DNV Container Ship Update

Information from DNV to the container ship industry No. 1 April 2008

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Napoli - special edition

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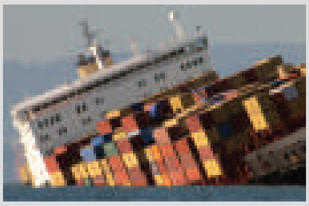

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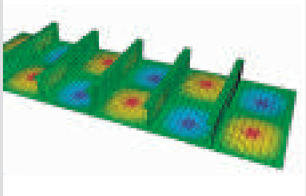

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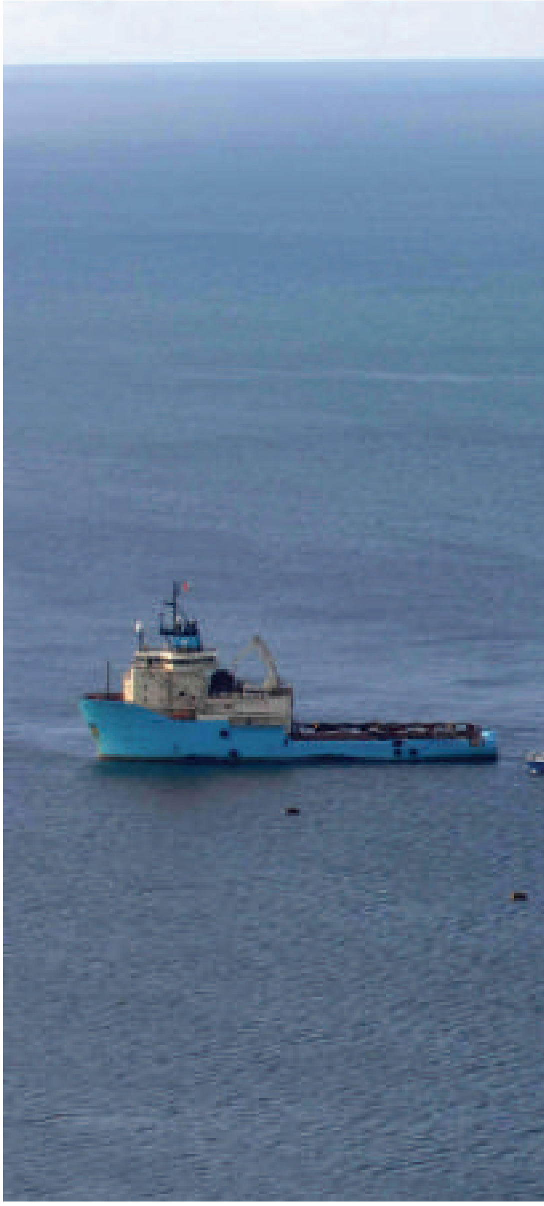

MSC Napoli a mile off Sidmouth in Devon

An unacceptable accident

The accident involving the MSC Napoli was a serious one that has consequences for and possible detrimental effects on the reputation of the container ship industry. The major structural failure of a container ship is a very rare event which has only happened a few times in the 50-year history of this ship type.

However, when a ship of that size breaks in half at sea, in rough weather, then something is fundamentally wrong. This should not happen.

We therefore made all our best resources available in an outright effort to discover the cause of the accident and fully understand why it happened. State-of-the-art technology has been put to work. All DNV's container ships in service have been screened to reveal if other ships are at risk. We had to make sure that all the appropriate steps had been taken in an effort to avoid this happening again.

We have left no stone unturned in our endeavours to prevent this from happening again. Our most senior technical officer has been in charge of the investigation and we have cooperated closely with the MAIB. Information has been shared with other IACS class societies too. Fortunately, there are not many ships in service at similar risk as the MSC Napoli.

Tor Svensen
Head of DNV Maritime

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Understanding why it happened

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Olav Nortun
DNV Technical Director

The early indication from the press pictures was clear. The Napoli had broken in half just forward of the engine room, giving clear evidence of a major structural breakdown. This is unusual for a container ship, which is designed with a double hull and bottom and in which every alternate bulkhead is watertight. This is in fact what we are striving for with other ship types, such as bulk carriers and tankers.

Our best resources were put on the job from day one. Our ambition was to understand the reason for the structural failure. The collapse of the hull girder was caused by excessive loading. The container load condition was inside permissible limits but the sea state was heavy. The total loading exceeded the capacity of the hull girder, causing the ship to break in half just forward of the engine room. The crack on both sides could be observed from the many pictures available as the incident developed.

If we could reproduce or simulate the accident on a computer, could we then deduce something about the root cause of the structural failure?

This was the hypothesis put forward by our researchers. So that meant making a reliable model of the ship structure itself, with bunkers, ballast and cargo correctly distributed. Then as good a picture as possible of the environmental conditions had to be established.

This is what designers and class normally do when new designs are to be built. Global FEM analyses and hydrodynamic models of the sea loading are made and it is more or less an everyday sort of happening. Such “newbuild type” analyses were the first to be conducted in our investigation.

But with the Napoli, the challenge went way beyond that point. Our ambition was to simulate a structural breakdown, involving the collapse of plating and stiffeners and the consequent deformation of major structures. A traditional linear analysis does not suffice for this purpose. As the structure is deformed beyond the steel’s yield point, non-linear tools had to be put to work. This was a major undertaking as regards modelling and computing time, and is not normally done. I do not recall us ever having created a similar model.

We were able to simulate the structural failure and reproduce the crack in the ship side. The results can be verified by anyone comparing the picture from the model and the helicopter picture of the Napoli at sea. All of this can be seen in the short film we made to illustrate our point.

The buckling strength in the forward part of the engine room was insufficient. Where longitudinal stiffening of the fore and mid ship ends and transverse stiffening of the engine room starts is where the critical area lies. The longitudinally stiffened plate field has about twice the buckling strength of a similar transversely stiffened plate field.

The remedy is to fit buckling stiffeners in way. This is a minor structural modification which may be done afloat and involves a small amount of steel. Alternatively, a reduction in the allowable still water bending moment could be introduced.

Were other container ships at risk? A screening programme was devised to identify candidates for further investigation. The screening revealed some designs that needed to be looked at more closely. That is being done now. DNV has also shared this screening procedure with other IACS societies, and I believe all container ships classed by IACS societies are now being looked at. The screening procedure and results have also been shared with the MAIB.

Newbuilding rules and procedures are being examined. DNV has invited all IACS societies to cooperate on a unified approach to dealing with both ships in operation and newbuilds.

Have we done all we can? As far as we can see now, yes, we have. But we should always be open for input from other investigations and from the industry itself to find good ways of rectifying such problems and paving the way for good quality ships in the future.

Olav Nortun
DNV Technical Director

Experience matters


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Knut Døhlie
Business Director – Container Ships

DNV is an emerging player in the field of container ship classification. The driving force of a strong domestic market has not been there for historical reasons. Entering a new arena where the existing players have a strong and competent hand means you have to have something to offer that makes it worthwhile for people to listen to what you have to say.

A significant track record and large portfolio of good quality ships is often seen as an indication of know-how and competence. Many prudent owners view their choice of class society as a matter of trust and confidence.

DNV's existing fleet of container ships is made up of two categories. Newbuilds and what we call "class entry ships". The newbuilds are ordered and built to DNV class, in compliance with the DNV container ship Rules in force at the time. This is the normal way of getting ships to class for all classification societies.

The "class entry" category comprises existing ships which have already been built and delivered. Owners may choose the class society under which the ship is to be operated in the years to come. That could well be a different class society to the one under whose Rules it has been constructed. The choice may depend on how the owners see their interests best being served. The service quality and cost effectiveness offered by the class society are important factors. The owners make an independent decision regarding this. The way in which the owner's operations will be regarded by clients and other stakeholders in the industry will probably also play an important role here.

Almost 70% of DNV's container ship fleet consists of "class entry ships" - ships that have been built to other class standards and classed by DNV while in service.

That gives DNV a unique experience base.

We can compare how other class standards measure up in operation and benchmark this against our Rules and procedures. That gives us a different kind of experience and provides us with continuous input so we can improve and enhance the way we conduct our business.

So what have we learnt? Some of our procedures are "square headed" and need to be changed. Container ships are different from tankers and bulkers. So it is essential that we adjust the way we do things in order to maintain standards and contribute to safe and reliable container shipping, and we will continue on that track.

However, we have seen that our structural bow impact standards are good, better than the classification average, and have been so for years. Our side shell fatigue standards fall into the same category. We saw that some years ago when the container ship industry had problems.

