Investigation of the Intact Stability Accident of the Multipurpose Vessel MS ROSEBURG

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ABSTRACT

This paper presents the results of the accident of the multipurpose vessel MS ROSEBURG. On the voyage from Riga to Barrow Haven the ship was laden with timber cargo on the deck and in the hold. In the Bay of Kiel the ship was caught by a gust of wind and reached a heeling angle of 10 to 15 degrees. The deck cargo began to slip and lashing straps for cargo securing broke. The ship reached a heeling angle of 40 degrees. About 75 percent of the deck cargo was lost. Afterwards the ship rested at a stable equilibrium.

Keywords: *Intact Stability; Ship Accident; Accident Investigation; Ship Safety; MS ROSEBURG*

1. INTRODUCTION

The investigation of accidents is useful to better understand the casualty roots. In this paper the accident of MS ROSEBURG is investigated which happened in an intact condition of the vessel. Hence conclusions can be made, whether the applicable intact stability criteria are sufficient.

MS ROSEBURG was built in 1990 as a combined freighter for timber and grain cargo. On the relevant voyage the vessel was laden with timber cargo in the hold and on deck and a few cable reels in the hold. The ship started in Riga on the evening of 02 November 2013. Three days later, on 05 November 2013, MS ROSEBURG reached the Bay of Kiel, where the accident occurred.

The sequence of events leading to the accident is reconstructed by the witness statements. The crew of the vessel, the harbour police and the company for the recovery of the timber cargo were asked to comment on the accident. According to this the accident happens as follows:

Figure 1 Consequences of the accident

At five o'clock the captain asked for the permission of anchoring to perform small repairs. Shortly afterwards the ship began to heel and reached a heeling angle of 10 to 15 degree caused by a gust of wind. As a result of the heeling angle and the related accelerations the timber cargo on deck slipped and the load securing failed. Hence the ship reached a heeling angle of 40 degree and the main part of timber cargo on deck went overboard. Following the stability of MS ROSEBURG was increased and the vessel reached a stable position of equilibrium. In Figure 1 the consequences of the accident are shown. People were not injured in the accident.

In this paper the questions will be answered, which stability condition resulted in the accident and why it occurred in the Bay of Kiel. Therefore, the paper begins with the presentation of MS ROSEBURG and the according calculation model. Afterwards the documents of the loading condition are analysed checking the consistency. In addition it is analysed why the voyage from Riga to the Bay of Kiel was without an accident. This is done by the calculation of the accelerations of the deck cargo taking into account realistic environmental conditions during the voyage. Finally the process of the accident and all related information are summarized in the conclusion.

All calculations are executed within the ship design environment E4 which is developed by the Institute of Ship Design and Ship Safety at the Hamburg University of Technology and partners.

2. SHIP AND CALCULATION MODEL

2.1 MS ROSEBURG

The multipurpose vessel MS ROSEBURG was originally built in 1990 as MV BALTIC BORG by the shipyard FERUS SMIT BV Hoogezand as Hull No. 257. The call sign of the vessel is V2PS2. MS ROSEBURG is classified at Lloyd's Register in Rotterdam. The ship is designed for timber and grain cargo with a maximum permissible deadweight of 3005 t. A side view of the vessel is presented in figure 2. At the time of the accident, the ship was registered in St. John's, Canada. In table 1 the main dimensions of MS ROSEBURG can be found.

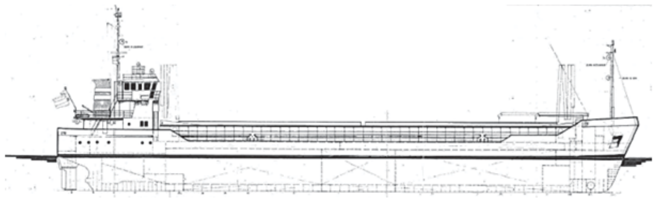

Figure 2 Side view of MS ROSEBURG

Length over all	78.00 m
Breadth	12.50 m
Draft at summer freeboard	4.95 m
Depth to main deck	6.60 m

Table 1 Main dimension of MS ROSEBURG

According to the stability booklet the safety requirements of the Intact Stability Code are applied. In the following investigation these rules are considered for the evaluation of the stability condition in the different loading conditions which means:

- $GM_0 \geq 0.15$ m
- $h(30°) \geq 0.20$ m
- h_{max} at $\varphi \geq 25°$
- Area(0°,30°) ≥ 0.055 m·rad
- Area(0°,40°) ≥ 0.090 m·rad
- Area(30°,40°) ≥ 0.030 m·rad
- Weather Criteria

2.2 Calculation Model

The calculation model of MS ROSEBURG is presented in figure 3. For the investigation the buoyancy body is composed of the forecastle (green) and the stern geometry (red) up to the height of 8.8 m which corresponds to the height of the hatch cover (blue). The sheer strake is not taken into account as a part of the buoyancy body. Furthermore the deckhouse is not modelled due to the fact that it is only relevant at a heeling angle of more than 45 degrees which did not occur during the accident.

