1. ASSESS REPORTED DEFECTS AND DAMAGES TO CARGO SPACES, HATCH COVERS AND BALLAST TANKS AND TAKE APPROPRIATE ACTION

<u>Scope</u>:

Module 2: This part addresses the competencies on the following:

Assess reported defects and damages to cargo spaces, hatch covers and ballast tanks and take appropriate actions

<u>Objectives</u>:

Module 2: Upon completion of this module, the candidate shall be able to:

a) Determine limitations on strength of the vital constructional parts of a standard bulk carrier
b) Interpret given figures for bending moments and shear forces
c) Explain how to avoid the detrimental effects on bulk carriers of corrosion, fatigue and inadequate cargo handling

1. ASSESS REPORTED DEFECTS AND DAMAGES TO CARGO SPACES, HATCH COVERS AND BALLAST TANKS AND TAKE APPROPRIATE ACTION

1.1 Bending moments and shear forces on bulk carriers

Structural integrity and design limitations of modern seagoing bulk carriers

Most seafaring nations have established classification societies which review standards for the construction of cargo vessels. Classification societies publish construction guidelines, stability and operating standards to ensure vessel safety and standardization of ship construction and other marine equipment.

A ship's structure is designed to withstand static and dynamic loads likely to be experienced by the ship throughout its service life.
The loads acting on the hull structure when a ship is floating in still (calm) water are called static loads.
These loads are imposed by the:

- Actual weight of the ship's structure, outfitting, equipment and machinery.

- Cargo load (weight).

- Bunker and other consumable loads (weight).

- Ballast load (weight).

- Hydrostatic pressure (sea water pressure acting on the hull).

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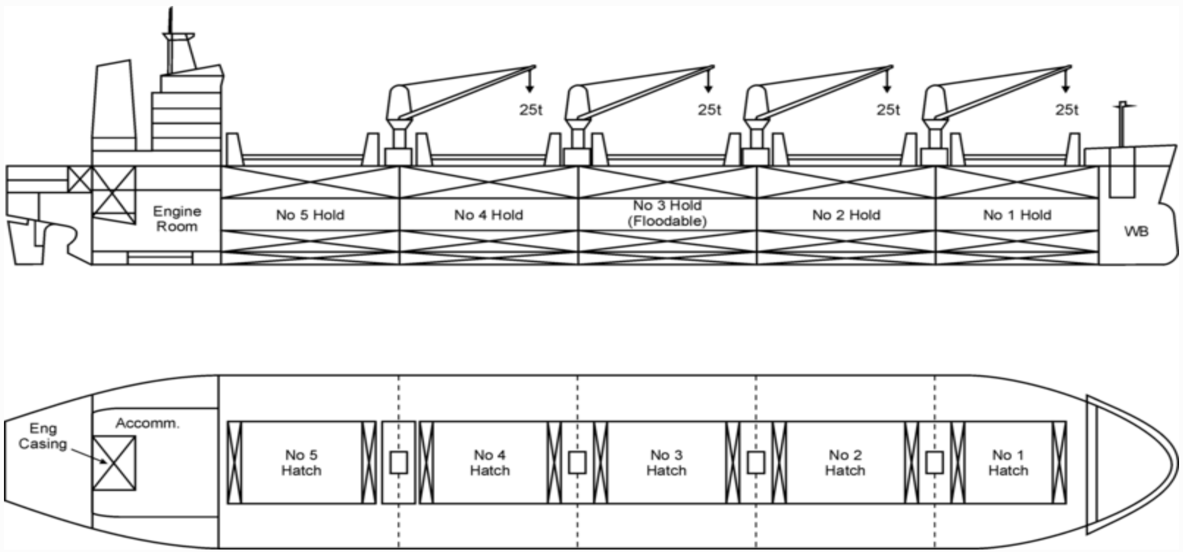
1.1 Bending moments and shear forces on bulk carriers

Defining a bulk carrier structural configuration

A typical bulk carrier is a single deck ship with a double bottom, hopper tanks, single skin transverse framed side shell, top-side tanks and deck hatchways. Bulk carrier design does not alter significantly with size; fundamentally, a bulk carrier of 35.000 tonnes deadweight usually has the same structural configuration as that of a ship of 70.000 tonnes deadweight. To carry the maximum amount of cargo, bulk carriers are designed with a high block coefficient (Cb).
The hold shape gives the bulk carrier a self-trimming property which minimises the likelihood of a dangerous shift of cargo. The shape ensures that during discharge the last of the cargo tends to run to a position below the hatchway. Hatchways are large and decks are clear. Salt water ballast can be carried in the upper and lower wing tanks as well as double bottoms and peaks. In most cases the total deadweight in ballast is about 40% of the load deadweight, which gives a good bodily immersion.



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1.1 Bending moments and shear forces on bulk carriers

Because of the high centre of gravity of the ballast in the top wing tanks, the ship is not unduly stiff in the ballast condition but still possesses adequate stability. The fact that a lot of the ballast is disposed towards the sides rather than the centreline also helps to give the ship a desirable relatively slow and easy rolling motion on a ballast passage. The distribution of ballast throughout the length of the ship should ensure relatively small bending moments and an absence of high shearing forces.

For cargo purposes they will be given small elliptical or oblong hatchways suitable for loading grain. Openings can be arranged in the lower part of the sloped tank plating to allow discharge via the lower hold. These openings will have either bolted watertight cover plates or hinged dogged covers and there is usually one such opening in each web space.

Loading a heavy cargo or an ore cargo in alternate holds, or in some other non-regular way, has several advantages. The increased height of stow achieved by alternate hatch loading gives a more reasonable height for the centre of gravity and avoids extreme stiffness. Furthermore there are fewer holds to suffer damage and to clean. However, the bending moments which are set up can be quite high and the shearing forces are bound to be much larger than in the ship which has been loaded more uniformly. The relative lengths of the various holds (some ships have alternate short and long holds) have a bearing on the resulting stresses but scantlings will always have to be increased to take account of the irregular loading pattern.

