OSK GROUP

M/F COLUMBUS

Vessel inspection report and Deck strength assessment

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Sign TCA

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Client

Client Name	Frederikssund Kommune
Contact Person	Karsten S. Haslund
Mail	kshas@frederikssund.dk
Phone	+45 21 52 15 02

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OSK-ShipTech

Author	Tiago Castilho	______________
	Preben H. Lauridsen	
Approved	Andreas Sorth	______________
Contact person	Preben H. Lauridsen	
Mail	phl@osk-shiptech.com	
Telephone	+45 8617 8099	
Department	Balticagade 12C 1.	
	DK-8000 Aarhus C	

Summary

The report presents a description of the findings during the inspection of the vessel M/F Columbus, with focus on deck strength and general seaworthiness of the vessel.

Document History

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1. Introduction

OSK-Shiptech has been requested to perform an inspection and assessment of deck strength of the vessel M/F Columbus, sailing between Sølager and Kulhuse.

The vessel was built in 1947 and undergone major deck repairs between 30-40 years ago. The original wood planking was replaced by a second steel plate on top of the original deck plating

The significant corrosion of the original deck plating and the lack of documentation on the deck strength raised some questions about the safety of the vessel.

This report presents the findings of the inspection and strength assessment.

2. Conclusion

The vessel inspection and deck strength assessment were carried out.

The current deck construction, with a top plate over the existing deck, and the original deck plating cut in several locations, mean the watertightness of the aft and fore bulkheads has been compromised. The vessel is non-compliant with rules at the time of keel laying and in case damage the size of flooding (the hole hull) may jeopardies the time for evacuation of passengers.

The strength of the as-is deck primary structure was calculated to be 2.2 ton/axle. If collar plates are installed in all web frame openings, the maximum load can be increased to 3.0 ton/axle.

Additionally, it is recommended to complete the welds of the brackets in way of MDO tank and void tank. This will improve the overall structure and avoid the development of cracks in the tanks' plating.

The required plate thickness to withstand a axle load of 3.0 ton is 7.0 mm. Since there is no documentation on the thickness of the top deck plating, it is recommended to perform thickness measurements to confirm that the top deck plating is above 7.0 mm.

It is recommended to perform an inspection of the wood planking under the passenger platform, to assess the level of rot on the original planking.

It is also recommended to perform a more thorough inspection of the deckhouse deck plating, and proceed with plate renewal where necessary.

3. Vessel inspection

The vessel inspection took place in Lynæs harbour, 26th January 2022, with the following participants:

Ole Kaspersen, Marine consultant for Frederiksund Kommune;

Tiago Castilho, Naval architect from OSK-Shiptech

The main findings of the inspection are presented in the following chapters.

3.1 Deck construction

The ferry was designed with 7.0 mm deck plating, intended to be covered by a 2" wooden deck and additional wear layer.

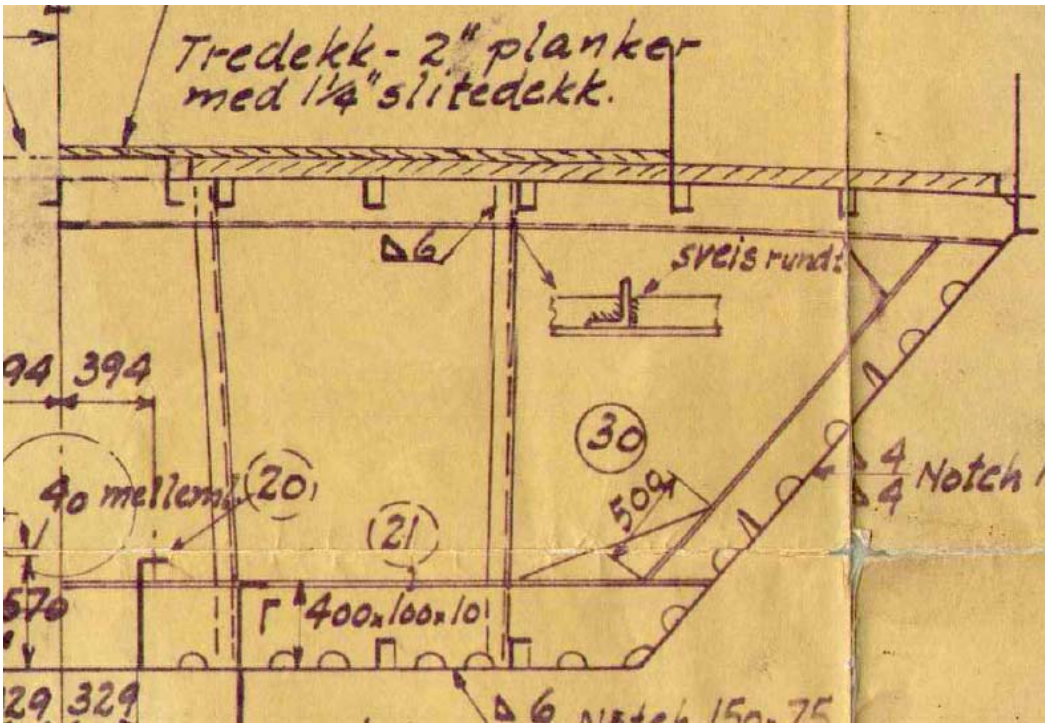


Figure 1 - Detail of deck, from original hull drawing

Between 30-40 years ago, the wooden deck was removed and replaced by steel deck plating, offset by around 50 mm from the original plating. The top deck plating is attached to the original deck plating via vertical flat bars, welded to the original web frames and deck longitudinals.

