red sling goes from pt.4 over the ramshorn hook around lifting bollard 3 back to the hook.

4. The angle with the horizon is approx. 60°

5. Sling force in pt.1 is: 58% of 120/2 = 34.8 Ton

6. The hook and the lifting bollards can be considered as pulleys, with a certain friction

7. The force of 34.8 Ton is in the red as well as in the green sling.

8. At point 2 and 3 the red and green sling pull with twice the force = 69.6 Ton, resulting in going up and point 1 and 4 going down.

9. This only occurs when the friction between the slings and the hook and around the lifting bollards is exceeded

# Lifting a 120 Tons Rotor into a river barge went wrong
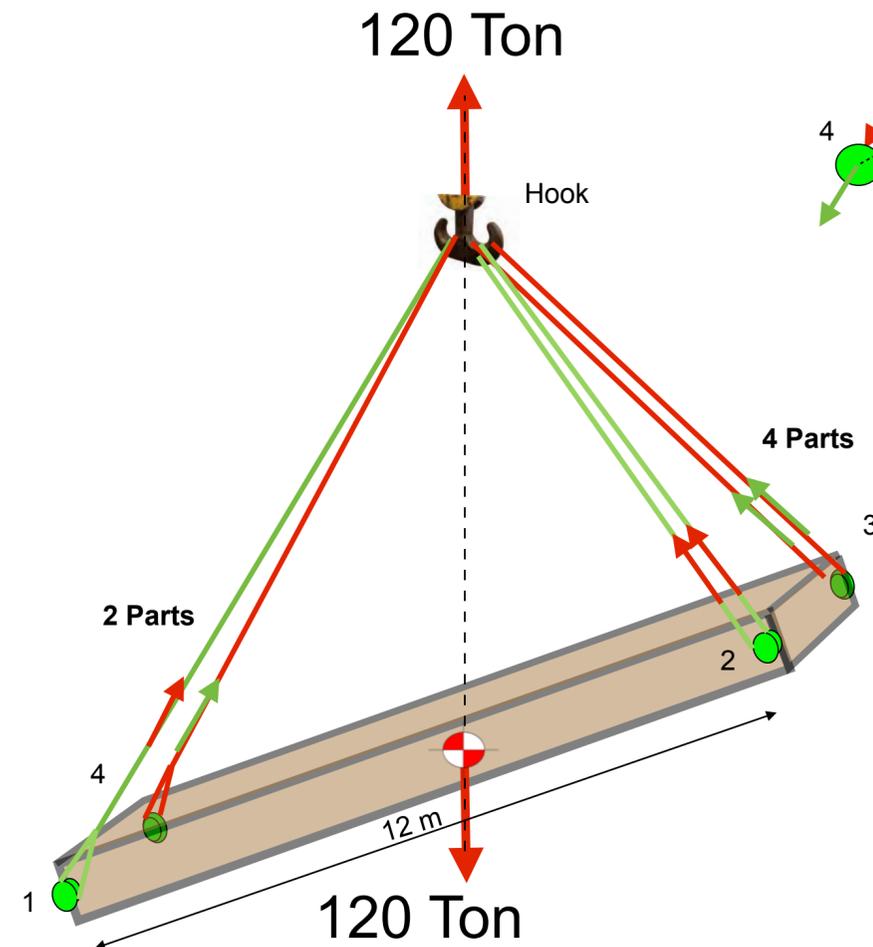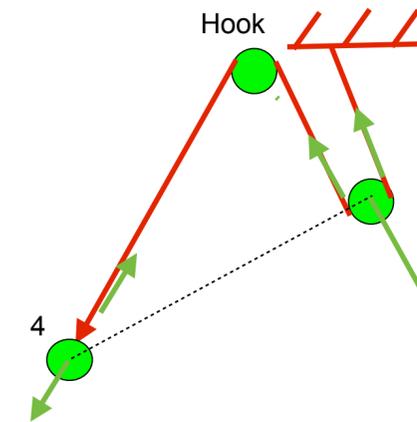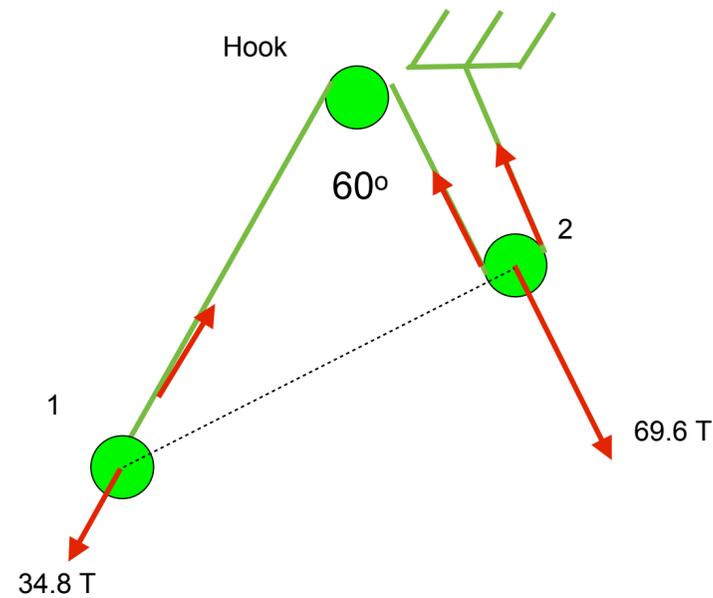
1. When we start lifting, the force in the green and the red sling pull with twice the force on pt.2 and 3.

2. When the friction between the sling and the hook and the lifting bollard is exceeded, it will start tipping

3. If friction is not exceeded, it will stay in horizontal position, but this can suddenly change due to a shockload.

4. Static friction co-efficient is higher then the dynamic friction co-efficient

5. The hook and the lifting bollards can be considered as pulleys, with a certain friction

Due to 2 parts in pt.2 and 3, there will be a bit of torsion in the load, but the load will stay horizontal