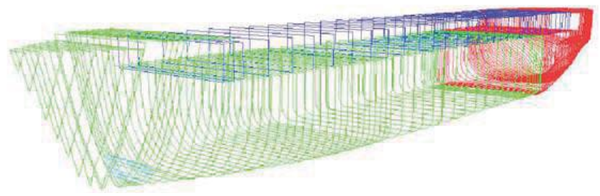

Figure 3 Calculation model

To control the calculation model, a comparison of a standard loading condition of the stability booklet ("Timber length packages Departure") is made between the given and calculated hydrostatic characteristics and the weight distribution. The values of the weight, the draft, the stability etc. are approximately similar. The comparison is shown in table 2 in detail. Therefore it can be assumed that the calculation model represents the real behaviour of MS ROSEBURG.

	Calc.		Stab. Booklet	
Displacement	4037.0	t	4037.070	t
Draft at AP	4.923	m	4.928	m
Draft at FP	4.949	m	4.950	m
LCG from AP	39.742	m	39.739	m
VCG a. BL	4.922	m	4.931	m
GM_0	0.449	m	0.454	m
GG’	0.030	m	0.038	m

Table 2 Comparison of the calculated and given values

3. THE DECISIVE VOYAGE

On the second of November 2013 MS ROSEBURG was laden with timber cargo and cable reels and left the port of Riga at 20.00 o'clock. The destination of the voyage was the harbour of Barrow Haven, UK. On the fifth of November 2013, the vessel reached the Bay of Kiel where the accident occurred. The track of the vessel is displayed in figure 4.

Following the documents of the loading conditions of the voyage are analysed at the departure and the arrival time. The stability condition must be significantly changed at the Bay of Kiel. Otherwise the accidents would already take place during the voyage.

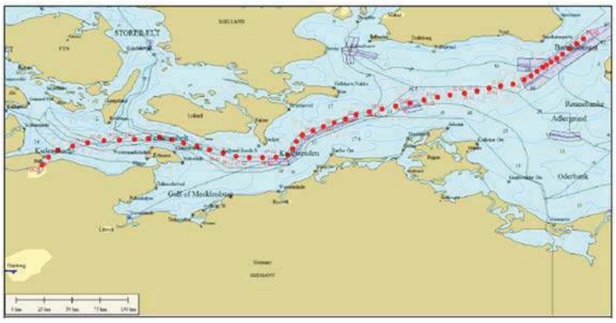

Figure 4 AIS Data of MS ROSEBURG

3.1 Departure Condition

Based on the documentation of the on board computer, the ship has an deadweight of 2886 t with a draft of 5.00 m forward, 4.90 m aft and a mean draft of 4.95 m. Furthermore, the lever arm curve is calculated which is presented in figure 5.

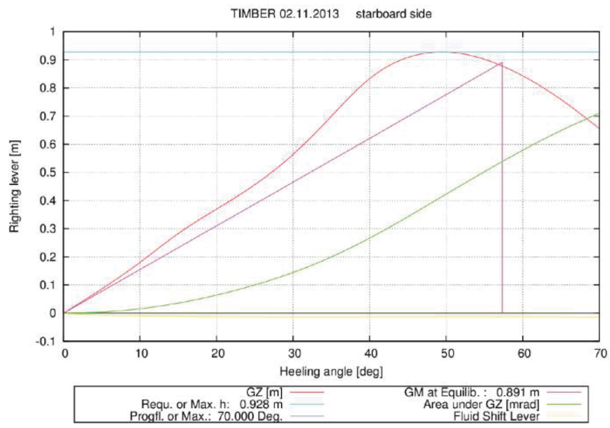

Figure 5 Lever arm curve during the departure time

From this, it can be said, the deadweight and the draft do not exceed the maximum values. Also the intact stability criteria are fulfilled by this loading condition.