There is no documentation on the thickness of the top deck plating. However, where the top deck plating has been recently replace, 10 mm plating was used:

-2018: Replacement of 4500x2000 mm of plate, Aft end;

-2020: Replacement of top deck plate over MDO tank and old cooling water tank (void)

<u>This indicates that the top deck plating is 10 mm all over, but should be confirmed by thickness measurements.</u>

The top deck plating is attached to the flatbars with few slot welds. Some of the welds can be seen from above deck, where the coating has failed locally (see Figure 2).

Figure 2 - Slot welds, visible from above deck

3.2 Original deck plating

The original deck plating is found to be severely corroded.

It is likely that the corrosion present at the time the wooden deck was removed was not properly addressed, and just continued to spread in the void space between the original deck and top deck.

The original deck plating is fully coated from the engine room side. Many irregularities can be seen under the coats of paint, indicating that the plating and old coating was not properly treated before applying new paint.

Figure 3 - Example of poor condition of coating below original deck plating

It is also possible to identify several holes through the deck plating (see Figure 4 and Figure 5).

Rust has been developing on the original deck plating, from the upper side, resulting in holes.

By inspection the holes and tapping the area around, it can be concluded that the flaking is not a local phenomenon.

Over the last years (5-10 years), some of the original plating has been removed. This has been done in the areas with higher levels of corrosion in the original deck plating. Figure 7 highlights the areas that have been cut (red). In these areas, it is possible to see the top deck plating.

In the aft end void space and in the old cooling water tank, the removal of the original deck plating was done in connection with the replacement of top deck plating and reinforcement of deck longitudinals.

Figure 7 also highlights the area belonging to the top of the MDO tank in green. The plating in this area was replaced in February 2020.

Figure 4 - Typical state of original deck plating, with irregularities and holes

Figure 5 - Original deck plate field with multiple holes and flaking of steel plate

Figure 6 - Typical state of original deck plating in FWD void space

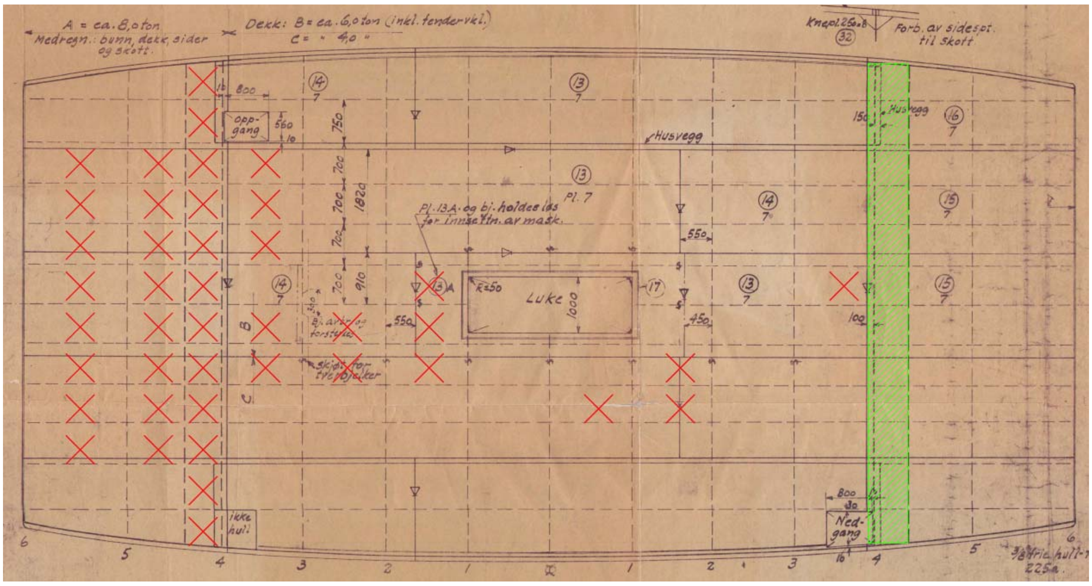


Figure 7 - Overview of cut outs in original deck plating (Red) and replaced original deck plating (green)

3.3 Top deck plating

Upon inspection of the top deck plating via the openings in the original deck plating, it can be stated that the top deck plating presents a low level of corrosion.

The condition of the top plate seems to be the same across all the openings. Therefore, it is fair to assume that the top plate hidden by the original plate presents a similar low level of corrosion.

Figure 8 - Top deck plating seen through opening in original deck plating

Figure 9 - Support of top deck plate

As previously mentioned, the top deck plating is supported on top of vertical flat bars, with few short slot welds.

Figure 9 shows the typical connection. Since the plate is just resting on top of the flatbars, it is prone to slide and rotation from side to side as the vehicle weight is applied to the plate. This movement seems to have cause a slight abrasion on the plate surface.

From the Deck side, the plating looks ok, considering its age. A few areas present localized coating failure and rust, but overall, the plating seems to have a good structural integrity.

The rusted area in Figure 10 corresponds to the top decking plate replaced 2 years ago (February 2020), in connection with the replacement of the MDO tank top plating.

This indicates that the coating was not correctly applied in this particular area.

Figure 10 - Condition of top deck plating

Figure 11 - Failure of coating system in way of slot welds

3.4 Deck longitudinals and Web frames

The deck longitudinals and web frames are generally in good condition, and according to original design. No flaking of the coating system has been identified.

