ICSA N005

International Crane Stakeholders Assembly

- Guidance -

"Working with Land-based Mobile Cranes on Floating Vessels"

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Legal Note: *This publication is only for guidance and gives an overview regarding the assessment of risks related to lifts where a load is lifted with a land-based mobile crane on a vessel. This document is an industry best practice document that is based on the consensus of member organizations of ICSA. It is not a regulation or standard and should not be treated as such. It neither claims to cover all aspect of the matter, nor does it reflect all legal aspects in detail. It is not meant to, and cannot, replace one's knowledge of the pertaining directives, laws and regulations. Furthermore, the specific characteristics of the individual products and the various possible applications have to be taken into account. This is why, apart from the assessments and procedures addressed in this guide, many other scenarios may apply.*

CONTENTS

1. INTRODUCTION

International Mobile Crane Manufacturers and Users organized as ICSA (International Crane Stakeholder Assembly) are aware of the use of land-based mobile cranes (both wheeled and tracked, with lattice or telescopic boom) on floating vessels such as barges. This type of use presents unique hazards that can increase risk, requiring additional considerations to be reviewed prior to commencing operations to ensure the crane and vessel are used as intended. It is recommended that manufacturer or qualified person approval is obtained for this type of operation.

Proper planning will help avoid negative influences that may affect the crane and/or vessel. Conditions such as excessive listing of the vessel, shifting of the load and/or crane, vessel movement, material storage, vessel layout, etc. can create unique hazards, all of which could result in a dangerous situation. Hence, it is recommended the lift planning flowchart found in Annex D be adopted as part of a pre-planning activity.

Since various types of vessels can be used to support crane operations, each application should be reviewed independently for any special considerations that may require additional planning or risk mitigation.

2. SCOPE

This document provides guidance for the use of land-based mobile cranes as defined in standards such as EN13000, AS 1418.5, ASME B30.5, and CSA-Z150, and used on floating vessels (e.g., vessels, pontoons). It is meant to provide guidance for additional considerations, in the assessment of risks and contains information related to the use of land-based mobile cranes on floating vessels in waterways that are protected from wave action.

The scope potentially covers a wide range of crane types and configurations as well as vessel types and sizes, hence in the use of this document it is necessary to make a distinction in the assessment of the different combinations of cranes and vessels that will be used.

This assessment should take the following characteristics of the ‘crane and vessel combination into account:

- The size of the crane, the crane configuration, and the loads to be handled in relation to the size of the vessel
- The sensitivity of the crane configuration to vessel movements or inclinations, when using longer boom systems with luffing jib and/or suspended counterweight.

- The tendency of the ‘crane and vessel combination’ to respond to load displacement and outside environmental influences such as wind and water movement
- The impact of stored materials, ancillary plant and equipment, and fixed plant and equipment on list and trim values during operations

This document does not cover the following topics:

- Land-based mobile crane operation on offshore vessels (also known as sea-going vessels)
- Land-based mobile crane operation on vessels in unprotected areas (operation area as defined by local maritime safety authorities) subject to wave action
- Land-based mobile crane lifting operations on jack up vessels or other non-floating vessels
- Land-based mobile crane load ratings when used on vessels

This document is not intended to, nor should it be used to replace any documents or guidance provided by the crane or vessel manufacturer nor any local or government regulations or codes. All laws, codes and regulations are to be followed.

3. DEFINITIONS

admissible deck loadings - the amount of weight per unit of area that can safely be carried by the vessel deck

anemometer - a device used for measuring wind speed.

anti-skid material - a surface applied to increase the coefficient of friction

ballast –material that is placed in the hold or on the deck of a vessel to provide stability or influence the trim of the vessel.

ballast plan - a calculation of the quantity and location of masses within a vessel in order to provide stability

barge - a shoal-draft flat-bottomed vessel built mainly for river and canal transport of bulk goods

bending strength - the resistance of a structure against bending force *bilge* - the part of a hull that would rest on the ground if the vessel were unsupported by water

blocking - blocks or brackets that are welded or bolted onto a vessel deck to prevent cargo from moving sideways

bollard - a sturdy, short, vertical post; the term usually refers to a post on a vessel or quay used principally for mooring vessels

breaking load - the load at which a beam or structure will fail

bulkhead - an upright wall within the hull of a vessel

buoyancy (Annex A) - an upward force exerted by a fluid that opposes the weight of a partially or fully immersed object

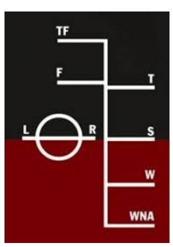
capstan - a vertical-axled rotating machine developed for use on vessels to multiply the pulling force of seamen when hauling ropes and cables

center of buoyancy (Annex A.4.) - the centroid of the immersed part of a vessel

center of gravity (CoG) (Annex A.3.) - a point from which the weight of a body or system may be considered to act

chock - a fitting with a gap at the top through which a rope or line is run

class approval - approval for a certain load to be on/in the vessel, as mentioned in the International Load Line Certificate which is part of the vessel's Classification Certificate. The maximum allowed load is displayed as a load line mark on the side of the vessel.



cleat - a T-shaped piece of metal or wood, especially on a vessel to which ropes are attached

clench plate - a steel plate welded to the vessel's structure in such a way that it locks in a part of a structure or load

crane and vessel combination - the combination of a ballasted and floating vessel with a crane placed thereon *cross-section* - a surface or shape exposed by making a straight cut through something at a right angle to an axis

deadweight (Annex A.2.) - a measure of a vessel's weight carrying capacity, not including the empty weight of the vessel.

deck loading - the forces exerted on a vessel's deck by equipment, cargo or structure placed upon it

displacement (Annex A.2.) - a vessel's weight based on the amount of water its hull displaces at varying loads

draft adjustment - the adjustment of the water depth on which a vessel floats by ballasting

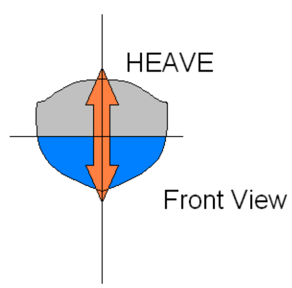
dynamic behavior - the characteristics of vessel movements based on the change of loadings, waves, acceleration forces, etc.

free fluid movement - an amount of fluid that can move freely in a space within a floating vessel

free surface effect - when the vessel holds are partially filled, the motion of the liquid (due to the vessel's rolling and pitching motions) would reduce the stability of the vessel.

GM value - in a vessel, the distance called "GM" or "metacentric height", being the distance between two points: "G" the center of gravity of the vessel and "M", which is a point called the metacentre (Annex A.5.)

heave - The linear vertical (up/down) motion; excessive downward heave can swamp a vessel.



heel - Be tilted temporarily by the pressure of wind or by an uneven distribution of weight on board.

hold - part of a vessel below deck where cargo is stored *jack up barge* - a mobile platform that consists of a buoyant hull fitted with a number of movable legs, capable of raising its hull over the surface of the sea

labile - apt or likely to change (synonym: unstable)

land-based mobile crane – a crane designed primarily for operation on land and as defined in standards such as EN13000, AS 1418.5, ASME B30.5, and CSA-Z150

lashing - a mechanical strap used to tie something down or last it to something

lateral force - forces to the side; of or pertaining to the side

lift on/lift off - load or discharge a certain weight from or onto a vessel by means of a lifting device

lightweight (Annex A.2) - the weight of the vessel excluding cargo, fuel, water, ballast, stores, passengers, crew

list - a vessel leaning to one side or the other due to changing loading condition of vessel or ‘crane and vessel combination’

load amplification factor (LAF) - A factor by which the expected hook load of the crane is multiplied in order to allow for unknown forces that might be introduced by vessel inclination and dynamic behaviour of the crane and vessel combination. Some classification societies refer to Dynamic Amplification Factor (DAF) or Vertical Amplification Factor (VAF)

load moment - the product of load x working radius at which it is suspended

load sensor - a force transducer which converts a force such as tension, compression or pressure into an electrical signal that can be measured and displayed to the operators in units (e.g., t, ton, kN, lbs)

load spreader - a device used for distributing loading over a larger area, such as the deck of a vessel

marine survey – an inspection of a vessel undertaken by a qualified person which may be undertaken in or out of water dependent on survey type

metacentre - a midway point between a vessel’s center of buoyancy when upright and its center of buoyancy when tilted *metacentric height (Annex A.5.)* - the distance between the center of gravity of a vessel and its metacentre. The metacentric height determines the vessel's ability to get back on an even keel.