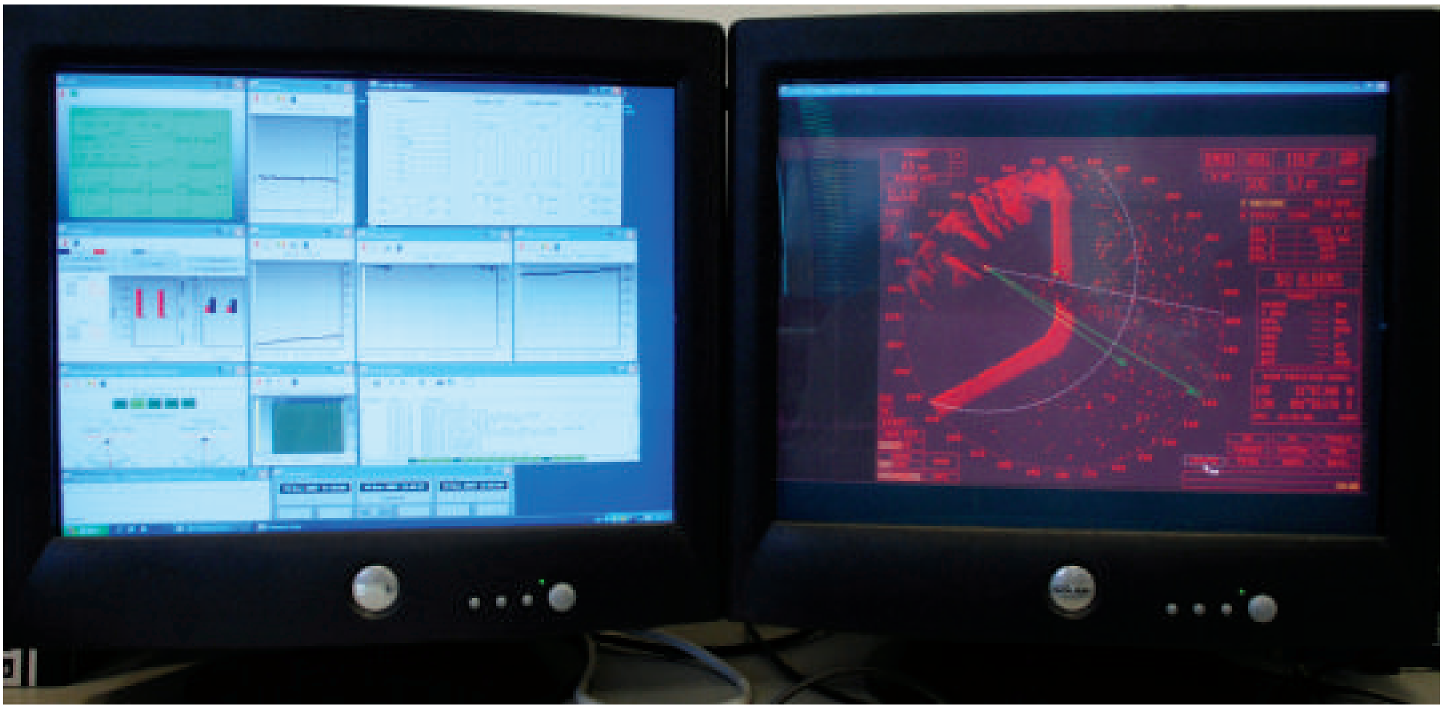
Is there a relevance to the Napoli case? Well, we are looking into that right now. We have screened all the ships in our fleet and are accumulating that knowledge. We have also taken an initiative in IACS to coordinate our common experience and the way that newbuilds and existing ships are handled. Other class societies may have a bigger fleet from which to gain experience. We will contribute what we know and make sure that the industry benefits from this.

Knut Døhlie
Business Director – Container Ships

What really happened?

- learning by in-depth accident investigation

In 1987 a serious accident occurred when a British ferry capsized off Zeebrugge in Belgium with the loss of 197 lives. In the troubled aftermath, there was a call for the creation of an unbiased and independent investigative body. This led to the establishment of the MAIB which has now served the British marine industry for nearly 20 years. Its sole purpose is to find and report causes and circumstances and make recommendations to avoid the recurrence of similar accidents.



The Voyage Data Recorder accumulates positions and central ship handling data which may serve as a basis for accident analysis.

Accidents Do Happen

It is a quiet day somewhere off the coast of Great Britain. On the bridge of a medium-sized ferry the calm is suddenly interrupted by shouts of distress followed by a thumping sound and the loud screech of metal. The unthinkable has suddenly become a reality: the ferry has been rammed by a bulk carrier leaving port.

The spine-chilling drama that is unfolding is a playback of sound, radar images and vessel data in the MAIB laboratories in Southampton. We are kindly - but firmly - made to understand that this lab is normally strictly out of bounds to unauthorised personnel due to the sensitivity of the data handled during ongoing investigations. No further information from this accident may therefore be disclosed...

"The introduction of the Voyage Data Recorder (VDR) has - when available - revolutionised our ability to dissect the chronology of accidents down to the minute, yes even seconds," says the head of the MAIB, chief inspector Stephen Meyer. "We can now also combine these VDR recordings with other data through our recently developed technology to give us a comprehensive, objective picture. This - along with other information - then constitutes part of the evidence from which we may draw our final conclusions."

Asking the Questions

"Our only objective is to investigate accidents to or on UK-flagged ships worldwide and ships under other flags in UK waters," says Meyer. "I must emphasise that we do not point fingers, thereby apportioning blame or liability. Our task is only to determine and report circumstances and causes in order to increase marine safety by avoiding a recurrence of related incidents and accidents in the future. Our role is in many ways therefore also to serve as an educator."

The MAIB VDR readout facilities allow inspection of technical parameters as well as sound from the bridge, and radar data.

The head of MAIB, Chief Inspector of Marine Accidents Mr Stephen Meyer reports directly to the Secretary of State for Transport.

All photos in this aricle © Det Norske Veritas

In the MAIB laboratory chief inspector Stephen Meyer and technical manager Mike Travis may follow the development of an accident based on VDR data.

There are four basic questions which need answers when an accident has occurred:

- What happened?
- How did it happen?
- Why did it happen?
- What can be done to prevent it from happening again?

The focus is on systemic failures, and to answer these questions the MAIB has at its disposal an advanced technological toolbox. But first and foremost it has an experienced and professional staff of former Masters, Chief Engineers and Naval Architects. These have all undergone the requisite two-year major accident investigation training course and constitute four teams, each led by a principal inspector.

In addition, external consultancy services are called upon when needed to assist in specialist fields. These may include various technical experts not available in-house and the involvement of special test facilities. The MAIB has also developed what it terms Recommendation Meetings where it invites experts from the specific industry involved in an accident to deepen the understanding of the lessons to be learned and so help in the development of recommendations.

Accident Reporting and Investigation

All UK seafarers and vessel owners are required by law to report accidents and serious injuries to the MAIB within a defined time limit. “And our watch is a 24-hour around-the-clock one,” says Mr Meyer. “Accident evidence must be considered perishable and our obligation is therefore to evaluate the need to collect available data as quickly as possible, if need be in remote locations.”

On a yearly basis, around 1,800 inci-

FACTS ABOUT THE MAIB

The MAIB's tasks include accident investigation, analysis and reporting related to merchant ships, fishing vessels and (with some exceptions) pleasure craft.

The MAIB has a staff of 39 and is located in offices in Southampton. It serves as a separate, independent, and government-funded branch of the Department for Transport. The head of the MAIB, the Chief Inspector of Marine Accidents, reports directly to the Secretary of State for Transport.

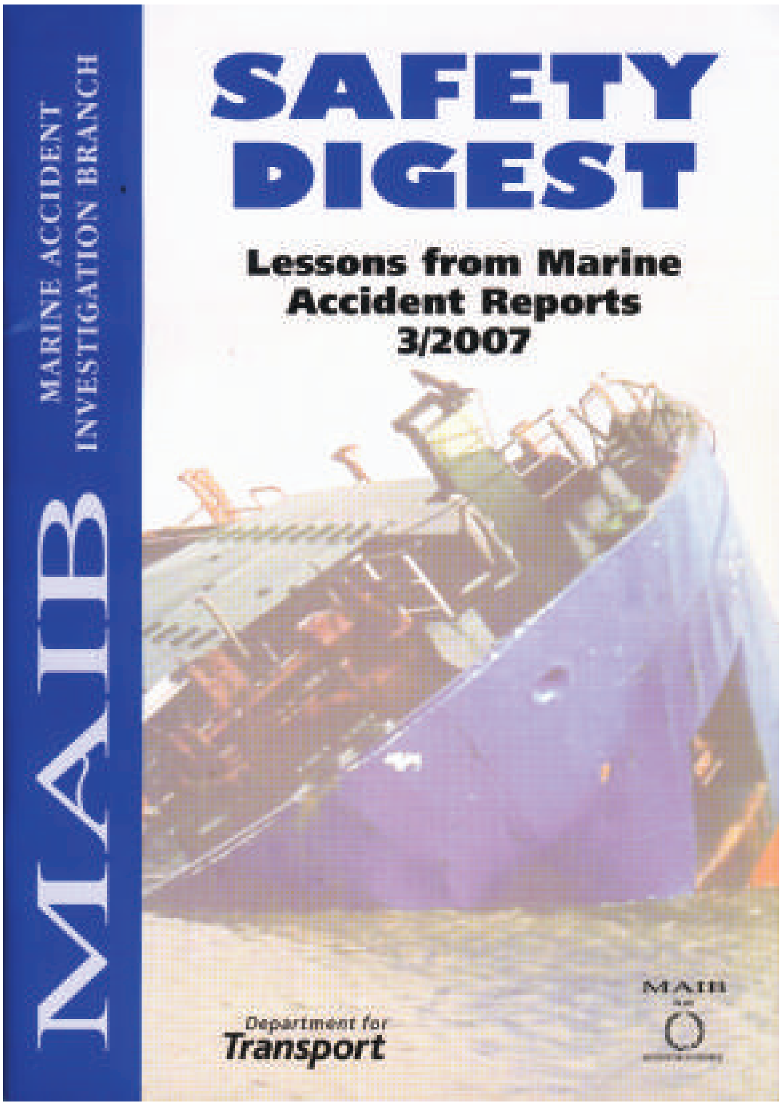
The foundation for the establishment of the MAIB in 1989 was laid in the wake of the capsizing of the *Herald of Free Enterprise ferry.* It was considered that an independent investigative body might have previously identified the systemic failures that led to this accident.