However, the integrity of the original deck plate is very poor, due to several reasons:

-severe corrosion and flaking of the original base plate;

-where the original plate has been removed, there is almost no plate left, and in some areas it is not continuous. Figure 14 shows a detail where the opening was overcut.

Due to these reasons, the deck strength calculations will be based on the strength of the stiffener alone.

Figure 12 - Typical condition of a deck longitudinal

Figure 13 - Typical condition of a web frame

Figure 14 - Typical details of cut outs: intersection of stiffener and frame (left), web frame with plate missing (right)

Figure 15 shows the stiffeners in the Aft void space, aft of the old cooling water tank. The original stiffeners terminate at the tank bulkhead and continue inside the tank, with a increased profile of L200x80x8 (see Figure 16).

Similar arrangement is found in way of the MDO tank, but with a UPN 100 profile (see Figure 18).

The deck longitudinal inside the MDO tank and cooling water tank were previously of a smaller profile L100x80x6.

Figure 15 - Stiffeners and flatbars in Aft void space

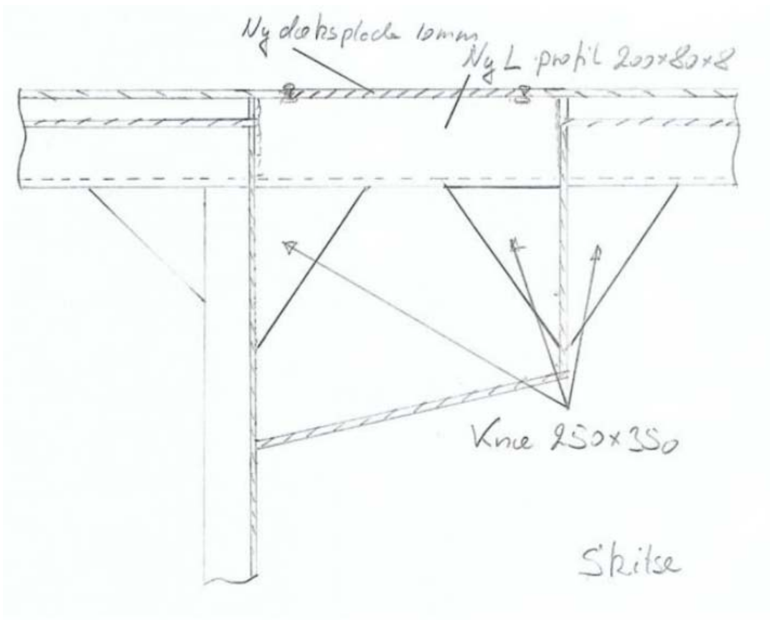


Figure 16 – Sketch of arrangement in way of cooling water tank (Reparationsarbejde på M/F Columbus, 28/03/2020)

Figure 17 – Stiffeners and original deck plating in Fwd void space

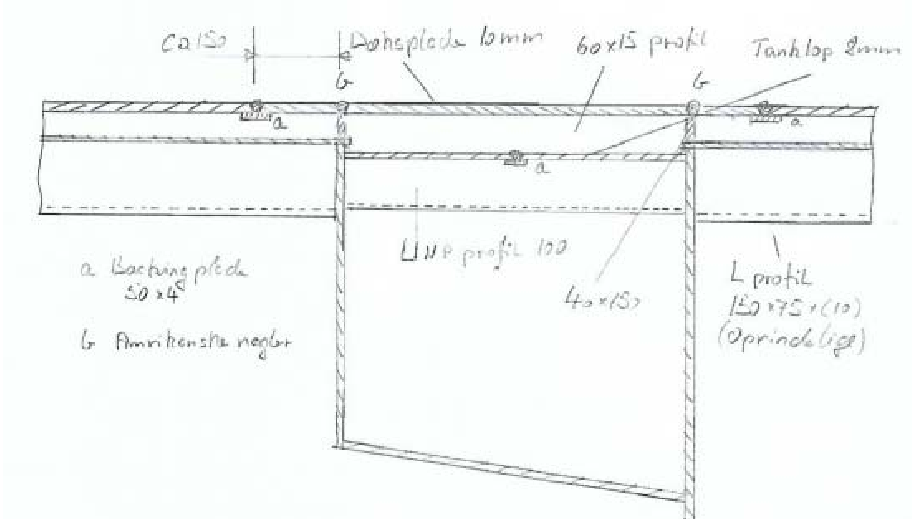


Figure 18 - Modified deck structure in way of MDO tank (Udskiftning af MDO tanktop, Februar 2020)

3.5 Pillars

The pillars are generally in good condition, similar to the deck stiffeners and web frames.

The only remark is that some of the pillars have been cut and joined by a lap bolted connection (see Figure 19).

These connections are present in the following 4 of the pillars:

-Frame #-3, Pillar 700 mm from CL (PS)

-Frame #-2, Pillar 700 mm from CL (PS)

-Frame #-1, Pillar 700 mm off CL (PS & SB)

It is believed that these modifications to the pillars were made when the main engines were replaced.

The strength of the pillars and bolted connections will be checked in the next chapter.

Figure 19 - Pillar bolted connection

3.6 Other observations

3.6.1 Bulkheads not tight

One of the consequences of the existing deck plating arrangement is that once the top deck plating was added and the original plating was cut, the watertight integrity of the vessel has been compromised. The Aft and Fore void spaces are now part of the Engine room space.

The lack of fore and aft peak collision bulkheads means that the vessel is non-compliant with the classification rules at keel laying date.