1. Two slings were used, each with a length of 36 m.

2. The green sling goes from pt.1 over the ramshorn hook around lifting bollard 2 back to the hook

3. The red sling goes from pt.4 over the ramshorn hook around lifting bollard 3 back to the hook.

4. The angle with the horizon is approx. 60°

5. Sling force in pt.1 is: 58% of 120/2 = 34.8 Ton

60°

3 Parts

12 m

3 Parts

60°

60°

60°

3

1

4

2

12 m

120 Ton
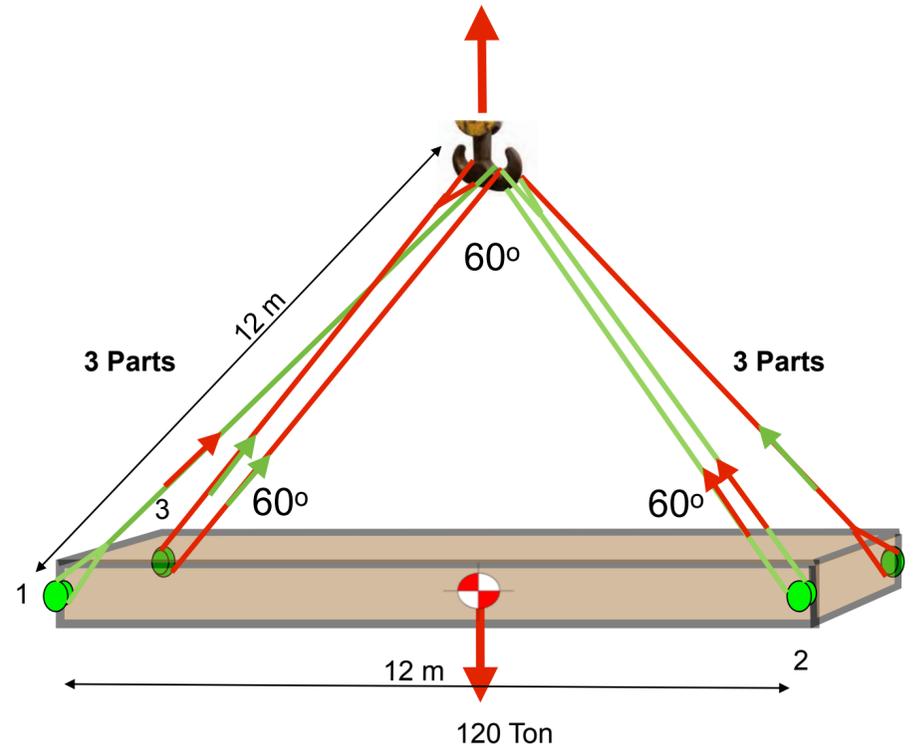
Difference between a Lifting- and Spreader Beam

Lift Beam
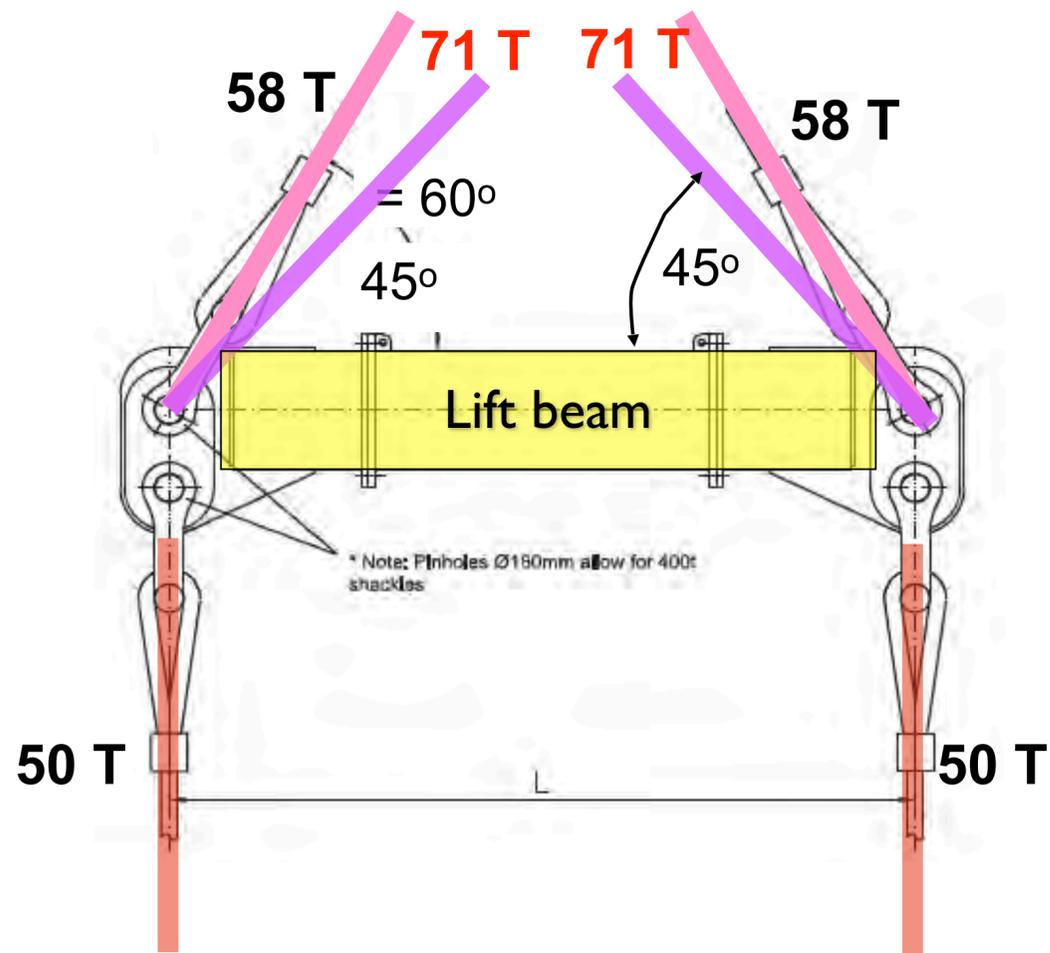
Spreader Beam

When lifting a load of **100 Ton**, the force in the **red slings** below the spreader will be 50 T

Due to the angle with the horizon, the force in the **purple slings** at:
$x = 60°$ will be **58 T**

and

at **45°** it will be **71 T**
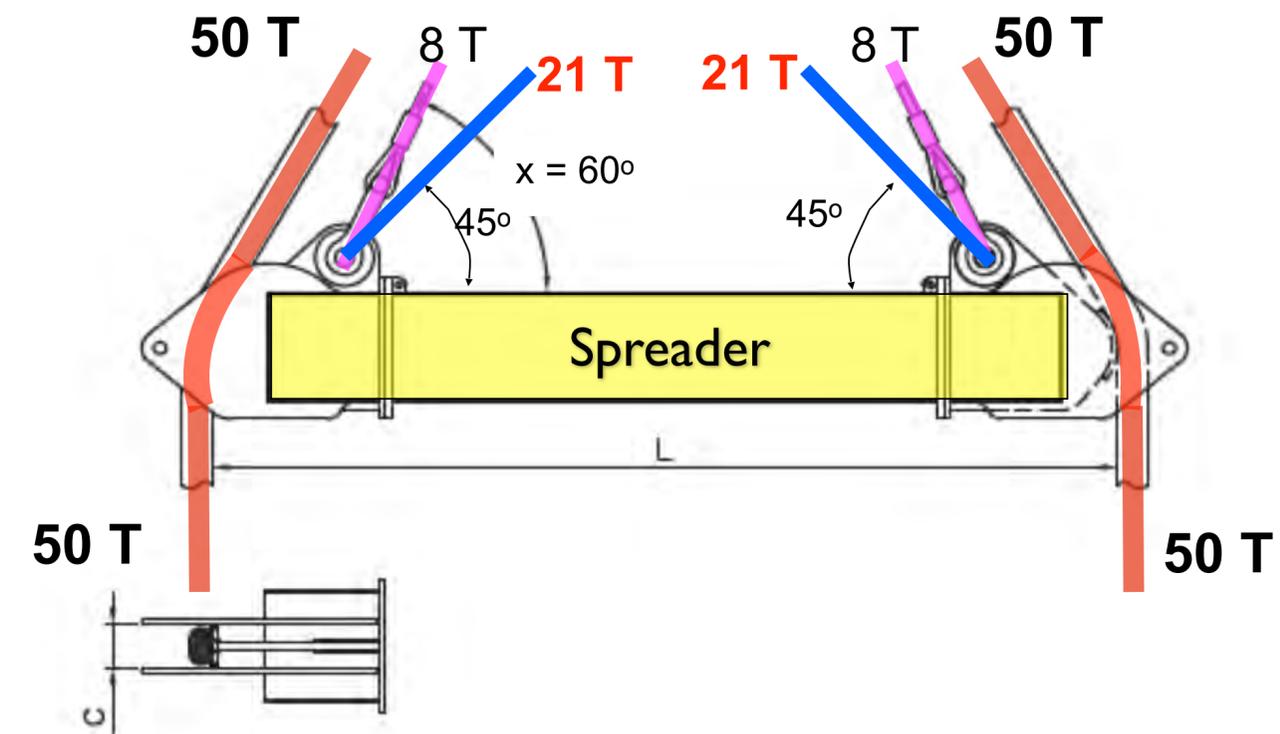
When lifting a load of **100 Ton**, the force in the **red slings** above and below the spreader beam remain the same, as it is one **continuous sling**. (50 Ton)

Due to the angle with the horizon, you would expect a higher force in the sling above the spreader beam. This extra force component is now absorbed by the **purple slings** (At $x = 60°$, the force in the purple sling will be **8 T**; and

at **45°** it will be **21 T (blue sling)**

Example:

1. Position **the hook on the vertical line** through the **CoG** and draw the slings from the lift points to one point in the hook

2. Draw the **force diagram** on scale starting at the top of the lift slings

3. Use e.g. **a scale of 1:100**, so that 1 cm = 1 Ton

4. **First draw 20 cms** straight down, this represents the weight of **20 Ton**

5. Then from the point of that force draw parallel lines and **complete a parallelogram** and one can now draw the blue forces

