Annex A

Wallem safety management system completed checklists

CHECKLIST NO. 1 - PRIOR LOADING / DURING LOADING

VESSEL NAME :	HOEGH OSAKA		
PORT :	SOUTHAMPTON	DATE:	03/01/2015

NO	DESCRIPTION	CHECKED
1	CONFIRM NUMBER OF RAMPWAYS TO BE USED	✓
2	CONFIRM SITUATION OF TIDES AT BERTH	✓
3	BEFORE LOWERING , CONFIRM RAMPS ARE CLEAR OF BOLLARDS AND OTHER SHORE OBSTRUCTIONS	✓
4	CONFIRM HEIGHT OF RAMPWAYS FROM PIER AND BALLAST AS REQUIRED CONFIRM RAMP ANGLE PLAN READY FOR DURATION OF CARGO OPERATION	✓
5	CONFIRM RAMPWAY IS LOWERED AS PER STANDARD PROCEDURE	✓
6	CONFIRM RAMPWAY IS RIGGED AT PROPER ANGLE OF INCLINATION (BETWEEN 3° - 13°) WITH PIER AND RAMP ANGLE INDICATOR SENSOR PLACED	✓
7	HAVE SAFETY LINES / CAR RAMP GUARDS BEEN RIGGED ON THE RAMPS	✓
8	HAVE PLYWOOD SHEETS / RUBBER MATS BEEN PLACED BELOW RAMPS ON THE PIER	✓
9	HAVE RAMPS BEEN RIGGED AS REQUIRED ? WELL ILLUMINATED AT NIGHT	✓
10	CONFIRM VESSEL IS WELL ALONGSIDE THE BERTH THROUGHOUT	✓
11	HAS AN OFFICER / CREW BEEN ASSIGNED TO MONITOR MOORING LINES, WATER / OIL OVERFLOW , RAMPS ETC. AT BERTH	✓
12	IF STRONG OFFSHORE WIND IS BLOWING THEN CONSIDER USING TUG(S) DURING CARGO OPERATIONS TO KEEP THE VESSEL ALONGSIDE (TUGS TO BE REQUESTED ONLY THROUGH AGENTS EXCEPT IN EMERGENCY)	✓
13	IF WEATHER GETS TOO ROUGH THEN CONSIDER POSSIBILITY OF SHIFTING VESSEL TO ANCHORAGE UNTIL WEATHER ABATED AND BERTHING / LOADING BECOMES POSSIBLE	✓
14	CONFIRM CARGO PLAN CHECKED AND HOLD VENTILLATION STARTED AS APPROPRIATE	✓
15	ALL HOLDS ARE CLEAN , WITHOUT SMELL AND READY TO RECEIVE CASES	✓
16	CONFIRM ALL HOLD LIGHTS ARE WORKING	✓
17	CONFIRM ALL FIRE DETECTING UNITS IN CARGO HOLDS TRIED OUT AND FOUND SATISFACTORY	✓
18	ALL HOLD BILGES TRIED OUT AND FOUND SATISFACTORY	✓
19	CONFIRM SUFFICIENT LASHING MATERIAL LAID OUT ON VARIOUS DECKS CORRESPONDING TO THE NUMBER OF CARS TO BE LOADED	✓
20	CARGO PLAN , SECURING PLAN AND FLOW CHART DISCUSSED WITH OFFICERS AND CREW	✓
21	OFFICERS AND CREW INSTRUCTED TO NOTE DAMAGE TO CARGO DURING LOADING OR PRIOR LOADING	✓
22	FLOWCHART AND CARGO PLAN DISCUSSED WITH STEVEDORES	✓
23	MAX. DRIVING SPEED 20 KM/HR (12 MPH) ADVISED TO STEVEDORES	✓
24	SUFFICIENT SAFETY CONES / MARKS PROVIDED / ARRANGED TO	✓

NO	DESCRIPTION	CHECKED
	FACILITATE PROPER LOADING OF CARS	✓
25	ALL DANGER ZONES MARKED WITH TIGER ROPES AND STOP/DAMAGE SIGNS	✓
26	VARIOUS POSTERS FOR SAFE CAR LOADING DISPLAYED IN CARGO SPACES	✓
27	STEVEDORES ADVISED OF : A.) NO SMOKING WITHIN CARGO HOLDS B.) NO OPERATION OF CAR MUSIC SYSTEM C.) CARS NOT TO BE USED FOR FERRYING PEOPLE / STEVEDORES D.) AFTER PARKING SWITCH OFF IGNITION & STOW KEYS IN ASHTRAY E.) APPLY HANDBRAKES AFTER PARKING F.) ROLL UP CAR WINDOWS AFTER PARKING G.) DO NOT LOCK DOORS ON DRIVER`S SIDE H.) HANDINGS TO BE TAKEN ONLY FROM PERMISSIBLE LASHING POINTS (CHECK CONDITION OF LASHING GEAR – SATISFACTORY)	✓
28	STICK FOAM PADS ON PILLARS / BEAMS / BULKHEADS WHICH MAY DAMAGE CAR DOORS AND ADVISE STEVEDORES ACCORDINGLY	✓
29	LIFT / LOWER MOVABLE CAR DECKS AS PER CARGO PLAN	✓
30	SHIPSTAFF TO WEAR APPROPRIATE RIG IN CARGO HOLDS DURING CARGO OPERATION	✓
31	IN PORTS WHERE THREAT OF STOWAWAYS AND DRUGS IN ENVISAGED HAS PLAN BEEN PREPARED , DISCUSSED AND IMPLEMENTED TO PREVENT THEM FROM COMING ON BOARD	✓
32	WHILE LOADING ENSURE THAT SPACE HAS BEEN PROVIDED FOR : A.) PILOT WALK B.) ENGINE ROOM ENTRANCE C.) TAKING BALLAST / F.O / D.O / L.O / TANK SOUNDING D.) BUNKER DOORS IF VESSEL IS TO RECEIVE BUNKERS DURING / AFTER LOADING E.) OPENING AND CLOSING WATERTIGHT AND GASTIGHT DOORS F.) ACCESS TO FIRE EXTINGUISHERS AND HYDRANTS / HOSES G.) EMERGENCY EXITS	✓
33	NOT SOOT BLOWING WHILE VESSEL ALONGSIDE OR NEAR BERTH	✓
34	ALL INSTRUCTIONS AS PER DAMAGE PREVENTION BOOKLET COMPLIED WITH	✓
35	OWNERS / CHARTERERS STANDING INSTRUCTIONS FOR LOADING COMPLIED WITH	✓
36	BOSUN / CH. COOK ADVISED ABOUT GARBAGE DISPOSAL MEASURES	✓
37	HAS SHIPCHANDLER BEEN ADVISED ABOUT MOST APPROPRIATE TIME TO DELIVER SHIP STORES / SPARES	✓
38	COMPRESSED AIR TYPE CO2 HORN IN HOLDS CHECKED AND FOUND OPERATIONAL	✓
39	OIL RECORD BOOK UP TO DATE	✓
40	GARBAGE DISPOSAL LOG UP TO DATE	✓
41	DRUMS PROVIDED WITH LIDS FOR GARBAGE DISPOSAL	✓
42	LOOSE LASHING GEAR REMOVED FROM PATH OF CARS	✓
43	PASSAGE OF CARS CLEAR OF ALL OBSTRUCTIONS	✓

NO	DESCRIPTION	CHECKED
44	NO PAINTING AT BERTH . CHECK WITH AGENT / STEVEDORES PRIOR PAINTING AT BERTH	✓
45	BLIND AREAS FOR COMMUNICATION EQUIPMENT IDENTIFIED AND PEOPLE ADVISED ACCORDINGLY	✓
46	EMERGENCY MEASURES DISCUSSED IN CASE OF ANY ACCIDENT	✓
47	CRITICAL TURNING AREA CAUTION MARK PLACED	✓
48	SPECIAL CARGOES (HEAVY / HIGH / LONG / CATERPILLARS ETC.) LOADING PROCEDURE PLANNED	✓
ADDITIONAL NOTES:		
1.	Keep car ladders and turn tables if any) in good working order.	✓
2.	Maintain the car decks, cargo hold, inner slope ways in good conditions; clean, dry, and free from rust/paint chips.	✓
3.	Check and remove foreign objects such as empty bottles which are often placed on the beams in the ceilings of the deck.	✓
4.	Provide and maintain caution marks such as "NO SMOKING" and "MAX SPEED. 20km/h" (12 MPH in USA) and other indications in the hold; number of deck, direction of driving way, exit sign.	✓
5.	Check the condition of lashing points on each car deck.	✓
6.	Check the lashing chains are fastened securely and extended to the lowest position on each tank top deck.	✓
7.	Confirm the ventilation system is working well and all the dampers are placed in correct positions. Sweep out the rust scale and dust on thp bottom of air ducts.	✓
8.	Check and ensure proper lighting is available in the cargo hold.	✓
9.	Check the lashing materials are sufficient in each compartment of the cargo hold.	✓
10.	Check the plywood or iron-sheets are ready for the protection of wharf surface to be used under the car ladder.	✓
11.	Check the materials for damage prevention programs; traffic cones surveyor's tapes, rubber matting, are supplied sufficiently and distributed properly in cargo hold.	✓
12.	Check a bag of sawdust is prepared in the vicinity of the car ladder for treatment of oil spill on decks.	✓

DUTY OFFICER

[redacted]

VERIFIED BY MASTER

CHECKLIST NO. 2 - PRIOR DISCHARGING / DURING DISCHARGING

VESSEL NAME :	HOEGH OSAKA		
PORT :	SOUTHAMPTON	DATE:	03/1/2015

NO	DESCRIPTION	CHECKED
1	CONFIRM NUMBER OF RAMPWAYS TO BE USED	✓
2	CONFIRM SITUATION OF TIDES AT BERTH	✓
3	BEFORE LOWERING , CONFIRM RAMPS ARE CLEAR OF BOLLARDS AND AND OTHER SHORE OBSTRUCTIONS	—
4	CONFIRM HEIGHT OF RAMPWAYS FROM PIER AND BALLAST AS REQUIRED CONFIRM RAMP ANGLE PLAN READY FOR DURATION OF CARGO OPERATION	✓
5	CONFIRM RAMPWAY IS LOWERED AS PER STANDARD PROCEDURE	✓
6	CONFIRM RAMPWAY IS RIGGED AT PROPER ANGLE OF INCLINATION (BETWEEN 3° - 13°) WITH PIER AND RAMP ANGLE INDICATOR SENSOR PLACED	✓
7	HAVE SAFETY LINES / CAR RAMP GUARDS BEEN RIGGED ON THE RAMPS	✓
8	HAVE PLYWOOD SHEETS / RUBBER MATS BEEN PLACED BELOW RAMPS ON THE PIER	✓
9	HAVE RAMPS BEEN RIGGED AS REQUIRED ? WELL ILLUMINATED AT NIGHT	✓
10	ANY DRAIN/DISCHARGE OVERFLOWING ON RAMP/PIER STOPPED /PLUGGED	✓
11	CONFIRM VESSEL IS WELL ALONGSIDE BERTH THROUGHOUT CARGO OPERATIONS . MONITOR MOORING LINES	✓
12	HAS AN OFFICER / CREW BEEN ASSIGNED TO MONITOR MOORING LINES , WATER / OIL OVERFLOW , RAMPS ETC, AT BERTH	✓
13	IF STRONG OFFSHORE WIND IS BLOWING THEN CONSIDER USING TUG(S) DURING CARGO OPERATIONS TO KEEP THE VESSEL ALONGSIDE (TUGS TO BE REQUESTED ONLY THROUGH AGENTS EXCEPT IN EMERGENCY)	✓
14	WEATHER GETS TOO ROUGH THEN CONSIDER POSSIBILITY OF SHIFTING VESSEL TO ANCHORAGE UNTIL WEATHER ABATES AND BERTHING / DISCHARGING BECOMES POSSIBLE	✓
15	CONFIRM CARGO PLAN CHECKED AND FLOWCHART DISCUSSED WITH STEVEDORES	✓
16	CONFIRM CARGO PLAN CHECKED AND FLOWCHART DISCUSSED WITH DUTY OFFICERS AND CREW DURING PRE DISCHARGE MEETING	✓
17	CONFIRM HOLD VENTILATION STARTED AS APPROPRIATE	✓
18	HAS CARGO BEEN INSPECTED AND DAMAGES, IF ANY NOTED	✓
19	HAVE NOTE OF PROTEST PREPARED IF CARGO DAMAGE IS DUE TO HEAVY WEATHER AND HAVE WSM / CHARTERER`S INFORMED	✓
20	CONFIRM ALL HOLD LIGHTS ARE WORKING	✓
21	HAVE OFFICERS AND CREW BEEN INSTRUCTED TO NOTE DAMAGE TO CARGO DURING DISCHARGING AND NOTE ANY DAMAGE CAUSED BY STEVEDORES	✓
22	MAX. DRIVING SPEED 20 KM/HR (12 MPH) ADVISED TO STEVEDORES	✓
23	SUFFICIENT SAFETY CONES / MARKS PROVIDED / ARRANGED TO FACILITATE SMOOTH DISCHARGE OF CARS	✓
24	SHIP`S COMPANY ADVISED NOT TO GET INTO ANY CAR EITHER ON BOARD OR ASHORE ON THE PIER	✓
25	CONFIRM ALL DANGER ZONES MARKED WITH (CORDONED OFF) TIGER	✓

NO	DESCRIPTION	CHECKED
	ROPES AND STOP/DAMAGE SIGNS	✓
26	NO SMOKING SIGNS DISPLAYED IN CAR HOLDS COMPLIED WITH	✓
27	NO OPERATION OF CAR MUSIC SYSTEM BY STEVEDORES	✓
28	CARS NOT TO BE USED FOR FERRYING PEOPLE / STEVEDORES	✓
29	STEPS TAKEN TO PREVENT PILFERAGE OF CAR PARTS	✓
30	AMPLE SAFETY POSTERS DISPLAYED IN CAR HOLDS	✓
31	STICK FOAM PADS , COVERED WITH TIGER TAPES ON PILLARS /BULKHEADS/BEAMS/FRAMES WHICH CAN DAMAGE CAR DOORS AND ADVISE STEVEDORED ACCORDINGLY	✓
32	ALL SHIPSTAFF TO WEAR APPROPRIATE RIG IN CAR HOLDS	✓
33	IN PORTS WHERE THREAT OF STOWAWAYS AND DRUGS IN ENVISAGED HAS PLAN BEEN PREPARED , DISCUSSED AND IMPLEMENTED TO PREVENT THEM FROM COMING ON BOARD	✓
34	HYDRAULIC SYSTEM OF VALVE OPERATION& OIL LEVEL CHECKED	✓
35	BOSUN / CH.COOK ADVISED ABOUT GARBAGE DISPOSAL PROCEDURES	✓
36	EMPTY DRUMS WITH LIDS PROVIDED FOR GARBAGE DISPOSAL	✓
37	HAS SHIP CHANDLER BEEN ADVISED ABOUT MOST APPROPRIATE TIME TO DELIVER STORES/ SPARES/ PROVISIONS	✓
38	FFA IN CARGO HOLDS IN READINESS	✓
39	CO2 ALARM IN CARGO HOLDS CHECKED AND IN ORDER	✓
40	SMOKE DETECTING SYSTEM IN CARGO HOLDS CHECKED	✓
41	OIL RECORD BOOK UP TO DATE	✓
42	GARBAGE DISPOSAL LOG UP TO DATE	✓
43	LOOSE LASHING GEAR REMOVED FROM PATH OF CARS	✓
44	DISCHARGE PASSAGE OF CARS CLEAR OF OBSTRUCTION	✓
45	BLIND AREAS FOR COMMUNICATION IDENTIFIED AND PEOPLE ADVISED	✓
46	NO PAINTING WHILE VESSEL AT BERTH	✓
47	GANGWAY RIGGED PROPERLY WITH SAFETY NET	✓
48	INSTRUCTIONS AS PER DAMAGE PREVENTION BOOKLET COMPLIED WITH	✓
49	OWNERS / CHARTERERS STANDING INSTRUCTIONS FOR LOADING CARS COMPLIED WITH	✓
50	NO SOOT BLOWING WHILE VESSEL ON OR IN VICINITY OF PIER	✓
51	INTERNAL MOVABLE RAMPS TO BE OPERATED UNDER THE SUPERVISION OF C/O OR D/O.	✓

DUTY OFFICER [redacted] VERIFIED BY MASTER

WALLEM SHIPMANAGEMENT LTD.	PCC/PCTC Operations Manual	Revised by : Manager SID Checked by : Director SID Edition No. 1 : December 2010 Rev. Date : - - - Approved by : Director SID **Appendix 2** Checklist No.3 Page 1/1

CHECKLIST NO. 3 - PRIOR DEPARTURE PORT

VESSEL NAME :	HOEGH OSAKA		
PORT :	SOUTHAMPTON	DATE:	03/1/2015

NO	DESCRIPTION	CHECKED
1	DEPARTURE SAILING CONDITIONS DISPLAYED	✓
2	ALL CREW MEMBERS ON BOARD ACCOUNTED FOR	✓
3	VESSEL CHECKED FOR STOWAWAYS – ENTRY IN LOGBOOK	✓
4	VESSEL CHECKED FOR CONTRABAND – ENTRY IN LOGBOOK	✓
5	CONFIRM ALL CARS LOADED / DISCHARGED AS PER CARGO PLAN	✓
6	ALL LOOSE LASHING GEAR SECURED TO PREVENT CARGO DAMAGE	✓
7	CONFIRM ALL CARGO LASHED AND SECURED PROPERLY	✓
8	ALL MOVABLE ITEMS SECURED IN CARGO HOLDS	✓
9	ALL RAMPWAYS HOVE IN AND SECURED. CHECK PHYSICALLY ALL AROUND THE RAMPS EQUIPMENT FOR PROPER SECURING AND TO ENSURE NO DAMAGE HAS OCCURRED A.) STERN RAMP B.) MIDSHIP RAMP	} ✓
10	HYDRAULIC SYSTEM SWITCHED OFF	✓
11	PILOT LADDERS / GANGWAYS SECURED	✓
12	ALL SHIPSIDE DOORS (PILOT / GANGWAYS / BUNKER) SECURED ENTRY IN LOGBOOK ALSO C/O MAKE POSITIVE REPORT TO MASTER	✓
13	ANCHORS SECURED	✓
14	DECK POWER SWITCHED OFF	✓
15	ALL CARGO PAPERS ON BOARD	✓
16	ALL LIFTABLE CAR DECKS SECURED	✓
17	BOTH LIFTER TRUCKS PROPERLY SECURED	✓
18	NO SOOT BLOWING WHILE VESSEL IS IN VICINITY OF BERTH	✓
19	ON COMPLETION OF CARGO WORK IRRESPECTIVE OF WHETHER VESSEL IS LEAVING PORT OR REMAINING IN PORT A.) ALL GAS TIGHT DOORS / RAMPS SECURED IN PLACE B.) BULK HEAD DOORS CLOSED AND SECURED C.) CARGO HOLD VENTILATOR FLAPS CLOSED	} ✓
20	STATUS OF VENTILATOR DAMPERS , WATERTIGHT , WEATHER TIGHT AND ENTRANCE DOORS AND BOOBY HATCHES OPEN / CLOSED A.) FIRE ZONE 'A' B.) FIRE ZONE 'B' C.) FIRE ZONE 'C' D.) FIRE ZONE 'D' E.) FIRE ZONE 'E' F.) FIRE ZONE 'F' (CLOSED: } ✓ for A–E)	

[redacted]

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CHECKLIST NO. 4 - LOADED PASSAGE