There was a call for the creation of an independent, unbiased, investigative body to minimise uncertainties over the "what and why" of accidents. Most importantly: to understand the underlying causes on the basis of free and independent expert analysis and thereby develop guidelines and recommendations to prevent similar accidents from occurring in the future.

The work of the MAIB is governed in part by the United Kingdom Merchant Shipping (Accident Reporting and Investigation) Regulations 2005 - Regulation 5:

"The sole objective of the investigation of an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005 shall be the prevention of future accidents through the ascertainment of its causes and circumstances. It shall not be the purpose of an investigation to determine liability nor, except so far as is necessary to achieve its objective, to apportion liability or blame."

http://www.maib.gov.uk



MARINE ACCIDENT INVESTIGATION BRANCH

MAIB

SAFETY DIGEST

Lessons from Marine Accident Reports 3/2007

Department for Transport

MAIB

The Safety Digest is popular reading with lessons to learn.

Peter Lee (left) and R

dents and accidents are reported to the MAIB. A significant number of these are classified as "straightforward" and may not need any other follow-up than a couple of phone calls. However, all reports are processed and entered in the reporting system as components in a statistical database dating back to 1991, to be used, for example, in trend analyses. In line with this, the MAIB encourages the reporting of hazardous incidents - or near misses - which may often teach lessons that are every bit as relevant as those arising from accidents.

When notified about more serious accidents, the inspectors collect evidence and a Preliminary Examination (PE) may be conducted. If the causes and circumstances relating to the accident found during the PE meet the criteria, a Full Investigation is performed through evidence recovery, interviews and the extensive collection of various other data. Finally a report is issued and made publicly available. A total of 70-80 accidents are investigated each year.

Often the true cause of an accident turns out to be very different from the convenient solution identified by people who are not accident investigators. Any leakage of initial accident data to external parties by the MAIB might therefore also lead to their misuse and misinterpretation by a variety of parties with financial and other interests, and is avoided at all costs. The data are therefore guarded as precious valuables and kept under wraps until the publication of the final MAIB accident investigation report with its conclusions.

A Full Investigation or PE is entirely independent of any enquiries made by the police or other authority collecting evidence for a possible prosecution. The MAIB accident investigation report is accordingly not written with liability in

oger Brydges are representig the MAIB staff of 39.

mind and is not intended to be used in court for the purpose of litigation.

Publications and Training

During investigation and analysis, the time may be spent interviewing a wide range of individuals and verifying evidence, in addition to examining suspect equipment and consulting with experts. Thus the publication of a full investigation report may in many cases take place seven months, or up to a year, after an accident.

The majority of these investigations lead to recommendations to prevent the occurrence of similar accidents. Since 2006, the MAIB has issued an annual report outlining the uptake of such safety recommendations.

A Safety Digest is published three times a year with a circulation of 9,000 and is freely distributed to any interested companies or institutions. This contains a collection of short reports and outlines the lessons learned from the examinations and investigations that have been carried out.

"We are very pleased to note that these have proven to be extremely popular reading," says Meyer. "One thing is of course the often dramatic stories that are told. Another is that they allow us to achieve our objective, namely to teach the reader a lesson." In accordance with the MAIB's "no finger-pointing policy", the stories told are often anonymised, for example by re-colouring the pictures of hulls and by the removal of names and logos. "However, we are aware that our efforts to attain anonymity often lead to intense discussions and have provided an entertaining pastime on board vessels."

The knowledge gained by the MAIB during its 20 years of existence is now a well developed science and as such a sought after commodity. Says Meyer: "The number of organisations similar to ours is on the rise. A European Union directive demanding the formation of such national organisations is in the pipeline and is expected to be implemented by 2010. For a couple of years now, we have been conducting week-long courses to train personnel from, for example, China, South Africa and Iran as well as a number of European states." These courses provide an introduction to how to gather evidence, how to conduct interviews and methodical analyses and how to interpret data.

"We have a good reputation and feel confident that our efforts are paying off. And we will remain committed to striving for an increasing level of safety in the marine industry in the interest of all parties," concludes Mr Meyer.

MSC Napoli timeline

MSC Napoli – its brief history

Keel laid 1991.04.01

Date of build 1991.12.01,
South Korea

Length over all: 275.66 m
Breadth: 37.13 m
Draught: 13.50 m
Gross tonnage: 53,409
Capacity: 4419 TEU

Class notation:
1A1 Container Carrier E0

Owner:
Metvale Ltd., British Virgin Island

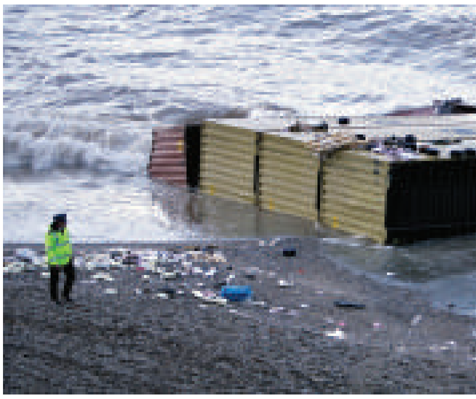
Charter:
MSC Mediterranean Shipping
Company S.A, Geneva, Switzerland

Manager:
Zodiac Maritime Agencies Ltd.,
London, UK

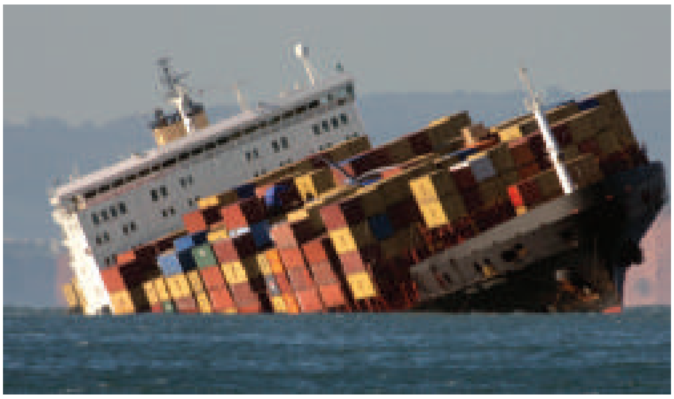
Flag: United Kingdom

IMO No: 9000601

1. MSC Napoli 3D model by DNV



2. The storm 18 January



5. Grounded full of containers

6. Salvage operation

11 January 1992
Sailed at its first trade as – at that time – the worlds largest container vessel.

28 March 2001
(Then named CMA CGM Normandie) ran aground on a reef in the Singapore Strait. En route from Port Klang, Malaysia to Jakarta, Indonesia. Grounded for several weeks.

6 June – 22 October 2001
The ship was repaired by the Khanh Hoa shipyard in Vietnam.

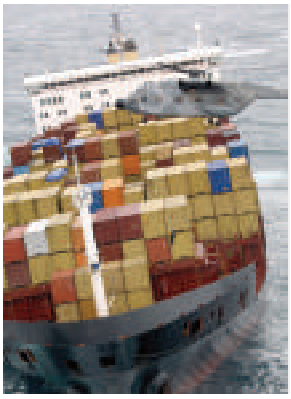
18 January 2007
While in the English Channel, some 50 miles off the coast of Cornwall en route from Antwerp, Belgium to Portugal got a major crack to the hull. The machinery room was flooded.

The ships master was captain Valentin Velev of Bulgaria. All 26 crew members were safely rescued.

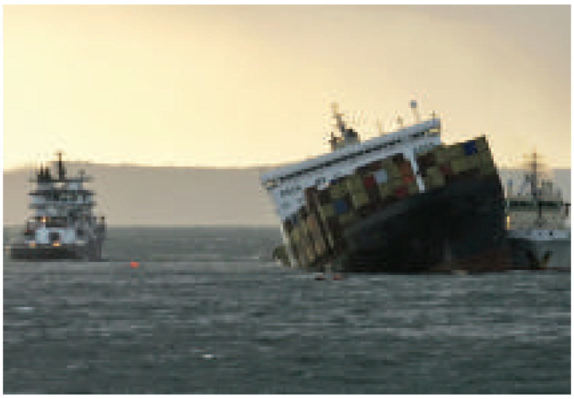
The actual weather there and then:
An unusually violent European windstorm Kyrill hit the channel forming an extra tropical cyclone with hurricane-strength winds. Kyrill caused widespread damage across Western Europe, especially in the United Kingdom and Germany. Described as the worst storm to hit UK in almost a decade.

19 January 2007
The ship was taken under tow. With increasing list and with strong winds, refuge was taken in Lyme Bay.

MSC Napoli
– its brief history



3. Rescue operation



4. Towing operation 19 January

7. Separation by explosives

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4. Leon Niel/Scanpix
5. Anthony Devlin/Scanpix
6. Anthony Devlin/Scanpix
7. Scoopt/Getty Images

Current and former names:

1991 – 1995: CGM Normandie
1995 – 2001: Nedlloyd Normandie
2001 – 2004: CMA CGM Normandie
2004 – 2007: MSC Napoli

Current and former ship managers

1991 – 2003: CMA CGM
2003 – 2007: Zodiac Maritime Agencies Ltd

Current and former class societies

1991 – 2002: Bureau Veritas (BV)
2002 – 2007: DNV

Current and former flags

1991 – 1995: France
1995 – 2002: French Southern Territories

2002 – 2007: United Kingdom

20 January 2007
MSC Napoli was grounded close to Branscombe in the counties of Devon.

Oil spill prevention and removing of containers from MSC Napoli were initiated immediately.