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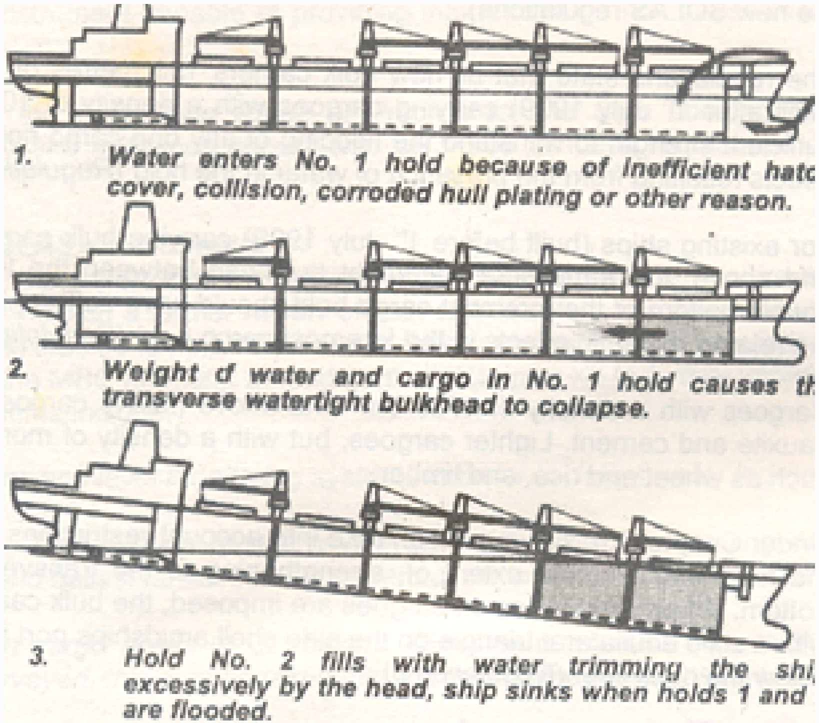
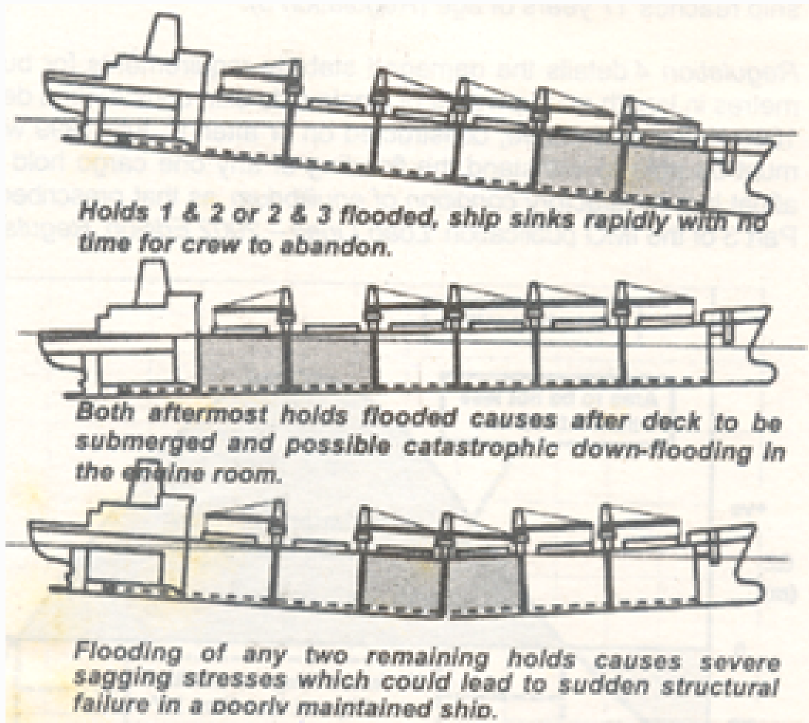
1.1 Bending moments and shear forces on bulk carriers





1. ASSESS REPORTED DEFECTS AND DAMAGES TO CARGO SPACES, HATCH COVERS AND BALLAST TANKS AND TAKE APPROPRIATE ACTION

1.1 Bending moments and shear forces on bulk carriers

Bulk carrier concerns

The modern bulk carrier is often described as being the workhorse of the marine transport industry, but in the early 1990's bulk carrier losses generated doubts as to their structural integrity as many ships sank rapidly due to catastrophic and sudden structural failure often with the loss of all lives of those on board. Single side skin ships were of particular concern.
A study into bulk carrier survivability was carried out by the International Association of Classification Societies (IACS) at the request of IMO. IACS found that if a ship is flooded in the forward hold, the bulkhead between the two foremost holds may not be able to withstand the pressure that results from the sloshing mixture of cargo and water, especially if the ship is loaded in alternate holds with high density cargoes (such as iron ore). If the bulkhead between one hold and the next collapses, progressive flooding could rapidly occur throughout the length of the ship and the vessel would sink in a matter of minutes.

IACS concluded that the most vulnerable areas are the bulkhead between numbers one and two holds at the forward end of the vessel and the double bottom of the ship at this location. During special surveys of ships, particular attention should be paid to these areas and, where necessary, reinforcements should be carried out.
The principlecausesof structural failure are wastage due to corrosion and fatigue stresses when the ship is atsea. Poor maintenance regimeswere a major contributory factor.

A further study into two-hold flooding by the U.S. Maritime Administration (MARAD) concluded that a mid-size bulk carrier should survive all one hold flooding scenarios provided that the ship was not suffering from steel corrosion wastage and undetected cracks but the flooding of any two adjacent holds would have disastrous consequences.

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1.1 Bending moments and shear forces on bulk carriers

Structural standards for bulk carriers

Bulk carriers are known to be more susceptible to structural failure than other similar sized ships, particularly when a hull breach causes water ingress into the cargo holds. The primary precaution however is still to vigilantly monitor the structure for any signs of deformation, fatigue or corrosion and apply preventive rather than reactive maintenance. Cargo operations should be carried out carefully, to ensure sufficient stability throughout the passage.

However, despite all these precautions, incidents on bulk carriers causing loss of both life and cargo have caused concern from the 1980s, leading to the development of new structural standards for bulk carriers.

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1.1 Bending moments and shear forces on bulk carriers

Shear forces and bending moments in still water conditions

Most large vessels are provided by their classification societies with maximum allowable still water values stated in the ship's loading guidance and stability information booklet and are included in the program of the ship's loading instrument or loading computers. These values are provided to ensure that the ship is not damaged by incorrect loading and must be calculated for every stage of a loading or discharge and of a voyage, and must never be exceeded.
Normally two or three sets of maximum values will be stated. The in-port values of shear forces and bending moments are the maximum to which a vessel can be subjected whilst in the 'still' (i.e. sheltered) waters of a port, where she is not exposed to swell conditions. It is permissible to incur a higher level of stress, (up to the in-port limits), during stages in the loading or discharging provided that the stresses are reduced to lower at-sea levels before the vessel puts to sea. The in-port values are higher than the at-sea values because the latter take account of the additional stresses to which a ship is subjected when moving in a seaway.

