PONTOON

Floating Structure

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Stability of Pontoons

The stability of any statical structure depends on the equilibrium of the external forces which act upon it. Considering a floating body, these external forces are:

- Gravity – due to intrinsic weight of the body acting vertically downwards
- Buoyancy – vertical component of hydrostatic pressure acting vertically upwards.

It is true that in addition there are the horizontal components of hydrostatic pressure, but as in still water, regardless of the shape and size of the body, these components must always and exactly neutralise one another, there is no necessity to bring them into consideration.

Stability of Pontoons

Pontoons shall be stable under the most adverse combination of dead and live loads applied to the pontoon deck. Under such loads, unless permitted otherwise, the following requirements shall be met:

(a)For pontoons with a rectilinear flotation system, the minimum freeboard shall be the greater of 50 mm or 5% of the moulded depth of the pontoon, measured from the top of the flotation unit;

(b)For pontoons with a horizontal cylindrical flotation system, the minimum freeboard shall be the greater of 50 mm or 25% of the diameter of the cylindrical float, measured from the top of the flotation system;

(c) The pontoon chine shall not emerge; and

(d) The angle of tilt shall not exceed 15 degrees.

Consideration shall be given to marine growth when designing pontoons. Pontoon stability shall be calculated in accordance with the metacentric height method

Stable and Unstable Structure

Centre of gravity (G) - imaginary point in the exact middle of a weight where the entire weight may be considered to act vertically downwards .

Centre of buoyancy (B) - imaginary point in the exact middle of the volume of *displaced* water where the entire buoyancy may be considered to act vertically upwards.

Metacentre (M) - a point in space where the vertical line upwards through the centre of buoyancy (B) *of the 'inclined' vessel* cuts through the vertical line upwards through the centre of buoyancy (B) *of the 'upright' vessel*.

Stable and Unstable Structure

Metacentric height (GM) - the vertical distance between the Centre of Gravity (G) and the Metacentre (M). If M is above G the vessel will want to stay upright and if G is above M the vessel will want to capsize. i.e. GM positive is Stable, GM negative is Unstable.

Righting lever (+GZ) or Overturning lever (-GZ) - the horizontal distance between the two vertical 'lines of action' of the buoyancy force (upwards), and the gravity force (downwards). The size of GZ is the measure of how stable or unstable the structure is at any particular angle of heel. For small angles of heel (less than 15°), the 'righting' or 'overturning lever' GZ = GM x sin θ (where θ is the angle of heel, in degrees

Stability

- To be adequately stable, the metacentric height (GM) of the loaded structure, floating upright in still water, is required to be above a minimum value.

- GM_{min}= 0.35 m (*recommended guidance value)*

- Metacentric height can be calculated using the formula:

$$GM = KB + BM – KG$$

  - K, B, G, and M are all in metres,
  - KB - vertical distance from the keel to the centre of buoyancy,
  - BM - vertical distance from the centre of buoyancy to
  - the metacentre, and
  - KG - vertical distance from the keel to the centre of gravity.

Initial Stability

The vertical distance between the centre of buoyancy (B) and the metacentre (M), that is

$$BM = I / V$$

where I is the *inertia of the water plane area, and V is the volume of displacement.*

For a rectangular water plane area, such as that displaced by a pontoon barge, the 'roll inertia' is,

$$I = (l \times b^3)/12,$$

and (for a box shaped barge) the 'displaced volume' is,

$$V = (l \times b \times t)$$

where l is the length, b is the beam, t is the draught.

