Containerised Cargo – Stowage and Securing

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Introduction

With the number of high profile container losses currently making the International news on an almost weekly basis, with vessels reportedly losing thousands of containers in an incident, particularly in the North Pacific, the Club considers it a timely opportunity to focus on some of the issues associated with cargo stowage and securing. These, and past incidents, have influenced campaigns by various agencies to ensure that there is some measure of control put in place to verify the cargo loading, distribution and securing arrangements on container ships.

This Risk Alert is intended to highlight some of the different types of incidents and provide consideration of likely contributory causes.

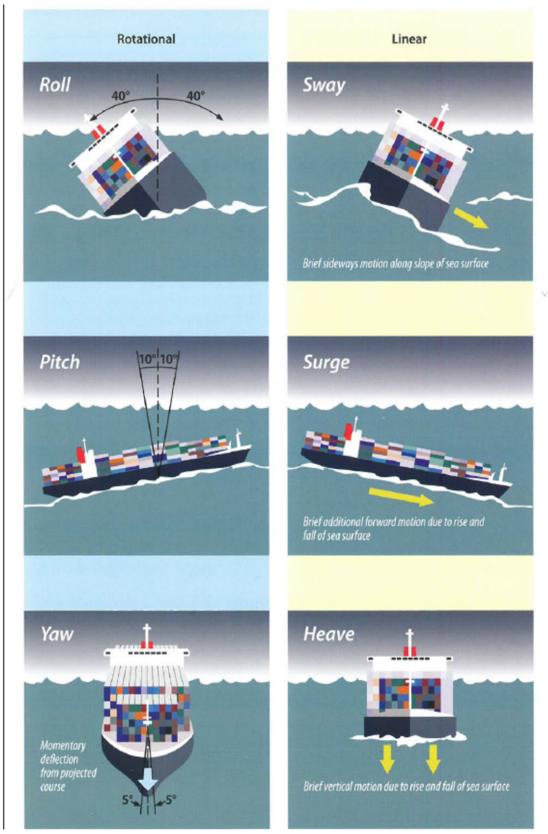
Considerations

Simply put, when a container ship is at sea there are forces acting in the longitudinal, transverse and vertical axes of the ship and consequently these forces are also acting on the cargo on board.

The Cargo Securing Manual (CSM) is designed to ensure that cargo transport units carried on or under deck are loaded, stowed and secured adequately such as to prevent any damage or hazard to the ship and the persons on board, and any damage or loss of the cargo. Additionally, container vessels use class approved loading software that considers the vessels' stability information and the distribution of cargo to evaluate the adequacy of lashing and securing arrangements in relation to the stowage and stability condition.

Each cargo container, unless empty, is affected by the nature of the cargo and the manner of securing the cargo inside the container. This will in turn influence how the containers interact with adjacent containers and the overall behaviour of the stack.

Strength, condition and application of securing gear, together with strength, condition and availability of strong points on the vessel, will be further influenced by the motion and vibrations of the vessel (in reaction to the weather and sea condition encountered).



Ships motions in heavy seas – MAIB REPORT NO 2/2020

Loads experienced by the securing gear and the securing points in a seaway will vary. The integrity of the equipment or the strong points used for securing will further depend on the condition and manner of application.

It should be remembered that the container itself forms an integral part of the composite structure created as a result of the stowage and securing plan. The structural integrity of the container is, therefore, also of great importance to the overall integrity of the lashing system – the container should not form the weak-link in the overall lashing plan.

The vertical compression forces within a stack (container masses and motion induce acceleration forces) act on the container corner posts. When a ship rolls, the lower containers in the stack are subjected to horizontal sideways (racking) forces. This movement is resisted by the container rod and turnbuckle lashings. As a container stack is subjected to a transverse force, the outside corner of the container(s) within the stack will be subjected to tensile loading.

If the force is excessive then the twistlock can be pulled out or, the container corner casting damaged.

A combination of factors such as the stowage plan, condition and strength of the various elements of this composite structure, vessels stability condition, environmental conditions and ship handling will all have a collective impact on the effectiveness of the cargo stowage and securing.

Stowage planning is done primarily ashore by cargo planners and needs to be verified on board. Collective awareness, coordination and cooperation between the different parties is essential to facilitate effective and safe planning of the stowage and securing of the cargo.