Cargo of 2318 containers. 103 containers were lost from the ship. Of these 56 were identified.

17 May 2007
The last container was removed and MSC Napoli was finally emptied for all cargo.

9 July 2007
The Napoli was refloated, but was immediately re-beached again.

20 July 2007
The ship was separated into two parts by use of explosives.

17 August 2007
The bow section was towed into the Harland and Wolff shipyard in Belfast, Northern Ireland for disposal and recycling.

The stern section is still at location, Lyme Bay, Branscombe. Once refloated, this section will also be towed to Belfast.

Hull girder collapse analyses

During some dramatic and stormy hours in the English Channel, 70 km south-east of the Lizard Point on the 18th of January 2007, the container vessel MSC Napoli, on its travel from Antwerp to Le Havre and Sines, Portugal, experienced unexpected problems. The vessel was suddenly suffering significant structural damages with hull skin collapse and plate cracking with violent water ingress and flooding of the engine room.

Reported incident and salvation operations

Immediately, an effective rescue operation was initiated and co-ordinated between the French and U.K. Coast Guards and the Royal Navy 771 Naval Air Squadron. All the 26 crew members where safely landed without injuries (Fig.1).

Following the rescue operation, the MSC Napoli was drifting in the waves for a period before two tug vessels started manoeuvring of the vessel towards Portland Harbour on the British side. However, it soon become clear that the aft part was on the limit of breaking away from the rest of the ship, and in order to avoid any major environmental disaster the vessel was beached off the Dorset coast in Lyme Bay, still in one piece, Fig. 2.

During this salvation operation more than 200 containers went overboard and drifted onto the Branscome beach among other places and a lot of valuables where located along the shoreline. And despite the rule and regulations embedded in the Merchant Shipping Act of 1995, clearly defining wreck stealing as an offence, more or less organized gangs ruled the beaches for a while.

Among the most interesting objects where around 50 motorbikes which where all nicely manoeuvred outside the normal public road system and into safe havens. How many of these which actually have been reported to Police within the limits of 28 days we don't know, we can only speculate.

After MSC Napoli was discharged for containers, a process that took around 6 months, the aft part where separated from the rest by explosives. The forward part was then towed to Belfast for dry docking further inspections and scrapping, while the aft part was left at the beach where the final dismantling still takes place. (Fig.4 p.14).

The rest of the salvage story will not be dwelled on here, but it has been unofficially reported that the total bill amounts to more that 400 mill Euros, covering everything from cargo and vessel insurance, salvation, cleaning up beaches to repair of overloaded public roads. The true figure may never be known.

MSC Napoli – Vessel data and Class – Previous incidents

MSC Napoli, was built to Bureau Veritas Class back in 1991 and transferred to DNV Class in 2002. The vessel had a length overall of 275 m, breadth 37 m and depth 21.5 m and was dimensioned for 4400 TEU containers.

The first step was to go through the vessel ship in service record and see if any relevant information could be of interest. The most important data found was a grounding accident on the Helene Mar Reef in Singapore Strait back in 2001. This case was therefore reassessed with the purpose of finding some possible links to the present incident. Simple grounding simulations and theoretical strength assessments were carried out concluding that no such links were likely and the 2001 grounding was ruled out as a possible implicit cause to actual 2007 incident.

The ship in service files also revealed that the hull was well maintained and there

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Fig.1 Rescue operation of MSC Napoli 18th of February 2007, south east of Lizard Point

Fig.2 French and British tug vessels beaching MSC Napoli off the Dorset coast in Lyme Bay

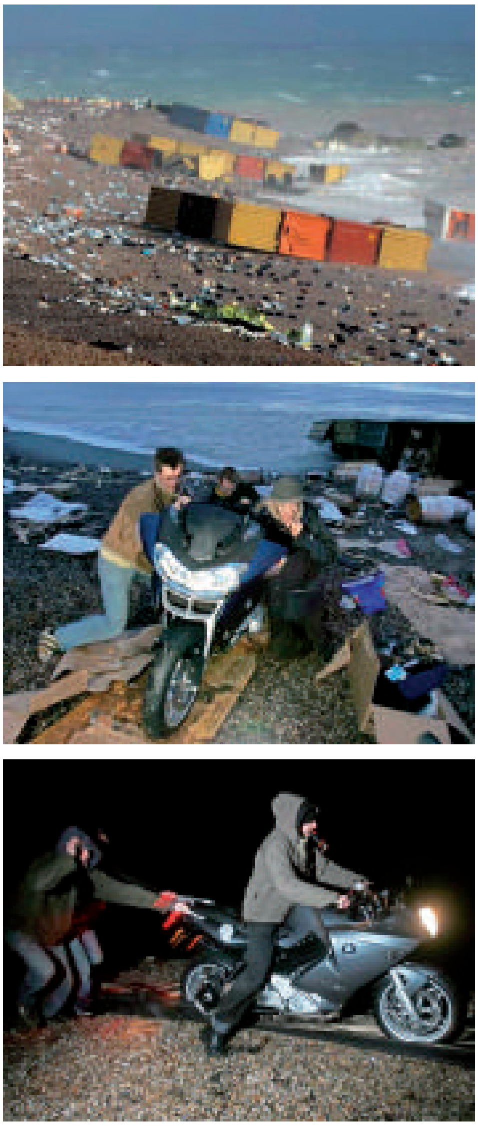

Fig.3 Ship disasters are not disasters to everybody. Intact BMW motorbikes were among the most popular valuables.

were not reported any corrosion or cracks of importance in the engine room.

DNV technical investigation team and their mandate

DNV Maritime promptly organised an internal project team, which involved the Hull Ships in Operation Section as well as the consultancy Section for Hydrodynamics, Structures and Stability. A project organization was established with Geir Dugstad, Head of Newbuilding Department, as the overall project manager with technical director Olav Nortun as overall project responsible.

The mandate was obvious; what was the cause of the accident and are there more ships sailing out there at risk? DNV wants to understand what happened and take actions to prevent similar incidents in the future.

Project organization for direct load and strength analyses - personnel

A dedicated project team in the maritime consultancy department, section for hydrodynamics, structures and stability was established with the scope of doing computerized load and strength assessment of the vessel. Eivind Steen, senior principle engineer with long experience within the field of ultimate strength assessment of ship structures, was appointed as project leader for this part. Their mandate was to carry out direct and detailed load and strength calculations of the vessel evaluating all possible scenarios. Key personnel were given part project responsibilities, Gaute Storhaug wave loads, Jon Kippenes non-linear FE and Octavi Sado linear FE. A QA team with senior and experienced people such as Thor Hysing, Tom K. Østvold, Torbjørn Lindemark, Frode Kamsvåg and Håvard Austefjord should ensure quality at all levels.

A hull support group, i.e. Ivar Håberg, Eirik Byklem, Håkon Skaret, Rossen Panev and Gjermund Skailand was linked to the project team as assistant QA personnel and ship type experts. They had also the responsibility to evaluate all class related matters of which the most important issue was to screen the existing sailing container fleet to assess if more ships out there could have a similar problem as MSC Napoli.

A part project team in the DNV Polen office, co-ordinated by Kryztof Padowski,

Fig.4 Forepart of MSC Napoli in dry dock in Belfast. What happened?? they wonder

All photos in this article © Det Norske Veritas

was also established and linked to the mtp361 team. They should make a FE model of the whole vessel. The key man here was Michal Moczulski, who subsequently joined the project team at Høvik.

Probable Incidents scenarios and project tasks

Immediately after the incident, speculations on what actually had happened and the cause of it were several and fragmented, ranging from fatigue failure speculations, main engine vibrations to overall hull girder collapse due to severe wave loads possibly amplified from a global hull vibration (whipping) response.

However, from the internet pictures (published on Canargo web site), taken during the salvation operation, it was rather obvious that the whole ship hull girder had collapsed and broken just aft of the engine room area in a hogging state. Thus, such a scenario was the main track to investigate and the computer analyses to be carried out should clarify if this was a possible one.

Phase 1

The direct load and strength analyses to be carried out were divided in two phases. Phase 1 was to be a quick and simplified ship strength assessment. It should cover a study of the change of the still-water hull girder loads due the flooding and the wave loads should be assessed using DNV WASIM hydro software with all available environmental data and wave observations used as input. Moreover, a simplified assessment of the hull girder capacity using Nauticus Hull software and PULS buckling code were needed in order to see if the global hull loads actually could have exceeded the corresponding hull girder ultimate capacity.

The still-water load (NAPA) calculations concluded soon that the filling and flooding of the engine room with possible progressive flooding of more compartments aft of the main engine room did not increase the hull sections loads as compared to the intact ship hogging moment. Rather the opposite was observed implying the static hogging moment was reduced as water was flooding into the engine room. This matched the simple concept of lost buoyancy in the flooded rooms.