A ship which is strengthened for heavy cargoes may be provided with two sets of maximum allowable values for bending moments in at-sea conditions, with one being for "Alternate Hold Loading Condition" and the second set for the "Ballast or Uniform Hold Loading Condition". The lowest bending moment values are allowed when alternate holds are loaded, since this is the condition in which the greatest stresses are created.

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1.1 Bending moments and shear forces on bulk carriers

The shear forces and bending moments must be calculated before commencement of any of the following processes:

1. Planned loading and deballasting sequence.
2. Planned discharging and ballasting sequence.
3. Any change of ballast.
4. Any change in loading or discharging sequence.
5. Any distance when deballasting is delayed and becomes out of sequence with loading.
6. Any instance when ballasting is delayed and becomes out of sequence with discharging.
7. Taking of bunkers, step by step (i.e. tank by tank).
8. Consumption of bunkers, step by step (i.e. tank by tank).
9. Docking.

If the allowable values are exceeded there is danger that the ship's structure will be permanently damaged — it is even possible for the ship to break into two. The importance of completing the calculations and ensuring that the stresses are not exceeded cannot be stated too strongly. The most likely reasons for failure to comply with this requirement, and they must be avoided, are as follows:

1. Failure to understand the calculation.
2. Data provided in language which is not understood.
3. Computer breakdown.
4. Inability to make the manual calculations when the computer has broken down.
5. Stability data unreadable.
6. Change in loading/discharging program.
7. Pressure of work.
8. Negligent practices.
9. Commercial pressure.
10. Routine procedure undertaken without planning.

Small vessels up to and including handy size may be provided with no maximum allowable values or programs for calculating shear forces and bending moments. This is because the short length and comparatively greater scantling of a small vessel make it impossible to expose her to excessive values of shear force and bending moment unless she is jump loaded (loaded in alternate holds).

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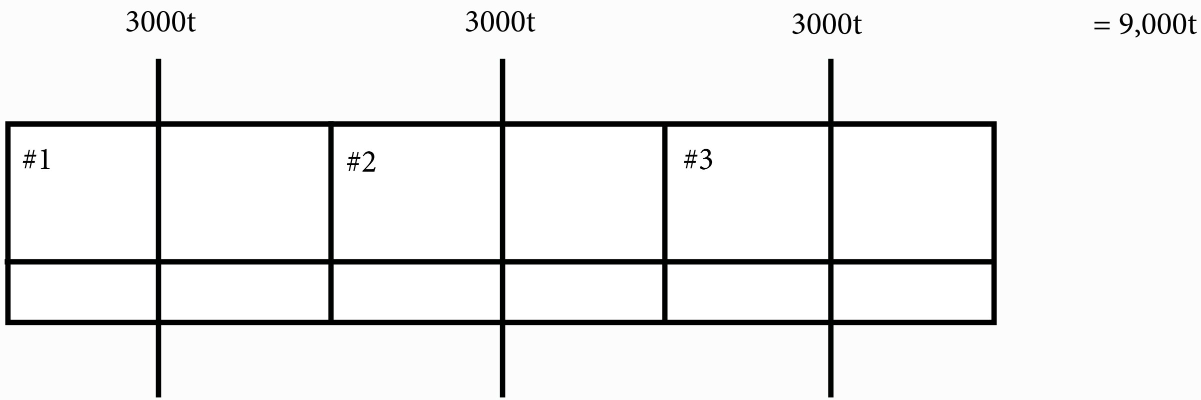
1.1 Bending moments and shear forces on bulk carriers

In still water a ship will experience shearing forces and bending moments as consequence of uneven distribution of weight forces and buoyancy forces acting along its length.

Consider a box-shaped vessel of uniform construction having three holds of equal length. The light displacement of the vessel is 9,000t and it is floating on an even keel.



The vessel will displace a mass of water equal to the displacement of the vessel in the light condition. The total weight force (Wf) acting downwards equals the total buoyancy force (8f) acting upwards. Since each of the holds are of the same length, the weight force attributable to each hold will be the same, being 3000 tonnes for each. The volume (and hence mass) of water displaced by each holdwill also be the same, 3000 tonnes. It can be seen that the distribution of weight force and buoyancy force exactly matches throughout the length of the vessel and in this condition the vessel's structure will experience no stress.

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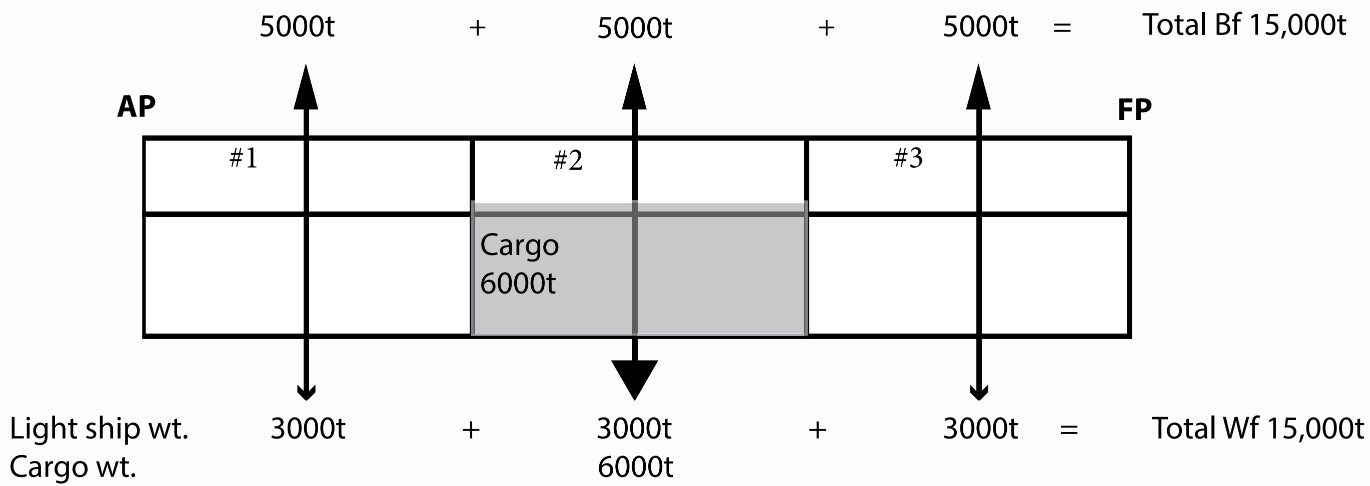
1.1 Bending moments and shear forces on bulk carriers



6000 tonnes of bulk cargo is now loaded into #2 hold and is trimmed level. The buoyancy force is evenly distributed along the length of the vessel, since 5.000 tonnes of water is displaced by each hold; however, the distribution of the weight force is not the same as can be seen.