6. By **measuring these forces**, and use the scale factor, one can define the magnitude of each force, which is the force in each sling

15 cm = 15 ton

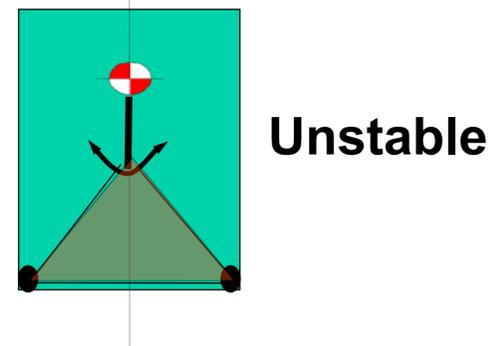8 cm = 8 ton

20 Ton = 20 cm

20 Ton
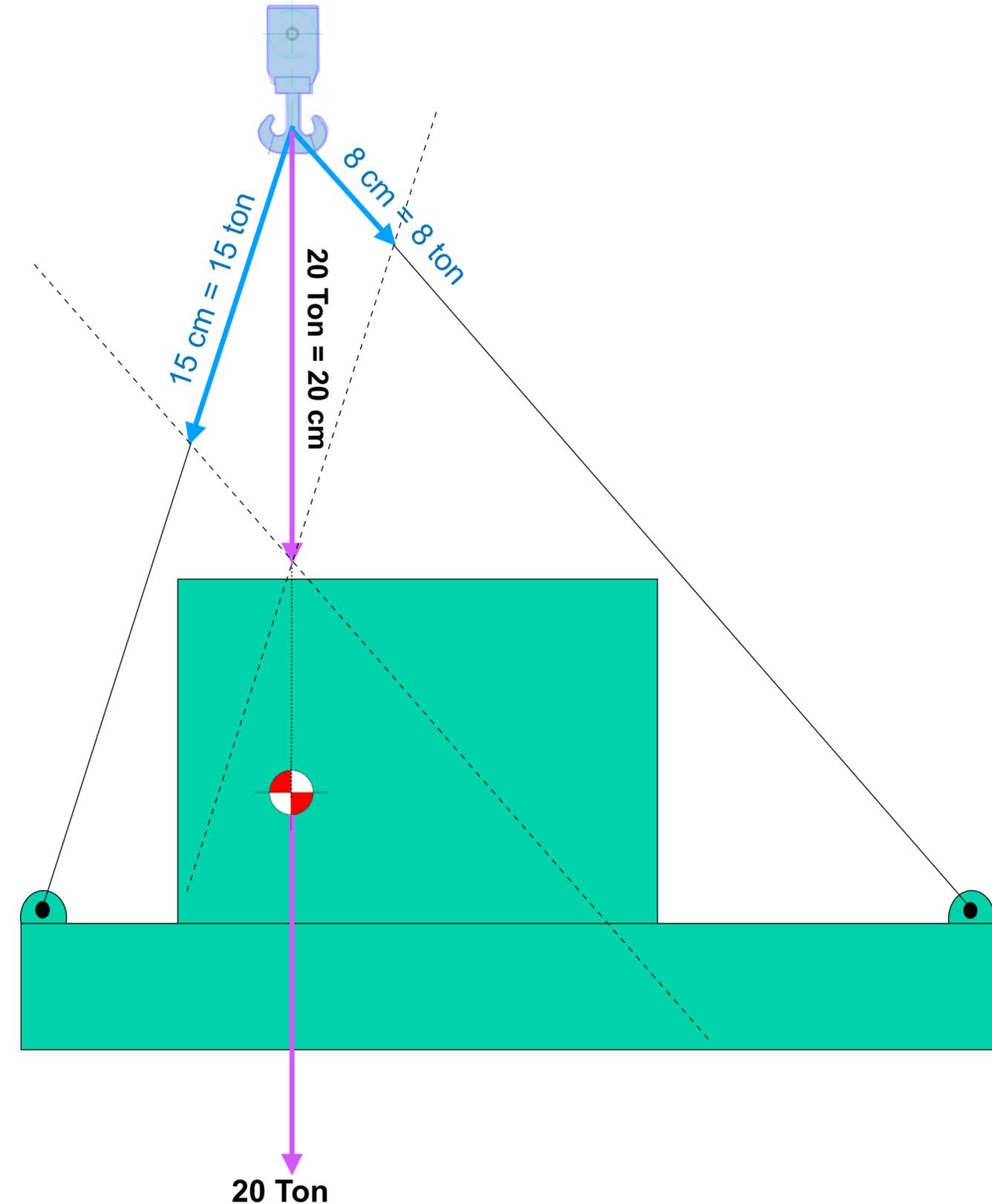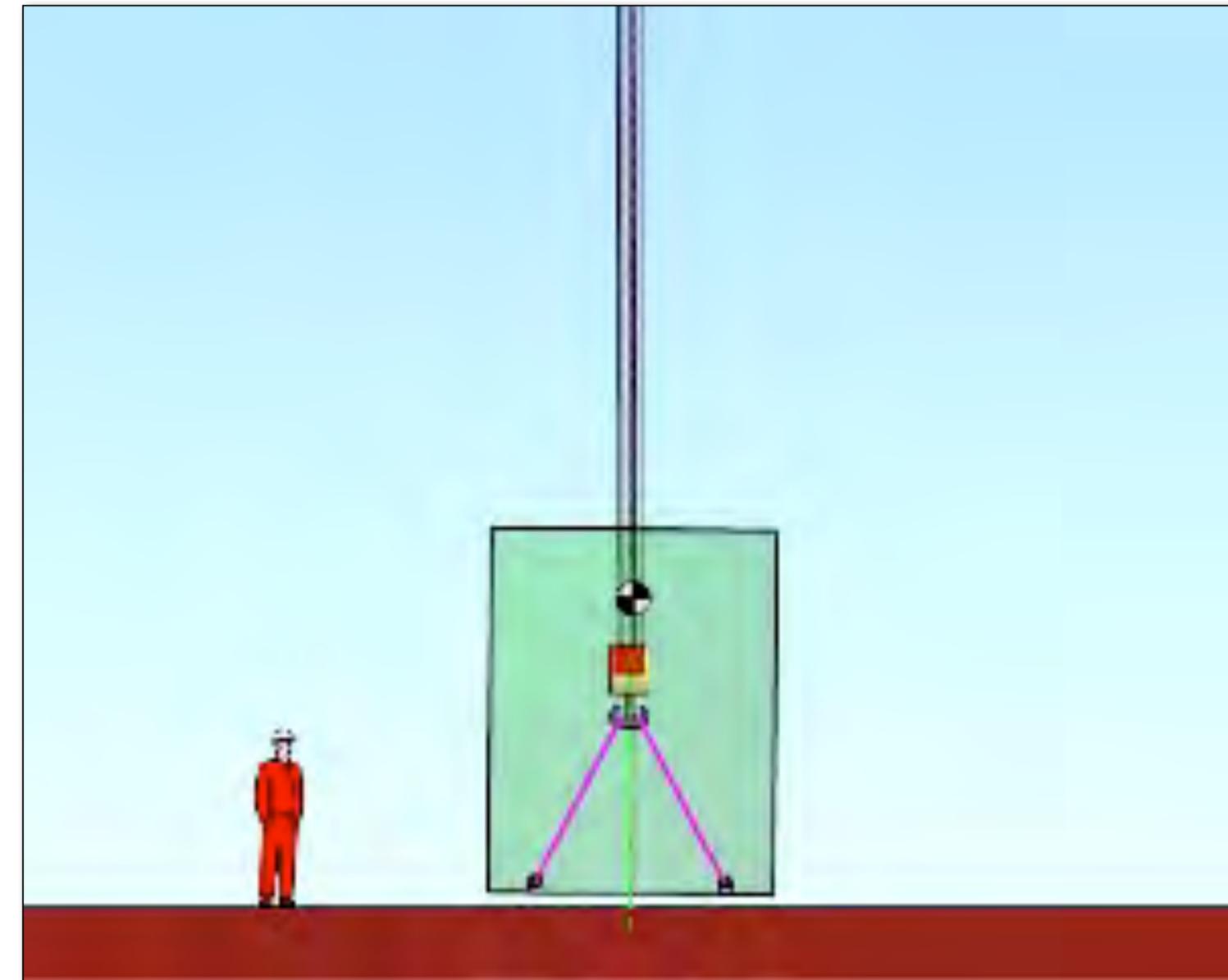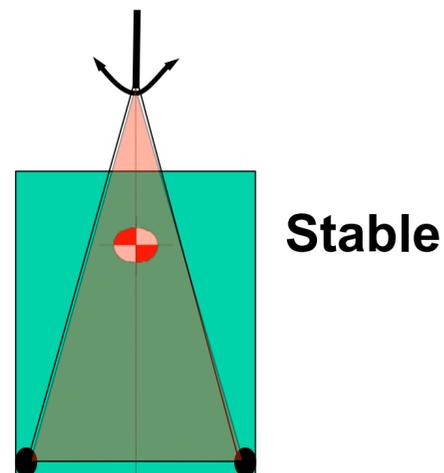
The Stability of the load to be lifted