Thus the first conclusion led to the belief that the significant hull skin cracking most likely was the results of some extreme localized buckling and collapse deformations following a hull girder collapse scenario. In other words, the hull skin cracking and flooding of engine room was the results of some extreme buckling and plate deformations opening up cracks and not the opposite.

Other damage hypothesis was also checked out, e.g. propeller out of water combined with engine induced vibrations could have led to fatigue and cracking of the double bottom in way of main engine support structure. However, such scenarios were subsequently ruled out as they did not match failure mechanism as observed onboard the vessel.

The Phase 1 study subsequently showed that the ultimate hull girder strength limit just aft of the engine room area could have been exceeded. This was concluded as the wave loads, possibly amplified due to a whipping response, was found to be close to the hull girder ultimate capacity.

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However, what was left to confirm was if the structural failure mode and cracks observed on the vessel could be the result of a wave hogging load exceeding the hull capacity.

The only way to provide such evidence was to apply advanced non-linear FE software as the simplified models used in the Phase 1 part give reasonable values for the ultimate loads but they are not capable of accurately describe the plastic deformations and progressive collapse pattern.

Phase 2

Thus a Phase 2 project was needed including an extensive and refined FE model of the whole vessel. The model should be analysed using standard linear methods, but more importantly also using non-linear methods. The latter is the only approach available capable of simulating inelastic material behaviour, load shedding phenomena due to local large buckling deflections etc. all effects which may lead to a progressive and localized collapse and ultimately total collapse of the whole vessel.

However, a main catch for such non-linear FE analyses to be carried out is the size of it, meaning both the long modelling and analyses time required (CPU). A proper balance between size of model and confidence in results is also crucial and had to be carefully considered. A rather ambitious plan, including automatic load transfer from the hydro program to the FE program, was also agreed in order to have the best basis for conclusions.

The whole ship was modelled, with particular attention to details of the structure in way of the engine room area and well into the first cargo hold. All structural and load carrying parts such as decks, bulkheads, girder, cut-outs, sea chest, stiffeners, plating, flanges etc. had to be modelled carefully in order to assess the correct stress flow in the structure and in order to predict the local buckling and collapse mechanism.

The non-linear FE model (ABAQUS) analyses were very time consuming and demanding and run for several weeks. But all the time and effort put into these analyses seemed to pay off, as a very realistic and well defined failure mechanism unfolded in the FE model. Compared to the failure mode as observed on vessel, the FE computer simulation gave a very close match.

The likely incident scenario is illustrated in a sequence of pictures in Figs.5,6,7 showing, the vessel heading up towards a severe irregular wave train as analysed using WASIM, then analysed in moment in time in the non-linear FE program ABAQUS for then in a damaged, heeled and flooded condition illustrate the vessel starts drifting without engine power and ends up rolling in beam sea.

Conclusions and discussions

From the advanced load and structural strength analyses carried out it has been shown that the MSC Napoli could have broken and collapsed in way of engine room due severe waves meeting the vessel close to head sea. The hull girder structural collapse mechanism assessed in the nonlinear FE model has been shown to be very similar the failure mode observed on the vessel.

The hull girder wave loads assessed are of the same order as the IACS North Atlantic design loads. This is an interesting observation since it is known that the IACS 20 year design condition correspond to wave heights around 14-15 m while the wave heights in the Channel the 18 of January 2007 where half of that, i.e. in the range of 7 to 9 m (Hs). One explanation to this may be the shallow water conditions in the Channel (water dept around 70 meter) combined with unfortunate wind and current conditions leading to steep and high energy waves. Such wave conditions may also have exerted a global hull vibration (whipping response), thus possibly amplifying severe hull loads to an even more severe level.

Another observation from the non-linear FE analyses was the low local buckling strength in the bilge, bottom and tank top area just forward of the engine room bulkhead. This was due to the transverse stiffening arrangement here, as opposed to the longitudinal stiffening forward of the engine room area. Transversely compressed plates are known to have significantly lower buckling strength than axially compressed stiffened plates.

Lessons learned

The extensive computer analyses carried out for MSC Napoli has revealed a potential problem for large container vessels of similar design with respect to the longitudinal structural strength of the engine room area. As a consequence and as described separately a procedure has been developed for screening of existing vessels and vessels under construction. This screening procedure has been applied by all IACS societies and a limited number of vessels have been identified to be potentially at risk.

Moreover, container vessels have been sailing and operating successfully for more than forty years without any major hull girder damage such as the one MSC Napoli experienced. This is indeed a very good damage record and shows that the probability of such events to happen is indeed vey low. However, the MSC Napoli incident has told us that rare events do happen and any responsible stakeholder will agree that it is important to use the new knowledge and experience in a positive setting leading to future improved vessel designs and Class Rules.

On a short term perspective DNV will take initiative in IACS for a review of it's current unified requirement to longitudinal hull girder strength and buckling of slender vessels.

In a longer perspective, and observing the trend of continuously larger vessels investment in R&D will be important in order to ensure safe design of the next generation of container vessels. DNV have continuous focus on this and has already initiated several R&D projects focusing on container ships such as extensive studies related to the whipping phenomenon.

Øivind Steen
Hydrodynamic & Structures Department

Illustrations of the incident
on the following pages

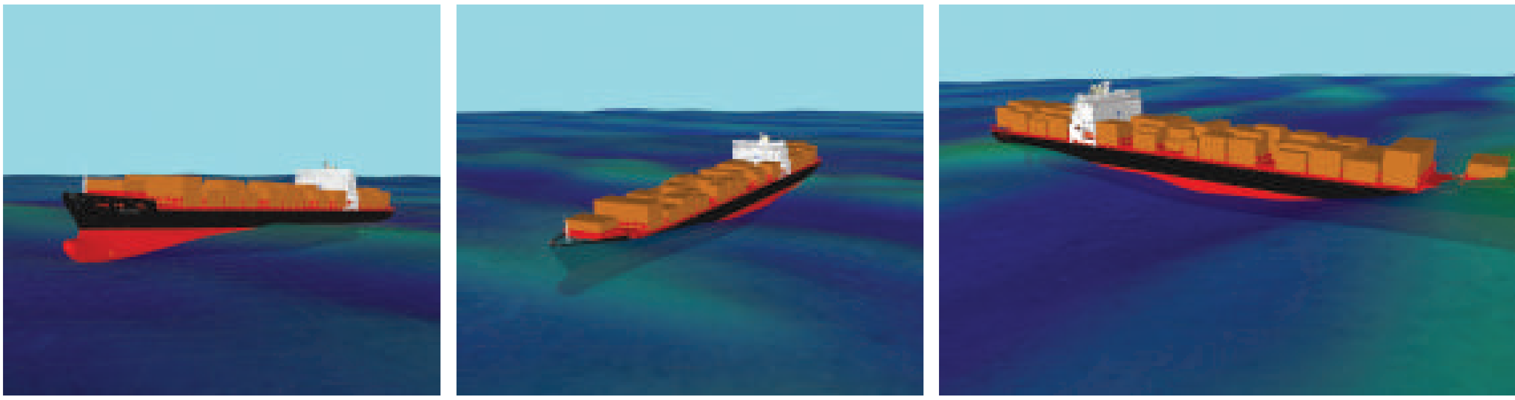


Fig. 5 MSC Napoli meeting a severe irregular wave train leading up to a severe hogging state (Hydro time serie simulation – WASIM)

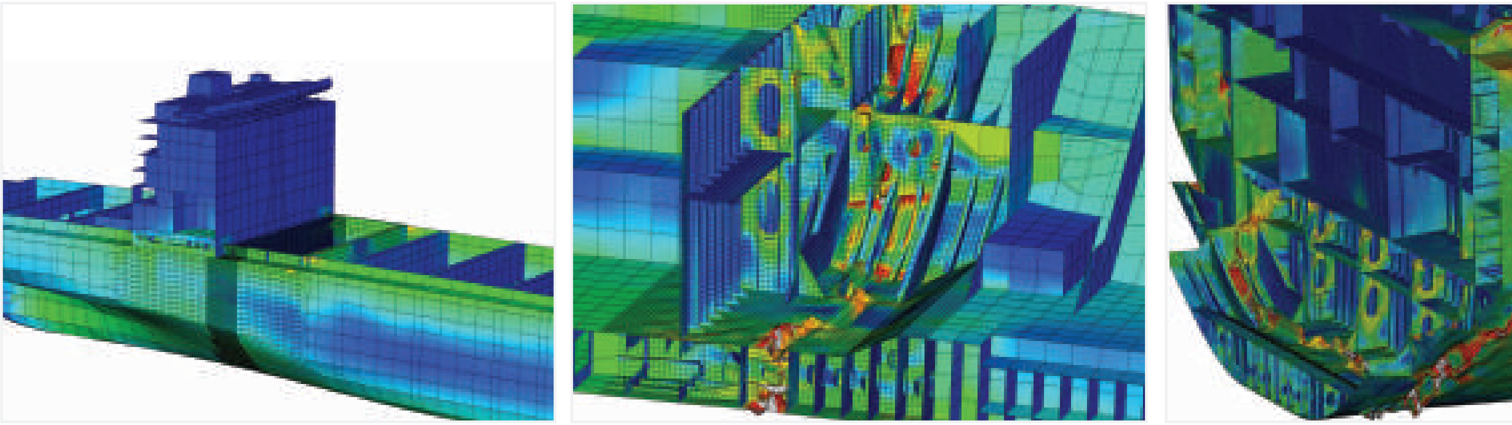


Fig. 6 MSC Napoli; structural progressive collapse development and hull girder failure (Non-lin FE ABAQUS)