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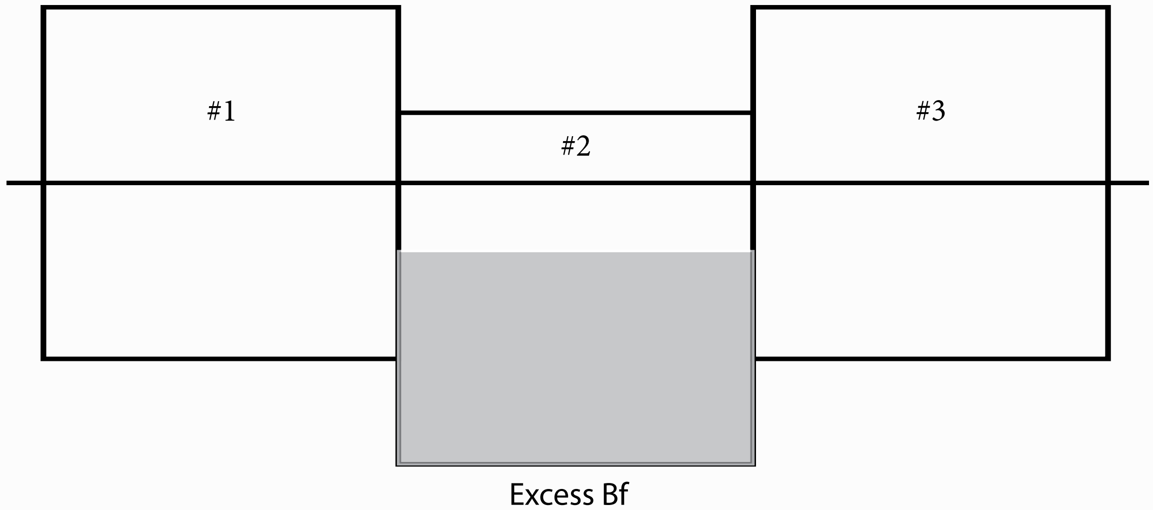
1.1 Bending moments and shear forces on bulk carriers



In numbers 1 and 3 holds there is an excess of buoyancy force of 2,000 tonnes, whereas in number 2 hold there is an excess of weight force of 4000 tonnes.

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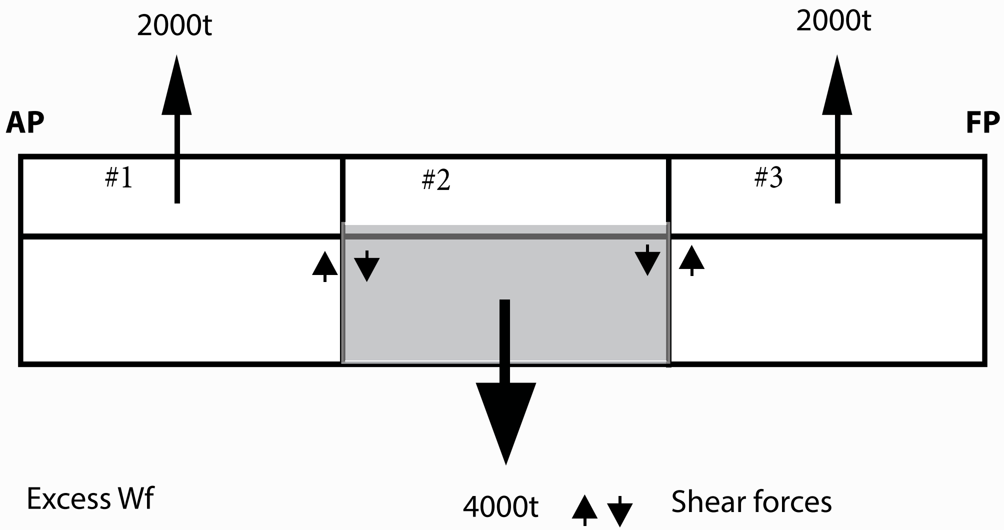
1.1 Bending moments and shear forces on bulk carriers



These excesses of weight forces and buoyancy forces create the shearing forces. The shearing forces are the vertical forces that tend to cause the ship to be sliced into different parts. Consider what would happen to the vessel if each hold could float independently of the others.

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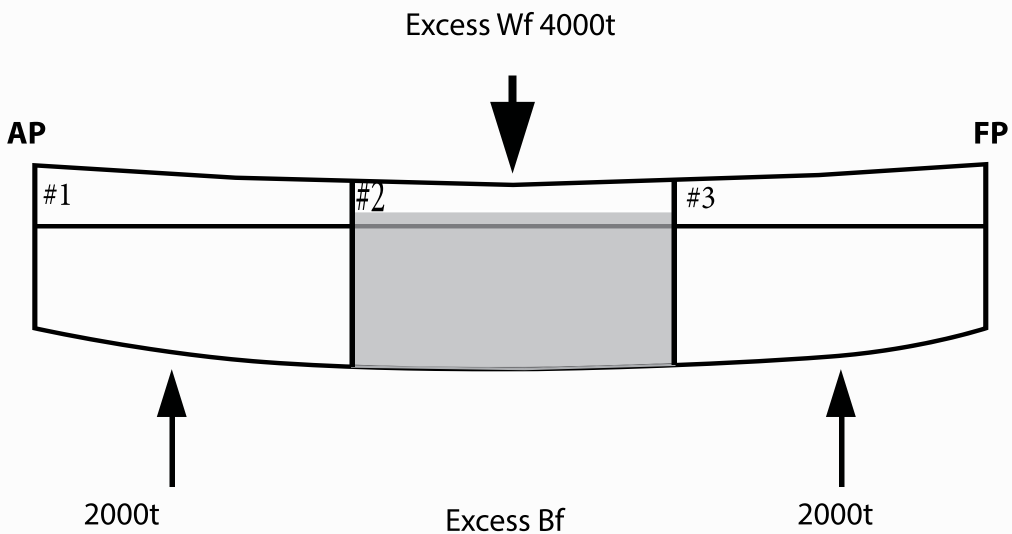
1.1 Bending moments and shear forces on bulk carriers



Sagging caused by loading the amidship only

It would be expected that the vessel would not shear at the bulkheads as illustrated; the ship would experience bending moments that in this instant would cause the vessel to be sagged. The opposite situation arises when a vessel is loaded at the ends and less in the amidships section, causing the vessel to be hogged.