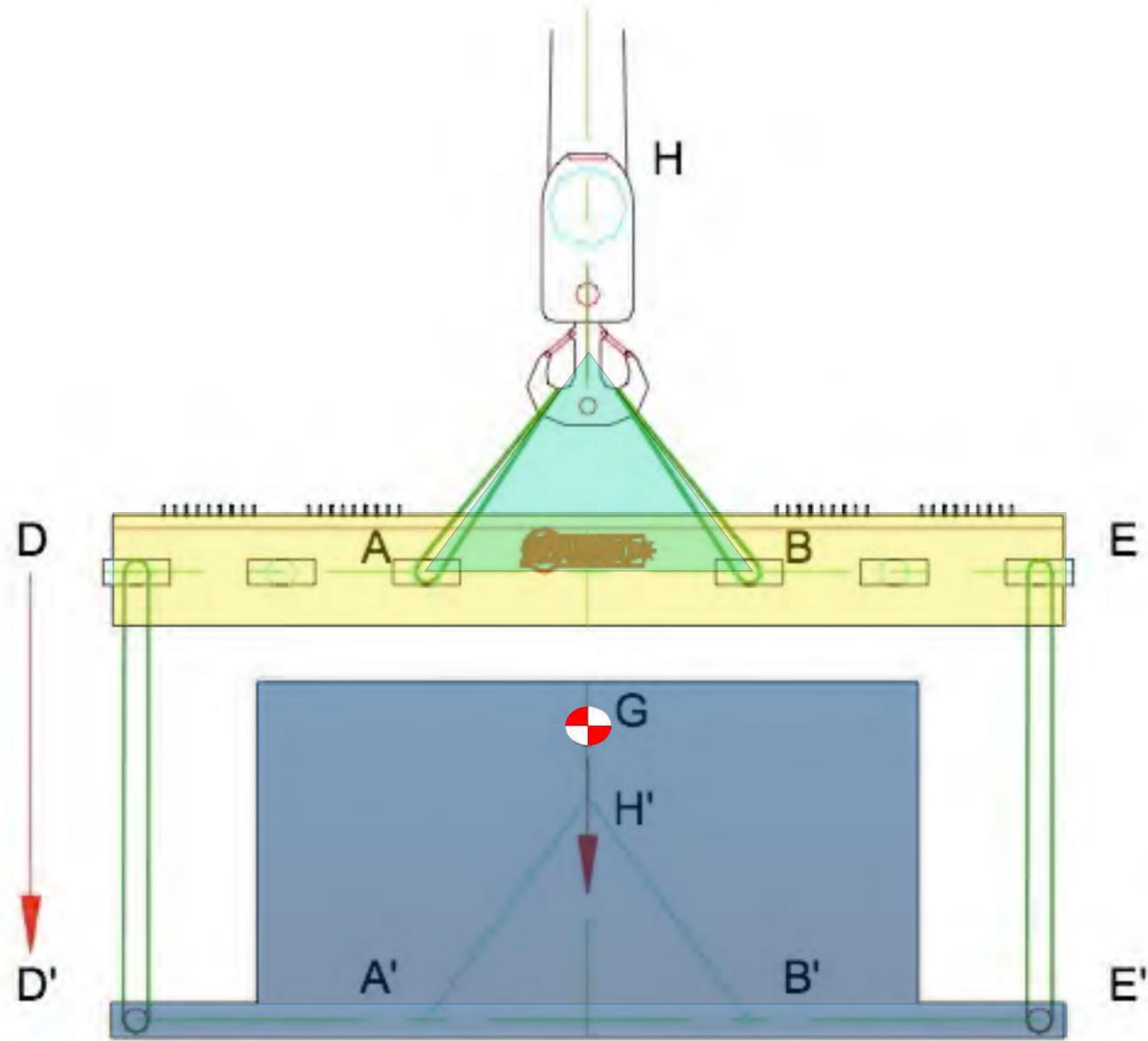1. A load with lifting points **above the CoG** is always a **stable** load
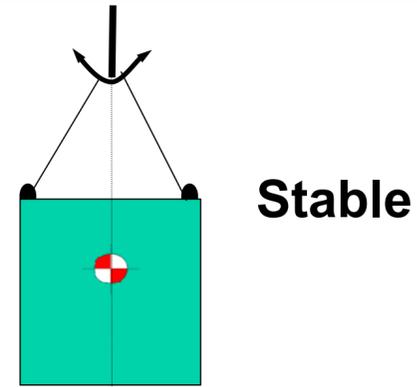
Stable

2. When lifting from liftpoints **below the CoG**, the load an become un stable.
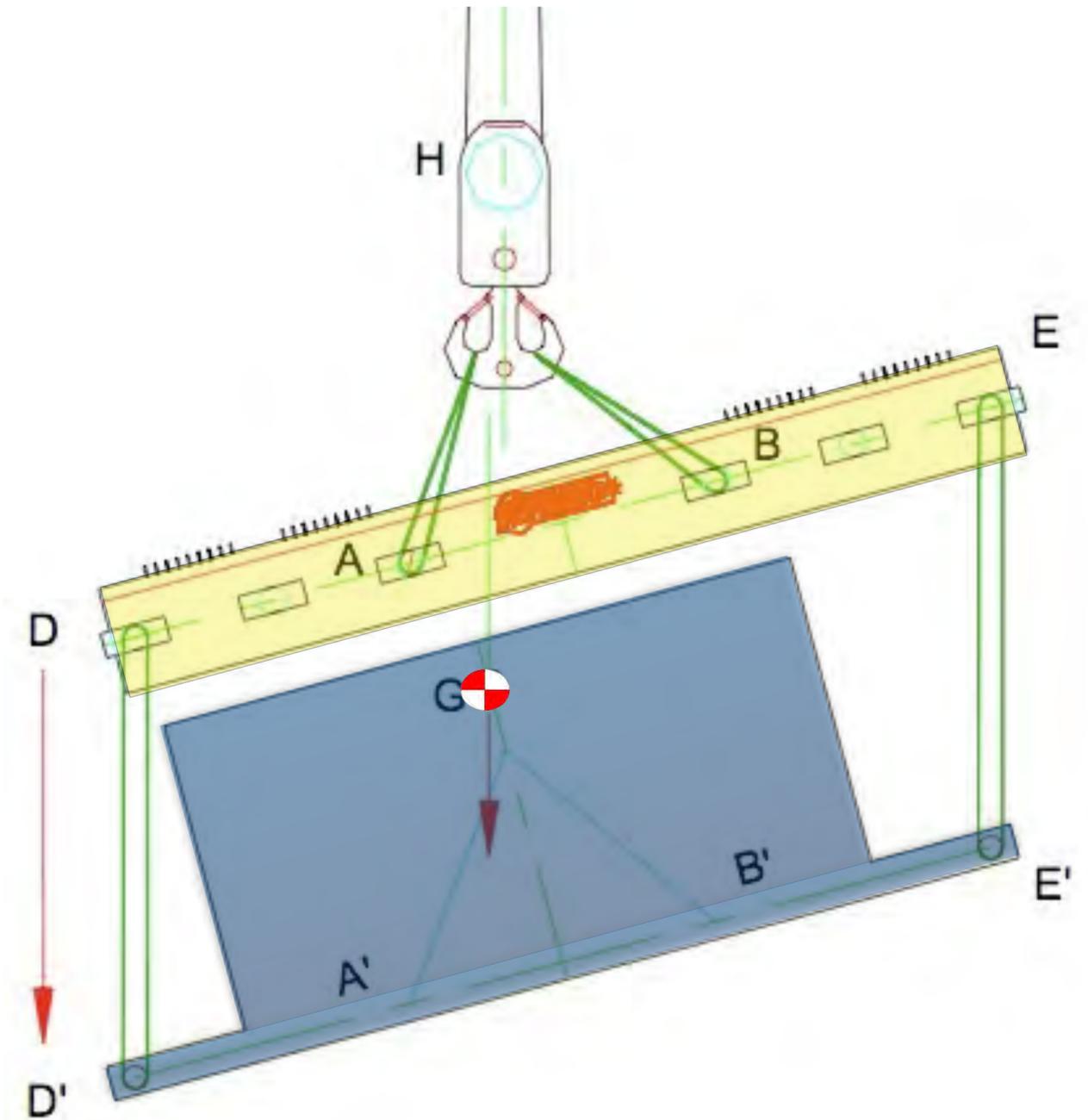The load is **unstable** when the CoG is **outside the lift triangle**