3.6.2 General safety concerns

The vessel is very old and do not comply with at damage stability requirements today and nor with the requirements at the time of built, as mentioned above.

Vessels today and for the past 30 years have had requirements to watertight subdivision of the hull, giving the crew sufficient time to evacuate the passengers and hereby saving life's. A new ferry with same length and breath as M/V Columbus would have to include the following to comply with the criteria:

- A double bottom extending from the fore to aft collision bulkhead. Make the vessel safe from any racking damages (damage to the bottom).
- Subdividing the hull with 5-6 transverse watertight bulkheads and two longitudinal watertight bulkheads.

With watertight integrity as this, the vessel will in the event of damage to a compartment have sufficient buoyancy in the remaining hull to keep it flooding and hereby secure a safe transit to harbour or safe evacuation of the passengers.

If damage occur to 'Columbus' today, the vessel will sink and be a total loss and pending the size of the damage and time to flood, jeopardies the evacuation of passengers on board.

3.6.3 Localized corrosion

It is noted that there is significant corrosion in way of the Engine room emergency exit, with possible water ingress at the bolted connection between the wooden belting and ship side (Figure 20).

Figure 20 - Corrosion hidden under coating, in way of Engine room emergency exit

Also in Portside, in way of the life vest locker, there is a visible crack that allow water to run into the locker (Figure 21).

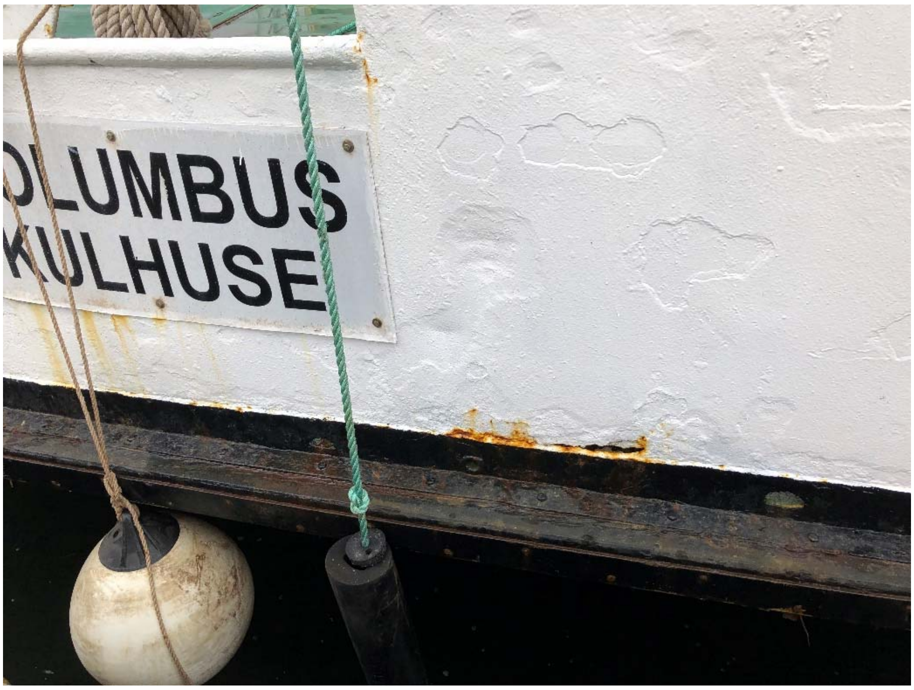


Figure 21 - Hole on ship side, above Deck

3.6.4 Deckhouse deck plating (SB)

The plating on the starboard deckhouse is in poor condition. It seems that the original plating was cut around the stiffeners, and new plating added on top. It is not clear how the connection was made.

Figure 22 – Plating of deckhouse, seen from below

From the outside, it can be seen that the coating is in poor condition, and that rainwater is not being drainer properly (Figure 23). This will lead to increase in the corrosion rate of the plate.

It should be kept in mind that in case of emergency and need for evacuation, at least a crew member will walk on deck in order to release the life rafts.

Based on the visual inspection, it is not possible to conclude on the structural integrity of the deck plating.

Therefore, it is recommended to do a more thorough investigation of the deckhouse deck plating during the next docking:

-Blast coating and corrosion;

-Perform thickness measurements;

-Replace the plating if necessary.

Figure 23 - Plating from deckhouse, seen from above

3.6.5 Wooden passenger platform (PS)

The wooden deck platform on Port side has been covered with aluminium plates. Upon analysis of the edges, it is noted that the original wooden planks are rotting (Figure 24).

It was not possible to inspect the wooden planks from below, to assess their integrity. There is a cover plate under the deck planking (see Figure 26).

Figure 25 shows the aluminium plates installed on top of the wood planks. The plates are installed in sections, screwed into the wood. Due to poor drainage, it is likely that water is finding its way through the joints and screw holes and accelerating the rotting process.

It is recommended to remove the aluminium plates above the planking and the cover plates underneath the planking. If the planking is rotten, it should be replaced.

Figure 24 - Passenger platform edge

Figure 25 - Passenger platform, presenting poor drainage

Figure 26 - Cover plate under passenger platform planking

4. Deck strength assessment

Currently there is no documentation on the deck strength and design loads.

The chapters below present direct calculations to define what is the maximum allowable load.

4.1 Deck beams and pillars

A direct calculation model of the main deck structure (Figure 27).