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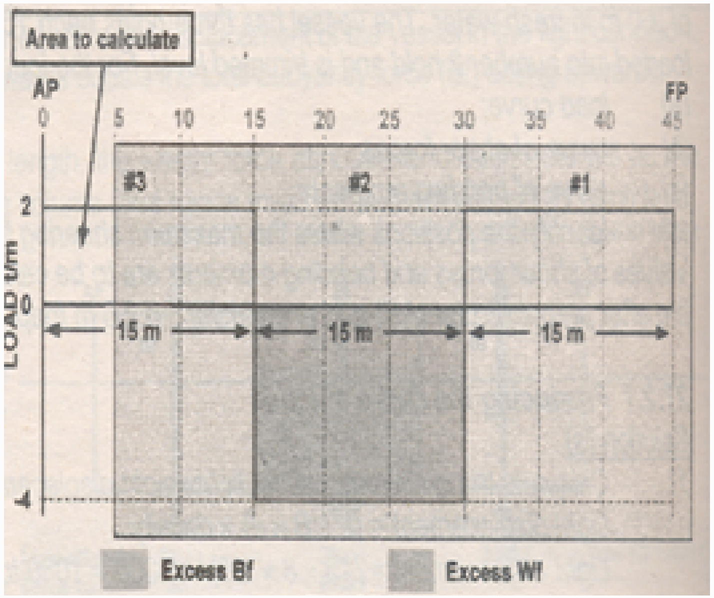
1.1 Bending moments and shear forces on bulk carriers

Producing the curve of shear forces

The shear force at any position is defined as being the algebraic sum of the loads acting to the left (or right) of the position in question and is measured in tonnes.
Integrating the load curve will produce the curve of shear forces but don't panic - there is an easy way to do this!
The maximum shear force values will arise at the positions where the loads change direction, being at the bulkhead positions.
Consider the aforementioned definition of shear force.



For our purposes this definition of shear force can be modified to read as being the area under the load curve to the left of the point in question.
Therefore: SF at AP = 0 tonnes (since there is no area to the left of the AP under the curve).

Placing a sheet of paper over the curve and moving it to the right at 5 metre intervals, calculate the net area to the left of the edge of the sheet for each point in question.

SF at 5 m foap = 2 t/m x 5 m = 10 tonnes.

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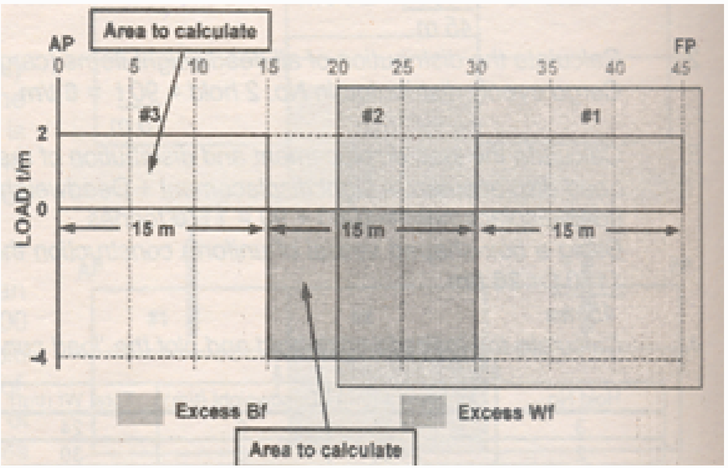
1.1 Bending moments and shear forces on bulk carriers



Now calculate the SF value at 10 m foap (by moving the paper further to the right and revealing more of the curve to the left.

SF at 10 m foap = 2 t/m x 10 m = 20 t

SF at 15 m foap (Bulkhead 3/2) = 2 t/m x 15 m = 30 t

At 20 m foap there is area revealed above and below the baseline and this is treated as positive and negative as per the load scale.

SF at 20 m foap = (2 t/m x 15 m) + (-4 t/m x 5 m) = 10 t

Continuing with this method gives:

SF at amidships (22.5 m foap) = (2 t/m x 15 m) + (-4 t/m x 7.5 m) = 0 t

SF at 25 m foap = (2 t/m x 15 m) + (-4 t/m x 10 m)= -10 tonnes.

SF at 30 m foap (bulkhead 2'1) = (2 t/m x 15 m) + (-4 t/m x 15 m) = -30 t

SF at 35 m foap = (2 t/m x 15 m) + (-4 t/m x /5 m) + (2 t/m x 5 m) = -20 t

SF at 40 m foap = (2 t/m x 15 m) + (-4 t/m x 15 m) + (2 t/m x 10m) = -10 t

SF at 45 m foap = (2 t/m x 15 m) + (-4 t/m x 15 m) + (2 t/m x 15 m) = 0 t

(Obviously the SF at the FP is 0 tonnes.)

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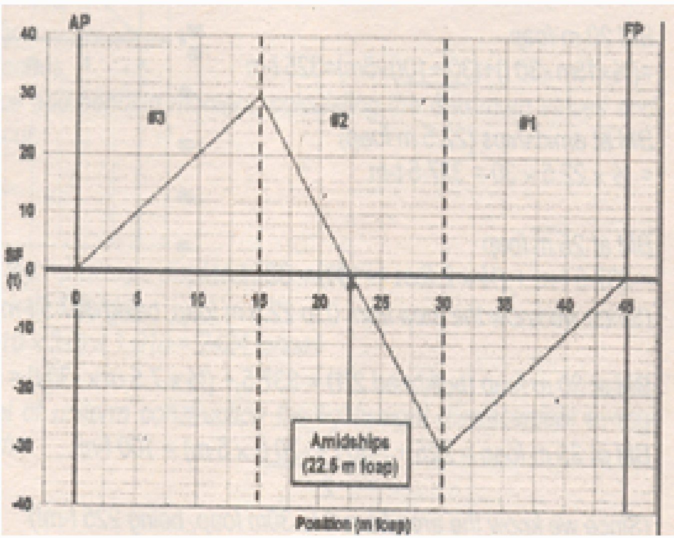
1.1 Bending moments and shear forces on bulk carriers