Unstable

3. To make it a stable load: **lengthen the slings.**
The load is stable when the CoG is **inside the lift triangle.**

Stable

1. This load **is unstable** as the projected lift triangle is **below the CoG**

2. **The load will tip over**
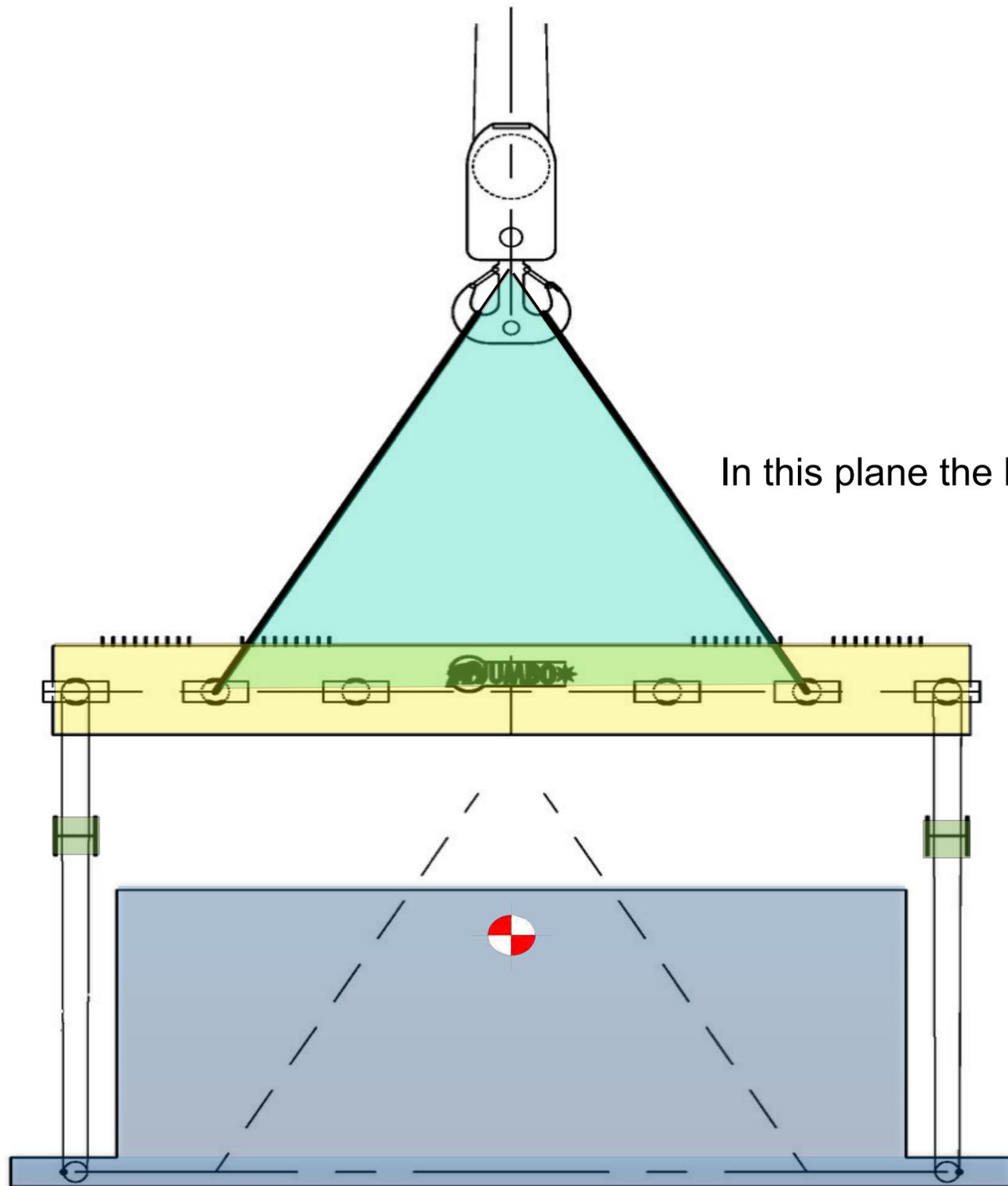
In this plane the load **IS** stable
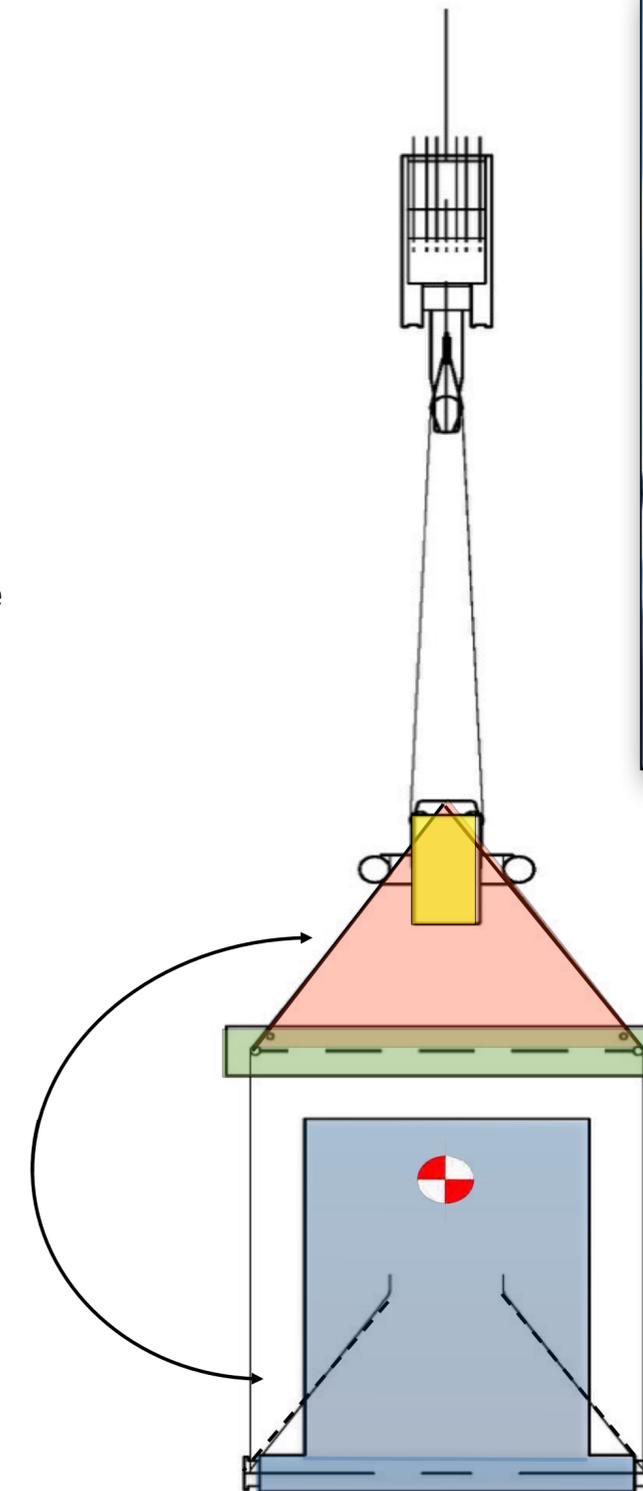
In this plane the load **IS NOT** stable