Initial Stability

Example – how to calculate BM

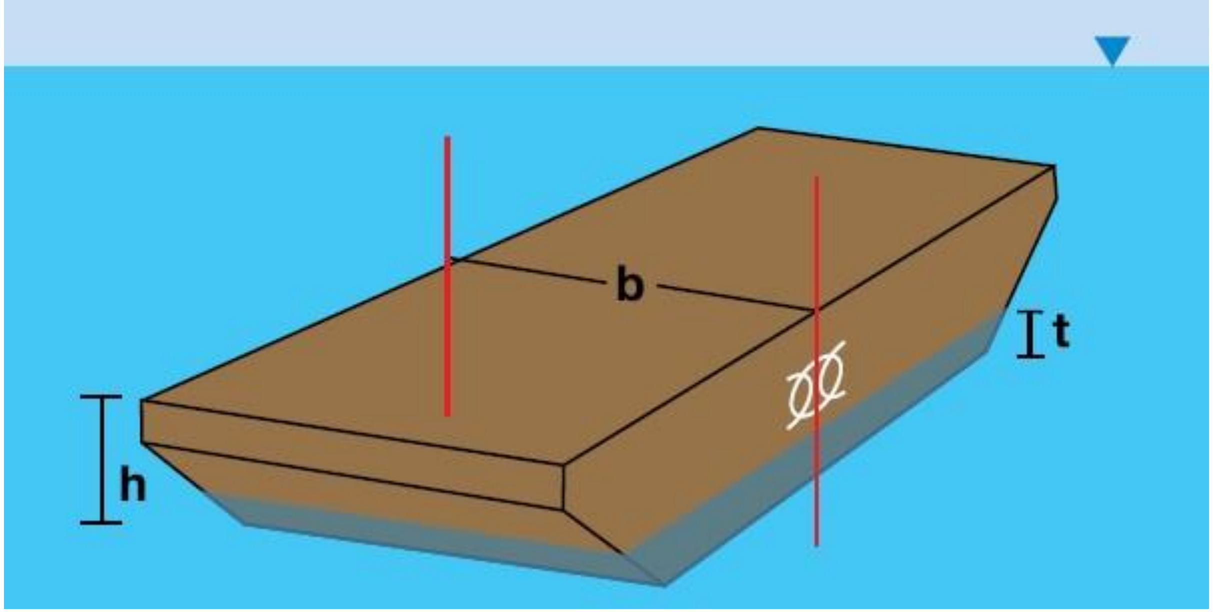
A box shaped barge 16 metres long, and 6 metres wide floats at a draft of 0.5 metres.

BM = I/V	
I = (l x b^3)/12:	(16 x 6^3)/12 = 288
V= l x b x t:	16 x 6 x 0.5 = 48
BM = 288/48 = 6 metres	

Initial Stability

- Determining GM,

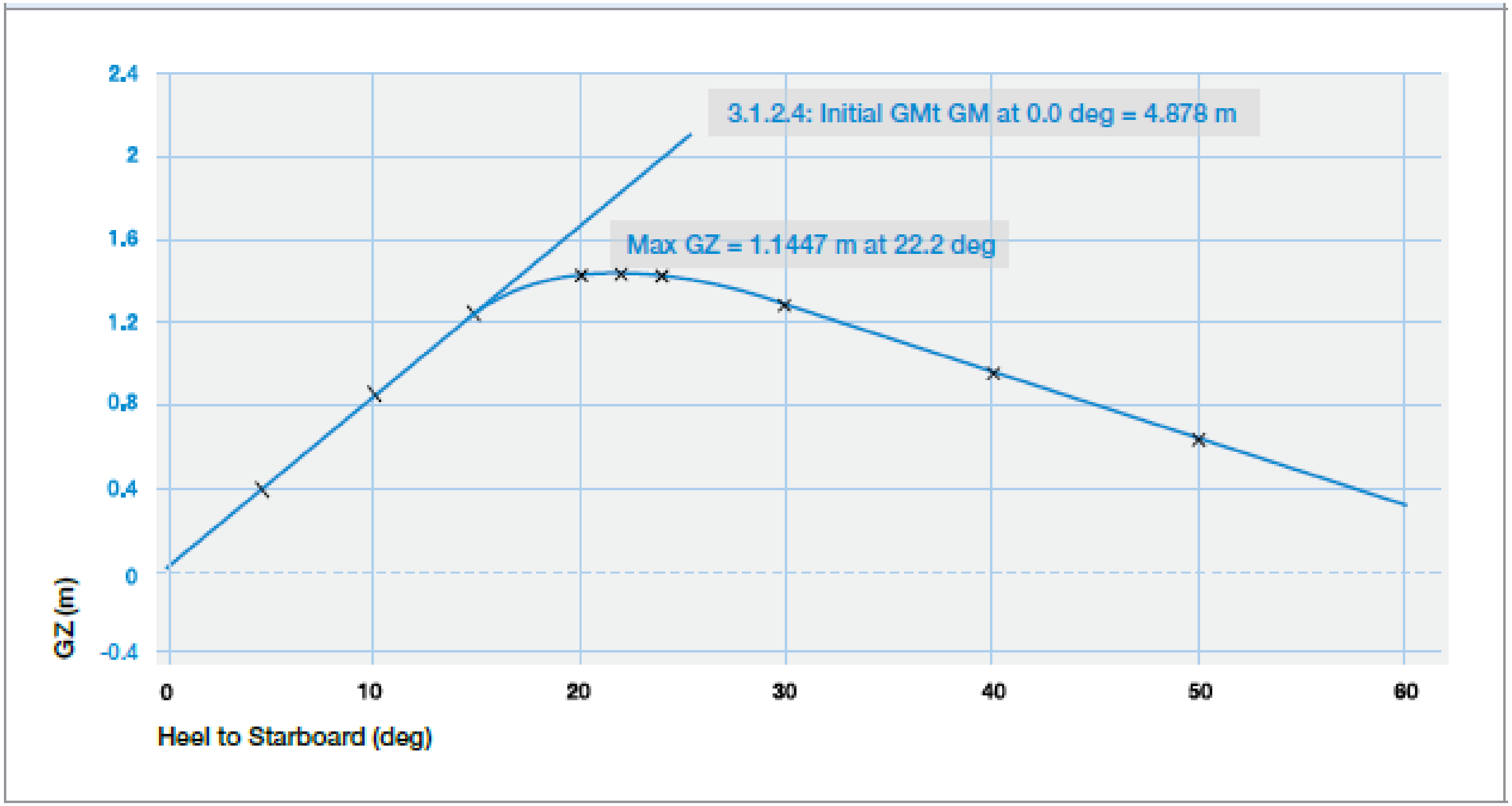
$$GM = KB + BM - KG = \frac{t}{2} + \frac{b^2}{12t} - h$$