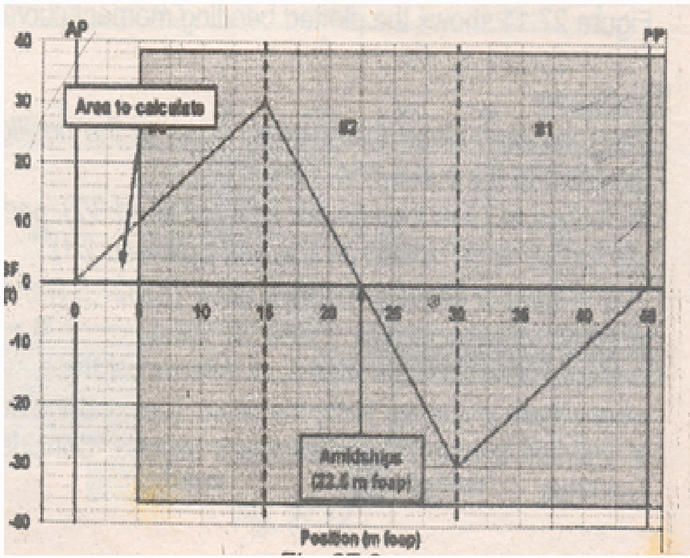
SF at AP =	0 tonnes
SF 5 m foap =	10 tonnes
SF 10 m foap =	20 tonnes
SF 15 m foap =	30 tonnes
(bulkhead 2/1)	
SF 20 m foap =	10 tonnes
SF 22.5 foap =	0 tonnes
(amidships)	
SF 25 m foap =	-10 tonnes
(bulkhead 2/1)	
SF 30 m foap =	-30 tonnes
SF 35 m foap =	-20 tonnes
SF 40 m foap =	-10 tonnes
SF 45 m foap =	0 tonnes
(FP)	

1. ASSESS REPORTED DEFECTS AND DAMAGES TO CARGO SPACES, HATCH COVERS AND BALLAST TANKS AND TAKE APPROPRIATE ACTION

1.1 Bending moments and shear forces on bulk carriers

Producing the curve of bending moments

The bending moment values are calculated in exactly the same way as the shear force values, by considering the areas under the shear force curve to the left of the position in question.



The area of a triangle is given by:
Area =1/2 Base x Perpendicular height
The area of a trapezium as shown is given by: Area = (a + b)/2 x base
The bending moment values are calculated as follows:
BM at AP = 0 tonnes (since there is no area to the left of the AP under the SF curve)
Placing a sheet of paper over the curve and moving to the right as far as the first bulkhead position (Bulkhead 3/2), calculate the areas as before.
BM 5m foap = ½ x 5m x 10 t = 25 t-m

BM 10m foap = ½ x 10m x 2 t = 100 t-m

BM 15m foap (bulkhead 3/2) = ½ x 15 m 30 t = 225 t-m

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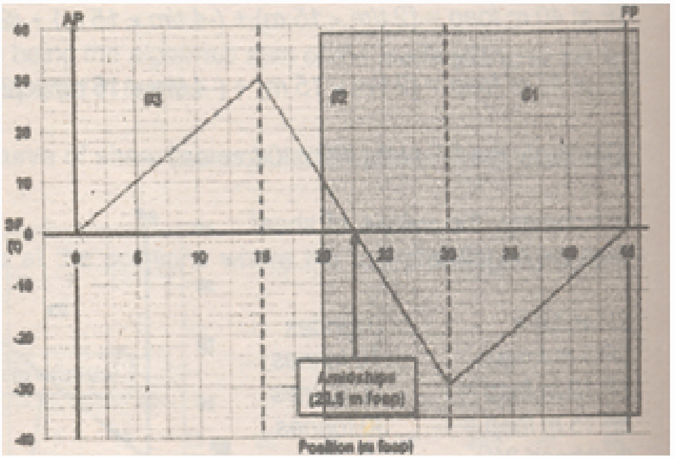
1.1 Bending moments and shear forces on bulk carriers



Once past bulkhead 3/2 it is necessary to consider the area of a trapezium formed by the area under the shear force curve to the right of the bulkhead as seen in figure:

BM 20 m foap = (1/2 x15mx30t) + [((30t+100)/2) x5m)] = 325 t-m

BM at amidships (22.5 m foap) = ½ x 22.5 x 30 = 337.5 t-m

BM at 25 m foap = 337.5 t-m + (1/2 x 2.5 m x -10 t) = 325 t-m

(Since we know the area from 0 to 22.5 m foap, being 337.5 t-m!)

BM at 30 m foap (bulkhead 2/1) = 337.5 + (1/2 x 7.5 m x -30 t) = 225 t-m

BM at 35 m foap = 225 + [((-30 t + -20 t)/2) x 5 m)] = 100 t-m

(Since we know the area from 0 to 30m foap, being 225 t-m!)

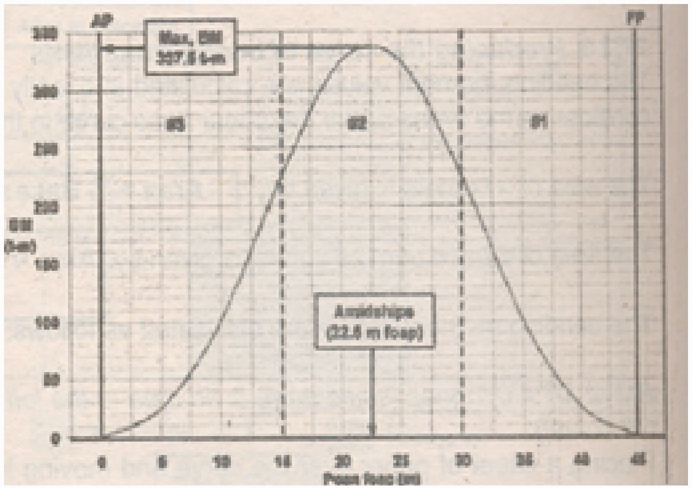
BM at 40 m foap = 225 + [((-30 t + -20 t)/2) x 10 m)] = 25 t-m

BM at FP =0 t-m

1. ASSESS REPORTED DEFECTS AND DAMAGES TO CARGO SPACES, HATCH COVERS AND BALLAST TANKS AND TAKE APPROPRIATE ACTION

1.1 Bending moments and shear forces on bulk carriers

In summary, the values of bending moment are as follows:



BM at AP=	0 t-m
BM at 5 m foap =	25 t-m
BM at 10 m foap =	100 t-m
BM at 15 m foap (bulkhead 2/1) =	225 t-m
BM at 20 m foap =	325 f-M
BM at 22.5 foap (amidships) =	337.5 t-m
BM at 25 m foap (bulkhead 2/1) =	325 t-m
BM at 30 m foap =	225 t-m
BM at 35 m foap =	100 t-m
BM at 40 m foap =	25 t-m
BM at 45 m foap (FP) =	0 t-m

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1.1 Bending moments and shear forces on bulk carriers

The maximum shear force values occur at the positions where the direction of the loads change direction; at the bulkheads being: 30 tonnes at 15 m foap (in line with bulkhead 3/2), and; -30 tonnes at 30 m foap (in line with bulkhead 2/1)

The maximum bending moment value of (337.5 t-m) occurs at amidships (22.5 m foap), where the shear force value is zero.
It should be noted that a point of inflexion of the bending moment curve will occur in any position where there is a shear force maximum (being at the bulkhead positions in this example).

Stress loading program representations

Calculation convetions

1. The ship profile considered is always for the starboard side (this is the accepted convention for all ship's plans);
2. Shear force and bending moment values where calculated starting from the after perpendicular (AP) working forward.

For the simple sagged and hogged conditions considered this gave shear force and bending moment curves as depicted in figure.
The convention used allows the condition of the ship, whether it be sagged or hogged, to be easily recognised. Quite often loading programme manufacturers might adopt this convention, however it is not crucial.
Had the shear force and bending moment values been calculated from the forward perpendicular working aft, then the same values would have been obtained, but the signs would be reversed to give a 'mirror' image of the curves using the convention that we have adopted.

1. ASSESS REPORTED DEFECTS AND DAMAGES TO CARGO SPACES, HATCH COVERS AND BALLAST TANKS AND TAKE APPROPRIATE ACTION

1.1 Bending moments and shear forces on bulk carriers

Stress calculating programs - systems requirements and data representation

Generally, ships over 150 metres in length and other ships that are likely to be subjected to excessive longitudinal stresses must be provided with a loading calculator to allow the values of shearing forces and bending moments to be calculated for any condition of loading. This will usually be in the form of a computer program that has been approved by the classification society whereby a certificate of approval will be issued. There are strict guidelines on the use and testing of such programs and compliance with the appropriate classification society regulations regarding such programs will be subject to verification during periodical classification society surveys.

The loading program should be capable of calculating the following hull girder shear forces and bending moments according to the appropriate classification society regulations:

1. Still water shear forces.
2. Still water bending moments.
3. Still water torsion moments, where applicable (mostly a requirement for container ships).
4. Sea-going condition shear forces.
5. Sea-going condition bending moments.
6. Sea-going condition torsion moments where applicable.

1. ASSESS REPORTED DEFECTS AND DAMAGES TO CARGO SPACES, HATCH COVERS AND BALLAST TANKS AND TAKE APPROPRIATE ACTION

1.1 Bending moments and shear forces on bulk carriers

Although the actual values of shear forces (in tonnes) and bending moments (in tonnes-metres) for positions along the vessels length will be given, these often have little relevance to the operator. It is the visual representation of the shear force and bending moment curves displayed along with the curves representing the maximum permissible values for both the harbour (still water) and sea-going conditions that will convey the true state of loading of the ship to the user.
This is a common form of representation adopted by many loading program manufacturers. It can be seen that the harbour (still water) limits are higher than those for when the ship is at sea. Provided that the shear force and bending moment curves do not extend into the red area leads that the ship will not suffer excessive stress in harbour. Once loading is complete it should be verified that the curves do not extend into the yellow area, representing the acceptable stress limits for when the ship is at sea. The limit settings will be determined by the classification society. Limits should be in the region of acceptable percentage of absolute maximum that the structure can withstand (around 80%). It should be noted that as the ship ages and the effects of corrosion start to take effect to weaken the structure, the maximum permissible shear forces and bending moments can be expected to reduce and this will require the program data to be modified to reflect this.

It will also be noted that a ship may experience both sagging and hogging at the same time in different parts in the length. This is particularly true at intermediate stages in a loading procedure and when alternate hold loading is required in the case of dense bulk cargoes. A typical fully loaded general cargo ship will invariably be sagged, whereby the aft and fore peak tanks will be empty (along with the excess of buoyancy force that will occur in the vicinity of the engine room) and cargo is in holds-extending forward and aft of the amidships region.

Finally, most loading programs include the ability to calculate the ship's stability also. However, it must be emphasised that the program must be approved by the classification society, and if provided it must be periodically checked by manual calculations. Testing procedures will be stipulated and must be followed.

1. ASSESS REPORTED DEFECTS AND DAMAGES TO CARGO SPACES, HATCH COVERS AND BALLAST TANKS AND TAKE APPROPRIATE ACTION

1.2. Corrosion, fatigue and inadequate cargo handling

Bulk Carriers structural problems associated with corrosion, metal fatigues & other operational factors

Deterioration of ship's hull / structure through corrosion, fatigue and damage is identified as a principal factor in the loss of many ships carrying cargo in bulk. Failing to identify such deterioration may lead to sudden and unexpected accident. Bulk carrier crews may be unaware of the vulnerability of these vessel types. The consequential loss of a ship carrying heavy cargo can be expected to be very rapid, should a major failure occur.
The following structural problems are associated with bulk carriers:

- Ships corrosion
- Metal fatigue
- Operational factors

Ships corrosion

Ships are built of steel, which in a marine environment exposed to water (both fresh and sea) and air is prone to the formation of rust. Contributing factors that accelerate the rate of corrosion include:

1. Cargo damage - this occurs when heavy bulk cargo is allowed to freefall from height onto the tank tops. The heavy impact of this cargo on the tank top causes damage and breakdown of the coatings on the ceiling of the double bottom tank underneath
2. Corrosive cargoes - a number of bulk cargoes contain chemicals of a corrosive nature and this is particularly the case in newly mined coal. It is essential that the data sheet is inspected prior to loading the cargo. For example, in the case of a high sulphur contact coal cargo, severe pitting can result. To counter this, the hold floor can be coated in lime, but this does not protect the bilges or bilge lines

1. ASSESS REPORTED DEFECTS AND DAMAGES TO CARGO SPACES, HATCH COVERS AND BALLAST TANKS AND TAKE APPROPRIATE ACTION

1.2. Corrosion, fatigue and inadequate cargo handling

3. equipment damage - grab damage to the hold floor, frames and ladders can occur at most discharge ports. This not only causes material damage to the ship's structure, but can also break down the paint coatings exposing the base steel to the atmosphere. The deliberate hammering of the floor and sides of the hold by grabs and bulldozers to free cargo residues trapped between the frames will result in structural damage and the breakdown of the paint coatings

4. seawater corrosion - in the majority of cases, this will take place in the ballast tanks. Many companies now place sacrificial anodes in the ballast tanks, which considerably reduce the corrosive effect of air and saltwater

5. under SOLAS Chapter II-1 double side skin spaces must be provided with a compliant protection coating.