VESSEL NAME :	HOEGH OSAKA		
PORT :	SOUTHAMPTON	DATE:	03/01/2015

NO	DESCRIPTION	YES	NO
1	MEASUREMENT OF LEL FREQUENTLY	✓	
2	DAILY INSPECTION OF CAR LASHING	✓	
3	DURING ROUGH WEATHER INSPECTION OF CAR LASHING TWICE DAILY	✓	
4	FIRE PATROL IN HOLDS AFTER EVERY WATCH	✓	
5	LEAKAGE , IF ANY , RECTIFIED WITHOUT DAMAGING CARS	✓	
6	DAILY INSPECTION OF THE HOLDS FOR THE FOLLOWING : A.) LEAKAGES FROM VARIOUS SERVICE PIPELINES BE CAREFUL IN COLD WEATHER (AVOID EXCESSIVE PITCHING) B.) LEAKAGE FROM HYDRAULIC PIPELINES C.) LEAKAGES FROM BALLAST SOUNDING PIPES , AIR PIPES D.) LEAKAGES FROM ANY OTHER CRACKS EITHER ON VENTILATOR DECK E.) LEAKAGE FROM F.O , D.O TANKS SOUNDING / AIR PIPES F.) LEAKAGE OF GASOLINE , ENGINE OIL , BRAKE OIL RADIATOR LIQUID FROM ANY CARS	✓	
7	AFTER TAKING F.O / D.O TANK SOUNDINGS ENSURE HANDS ARE CLEAN AND THE AREA CLEANED . NO CARS TO BE TOUCHED.	✓	
8	DAMAGED LASHING REPLACED	✓	
9	HOLD VENTILATED IF LEL REACHES 0.5%	✓	
10	ALL MOVABLE MATERIAL SECURED	✓	
11	DO NOT CARRY ANY EQUIPMENT IN CAR HOLD THAT MAY CARS.	✓	
12	CHECK ALL CAR LIGHTS ARE OFF	✓	
13	CHECK FOR DAMAGE WHICH UNNOTICED DURING LOADING	✓	
14	CHECK FOR RUST , FLAKES ON DECK HEADS	✓	
15	CHECK CARGO SEGREGATED PROPERLY	✓	
16	AFFIX SAFETY STICKERS ON IMPOTENTIAL DAMAGE CARS	✓	
17	ANY DAMAGE DUE TO HEAVY WEATHER REPORTED IMMEDIATELY	✓	
18	ALL GAS TIGHT / WATERTIGHT PASSAGE & BOOBY ENTRANCE SECURED.	✓	
19	CHECK FOR FLAT TYRES WHICH MUST BE INFLATED PRIOR ARRIVAL DISCHARGE PORT	✓	
20	DO NOT WEAR CLOTHES WITH BUCKLES , BELTS OR EXPOSED BUTTONS WHICH MAY SCRATCH CARS DURING INSPECTION	✓	
21	WEEKLY INSTRUCTION TO CREW AGAINST DAMAGE PREVENTION	✓	

[redacted]

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CHECKLIST NO. 4 - LOADED PASSAGE (CONTINUED)

VESSEL NAME :	HOEGH OSAKA		
PORT :	SOUTHAMPTON	DATE:	03/01/2015

NO	DESCRIPTION	YES	NO
1	PRIOR ARRIVAL MEETING HELD AMONG OFFICER`S AND CREW	✓	
2	MEETING HELD WITH STEVEDORE	✓	
3	CARGO PLAN AND PORT RESTRICTIONS DISCUSSED	✓	
4	CARGO SECURING PLAN DISCUSSED	✓	
5	EMERGENCY MEASURES DISCUSSED IN CASE OF ANY ACCIDENT	✓	
6	E/R INFORMED FOR VENTILATION POWER	✓	
7	ALL CARGO GEAR CHECKED	✓	
8	V/L`S STABILITY CONDITION ASSESSED	✓	
9	BALLASTING / DEBALLASTING PLANNED	✓	
10	ALL DECK SCUPPERS BLOCKED (STBD SIDE)	✓	
11	ANCHOR WASH KEPT SHUT	✓	
12	PROPER ROUTE MADE WITH CONES AND ARROWS FOR EACH LOADING AND DISCHARGING PLACE	✓	
13	MAXIMUM DECK CLEARANCE HEIGHT CAUTION MARK PLACED	✓	
14	CRITICAL TURNING AREA CAUTION MARK PLACED	✓	
15	VENT FLAPS OPENED AND VENTILATION STARTED	✓	
16	TIDE CALCULATED	✓	
17	CHANGE OF RAMP ANGLE WITH CHANGE OF TIDE PLANNED	✓	
18	WALKWAY SAFETY LINE PLACED	✓	
19	SAFETY NOTICES IN PLACE	✓	
20	RAMP ANGLE CHECKED	✓	
21	PANEL POSITIONS CHECKED	✓	
22	SPECIAL CARGO (HEAVY / HIGH/ LONG/ CATERPILLERS ETC.) LOADING / DISCHARGING PROCEDURE PLANNED	✓	

[redacted]

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CHECKLIST NO. 5 - DURING LOADING/ DISCHARGING

VESSEL NAME :	HOEGH OSAKA		
PORT :	SOUTHAMPTON	**DATE:**	03/01/2015

NO	DESCRIPTION	YES	NO
1	LOADING / DISCHARGING DONE AS PER PLAN	✓	
2	STABILITY OF THE VESSEL ASSESSED	✓	
3	ESTIMATED TIME OF COMPLETION OF CARGO NOTIFIED TO E/R AND MASTER	✓	
4	SIMULTANIOUSLY CARGO LASHING CHECKED	✓	
5	EFFECT OF CHANGE OF WEATHER ASSESSED	✓	
6	MOORING LINES AND RAMPS CHECKED	✓	
7	BALLASTING / DEBALLASTING CARRIED OUT AS PER PLAN	✓	
8	WHEN BUNKERS ARE BEING TAKEN ; VESSEL`S STABILITY , TRIM /LIST MONITORED	✓	
9	C/O`S INSTRUCTIONS TO CARGO WORK FOLLOWED	✓	
10	WALKWAY SAFETY LINE IN PLACE	✓	
11	TALLY BEING TAKEN AND VERIFIED WITH SHORE FIGURE	✓	
12	SAFE LOADING AND DISCHARGING PROCEDURE BEING FOLLOWED	✓	
13	CARGO BEING SEPARATED AS PER PLAN	✓	
14	RAMP ANGLE BEING MONITORED	✓	
15	ANY DAMAGE TO VESSEL / CARGO BROUGHT TO C/O'S NOTICE	✓	
16	SAFETY PROCEDURES BEING FOLLOWED BY EVERYONE	✓	

CHECKLIST FOR SETTING CARS IN DESIGNATED POSITION

1.	The driver shall stow the vehicles at designated spots in the cargo hold under the directions of the lead man.	✓
2.	All loading operations shall be conducted with due consideration to unloading feasibility.	✓
3.	The vehicles tires should not be parked on projecting parts, such as lashing ring plates.	✓
4.	Vehicles should be stowed head-out on the inner slope way.	✓
5.	Clear space must be allowed for closing/opening operations of water tight and or gas tight doors.	✓
6.	Clear space must be allowed on the driver's side along the walking passage, especially for vehicles stowed on the inner slope ways.	✓
7.	After setting car in designated position check that the hand brake is fully on, Transmission; Manual transmission vehicles shall shift the lever to "LOW" position. Automatic transmission vehicles shall shift the lever to "PARKING" position.	✓
8.	All electric switches shall be placed in "OFF" position.	✓
9.	Ignition keys shall be removed and placed in ash-tray, or glove box if instructed to do so on above table.	✓
10.	All windows shall be closed completely.	✓
11.	Driver's seat shall be set at a position farthest at back.	✓
12.	Make sure all doors are closed perfectly, but never locked.	✓
13.	Key car label (sticker) shall be affixed on the wind-shield of the key car and following seven units should be affixed with consecutive labels.	✓

NO	DESCRIPTION	YES	NO
CHECKLIST FOR LOADING OPERATIONS		YES	
1.	Smoking in cargo holds and vehicles is strictly prohibited.	✓	
2.	Working apparel should be clean and not cause scratches or any form of damage to vehicles from exposed metal or buttons.	✓	
3.	Maximum driving speed inside the cargo hold must be limited to 20 km/hour (12.4 mph).	✓	
4.	All cargo work must be carried out under the supervision of the Stevedore's superintendent.	✓	
5.	Non-start vehicles or dead cars not to be loaded on the vessel.	✓	
6.	All drivers shall drive the vehicles under the directions of the signalman.	✓	
7.	Vehicle's engines shall be properly warmed up before driving vehicle, especially in the winter season.	✓	
8.	No person shall pass between the sides of motor vehicle, except through the passage which is normally provided in the middle of the deck or marked as passage.	✓	
9.	When working in cargo hold, care must be exercised to avoid contact with vehicles. Belt buckles, buttons and other metal objects should be covered completely to-avoid paint scratch damage. String of torch lamps should be tied shortly and hold it carefully.	✓	
10.	Duty officers and crew members must always be present during the cargo operations to ensure correct cargo handling procedures are adhered to by all concerned parties.	✓	

[redacted]

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Analysis of *Hoegh Osaka* cargo securing web lashings

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Tensile Tests & Failure Analysis of 2T Lashing Straps from the Hoegh Osaka

Client: [redacted] MAIB Mountbatten House Grosvenor Square Southampton SO15 2JU	**Date:** 01/04/2015	**Mat Tech Job No:** F2053

Request Details:
This report details a tensile test and an examination of the failure mode performed on the samples detailed below:

Sample ref	Lashing Colour	Condition	Breaking Load	Actions
001/ET/OH	Yellow	Failed	2T	Examine mode of failure

Sample ref	Lashing Colour	Condition	Breaking Load	Actions
002/ET/OH	Yellow	Used/intact	2T	Tensile Test

Results are detailed on the following pages

-2T Straps-

001/ET/OH			
Rated Breaking Load:	2T	**Condition as received:**	Failed
Action:	Comment on mode of failure	**ID Markings:**	None

Comments:	Failed around tensioner, no evidence of cutting. Image below shows failed end after removal from the tensioner.

Mode of Failure:	Tensile Overload

-2T Straps-

002/ET/OH			
Rated Breaking Load:	2T	**Condition as received:**	Used/Intact
Action:	Tensile Test		
ID Markings:	*'BL 2000kg Jun2000 Ro-Ro Lash Polyester'* Final line suspected to say *'not for lifting'*		

Actual Failure Load:	1.65T
Comments:	Failed around tensioner at below the rated 2T breaking load. No specific features seen on the strap which would have predisposed this item to fail at below 2T, however it is noted to be nearly 15 years old and may have suffered age related degradation. Image below shows the failed end.

-2T Straps-

Discussion:
The tensile test strop (002) and the service failure (001) both failed from tensile overload in a similar manner around the tensioner. It is of note that the tensile test strop failed at 1.65T which is lower than the 2T specified breaking load. Despite the relatively low breaking load this is still significantly above the anticipated SWL of 1T. It is of note that the strop is relatively old (nearly 15 years) and may have degraded over the years.

Author:

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[redacted]

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Tensile Tests & Failure Analysis of 5T Lashing Straps from the Hoegh Osaka

Client: [redacted] MAIB Mountbatten House Grosvenor Square Southampton, SO15 2JU	**Date:** 01/04/2015	**Mat Tech Job No:** F2053

Request Details:
This report details a tensile test and examination of the failure mode performed on 5T lashing straps recovered from the Hoegh Osaka:

Note Sample 003 was too damaged to be used for a tensile test. As a result samples 003 & 004 were combined to make a single sample suited to tensile testing. Examination & testing of both have been detailed in a single examination sheet.

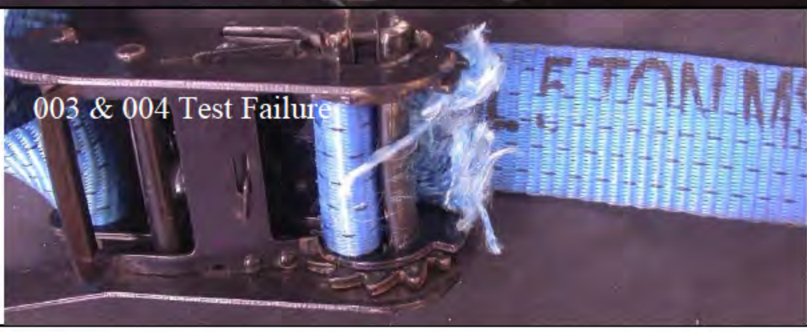
Sample ref	Lashing Colour	Condition	Breaking Load	Actions
003/ET/OH	Blue	Failed	5T	Tensile Test when combined with 004
				
004/ET/OH	Blue	Failed	5T	Examine mode of failure & tensile test when combined with 003
				
005/ET/OH	Blue	Used/intact	5T	Tensile Test
				
006/ET/OH	Blue	Unused	5T	Tensile Test
				

Test results are detailed on the following pages

-5T Straps-

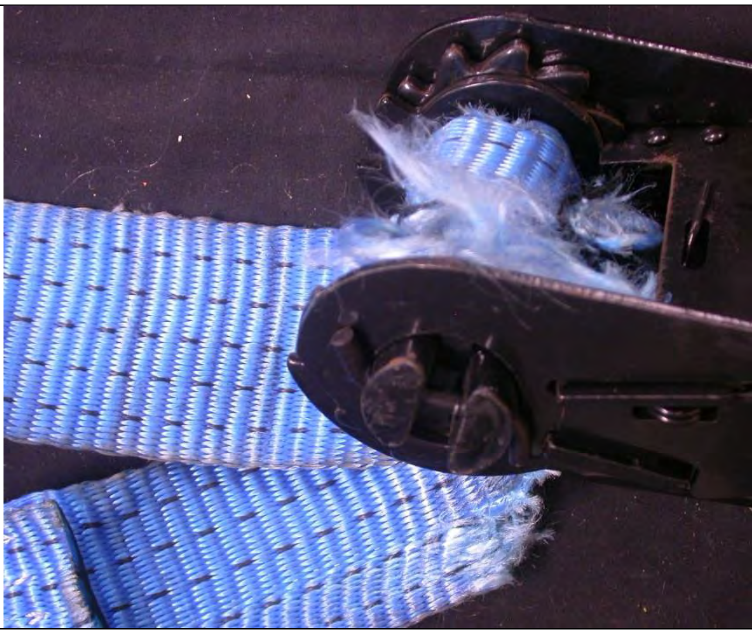
003/ET/OH & 004/ET/OH			
Rated Breaking Load:	2.5T SWL 5T Breaking load	**Condition as received:**	Both failed
Action:	Examination of failure & tensile test. Note tensile test was performed by combining the ratchet from 003 with the unfailed length of strop from 004.		
ID Markings:	*'HOEGH BL 5 TON MSL 2.5 TON'*		

Actual Failure Load:	5.4T
Comments:	Service failures both tensile overloads, see image below. Tensile tests resulted in a failure at ratchet at above the 5T rated breaking load. Bottom image below shows the test failure.



<table>
<tr><th colspan="5">005/ET/OH</th></tr>
<tr><td>Rated Breaking Load:</td><td>2.5T SWL
5T Breaking load</td><td>Condition as received:</td><td colspan="2">Used/intact</td></tr>
<tr><td>Action:</td><td colspan="4">Tensile Test</td></tr>
<tr><td>ID Markings:</td><td colspan="2">‘HOEGH BL 5 TON MSL 2.5 TON’</td><td colspan="2">
</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Actual Failure Load:</td><td colspan="4">4.05T</td></tr>
<tr><td>Comments:</td><td colspan="4">Tensile tests resulted in a failure at the hook at 4.05T below the 5T rated breaking load. Examination the eye of the hook did not reveal any sharp edges which could have contributed to this. Image below shows the failure.</td></tr>
<tr><td colspan="5"></td></tr>
</table>

-5T Straps-

006/ET/OH			
Rated Breaking Load:	2.5T SWL 5T Breaking load	**Condition as received:**	Unused
Action:	Tensile Test		
ID Markings:	*‘HOEGH BL 5 TON MSL 2.5 TON’*		
			
Actual Failure Load:	5.55T		
Comments:	Tensile tests resulted in a failure at the ratchet at 5.55T exceeding the 5T rated breaking load. Image below shows the failure.		
			

-5T Straps-

Discussion:

The tensile test results for the strops are summarised below. As can be seen 005/ET/OH failed at 4.05T, which is below the 5T breaking load, despite the relatively low breaking load this is still significantly above the anticipated SWL of 2.5T.

Sample ref	Condition	Breaking Load	Failure Load (T)	Comments
003/ET/OH	Used/intact	5T	5.4	Believe that 3 & 4 originally were 1 unit. Test performed on unit re-made from 3/4. Failed at jaw
004/ET/OH	Failed	5T		
005/ET/OH	Used/intact	5T	4.05	Failed around hook
006/ET/OH	Unused	5T	5.55	Failed at jaw

Service failures 003 & 004/ET/OH are both consistent with tensile overloads.

Author:

[redacted]

[redacted]

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Tensile Tests & Failure Analysis of 10T Lashing Straps from the Hoegh Osaka

Client: [redacted]
MAIB
Mountbatten House
Grosvenor Square Southampton, SO15 2JU

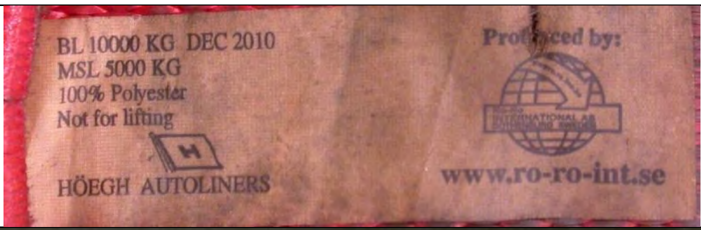
Date: 01/04/2015

Mat Tech Job No: F2053

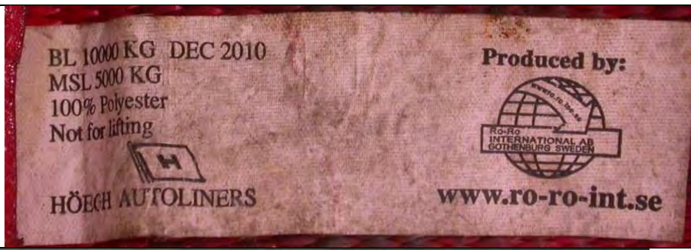
Request Details:
This report details tensile tests and failure mode examination performed on 10T lashing straps recovered from the Hoegh Osaka as detailed below:

Sample ref	Lashing Colour	Condition	Breaking Load	Actions
007/ET/OH	Red	Unused	10T	Tensile test
009/ET/OH	Red	Failed	10T	Failure examination
010/ET/OH	Red	Failed	10T	Failure examination
013/ET/OH	Red	Used/intact	10T	Tensile test
015/ET/OH	Red	Used/intact	10T	Tensile test

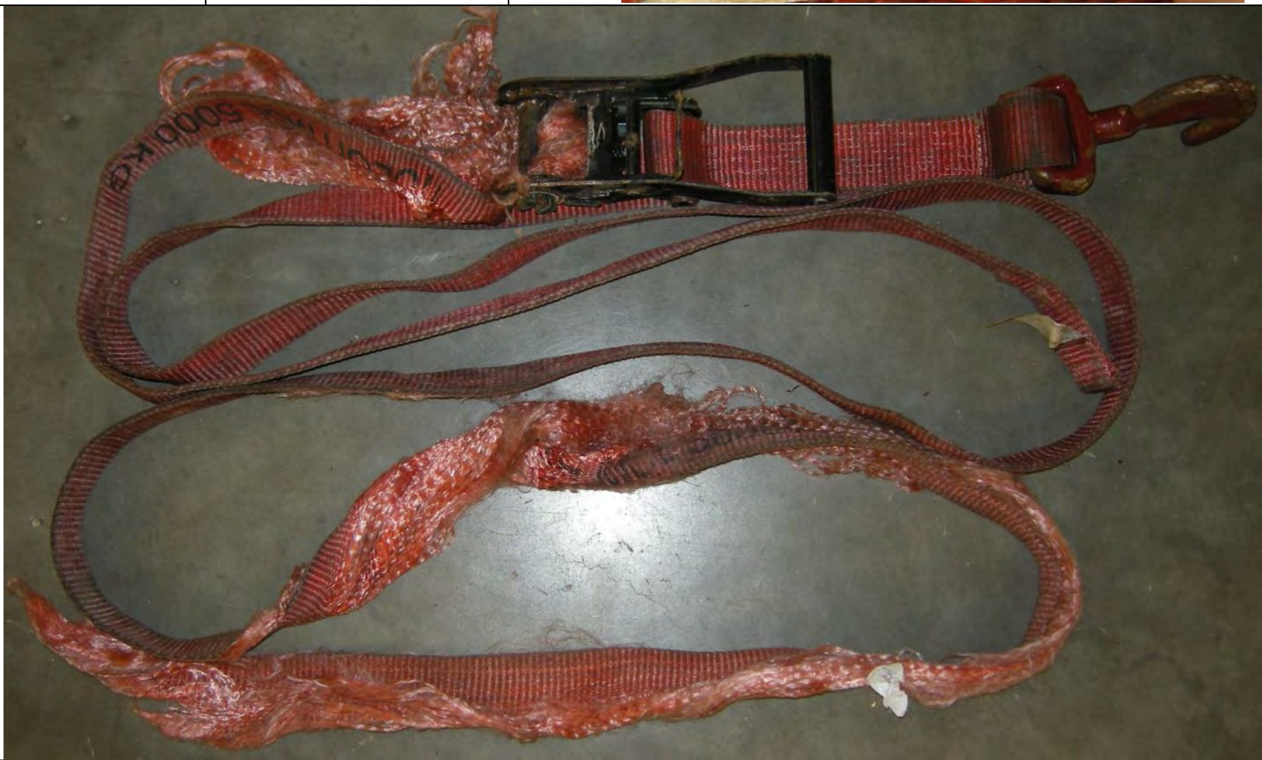
Test/examination results are detailed on the following pages:

<table>
<tr><th colspan="4">007/ET/OH</th></tr>
<tr><td>Rated Breaking Load:</td><td>5T SWL
10T Breaking load</td><td>Condition as received:</td><td>Unused</td></tr>
<tr><td>Action:</td><td colspan="3">Tensile Test</td></tr>
<tr><td>ID Markings:</td><td>'BL 1000 KG DEC 2010
MSL 5000KG 100%
Polyester
Not for lifting'</td><td colspan="2">
</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>Actual Failure Load:</td><td colspan="3">11.4T</td></tr>
<tr><td>Comments:</td><td colspan="3">Tensile tests resulted in a failure at the hook at 11.4T exceeding the 10T rated breaking load. Image below shows the failure.</td></tr>
<tr><td colspan="4"></td></tr>
</table>

-10T Straps-

<table>
<tr><td colspan="5">009/ET/OH</td></tr>
<tr><td>Rated Breaking Load:</td><td>5T SWL
10T Breaking load</td><td>Condition as received:</td><td colspan="2">Failed</td></tr>
<tr><td>Action:</td><td colspan="4">Examination of failure</td></tr>
<tr><td>ID Markings:</td><td colspan="2">‘BL 1000 KG DEC 2010
MSL 5000KG 100%
Polyester
Not for lifting’</td><td colspan="2">
</td></tr>
<tr><td colspan="5">
</td></tr>
<tr><td>Comments:</td><td colspan="4">Strop has failed adjacent to the ratchet through tensile overload, possibly where the strop has been in contact with another surface (see witness mark in image below).</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Mode of Failure:</td><td colspan="4">Tensile overload</td></tr>
</table>

-10T Straps-

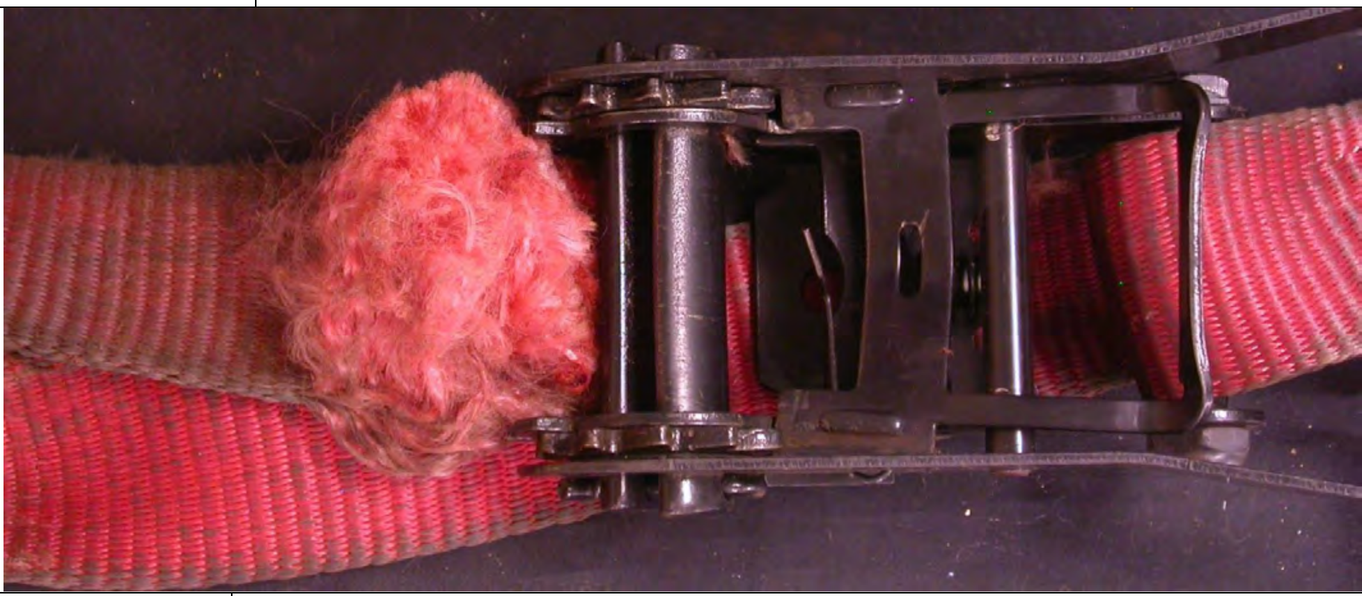
<table>
<tr><td colspan="4">010/ET/OH</td></tr>
<tr><td>Rated Breaking Load:</td><td>5T SWL
10T Breaking load</td><td>Condition as received:</td><td>Failed</td></tr>
<tr><td>Action:</td><td colspan="3">Examination of failure</td></tr>
<tr><td>ID Markings:</td><td>'BL 1000 KG DEC 2010
MSL 5000KG 100%
Polyester
Not for lifting'</td><td colspan="2">
</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>Comments:</td><td colspan="3">Strop has failed adjacent to the ratchet through tensile overload, extensive damage along the strop.</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>Mode of Failure:</td><td colspan="3">Tensile overload</td></tr>
</table>

-10T Straps-

013/ET/OH

Rated Breaking Load:	5T SWL 10T Breaking load	**Condition as received:**	Used/intact
Action:	Tensile test		
ID Markings:	*'BL 1000 KG DEC 2010 MSL 5000KG 100% Polyester Not for lifting'*		

Actual Failure Load:	11.05T
Comments:	Failed at ratchet at 11.05T, exceeding the 10T breaking load.



Mode of Failure:	Tensile overload

-10T Straps-

015/ET/OH			
Rated Breaking Load:	5T SWL 10T Breaking load	**Condition as received:**	Used/intact
Action:	Failure investigation		
ID Markings:	No label, markings on strop difficult to read but say: *'HOEGH BL 10T MSL 5T APR 2009'*		

Actual Failure Load:	9.05T
Comments:	Failed remote from the ratchet resulting in substantial amounts of loose fibres (see image below) at below the 10T breaking load. The strop was noted to have a number of small cuts on its surface prior to the tensile test and it is believed it failed at the one shown in the image below.

-10T Straps-

Discussion:
The tensile test results for the strops are summarised below. As can be seen 015/ET/OH failed at 9.05T, which is below the 10T breaking load, this is suspected to be due to a cut in the strop noted when it was assembled in the tensile tester. Despite the relatively low breaking load on this item it is still significantly above the SWL of 5T.

Sample ref	Condition	Breaking Load	Failure Load (T)
007/ET/OH	Unused	10T	11.4T
013/ET/OH	Used/intact	10T	11.05T
015/ET/OH	Used/intact	10T	9.05T

Service failures 009 & 0010/ET/OH are both consistent with tensile overloads.

Author:
[redacted]

[redacted]

Annex C

Technical analysis of water sample removed from fore deep tank

REPORT ON THE ANALYSIS OF WATER SAMPLES

(MARINE ACCIDENT INVESTIGATION BRANCH)

Marine Investigation Branch

Mountbatten House

Grosvenor Square

Southampton

SO15 2JU

24 March 2015

Introduction

Two water samples (1: a sample taken from Fore deep tank, Hoegh Osaka 2: a control sample taken from the Solent) were received (06 March 2015) at the Marchwood Scientific Services Laboratory to determine if the water in the tank was fresh water or sea water or a combination of both.

As seawater has a high chloride content compared to freshwater, the comparison of chloride content would be a reliable identifier.

Experimental

Due to the expected chloride content the samples were diluted 100x with laboratory grade water.

The samples were then analysed by Ion Chromatography using a Dionex ICS 2100 Ion Chromatograph (Chloride has an expected retention time of 6.2 mins +/- 0.2 mins).

Results / Discussion

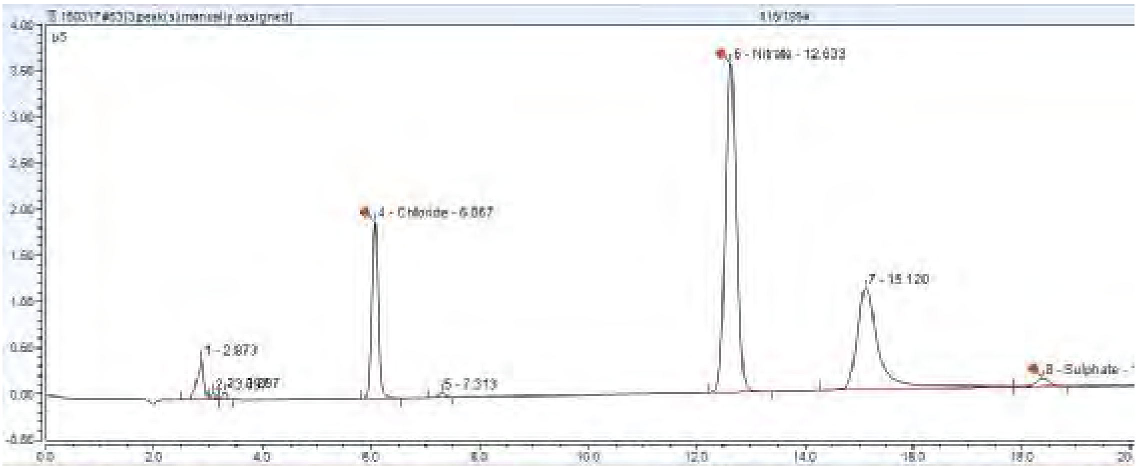
The results indicate a significant difference in concentration between the tank water and a seawater sample (Solent).

Tank water 2uS - 20mg/l

Seawater 160uS – 2910mg/l.

From the above analyses it can be concluded that the supplied tank water is not seawater but from a freshwater source.

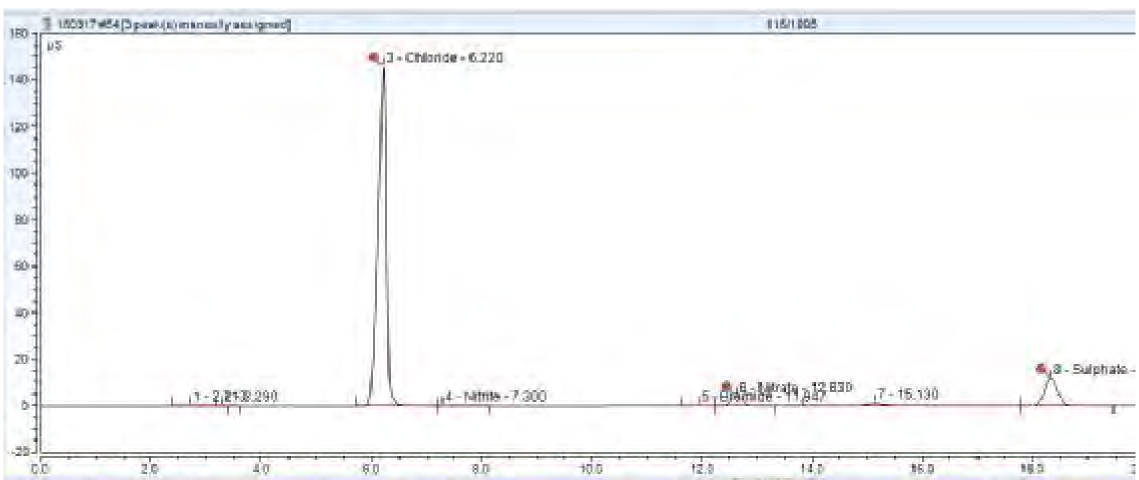
Sample 115/1994 – Tank Water



	A	B	C	D	E	F	G	H	I	J	K	L
1	Peak	Peak Name	Ret.Time	Amount	Rel.Area	Area	Height	Type	Width (50%)	Asym.	Resol.	Plates
2	No.		min	mg/l	%	µS*min	µS		min	EP	EP	EP
6	3		3.297	n.a.	0.39	0.0068	0.08	Rd	n.a.	n.a.	n.a.	n.a.
7	4	Chloride	6.067	20.9249	14.72	0.2542	1.91	M *	0.120	1.03	5.66	14141
8	5		7.313	n.a.	0.40	0.0070	0.05	M	0.140	0.97	17.57	15137
9	6	Nitrate	12.633	218.5577	48.82	0.8431	3.57	M *	0.217	1.03	5.08	18695
10	7		15.120	n.a.	30.03	0.5185	1.10	M	0.361	1.60	6.31	9743
11	8	Sulphate	18.393	n.a.	1.56	0.0269	0.09	M *	0.252	0.88	n.a.	29630
12	Maximum			218.5577	48.82	0.8431	3.57		0.361	1.60	17.57	29630
13	Minimum			20.9249	0.20	0.0044	0.05		0.120	0.83	5.08	2490
14	Sum			239.4826	100.00	1.7270	7.30					

At 100x dilution

Sample 115/1995 – Solent Water



	A	B	C	D	E	F	G	H	I	J	K	L
1	Peak	Peak Name	Ret.Time	Amount	Rel.Area	Area	Height	Type	Width (50%)	Asym.	Resol.	Plates
2	No.		min	mg/l	%	µS*min	µS		min	EP	EP	EP
6	3	Chloride	6.220	2910.1303	84.52	25.5177	145.62	M *	0.161	0.75	n.a.	8282
7	4	Nitrite	7.300	n.a.	0.02	0.0076	0.02	M	n.a.	n.a.	n.a.	n.a.
8	5	Bromide	11.947	31.6478	0.11	0.0343	0.16	M	0.202	0.97	1.92	19441
9	6	Nitrate	12.630	245.8401	3.21	0.9694	4.10	M *	0.218	1.04	5.11	18613
10	7		15.130	n.a.	1.66	0.5002	1.02	M	0.369	1.83	6.22	9847
11	8	Sulphate	18.333	554.7718	10.44	3.1514	11.89	M *	0.248	1.04	n.a.	30176
12	Maximum			2910.1303	84.52	25.5177	145.62		0.369	2.11	17.66	30176
13	Minimum			31.6478	0.00	0.0006	0.01		0.142	0.75	1.92	2012
14	Sum			3742.3000	100.00	30.1907	162.66					

At 100x dilution

Annex D

Extract from Report: Investigation into Cargo Securing Arrangements and Simulation of Incident

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No. S150097/KD/GH 7th March 2016

REPORT

HOEGH OSAKA

Investigation into Cargo Securing Arrangements

and Simulation of Incident

IN ACCORDANCE with instructions received from the U.K. Marine Accident Investigation Branch MAIB), on behalf of the Secretary of State for Transport, we have been asked to review the documents provided which relate to an incident on 03rd January 2015, in Southampton, United Kingdom, when HOEGH OSAKA was departing after completion of loading. After clearing the port the vessel developed a list and subsequently grounded in shallow waters.

In this report we provide our technical analysis of the securing arrangements required for four cargo units identified by the MAIB. We also provide our technical opinion on the contents of the vessels' Cargo Securing Manual, Hoegh Autoliners' Cargo Quality Manual and the use of nylon web lashings for 'High and Heavy' cargo loaded on board. We provide details of simulations performed using our ship handling software BBSIM and our analysis of the VDR data taken from the vessel.

[redacted]

1. EXPLANATION OF TERMS USED IN THIS REPORT

1.1 *Moment.* For every concept related to forces applied in a straight line (e.g. acceleration, speed, inertia) there is a rotational equivalent. A moment is a term used in naval architecture and hydrodynamics to describe the rotational equivalent of a force. A force applied perpendicular to a lever creates a moment, sometimes known as a couple or a torque depending on the application.

1.2 *Resistance* is the force required to push the vessel through the water, neglecting any influence from the propeller.

1.3 *Surge, Sway and Yaw*. In considering vessel interaction in still water, there are three directions of vessel motion that are of interest. These are forwards/aftwards in the direction of its own centreline (surge), athwart ship in a horizontal direction perpendicular to its centreline (sway) and rotationally causing changes in vessel heading (yaw).

1.4 *Computational Fluid Dynamics (CFD)*. The branch of hydrodynamics which uses computers to solve fundamental equations. In general, CFD is computationally intensive and often requires a large number of micro-chips working in parallel over days, or even months.

1.5 *Navier Stokes Equations*. Fundamental equations of fluid mechanics named after the physicists who first derived them. The equations are themselves based on fundamental equations of mechanics such as Newton's second law. For most fluid types (including water), the Navier Stokes are a complete mathematical description of the movement and pressure of a fluid.

1.6 *Reynolds Averaged Navier Stokes Equations (RANSE)*. This is an extremely common and useful approximation of the Navier Stokes equations named after the physicist who first proposed it. The RANSE form of the Navier Stokes equations is solvable by modern computers and is the basis of most contemporary CFD.

1.7 *Equilibrium*. A state of equilibrium is when no net forces/moments act on a body such as a floating ship. If a vessel is symmetrically ballasted/loaded, its equilibrium position

Contd/...

is upright. If an overturning moment is applied to the ship (for example if cargo shifts) the vessel will heel until the righting moments caused by the hydrostatic pressure acting on her hull increase sufficiently to balance the overturning moment. In this case, the vessel will have a new equilibrium position which is at some angle to the upright position (i.e. she is said to have an angle of list).

1.8 *Roll/Heel/List.* In naval architecture Roll, Heel and List all refer to the angle a vessel adopts to the vertical considering rotations around its longitudinal axis. Roll normally refers to the instantaneous angle (including the effects of waves) whereas Heel and List refers to the average angle (at equilibrium) where static forces such as shifted cargo are taken into account. As this analysis concerns the sudden movement of cargo, and the loss of the vessel's stability, the normal distinction made between these terms is not helpful. We have therefore used the term "roll" in this report.

2. THE VESSEL

2.1 HOEGH OSAKA is a Pure Car and Truck Carrier with the following principal particulars;

IMO	9185463
DWT	16,886 tonnes
LOA	179.90 metres
LBP	171.30 metres
Summer draught	9.622 metres
Breadth	32.20 metres
Depth	34.50 metres
Built	September 2000
Shipyard	Tsuneshi Shipbuilding, Japan
Class	Lloyd's Register
Flag	Singapore

2.2 The vessel was constructed with 12 vehicle decks along the length of the vessel, subdivided into four gas tight vertical holds. According to the ships' particulars, the cargo carrying capacity is recorded as 4474 standard cars. Loading and off-loading of the cargo is by one stern ramp and one side ramp on the starboard side.

2.3 Propulsive power was provided by a single Mitsubishi engine, type 8UCE60LS, giving a service speed of 19.2 knots. HOEGH OSAKA was also fitted with one bow-thruster, rated at 1700HP and one stern-thruster rated at 1050HP.

2.4 HOEGH OSAKA is reported to have been constructed to Det Norske Veritas (DNV) Classification Society Rules, and in accordance with International SOLAS, LSA and FFA regulations. At the time of the incident under discussion the vessel was classed by Lloyd's Register with the following ship specific class annotation[1];

100 A1, vehicle carrier; movable decks; IWS; LI; LMC; UMS

2.5 HOEGH OSAKA was owned by Hoegh Autoliners AS of Oslo, Norway and managed by Wallem Shipmanagment Ltd, of Hong Kong, China.

[1] Information taken from IHI Sea-web website http://www.sea-web.com

3. STRUCTURE OF THE REPORT

3.1 The MAIB have instructed us to review the documents provided and supply our technical comments upon various aspects of the incident under discussion.

3.2 [redacted] was responsible for **sections 4** to **9** concerning the various cargo units on Deck 6 which shifted at some point during the incident. **Section 4** provides details on those units relevant for their securing. In **Section 5** we provide a description of the relevant regulations for securing cargo - the IMO Code of Safe Practice for Cargo Stowage and Securing (CSS Code). In section 6 we provide our calculations for the minimum number of web lashings (the type of securing equipment onboard the HOEGH OSAKA) required for compliance with the CSS Code for each of the shifted cargo units. In **section 7** we provide our review of the HOEGH OSAKA's Cargo Securing Manual and in **section 8** we comment on the HOEGH AUTOLINERS Cargo Quality Manual. In **section 9** we comment on the use of web lashings for the securing of heavy cargo units.

3.3 [redacted] was responsible for **sections 10** to **13** which details the analysis performed on the VDR data and the simulations of the incident using our ship handling simulation software BBSIM. **Section 10** describes the process of extracting the VDR data and presents the ship trajectory on a chart of the area. **Section 11** provides details on our analysis of the VDR data and the likely roll angles reached by the HOEGH OSAKA as it navigated the Brambles turn. **Section 11** provides details of the manoeuvering model of the HOEGH OSAKA and **Section 12** describes BBSIM simulations replicating the initial part of her port turn around the Brambles Bank.