Some broad considerations when planning effective stowage and securing are:

Container fitness
- Type / Purpose / Specifications
- Verification of CSC plate (safety limits – payload, stacking load, racking force)

Note: It is recognised that while being loaded or when stowed at a high tier it may not be possible for the ship's crew to perform a close-up inspection of every container. However, even from a distance, visually conspicuous conditions that might indicate potential issues should be discernible.

Visual monitoring could pre-empt risks due to:
- structural damage to container frame (including corner posts, cross members, top/bottom/side/end rails, corner fittings, forklift pockets)
- visible signs of significant corrosion / deterioration in plate thickness of strength members
- side/back wall panels – bulged, torn, temporary patches or other signs such as leaks, spills that may be indicative of a structural failure or poor stuffing and securing of cargo within the container

Fitness of cargo lashing gear, hatch covers and fixed appurtenances including:-
Lashing bars, hooks, turnbuckles, twist-locks, base-locks, cell guides, pad eyes, ISO sockets, actuator poles, hatch covers and hatch cover securing arrangements
- Operational limits - SWL (safe working load)
- Condition - Inspection, Maintenance, Lifecycle (where applicable)

Cargo stowage and securing
- Stack load / Maximum load (tank-top/hatch cover/deck plate)
- Load distribution / Centre of gravity
- Windage area / Wind load / Pyramid stack
- Streamlined vs unbalanced cargo distribution - Stack interactions / Isolated Tall Stacks / Exposed Stacks / Heavy over light
- Stack weight
- Racking stress
- Securing arrangements – sufficient availability
- Correct application of lashings (such as following the lashing plan correctly, position and tightness of turnbuckle check nuts, proper rigging (no overloading of securing points)
- Lashing patterns and wind lashing

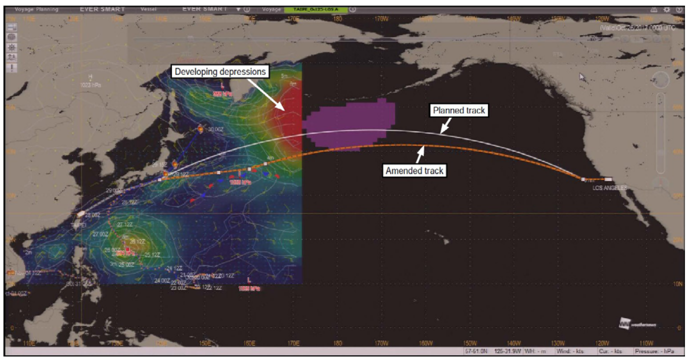
Stability condition
- Metacentric height (GM)
- Roll period
- Deadweight / Draught / Trim / Propeller immersion

Voyage planning
- Forecast
- Weather routeing and Passage planning
- Allowances for environmental conditions such as ice accretion
- Effects of Speed, motion, vibrations & accelerations such as:
  - Roll, Sway, Pitch, Surge, Yaw, Heave
  - Parametric rolling
  - Resonance frequency
  - Whipping or springing accelerations
  - Hull vibrations and effect on lashing gear
  - Lifting forces

Other considerations
- Vessel design
- Misdeclaration of cargo weights / contents

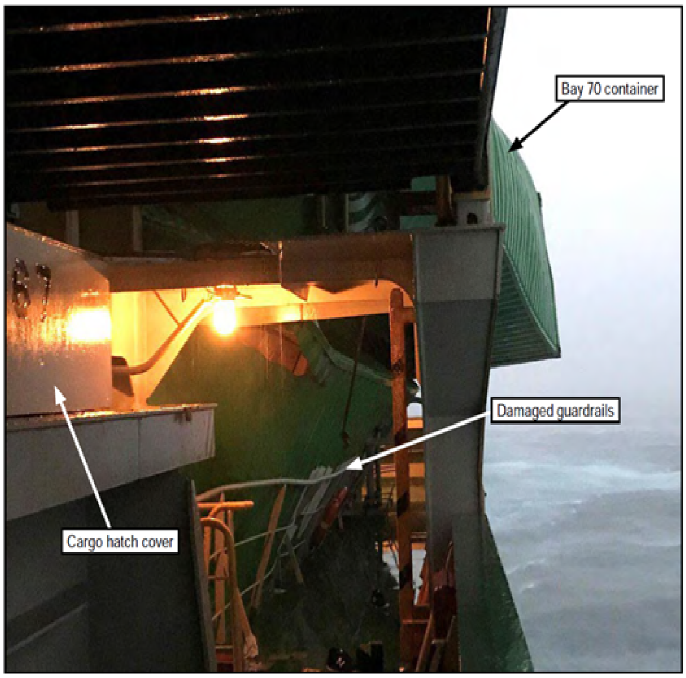
Case study
The following case extracts are intended to highlight interesting aspects of container losses that should be considered along with the likely causes. It is not the Club's intent to make any comment or judgement on the causation as may have been determined by the investigators or the presumption of any liability.