It was recognized that the printout from the on board computer has a discrepancy regarding the cargo on deck. The timber packages on deck are specified with a volume of 609 m³, but without a mass and a centre of gravity. From further documents it is clear that the mass of the hold cargo must include the mass of the timber packages on the hatch covers/ on deck.

Therefore, a new calculation is performed with a corrected centre of gravity for the load of the timber cargo on deck. It is assumed that the mass of the cargo is 1845 t in the hold and 300 t on deck. This corresponds to the loading condition of comparison from the stability booklet. As a result the initial stability of the ship is reduced from 0.891 m to 0.412 m, also the lever arm for greater heeling angles. In figure 6 the lever arm curve with a corrected centre of gravity is presented. In this case MS ROSEBURG do not comply the applicable intact stability criteria.

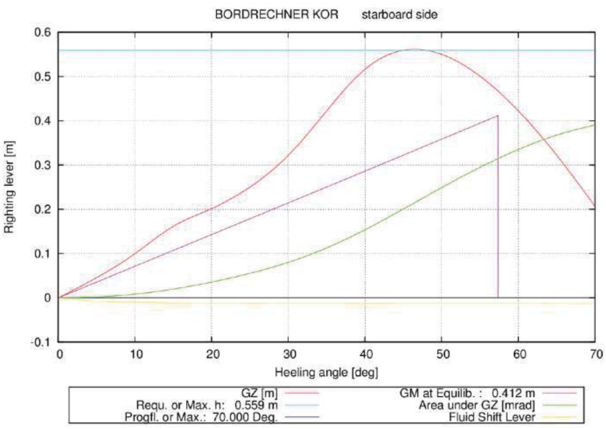

Figure 6 Lever arm curve during the departure time with corrected centre of gravity

3.2 Arrival Condition according to Shipping Company

Furthermore the shipping company created an additional loading condition, which must describe the loading condition at arrival time in the Bay of Kiel. This document was ensured by an inspector at the office of the shipping company.

In comparison to the corrected on board document (departure condition, corrected) the information about the mass of the cargo load and the water ballast differ partly. The total mass of the timber cargo is 2555 t in this case, which is 323 t greater than the given value of the on board computer with 2232 t. Looking at the mass of the timber cargo in hold the values are practically equal. But the mass of the decks cargo is increased by 323 t in case of the information by the shipping company. Additionally the mass of the ballast water is reduced from previous 563 t (departure condition, corrected) to 250 t. Therefore the double bottom tanks are empty. Figure 7 shows the regarding lever arm curve. In this condition MS ROSEBURG has a significant reduced stability based on the additional weight on deck and the missing water ballast in the double bottom tanks.

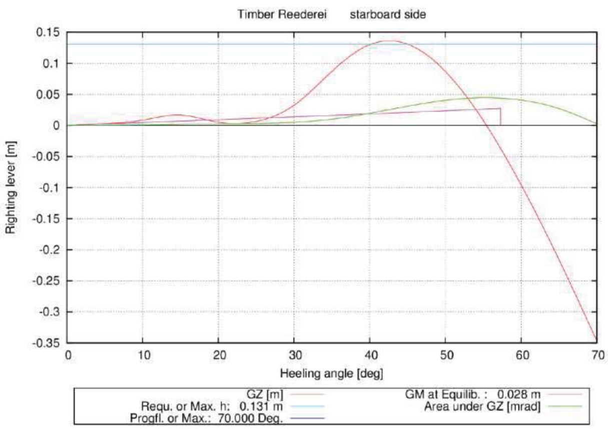

Figure 7 Lever arm curve according to shipping company

It has to be mentioned the draft with 4.90 m forward, 5.18 m aft and a mean draft of 5.04 m exceeds the limit of 4.95 m. Accordingly the vessel is formally overloaded. In this condition the intact stability criteria are not fulfilled. From this it is not clear, why the shipping company did not noticed that the stability condition is insufficient.

3.3 Consideration about the Cargo Plan

Due to the disagreement about the timber cargo (difference of 323 t) further documents and information are analysed to find the true loading condition during the voyage. In figure 8 the cargo plan of MS ROSEBURG can be found. From this it can be said that there are no deviations between the data of the on board computer and the cargo plan. The mass of the cargo on deck is also included in the mass of the cargo in hold which does not represent the centre of gravity correctly.