3.4 Both authors were responsible for the concluding comments in **Section 14** and their separate contributions are identified in that section

4. CARGO TO BE REVIEWED

4.1 The four individual cargo units identified by the MAIB consisted of two 'Atlas Copco Powercrusher PC 21's, one 'Caterpillar D8T Track-Type Tractor' and one 'Powerscreen Trakpactor 500'. All of these units were loaded onto the after end of deck no. 6

4.2 The 'Atlas Copco Powercrusher PC 21' is a mobile stone crusher, mainly used in quarries to reduce large stone rocks to smaller aggregates and stone products[2]. Each unit consists of an input hopper and conveyor belt at one end, a crusher and power unit in the central body unit, and a discharge conveyor belt system at the opposite end to the hopper. Each unit is powered by a diesel engine and locomotion is provided by two separate tractor-type tracks connected on either side of a crawler unit under the centre of the main unit. The transportation dimensions for each unit are recorded in the manufacturers technical information sheet as 14.60m x 2.87m x 3.83m (L x W x H). The shippers declared weight for each of these units was 49,770 kilograms, corresponding to the manufacturers' plaque, attached to each of the units that recorded the 'Machine Weight' as 49,770 kilograms.

4.3 The 'Caterpillar D8T Track-Type Tractor' is multi-purpose tracked bulldozer type unit, which can be used for dozing, ripping, scraping or land clearing depending on the particular attachments used. Each unit is powered by a diesel engine and locomotion is provided by two tractor-type tracks, one on either side of the undercarriage. This unit was shipped with no attached blade. According to the manufacturers' technical information sheet the length of the basic tractor is 4.554 metres, the width (without trunnions) is 2.642 metres and the height (to the top of the exhaust stack) is 3.304 metres. This unit, when weighed after the incident, was found to weigh 37,400 kilograms.

4.4 The 'Powerscreen Trakpactor 500' is a mobile stone crushing unit, principally used in quarrying, and for recycling and demolition purposes. Each unit consists of a hopper and feed conveyor at one end, a crusher and power unit comprise the main body of the unit, with a discharge conveyor at the opposite end to the input hopper. Each unit is powered by a diesel engine, and locomotion is provided by two tractor-type tracks, one on either side of a crawler unit under the centre of the main body. The transportation dimensions for each unit are recorded in the manufacturers technical information sheet as 17.30m

[2] Information concerning the description of the units was obtained from various trade and sales websites.

x 3.00m x 3.80m (L x W x H). The shippers declared weight for this unit was 56,000 kilograms, which was higher than the 'Machine Mass' of 54,000 kilograms recorded on the manufacturers' plaque, attached to the unit.

4.5 According to the documents provided, prior to the incident the units were stowed in the following positions:

Trakpactor 500	In a fore-and-aft direction, at the after end of deck no. 6, on the starboard side, adjacent to the centreline.
Powercrusher PC 21 (1)	In a fore-and-aft direction, approximately one quarter of the length of deck no. 6 from the after end, on the starboard side, adjacent to the centreline.
Powercrusher PC 21 (2)	In a fore-and-aft direction, directly forward of PC 21 (1).
D8T Dozer	In a fore-and-aft direction, approximately one fifth of the length of hold no. 6 from the after end, on the port side.

5. IMO CARGO AND STOWAGE (CSS) CODE ANNEX 13

5.1 When considering the forces acting upon any cargo units loaded on-board, I use the following guidance from the IMO Code of Safe Practice for Cargo Stowage and Securing, 2011 Edition (CSS Code), Chapter 1;

> "*1.3.1 Forces which have to be absorbed by suitable arrangements for stowage and securing to prevent cargo shifting are generally composed of components acting relative to the axes of the ship;*
>
> - *longitudinal*
> - *transverse; and*
> - *vertical*
>
> *Remark: For the purpose of stowage and securing cargo, longitudinal and transverse forces are considered predominant.*
>
> *1.3.2 Transverse forces alone, or the resultant of transverse, longitudinal and vertical forces, normally increase with the height of the stow and the longitudinal distance of the stow from the ship's centre of motion in a seaway. The most severe forces can be expected in the furthest forward, the furthest aft and the highest stowage position on each side of the ship.*"

5.2 In Annex 13 of the CSS Code, three methods are introduced to assist the Master to assess the "*efficiency of securing arrangements for non-standardized cargo*". These consist of the 'Rule-of-thumb method', the 'Advanced calculation method' and the 'Balance of forces – alternative method'.

5.3 The 'Rule-of-thumb method' states that the "*Total of the MSL[3] values of the securing devices on each side of a unit of cargo (port as well as starboard) should equal the*

---

[3] Maximum Securing Load (MSL) is a term used to define the load capacity for a device used to secure cargo to a ship. The MSL of the device is determined as a percentage of the Mean Breaking Load (MBL). With the majority of the standard lashing equipment used the MSL is determined to be 50% of the MBL; the exceptions being fibre rope, wire rope (single use), wire rope (re-useable) and steel band (single use).

weight of the unit[4]". The 'Rule-of-thumb' method is a valuable, tried and tested, means for the Master to quickly, and easily, prepare a lashing plan for any item of cargo which may be loaded in any position on-board his vessel.

5.4 The 'Rule-of-thumb method' assumes that the securing devices are equally positioned and tensioned on either side of the unit, The method does not take into account the lashing angles, the distribution of forces among the lashings or the effect of friction. According to paragraph 5.3, "*Transverse lashing angles to the deck should not be greater than 60° and it is important that adequate friction is provided by the use of suitable material*".

5.5 This method does not specify the requirements for restricting movement in a longitudinal direction; the common practice when using the 'Rule-of-thumb method' is to distribute the securing arrangements such that "*40% of the lashings' strength are to port and 40% are to starboard, with 10% leading forward and 10% leading aft; the 40:40:10:10 rule*".[5]

5.6 The 'Advanced calculation method' is a more precise calculation which calculates the acceleration forces acting upon an individual cargo unit based upon the longitudinal and vertical position on-board. The basic acceleration data is presented in Annex 13 of the CSS Code and reproduced in **Figure 1** below;

Figure 1 – Table of basic accelerations from CSS Code

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[4] The weight of the unit should be taken in kN.

[5] Page 32, North of England P&I publication, Cargo Stowage and Securing, 2nd Edition 2007

	Transverse acceleration a_y in m/s^2									Longitudinal acceleration a_x in m/s^2
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
on deck, high	7.1	6.9	6.8	6.7	6.7	6.8	6.9	7.1	7.4	3.8
on deck, low	6.5	6.3	6.1	6.1	6.1	6.1	6.3	6.5	6.7	2.9
'tween-deck	5.9	5.6	5.5	5.4	5.4	5.5	5.6	5.9	6.2	2.0
lower hold	5.5	5.3	5.1	5.0	5.0	5.1	5.3	5.5	5.9	1.5
Vertical acceleration a_z in m/s^2	7.6	6.2	5.0	4.3	4.3	5.0	6.2	7.6	9.2	

(Scale along ship length: 0 to L)

5.7 The basic acceleration data described above has been calculated based upon a 'model' vessel with, amongst several other criteria;

Length of ship is 100m

Service speed is 15 knots

B/GM ≥ 13 (B = breadth of ship, GM = metacentric height)

Where the operational conditions of the vessel in question vary from these criteria, additional correction factors should be included.

5.8 The CSS Code considers that the 'Advanced calculation method' described above "*...will normally furnish a sufficiently accurate determination of the adequacy of the securing arrangement*"[6]. However the 'Balance of Forces – alternative method' is recommended for calculating the;

- *transverse sliding in port and starboard directions*

- *transverse tipping in port and starboard directions*

- *longitudinal sliding under conditions of reduced friction in forward and aft directions*

[6] IMO CSS Code, Annex 13, paragraph 7.3

6. ASSESSMENT OF THE CARGO UNITS LOADED ON-BOARD HOEGH OSAKA

6.1 In my assessment I have used the DNV Lashcon IMO Excel programme, version 9.00.0 Jan 2004. This programme has been developed by DNV to enable ships' officers to easily calculate the lashing requirements for any cargo unit by calculating the acceleration forces in accordance with Annex 13 of the CSS Code.

6.2 The programme enables the user to use the Alternative calculation (Recommended) or the Advanced Calculation. I have used the Alternative calculation method.

6.3 I have assumed the following general criteria in all of the calculations;

Vessel Speed	19.2 Knots[7]
Vessel G_oM	0.7 metres
Height of cargo unit	Deck High[8]
MSL of each lashing	5,000 kilogrammes (Hoegh Heavy Duty Weblashing, Red)

6.4 The securing arrangements have been fitted to restrict movement in the longitudinal, transverse and vertical directions. The most effective lashings are fitted directly to a designated lashing point, or suitable strong point on each unit, with an angle to the horizontal between 30° to 60°. I have assumed an angle of 45° for each lashing, though the final angles would be dependent upon the height of the lashing points on the cargo units and the positioning of the vessels' fixed securing points.

6.5 For the final calculations, the lashings have been fitted evenly to port and starboard and designed to also act evenly in a forward and aft direction.

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[7] Based upon the Full Sea Ahead speed quoted in the Deck Operating Manual

[8] This is based upon deck 6, where each of the cargo units were stowed, having a Vertical Centre of Gravity of 16.550 metres, which is above the vessels' calculated vertical Centre of Gravity of 15.420 metres.

6.6 Friction has been increased by the use of rubber mats placed between the tracks and the deck plating to give a co-efficient of 0.3[9].

6.7 For each unit I have calculated the absolute minimum number of lashings that would be required in order to overcome the acceleration forces detailed in Annex 13 of the CSS Code.

Atlas Copco Powercrusher PC 21 (1)

6.8 The Centre of Gravity for these units is not identified on the manufacturers' information sheets. The declared maximum height of the unit is 3.83 metres; therefore the half height would be 1.91 metres. Based upon the construction of the unit, with most of the mass being above the lower tracks, we estimate that the Centre of Gravity will be approximately 2.30 metres above the base. For tracked units of this nature the lashing points are usually near to the height of the crawler unit, in this instance we estimate that the lashing points will be approximately 1.00 metres above the base.

6.9 The centre of the unit was positioned just forward of 0.25 length of the vessel, in this instance we have calculated the longitudinal position as 0.3 length. This longitudinal position, with a 'Deck, high' vertical position, results in the following acceleration forces:

Transverse sliding force (kilonewtons)	275.1
Longitudinal sliding force (kilonewtons)	153.7
Cargo tipping moment (kilonewton-metres)	632.7

6.10 It was found that the minimum securing arrangements required to overcome these forces consisted of two web lashings leading directly from each corner, at an angle of 45° to the fore and aft axis and two web lashings secured in a transverse direction, one leading directly to port and the other leading directly to starboard. With all lashings set at a vertical securing angle of 45°, this arrangement would give the following securing capacity **(Appendix 2)**:

Transverse capacity (kilonewtons)	286

[9] The Friction coefficient is based upon the contents of Table 5 in paragraph 7.2 of Annex 13 of the CSS Code.

Longitudinal capacity (kilonewtons)	191
Tipping capacity (kilonewton-metres)	1224

Atlas Copco Powercrusher PC 21 (2)

6.11 This unit was situated directly forward of PC 21 (1) and in making my calculations I have considered this unit to have identical acceleration forces acting upon it **(Appendix 2)**.

Caterpillar D8T Track-Type Tractor

6.12 The Centre of Gravity for this unit is not identified on the manufacturers' information sheets. The declared maximum height of the unit is 3.304 metres. With the upper body consisting of the cab unit, we estimate that the Centre of Gravity will be approximately 1.20 metres above the base, and that the lashing points will be approximately 1.00 metre above the base.

6.13 The centre of the unit was positioned aft of 0.25 length of the vessel, in this instance we have calculated the longitudinal position as 0.2 length. This longitudinal position, with a 'Deck, high' vertical position, results in the following acceleration forces:

Transverse sliding force (kilonewtons)	209.8
Longitudinal sliding force (kilonewtons)	115.5
Cargo tipping moment (kilonewton-metres)	251.7

6.14 It was found that the minimum securing arrangements required to overcome these forces consisted of two web lashings leading directly from each corner, at an angle of 45° to the fore and aft axis. With all lashings set at a vertical securing angle of 45°, this arrangement would give the following securing capacity **(Appendix 3)**:

Transverse capacity (kilonewtons)	216
Longitudinal capacity (kilonewtons)	159
Tipping capacity (kilonewton-metres)	902

Powerscreen Trakpactor 500

6.15 The Centre of Gravity for this unit is not identified on the manufacturers' information sheets. The declared maximum height of the unit is 3.80 metres. With the limited

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information available we have estimated the Centre of Gravity to be mid height, at 1.90 metres above the base. The body of the unit is contained in a substantial steel frame and, though no lashing points have been identified, we consider that there would be a sufficient number of strong points along the length at mid height to secure the unit.

6.16 The centre of the unit was positioned just forward of the stern door, in this instance we have calculated the longitudinal position as 0.0 length (Aft Peak). This longitudinal position, with a 'Deck, high' vertical position, results in the following acceleration forces:

Transverse sliding force (kilonewtons)	336.8
Longitudinal sliding force (kilonewtons)	173.0
Cargo tipping moment (kilonewton-metres)	640.0

6.17 It was found that the minimum securing arrangements required to overcome these forces consisted of four web lashings leading directly from each corner, at an angle of 45° to the fore and aft axis. With all lashings set at a vertical securing angle of 45°, this arrangement would give the following securing capacity **(Appendix 4)**:

Transverse capacity (kilonewtons)	376
Longitudinal capacity (kilonewtons)	250
Tipping capacity (kilonewton-metres)	1891

7. REVIEW OF HOEGH OSAKA CARGO SECURING MANUAL (CSM)

7.1 HOEGH OSAKA's Cargo Securing Manual (CSM) was approved by Det Norske Veritas (DNV) on 07th September 2000, updated on 24th April 2007 by DNV and accepted by Lloyds Register (LR) on 17th February 2014 when the vessel changed Classification Society.

7.2 The CSM is generic in nature and based upon the DNV 'Cargo Securing Model Manual' in accordance with IMO MSC/circ. 745 'Guidelines for the Preparation of the Cargo Securing Manual', dated 13th June 1996. As stated in the introduction to the CSM:

"*Version 1.0 of the Model Manual (April 1996) used a RO-RO ship as an example. This version includes the material from the first version and is generalised to include all ship types*".

7.3 Chapter 2.2 of IMO MSC/circ. 745 'Specification for portable cargo securing devices' offers guidelines on the information to be provided in the CSM concerning the "*...number of and the functional and design characteristics of the portable cargo securing devices carried on board the ship...*"

7.4 Chapter 2.2 of the CSM includes a list of the Portable Securing Devices on board when the manual was initially issued as detailed in **Table 1** below.

Table 1 – Summary of Lashing Equipment listed in HOEGH OSAKA CSM

Type	Manufacturer	Id. marking	Quantity	MSL (kilonewtons)	Sketch
Chain Lashing	Ro-Ro International	Chain Lashing 13mm	300	T = 98	See Appendix IV
Webb lash	Ro-Ro International	Rollash 3.2m	2000	T = 34.3	See Appendix IV
Car lashing	R0-Ro International	Ro-Ro Lash 2m	24000	T = 13	See Appendix IV

T = Tension

7.5 Appendix IV of HOEGH OSAKA's CSM contains the details of the Portable Cargo Securing Devices on board. The equipment listed consists of '*Webblash – Rollash*' lashing belts, with a standard length of 3.2 metres, a BL of 5,000 kilogrammes and an MSL of 2,500 kilogrammes; and '*Carlashing type Ro-Ro Lash*' lashing belts, with a BL of 2,000 kilogrammes. Both types of belts were manufactured by Ro-Ro International A.B. of Gothenburg, Sweden.

7.6 The Test Certificates included in Appendix IV, issued by Ro-Ro International, include '*Webblashing type Heavy Duty Hook + Hook, Red Length 3m*' with a minimum BL of 10,000 kilogrammes and an MSL of 5,000 kilogrammes, and '*Webblashing type HOEGH Rollash 3.2m Blue*' with a min BL of 5,000 kilogrammes and an MSL of 2,500 kilogrammes. The latest certificates for both type of lashing belts are dated 19th December 2013.

7.7 The current list of Portable Cargo Securing Devices on board does not include any additional chain lashing equipment; however, in Appendix IX 'Log for Maintenance of Cargo Securing Equipment', several references are made to chains, with examples listed below;

"*05.09.05* *3 chains…condemned*

02.03.06 *8 chains…condemned*

12.06.06 *Rcvd 600 Pce new chains + tension bars for replacement of same*

15.06.06 *Rcvd 900 Pce used chains + tension bars for replacement of same*

20.04.10 *Rolash/Chains/Car Lashings – Arrange, equalize and inspected*"

The last mention of chains in the Maintenance Log is dated 22.06.11 when the entry states "*Received 2000 pcs of web lash. Offloaded Chain bins & (*illegible*)*" From the above we understand that the vessel was initially supplied with lashing chains but these were removed in June 2011 (or thereabouts).

7.8 Paragraph 2.2.5 of the CSM discusses the use of Web Lashings on board vessels'.

"*Web lashings made of synthetic fibres are extensively used onboard ships for securing of cargo. Such web lashings certainly elongate more than steel chains. However, chain lashings often become slack after some time, due to the motions of the ship and cargo,* *and slack chains with low elasticity will give jerking forces on securing points, cargo and lashings. The more elastic web lashings, with proper pre-tensioning, will largely avoid this problem. Modern web lashings have improved resistance to ripping and chafing compared to those available only few years ago*".

This paragraph finishes with the warning "*Web lashings should be used and handled with great care, and it should be borne in mind that the maximum securing load decreases considerably if the synthetic fibre is ripped*".

7.9 After outlining the Portable Cargo Securing equipment used on-board, the CSM then considers the "*Stowage and securing of non-standardised and semi-standardised cargo*" in Section 3. Paragraph 3.1.1 lists the "*General principles of cargo securing*" and includes the following additional instructions for RO-Ro ships;

18. Only one lashing shall be attached to any one aperture, loop or lashing ring at each vehicle securing point.

19. Where practicable, the arrangement of lashings on both sides of a vehicle should be the same, and angled to provide some fore and aft restraint with an equal number pulling forward as are pulling aft.

21. Caterpillar treaded vehicles such as bulldozers and cranes are prone to sliding when parked on bare steel decks owing to the low degree of frictional resistance between the threads and the deck. Such vehicles shall be stowed on dunnage or soft boards before being secured.

7.10 This section also includes a drawing to show the "*Standard lashing arrangement for vehicles*". This drawing has been stamped as approved by DNV on 24th July 2007. The drawing indicates the lashing arrangement for a standard family saloon car, it does not include any reference to any other type of vehicle which would be expected to be loaded on-board the vessel.

7.11 The CSM includes the procedures to be followed for calculating the forces in semi- and non-standardised lashing arrangements. As well as including the guidelines issued in Annex 13 of the CSS Code, the CSM makes reference to the DNV Lashcon programme for calculating forces; it is noted that the instructions included are for an early version of this programme, version 1.1 dated 02nd February 1997. Additional instructions are included later in the CSM for version 3.0 dated 15th January 1998.

7.12 Section 3.4 of the CSM includes "*Supplementary Requirements for Ro-Ro Ships*", which includes part 6 "*Lashings*". This section states that;

6.1 The maximum securing load, MSL, of lashings should not be less than 100kN[10]*, and they should be made of material having suitable elongation characteristics.*

6.6 Lashings should be attached to the securing points on the vehicle in such a way that the angle between the lashing and the horizontal and vertical planes lies preferably between 30° and 60°.

6.7 Bearing in mind the characteristics of the ship and the weather conditions expected on the intended voyage, the master should decide on the number of securing points and lashings to be used for each voyage.

7.13 Though the CSM clearly states that "*The maximum securing load, MSL, of lashings should not be less than 100kN*"; the vessel was not supplied with lashing equipment which complied with these requirements.

[10] kN is a shortened form of the kilonewton unit

8. <u>REVIEW OF HOEGH AUTOLINERS CARGO QUALITY MANUAL</u>

8.1 The Hoegh Autoliners Cargo Quality manual, updated February 2013, details the Company standards to be followed for loading, stowing and securing the various types of cargo units carried by the Company vessels'. The relevant sections concerning the stowage and securing of High and Heavy units are detailed in the paragraphs below.

8.2 Page 46 – Hoegh Autoliners Lashing Standard

"*High and Heavy units with weights above 10000 kg*[11] *shall be secured by Heavy Duty Webb Lash with a break load of minimum 10000 kg and MSL minimum 5000 kg. Rollash can be used as an alternative provided total MSL sufficient. NB do not mix heavy duty and Rollash on same unit*."