Case 1 – Stack collapse – Loss of 42 Containers at sea (heavy weather)
Ever Smart - Taipei, Taiwan to Los Angeles, USA / 700 miles east of Japan, North Pacific Ocean - Oct 30, 2017



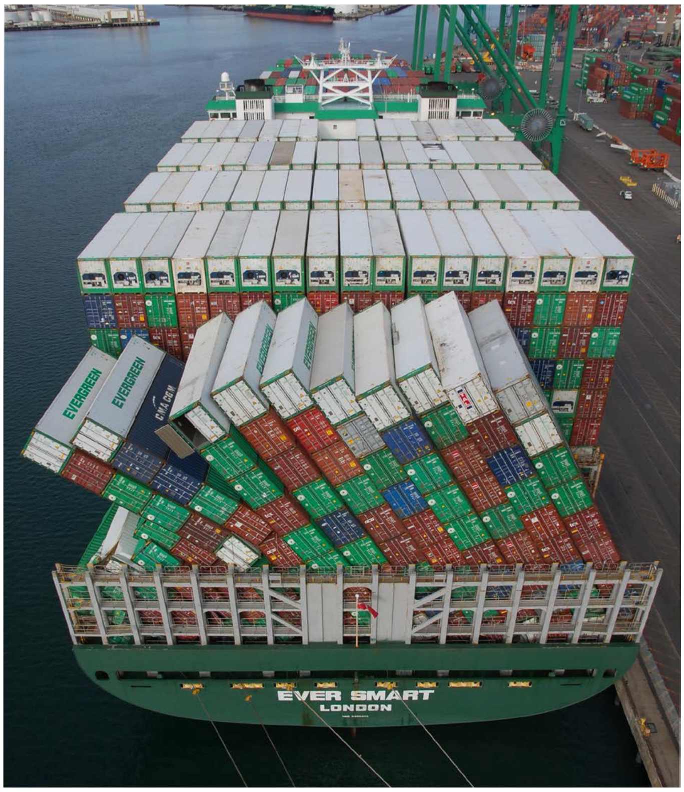
Vessel's Track (local time): Ref: MAIB REPORT NO 14/2020

Master had changed the ship's passage plan to avoid severe weather caused by a developing depression east of Japan. The ship continued in heavy seas; **rolling and pitching heavily with frequent bow flare slamming**.



View from main deck: Ref: MAIB REPORT NO 14/2020

Once the weather had abated, the crew discovered that the container stacks on the aft most bay had collapsed and toppled to port. Of the 151 containers in the stow, 42 were lost overboard and 34 were damaged. Superficial damage was caused to the ship.



Stern: Ref: MAIB REPORT NO 14/2020

As per the investigation report following was noted:

- **Combination of factors** - container weight distribution, container lashing arrangements, effect of prevailing weather and the ship's motion
- Master's **course and speed alterations were effective** in avoiding the worst of the weather and reduced hull vibrations. Roll amplitude remained well below the calculated maximum and the frequency of stern shaking was reduced.
- Stack collapse **probably initiated** by a lashing system or structural container failure in bay 70's starboard outer stack
  - Many lashing rod turnbuckle **lock nuts not applied**
  - Likely that the incident occurred when the hull vibrations and frequency of stern shaking were at their worst (vibration probably the result of whipping forces transferred through the hull as the ship's bow slammed into the sea)
- **Stowage plan - not complying with CSM**
  - Container **weight distribution** not in accordance with stack weight tables;
  - Outer stacks – **hi-cube containers loaded eight-high** >> **higher centre of gravity** for stack >> **increased acceleration forces** on containers and lashings, **increased windage area** of the outer stacks;
  - **Ship's GM exceeded** that used by the CSM to calculate stack weight limits, weight distribution and lashing patterns in the aft bays when loaded to maximum capacity;
  - **Weights in upper tiers more** than stack weight table values and weights in lower tiers much reduced >> **higher centre of gravity** for stack >> **increased acceleration forces** on lashings and bottom containers
  - Ship's **loading computer alarms/warnings** for overloaded lashings were ignored
- **Gale force wind** was acting directly on the starboard outer stack, and its effect would have been significantly amplified due to the increased height and lack of the additional wind lashings prescribed in the CSM