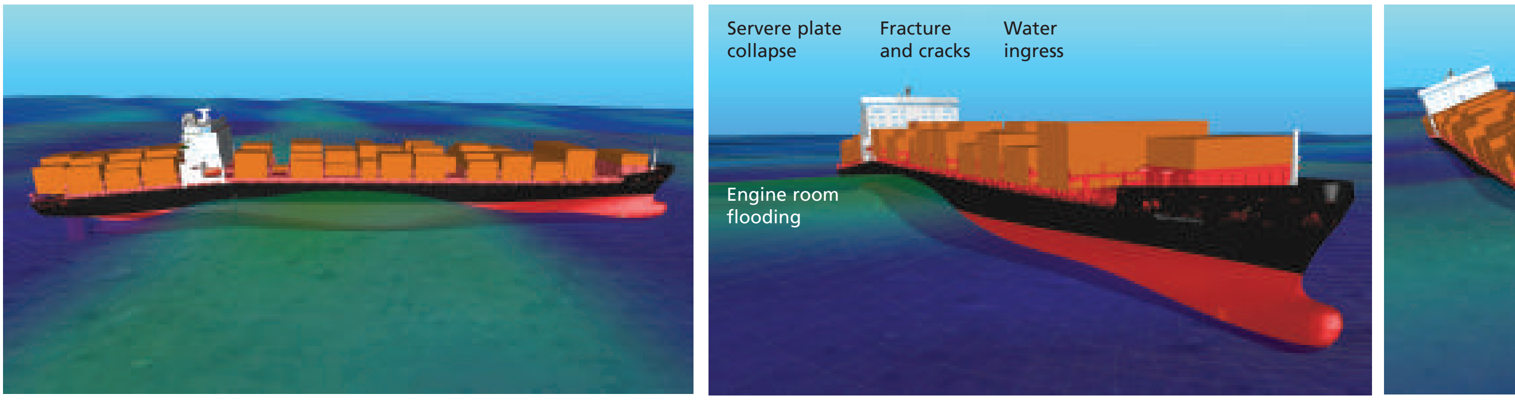
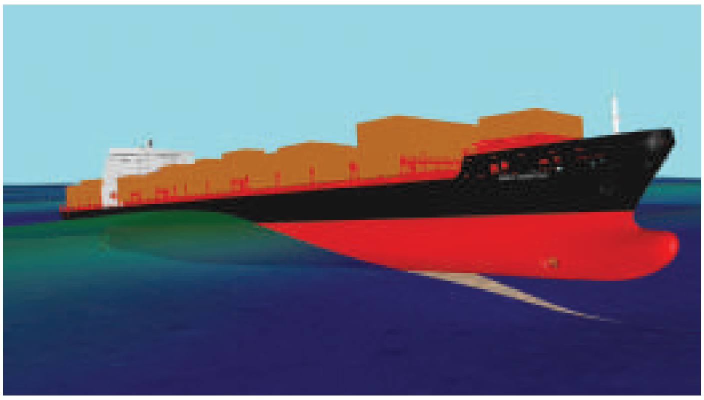
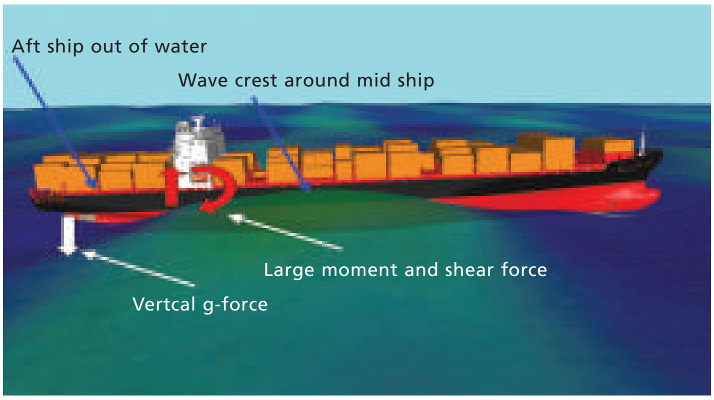
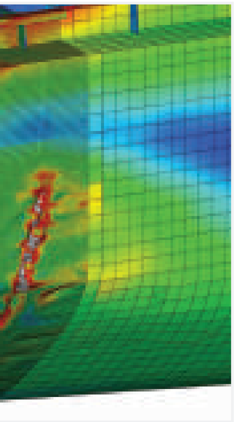
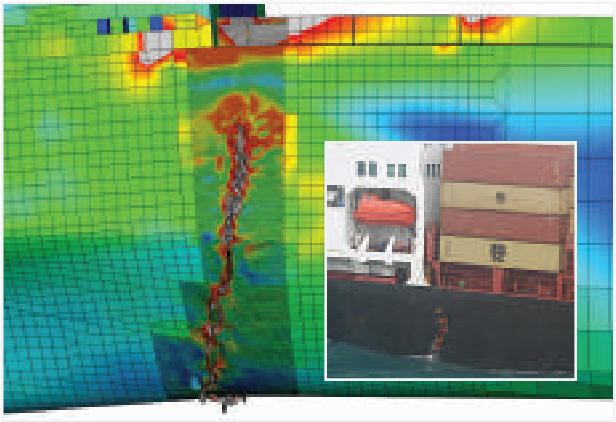


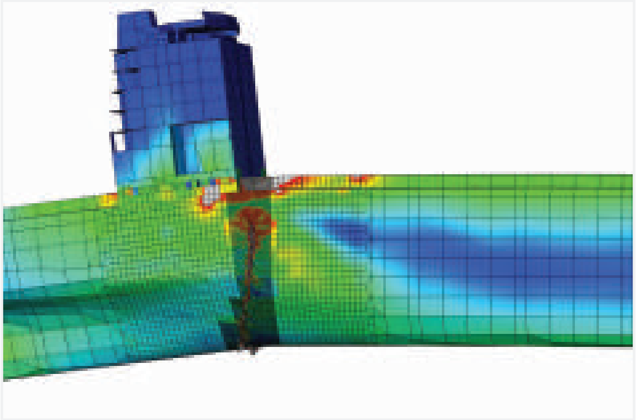
Fig. 7 MSC Napoli in a heeled and drifting state after hull girder collapse, plate cracking and engine room flooding

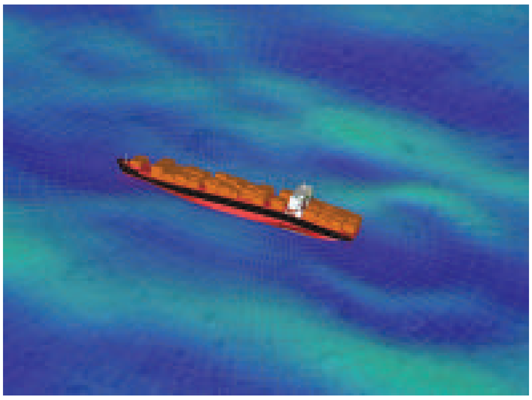



Aft ship out of water
Wave crest around mid ship
Large moment and shear force
Vertcal g-force



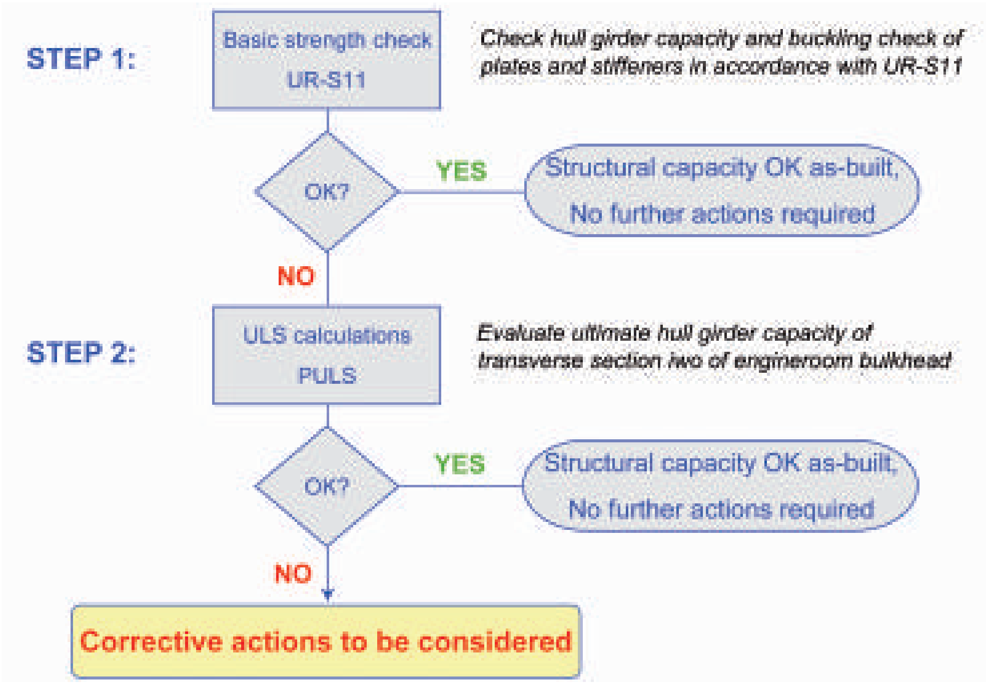






Are other ships at risk?