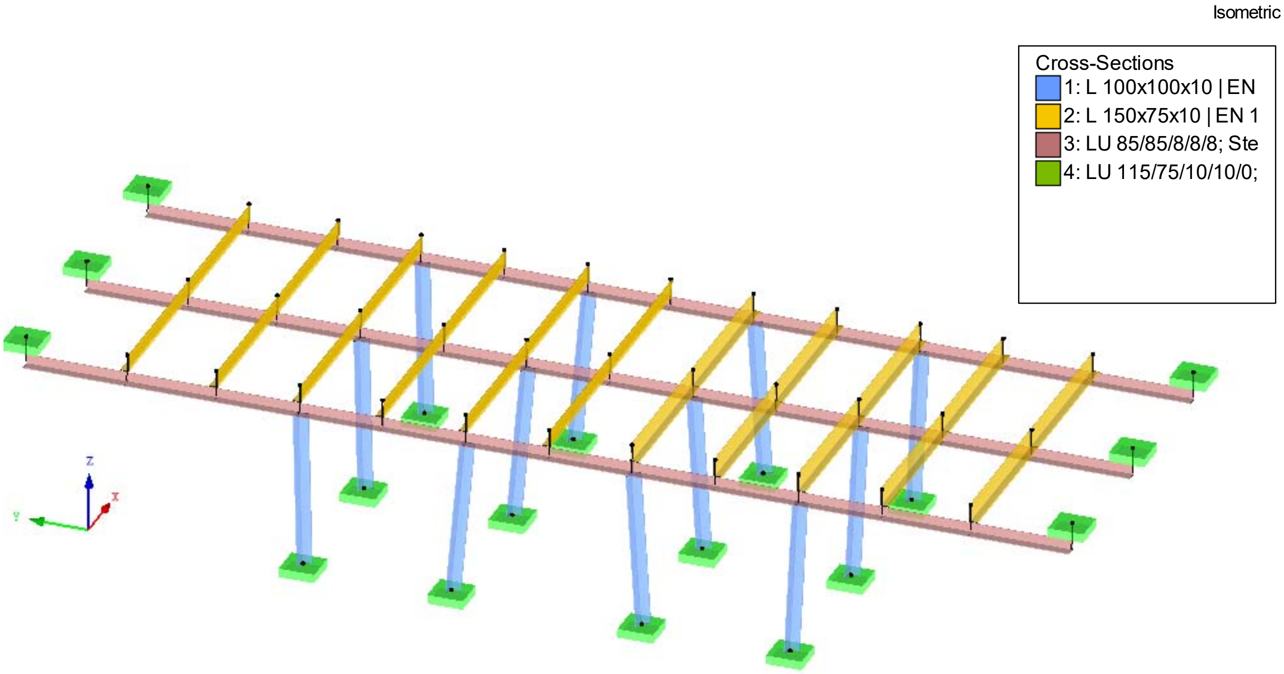


Figure 27 - Beam model of midship section, between 3 web frames

4.1.1 Design loads and acceptance criteria

The vessel operates in sheltered waters. Therefore, the deck structure is mainly subjected to the static loads from the vehicles. Accelerations and dynamic loads are not considered in this analysis.

Global loads from the hull are not considered.

The analysis is done following guidelines from DNV for the design of primary members (DNV-Ru-SHIP Pt3Ch6 section 6 Primary supporting members and pillars).

The design loads will be defined as point loads, applied at different locations of the model. This will be done to capture the worst possible load location.

The following loads will be tested:

-Car/SUV. Assumed maximum 1200 Kg per axle   Corresponding wheel load:600 Kg

-Light van (3.5 ton). Assumed 2200 Kg rear axle   Corresponding wheel load:1100 Kg

-Arbitrary axle load. Load will be increased until failure of structure.

Figure 28 shows the locations where the loads are applied:

-Mid span of deck longitudinal;

-Mid span of web frame, between 2 pillars;

-Above a pillar

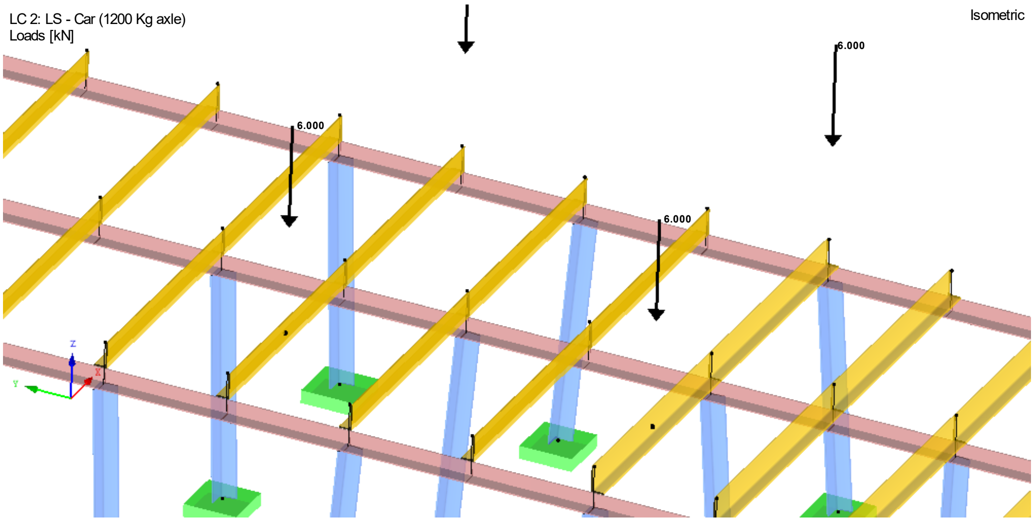


Figure 28 - Example of load application on deck longitudinals and web frames

According to DNV, the acceptance criteria for AC-I (operational static loads) for mild steel (235) is:

-Bending stresses: 0.7 x Reh 164 MPa

-Shear stresses: 0.7 x τeh 94 MPa

4.1.2 Beam model – As-Is

The beam model has been developed in RFEM (Figure 27). This model conservatively represents the deck structure in its current state. The model contains deck longidudinals, web frame and pillars between 3 arbitrary web frames. Due to its poor integrity, the original deck plating is not considered in the calculations. The deck longitudinals and web frames are defined with the cross section in way of the cut outs, as defined below.