8.3 Page 55 – Securing of Static, Roll trailer, Excavators and other H/H not on rubber tyres

"*The number of lashings shall be selected by the following Rule of Thumb method.*

THE TOTAL OF THE MSL VALUES IN TON OF THE SECURING DEVICES ON EACH SIDE OF A UNIT OF CARGO (PORT AS WELL AS STARBOARD) SHOULD EQUAL THE WEIGHT OF THE UNIT IN TON".

8.4 The following conditions are included for the use of the Rule of Thumb method prescribed in **paragraph 8.3** above:

1. *Good friction between the contact surfaces. At least one of the surfaces should consist of wood or rubber.*
2. *Lashings working together should be of about equal length.*
3. *Lashings should be placed symmetrically on both sides of the units.*
4. *Lashings with a vertical angle (α) towards the ships deck larger than 60 degrees may not be taken into account.*

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[11] Kg is the shortened form of the kilogramme unit

5. *Lashings with a horizontal angle (ß) towards the ships transverse axle larger than 60 degrees may not be taken into account.*

6. *For units which are not rigid in form or which has a high centre of gravity the number of lashings may have to be increased*.

8.5 Page 56 – Securing of Static, Roll trailer, Excavators and other H/H not on rubber tyres

MINIMUM NUMBER OF HEAVY DUTY WEB LASH

Unit weight	*Number of lashings per side*	*Total number of lashings*
20 000 – 40 000	*8*	*16*
40 000 – 60 000	*12*	*24*

The lashings shall be placed symmetrically on both sides of the unit.

8.6 Based upon the above requirements, the minimum number of lashings to be fitted to each of the units in question should have been;

Atlas Copco Powercrusher PC 21	12 Heavy Duty Web Lashings per side
Powerscreen Trakpactor 500	12 Heavy Duty Web Lashings per side
Caterpillar D8T	8 Heavy Duty Web Lashings per side

8.7 Page 64 – Securing of Static, Roll trailer, Excavators and other H/H not on rubber tyres

Tracked units

Once in final stowage position, all steel pieces should rest on rubber mats.

Use chain extension if needed when lashing in unit tracks.

8.8 The Hoegh Autoliner Cargo Quality Manual states, on page 55, that when considering the number of lashings for '*Excavators and other H/H not on rubber tyres*" the 'Rule of Thumb method should be applied. We consider this to be a sensible precaution as this method invariably requires more lashings being fitted than the 'Advanced calculation method'.

8.9 The manual also correctly identifies the requirements for the lashings to be fitted evenly on both sides and for rubber matting to be placed under tracked units to induce friction.

8.10 The manual does not consider the use of lashing chains for securing heavy cargo units.

9.0 USE OF WEB LASHINGS

9.1 The use of nylon web lashings on Ro-Ro's and Pure Car Carriers is an established and safe method for quickly securing and un-securing similar sized automobiles in port. The turnaround time in port may only be a few hours, and the time saved using easy to use preformed belt lashings is appreciable.

9.2 Normally four lashings are fitted to each vehicle; with an MSL for each belt in the region of 2,500 kilogrammes, this will result in a holding power of five tonnes for each side, which is sufficient for the vast majority of vehicles carried.

9.3 We are not aware of an industry wide accepted standard for the maximum weight which can be secured by belt lashings, however the MCA Code of Safe Practice for Ro-Ro Stowage and Securing states that "Steel chains are commonly used for lashing freight vehicles of more than 3.5 tonnes". In our experience the majority of Ro-Ro operators commonly use steel chains to secure wheeled cargo units.

9.5 IMO MSC.1/Circ.1355 amends IMO Resolution A.581(14) 'Guidelines for securing arrangements for the transport of road vehicles on Ro-Ro ships' with the following;

6.1 "*The maximum securing load (MSL) of lashings should not be less than 100 kN and they should be made of material having suitable elongation characteristics. However, for vehicles not exceeding 15 tonnes (GVM), lashings with lower MSL values may be used. The required number and MSL of lashings may be calculated according to annex 13 to the Code of Safe Practice for Cargo Stowage and securing (CSS Code), taking into consideration the criteria mentioned in paragraph 1.5.1 of the Code.*"

9.6 It should be noted at this point that according to Annex 4 of the IMO CSS Code 'Safe stowage and securing of wheel-based (rolling) units', the definition of wheel-based cargoes is;

"*Wheel-based cargoes, in the context of these guidelines, are all cargoes which are provided with wheels or tracks, including those which are used for the stowage and transport of other cargoes, except trailers and road-trains (covered by chapter 4 of this Code), but including buses, military vehicles with or without tracks, tractors, earth-moving equipment, roll-trailers, etc.*"

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9.7 While nylon web lashings are a suitable alternative for many lashing requirements, they require careful handling and maintenance. Belts will fail physically due to damaged belts, cuts and nicks, frayed edges, excessive dirt, elongation and compression. They will also fail mechanically at the ratchet lever due to excessive forces being applied or general wear and tear. For this reason a strict and effective inspection regime needs to be implemented to ensure that any defective equipment is removed from service before failing in use.

9.8 IMO guidelines state that any lashing equipment used should have an MSL of at least 100 kilonewtons; the lashing equipment required to be used by Hoegh Autoliners, according to their Cargo Quality Manual, has a maximum MSL of 50 kilonewtons. The inherent danger when using lashings with a small MSL is the increased possibility of one weak, or poorly fastened lashing failing, which will result in additional weight being placed upon the remaining lashings. This could result in a domino effect, with the lashings failing one after the other until the remaining lashings are insufficient to restrain the cargo.

9.9 In my technical opinion, nylon web lashings are suitable for securing the majority of standard vehicles which would be expected to be carried on-board Pure Car Carriers, however these are not suitable for heavier cargo units. By following the general guidance offered in IMO MSC.1/Circ.1355, I would consider that any unit weighing over 15 tonnes in weight should be secured by an alternative method. The industry standard alternative is 13 millimetre diameter long link steel chain and tensioner.

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10. VDR DATA AND POSITION PLOTS

10.1 VDR data has been provided to us which we understand to have been downloaded from the bridge as well as the relevant playback software. The VDR data includes audio files from three microphones on the bridge, radar images as well as information on the vessel position, heading, course and speed. The VDR data includes the various sensor readings in NMEA[12] sentence format. Engine speed and rudder angles are not available in the VDR data.

10.2 Based on the audio files the rudder orders detailed in Table 2 below were made, presumably by the pilot who was onboard at the time of the incident. For the purposes of the simulations described in section 13 below, we have assumed that the orders were enacted without delay. According to the telegraph print out, Full Ahead Manoeuvering was ordered at approximately 20:46:00 before the Calshot Turn and Full Ahead Navigational was ordered at 21:02:30. It should be noted that the telegraph printer only provides the orders in 30 second increments so it is not possible to be precise about the times these orders were made.

10.3 We understand the Full Ahead Navigational Order was the initiation of an automatic program which increases the engine speed over a period of time up to the Full Ahead Navigational telegraph of 94.7 RPM. The increases in engine speed were calculated by using the BBSIM simulator as described in paragraph 13.4.

10.4 According to the VDR data, the heading of the vessel was 126 degrees when the vessel came to rest on the Bramble bank. However, photographs taken of the vessel in her final resting position indicate that she had an approximate North-East heading (around 45 degrees) which is the reciprocal heading of her passage down the Thorn Channel (i.e. her heading was back up the channel towards Southampton). During her passage down the Thorn Channel the Heading and COG data is almost identical which indicates that the heading data was accurate for that part of her passage.

[12] National Marine Electronics Association

10.5 The NMEA sentences in the VDR data that provide the heading data have the code “HEHDG” which indicate that they were from a North-Seeking Gyro Compass. The model of gyro compass onboard the HOEGH OSAKA is not known but many models specify a maximum roll/pitch angle of 40 – 45 degrees. As discussed later in this report, once the vessel lost stability she would have heeled quickly to an angle in excess of this limitation. Therefore, the likely reason for the inaccuracy of the heading data stored in the VDR data was the large angle the vessel was inclined to.

Table 2 - Rudder and Telegraph Orders Based on Bridge Audio Files

Time	Order
Calshot Turn	
20:46:00 (Approx.)	Full Ahead (Manoeuvering)
20:57:36	Stbd 10
20:58:25	Midships
20:59:00	Stbd 10
20:59:30	Midships
20:59:48	Port 10
21:00:06	Port 20
21:00:16	Midships
21:00:50	Steer 210
21:02:30 (Approx.)	Full ahead (Navigation)
Brambles turn	
21:07:32	Port 10
21:08:20	Port 5
21:09:10	Midships
21:09:36	Hard to stbd

10.6 Data for the vessel position, heading, Course Over Ground (COG), Speed Over Ground (SOG) and Rate of Turn (ROT), was extracted from the NMEA sentence file and compiled in a tabular format using our own in-house software written for this purpose. The vessel position (in latitude and longitude) is converted into the Universal Mercator System (Eastings and Northings in metres) using the US National Geospatial-Intelligence Agency

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(NGA) software "GEOTRANS"[13]. Tabulated data is provided in **Appendix 5** of this report. A plot of the vessel's position at 60 second intervals from the time of her starting the Calshot Turn to the Brambles Bank turn is overlaid on the Admiralty Chart 2036 "The Solent and Southampton Water" is shown in **Figure 2** below. As discussed above, the heading data is unreliable for the later stages of the incident and the vessel orientation has been taken from the COG data. A close-up of the Brambles Turn with the vessel position displayed at 30 second intervals is shown in **Figure 3**

[13] http://earth-info.nga.mil/GandG/geotrans/

Figure 2 - Vessel positions during Calshot turn and Brambles turn at 60 second intervals

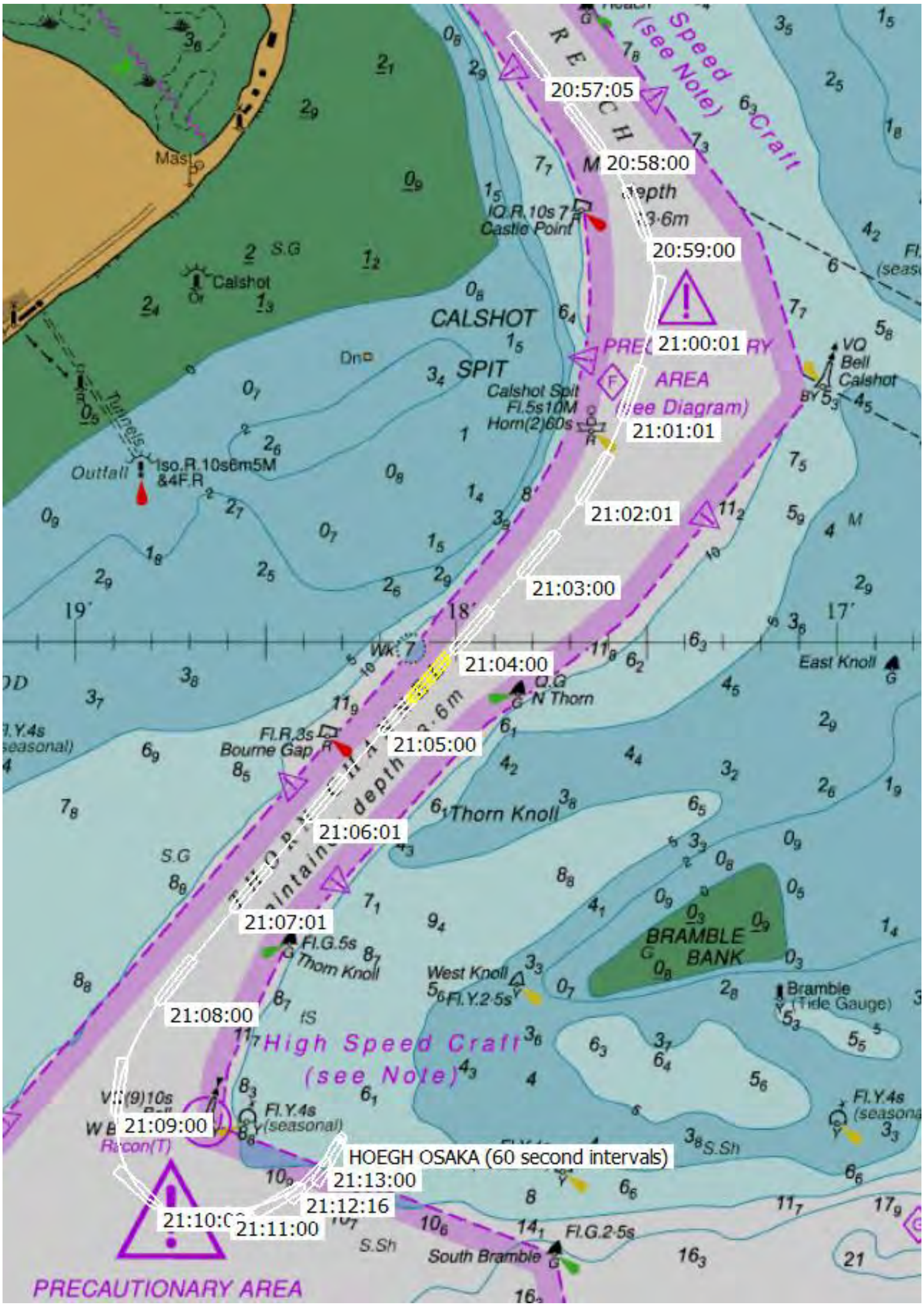


Figure 3 - Vessel positions during Brambles Turn at 30 second intervals,

11. ANALYSIS OF ROLL ANGLE FROM VESSEL TRAJECTORY

11.1 A reasonable estimate of the vessel roll can be made by analysing the trajectory of its centre of gravity and from knowledge of its stability. The analysis described in this section is based on the position information extracted from the vessel's VDR system discussed in **paragraph 10.1** above. The position information from the VDR applies to the vessel's GPS antenna which was assumed to be on the vessel's forward mast positioned approximately 152 metres forward of the Aft Perpendicular and on the ship's centreline. The horizontal position of the vessel's centre of gravity was determined from the assumed position of the GPS antenna and the vessel's heading using the principles of trigonometry.

11.2 For a vessel to describe a curved trajectory there must be a horizontal hydrodynamic force applied to the hull acting towards the centre of the turn. For the purposes of approximation this force can be assumed to act at a vertical position half way between the keel and the waterline. The magnitude of the horizontal force (in tonnes) is given by the following relationship:

Horizontal Force (Caused By Turn) = Displacement x SOG x Rate of Change of COG x 0.0000150

where "Displacement" is the mass of the ship in tonnes, "SOG" is the speed over ground (in knots) and "COG" is course over ground. The rate of change of COG is the angle (in degrees) that COG changes by over a minute[14]. The factor of 0.0000150 is required to convert the resulting forces into tonnes. The method used to calculate the SOG and Rate of change of COG is explained in **Appendix 6** of this report.

11.3 The magnitude of the heeling moment acting to heel the ship away from the centre of the turn is given by the following equation:

Heeling Moment (Caused By Turn) = Horizontal Force (Caused By Turn) x (KG –Draught/2)

where KG is the height of the centre of gravity above the keel.

[14] This is very similar to the widely used Rate of Turn (ROT) parameter which is the rate of change of heading. The only difference is that we must use the rate of change of COG rather than the rate of change of heading that ROT applies to.

11.4 In addition to the heeling moment caused by the vessel's turn, we must also consider the effect of the cargo shift which (according to the sound recordings on the VDR) occurred around 21:09:20. The magnitude of the heeling moment was calculated to be 2,594 tonne-metres as detailed in **Appendix 7**

Quasi-Static Solution

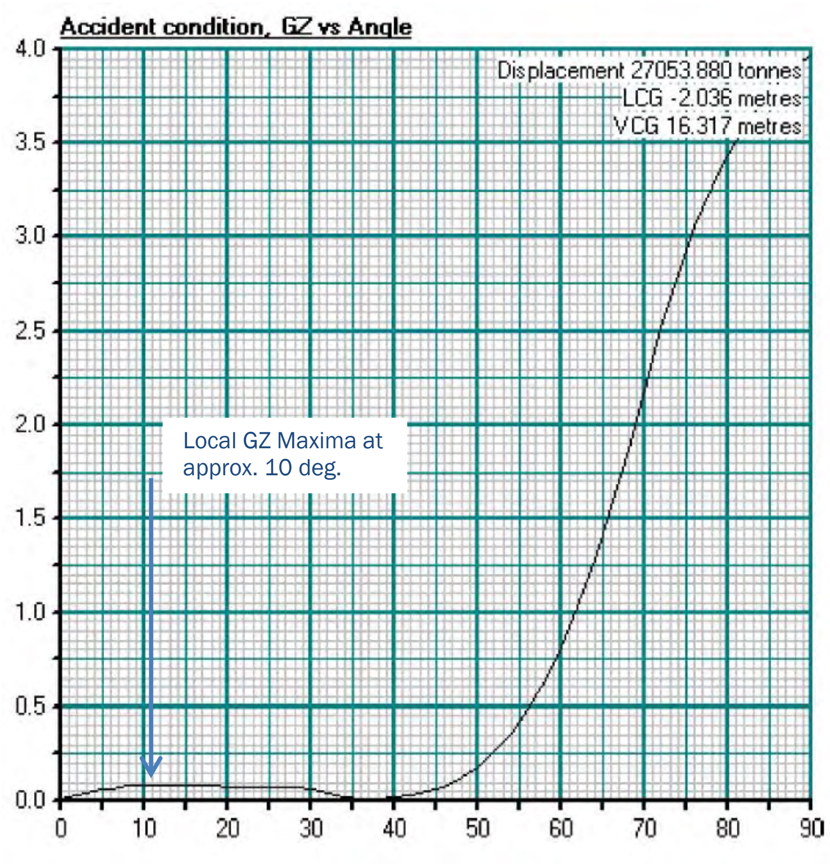
11.5 In general, corrections to the course occur over a period of several minutes whereas the roll period is relatively short (around 30 seconds for the HOEGH OSAKA). This means that the heel angle can normally be calculated by equating the applied heeling moment with the Righting moment as dynamic effects are not significant. We re-address this assumption later on in this report.

11.6 We have been provided with a stability print out for the vessel in its incident condition prior to any movement of cargo (see **Figure 4**). We understand that this is based on an estimate of the vertical centre of gravity based on the evidence of the crew that a 7 degree heel was corrected by transferring ballast between wing tanks which was achieved in 12 minutes. This loading condition shows a GM of 0.7 metres. The stability condition also provides the GZ curve (GZ vs. heel angle) from which the Righting Moment (in tonne-metres) can be calculated by the following equation:

$$\text{Righting Moment}(\theta) = \text{Displacement} \times GZ(\theta)$$

11.7 In this equation heel angle (denoted by the Greek symbol theta θ) is included in brackets to show that Righting Moment and GZ vary with heel angle.

Figure 4 HOEGH OSAKA GZ curve for loading condition with GM = 0.7 metres



11.8 Using a computerised search algorithm, it is possible to find the heel angle (θ) which equates the Righting Moment to the Heeling Moment. This assumption is known as a quasi-static approximation. This was performed for all time instances describing the vessel's starboard turn around Calshot Spit and its port turn around the Brambles Bank (see **Appendix 8** for details). **Figure 5** below shows the heel of the vessel (calculated by the quasi-static approach) during the vessel's turn around the Calshot Spit and **Figure 6** shows the same data for the vessel's turn around the Brambles Bank.