This is the question to ask now that the *Napoli's failure* mechanism has been identified. We should therefore focus on the critical area where the accident occurred on the Napoli. What we are looking for are ships with a similar arrangement in the transition from hold to engine room.



It is customary to arrange the engine room with transverse stiffeners to support the shell plating. This is to ensure sufficient stiffness and support for the engines and ER equipment. In smaller container ships, the superstructure is normally right at the aft end of the ship. As the ships get bigger, the superstructure is moved forward, allowing more space for the engines and equipment. However, the hull girder bending moment increases towards the midship area. We need therefore to verify that this area has been properly taken into consideration when the ship was built.

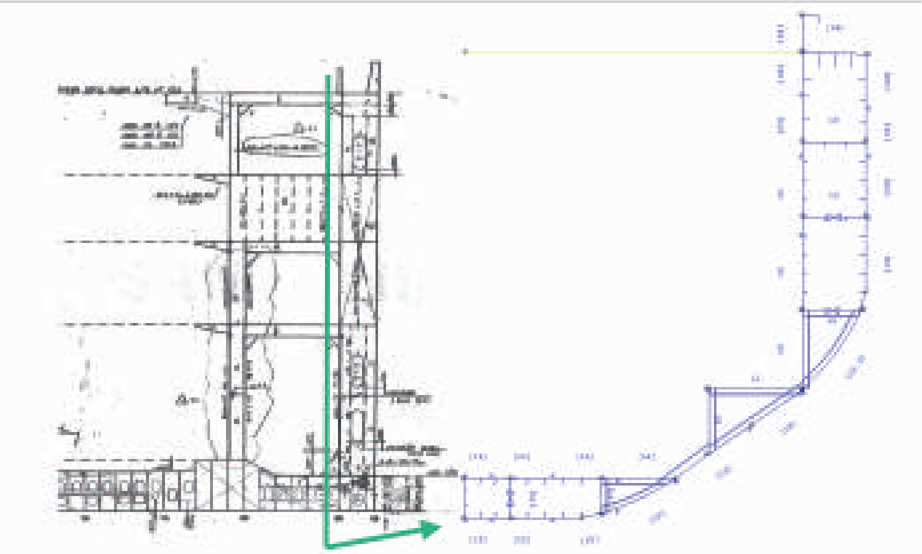
Our initial criterion for selecting critical ships was thus to select ships with a container hold aft of the superstructure, i.e. ships of around 2500 TEU and bigger.

These ships were then subjected to technical screening, which is divided into two steps as shown in the illustration. In the first step, the "basic strength check", the hull girder capacity is determined together with a buckling check of plating and stiffeners in the critical area, i.e. the forward engine room area where the longitudinal stiffening forward ends and the transverse stiffening in the ER begins.

STEP 1: Basic Strength Check

The hull girder cross section at this location is determined according to IACS Unified Requirement UR-S11 (which is the same for all IACS class societies). The DNV tool is the "Nauticus Section Scantlings" which calculates the cross-sectional properties of the hull girder. The required hull girder section modulus is established according to the same UR-S11. The design still water bending moment is taken from the approved trim and stability booklet. The "wave bending moment" (also according to UR-S11) and the "still water bending moment" provide the "total bending moment". Combining this with the "allowable stress level" gives us the required "minimum section modulus". The "as built section modulus" should have a higher value than this minimum value.

The buckling capacities of the plating and stiffeners of the double bottom and lower side shell are determined using a similar way of reasoning. Container ships are hogging ships, which means that the bottom and lower parts of the sides are always in compression and therefore prone to plate and stiffener buckling. A typical cross section is shown on top of page 21:



Critical buckling stress (the stress where the plate or stiffener collapses) is determined according to a Unified Requirement procedure (UR-S11). Usage factors are the actual stress divided by the critical buckling stress. A total of three local usage factors for plate buckling are determined in step 1, one for the shell plate in the double bottom, one for the inner bottom and one for the bilges. The following criteria are then used to evaluate whether step 2 is activated:

- all three usage factors (σl / σc) are less than 1.0, no further action is necessary
- the average usage factor is less than 0.90 , one usage factor is slightly above 1.0, no further action is necessary
- two usage factors are greater than 1 or one single usage factor is much greater than 1, proceed to STEP 2

STEP 2: Ultimate Limit State Buckling Check

If for instance there is a typical bottom structure with a plate field buckle and loose capacity, are the stiffeners able to withstand the loads without the plate support? If yes, then the structure still has redundant buckling capacity. In the ultimate state analysis, the various structural members making up the total buckling resistance are studied to determine the effectiveness of the various parts. This is similar to the effective breadth concept introduced by von Karman, but used on a global scale.

The PULSE code is a modern algorithm that calculates the ultimate state non-linear bi-axial buckling strength of typical plate and stiffener panels as pictured below. On the left, a longitudinal stiffened panel and on the right a transversely stiffened panel.

The local buckling capacities from the PULSE ultimate state analyses are then fed into Section Scantlings to determine the global “effective hull girder section modulus”. The “ultimate moment capacity” is then determined by multiplying the “effective section modulus” by the yield strength of the material in the plating. The ultimate hull girder capacity is determined by dividing the “actual design moments” by the “ultimate moment capacity”. This value must not exceed a limit, set at 0.9. If it does, corrective action is to be considered.

1) ***The effective hull girder section modulus Zeff*** is calculated using DNV Nauticus Section Scantlings, with effective local scantlings based on non-linear PULS buckling calculations.

2) ***The hull girder ultimate moment capacity Mu*** is calculated ***as the effective hull girder section modulus multiplied by the yield-strength of the bottom plate Sigf:***

$$Mu = Zeff \times Sigf$$

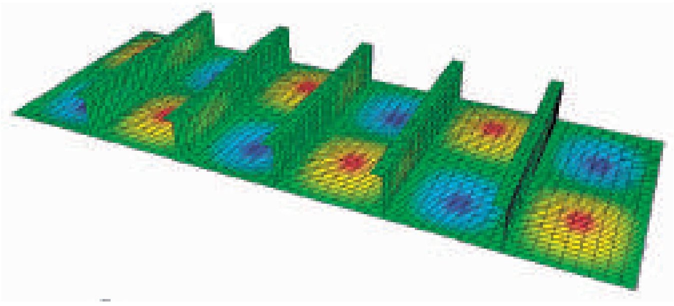
3) ***The ultimate hull girder capacity in bending*** at the transition between the engine room and cargo area is found by comparing the actual design moments* to the ***ultimate moment capacity:***

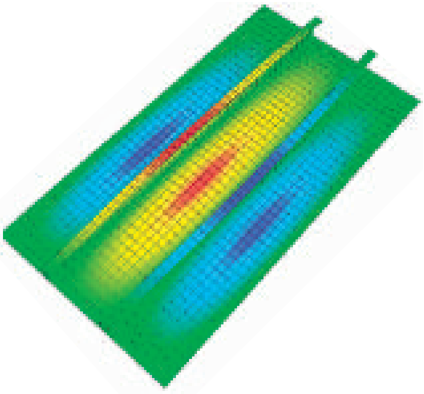
$$\eta = M/Mu$$

Where M = Ms + Mw
Ms= still water bending moments (sea condition, hogging) according to loading manual
Mw =standard rule wave at cross section considered, hogging condition

The capacity η should be 0.9 or lower in order for “no further action to be considered”.