where t is the draught,
b is the beam, and
h is the height of the barge

Static Stability

- For stability to be adequate, the *righting lever (GZ) resulting from the heeling of a loaded barge* is required to be greater than zero (positive) for all angles of heel up to a certain minimum heel angle (35° *is recommended)*



Static Stability

- This particular curve is for a 24m by 8m barge with a loaded displacement of 148 tonnes.
- It can be seen that the GZ value (measured in metres) is greater than zero for all heel angles up to more than about 60°.

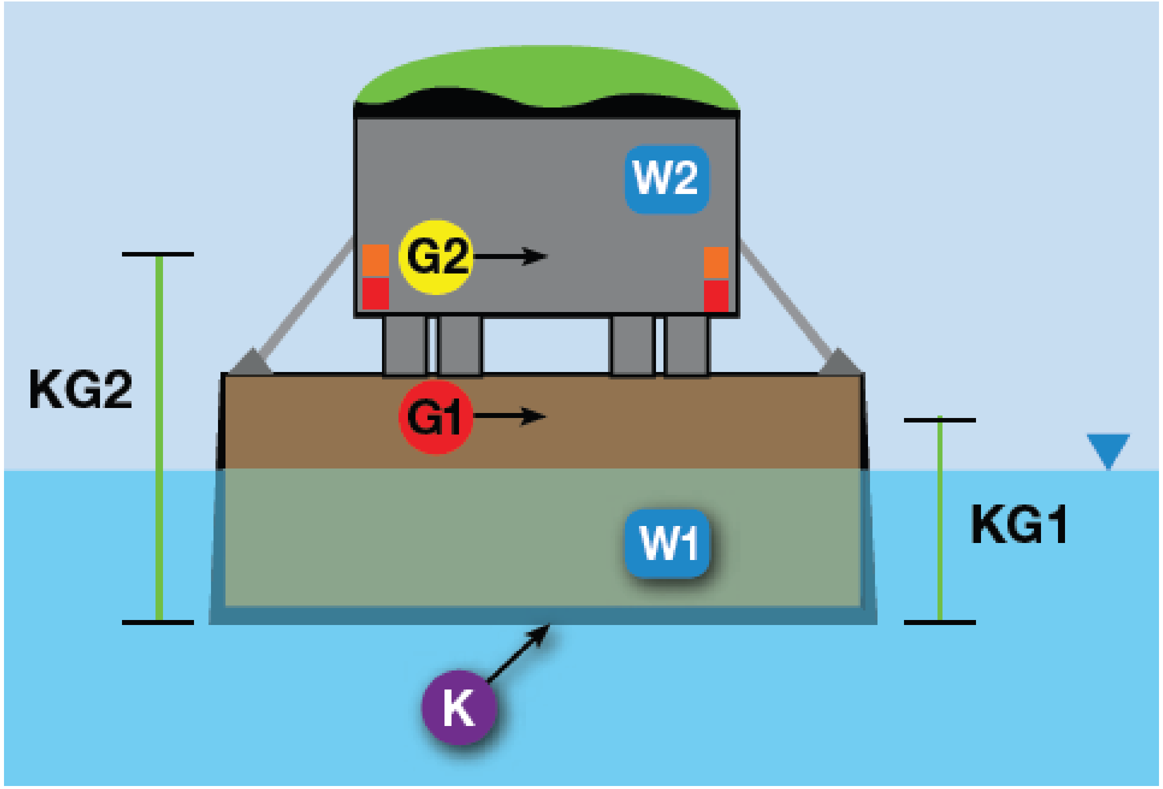
Dynamic Stability

- The *area under the GZ curve and above the horizontal (0) axis, is a product of metres and* degrees, and is also an important measure of the stability of a structure. The larger this area the greater the capacity of the strcuture to right itself as it rolls from side to side.

- This is known as righting energy.

- A recommended minimum value for the area under the GZ curve is 5.73 metre x degrees.

Combined KG



$$\text{COMBINED KG} = \frac{(KG1 \times W1) + (KG2 \times W2)}{(W1 + W2)}$$

KG1	Vertical distance from keel to G1
KG2	Vertical distance from keel to G2
W1	Weight 1
W2	Weight 2

Combined KG