Deck stiffener section is reduced from L150x75x10 to **L115x75x10**.

Web frame section is reduced from L250x85x8 to **L85x85x8.**

Pillars are modelled with the original section, **L100x100x10**.

Figure 29 - Web height for stiffener (115 mm) and web frame (85 mm)

4.1.3 Results – As-Is

The maximum stresses are summarized below, in Table 1.

Under the loads of a light van, the deck stresses are above the allowable limit. The critical point is the midspan of the web frame, between 2 pillars. Figure 30 shows the bending stress plot for the critical load case.

For the maximum axle load case, the point loads are reduced to 1000 Kg per wheel. With this load, the bending stresses reach 158 MPa, slightly below the limit of 164 MPa.

Table 1 - Summary of maximum stresses in beam model of existing structure

	Deck beams (stiffener and frames)		Pillars
Load	Bend. stress [MPa]	Shear stress [MPa]	Axial stress [MPa]
Car - 600 Kg point loads	95	6	3
Light van – 1100 Kg point loads	**173**	11	5
Max. axle load 2 tons – 1000 Kg point loads	**158**	10	5

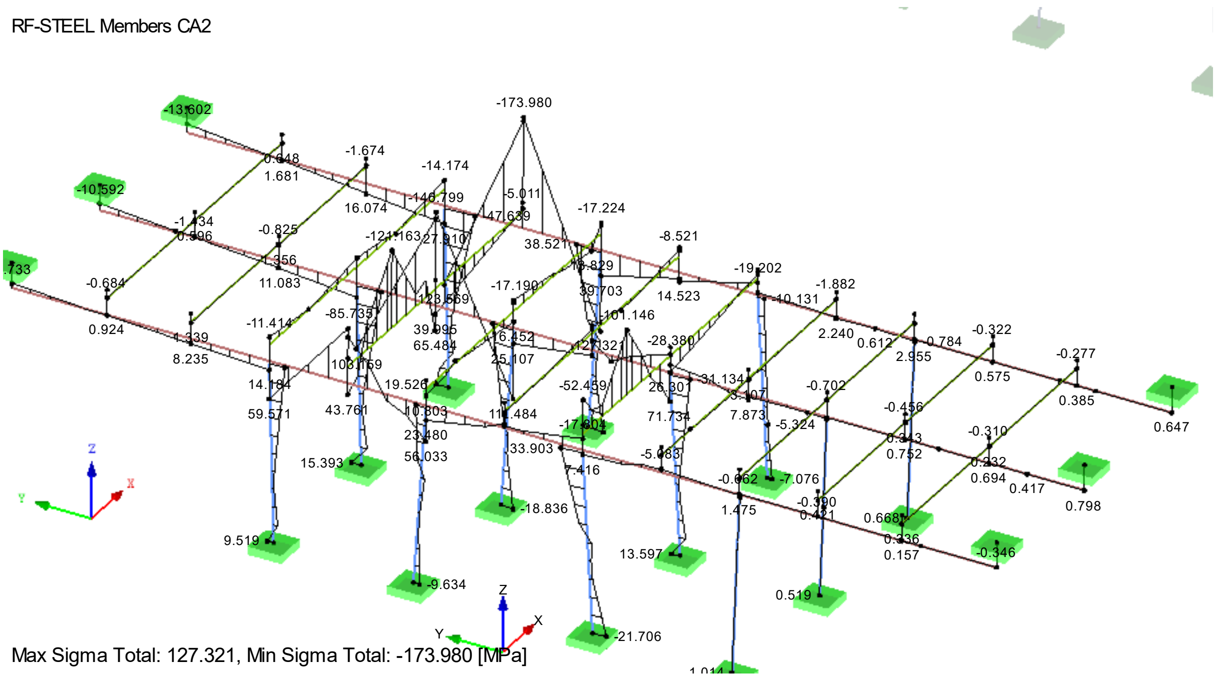


Figure 30 - Plot of bending stresses under loads from a light van

4.1.4 Beam model – Modified web frames (collar plates added)

In order to improve the load bearing capacity of the deck and fully utilize the cross section of the web frames, it is recommended to install collar plates in all web frame openings, as shown in green in Figure 31.