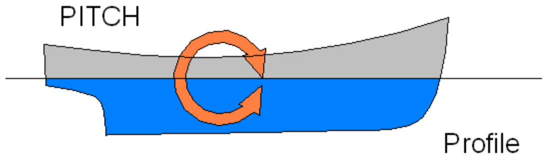
mooring (Annex B) - to tie up a vessel at a designated place

mooring furniture - all objects designed for the purpose of mooring a vessel

mooring winch - a winch designed for the purpose of mooring a vessel

non-floating vessel - situation when a vessel is not free-floating but is resting on support legs (jack up) or grounded on the seabed or at the shore

operating radius - the working radius of a crane or lifting appliance *pitch* - the swaying or oscillation of a vessel around a horizontal axis perpendicular to the direction of motion



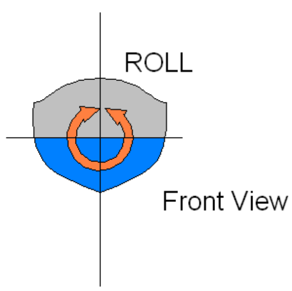
pontoon – a flat bottomed lighter or barge used as a work platform for loading or unloading vessels or transporting bulky cargo

pre-ballasting - adjusting the trim of a vessel prior to an operation to a desired state by adding ballast

quay - a stone or concrete structure on navigable water used for loading and unloading vessels

righting arm GZ (Annex A) - the horizontal distance between the lines of buoyancy and gravity; a notional lever through which the force of buoyancy acts

roll - the tilting rotation of a vessel about is longitudinal/X (front-back or bow-stern) axis



roll-on/roll-off (Ro-Ro) – load or discharge a certain weight from or onto a vessel using wheels or tracks (e.g., a mobile crane on tracks or a load on a wheeled transport vehicle)

sea fastening - a structure or installation devised to securely tighten cargo onto a vessel so it will not shift as a result of the vessel movement at sea

significant wave height - the average wave height, from trough to crest, of the highest one-third of the waves. It means the average of heights of 10 per cent of the total number of waves having the greater heights measured between wave trough and wave crest, observed over a short period.

spud - a shaft that is usually made of steel used to anchor or moor a barge to a particular area

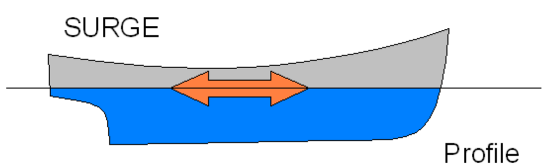
spudwell - the vertical sleeve for a spud that attaches to the side of a sectional barge, usually connecting to the perimeter of a sectional barge using a lock system

stability - the property of a body that causes it when disturbed from a condition of equilibrium or steady motion to develop forces or moments that restore the original condition.

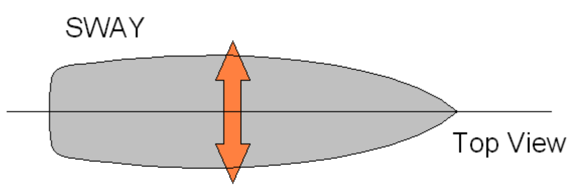
stability booklet (manual) - A document which contains information to safely operate the vessel and enable the master to operate the vessel in compliance with the stability requirements applicable to the vessel.

static behavior - lacking in movement, action, or change, especially concerned with bodies at rest or forces in equilibrium

surge - the linear longitudinal (front/back to bow/stern) motion imparted by maritime conditions



sway - the linear transverse (side-to-side or port-starboard) motion



swell - a long series of ocean waves, generally produced by wind and lasting after the wind has ceased

tension monitoring device - a device monitoring the tension in a wire, rope, or mooring line

tidal movement - the rise and fall of sea levels caused by the combined effects of the gravitational forces exerted by the moon, the sun, and the rotation of the earth *tidal variation* - tides vary on timescales ranging from hours to years due to a number of factors which determine the lunitidal interval

tie-down - a fastener used to hold down cargo or equipment during transport

trim - to modify the angle relative to the water by shifting cargo or ballast; to adjust for sailing; to assume, or cause to assume, a certain position or trim in the water

trim angle - the inclination angle from bow to stern to which a vessel is trimmed by ballasting or loading

trusses - framework of beams in the interior of a vessel's hull which collectively ensure a rigid hull

valve actuators - the mechanism for opening and closing a valve

vessel - any craft designed for transportation on water

vessel freeboard - the distance from the waterline to the upper deck level measured at the lowest point of sheer where water

vessel heel - the angle of inclination about longitudinal axis of the vessel

vessel list - see vessel heel

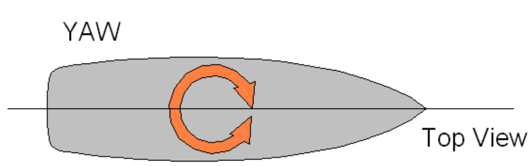
vessel trim - angle of inclination about transverse axis of the vessel

wave action - the complex of forces exerted on a vessel as a result of wave movements

winch - a mechanical device used to pull in (wind up) or let out (wind out) or otherwise adjust the tension of a rope or cable

winch brake - brake system fitted on a winch to control the unrolling movement

yaw - a vessel's motion rotating about the vertical axis so the bow yaws from side to side; a characteristic of unsteadiness



4. THE VESSEL

“Vessels” and “crane and vessel combinations” may show a number of movements separately or in combination as heave, heel, pitch, roll, surge, sway and yaw (see definitions). Such movements are the result of wave action, wind action and, ballast configuration of the vessel. The actual movements observed, and their amount depend largely on the actual condition of the vessel, from free floating (during transport), anchoring, mooring (see 5.4) to beaching the vessel (see 5.3.3).

The utilization of a land-based mobile crane on a vessel such as a barge can change the technical requirements and conditions required for this type of crane’s design, manufacture, and use. In addition, it may change the equipment type to a floating crane and require further approvals and/or compliance with regards to standards, regulations, and insurance details. Therefore, prior to using a land-based mobile crane in a vessel application, a thorough review of the applicable regulations, standards and class rules should be performed, see section 6.

The static and dynamic behavior and more specifically the stability of the ‘crane and vessel combination’ consisting of the floating body, crane and intended loadings is most important for the safe operation and transport or transit including installing the crane on the vessel. It is important to analyse and approve the ‘crane and vessel combination’ as an individual case by persons with adequate knowledge and experience in naval architecture or marine engineering. This analysis should take into account the forces and loadings that will arise during lifting operations, but also during transport and installation of the crane on the vessel and as a result of environmental circumstances, such as wind, tide and water flow forces.

Before loading the crane, a conditional inspection of the vessel should be conducted. This quantifies the vessel condition before the crane is installed and lifting commences. Dependent on class rules and local regulations marine surveys are completed at specific intervals and may be required for insurance purposes.

It is important to consider that vessel classification differs worldwide, and class rules and local regulations needs to be understood in the production of structural and stability books such that the class society rules and regulations can dictate specific operational parameters for crane operations on vessels.

Vessels will have a class approved stability booklet produced as part of the initial marine engineering design during ship building which provides the limitations on the vessel loading. Organizations need to be mindful and consult with a specialist such as a Naval Architect, Marine Engineer, or local regulators for requirements, where crane operations on vessels need to be confirmed to be within the original class approved books. This consultation may determine if additional class approval is required for the operations regardless of being within the original structural or stability class approvals.

4.1. Vessel Stability

Stability is the ability of the ‘crane and vessel combination’ to sustain a changing loading condition without excessive heeling or turning over and its ability to get back on an even keel or keep the floating complex stable on a certain inclination.

A detailed explanation for understanding the stability of a vessel is given in Annex A.

It is necessary for the vessel to be of adequate size (width and length) and capacity to support both the weight of the crane and suspended load. The maximum allowed vessel list and/or trim during crane operation should be lesser of 5 degrees or the maximum allowed by the crane manufacturer or qualified person. It is common that the vessel and crane combination is limited by the crane list values from the stability assessment rather than the combined stability of the crane and vessel. In addition, several situations that may require special attention with respect to stability of the vessel include the following:

4.1.1. Lifting a load onto the vessel

Lifting a load onto a floating vessel (e.g., from a quay) will change the height and horizontal position of the vessel’s center of gravity at the same time (see section 7.1 and Annex A) resulting in vessel heel and/or trim if not compensated. Any additional horizontal movement of the load will further change the CoG accordingly, which should also be considered.

4.1.2. Lifting a load from the vessel

Lifting a load from a vessel will change the displacement of the vessel with the effect of the vessel lifting up and possibly heeling. These effects need to be considered. Moreover, this change may restrict the ability to place the load back to the previous position. See section 7.1 and Annex A for further considerations.

4.1.3. Sudden release of the load

A potential sudden release of a load should be considered to avoid an extraordinary heeling to the backside and in consequence a potential falling back of the boom system. Sudden release of the load may be the consequence of e.g., lifting gear breaking or slipping.

4.2. Vessel freeboard

The freeboard of the vessel utilized will vary in relation to the loading of the vessel and the position of the load lifted. Typically, a vessel has a large righting moment as a result of its cross-section. However, this cross-section shape also means that when the freeboard is lost, the righting moment is dramatically reduced instantly. Hence an allowance for a freeboard safety margin should be made.

When engineering lifts using a land-based crane on a vessel, care should be taken to consider the most unfavourable crane position in relation to heel and list of the vessel, and in that position, the remaining freeboard should be determined. The minimum allowable freeboard is recommended to be between15% to 25% (depends on which standard to adopt) of the vessel moulded depth with a minimum of 0.30 – 0.40 m which increases with vessel length overall. Minimum freeboard guidance should be sought through local and international guidance and class rules.

4.3. Moving a crane on and off a vessel

When conducting crane work with a land-based crane on a vessel that requires the crane to be transported on and off the vessel, a comprehensive lift plan should also include a method statement and calculated steps to load and off-load the crane. It is recommended to ascend or descend the floating vessel along its longitudinal center line without a load on the hook with as low center of gravity height as possible.