1. We will demonstrate this with a small model

The Stability of the load to be lifted using a Liftbeam

Large stability range **Small Stability range**

1. Only a **small force** is needed to disturb the stability of a load when the **stability range is small.**
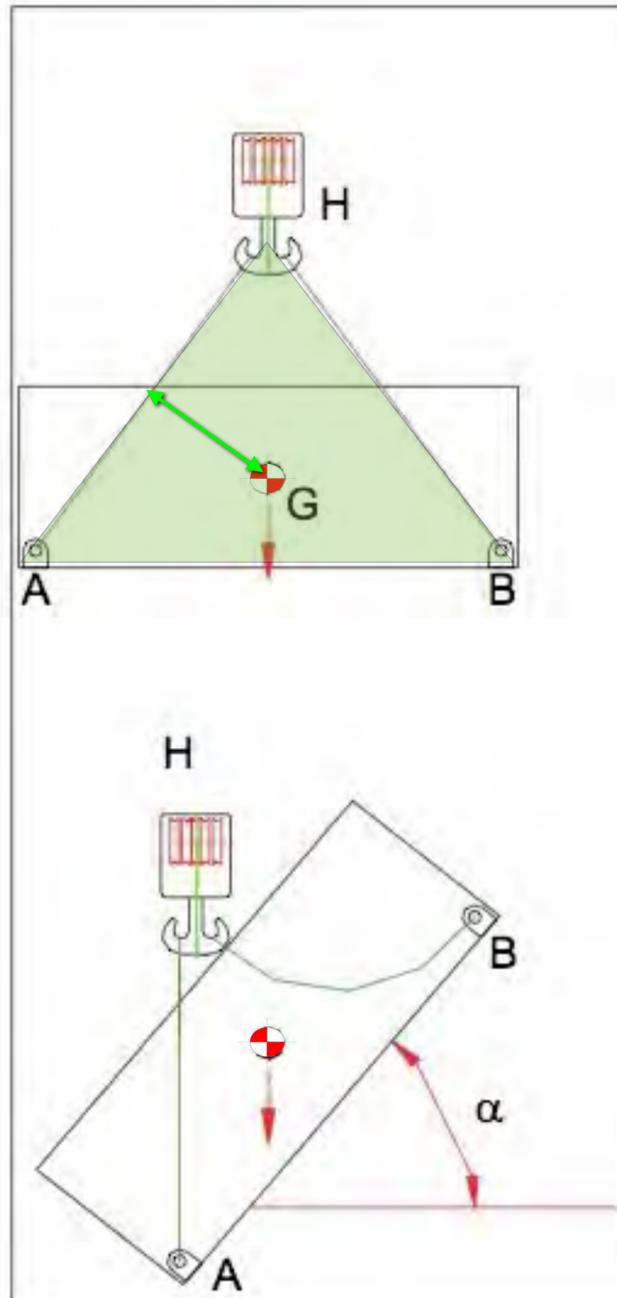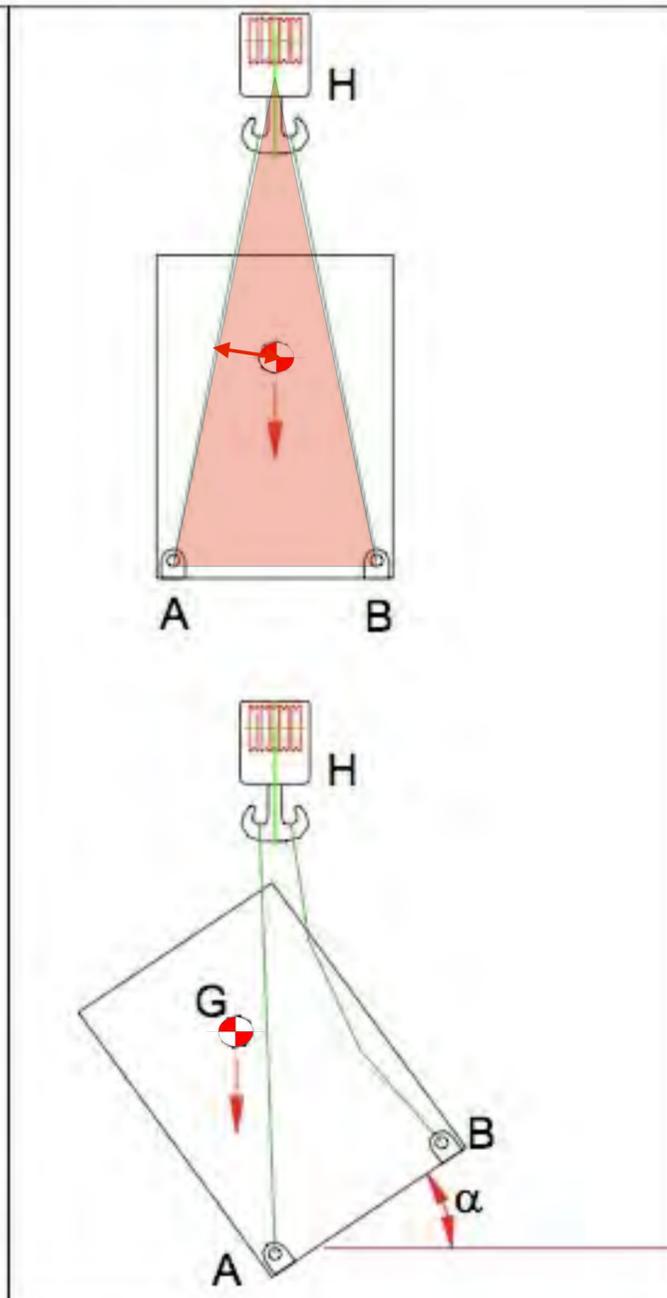
The Stability of the load to be lifted using a Liftbeam

Dangerous type of lift beams, when lifting a load from bottom lift points

Stability of the load is never at risk when lifting from lift points above the CoG

Lift slings above lift beams are of sufficient length to make a safe lift, when lifting a load from bottom lift points

How to prepare a Loading/Unloading Operation (Lo-Lo) (Lift Plan)

1. **To prepare a loading/unloading plan, following information is needed:**

   - **Length x Width x Height** of Cargo (over all). Even better an Autocad drawing