There were other issues noted that did not directly contribute to this incident, some of these are:

- **Defective lashing and securing gear** – Some twistlocks used to secure the containers in bay 70 were corroded - should have been discarded
- **Corroded container at the bottom** – One container stowed at the bottom of the starboard outer stack was the only container in the stack to suffer buckling damage and it was corroded

MAIB REPORT NO 14/2020

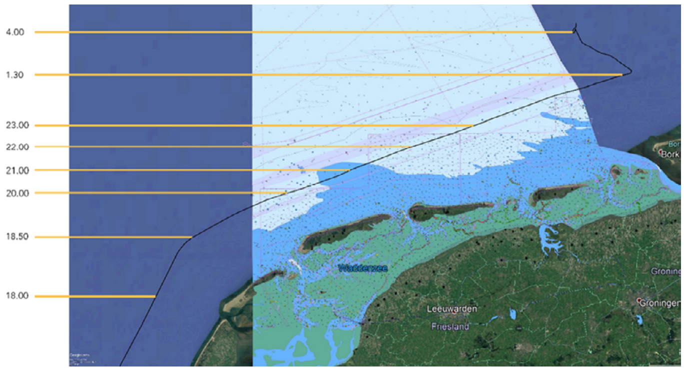
Case 2 – MSC Zoe - Stack collapse – Cargo overboard - washed ashore – Environmental damage / Clean-up

On passage from Sines, Portugal to Bremerhaven, Germany - While sailing along the North Sea Traffic separation scheme (TSS) Terschelling – German Bight January 1 & 2 2019 vessel lost 342 containers overboard.

On 1 January 2019, vessel observed wind speeds increasing from 4 to 5 Bft during the day up to 8 Bft by around 1800 hours. At 1850h as the vessel changed course to starboard to enter the southern track of the Terschelling - German Bight TSS the wind increased to force 9 Bft. Vessel was on manual steering and rolling between 5 and 10°, with occasional 15° peaks. At 2300h, the vessel suddenly started to roll violently (20° - 30°), for around 30 seconds.

These violent movements caused equipment to shift in the fitness area and on the bridge. The vessel returned to the previous 5 to 10° roll soon after, the speed at the time was 8 - 10 kn.

Starboard side: Ref: [Joint investigation report - MSC ZOE 01 - 02 January 2019]



Track of MSC ZOE (time indication local time): Ref: [Joint investigation report - MSC ZOE 01 - 02 January 2019]

At 0100h on 2 January 2019, when looking aft, the Master noted several containers were no longer visible in the expected position. Upon shining an Aldis lamp it appeared that several containers had fallen over. During a subsequent inspection several containers were noted to be hanging overboard.

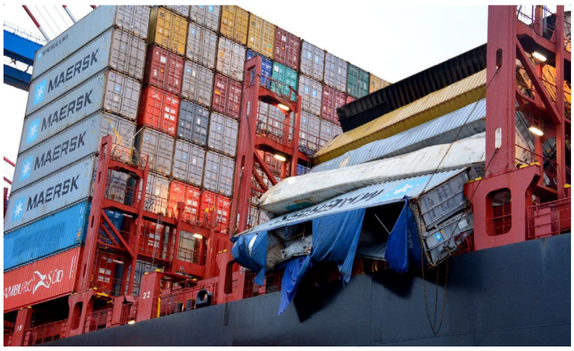
At 0130 hours, the vessel once again experienced a short period of severe rolling of 20° - 30° at which time containers from bay 26 collapsed and fell overboard. German Bight Traffic was notified, course changed from 074° to 315° and speed reduced to 2 kn (to direct the vessel into the wind and waves and stabilize the motion).