A crane can be loaded by its own propulsion using its wheels or tracks (Ro-Ro) or can be lifted on and off by means of a second crane.

When doing this, the following points should be considered:

4.3.1. Roll-on/Roll-off (Ro-Ro)

For the execution of Ro-Ro operations, a load-in/out plan to address ballast and Ro-Ro ramp calculations, quay height assessment, ballasting tidal marks and mooring arrangements may be necessary. The possible increased inclination of the floating unit during Ro-Ro procedure provisions against sliding should be taken, all deck surfaces should be above water and the entire bottom of the floating unit should be submerged. Generally, a pre-set ballast with Ro-Ro is a simpler operation however a live ballast can generally accommodate a larger crane mass. It is preferred to Ro-Ro cranes longitudinal to the vessel with less trim rather than broadside with list where the vessel is longer than wider. Considerations to the structural loading including point loading from stiff tracks and Ro-Ro ramps will need to be considered in the vessel structural assessment. The use of fenders, moorings, and degrees of freedom of the different elements need to be considered so that no adverse structural or stability issues occur.

4.3.2. Lift-on/Lift-off

A crane can be lifted on and off by means of a second crane. In case of lifting the crane on board, an assessment of the quay strength at the lift location should be included. Often larger crawler cranes are lifted on to vessels in smaller sub-assemblies. The location of the sub-assemblies and their structural impact on the strength of the vessel or the quay need to be considered.

4.3.3. Beaching the Vessel

Cranes are not always driven onto a floating vessel. There are cases that a crane drives onto a beached vessel via ramps and then waits for the next high tide before re-entering the water. In these cases, a survey of the grounding area should be conducted to make sure the resting area of the vessel is free of stones, debris etc. A beached vessel can have higher structural loads on external vessel plates and cause concentrated load paths through internal frames and bulkheads.

4.3.4. Tidal movement

In the environment addressed in this guideline (ports and protected inland water), tidal influences might occur that should not be neglected, in particular, during loading and off-loading operations from a vessel. Such loading/un-loading may require a special time slot and as it lasts a certain period of time, this needs to be observed as well.

A check should be done to determine if tidal movements do take place at the location of the vessel operation and if so, take the effects of the tidal movement into account when producing a load out plan, designing mooring arrangements or connecting walkways to the vessel.

4.4. Mooring of a vessel

4.4.1. General

During lifting operations, it is recommended to secure the floating vessel. A vessel can be secured to any variety of specially constructed areas such as piers and quays. Alternatively, a vessel may be secured by using anchoring arrangements (e.g., spuds and spudwells), or by a combination of both. A detailed explanation for understanding mooring of a vessel is given in Annex B.

4.4.2. During loading/off-loading and lifting operations

Loading/off-loading and lifting will normally be considered weather restricted operations. Limiting weather conditions for the loading/off-loading and lifting operation should be defined and take into account:

- the forecast reliability for the area
- the tidal movements in the area
- the duration of the operation including a suitable contingency period for the exposure of the worksite
- the time required for any operations before or after the loading or lifting operation including vessel movements and moorings, ballasting, system testing, final positioning, and initial sea fastening
- currents during and following the operation, if applicable
- the wind area of the cargo and the vessel

Moorings for the loading or lifting operations should be designed for weather conditions as defined above.

Mooring lines, wires, shackles, mooring furniture including bollards, chocks, cleats, clench plates, winch to deck anchoring arrangements, spuds, spudwells and other steel components should be designed to the certified safe working load where applicable, or to give a factor of safety of not less than 3.0 on the breaking load for moorings. Where a safe working load cannot be determined (e.g., for bollards, chocks etc.), then its adequacy should be documented by design calculations offset against the maximum expected loads.

Mooring winches should be adequately designed, with structural capacity not less than 2.2 times the expected loading. If the mooring load is to be held on the winch brake, then the brake capacity, with the outer wrap on the drum, should exceed the mooring design load by a minimum factor of 1.3. Where mooring winches are used, tension monitoring devices/meters should be used to prevent overloading.

In cases where existing yard mooring equipment (i.e., already available at the yard) is being used, wires and winches may have a breaking load greater than the vessel equipment to which they are connected. When using anchors, it is good practice to have anchors pulling out before anchor lines break or mechanical failure occurs. Great care is needed in such situations, and the wire loadings should be controlled and monitored.

When designing mooring arrangements for vessels during loading/off-loading operations, an allowance should be made for draft adjustment of the vessel as a result of increasing or decreasing loading of the vessel during the operation. This is primarily a point of attention when short mooring lines between the quay and vessel are utilized.

4.5. Ballasting of a vessel

All calculations and engineering standards used in this document start with the assumption the vessel used in the engineered operation is “dry’’, meaning the absence of bilge water or free-floating fluids in holds, tanks or bilges. Free fluid movement within the holds or tanks will negatively impact the stability of a floating vessel.

Hence, it is important to check the vessel condition prior to commencing any operation on deck to establish the dry or filled state of the tanks, holds and bilges to ascertain the starting situation of any operation.

Planning consideration should be given to the source of the water (freshwater vs saltwater ballasting), and environmental policy for the discharge of the ballast water during operation. The ballast system should be checked to ensure that the system is operative, is still the same as considered during planning (often changes over time) and that the operator is familiar with the system.

4.5.1. Pre-ballasting

When loading of a vessel will lead to a heel or trim angle, these effects can be reduced by pre-ballasting the vessel. This ballasting should be executed per an engineered ballasting plan, based on the vessels' as built drawings. Care should be taken that tanks used to hold the ballast water are completely filled, in order to avoid free surface effect. If pre-ballasting is incorporated, ballasting during lifting operations may not be necessary.

4.5.2. During lifting operations

In some cases, lifting of a load with a crane on a vessel can lead to unwanted heel or trim angles as a result of the load moment introduced to the system.

It is possible to use ballasting as a means to correct the unwanted heel or trim angles of the system, but this can only be done based on a step-by step engineered lifting procedure, in which the movements of the crane and the subsequent required ballasting are aligned with each other.

A correct timing of all interacting activities is essential as ballasting is a time-consuming activity in comparison with the operational speed of a land-based mobile crane. Therefore, during lift planning, consideration should be given to the operational movements that may impact the balance of the vessel (e.g., hoisting, slewing, booming up or down).

4.6. Crane stands on vessels

Prior to positioning a land-based mobile crane on a vessel, a check of the vessel's structural integrity should be performed. Generally, a calculation of the static loadings to the floating vessel from the crane including erection, assembly, lifting loads while in operation, or traveling with a load should be performed, i.e., a check for admissible deck loadings. These should also take into consideration deck loadings as a result of the placement of cargo or loads to be lifted on the vessel deck and ballast conditions.

4.6.1. Position of the crane stand

The position of the crane stand on the vessel deck is determined by a number of factors:

- the preferred position for the execution of the designed lifting operation
- the location of trusses and bulkheads in the vessel
- the stability requirements for the ‘crane and vessel combination’ (see section 7.1)

A decision on the most suitable position of the crane on the vessel should only be made after making an engineered lift plan that takes the above factors into consideration.

If the crane cannot be positioned centric on the vessel deck (preferred location), it is recommended to appropriately pre-ballast the floating vessel, compensating the eccentric position of the crane to keep additional vessel inclination to a minimum.

4.6.2. Strength of the vessel / crane stand

After establishing the crane position on the vessel (5.6.1), the positions and weights of other deck loadings and if necessary, calculating a ballast plan (5.5), a check on the bending strength, particularly in the pre-ballasted bow/stern lift cases, of the vessel in the most unfavourable load case, should be performed as part of the overall engineered lift plan. The structural strength should be calculated by a verified, acceptable engineering method.

Local and global structural assessments are necessary to assess areas such as local deck plate and frames as well as complete vessel bending strength.

4.6.3. Crane Load Distribution

The deck carrying capacity of a vessel may not be capable of supporting the bearing pressure directly from the crane. Therefore, it may be necessary to distribute the bearing pressure. Undesirable introduction of crane loadings to the vessel structure can be mitigated by load distribution between crane tracks or outriggers and the vessel deck. Care should be taken not to create an extra ‘sliding surface’ between the crane and the vessel deck when using steel load spreaders. The deck carrying capacity of most vessels varies between10 t/m^2 – 30 t/m^2. Track pressures are much higher, and distribution needs to travel into frames and bulk heads typically via longitudinal load spreaders. Load distribution is part of the ‘crane and vessel combination’, and the additional weight resulting from the use of load spreaders should be taken into account.

Photo showing an example of load spreading

4.7. Vessel arrangement

The vessel arrangement should be designed in such a way that:

- there is sufficient room for personnel to safely access and egress the crane and crane components as needed for the operation
- all crane components can be transported on board of the vessel, adjacent to the crane before lifting into position, or
- all necessary lifts of crane parts can be executed safely from the shore onto the vessel, whereby special attention should be given to the handover of taglines from shore to vessel
- the vessel area should allow space for consideration of laying boom down during heavy winds or storms
- the handling of crane parts can be executed without the need to lift over persons, personnel accommodations etc.

4.8. Special considerations for personnel

Working on a vessel requires all personnel to wear life jackets in addition to any other personal protective equipment otherwise needed for the execution of the work, i.e., safety harnesses for working at height. In view of ergonomics, self-inflating life vests are recommended in these situations.