Figure 5 Heel Angles Around Calshot Turn By Quasi-Static Solution (GM 0.7 metres)

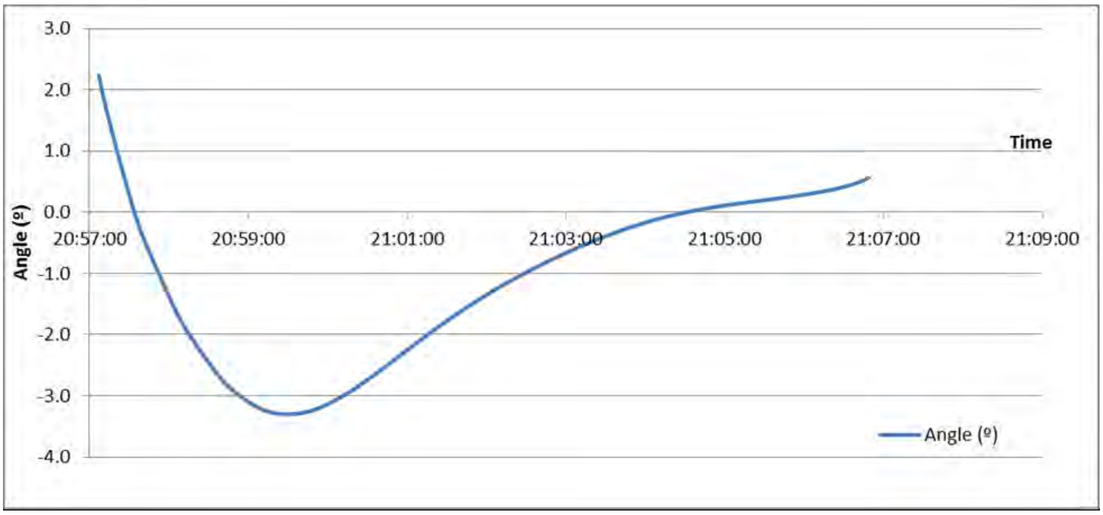
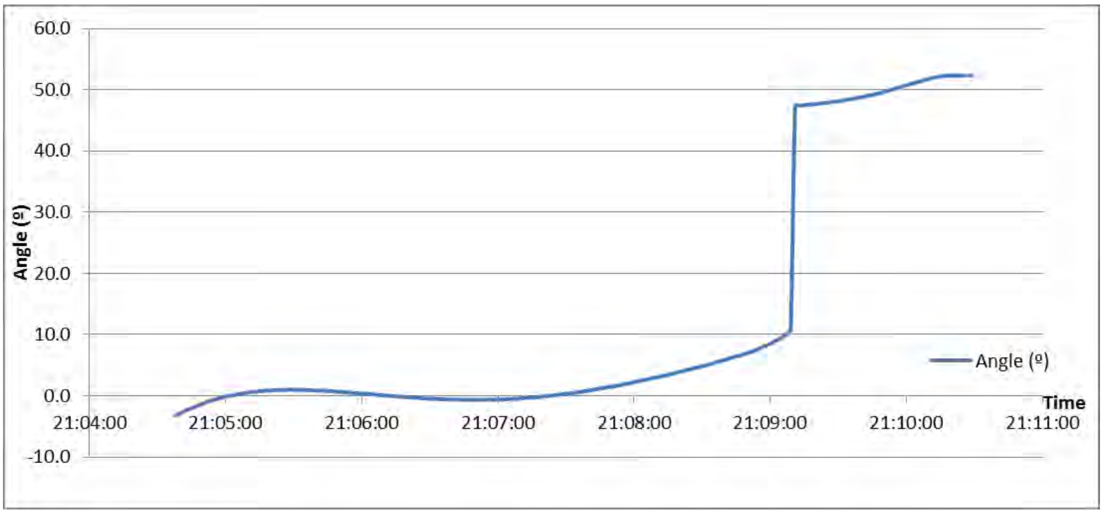


Figure 6 Heel Angles Around Brambles Turn By Quasi-Static Solution (GM 0.7 metres)



11.9 As can be seen from **Figure 5** the vessel makes the turn around Calshot Spit reaching a maximum angle to port of just over 3 degrees. This is not a large heel angle and we believe this would not have been remarked upon by the crew at the time.

11.10 According to **Figure 6** the heel angles around Brambles Bank increased steadily to around 12 degrees before jumping to 48 degrees at around 21:09:11. After this sudden jump, the heel remained constant for around a minute before gradually increasing again beyond 50 degrees.

11.11 The reason for the sudden increase in roll angle can be found from the examination of the GZ curve provided by the MAIB (see **Figure 4** above). In this diagram the GZ increases to 0.085 metres (corresponding to a righting moment of 2,300 tonnes-metres) at an angle of 10 degrees. After this point, further increases to heel angles result in a reduction in Righting Moment. The Righting Moment only starts to increase again after an angle of 40 degrees. Once the heeling moment increases above 2,300 tonne-metres, the vessel will heel suddenly to above 45 degrees before finding new heel equilibrium.

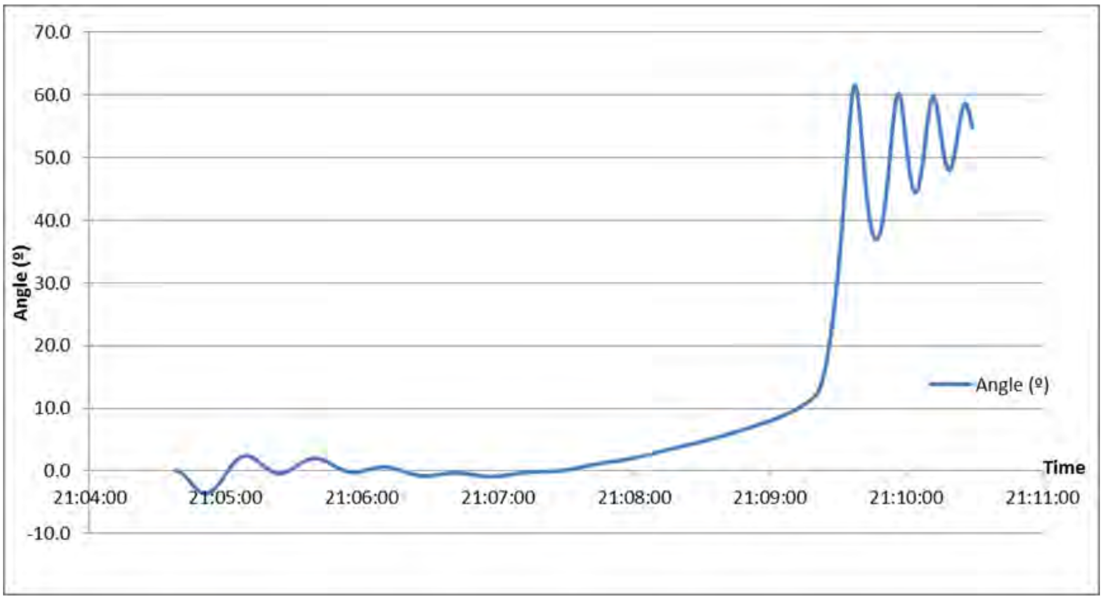
11.12 The loss of stability which occurred at 21:09:11 according to our analysis ties in with the cargo shift which occurred at 21:09:20 according to the audio files in the VDR data. Although there is a 9 second delay between the predicted loss of stability and the time of the cargo shift, some delay is to be expected due to the dynamics of the roll motion and the time taken for the cargo to traverse the deck. As a shift in cargo at or below 12 degrees is highly unlikely it is most likely that the cargo shift occurred during this sudden heel to starboard.

Simple Dynamic Roll Model Solution

11.13 According to the above discussion, the vessel experienced two sudden changes in her stability within a few seconds. First the vessel's heel exceeded 12 degrees and the vessel heeled rapidly to starboard. Next the cargo shifted which increased the vessel's heel even further. Due to these sudden events the actual heel angles will be different from those computed by quasi-static approximation.

11.14 To assess the effect of these events a simple one degree-of-freedom roll model was used to assess the roll during the Brambles Bank turn. This model includes the roll inertia of the vessel as well as the roll damping as it reacts to the abrupt changes in its stability due to the sudden events discussed in **paragraph 11.13** above. Details of the simple roll model can be found in **Appendix 8** and the roll angle during the Brambles Bank turn is shown in **Figure 7**.

Figure 7 – Simple Dynamic Roll Model (GM 0.7 metres)



11.15 According to the these results, the roll angle increases rapidly from the time when the critical angle of 10 degrees is first exceeded at 21:09:21 to a maximum of 60 degrees which occurs at 21:09:39. The roll angle then oscillates around an angle of 48 degrees.

11.16 The simple dynamic roll model predicts that the roll angle at 21:09:20 (the time the cargo is thought to have shifted at) was 12 degrees. The cargo would not have shifted at this angle. However, the heel was increasing rapidly at this time. The roll angle at 21:09:40 was calculated to be 60 degrees which is certainly high enough to cause cargo to shift. Therefore, the analysis described in this section does predict the behaviour of the vessel reasonably well although the timing of the cargo shift has not been replicated to the nearest second.

11.17 It should also be noted that the maximum roll angle of 60 degrees is likely to be overstated by the simple one degree-of-freedom model. The model assumes a 10% roll damping ratio[15] which (although reasonable for small roll angles) is likely to be too low

[15] The roll damping ratio is expressed as a percentage of the critical damping coefficient. The critical damping coefficient is the value of damping that returns the ship to its equilibrium position in the shortest possible period

for large angles. The effect of high damping would decrease the maximum roll angle but not the value the roll oscillates around (48 degrees) (see **paragraph 11.10**). The effect of a more accurate roll model would be to reduce the maximum angle reached (although it would almost certainly have exceeded the equilibrium position of 48 degrees established by the quasi-static approach.

11.18 The behaviour of the vessel described in **paragraphs 11.15** to **11.17** above replicates the observations of the crew and the timing of the cargo shift established from the VDR audio files. From this analysis, the cargo would have needed to have shifted at any angle up to 60 degrees

Calculation of Loads on Cargo

11.19 As discussed in **paragraph 11.16** above, the maximum roll angle reached may have been as high as 60 degrees which would have occurred as soon as the vessel lost stability before roll angles settled down to around 50 degrees. We have calculated the maximum forces on the four cargo items requested by the MAIB and provide a summary in **Table 3** below. Details of the calculation are provided in **Appendix 9**. As can be seen in this table, the transverse capacity of all units were exceeded by a significant margin.

Table 3 –Summary of loads on cargo

Item	**Transverse sliding Force (kilonewtons)**	**Transverse capacity (kilonewtons. See Section 5)**	**Cargo tipping Moment (kilonewton-metres)**	**Tipping capacity (kilonewton-metres. See Section 5)**
Atlas Copco Powercrusher PC 21 (1+2)	423	286	973	1215
Caterpillar D8T Track-Type Tractor	318	216	382	902
Powerscreen Trakpactor 500	459	376	872	1891

of time without oscillation. If a damping coefficient less than the critical damping coefficient is applied (as is normal for roll motions) the vessel will oscillate about its equilibrium position.

12. THE BBSIM MODEL FOR THE HOEGH OSAKA

12.1 The manoeuvring model entitled “BBSIM” has been developed at Safety at Sea Ltd. (now Brookes Bell Safety at Sea) over the last 6 years and is built on the work of the so-called Japanese manoeuvring Mathematical Modelling Group (known as MMG). The initial principles of the model were defined in a paper by Inoue, Hirano and Kijima in 1980 but a considerable body of work has been completed by Kijima and other researchers since then. The MMG model is by far the most widely researched and discussed manoeuvring model in the open literature. Although this is not the only manoeuvring model used by organisations involved in the field, we have adopted this model due to the openness and scientific rigour with which this model is discussed. The MMG model considers the vessel movement in three “Degrees of Freedom” (DOF) - namely surge, sway and yaw.. For a stable vessel with cargo well secured, other motions such as roll are small enough to not influence the results and can reasonably be neglected. Prior to the loss of stability somewhere around 21:09:20 the roll angles were high for a vessel proceeding in calm weather but not extreme (below 10 degrees) so this model should reasonably replicate the motion of the vessel prior to the loss of stability.

12.2 As described in the Specification, the MMG model is described as modular as the various components of forces and moments are calculated using various empirical relationships. The BBSIM model has been created by taking what we consider to be the most scientifically sound methods from publically available papers and which have been shown to provide reliable results for the simulation of collisions and groundings.

Propulsion and Resistance Model

12.3 The propulsion model is based on the B-Series propeller data published by the internationally renowned hydrodynamics laboratory MARIN in the Netherlands. The B-Series is known as a “stock propeller” which is a series of propellers with the same basic shape but variations in the pitch, blade area ratios and number of blades. This is the most comprehensive propeller data set available for commercial vessels suitable for manoeuvring simulations and is broadly in line with propellers produced by modern manufacturers.

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12.4 The propulsion model of the HOEGH OSAKA was created by selecting a 6-bladed B-series propeller by normal design practice. The propeller selected has a pitch ratio of 1.2 and a Blade Area Ratio of 1.1

12.5 The actual propeller performance for the propeller on the HOEGH OSAKA will not vary significantly from the B-Series propeller as differences in the thrust generated by propellers is only very small. Any variance will affect primarily the amount of torque required to turn the propeller and therefore its efficiency. As the propeller RPM is prescribed in the calculation, torque does not play a role in the calculation and this variance has no impact on the calculation results.

12.6 The resistance curve and propulsion coefficients were taken from similar vessels available in our in-house database. Small adjustments were then made to the resistance curve to achieve correspondence between the telegraph speeds and the engine revolutions.

Model Tuning and Calibration Against Sea Trial Data

12.7 The process of developing a simulation model starts with the use of the various empirical relationships available in the open literature to produce a Base Model. This Base Model is defined by a number of coefficients which are used by BBSIM to compute the various components of manoeuvring forces and moments such as the lateral force/moments, hull resistance, and propeller thrust etc.

12.8 Once the Base Model is defined, an automatic tuning process is applied to further improve the accuracy of the turning performance of the model. The tuning involves the definition of a quality metric defined below[16] which quantifies the difference between the simulated vessel manoeuvres and those stated on the wheelhouse poster. As the vessel's mean draught at the time of the incident (around 8.6 metres) was close to the Design Draught (8.8 metres), and as the engine telegraph was somewhere between Full Ahead Manoeuvering and Full Ahead Navigation, the model was tuned against the

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16 The term $\delta_{\text{Port Advance}}$ is the simulated Advance parameter of the Port Turning Circle divided by the equivalent figure provided in the wheelhouse poster minus 1.0. The other parameters provided in this equation are similarly calculated for Port Transfer, Starboard Advance and Starboard Transfer.

manoeuvering performance stated in the wheel house poster for the “Normal Loaded Condition”, “Full Sea Speed”. The quality metric is iteratively reduced by the software until no further significant improvements in the model are made (i.e. it has “converged”). The term “tuning” is a colloquial term for what is known scientifically as “System Identification”.

$$\text{Quality Metric} = \delta_{\text{Port Advance}}^{2} + \delta_{\text{Stbd Advance}}^{2} + \delta_{\text{Port Transfer}}^{2} + \delta_{\text{Stbd Transfer}}^{2}$$

12.9 A comparison of the deep water manoeuvring characteristics simulated by the tuned BBSIM model and the Wheelhouse Poster data is provided in Table 4 below. The simulation model of the HOEGH OSAKA is restricted to ahead orders only as this is all that is all that is necessary for the simulation of the incident. The model was therefore not tuned against the crash-stop performance stated on the wheelhouse poster.

<u>Table 4 – Comparison of Simulated Standard Manoeuvres for Tuned Model Against Wheelhouse Poster (Ballast Condition)</u>

Engine order	**N (RPM)**	**Vs sea trials (knots)**	**Vs simulated (knots)**
Full sea ahead	94.7	19.2	19.2
Full ahead	55	12.1	12.1
Half ahead	45	9.9	9.9
Slow ahead	35	7.7	7.7
Dead slow ahead	25	5.5	5.5
Full at sea port turning circle		**Sea trials (nautical miles)**	**Simulated (nautical miles)**
Maximum advance		0.39	0.38
Maximum transfer		0.35	0.36
Full at sea starboard turning circle		**Sea trials (nautical miles)**	**Simulated (nautical miles)**
Maximum advance		0.39	0.39
Maximum transfer		0.38	0.38

Calculation of Roll-Related Effects

12.10 As discussed above the BBSIM simulations used in the case of the HOEGH OSAKA only consider 3DOF. Although BBSIM has the capability of modelling 4DOF motions, the roll motion of the HOEGH OSAKA is too extreme to make this possible as it involves a partial capsize. As discussed below, the influence of the roll on the vessel's trajectory are important and this has been quantified using a Computational Fluid Dynamic approach. Further details of the calculations and results are provided in **Appendix 10** of this report.

13 MANOEUVERING SIMULATIONS

Environmental parameters

13.1 The Admiralty Chart of the area shows a maintained water depth of 13.6 metres over the area of interest. According to data for Southampton from the Admiralty software "TOTALTIDE" the tide at the time of the incident was 3.9 metres at 21:00 when the incident occurred.

13.2 The nearest current data point in the channel on the chart is point "C[17]" which shows a spring tide current of 1.6 knots and a neap tide current of 0.8 knots flooding up the channel in a North-Easterly direction. The tidal range on the day of the incident was 3.0 metres compared to a spring tide of around 4.5 metres and a neap tide of 1.9 metres. We have assumed the current at the time of the incident to be around 1.2 knots which is half way between the spring and neap tide currents.

13.3 No significant wind or waves were reported at the time of the incident so these environmental effects were assumed to be absent in the simulations.

Engine speeds after Calshot turn

13.4 As detailed in **Table 2** above, the order for full ahead navigational was made at 21:02:30 shortly after the Vessel had navigated the Calshot turn. We understand that this was the initiation of an acceleration program whereby the engine speed is slowly increased to full ahead navigational by the engine control system from full ahead manoeuvering. As the nature of that engine control program is not known, we have determined the engine speeds by iteratively increasing the engine speeds to match the vessel's positions along the Thorn Channel. Based on this approach, the engine speed was approximately 80 RPM by the time the vessel entered the Brambles Turn.

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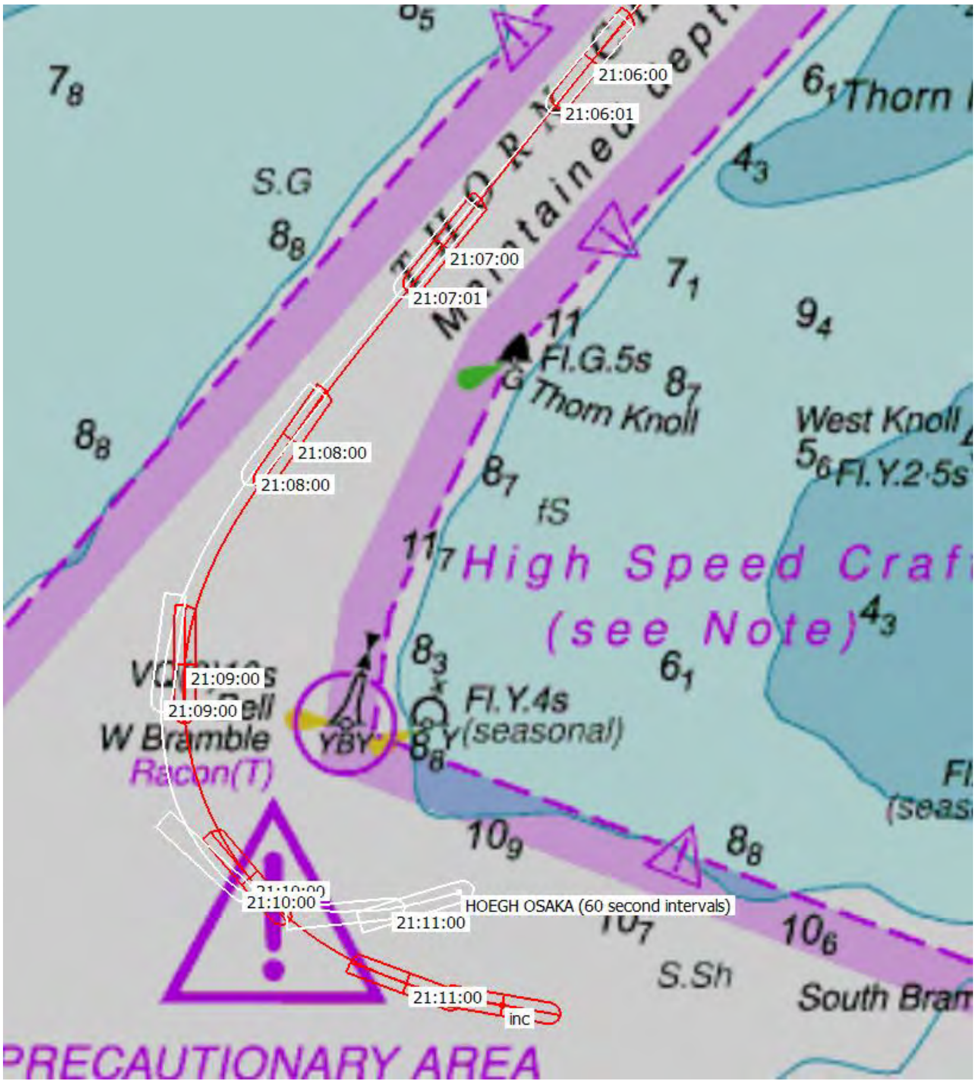
[17] The chart shows another current data point "D" which is closer to the site of the incident but north of the channel and in an area of more shallow water.

Simulation of the Incident

13.5 A simulation using the engine and rudder orders detailed in **Table 2** with engine speeds detailed in paragraph 13.4. A comparison of the simulated trajectory and the trajectory recorded in the VDR is provided in **Figure 8.**

Figure 8 – Comparison of simulated trajectory and recorded trajectory.