   - **Weight and CoG** location of the cargo in relation to the position of the lifting points
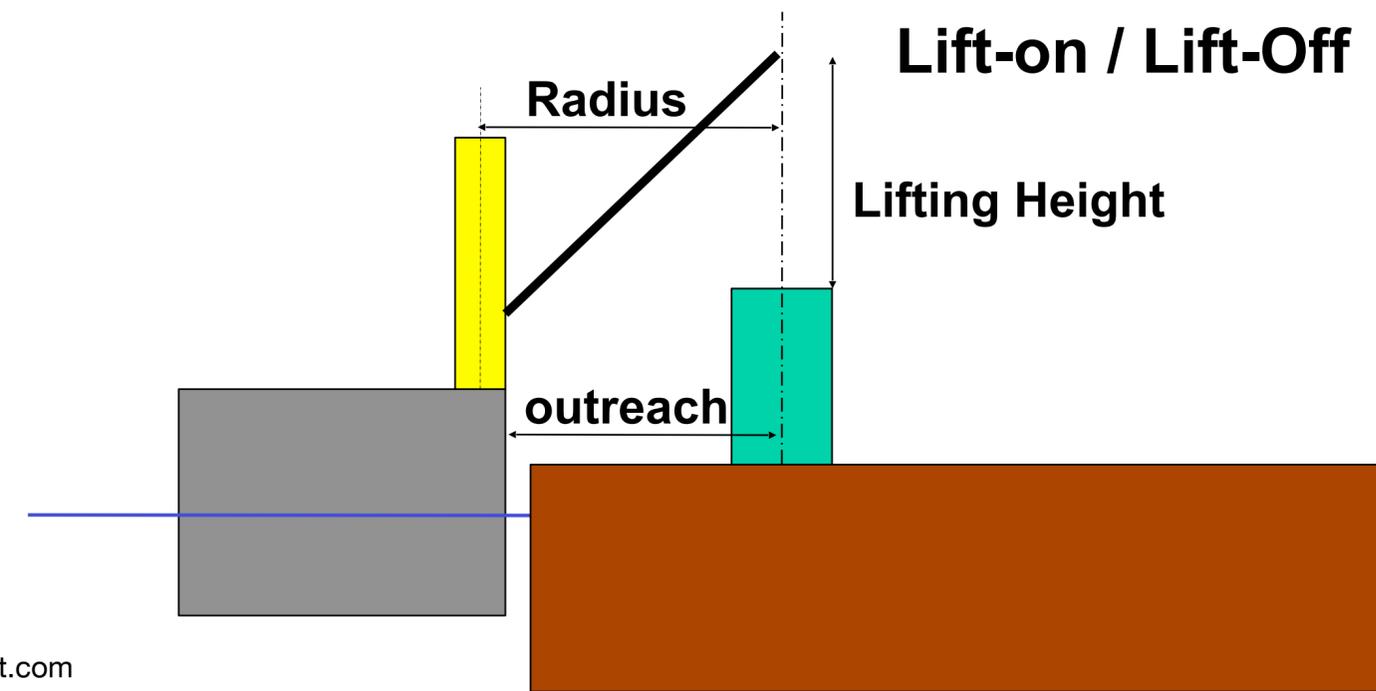
2. **In addition, details on:**

   - **Lifting points** and **Transport saddles**

   - **Required "outreach"**, this is the **distance** between the ships hull over the side of lifting, to the **Center of Lifting points** measured perpendicular

   - At what **radius** can we lift the cargo and at what radius must it be placed **at unloading location**.

   - **Infra structure** of the port. Do we berth PS or SB side along the quay?

   - **Loading** and **unloading place** and trailer details on which the cargo is transported alongside

   - **Quay height / Quay Strength / Tidal difference**

   - **Water depths**

   - Location of Port (**Swell or No Swell**)

3. **On basis of this information a detailed lift plan must be prepared.** Taking into account the following points:

   - Is there **sufficient lifting height** during lifting and lowering? Adjust the grommets or slings lengths with shackle(s) if needed

   - Do we stay **clear from crane jib** and slings or grommets? Draw this on scale and check the **most critical situations.**

   - Make a choice for the **correct SWL (or WLL)** of the lifting grommets, shackles and lifting- or spreader beams on basis of the **expected forces in the lift points**


Lift-on / Lift-Off

Radius

Lifting Height

outreach

4. Pay Attention:

- The **max. lift capacity** of the crane is defined at a certain radius (check the load chart)

- The max. available so-called **"anti heeling"** defines the max. **"Outreach"**

- The ship is kept levelled by **pumping ballast** water from **SB** to **PS** anti heeling tanks and vice versa

- Lifting is done up to a **max. heel of approx. 2º**, and then stopped, until the vessel is levelled again by **pumping**

- **Define the max. length of grommets** by taking into account the max. **available** lifting height

- **Check the available lifting height and jib clearance in different critical situations**

- **Prepare a detailed Stow plan, by drawing all cargo as box shapes and fit them in the hold and on deck**

Lift-on / Lift-Off

BOW

Outreach

Radius

STERN

Radius

Lifting Height

Anti heeling tanks

Clearance between load and jib

Outreach

PS   SB

Double Bottom tanks

How to lift a Heavy Load on board (animation)

Stability of a Heavy Lift Vessel must be calculated:

- before loading
- during sailing
- before unloading

A heavy Lift Ship needs to be stable during loading, sailing as well as unloading in Port

www.heavyliftspecialist.com
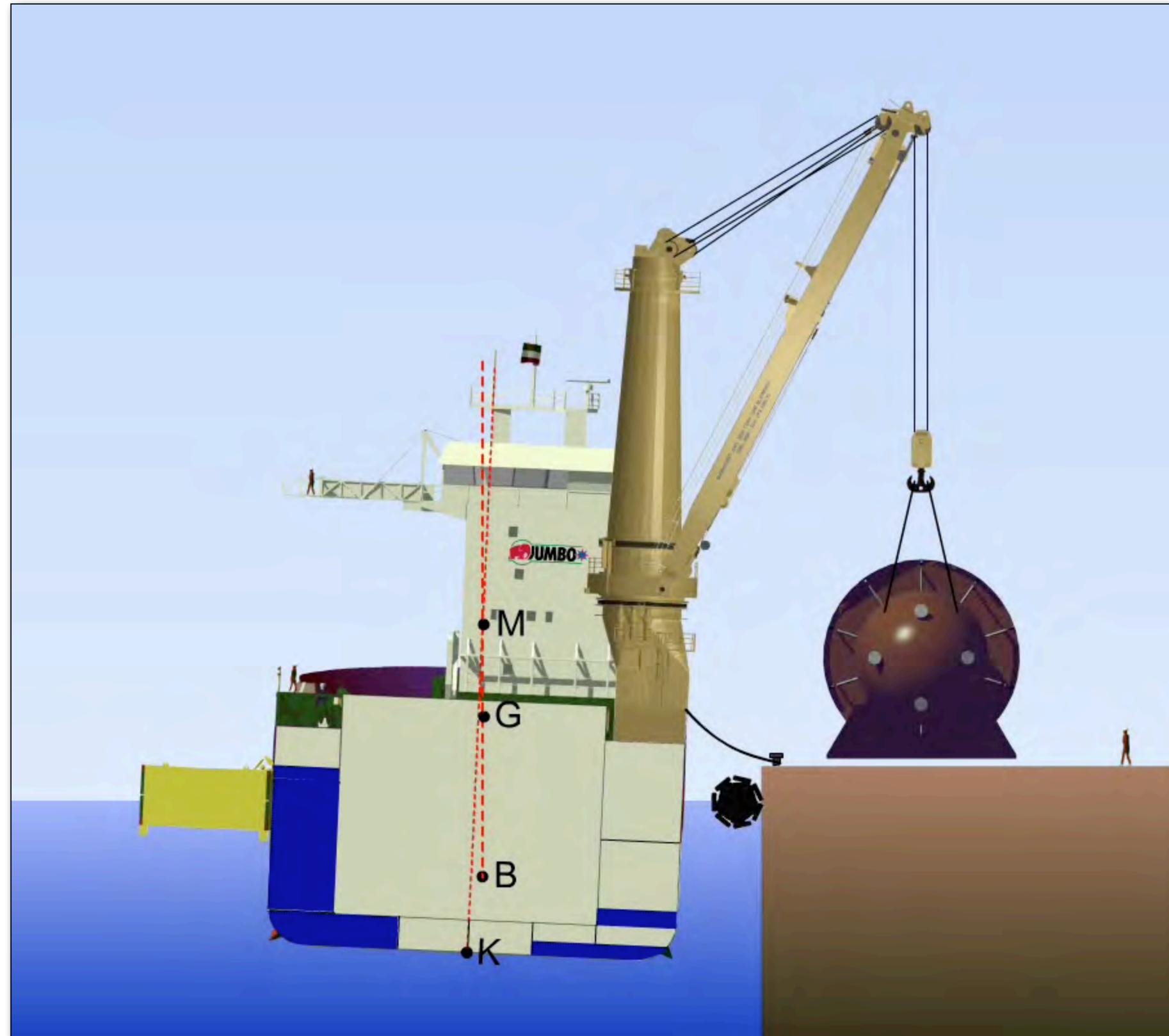
How to load a Heavy Lift Vessel correctly