Attempts to assess the damage was difficult due to the darkness and fallen containers on deck obstructing access. Containers in bay 58 were noted to have collapsed and were hanging overboard and a similar situation was noted in bays 10 and 26.

At daybreak vessel noted that 2 hazmat containers were missing, and 1 hazmat container was hanging half over the starboard side.

View from top: Ref: [Joint investigation report - MSC ZOE 01 - 02 January 2019]

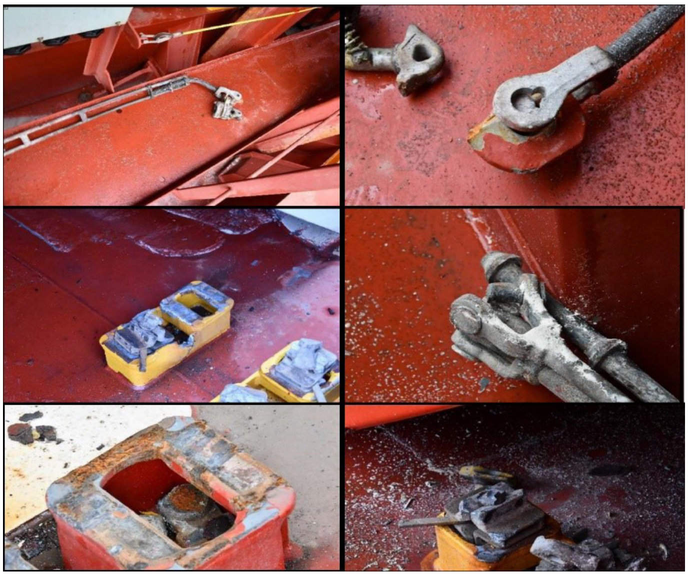
Crew retightened loose lashings. Various loose parts of the lashings were noted, including tensioners from the lashing rods, hooks and locking pins, some twistlocks were noted broken in two.



Container with polystyrene balls hanging overside Bay 26: Ref: [Joint investigation report - MSC ZOE 01 - 02 January 2019]

The vessel moored in Bremerhaven, at 0100 hours in the morning of 3 January 2019.

Damage to vessel:
Bays 10 (9/11), 26 (25/27), 50(49/51) and 54(53/55) were severely damaged and temporarily decommissioned. Damage was noted to several handrails, lashing bridge structures, fire valves, ventilation openings and hatches. The vessel also suffered a series of minor dents in the hull above the waterline.

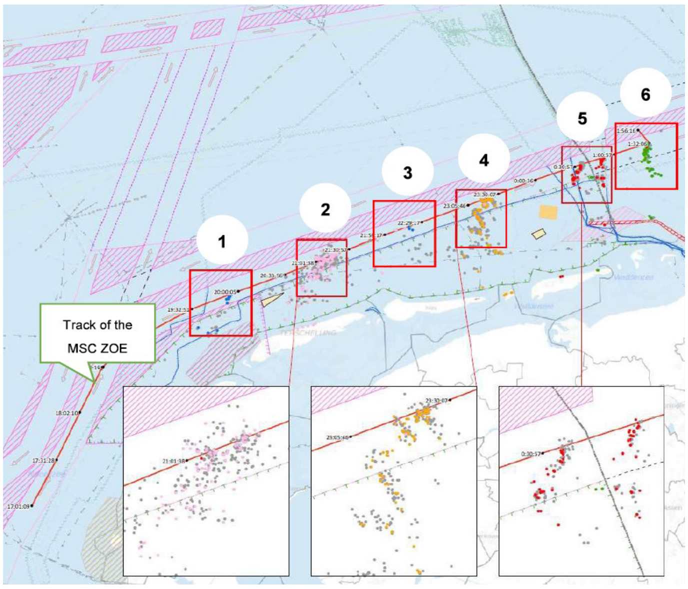


Broken lashings (Source: German water police) : Ref: [Joint investigation report - MSC ZOE 01 - 02 January 2019]

None of the damage, however, impacted the seaworthiness of the vessel such as to prevent sailing to its subsequent port of destination. On 16th January 2019, the vessel sailed for Gdansk to discharge the remaining cargo and undertake a detailed assessment of the damage.