13.6 As shown in **Figure 8**, the simulated trajectory closely matches the recorded trajectory until after 21:09:00 at which time the vessel is thought to have lost her stability (see

paragraph 11.10 to **11.11** for further discussion on this). After that time, the actual trajectory takes a much tighter turn to port.

13.7 The deviation of the actual data from the simulated data is to be expected as the estimated roll angle at this time is around 50 degrees. This large roll to starboard would have caused a significant alteration in the underwater shape of the hull as well as the propeller and rudder emersion which is not accounted for in the BBSIM model used for this analysis.

13.8 **Figure 9** below shows the variation in hydrodynamic forces for the vessel calculated by CFD (see **Appendix 10** for further details). The roll to starboard is plotted on the x-axis. According to these results a negative yaw moment (acting to turn the vessel to port) reaches a value of -11,000 kilonewton-metres at around 20 degrees and remains negative until a roll of around 27 degrees is reached. This is a significant moment and would have acted to turn the vessel to port at a larger rate than can be explained by the 20 degree port rudder applied at this time. The cause of the large yaw moment can be seen in the pressure distribution around the hull due to its large roll angle to starboard (see **Figure 10**). The asymmetry of the hull produces an area of high pressure (shown in orange) over the starboard side of the bow and another area of high pressure over the port side of the stern. These areas of high pressure act to turn the vessel to port.

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Figure 9 – Hydrodynamic forces and moments on hull for zero drift angle and 10 knots forward speed.

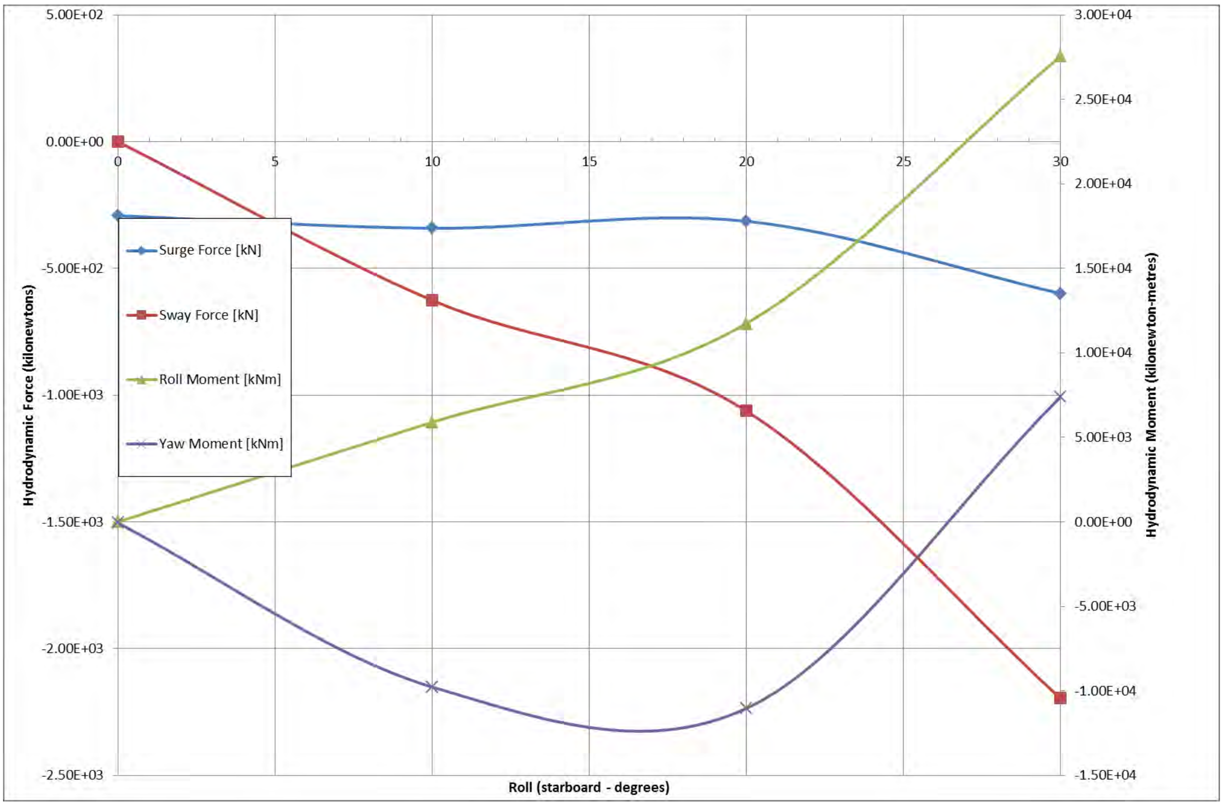
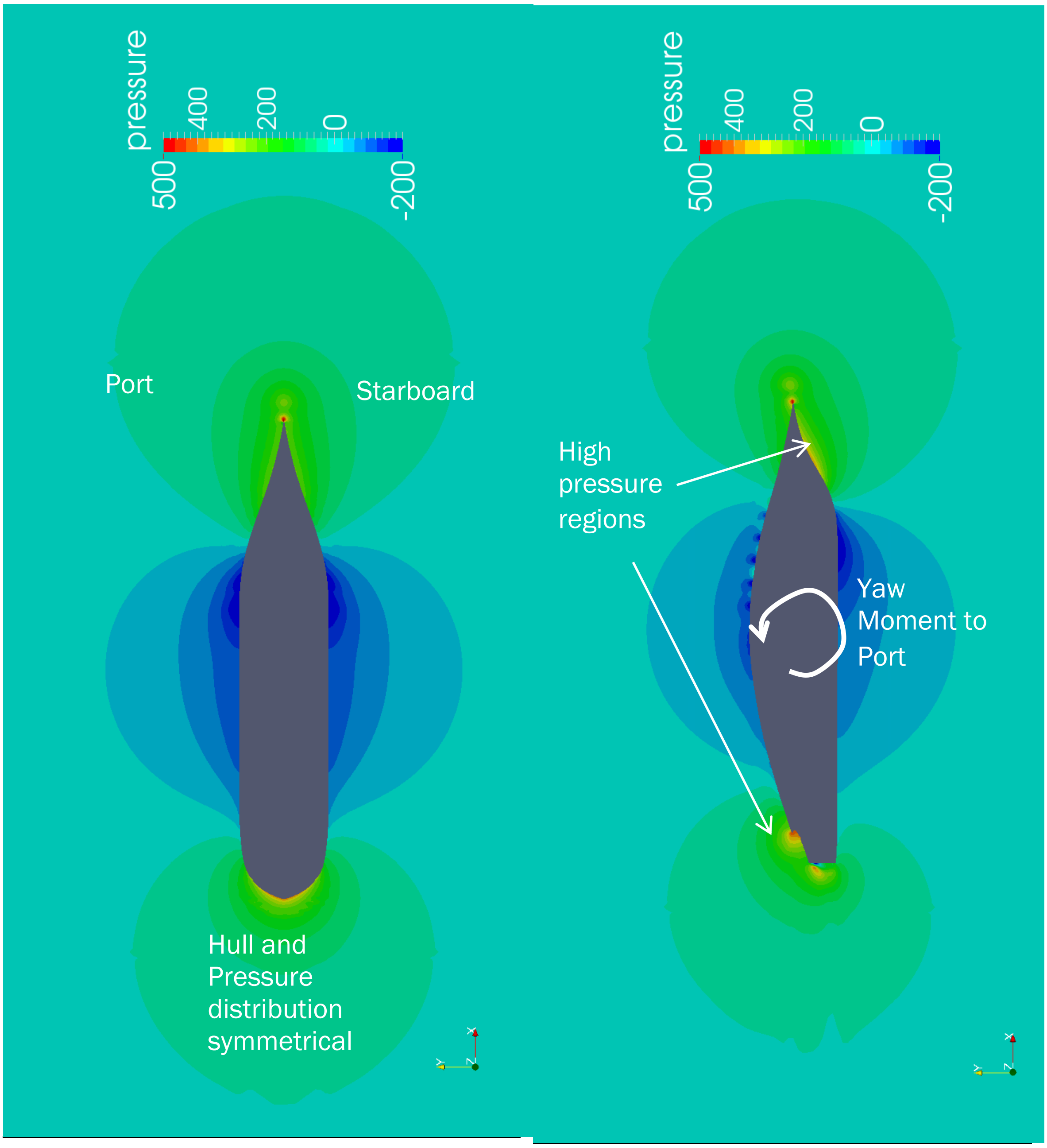


Figure 10 – Pressure Distribution over symmetry plane representing free-surface



upright

20 degree roll to starboard

13.9 We have not performed a full compliance check of the stability of the vessel with regards to the Intact Stability Code of the IMO, however, it is clear from the loading condition we have been provided with, that the vessel failed at least some of the relevant criteria[18]. In our opinion the safest way that the risk of a loss of stability event could have been minimised during her entire voyage would have been to load the vessel in compliance with the statutory requirements of the IMO. This would entail the vessel having a lower centre of gravity prior to departure. Had the vessel been loaded in this manner it is highly unlikely that the vessel would have lost stability while navigating the Brambles Turn.

[18] The area under the GZ curve is required to be at least 0.055 metre-radians up to 30 degrees and at least 0.090 metre radians up to 40 degrees by the IMO code. The figures for the HOEGH OSAKA loading condition, the figures are 0.037 and 0.042 metre-radians respectively

14. CONCLUSIONS

Concluding comments of [redacted]

14.1 In my technical opinion, the contents of the vessels' Cargo Securing Manual (CSM) and the Hoegh Autoliners' Cargo Quality Manual satisfy the requirements of the IMO Code of Safe Practice for Cargo Stowage and Securing (CSS Code) , Annex 13.

14.2 Section 3.4, part 6.1, of the CSM states that the MSL of lashings should not be less than 100kN. The equipment available on the HOEGH OSAKA had a maximum MSL of 50 kN and therefore did not comply with the CSM requirements.

14.3 13mm diameter steel chain is a suitable, industry standard, alternative for nylon web lashings and complies with the IMO requirements of a minimum MSL of 100kN.

Concluding comments of Dr [redacted]

14.4 The analysis we have performed on the positional information in the VDR data and the loading condition we have been provided was able to reproduce the actual behaviour of the vessel as she made the Brambles turn. According to this analysis, the vessel would have lost stability once she had rolled to an angle of around 12 degrees at 21:09:11 causing her to roll rapidly to a large angle of inclination (possibly as high as 60 degrees) before settling down to around 48 degrees. It is most likely the cargo shifted during this loss of stability event and was not causative to the incident.

14.5 The transverse loads on the cargo during the loss of stability event were well in excess of the capacity of the lashing equipment.

14.6 Following the loss of stability occurring at around 21:09:11, the vessel appears to have made a tight port turn which cannot be attributed to the rudder which was at midships at this time. The cause of that tight turn is likely to have been the asymmetric pressure distribution over the hull caused by the large roll angles the vessel was inclined to following the loss of stability.

14.7 The vessel could have navigated the Brambles Turn without losing its stability had it executed a larger-radius turn and maintained a lower speed. However, given the vessel most likely had poor stability there is every possibility that she would have lost stability at some later juncture had she navigated the Brambles Turn successfully. In our opinion, a safer course of action for the crew would have been to have loaded the vessel with a lower centre of gravity in compliance with the IMO Intact Stability Code.

[redacted]

[redacted]

For Brookes Bell

[redacted]

[redacted]

For Brookes Bell

APPENDIX 2 – CALCULATION OF SECURING CAPACITY FOR ATLAS COPCO POWERCRUSHER PC 21 (1)

NAUTICUS hull	Code of Safe Practice for Cargo Stowage and Securing 2003 Edition, Annex 13	LASHCON IMO Version 9.00.0 Jan 2004	Sign: Time: 15:09 Date: 15.09.14

Input of cargo unit data

Cargo unit specification:		PC210 - 1		
Mass of cargo unit:	m	49.77	ton	
Coefficient of friction:	μ	0.30	(-)	
		Transv.	Long.	
Wind exposed area:	Aw			m2
Sea exposed area:	As			m2
Lever arm of tipping:	a	2.30	m	
Lever arm of stableness:	b	1.43	m	

Give cargo unit stowage position

Vertical: Deck, high

Longitudinal: 0.3 L

Calculation method:

(●) Alternative calculation — Recommended.

( ) Advanced calculation

Input of lashing data		1	2	3	4	5	6	7	8	9	10
Max securing load [kN]:	MSL	100	100	100	100	50	50				
Transverse lashing direction		PS	PS	SB	SB	PS	SB				
Longitudinal lashing direction		Fwd	Aft	Fwd	Aft						
Vertical securing angle [degr]:	α	45	45	45	45	45	45				
Horizontal securing angle [degr]:	β	45	45	45	45	0	0				
Horizontal securing distance:	d [m]	3.9	3.9	3.9	3.9	3.9	3.9				

RESULTS:

Actual forces		**Securing capacity**	[kN / kNm]		
Transverse sliding force [kN]:	275.1	Transv. capacity:	PS [kN]	286	OK
			SB [kN]	286	OK
Longitudinal sliding force [kN]:	153.7	Long. capacity	Fwd [kN]	191	OK
			Aft [kN]	191	OK
Cargo tipping moment [kNm]	632.7	Tipping capacity:	PS [kNm]	1215	OK
			SB [kNm]	1215	OK

Accelerations			
Transverse:	a_t =	5.53	m/s2
Vertical:	a_v =	4.06	m/s2
Longitudinal:	a_l =	3.09	m/s2

Main Vessel Data:

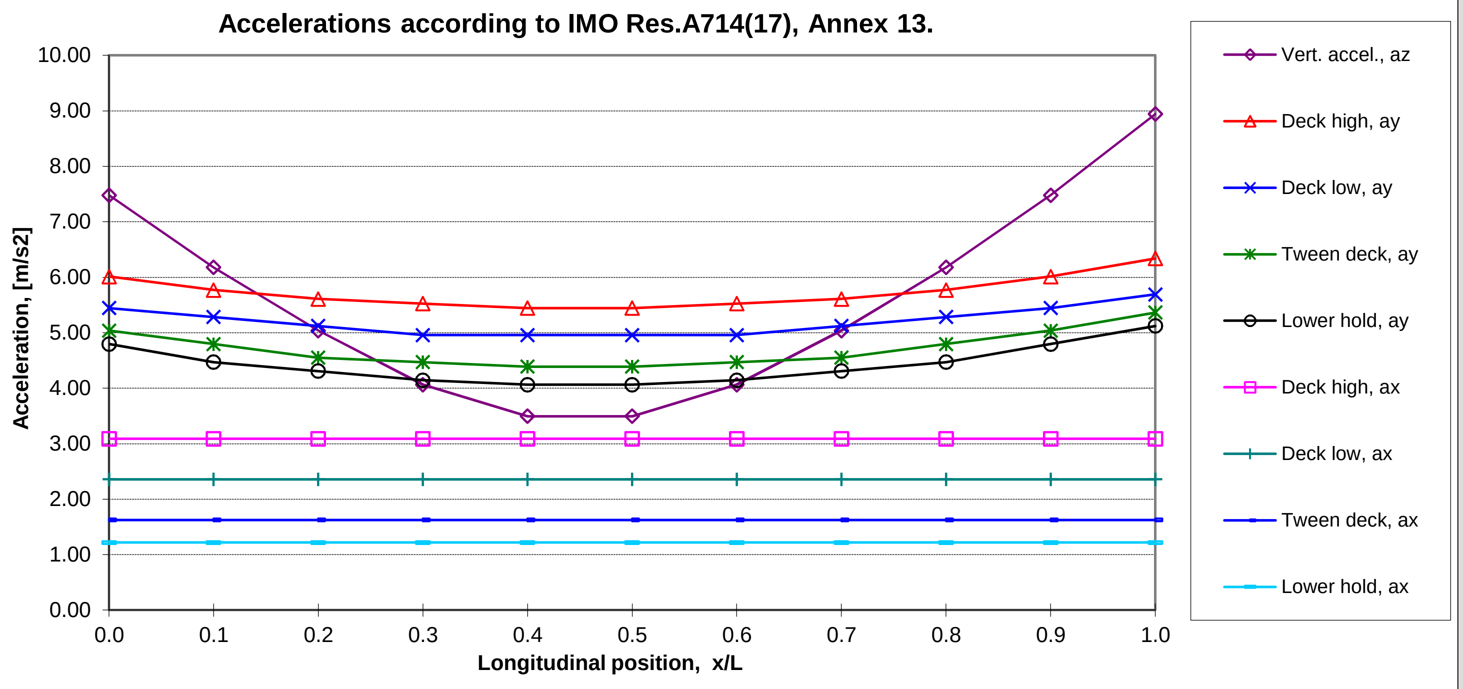
Vessel Name:	Ship Id:	Lpp [m]:	B [m]:	V [kn]:	GM [m]:
HOEGH OSAKA	9185463	171.30	32.20	19.20	0.70

Vessel Name: HOEGH OSAKA **Ship Id:** ######

Accelerations according to Annex 13 to IMO Res. A714(17)

Long. position:	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	Long acc a_x in m/s^2
	Transverse acceleration a_y in m/s^2											
Deck, high	**6.01**	**5.77**	**5.61**	**5.53**	**5.45**	**5.45**	**5.53**	**5.61**	**5.77**	**6.01**	**6.34**	**3.09**
Deck, low	**5.45**	**5.28**	**5.12**	**4.96**	**4.96**	**4.96**	**4.96**	**5.12**	**5.28**	**5.45**	**5.69**	**2.36**
Tween-deck	**5.04**	**4.80**	**4.55**	**4.47**	**4.39**	**4.39**	**4.47**	**4.55**	**4.80**	**5.04**	**5.36**	**1.63**
Lower hold	**4.80**	**4.47**	**4.31**	**4.15**	**4.06**	**4.06**	**4.15**	**4.31**	**4.47**	**4.80**	**5.12**	**1.22**
	Vertical acceleration a_z in m/s^2											
	7.48	**6.18**	**5.04**	**4.06**	**3.50**	**3.50**	**4.06**	**5.04**	**6.18**	**7.48**	**8.94**	

Note !
These accelerations apply only for GM=0.70m



APPENDIX 3 – CALCULATION OF SECURING CAPACITY CATERPILLAR D8T TRACK-TYPE TRACTOR

NAUTICUS hull	Code of Safe Practice for Cargo Stowage and Securing 2003 Edition, Annex 13	LASHCON IMO Version 9.00.0 Jan 2004	Sign: Time: 15:16 Date: 15.09.14

Input of cargo unit data

Cargo unit specification:		D8T			
Mass of cargo unit:	m	37.40	ton		
Coefficient of friction:	μ	0.30	(-)		
		Transv.	Long.		
Wind exposed area:	Aw			m2	
Sea exposed area:	As			m2	
Lever arm of tipping:	a	1.20	m		
Lever arm of stableness:	b	1.30	m		

Give cargo unit stowage position

Vertical: Deck, high

Longitudinal: 0.2 L

Calculation method:

- (●) Alternative calculation — Recommended.
- ( ) Advanced calculation

Input of lashing data		1	2	3	4	5	6	7	8	9	10
Max securing load [kN]:	MSL	100	100	100	100						
Transverse lashing direction		PS	PS	SB	SB						
Longitudinal lashing direction		Fwd	Aft	Fwd	Aft						
Vertical securing angle [degr]:	α	45	45	45	45						
Horizontal securing angle [degr]:	β	45	45	45	45						
Horizontal securing distance:	d [m]	3.9	3.9	3.9	3.9						

RESULTS:

Actual forces		Securing capacity	[kN / kNm]		
Transverse sliding force [kN]:	209.8	Transv. capacity:	PS [kN]	216	OK
			SB [kN]	216	OK
Longitudinal sliding force [kN]:	115.5	Long. capacity	Fwd [kN]	159	OK
			Aft [kN]	159	OK
Cargo tipping moment [kNm]	251.7	Tipping capacity:	PS [kNm]	902	OK
			SB [kNm]	902	OK