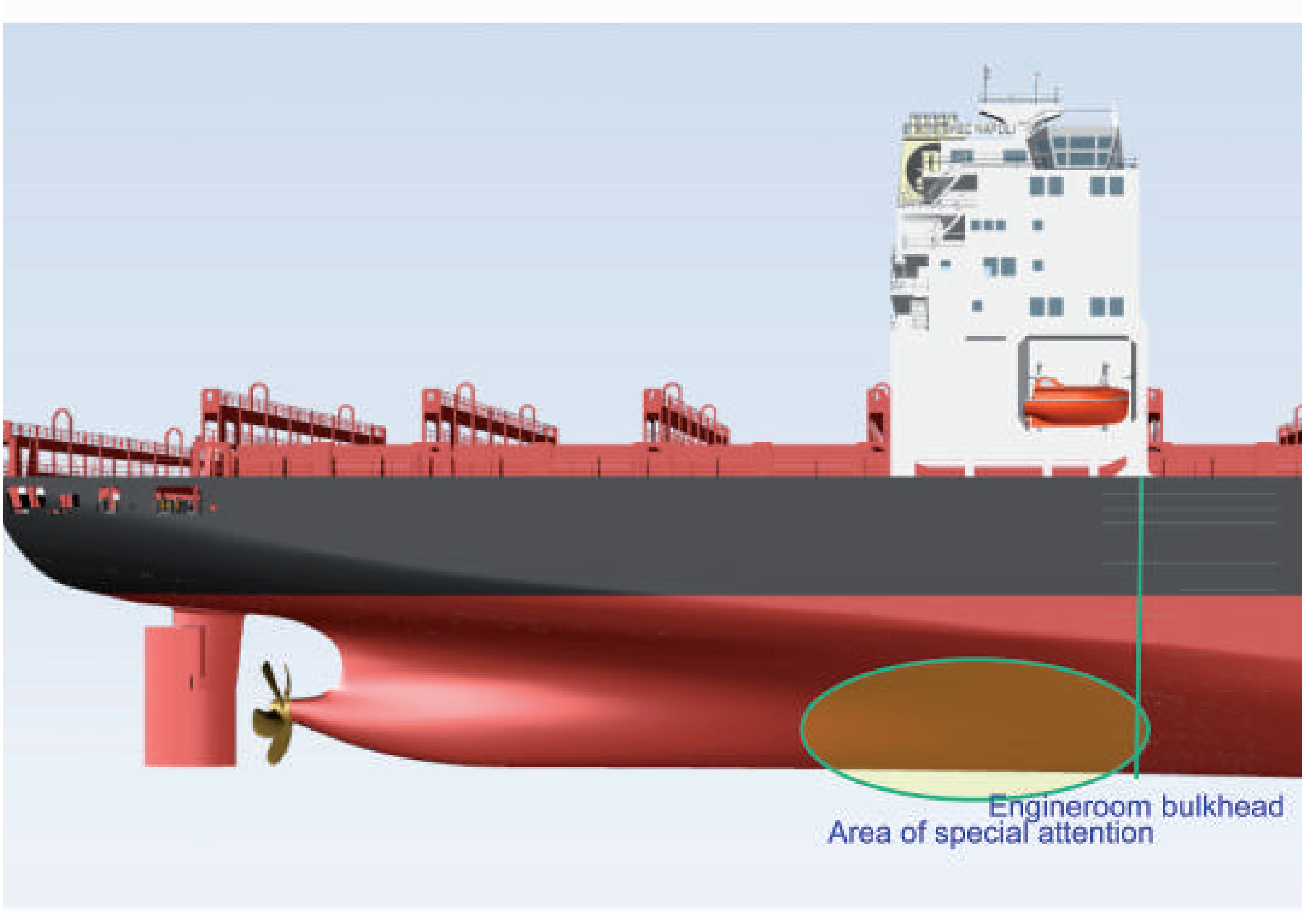
Gjermund Skailand and Catrine Vestereng
Head of Section Hull SIO





The remedy

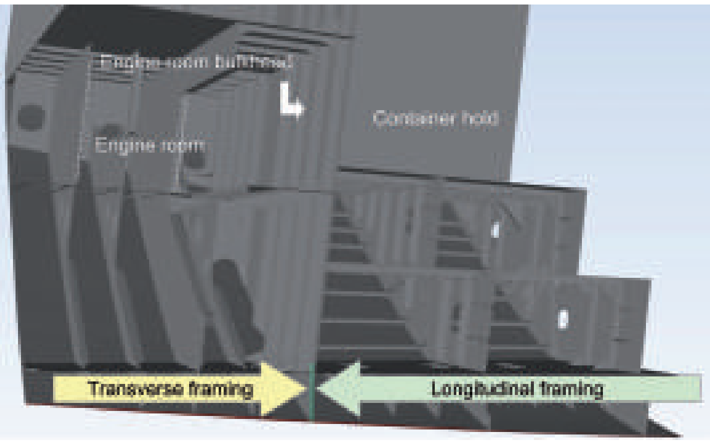
The challenge of rectifying a shortcoming in buckling capacity in the critical area can be solved in two alternate ways, either by reducing the compressive load or increasing the structure's capacity to withstand the load.

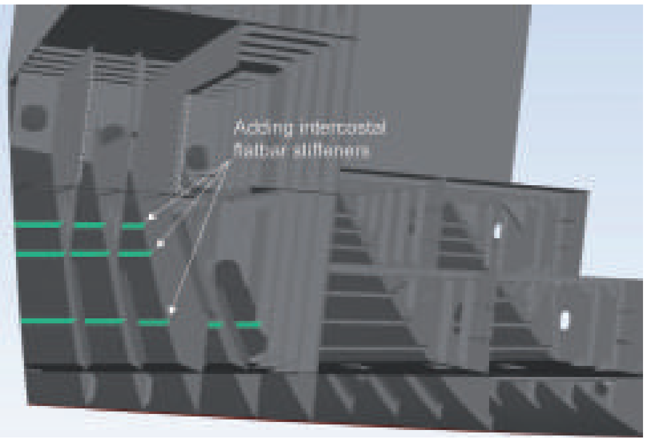


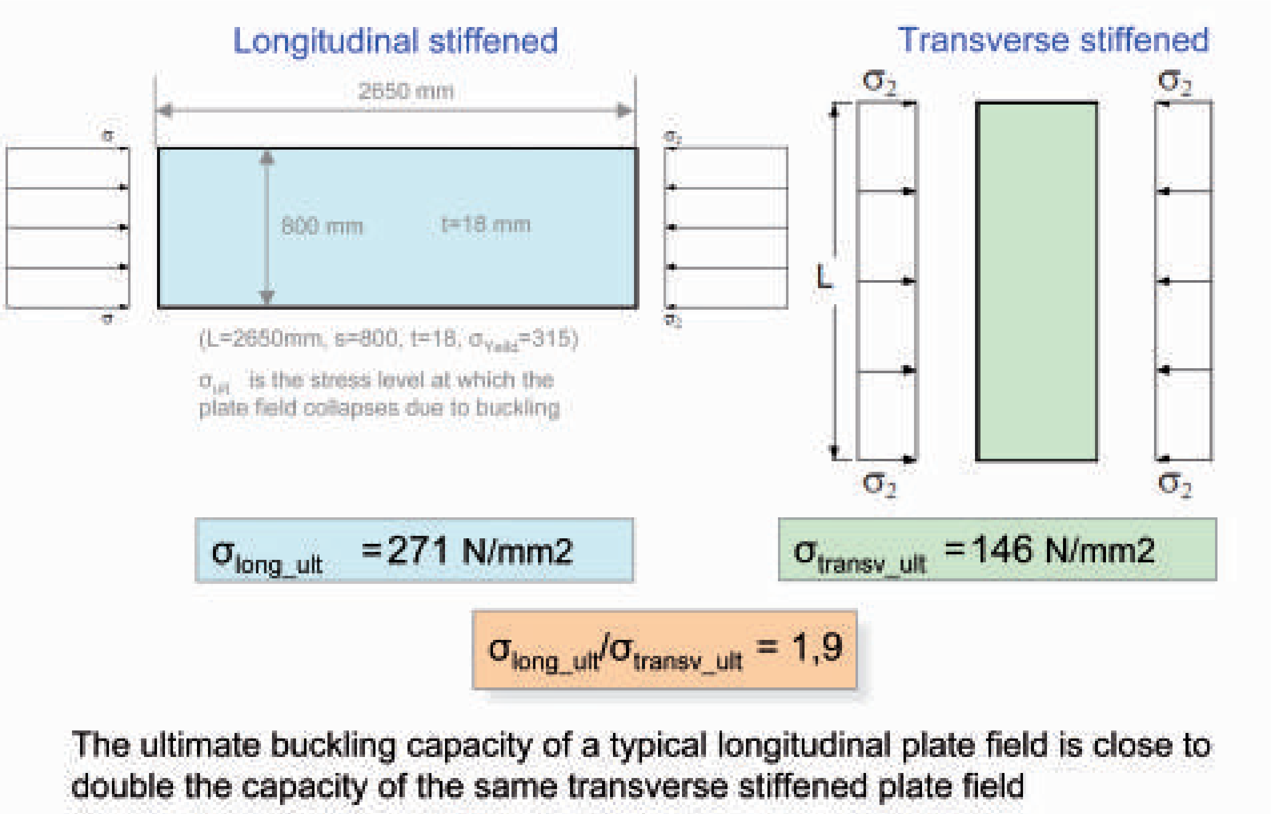
A reduction in the allowable still water bending moment will reduce the compressive load in the lower part of the hull girder cross section. This is probably the most cost-effective way provided the cargo operations allow such a measure. Not all ships may utilise their full potential with regard to container loading on the hull girder, and in such case this may be the best way out of the problem.

The alternative is to increase the buckling capacity, which involves steel work. In most cases, this will be a minor job involving limited additional steel and may typically be carried out afloat, probably with a riding crew. Intercostal buckling stiffeners need to be installed in the critical area. This is illustrated in the model snapshots shown below.

The reason why the intercostals work is simply that the aspect ratio of the plate field is changed by dividing the plate up into almost square panels. The effectiveness of the orientation of the stiffeners is quite significant as can be seen from the comparison below. Two plate fields of the same dimensions are subjected to the same loading, one transversely stiffened and the other longitudinally stiffened. The ratio of the critical buckling stresses







(L=2650mm, s=800, t=18, σ_{Yield}=315)

σ_{ult} is the stress level at which the plate field collapses due to buckling

σ_{long_ult} =271 N/mm2

σ_{transv_ult} =146 N/mm2

$\sigma_{long\_ult}/\sigma_{transv\_ult}$ = 1,9

The ultimate buckling capacity of a typical longitudinal plate field is close to double the capacity of the same transverse stiffened plate field

is 1.9, indicating that the longitudinal orientation is almost twice as effective as the transverse orientation.

The orientation and location of the intercostals are shown in the figure below, where the flat green bars are the modifications needed. The dimensions are typically some 150 x 12 mm flatbar section to be fitted in between the vertical framing. Depending on the size of the ship, the total steel weight should only amount to a few tonnes.

Ivar Håberg
Container Hull Newbuild Section

MSC Napoli

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We welcome your thoughts!

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