Environmental damage:

- Impact on the Dutch and German coasts, marine life and environment attracted considerable public concern in the Netherlands and in Germany.
- Debris sank or washed ashore as the fall from height and the waves destroyed most of the containers.
- Seabed survey identified more than six thousand objects.
- 2 of the lost hazmat containers contained IMDG cargo of Class 5 (Oxidising Agents and Organic peroxides) and Class 9 (lithium-ion batteries).
- Loss of raw materials destined for the plastics industry (Millions of small particles of plastic dispersed by wind and difficult to remove from the environment).



Six main recovery locations of lost containers. Ref: [Joint investigation report - MSC ZOE 01 - 02 January 2019](#)

Cargo Debris on Wadden Island: Ref: [Joint investigation report - MSC ZOE 01 - 02 January 2019](#)

As per the investigation report the following was noted:
The vessel experienced four different hydrodynamic phenomena, either individually or in combination, that played a role in the loss of containers:

- Extreme motions and accelerations;
- Contact or near contact with the sea bottom;
- Green water;
- Slamming.

The effects of a **high GM** of 9.01m were underestimated. In a scenario with beam seas, shallow waters and severe weather conditions this resulted in strong ship movements and increased transversal accelerations close to the design limits, thereby, leading to failure of the container structure and/ or the lashing equipment and subsequent container loss.

Shorter roll periods were closer to the wave periods estimated, resulting in larger **resonant roll motions** in the beam seas.

Insufficient roll damping capability of the vessel in situations with high GM.

Low UKC clearances of 5m were observed during the Terschelling - German Bight TSS transit. While the diver inspection did not reveal any signs of contact with the seabed, there is a possibility of **soft contact with the sandy sea bottom** when transiting the shallow section of TSS, which would have caused a propagation of additional **vibrations and deformation stresses** due to the **flexural response** of the ship.

Investigation determined that the maximum roll angle was likely in the order of 16° - the observed deflections of 30° on the **mechanical inclinometer** could be attributable to the instrument's inherent **sensitivity to accelerations**, consequently insufficient for an insight into the dynamic roll angles the ship experienced. Electronic inclinometers or similar (inertia) systems can measure and display this information in real-time and this data could also be captured by the VDR.

The Loading computer shown to investigators had red boxes indicating excess of lashing and securing tolerance limits. Per the report – there were 6 possible reasons for displaying red boxes:

- Racking force
- Side wall racking force
- Vertical tension
- Vertical compression
- Corner post load
- Shearing force at twistlock

It could not be determined how these excess of tolerance limits had been recognized and addressed.

The first loss of containers was not noticed by the crew. This is an undesirable event since necessary mitigating actions could have been taken and further container losses possibly avoided.

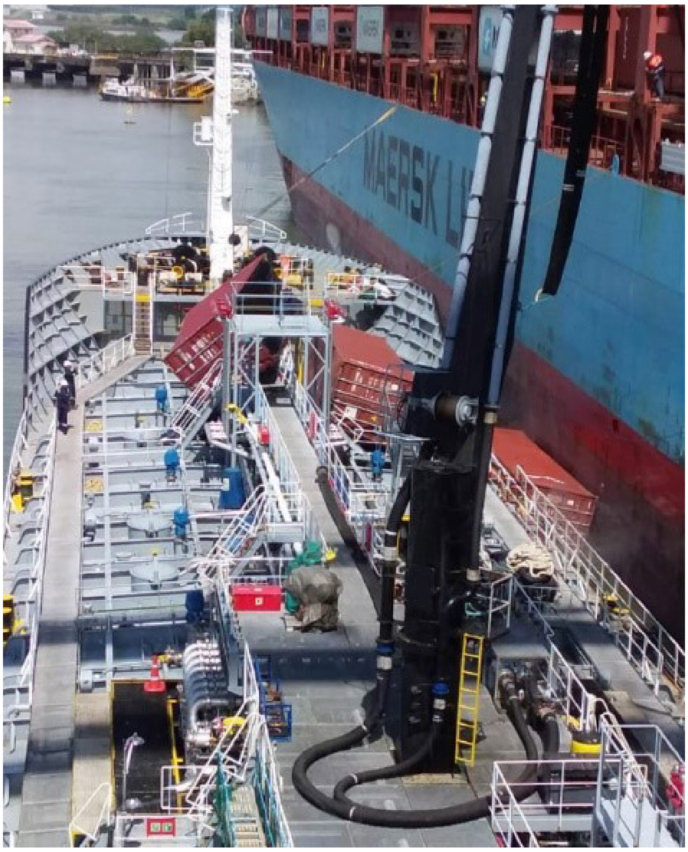
The investigation revealed that the concept of the lashing of containers on deck of these large and wide ships needs to be reviewed and international technical and operational standards to be amended or developed where necessary.