When lifting a Load on board:

1. Bring Hook of Crane **above CoG** of Load
2. Connect Rigging and **tighten** slings
3. While doing so **keep vessel levelled** by ballasting
4. Keep **lifting tackle vertical** in all directions
5. Have **sufficient slack in mooring lines** so that vessel can adjust itself under the load
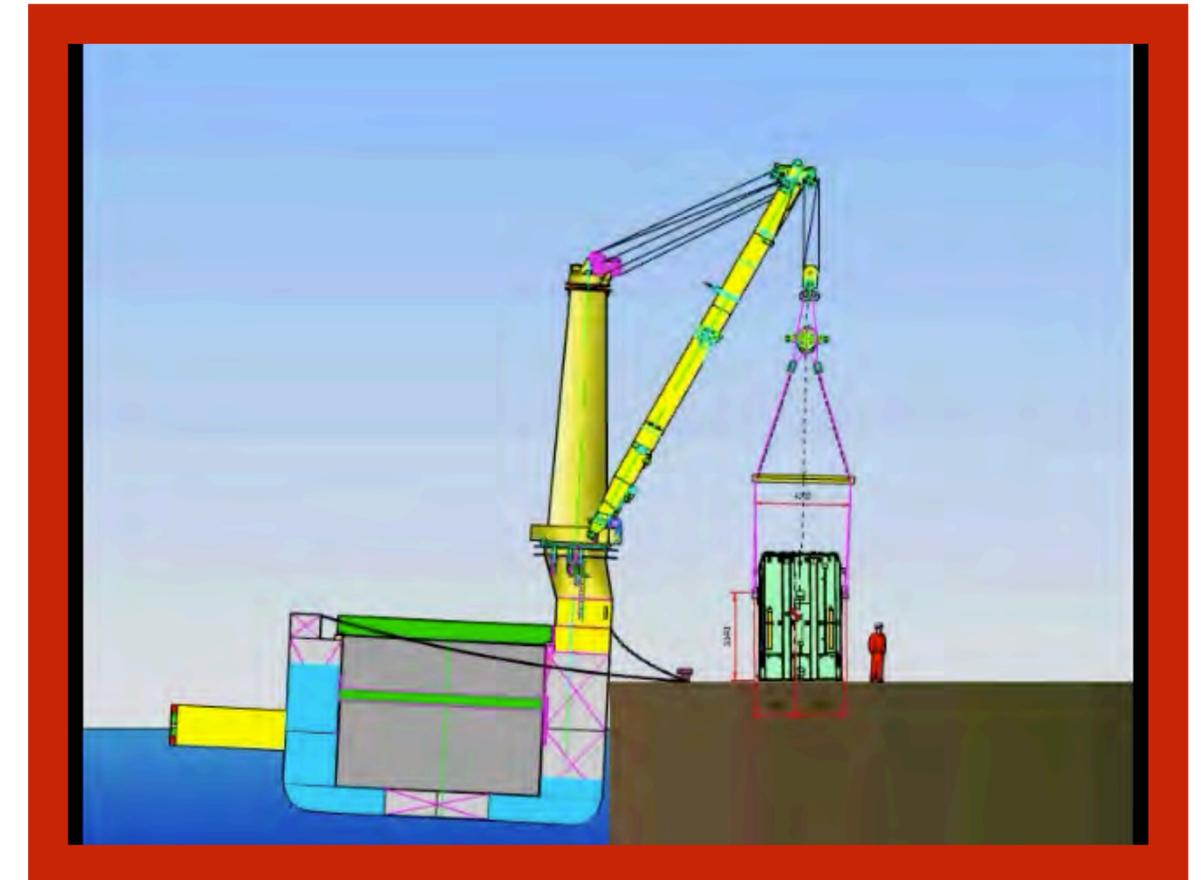
CORRECT

What went wrong here?

1. Bring Hook of Crane above CoG of Load
2. Connect Rigging and tighten slings
3. When they started lifting the load, they **did not keep the tackle in vertical position**
4. They **did not** properly ballast the vessel
5. **Not sufficient slack** in mooring lines

WRONG

Public Seminar on 2, 3 and 4 Oct. 2019, Rotterdam
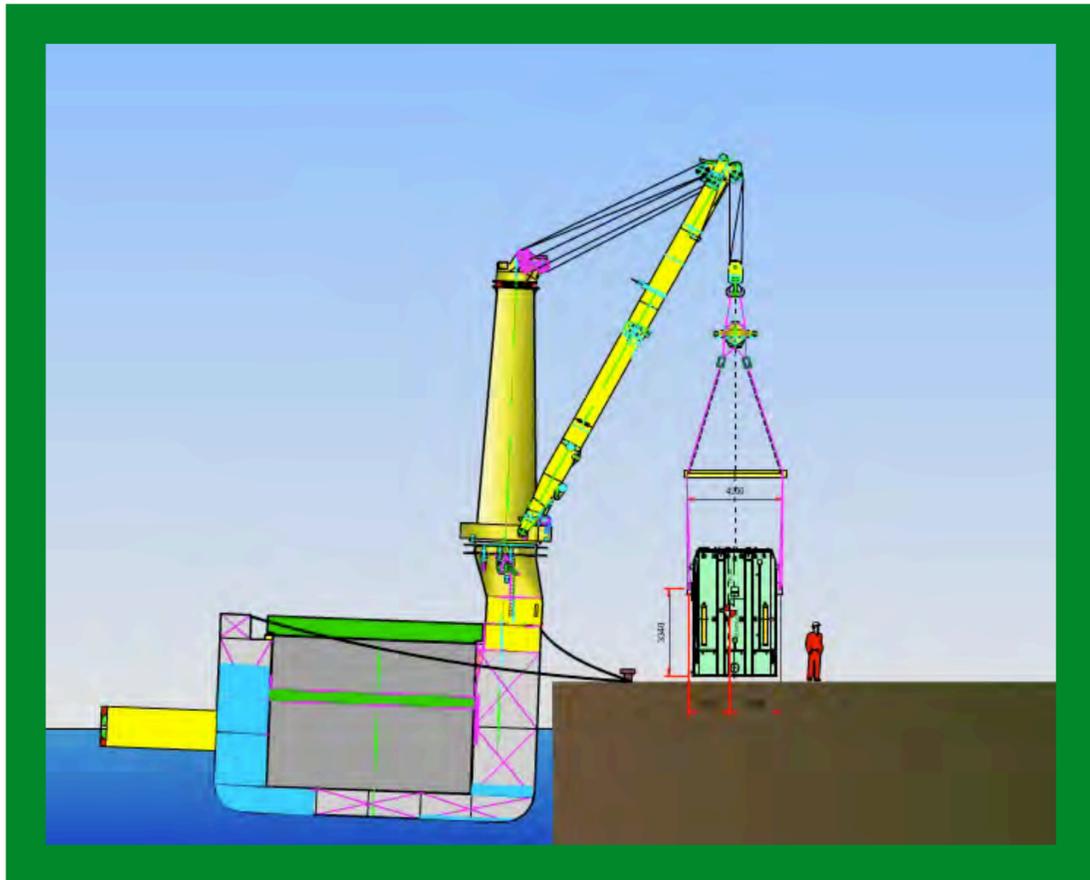
The program

Day 1

- General Knowledge on transport & lifting equipment
- Mass, Forces, Centre of Gravity
- Heavy Transport with Hydraulic Platform trailers
- Lifting loads with one, two or more cranes

Day 2

- Maintenance & Inspection of equipment
- Skidding & Jacking Techniques
- Set-up of a Project Planning
- Preparation of a Cost Estimate and conclude a deal
- Load-outs of extreme heavy loads
- Safety & Risk analysis
- Accidents & How to avoid them
- Heavy Lift Shipping

Day 3 (additional day)

- Wind Turbines: Onshore & Offshore Installation
- Offshore Lifting and Installation Technique

Heavy Lift & Transport

Safety & Accidents

Offshore Installations

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Thank you for your attention

ANY QUESTIONS?

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