The vessel should be equipped with a suitable side railing system and suitable gangways for the access and egress of personnel. Also, sufficient floating life-saving appliances should be readily available on deck.

As a safety precaution, emergency ladders designed to allow a man overboard to climb back on deck should be fitted to the outside of the vessel. These ladders should reach a minimum of 0.5 m below water level with a maximum spacing of 30 m. between them. The ladders are to be fitted on all sides open to the water.

Vessels are not designed as work area's; this implies that in certain places a lot of nautical equipment such as bollards, winches, capstans, hatches and valve actuators may be in the way of unhindered walking or passage. When designing the vessel arrangements and determining the crane position, the position of this equipment on deck should be identified, possible interaction with personnel considered and preventive safety measures designed and implemented as part of the engineering plan.

5. THE CRANE

As previously stated, prior to using a land-based mobile crane in a vessel application, it is important to do a thorough review of the applicable regulations and standards where the application will take place.

Crane manufacturers may have or create special capacity ratings for their cranes when being operated on floating vessels that permit the crane to operate at a greater incline than when operating on land.

A manufacturer's special ratings take into account the effects of greater list and trim angles that the crane may be subject to while being operated on a vessel. Crane list (see Figure 1) will induce lateral forces on the boom, superstructure, and slewing mechanism, while crane trim (see Figure 2) may increase the operating radius of the load in relation to the crane, therefore increasing the minimum attainable load radius. Increasing the minimum attainable load radius decreases the allowable capacity of the crane. These ratings may also limit the use of specific boom lengths, crane configurations and attachments when used on vessels.

Therefore, it is recommended to consult the crane manufacturer to obtain the capacity rating of the crane along with any configuration limits applicable to the lifting operations to be performed on the vessel. If a crane manufacturer's capacity ratings are unavailable, a qualified person should be consulted to provide appropriate capacity reductions and any changes to the allowable configurations of the land-based capacity charts. Local regulations are to be followed.

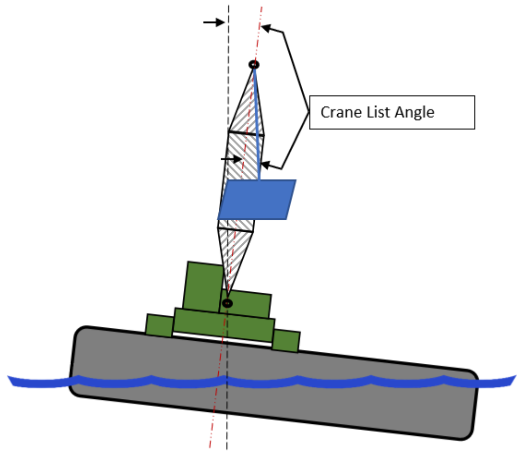


Figure 1 – Example of list causing an offset load

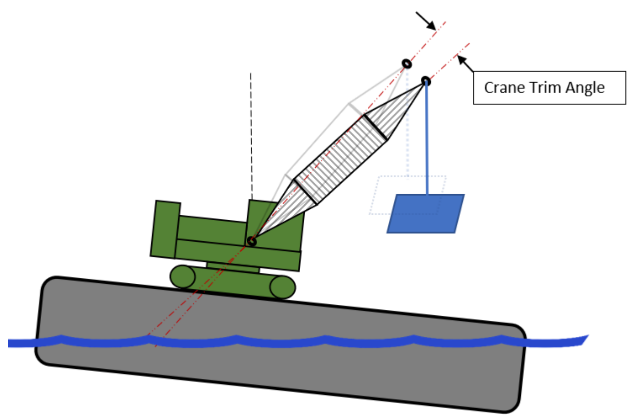


Figure 2 – Example of trim causing an increase in load radius

During planning, it is important to analyse the resultant of the list and trim changes to the vessel and the crane. A list/trim measuring and indication device to ensure the crane is not operated outside of the allowable inclinations as given on the special capacity chart should be visible to the operator.

Crane operation, i.e., lifting/lowering load, slewing, etc. impacts list and trim angles of the vessel. This also has an influence on the actual crane radius. If the inclination of the vessel increases, although the luffing gear is not operated, the crane radius increases and vice versa.

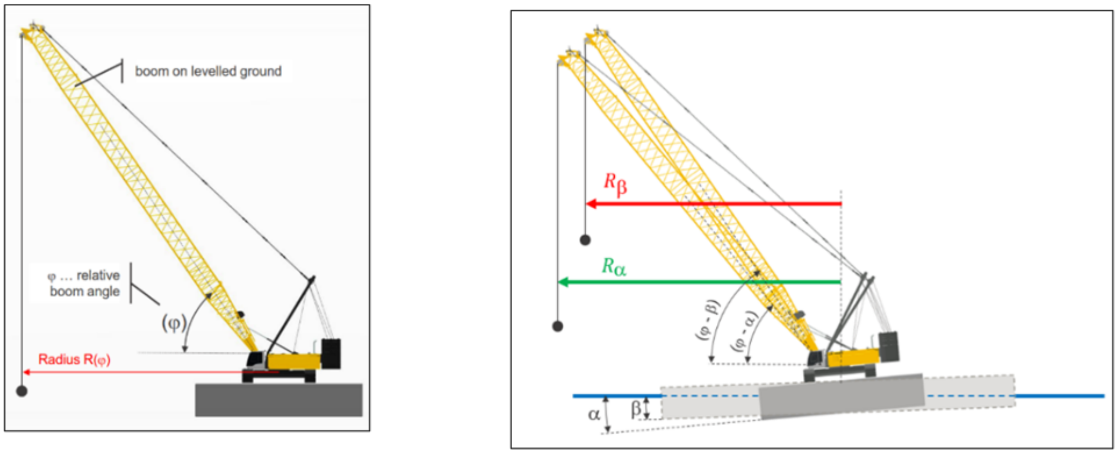


Figure 3 – Relation between radius and vessel heel

Special attention should be paid to the fact that slewing the crane can also influence the radius (see Figure 3). If, for example, the loaded crane slews from a position with the boom parallel to the longitudinal vessel side (more stable side) to the transverse side (less stable side), the crane radius increases. Figure 3 shows this effect in the sketch on the right side; compare the vessel loaded in longitudinal direction (vessel as light grey rectangle and resulting heel angle β) with the same load lifted over the transverse side (vessel as dark grey rectangle and resulting heel angle α).

This sometimes means that when working at a high rated capacity utilization, the limitation of the crane's rated capacity system could be activated during rotation. For cranes that have slew limiting available, there is also a risk that crane functions such as the slew motion, boom hoist or load hoist may cease due to a rated capacity system limitation. Indications from the rated capacity system should be monitored, and corrective actions taken when necessary.

All changes in inclination caused by the operated crane should be adjusted appropriately to minimize side and/or longitudinal pull that could result in a possible load pendulum during lift off (see Figure 4 below).

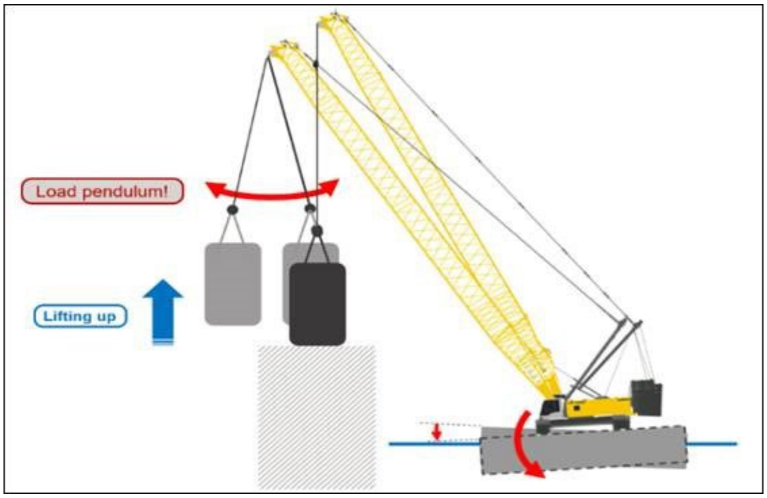


Figure 4 – Relation between load movements and vessel heel

Multiple cranes operating on one vessel at the same time can simultaneously impact vessel inclinations. The vessel becomes unpredictable for the single crane operator. When multiple cranes are on a vessel, only one crane should be operated at a time.

Multiple crane operation of two or more cranes on two or more different vessels (e.g., tandem lift from two different vessels) may result in unpredictable horizontal forces to the boom head and therefore it is not recommended unless special preparations are implemented.

5.1. Transport on a vessel

5.1.1. General

Dynamic loads can impact a crane during transportation. Mobile cranes should be secured during transportation of the vessel to prevent damage or cyclical loading of the crane. Methods of securing may include tie-downs between the crane chassis and the vessel, swing locks and placing the crane boom on the vessel deck or a boom cradle. Damage could occur if the crane is not properly secured to the vessel during transport.

Photo of a secured boom during transport

Note: Care should be taken when supporting booms. Damage to boom lacings and chords may occur.

To aid in the avoidance of negative influences on the crane, with a review of the inspection requirements and frequencies in the operator's manual, relevant industry standards and guidance should be conducted. Considerations should be given to increased corrosion and dynamic loading due to the presence of the crane in a maritime environment.