There are currently no specific requirements or restrictions for (large) container ships for such routes through areas designated as a Particularly Sensitive Sea Area and a UNESCO World Heritage.

[Joint investigation report - Container overboard from the MSC ZOE 01 - 02 January 2019]
[Joint Investigation Report - Annex C]
[Joint Investigation Report - Annex D]
[Joint Investigation Report - Annex E]

Case 3 - Containers toppled during cargo operations – Containers fell from Charlotte Maersk on bunker barge (Kollum) alongside

Panama City - Nov 6, 2018: Three containers fell from container ship during cargo and bunkering operations.



2 containers on deck / 1 container between the vessels Ref: FLEETMON - Containers crashed on bunker tanker from MAERSK container ship

Two containers landed on the bunker tanker KOLLUM, moored alongside the container ship (Charlotte Maersk) and one container fell into water between the vessels.

Bunker tanker sustained some damages, but thankfully, no injuries were reported, and the containers landing on the deck didn't spark off a fire.

FLEETMON - Containers crashed on bunker tanker from MAERSK container ship

Possible cause

Stack collapse or falling containers when alongside a berth during cargo operations is possible since during this period (loading discharging of containers) the twist-locks/ base locks of the bays being worked would ordinarily be in an unlocked position and the cargo lashings removed.

The loading/discharging operations on large container vessels in a container terminal would ordinarily be carried out at a very fast pace using gantry cranes. The operators of these gantry cranes need to be very focussed and exercise extreme caution during this time especially when operating in proximity of stacks close to the shipside or when operating near tall slim towers.

Other noteworthy cases –

UNLOCKED MIXED GEAR

Fehn Mistral - 8 miles south east of Start Point, Sanday Island, Orkney, Scotland - 29 December 2006
Lost 20 containers overboard while other containers toppled from their stowed position onto deck during heavy weather (force 9) at sea - **Several twistlocks were later noted to have been left in open position** during the passage (vessel had a **mix of left handed and right handed twistlocks**).
Ref: MAIB report - Fehn Mistral

MAXIMUM ALLOWABLE STACK WEIGHT EXCEEDED

1. Annabella - Baltic Sea - 26 February 2007
The collapse of cargo containers occurred as a result of downward compression and racking forces acting on the lower containers of the stack, which were not strong enough to support the stack as their maximum allowable stack weight had been exceeded.
The total weight of the seven containers in the stack was 225 tonnes. The cargo securing manual indicated that the maximum permissible stack weight for 30 foot containers loaded in this location was 150 tonnes. Furthermore, the lower four containers in the stack each had a maximum allowable stacking weight of approximately 100 tonnes.
Ref: MAIB Report No 21/2007

Looking down on the aft end of the collapsed stack of containers, Ref: MAIB Report No 21/2007

Crushed container at the bottom of the stack, Ref: **MAIB Report No 21/2007**

2. Dutch Navigator – Bilbao to Avonmouth - 25-26 April 2001

The investigation found that the masses of each of the three stacks of containers in Bay 1 of Dutch Navigator exceeded the limits set out in the vessel's cargo securing manual. This resulted in the lower containers being subjected to racking loads, greater than their design value, while the vessel was on passage. A damaged tank container was one of these at the bottom of a stack and was severely damaged. Further, both tank containers were over-stowed, which is not in compliance with the International Dangerous Goods Code and UK Regulations.
Ref: MAIB Report No 37/2002