A straightforward check of initial stability involves determining the combined KG value for a barge and its cargo. The pontoon barge loaded with secured deck cargo. The centre of gravity of the lightship barge is marked as G1 and the centre of gravity of the cargo is marked as G2.

The distance from the keel to these positions are the distances KG1 and KG2. The lightship weight of the barge is W1 tonnes, and the cargo weight is W2 tonnes.

Combined KG

Example – how to calculate KG

KG = total moment ((KG1 x W1) + (KG2 x W2)) / total weight (W1 + W2)

A box shaped barge has a *lightship displacement of 85 tonnes and a KG of 1.8 metres.* A weight of 65 tonnes with a KG of 3.8 metres is loaded on to the barge deck.

Calculate the combined KG

Barge's weight	85t	Barge's KG	1.8m	Weight x KG =		Barge's moment	153tm
Load weight	65t	Load KG	3.8	Weight x KG =		Load's moment	247tm
Total weight	**150t**					Total moment	**400tm**

Combined KG = total moment/total weight, which is 400/150 = 2.67 m

Limiting KG Curves

Limiting KG curve to be drawn as part of a stability analysis.

The limiting KG curve is used, in conjunction with the combined KG and loaded displacement to establish whether the loaded condition is safe.

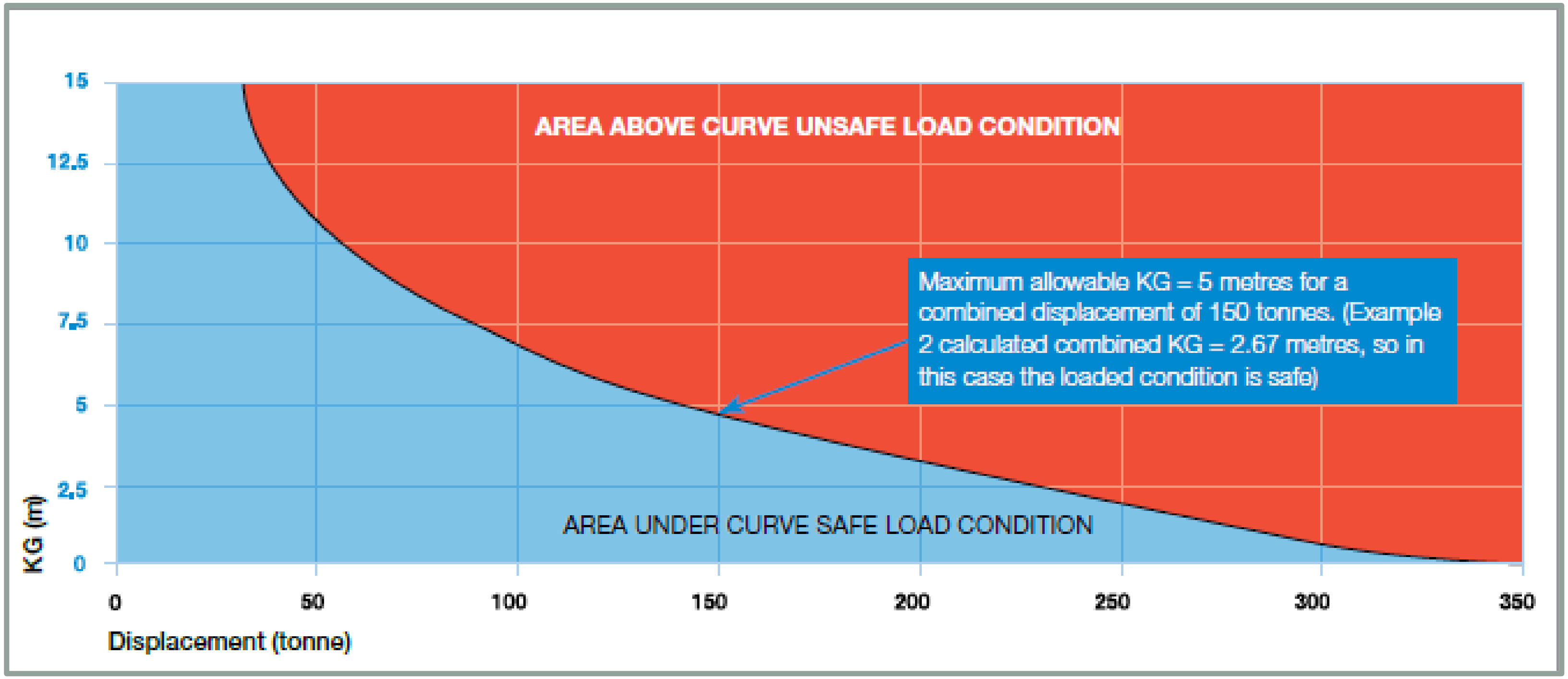
The limiting KG curve has safety margins built in.