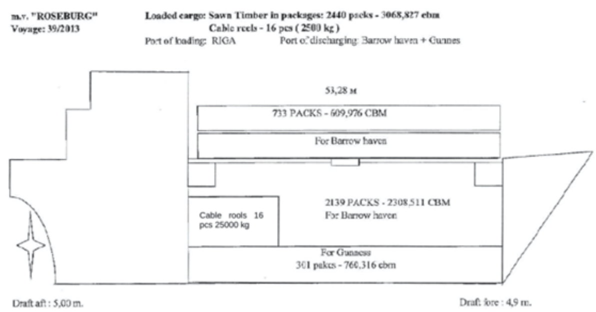

Figure 8 Cargo Plan

The company, which recovered the lost timber packages, specifies the cargo with 700 packages of timber. According to evidence up to 75 percent of the on deck cargo went overboard. Thereby the total number of timber packages on deck can be calculated with a result of at least 933 packages. The cargo plan gives a value of only 733 timber packages. Hence the information of the cargo plan and the printout of the on board computer are doubtful.

Furthermore timber packages with a mass of around 750 to 800 t were recovered from the water. Taking into account wet wood has a 1.7 times major mass density than dry wood, the loss of cargo is determined to 440 to 470 t. This corresponds to the loss of 75 percent deck cargo. Hence the cargo on deck is assumed to 587 to 626 t. The range of the calculated deck cargo fits to the given value by the shipping company.

But how is the difference of the deck cargo between the information of the on board document and the shipping company explainable? Firstly, it was established that the loading condition at departure time does not include a mass of a deck cargo but a volume with 609 m³ of timber packages. Hence the assumption is made the mass of this cargo is considered in the value of the cargo in hold. However this hypothesis seems to be incorrect. Such a volume is approximately equivalent to a mass of 300 t which corresponds to the difference between the cargo plan and the information of the shipping company. From this and the above considerations it follows immediately that the printout of the on board computer does not include the mass of the deck cargo with the given volume of 609 m³.

3.4 Most Likely Loading Condition at Departure Time

Following from the previous considerations the cargo on deck was not correctly declared regarding the mass and the centre of gravity in the printout of the on board computer. Hence the loading condition at departure time is corrected in accordance to the previous investigations. This loading condition is considered to be the most likely loading condition at departure time in Riga. In figure 9 the corrected lever arm curve is presented.

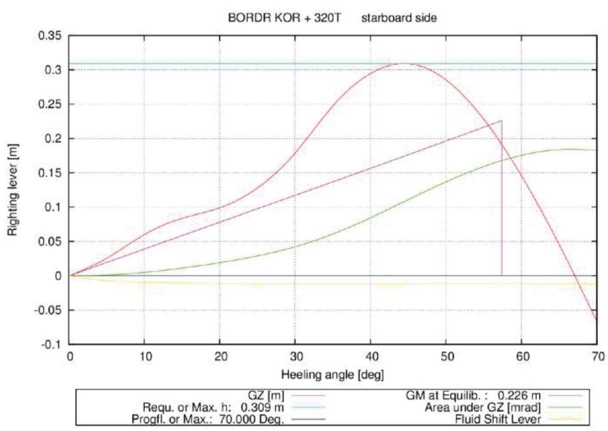

Figure 9 Lever arm curve at departure time in Riga with corrected centre of gravity and cargo load

The corrections take into account the centre of gravity of the timber cargo on deck and the missing mass. The additional deck cargo is estimated with 320 t. This value is calculated from the difference between the information s of the timber cargo from the on board computer and the shipping company. The centre of gravity is assumed with the value of the loading condition of comparison of the stability booklet.

In consideration of this the deadweight is determined to 3206 t in the loading condition on departure from Riga. Thus the maximum value of 3005 t is exceeded. Furthermore the intact stability criteria are not complied.

3.5 Summary of the Loading Condition during the Voyage

From the analysis of the documents and all information MS ROSEBURG is overloaded at departure. At this time it is not possible that some ballast water tanks were empty because that results in a stability condition according to the lever arm curve in figure 7 which is with high probability the accident condition. Based on the departure loading case the accident condition is produced by draining the ballast water tanks. Consequently it is most likely that the accident at the Bay of Kiel was a result of the intention to comply with the load lines because the maximum draft was checked before entering the Kiel Canal. Otherwise the accident would have happened much earlier during the voyage. In section 4 the assumption of the loading conditions is investigated in detail.

4. ANALYSIS OF THE ROLL MOTION AND THE HEELING MOMENTS

Following, dynamic investigations of the roll motion and the heeling moments are made for the validation of the stability condition at accident time. Furthermore it is check whether the vessel could have achieved the Bay of Kiel in the most likely loading condition without any loss of cargo and further stability problems.