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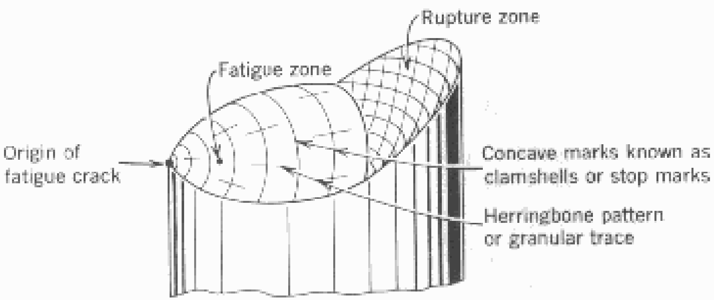

<u>Metal fatigue</u>

The weakening of the steel in a structure due to constant flexing, under the repeated cycles of stress may result in structural fatigue failure. The concern about fatigue failure is that it occurs without any apparent forewarning (eg. deformation of a structure that results in a crack). Fatigue usually begins at welded joints, notches, discontinuities in structures and areas of high rigidity in particular. However, variations in the size, shape and design of each component and the conditions that the ship operates mean this may not necessarily result in a structural failure. Areas where extra vigilant inspection is recommended include:

1. The brackets at the connection of frames to the upper and lower wing tanks

2. the upper and lower connection of corrugated transverse bulkheads

3. corners of the hatch coamings where they are joined to the main deck.

1. ASSESS REPORTED DEFECTS AND DAMAGES TO CARGO SPACES, HATCH COVERS AND BALLAST TANKS AND TAKE APPROPRIATE ACTION

1.2. Corrosion, fatigue and inadequate cargo handling

Bulk carriers in particular become progressively weaker due to continuous corrosion. In addition, the repetitive cycles of changing loads and the resulting stresses due to hogging, sagging, panting, pounding and vibration all increase fatigue. High tensile steel (which is stronger than mild steel) is used in all areas likely to experience high levels of stress. It means that scantlings can be reduced but the vessel will still have higher strength and resistance to stresses, eg. slamming due to heavy pitching that may cause fatigue on the forward section of the hull.

It is recommended that, as soon as any cracks are seen, arrangements are made immediately to repair them. Where possible, a crack arrestor hole should be drilled at each end of the crack before any temporary repair is made. If the extent of the crack is not evident, a detector dye can be used to establish this. As soon as possible, Class should be called for a survey to make a permanent repair because a crack that is overlooked may become a central point for localised stress resulting in structural failure. A crack may also damage protective coatings such as paintwork, creating an `open' area for corrosion.

While cracks may not initially be apparent, corrosion in any area should be carefully checked for signs of minor cracks, particularly if there are dents in the structure.

1. ASSESS REPORTED DEFECTS AND DAMAGES TO CARGO SPACES, HATCH COVERS AND BALLAST TANKS AND TAKE APPROPRIATE ACTION

1.2. Corrosion, fatigue and inadequate cargo handling

Operational factors

Corrosion and fatigue will gradually weaken the hull over time. This can be increased by variations in loading patterns and particularly heavy density cargoes such as iron ore.

Another factor that gradually weakens a ship's structure is the abrasive and corrosive nature of bulk cargoes such as coal, which can cause unintentional damage to cargo hold coatings. Areas such as welded frame joints with tanktop or deck plating are very likely to develop corrosion and subsequently crack if the coatings are damaged.

Other factors include:

- Liquefaction of cargoes, caused by water ingress or moisture in the cargo, can cause cargo shift during the voyage
- movement of ballast water in partly filled ballast water tanks or holds can cause damage and create corrosion. To avoid this, tanks and holds should be completely filled.

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1.2. Corrosion, fatigue and inadequate cargo handling

Precautions to bulk carriers hull corrosion, metal fatigues & other operational factors

Deterioration of ship's hull/structure through corrosion, fatigue and damage is identified as a principal factor in the loss of many ships carrying cargo in bulk . Failing to identify such deterioration may lead to sudden and unexpected accident. Bulk carrier crews may be unaware of the vulnerability of these vessel types. The consequential loss of a ship carrying heavy cargo can be expected to be very rapid, should a major failure occur.
The following precautions associated with ships structural problems need to be considered:
Solas Chapter XI-1, requires bulk carriers to comply with the enhanced survey programme (ESP) of inspections, including regular inspection of the cargo hold by ship's personnel. However, owing to the time constraints in port, ships' manning levels and charterers' requirements, it is recognised that this may not always be feasible.

Findings by the ship's officers should be reported to the owner immediately so that a subsequent detailed inspection may be carried out by expert surveyors and repairs effected as necessary, if possible when cargo discharging is complete. A close inspection should be made for any damage to the structure of the ship and the coatings caused by stevedores. There are times during discharge when an impact caused by the grabs is heard and a tremor is felt through the ship. On such occasions, an inspection of the hold should take place. Areas particularly susceptible to damage include:

- Ladders
- pipe guards
- manhole and bilge covers
- hatch coamings
- compression bars
- ship's rails.

1. ASSESS REPORTED DEFECTS AND DAMAGES TO CARGO SPACES, HATCH COVERS AND BALLAST TANKS AND TAKE APPROPRIATE ACTION

1.2. Corrosion, fatigue and inadequate cargo handling

This damage can easily be identified and should be repaired before departure. Officers observing such damage should immediately put the foreman on notice of their obligation to repair the damage. A stevedore damage report form should be completed.

To overcome the problems associated with operational factors such as stresses during loading and discharging, the ship's officers should prepare and plan a sequence for loading/discharging and deballasting/ballasting. Contingencies should be planned by identifying hazards and carrying out and documenting risk assessments. The control measures identified in risk assessments should be closely monitored.
A thin layer of high density cargoes should be spread on the tank top before fixing the loader in a central position within the hold. This will help protect the tank top from damage.