The transport of a crane while installed on a vessel requires special attention with respect to the environment in which the crane is to be transported. The sailing areas considered herein are the protected inland waterways and (sea) ports. The transport in protected water conditions typically does not affect the crane with dynamic loadings. Irregular significant waves and wave heights that might arise during transport (i.e., due to vessel traffic) should be checked in advance, and the stability of the 'crane and vessel combination' as a whole should be checked and approved.

The following should be considered:

- wind speed, significant wave heights specific for the selected transport route
- water depth, wind induced water level changes, high water cable and bridge overhead clearance, tidal variations
- currents (speed and direction)
- turning circle of long components in narrow areas

- dimensional limitations on the transport route through bridges, locks, etc.
- after travelling on the vessel for extended periods of time, the crane structure should be checked for fatigue cracks

5.1.2. Lashing and support of crane and crane parts

The stability of the transport can be improved and sensitivity against swell could be reduced significantly by laying down or supporting the boom.

The machine should be put in a rest position, with the outriggers extended and the boom and counterweight supported on the deck of the vessel or the crane deck (as applicable). The use of friction material (anti slip rubber or plywood) under outriggers or tracks and the boom and counterweight support points is recommended. In addition to this, lashing the crane and the boom and counterweight to the vessel deck might be required if the transport is to cross lakes or tidal rivers or in case waves are to be expected (i.e. due to vessel traffic).

Care should be taken that no parts of the crane protrude beyond the profile of the vessel.

Photo showing an example of tie-downs used during transport.

Note: Lashing down cranes may cause damage due to loading the crane in a manner not intended by the manufacturer. Consult the crane manufacturer or a qualified person to determine an appropriate tie-down plan.

5.2. Shifting or sliding of the crane

During operations, the crane should be secured to prevent shifting or sliding (Figures 5a & 5b). The use of anti-skid material or blocking are common methods to achieve this. The use of anti-skid material directly under outrigger supports should be avoided as this prevents the outrigger support from "setting" itself under crane loadings. Tie-downs should only be used according to the instructions of the crane manufacturer or tie down parts manufacturer. Without manufacturers approval, tie-downs should be avoided during operation due to additional forces being induced to the crane chassis or the vessel itself. Additional vertical loading could result in over constraining the crane and prevent the chassis from flexing as intended by the manufacturer. Never use tie-downs as a method to gain greater capacity.

The chosen method of securing the crane from moving sideways should be designed to withstand the lateral forces that occur during lifting operations and transport. Calculations of the lateral forces are to be based on the expected maximum deck angle times a safety factor of 1.5.

When a crane is parked or during transport, the crane may be secured by using tie-downs. Exercise caution when using tie downs as the method of securement. Tie-downs may cause loading in the crane that was not intended by the manufacturer. Consult the crane manufacturer or a qualified person to determine an appropriate tie-down arrangement.

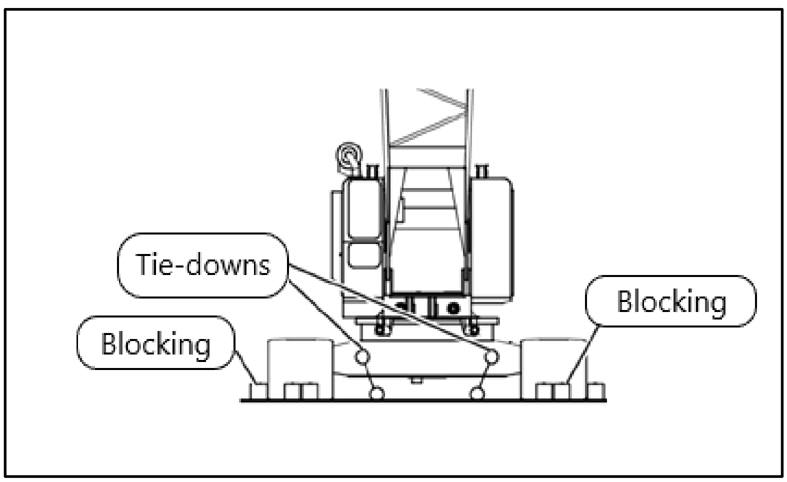


Figure 5a – Crawler crane secured with blocking

Figure 5b – Timber pads or matting needs to be secured on vessel deck

5.3. Preserving the crane

When using a crane in a seaport area or in an inland area near shore, the negative effect of the influence of corrosion on the various exposed crane parts should be taken into account. It is recommended to take protective measures like wrapping machine parts or applying protective coating.

An increase in the inspection/maintenance schedules may also be required. As an extra measure, and if not already required, the functioning of limiting switches, load sensors and anemometers should be checked on a daily basis.

5.4. Assembling / Disassembling of cranes on board of a vessel

If a crane cannot be transported onto the vessel in a rigged configuration, it may be necessary to assemble / disassemble the crane in the required configuration on-board the vessel.

6. LOAD HANDLING OPERATIONS

6.1. System Stability

6.1.1. General

When engineering load handling operations with a land-based mobile crane on a floating vessel, the stability issues as stipulated in this section and Annex A should be considered.

Stability is the ability of the ‘crane and vessel combination’ to sustain a changing loading condition without excessive heeling or turning over and its ability to its ability to maintain a constant list angle.

The static and dynamic behavior and more specifically the stability of the combination “land-based cranes on floating vessels” consisting of the floating vessel, crane and intended loadings is most important for the safety of operation and transport or transit including installing the crane on the vessel.

The combined “system” of crane and vessel (aka ‘crane and vessel combination’) should be analysed and approved as an individual case by persons with adequate knowledge and experience in naval design. If loads applied go beyond class approval of the vessel, a naval architect needs to push the structural book for class approval prior to operation.

This analysis should take into account the forces and loadings that will arise during lifting operations, but also during transport and installation of the crane on the vessel and as a result of environmental circumstances, such as wind forces.

6.1.2. Suspending a load on the vessel

Lifting a load which is placed on the vessel has great impact on the change of the center of gravity of the vessel system and, with that, on the change of the GM value.

The examples in the following figures show the effects of lifting a load from the deck of a vessel

Figure 6 below shows a vessel with a land-based mobile crane and a load resting on the deck. The CoG’ s of the three components of the vessel system add up to a combined CoG (GT) that is situated at a height just below the vessel deck. The Metacenter is high above the vessel deck.

Figure 6 - Load Sitting on Vessel Deck

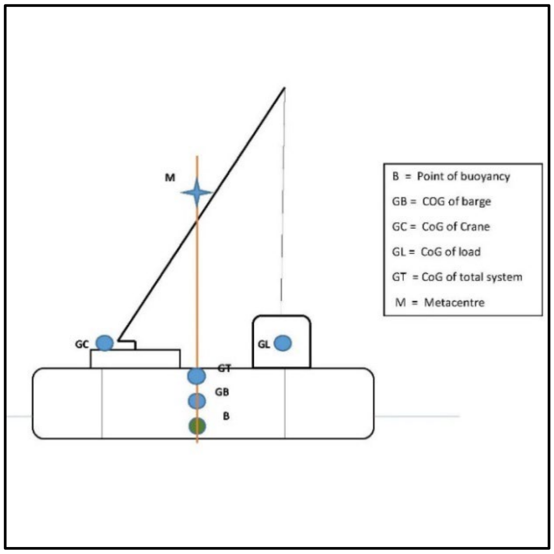


Figure 7 - Load Lifted Off Vessel Deck

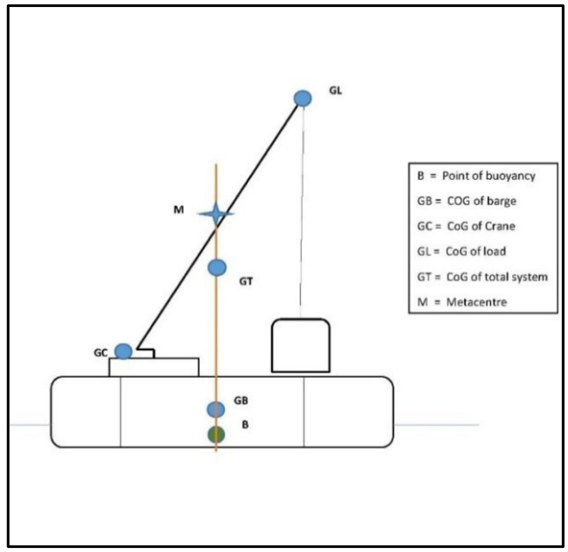


Figure 7 above shows the situation that occurs after lifting the load free from the vessel deck. Although the load is only lifted a few centimetres above the vessel deck, the application point of the load is now at the boom head sheaves center.

This will result in the center of gravity of the crane, load and vessel combined, shifting from just below deck height to approximately 18 – 22 meters above deck in a matter of seconds, causing the Metacentric height (GT-M) to drop in a similar way.

This effect is the reason why the stability of the vessel and crane system should be analysed prior to lifting any loads.