4.1 Accident Condition

At the accident time it is assumed that MS ROSEBURG has the stability condition according to the loading condition of the shipping company. In figure 7 the related lever arm is already presented. It shows the vessel has an equilibrium position at zero degree without a resulting moment. But small heeling moments result in a roll motion around the equilibrium position. Thereby there is a limit for the moment which has the effect that the vessel has the new equilibrium position of approximately 25 degree.

For the investigation the roll motion is calculated for defined heeling moments acting on the vessel in still water. The heeling moment M_{heel} is determined by the shift of the transverse centre of gravity dy_G which is incrementally increased. Thereby the calculation is made for the determination of the maximum roll angle φ_{max} the static angle of the equilibrium φ_{stat} and the maximum transverse acceleration a_y on deck during the roll motion. In table 3 the results are summarized.

dy_G [mm]	M_{heel} [mt]	φ_{max} [°]	φ_{stat} [°]	a_y [m/s²]
1	4	9.5	3.8	1.6
2	8	10.7	5.1	1.8
3	12	12.1	5.9	2.0
4	16	13.6	6.6	2.2
5	20	15.4	7.0	2.5
6	24	19.0	7.8	3.2
7	**28**	**28.2**	**8.4**	**4.5**
8	32	29.5	9.0	5.0
9	36	30.4	9.8	5.1
10	**40**	**31.1**	**25.5**	**5.3**
11	44	31.8	25.8	5.5

Table 3 Results of the calculation of the roll motion for different heeling moments

The results correspond to the previous assumptions. Small heeling moments cause small static and maximum heeling angles and moderate accelerations in transverse direction. From a heeling moment of 28 mt (see table 3, printed in bold type) the ship reached a maximum heeling angle of 28 degree because the first stability level is passed. The equilibrium position is found at a heeling angle of 8.4 degree providing the cargo on deck does not slip. In figure 10 the roll angle is shown in time domain. The related maximum acceleration is 4.5 m/s².

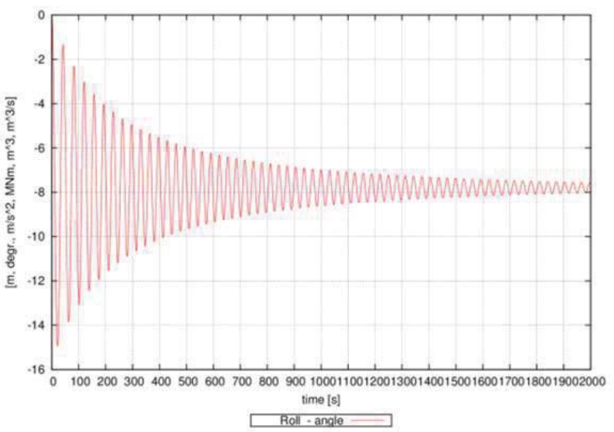

Figure 10 Roll angle for a heeling moment of 28 mt

In case of a heeling moment of 40 mt (see table 3, printed in bold type) the equilibrium position is at a heeling angle of 25 degree, but the transverse acceleration is slightly larger in comparison to the previous calculation. In figure 11 the heeling angle in time can be found. Hence it is assumed the lashings of the timber packages on deck fail not later than in case of a resulting acceleration of 4 to 5 m/s². But it is also possible the cargo securing breaks down earlier because from the described sequence of events leading to the accident the heeling angle is 10 to 15 degree caused by the gust of wind. With high probability it can be assumed that the acceleration of 4.5 m/s² is sufficient to trigger the failure of the load securing. Hence the value is used for the following calculation in section 4.2.

According to the calculations the accident takes place in the assumed stability condition (loading condition of the shipping company) as a result of a heeling moment of 28 mt. Using equation 1 the wind speed can be calculated for a given heeling moment. The wind lateral area A_{lat} is determined with 600 m² and a wind lever z_w of 6.5 m. The density of air ρ_{air} is 1.226 kg/m³. Thereby the influence of waves and others is not taken into account.

$$M_{heel} = \frac{1}{2} \cdot \rho_{air} \cdot v_w^2 \cdot A_{lat} \cdot z_w \qquad (1)$$

The assumed heeling moment of 28 mt corresponds to a wind speed of 10.7 m/s which is equivalent to 5.5 Beaufort. In addition the calculation is made for a heeling moment of 40 mt which is caused by a wind speed of 12.8 m/s or 6.0 Beaufort.