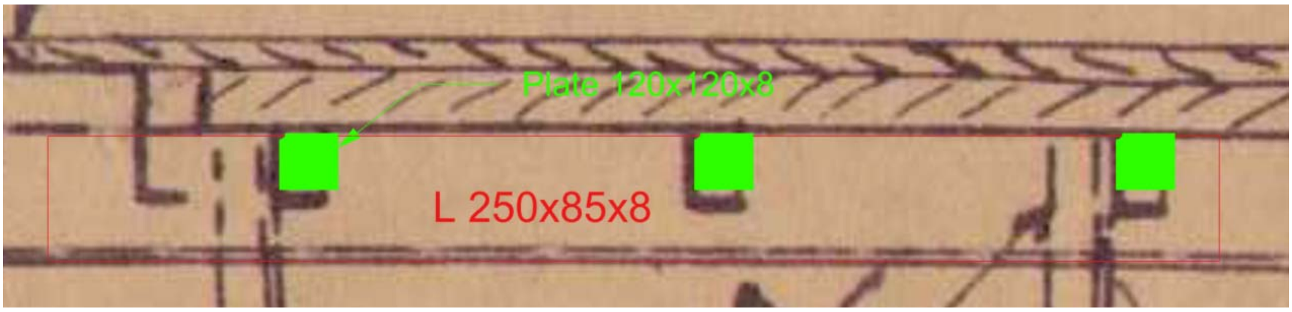


Figure 31 -Collar plates in web frame stiffener openings

The beam model is updated to match the original web frame section properties, L250x85x8.

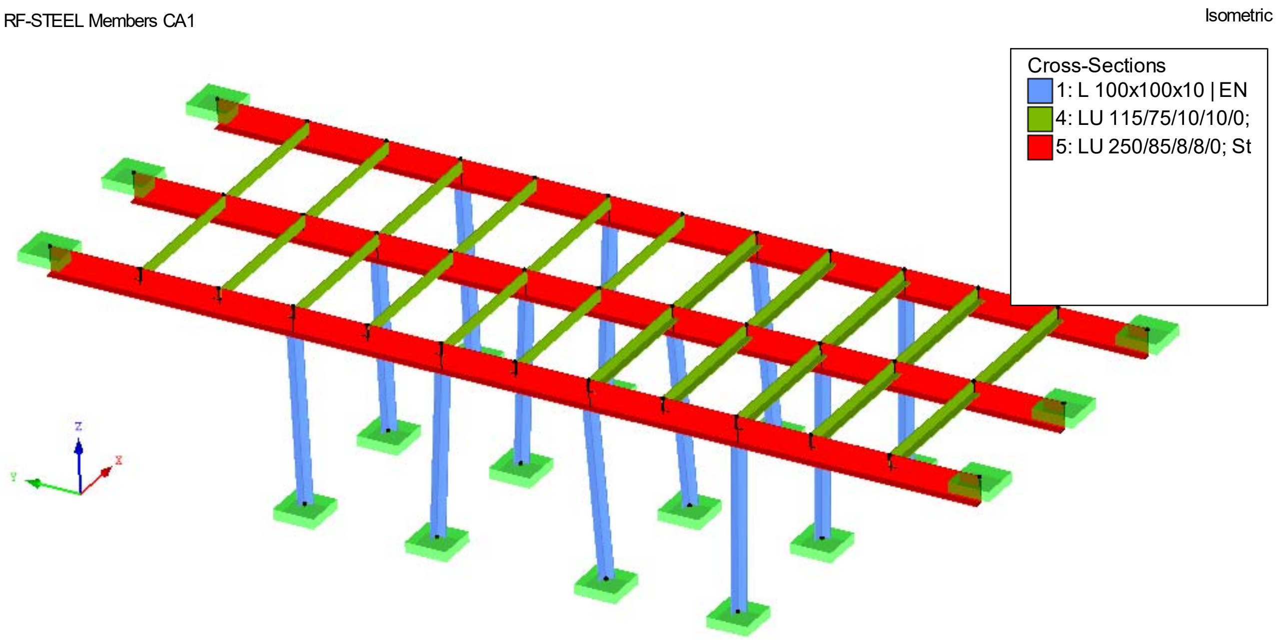


Figure 32 - Beam model of modified deck structure

4.1.5 Results – Modified web frames (collar plates added)

The maximum stresses in the modified structure are summarized below, in Table 2. The maximum stresses in the web frames are reduced from 173 MPa to 120 MPa.

The maximum axle load is recalculated to be 3 ton. Under this load, the maximum bending stress reaches the limit of 164 MPa.

Table 2 - Summary of maximum stresses in beam model of existing structure

	Deck beams (stiffener and frames)		Pillars
Load	Bend. stress [MPa]	Shear stress [MPa]	Axial stress [MPa]
Car - 600 Kg point loads	65	4	3
Light van – 1100 Kg point loads	120	8	5
Max. axle load: 3 ton – 1500 Kg point loads	**164**	11	7

4.1.6 Pillar bolted connections

During the vessel inspection, the bolts were measured. The head of the bolts measures 30 mm between flat sides. This corresponds to a M20 bolt.

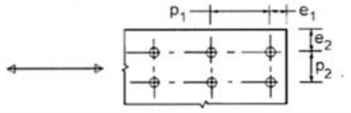
Since there is no information on the bolt grade, the calculations are based on the lowest grade of structural bolts, Grade 4.6, with ultimate strength equal to 400 MPa.

There is also no information on the bolt hole clearance or bolt tightening torque. The calculations will conservatively assume that all the pillar load is being transferred by 1 bolt.

The bolted connection will be tested assuming a compression load of 3 ton on the pillar. This would correspond to the load induced by 2 vehicles with 3 ton axles, parked side by side.

The calculation for the bolted connection is shown in Table 3.The maximum utilization of the bolted connection under the assumptions above is **0.66** and considered acceptable.