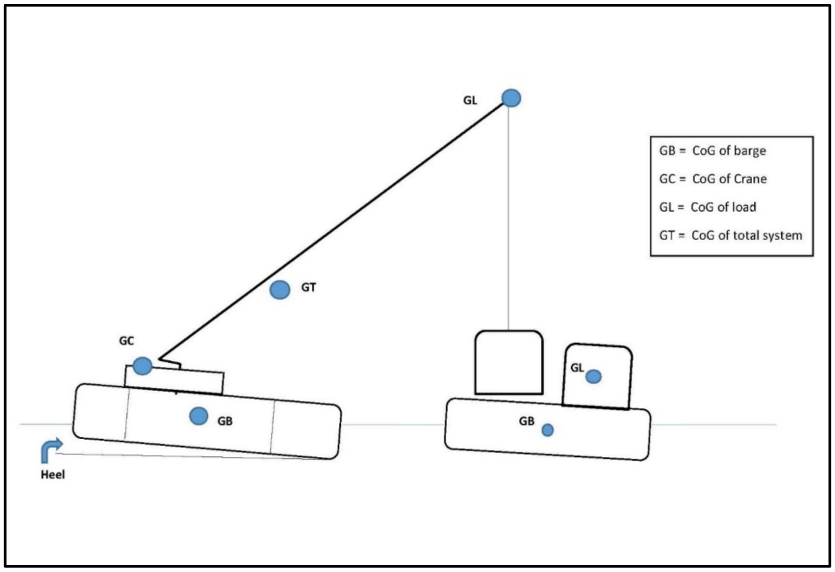


Figure 8 – Placement of Suspended Load

Repositioning the suspended load to other radii (horizontal movement) will change the horizontal position of the combined center of gravity and will induce heel as shown in Figure 8 above. As such these effects should be considered.

6.2. Recommended minimal GM value

Although the actual metacentric height value (GM, see Annex A section 1.5) value should be positive in any situation occurring during the entire operation, a minimal GM value to be advised is dependent on a variety of factors affecting the complete 'system' of vessel plus crane and load.

For the use of cranes on vessels in the environment and circumstances provided for within this document, generally a minimum calculated GM of 10.0 m. can be used. If this GM value cannot be adhered to, detailed calculations of the 'crane and vessel combination' by a naval architect or marine engineer are required

It is recommended that a naval architect or marine engineer verifies the minimal GM value and the maximum vessel inclination that will occur during operations also taking the environmental circumstances (wind) into consideration.

ANNEX A – Vessel Stability

A.1 Stability

Stability is the property of a body that causes it, when disturbed from a condition of equilibrium or steady motion, to develop forces or moments that restore the original condition.

Metacentric height (GM) the distance between the center of gravity and its metacentre. The metacentric height determines the vessel's ability to get back on an even keel.

A.2 Lightweight, deadweight and displacement

The vessel's own weight and the distribution of the weights on the vessel are essential for determining the vessel's stability. The vessel's weight is composed as follows:

- **Lightweight**
  This is the weight of the unrigged vessel without gear, fuel oil, water, containers, crew, provisions, etc. lightweight changes e.g. when the vessel is fitted with optional equipment, when replacing engines, winches or other fixed components.

- **Deadweight**
  This is the term for all the weights the crew takes on board during sailing. Deadweight includes equipment, fuel oil, water, crane, crane supports, load (cargo), crew, provisions, etc.

- **Displacement**
  Displacement is the term for the vessel's total weight. That means displacement = lightweight + deadweight. During sailing, the vessel's displacement changes constantly, e.g. as a result of fuel consumption.

- **Buoyancy**
  Buoyancy is the force acting upwards on the vessel created by the displaced amount of water. A vessel floating on the water will displace an amount of water equal to the weight of the vessel (displacement).

A.3 Center of gravity - CoG

The center of gravity (CoG) (Figure 9) is a concept combining theoretically all weights in a single point. Thus, it is composed of all weights on board, including the vessel's own weight (lightweight). For example, the total weight of the vessel (displacement), including deadweight such as gear, cargo, etc. can be replaced by one total weight located in the center of gravity.

For most vessels, the CoG is just above the waterline. The center of gravity can change as follows:

- Cargo and gear on deck pull the center of gravity up
- Installation of new equipment on deck or in the wheelhouse pulls the center of gravity up

The results may be:

- A high center of gravity makes the vessel roll more slowly and can be a danger signal
- Vessels may become unstable if the center of gravity is positioned too high

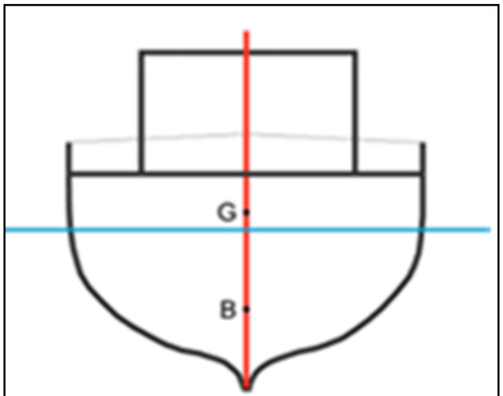


Figure 9

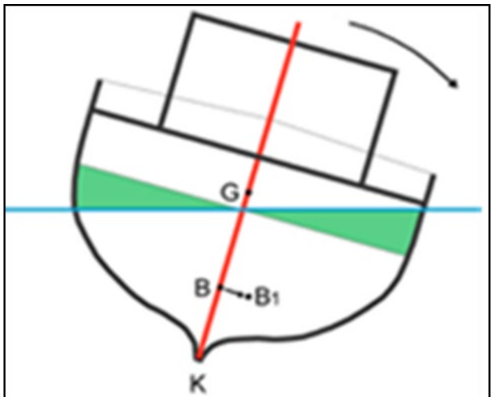


Figure 10

A.4 Center of buoyancy

All parts of the hull under the waterline contribute to the vessel's overall buoyancy. The total buoyancy can, just like the center of gravity, be merged in one single point called the center of buoyancy and this is indicated by the letter B as shown in Figure 10 above.

The center of buoyancy (B) is not fixed, it changes all the time depending on the vessel's draft, heel and trim. The center of buoyancy (B) moves when the vessel heels.

When the vessel is upright, and not tilted, the center of gravity G is in the vessel's center line. In a straight line below is the center of buoyancy B, and the vessel is in balance.

If the vessel is heeled, the buoyancy center moves immediately off to the side of the vessel. See Figure 11 below where B is moved to one side and labelled as B1.

If the gear and cargo are stowed away safely, there is no weight on board that can move during the roll. Therefore, the center of gravity G remains in the same position.

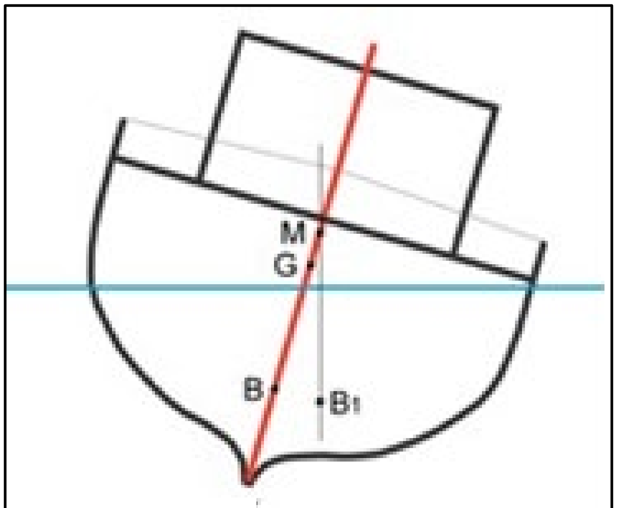


Figure 11

A.5 Metacentric height GM

Under a light heeling, the vertical line of buoyancy intersects with the vessel's center line at a point called the meta center, which is indicated by the letter M. The distance between the center of gravity G and metacenter M is called the metacentric height GM (see Figure 12).

The GM value is a measure of the vessel's stability under small heeling, also called initial stability. The higher the GM value, the better the vessel's initial stability and the harder it is to get the vessel to heel.
The following three situations may arise:

- GM > 0 the vessel is stable
- GM = 0 the vessel is labile
- GM < 0 the vessel is unstable

A.6 Righting arm GZ

When the vessel suffers a heel, the center of gravity G and the center of buoyancy B are no longer on the same vertical line above one another. The vessel is brought out of balance.

As figure 12 shows, there is a distance between the vertical line that expresses the vessel's weight through the center of gravity G and the vertical line that expresses the vessel buoyancy through the current center of buoyancy B1.

The horizontal distance between the two lines is called the righting arm, GZ, and the size of the righting arm GZ is crucial to whether the vessel can straighten up and get back on an even keel. The greater the righting arm, the better the ability of the vessel is to get back on an even keel.

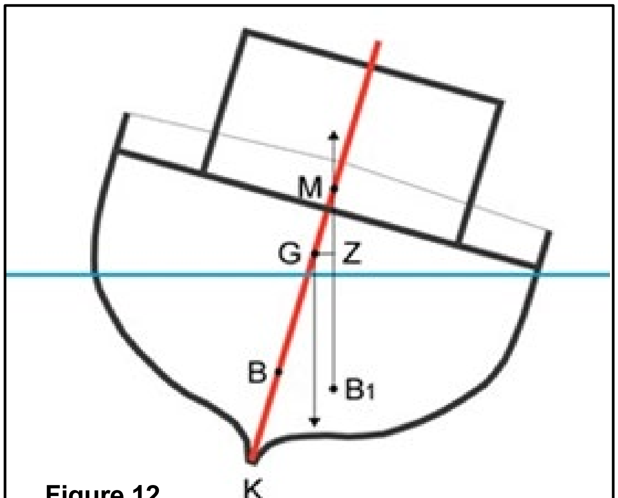


Figure 12

Figure 13 below shows how the crew can influence the size of the righting arm GZ depending on how the vessel is loaded.