Margins are achieved by using recommended minimum values:

- *Initial GM* greater than 0.35 metres;
- *vanishing stability (positive GZ) to greater than 35°; and*
- *area under the GZ curve not less than 5.73 metre x degrees).*

Limiting KG Curves

Limiting KG curve for a barge 24m in length & 8m in beam



The area **under** the curve is a **safe** load condition.

The area **above** the curve is an **unsafe** load condition.

Limiting KG Curves

How to use limiting KG curve

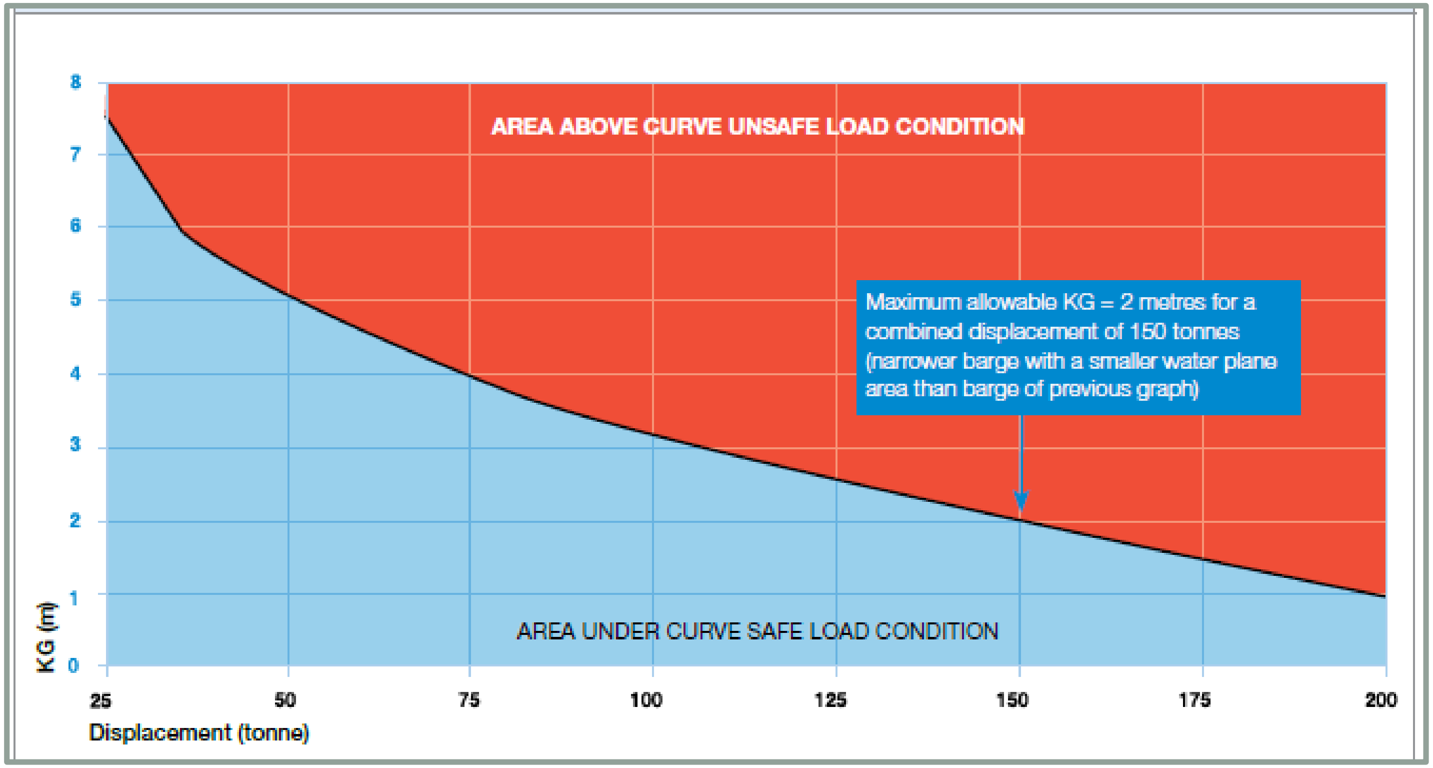
Using graph KG vs Displacement, say
•combined KG = 2.67 metres,
•loaded displacement = 150 tonnes
Establish if the load condition is safe or unsafe?