Table 3 - Calculation of bolt and plate according to Eurocode 3

Input values		Bolt: M20		*comment/reference*
Design tensile load	$F_{t,Ed}$	**0.00**	kN	
Design shear load	$F_{v,Ed}$	**30.00**	kN	
Diameter of bolt	d	20	mm	
Hole diameter	d_0	24	mm	Loose fit
Distance btw. Holes in boltflange	p_1	50	mm	Connection details: CL beam side - Existing (Conservative: p2=p1, e1=e2) 
Distance btw. holerows in boltflange	p_2	50	mm	
Distance from hole center to edge in load direction	e_1	50	mm	
Distance from hole center to edge perpendicular to load direction	e_2	50	mm	
Mean-diameter of bolt head	d_m	30	mm	1.5d should be conservative for regular hex head bolts
Bolt tensile stress area	A_s	245	mm^2	
Bolt tensile strength	f_{ub}	400	MPa	Grade 4.6
Bolt yield strength	f_{yb}	240	MPa	Grade 4.6
Yield stress of the plate material	f_{yp}	235	MPa	Mild steel
Tensile stress of plate material	f_{up}	360	MPa	Mild steel
Thickness of mounting plate	t_p	10	mm	
Material reduction factor	γ_{M2}	1.3		
Shear plane parameter	α_v	0.6		EC3.1-8 table 3.4
Output values				comment/reference
Shear utilizaton		**0.66**		
Bearing utilization		**0.64**		
Tension utilization		**0.00**		
Punching shear utlization		**0.00**		
Combined shear / tension utilisation		**0.66**		

4.2 Deck plating

The required deck plate gross thickness for the maximum axle load of 3 tons is presented in Table 4. The calculation is done according to DNV-RU-SHIP Pt3 Ch10 Sec5.

The required deck plate thickness to withstand a 3 ton axle load is 7 mm.

Table 4 - Calculation of minimum plate thickness according to DNV-RU-SHIP Pt3 Ch10 Sec5

Design of deck for wheel loads	Project name: **MF COLUMBUS**	User: TCA	Date: 07/02/2022
DNVGL, Part 3, Chapter 10, Section 5	ShipTech project no.: **210500.01**		Time: 21:43:57

It is assumed that the considered plate or stiffener is subjected to one load area only.

Subject

Generic axle 3 ton

Stiffener spacing	Stiffener length	
b = 0.7	l = 1.4	s/l = 0.500

Description	**Q [ton]**	**w**	**p_0 [kN/m2]**	**av**	**p [kN/m2]**	**k1**	**A [m2]**	**k2**	**wQ/n0s2**	**k**	**a_1 [m]**	**b_1 [m]**
Harbour, Long driving	3.00	1.0	293.9	N/A	345.84	2.0	0.0501	0.1598	3.0612	2.0	0.3164	0.1582
Harbour, Turning	3.00	1.0	293.9	N/A	345.84	2.0	0.0501	0.1598	3.0612	2.0	0.1582	0.3164

Plate

Description	**alpha_p**	**kw**	**c**	**b_1/b**	**m**	**Ca**	**t_{net}**	**t_{c1}**	**t_{c2}**	**t_c**	**t_{gross}**
Harbour, Long driving	0.9619	0.4719	0.158	0.2260	6.9232	1.80	5.85	0.5	0	1	6.85
Harbour, Turning	0.9619	0.2768	0.316	0.4520	8.2973	1.80	5.79	0.5	0	1	6.79

5. Recommendations related to the deck structural integrity

In order to improve the structural integrity of the deck structure, the following operations should be carried out:

-Ensure all bracket ends are welded to the base plate. Below an example of a bracket inside the cooling water tank that is not fully welded at the end (highlighted red). The bracket should be welded at both ends (highlighted green).

Figure 33 - Example of brackets inside old cooling water tank, with missing weld at ends (red)

-Install collar plates in all web frame cut outs for deck stiffeners. The collars are to be welded all around, from both sides, with a weld throat thickness a=5.0 mm.

If this operation is performed, the maximum axle load can be increased from 2.2 ton/axle to 3 ton/axle.

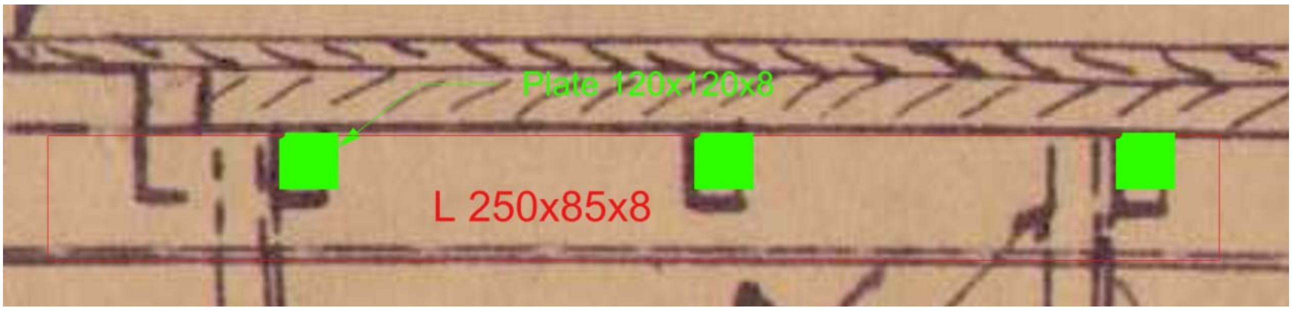


Figure 34 -Collar plates in web frame stiffener openings. Plate 120x120x8 mm

-Where the original deck plating has been cut out, the top plate can be welded to the vertical flatbar with chain weld. This will improve the connection between plate and stiffener, and minimize the failure of the slot welds.

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