The deeper the weight is placed in the vessel; the further down the center of gravity G (G becomes G_1). Thus, the righting arm G_1Z_1 is larger than GZ.

Conversely, the distance GZ is smaller if the weights are placed high up in the vessel (G becomes G_2), so that the center of gravity moves higher up in the vessel and the righting arm G_2Z_2 is smaller than GZ.

For smaller heel angles (up to 10º) the righting arm can be calculated using the following formula:

$M_r = D \cdot GM \cdot \sin(\text{Ø})$ in which:

M_r = righting Moment
Ø = heel angle (°)
D = Displacement (Ton)
GM = Metacentric Height (m)

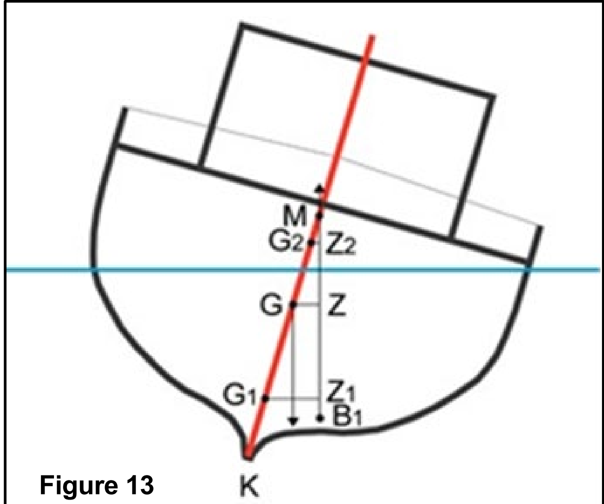


Figure 13

A.7 Eccentrically Loaded Vessels

In addition to the guidance provided above, which refers to a centrically loaded vessel, a crane on a vessel can have an eccentricity (e) to its center of gravity position. Performing the mathematics to reduce the center of gravity GT to point G results in a load moment ML as shown below:

$$M_L = G_T * e * \cos(Ø)$$

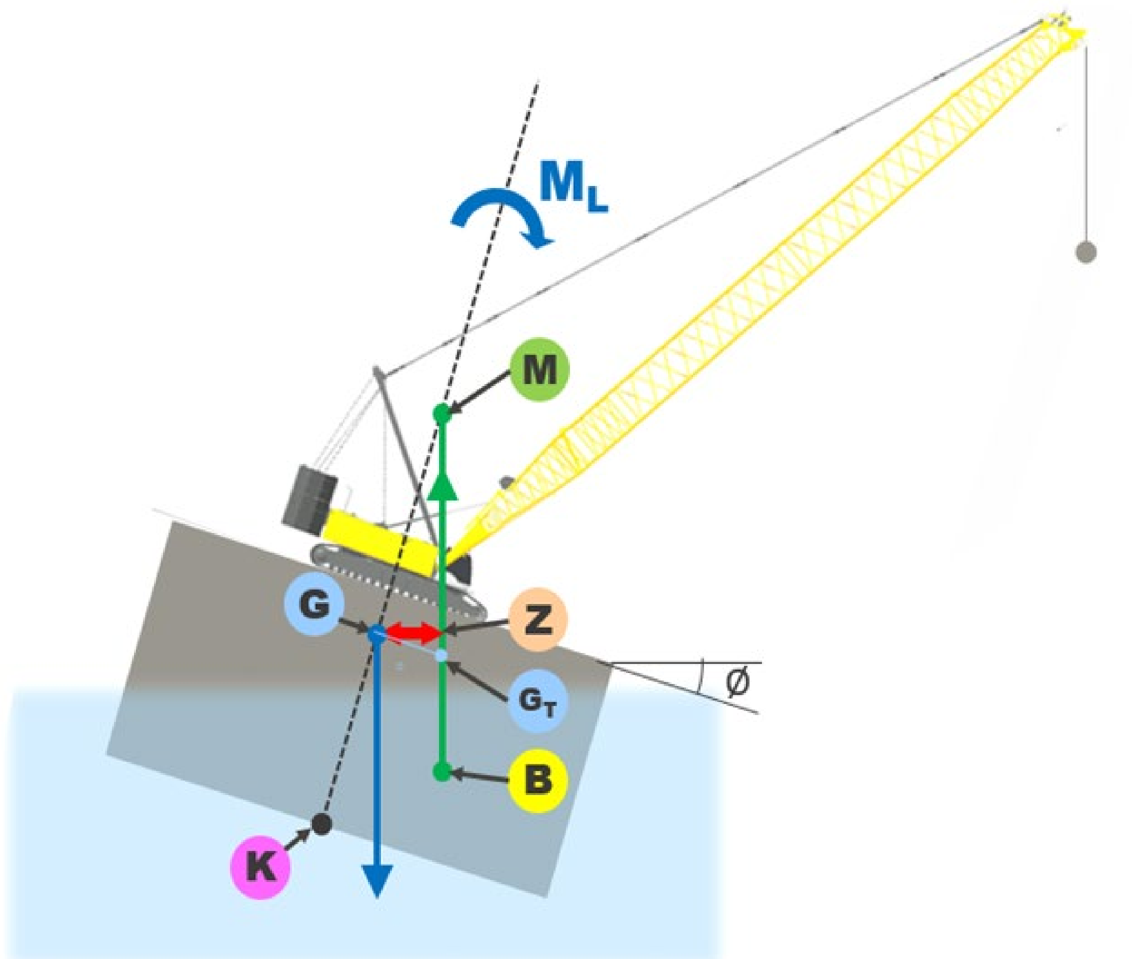


Figure 14 Float Stability

K ⇨ keel
G_T ⇨ total weight (floating device & crane & load)
G ⇨ total weight (floating device & crane & load) related to vessel center line
B ⇨ center of buoyancy (center of underwater displaced volume)
M ⇨ metacenter
GM ⇨ metacentric height
GZ ⇨ righting arm
Ø ⇨ heel angle (º)
“e” ⇨ eccentricity

Float stability is given if: **ML $\leq$ GZ * B**

ANNEX B – Mooring Arrangements

Mooring is often accomplished using thick ropes called mooring lines or hawsers. The lines are fixed to deck fittings on the vessel at one end and to fittings such as bollards, rings, and cleats on the other end.

Mooring requires cooperation between people on a pier and on a vessel. Once a mooring line is attached to a bollard, it is pulled tight. Large vessels generally tighten their mooring lines using heavy machinery called mooring winches or capstans.

The heaviest vessels may require more than a dozen mooring lines. Small vessels can generally be moored by four to six mooring lines.

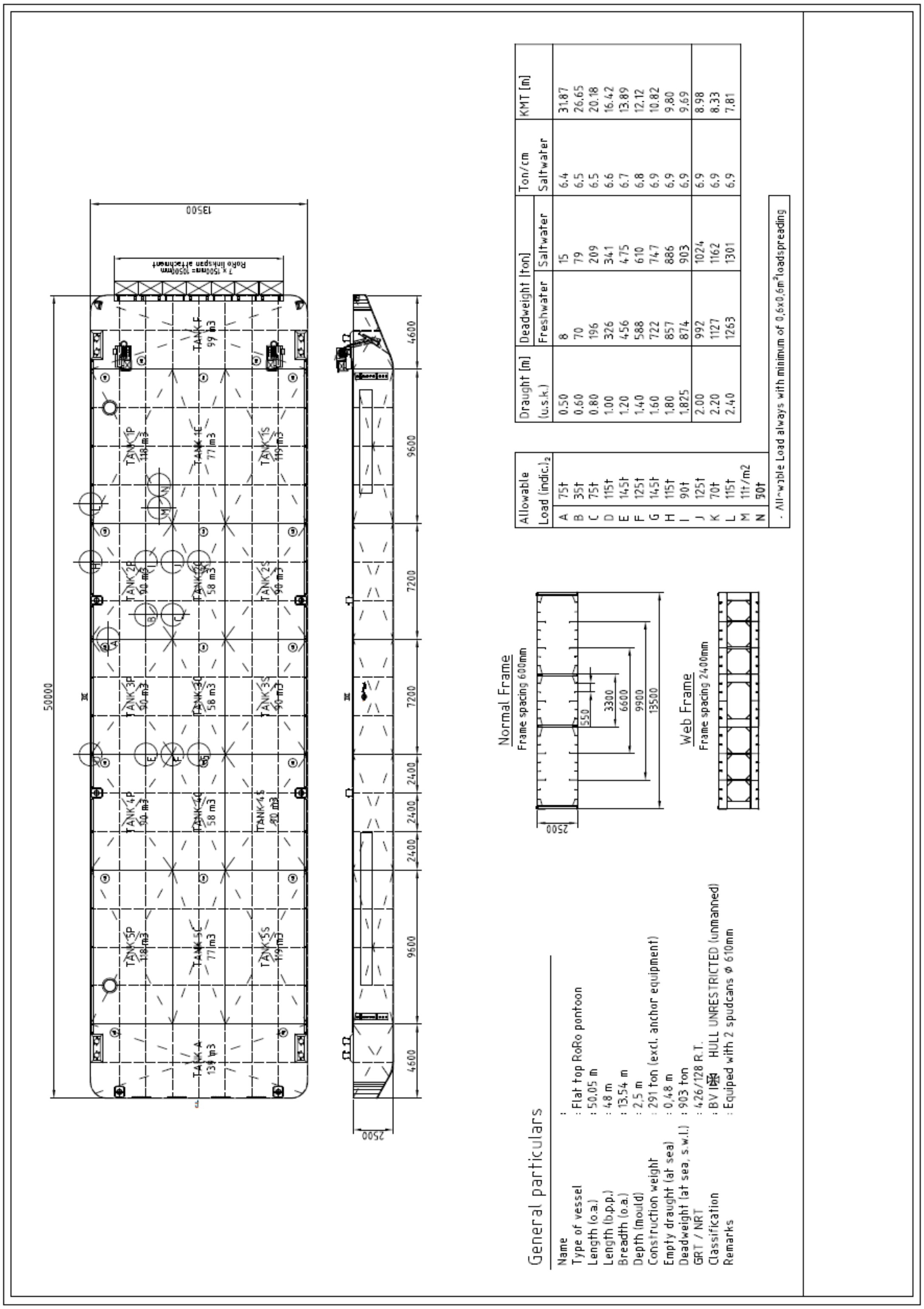
Mooring lines are usually made from manila rope or a synthetic material such as nylon. Nylon is easy to work with and lasts for years, but it is highly elastic. This elasticity has advantages and disadvantages. The main advantage is that during an event, such as a high wind or the close passing of another vessel, stress can be spread across several lines. However, should a highly stressed nylon line break, it may part catastrophically, causing snapback, which can fatally injure bystanders. A blow from a heavy mooring line carries much force and can inflict severe injuries or even sever limbs. Mooring lines made from materials such as steel, Dyneema® and Kevlar® have much less elasticity. However, such lines do not float on water, and they do tend to sink. In addition, they are relatively more expensive than other sorts of line.