For a loaded displacement of 150 tonnes and a combined KG of 2.67 metres the load is safe provided the combined KG of the lightship barge and cargo is less than 5 metres.

Answer: 2.67m is less than 5m, therefore the loaded condition is safe.

Limiting KG Curves

Limiting KG curve for a barge 24m in length & 6m in beam



The area **under** the curve is a **safe** load condition.

The area **above** the curve is an **unsafe** load condition.

Limiting KG Curves

How to use limiting KG curve

Limiting KG curve for a barge of 24 m length and beam of 6 m.

Using the same values; combined KG 2.67 metres,
loaded displacement of 150 tonnes
Establish if the load condition is safe or unsafe.

For a loaded displacement of 150 tonnes and combined KG of 2.67 metres the load condition is unsafe.

A load displacement of 150 tonnes is only acceptable provided that the combined KG is less than 2 metres above the keel. The Measures of Stability; initial (GM) the righting levers (G2) and the righting energy will be much less for a barge with a narrower beam.

Other Stability Considerations

Crane Outreach

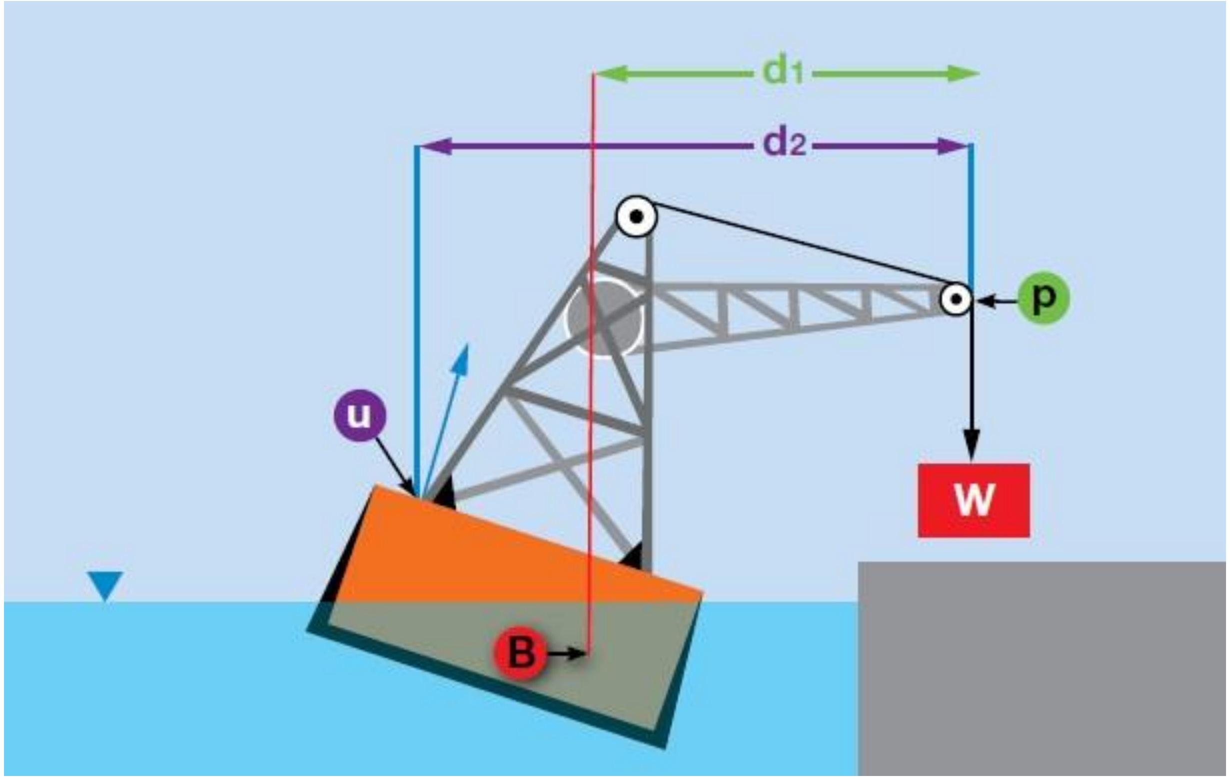
When using cranes and other lifting gear such as A frames that are barge mounted, it must be noted that the weight of the lifted load acts *at the point of suspension – not at the base of* the crane.