Damaged front end frame - Ref: **MAIB Report No 37/2002**

Stow in Bay 1 looking forward - Ref: **MAIB Report No 37/2002**

Collateral Damage and Liabilities of incorrect stowage and securing

Hazardous cargo affected
Pollution / damage to marine environment
Loss of stability / Damage to vessel
Fire/spill/contamination/exposure (crew health)/other
Cargo loss
Damage to third party/property
Navigation hazard
Risk of Injury/Fatality
Wreck removal / Recovery

Of particular note is the increasing focus of coastal states on the potential impact of container losses on the marine environment in the form of pollution from not only the containers, but perhaps more significantly the contents of those containers. The cost of wreck removal resulting from container losses can frequently run into the millions of dollars with such considerations as the requirement to undertake detailed sonar scans to locate lost containers, and the costly activity of recovery of the container and associated contents, often from remote and often inaccessible locations. The earlier example of the MSC Zoe presenting graphic examples of the pollution that is possible.

Containers washed up on remote beach

Recommendations and Conclusion

The Marin "Lashing@Sea report" published in 2009, noted that:

- Increased accelerations due to flexible hull deformations (whipping/springing) are observed regularly in severe head seas.
- Multiplication of the expected forces in cargo stacks can occur if gaps open between adjacent stacks (allowing impacts when stacks sway sideways concentrating inertia loads on the most rigid row.
- Unexpected high loads occur in the securing system and container stacks due to stack interactions when there are one or more stacks within the bay that are overloaded or not lashed correctly – a mechanism most likely responsible for progressive collapse of entire bays.

The conclusions of this report highlighted the need for masters to be able to choose "appropriate speed, heading and ballast configuration in relation to the weather", but that evaluation of dynamic loads was not always possible without movement feedback sensor equipment.

The report recommended that ships should have some means of monitoring motion and acceleration; this would enable the crew to identify when high stresses were developing and alter the ship's speed and heading to reduce any excessive forces.

In the interim, **due diligence** during cargo loading and securing and monitoring during the voyage could considerably improve the overall success of a voyage.

It is imperative that focus be given towards managing the **maintenance and repairs** of the cargo securing gear on board (including the on board strongpoints/permanent fittings, associated appurtenances and strength members).

Colour coding of lashing gear allowing for easy identification and **segregating of batches** based on supply or last maintenance/inspection is one of the most commonly used methodologies.

Taking appropriate remedial measures such as repair and overhaul where possible and marking/tagging, removal and subsequent disposal of condemned gear to reduce the possibility of defective, damaged or /condemned lashing gear being inadvertently used.

Identifying fitness of fittings and structure that may be detrimental to the safety of the stow.

Taking necessary remedial measures before approving the affected slots for cargo operations.

Never sail out of a port without correcting a potentially dangerous condition that has been identified.

At sea, where a dangerous situation is identified, stakeholders should be notified, and, if necessary, expert advice promptly sought to plan the best possible course of action to mitigate or minimise the risk. An example of such a situation could be an updated cargo plan received after sailing with corrections to weights, location, height or type of container resulting in new alarms on the loading software. If these alarms are not possible to be addressed by applying lashings or adjusting stability parameters alone risk assessment and shore advise may be necessary.

Safety should be always given priority above commercial considerations

The above guidance supplements other widely available industry guidance which is not addressed in this risk alert.

Suggested References (best viewed in Chrome)

- Regulation 5 of Chapter VI of the Safety of Life at Sea (SOLAS) Convention

International Convention for Safe Containers (CSC)

Code of Practice for the Packing of Cargo Transport Units (CTU Code)

On SIMSL website

An Investigation of Head-Sea Parametric Rolling and its Influence on Container Lashing Systems (William N. France, Marc Levadou, Thomas W. Treakle, J. Randolph Paulling, R. Keith Michel, and Colin Moore - SNAME Annual Meeting 2001 Presentation)

Sea Venture - Issue 2 - Cargo Securing Manuals

Containerised Cargo; Claims Prevention Guidelines

Others

Whilst this AMSA Focused Inspection Campaign (FIC) has now ended it provides guidance on the proper stowage and securing of containers.

AMSA - 05/2020—Focused Inspection Campaign—Proper stowage and securing of cargo containers. which gives effect to Chapter VI of SOLAS in Australia.

AMSA Checklist for the focused inspections.

AMSA Marine Notice 03/2018 - Proper stowage of cargo containers