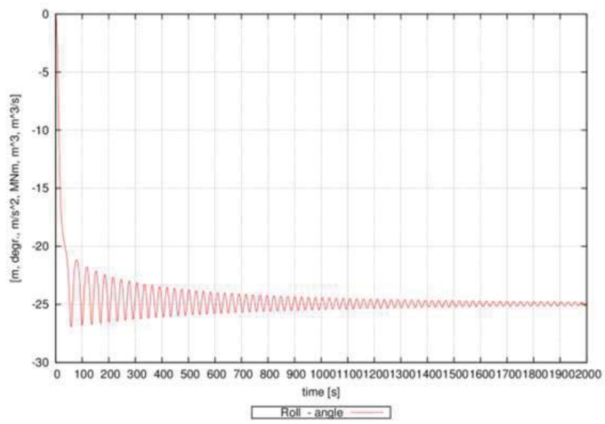

Figure 11 Roll angle for a heeling moment of 40 mt

The information about the weather condition is given by the German Weather service, which based on measurements and observations of surrounding stations. At the accident time the significant wave height is specified with 0.5 m and wind strength of 4 to 5 Beaufort, in gusts 6 to 7 Beaufort. Following it can be said the wind heeling moment caused the accident with a high probability of occurring.

The investigation confirms the accident progresses in this stability condition. Furthermore it is clear the voyage of MS ROSEBURG would not occur without a critical incident in this loading condition.

4.2 Most Likely Loading Condition at Departure Time

In addition the most likely loading condition at departure time has to be investigated to proof that the voyage would happen without a loss of cargo. Therefore a polar diagram is calculated which presents the significant wave height for the transverse acceleration of 4.5 m/s² in real sea condition. This acceleration is determined from the previous considerations which have to occur to cause the loss of the cargo on deck during the voyage. In figure 12 the polar diagram is exemplarily shown for a wave period of 7.5 s and 8.5 s. The sea condition is generated by a JONSWAP-spectrum.

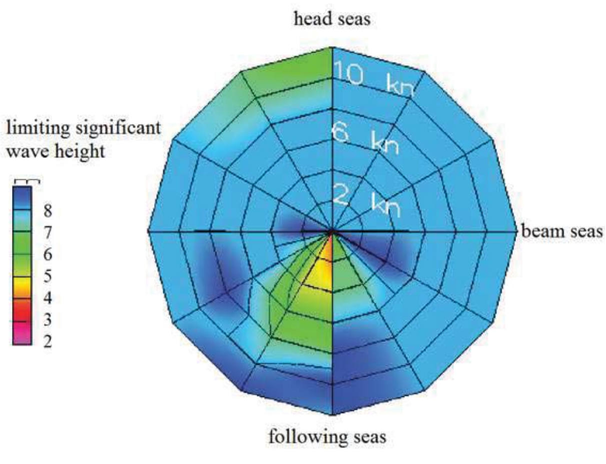

Figure 12 Polar diagram for a wave period of 7.5 s (left) and 8.5 s (right)

The significant wave height has to be not less than 5.0 m to cause a loss of cargo on deck. That is not occurred with high probability. The sea state and weather information confirm this assumption. Hence the vessel has started the voyage with ballast water which corresponds to the reconstructed loading condition. Otherwise the accident would have happened during the voyage.

5. CONCLUSIONS

The paper presents the intact stability accident of MS ROSEBURG. Therefore the investigations are carried out based on the documents found by the competent authorities during the recovery of the lost cargo of the vessel, the description of the weather conditions and the given evidence.

MS ROSEBURG left the port of Riga with a sufficient stability but without the compliance of the established intact stability criteria. Also the permitted deadweight was exceeded caused by the timber load and additional ballast water to have a sufficient stability. The analysis of the roll motion in natural seaway shows the voyage could take place without a loss of cargo in this loading condition.

As a result of the presented investigation the ballast water was pumped out in the Bay of Kiel. Hence the maximum draft was complied, but the stability of the vessel was reduced significantly. Consequently a small gust of wind caused the accident of MS ROSEBURG.

Such an investigation of an intact stability accident shows that the existing intact stability criteria are sufficient. The compliance of the applicable regulations would have avoided this accident.

6. ACKNOWLEDMENTS

The author would like to thank for the support of the German Federal Bureau of Maritime Casualty Investigation (Hamburg) and the permission to use the information of MS ROSEBURG.

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