The *overturning moment on the barge, tending to cause it to capsize, is the product* of the weight of the lifted load, and the (horizontal) distance (d1) of the *point of suspension (p)* from the *centre of buoyancy (B)*

Other Stability Considerations

CRANE OVERTURNING MOMENT = d1 x W

MAXIMUM UPLIFT FORCE = d2 x W



Other Stability Considerations

The greatest uplift or detachment force, acts *at the point of attachment (of the crane to the* barge) *furthest from the point of suspension. This is the force tending to turn the crane over* and the moment of this force is the product of the weight of the lifted load, and the (horizontal) distance (d2) of the point of suspension (p) from the point of uplift (u).

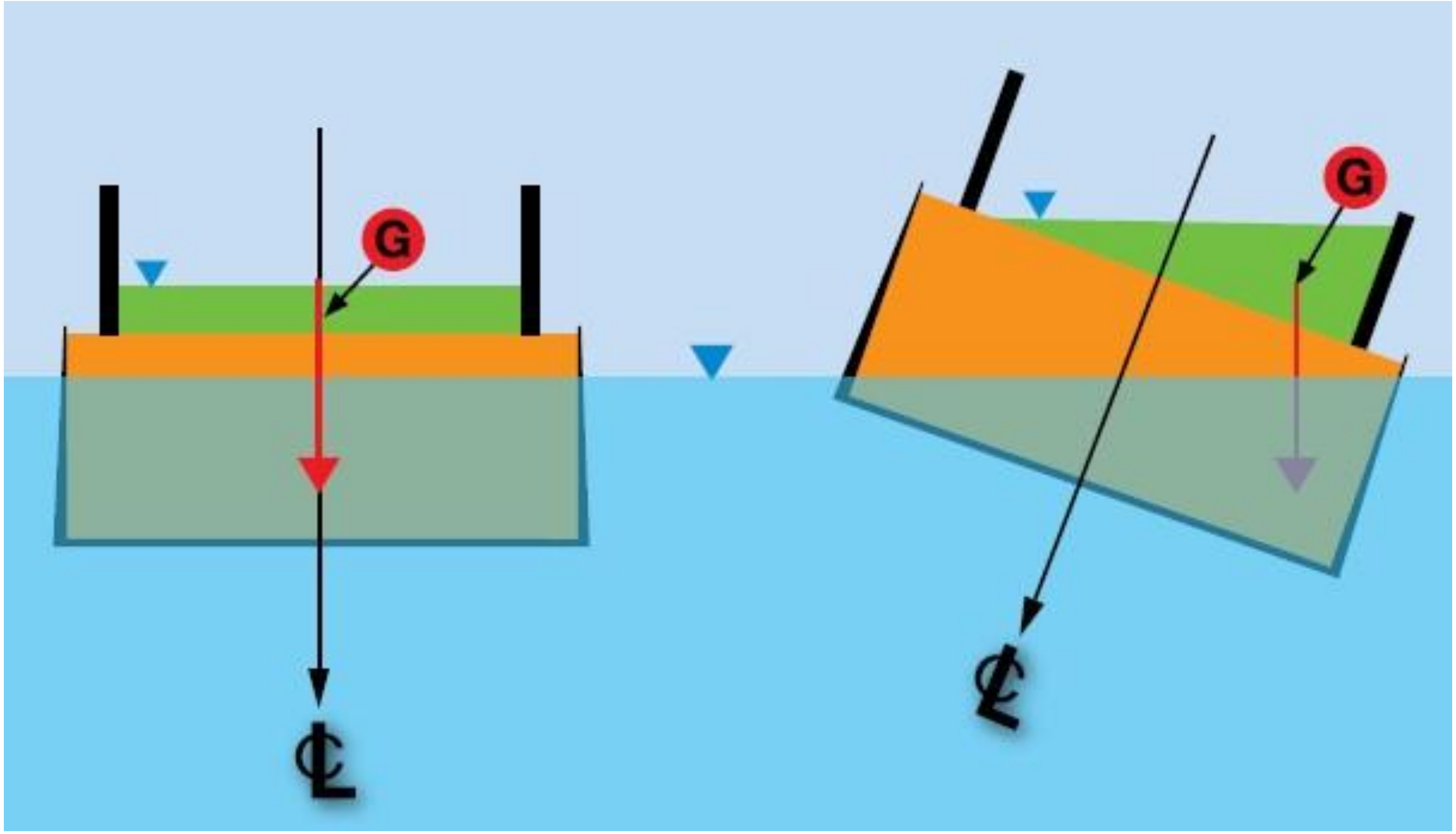
Other Stability Considerations

Fluids such as fuel and water can adversely affect the stability of a moving floating structure. The weight of a tank of fluid – acting at the centre of gravity – moves further off the centreline of the structure. Even a shallow covering of water over a large enclosed deck can cause a significant problem.

150 mm of fresh water covering a 24 m by 6 m deck weight of 21.6 tonne, and as the structure rolls this weight will be transferred outboard to the down side of the roll. *Sloshing is another phenomenon, which can greatly amplify the destabilising effect of a* large free surface of fluid. The effect of sloshing is worst if the movement of fluid coincides with the movement of the structure.