When designing mooring arrangements, the allowed movement of the vessel should be checked against the envisaged operations, as lifting operations will have different movement restrictions than ro-ro operations will do. The outcome of this check will influence the choice for a mooring line material.

Some vessels use steel wire rope for one or more of their mooring lines. Wire rope is hard to handle and maintain. There is also risk associated with using wire rope on a vessel's stern in the vicinity of its propeller.

Mooring lines and hawsers may also be made by combining wire rope and synthetic line. Such lines are more elastic and easier to handle than wire rope, but they are not as elastic as pure synthetic line.

ANNEX C – Example of a Barge

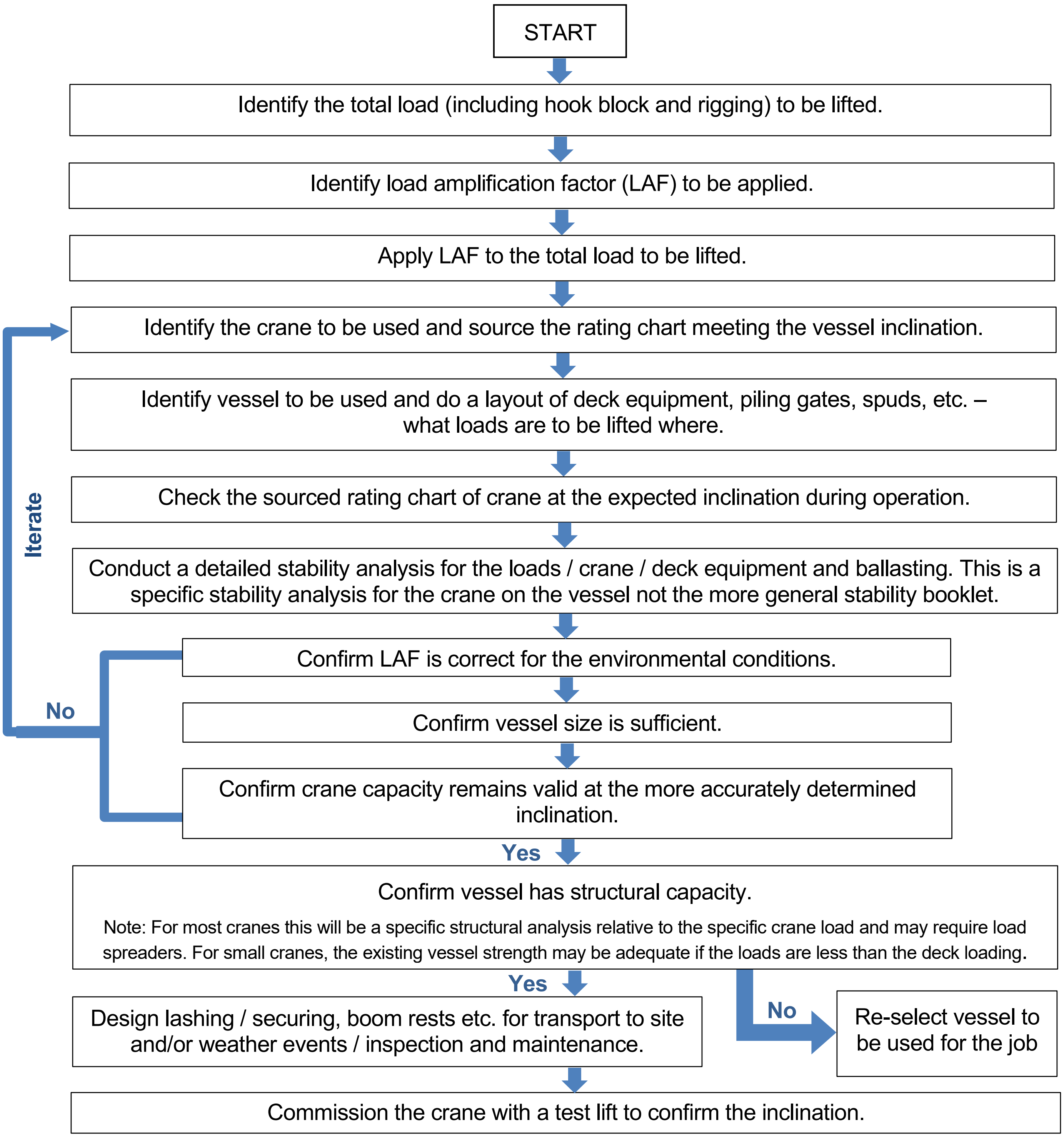


Allowable Load (indic.)$_2$	
A	75t
B	35t
C	75t
D	115t
E	145t
F	125t
G	145t
H	115t
I	90t
J	125t
K	70t
L	115t
M	11t/m2
N	50t

- All~wable Load always with minimum of 0,6x0,6m^2 loadspreading

Draught [m] (u.s.k.)	Deadweight [ton] Freshwater	Deadweight [ton] Saltwater	Ton/cm Saltwater	KMT [m]
0.50	8	15	6.4	31.87
0.60	70	79	6.5	26.65
0.80	196	209	6.5	20.18
1.00	326	341	6.6	16.42
1.20	456	475	6.7	13.89
1.40	588	610	6.8	12.12
1.60	722	747	6.9	10.82
1.80	857	886	6.9	9.80
1.825	874	903	6.9	9.69
2.00	992	1024	6.9	8.98
2.20	1127	1162	6.9	8.33
2.40	1263	1301	6.9	7.81

ANNEX D – Planning Flow Chart (Informative)



BIBLIOGRAPHY

There are various standards, regulations and guidance documents from different countries and organizations that address the complexity of using land-based cranes on vessels and provide guidance for such operations:

- American Bureau of Shipping (ABS) Guide for Certification of Cranes
- American Petroleum Institute (API) Specification 2c
- ASME B30.8 Floating Cranes and Floating Derricks
- Cranes and Derricks, Fourth Edition, by Jay P. Shapiro and Lawrence K. Shapiro– Chapter 4.4 Barge and Ship-Mounted Cranes
- Det Norske Veritas (DNV) Guidelines for Marine Lifting and Lowering Operations
- International Maritime Organization (IMO)
- Japan Construction Code for Mobile Cranes, Article 15
- Lloyds Register Lifting Appliances in a Marine Environment
- OSHA 1926.1437 – Floating Cranes/Derricks & Land Cranes/Derricks on Barges
- United States Army Corps of Engineers Safety and Health Requirements Manual EM385-1-1

There may be other publications to consider depending on location (e.g., local, state, country regulations).

ICSA MEMBERS

This document has been reviewed and jointly adopted by the following member associations of the ICSA:

- **Association of Equipment Manufacturers [AEM]**
- **The Crane Industry Council of Australia [CICA]**
- **Crane Rental Association of Canada [CRAC]**
- **The European Association of abnormal road transport and mobile cranes [ESTA]**
- **European Materials Handling Federation [FEM]**
- **Japanese Crane Association [JCA]**
- **Specialized Carriers & Rigging Association [SC&RA]**

This document is maintained by the Specialized Carriers & Rigging Association (SC&RA).

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