Baffles are used to break up the free surface within a tank and to prevent sloshing. Baffle strength needed to minimise the adverse effects of free surfaces.

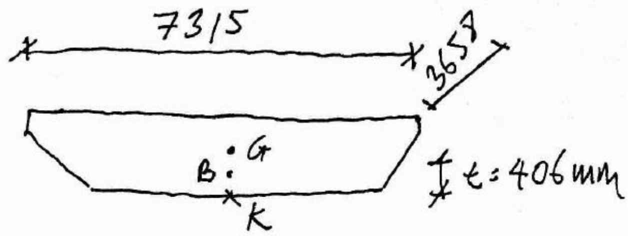
Other Stability Considerations



Example:

25 April 2016

Pontoon



Initial stability

Dead Weight = 2 tonne.

Metacentric Height (GM).

Person & Cargo = 7 tonne

BM, centre of buoyancy to the metacentre.

$BM = I/V$

$I = (7.315 \times 3.658^3)/12$

$= 29.84$

$V = 7.315 \times 3.658 \times 0.4$

$= 10.7$

$$BM = \frac{29.84}{10.7} = 2.78\ m > 0.35\ m \ (ok)$$

$KB = 0.203\ m$ (keel to centre of buoyancy)

$KG = 0.300\ m$ (keel to CG)

$$GM = KB + BM - KG$$

$$= 0.203 + 2.78 - 0.3$$

$$= 2.683 > 0.35\ m \ (ok).$$

Checking

$$GM = \frac{t}{2} + \frac{b^2}{12t} - h$$

$t = 0.4\ m$

$h = 0.6\ m$

$b = 3.658\ m$

$$= \frac{0.4}{2} + \frac{3.658^2}{12(0.4)} - 0.6$$

$$= 0.2 + 2.788 - 0.6$$

$$= 2.38\ m > 0.35\ m\ (ok)$$

Curve of Limiting KG

Displacement = 9 tonne

KG = 0.3 m

Area under curve safe Load Condition.

References

- Barge stability guideline – Maritime NZ
- Dock and Harbour Engineering - Charles Griffin & Company
- Stability and Metacentric Height - Codecogs
- Port Designers Handbook – Carl A. Thoresen

Thank You