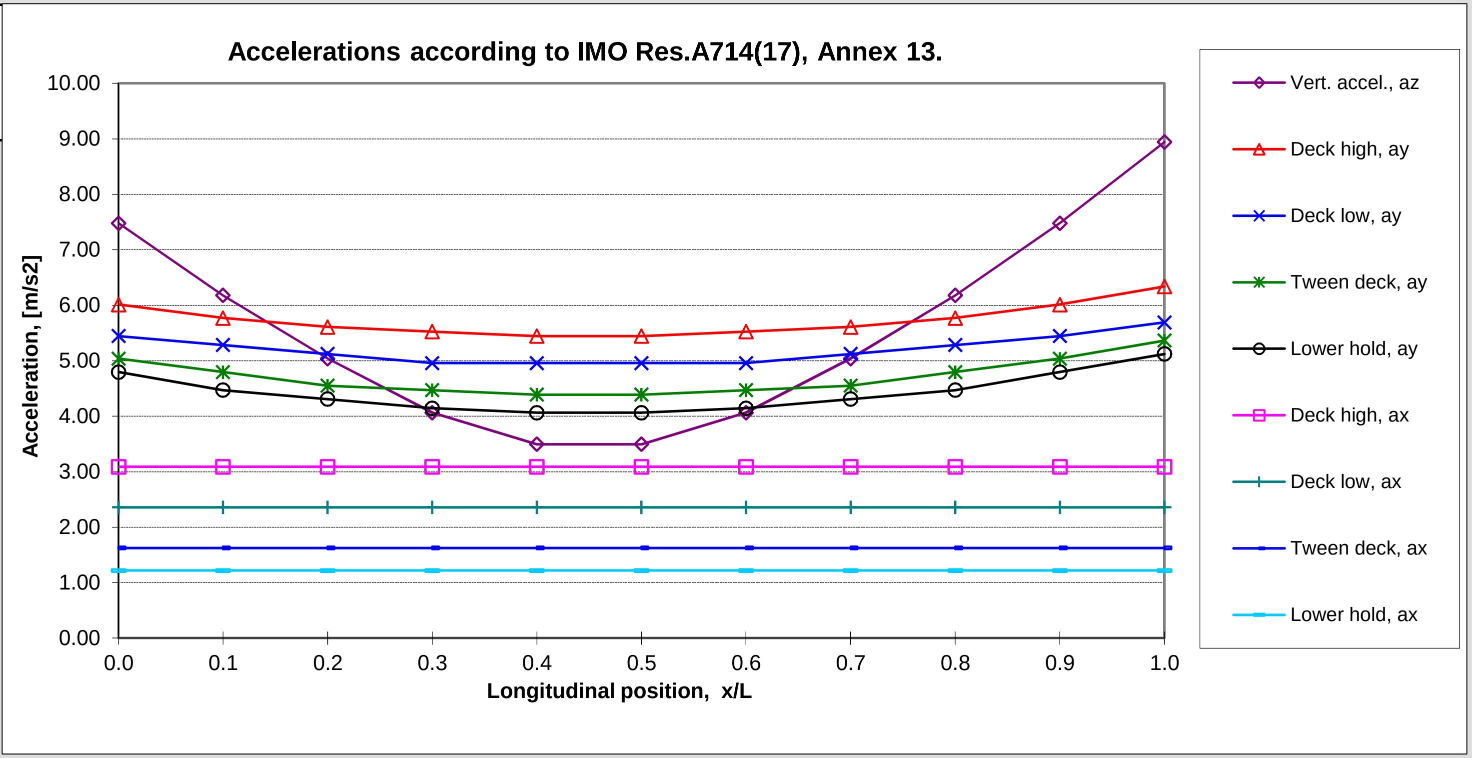
Accelerations			
Transverse:	a_t =	5.61	m/s2
Vertical:	a_v =	5.04	m/s2
Longitudinal:	a_l =	3.09	m/s2

Main Vessel Data:

Vessel Name:	Ship Id:	Lpp [m]:	B [m]:	V [kn]:	GM [m]:
HOEGH OSAKA	9185463	171.30	32.20	19.20	0.70

Vessel Name: HOEGH OSAKA					Ship Id: ######							
Accelerations according to Annex 13 to IMO Res. A714(17)												
	Transverse acceleration a_y in m/s^2											Long acc a_x in m/s^2
Long. position:	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	
Deck, high	**6.01**	**5.77**	**5.61**	**5.53**	**5.45**	**5.45**	**5.53**	**5.61**	**5.77**	**6.01**	**6.34**	**3.09**
Deck, low	**5.45**	**5.28**	**5.12**	**4.96**	**4.96**	**4.96**	**4.96**	**5.12**	**5.28**	**5.45**	**5.69**	**2.36**
Tween-deck	**5.04**	**4.80**	**4.55**	**4.47**	**4.39**	**4.39**	**4.47**	**4.55**	**4.80**	**5.04**	**5.36**	**1.63**
Lower hold	**4.80**	**4.47**	**4.31**	**4.15**	**4.06**	**4.06**	**4.15**	**4.31**	**4.47**	**4.80**	**5.12**	**1.22**
	Vertical acceleration a_z in m/s^2											
	7.48	**6.18**	**5.04**	**4.06**	**3.50**	**3.50**	**4.06**	**5.04**	**6.18**	**7.48**	**8.94**	

Note !
These accelerations apply only for GM=0.70m



APPENDIX 4 – CALCULATION OF SECURING CAPACITY POWERSCREEN TRAKPACTOR 500

NAUTICUS hull	Code of Safe Practice for Cargo Stowage and Securing 2003 Edition, Annex 13	LASHCON IMO Version 9.00.0 Jan 2004	Sign: Time: 15:29 Date: 15.09.14

Input of cargo unit data

Cargo unit specification:		Trakpactor 500		
Mass of cargo unit:	m	56.00	ton	
Coefficient of friction:	μ	0.30	(-)	
		Transv.	Long.	
Wind exposed area:	Aw			m2
Sea exposed area:	As			m2
Lever arm of tipping:	a	1.90	m	
Lever arm of stableness:	b	1.50	m	

Give cargo unit stowage position

Vertical: Deck, high

Longitudinal: AP

Calculation method:

- (•) Alternative calculation — Recommended.
- ( ) Advanced calculation

Input of lashing data		1	2	3	4	5	6	7	8	9	10
Max securing load [kN]:	MSL	200	200	200	200						
Transverse lashing direction		PS	PS	SB	SB						
Longitudinal lashing direction		Fwd	Aft	Fwd	Aft						
Vertical securing angle [degr]:	α	45	45	45	45						
Horizontal securing angle [degr]:	β	45	45	45	45						
Horizontal securing distance:	d [m]	4.9	4.9	4.9	4.9						

RESULTS:

Actual forces		**Securing capacity**	[kN / kNm]		
Transverse sliding force [kN]:	**336.8**	Transv. capacity:	PS [kN]	**376**	**OK**
			SB [kN]	**376**	**OK**
Longitudinal sliding force [kN]:	**173.0**	Long. capacity	Fwd [kN]	**250**	**OK**
			Aft [kN]	**250**	**OK**
Cargo tipping moment [kNm]	**640.0**	Tipping capacity:	PS [kNm]	**1891**	**OK**
			SB [kNm]	**1891**	**OK**

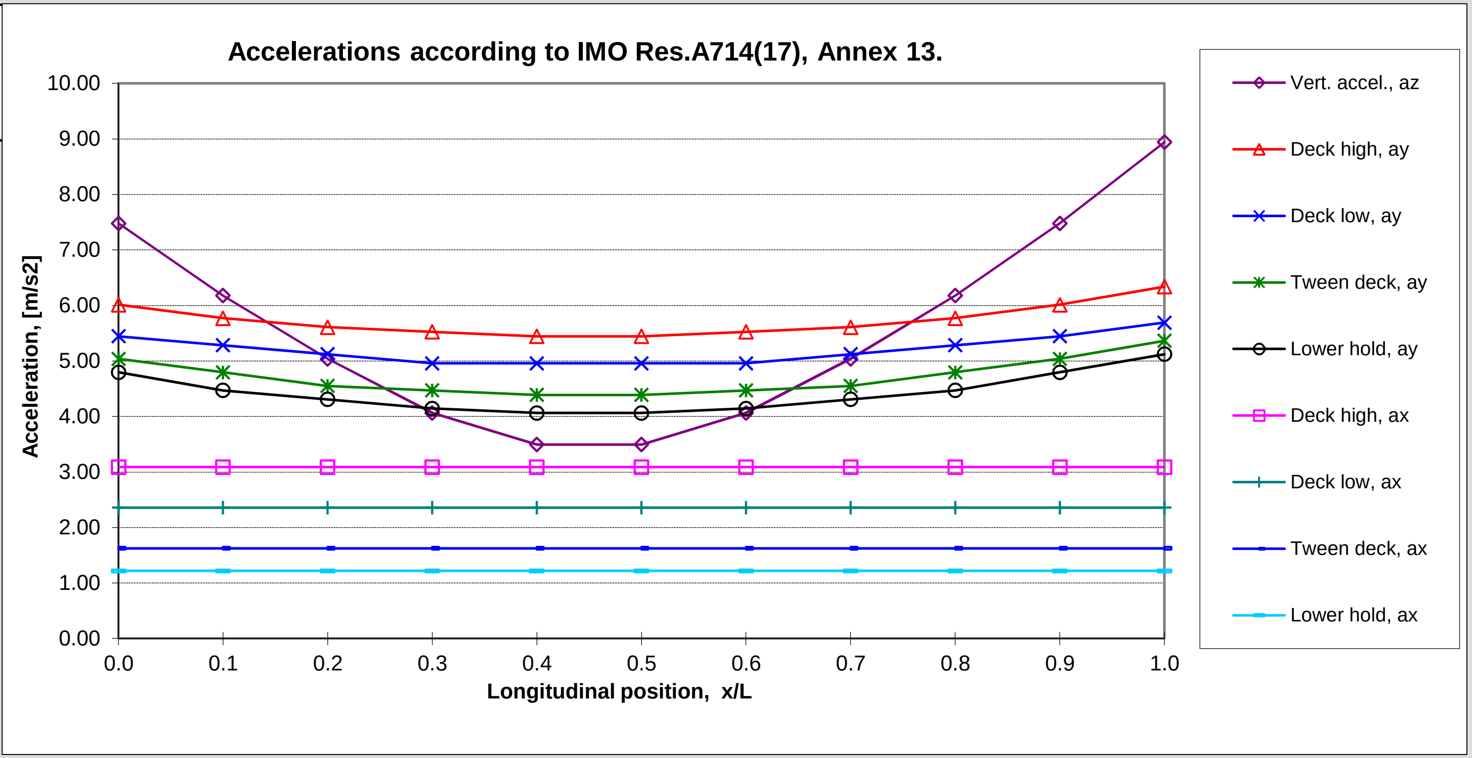
Accelerations			
Transverse:	a_t =	6.01	m/s2
Vertical:	a_v =	7.48	m/s2
Longitudinal:	a_l =	3.09	m/s2

Main Vessel Data:

Vessel Name:	Ship Id:	Lpp [m]:	B [m]:	V [kn]:	GM [m]:
HOEGH OSAKA	9185463	171.30	32.20	19.20	0.70

Vessel Name: HOEGH OSAKA						Ship Id: ######					
Accelerations according to Annex 13 to IMO Res. A714(17)											
	Transverse acceleration a_y in m/s^2										Long acc
Long. position:	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	a_x in m/s^2
Deck, high	**6.01**	**5.77**	**5.61**	**5.53**	**5.45**	**5.45**	**5.53**	**5.61**	**5.77**	**6.01**	**6.34**	**3.09**
Deck, low	**5.45**	**5.28**	**5.12**	**4.96**	**4.96**	**4.96**	**4.96**	**5.12**	**5.28**	**5.45**	**5.69**	**2.36**
Tween-deck	**5.04**	**4.80**	**4.55**	**4.47**	**4.39**	**4.39**	**4.47**	**4.55**	**4.80**	**5.04**	**5.36**	**1.63**
Lower hold	**4.80**	**4.47**	**4.31**	**4.15**	**4.06**	**4.06**	**4.15**	**4.31**	**4.47**	**4.80**	**5.12**	**1.22**
	Vertical acceleration a_z in m/s^2											
	7.48	**6.18**	**5.04**	**4.06**	**3.50**	**3.50**	**4.06**	**5.04**	**6.18**	**7.48**	**8.94**	

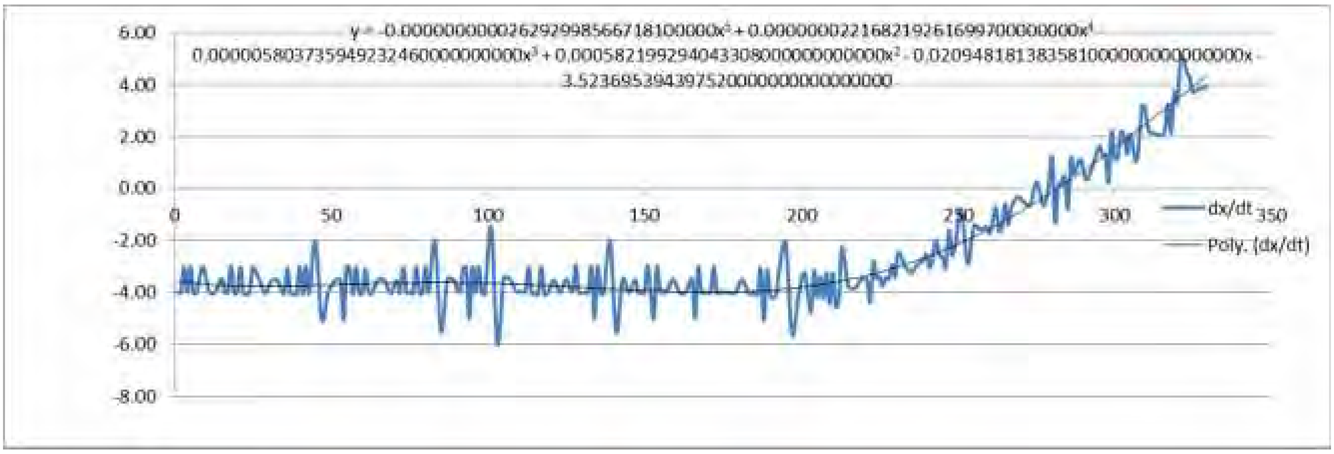
Note !
These accelerations apply only for GM=0.70m



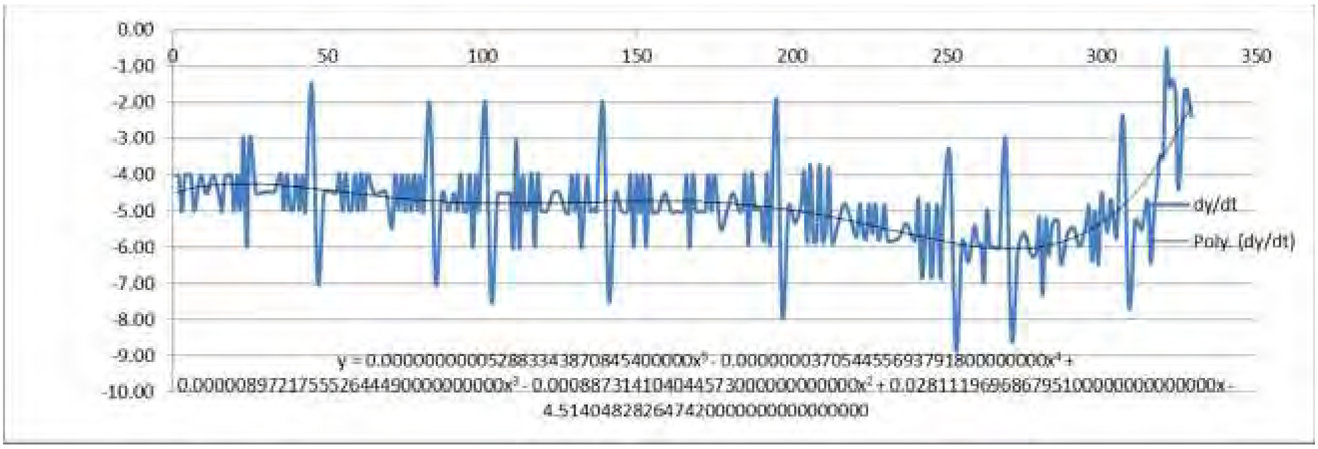
APPENDIX 6 – CALCULATION OF SOG AND RATE OF CHANGE OF COG

A6.1 The position of the HOEGH OSAKA was converted from the VDR data into the Universal Transverse Mercator system which gives the position in terms of Eastings (denoted as "x") and Northings (denoted as "y") (measured in metres). The rate of change of Eastings and Northings with respect to time was calculated by a finite difference approach. The resulting data was "smoothed" by using a 5th order regression curve as shown in **Figure A2.1** and **A.2.2** below.

<u>Figure A6.1 – Rate of change of Easting $\left(\frac{d}{d}\right)$</u>



<u>Figure A6.2 – Rate of change of Northing $\left(\frac{d}{d}\right)$</u>



A6.2 The second derivative of the Easting and Northing values (the rate of change of dx/dt and dy/dt respectively) were calculated by differentiating the best-fit curve with respect to time. The rate of change of COG was derived from the first and second derivatives of the Easting and Northing values as follows.

$$C \quad = \tan^{-1}\left(\frac{d}{d}\frac{d}{d}^{-1}\right)$$

$$\frac{d}{d} = \frac{1}{1+\frac{d}{d}^{2}\frac{d}{d}^{-2}}\frac{d}{d}\left(\frac{d}{d}\frac{d}{d}^{-1}\right)$$

$$\frac{d}{d}\left(\frac{d}{d}\frac{d}{dt}^{-1}\right) = \frac{d^2y}{d^{\ 2}}\frac{d}{d}^{-1} - \frac{d}{d}^{-2}\frac{d^2x}{d^{\ 2}}\frac{d}{d}$$

$$\frac{d}{d} = \frac{1}{1+\frac{d}{d}^{2}\frac{d}{d}^{-2}}\left(\frac{d^2y}{d^{\ 2}}\frac{d}{d}^{-1} - \frac{d}{d}^{-2}\frac{d^2x}{d^{\ 2}}\frac{d}{d}\right)$$

where $\frac{d^2x}{d^{\ 2}}$ and $\frac{d^2y}{d^{\ 2}}$ are the second derivatives with respect to time of the Easting and Northings respectively.

A6.3 The SOG is was calculated from the smoothed values of $\frac{d}{d}$ and $\frac{d}{d}$ from the following equation.

$$S \quad = \sqrt{\frac{d}{dt}^{2} + \frac{d}{d}^{2}}$$

APPENDIX 7 – CALCULATION OF HEELING MOMENT CAUSED BY CARGO SHIFT

Item	Mass (tonnes)	Shift (m)	Moment (tonne-metres)
Power Crusher 1	49.77	8.80	438.0
Power Crusher 2	49.77	9.40	467.8
Bulldozer	37.40	20.43	764.1
Ships equipment (total)	11.50	15.58	179.2
Chassis 00063, 353452	61.80	1.50	92.7
Trakpactor 500	56.00	11.65	652.4
		Total Moment	2594.2

APPENDIX 9 – CALCULATION OF LOADS ON CARGO

Maximum Loads on Cargo

Mean angle	48	deg
	0.83775804	rad
Max angle	60	deg
	1.04719755	rad
Amplitude of oscilation	12	deg
	0.20943951	rad
Roll Period	30	s
Roll freq	0.20943951	rad/sec
Height of Deck 6 Cargo above CoG	0.8	m
Transverse Acceleration	0.00734964	ms-2
Gravitational acceleration	8.49570921	ms-2
Total Horizontal Acceleration	8.50305885	ms-2

Item	Height of COG above base (metres)	Mass (tonnes)	Transverse sliding Force (kilonewtons)	Transverse capacity (kilonewtons. See Section 5)	Cargo tipping Moment (kilonewton-metres)	Tipping capacity (kilonewton-metres. See Section 5)
Atlas Copco Powercrusher PC 21 (1+2)	*2.3*	*49.8*	423.2	286	973	1211
Caterpillar D8T Track-Type Tractor	*1.2*	*37.4*	318.0	216	382	869
Powerscreen Trakpactor 500	*1.9*	*54.0*	459.2	376	872	1891

APPENDIX 10 – CFD CALCULATION OF FORCES AND MOMENTS DUE TO ROLL

A10.1 Hydrodynamic Models are created using computer software from a branch of engineering called Computational Fluid Dynamics (CFD). The hydrodynamic model used in this case is what is termed a Reynolds Averaged Navier Stokes Equation (RANSE) method. The Navier-Stokes equations were named after the physicists that first derived them and are based on fundamental principles such as Newton's second law[19]. Due to turbulence, the direct solution of Navier Stokes equations is, for many engineering problems, not feasible within the capability of even modern computers. Their solution requires an approximation called "Reynolds Averaging", named after the physicist that proposed it. This approximation allows the average effect of turbulence to be calculated without attempting to solve the tiny, random movements of fluids that will occur in reality. This form of CFD has been widely adopted in the marine industry but is used in most branches of engineering where fluid flows are important.

A10.2 The analysis presented in this document has been carried out using the open source CFD software OpenFOAM, specifically the solver simpleFOAM, which is a steady-state solver for incompressible, turbulent flow.

A10.3 RANSE solutions require the choice of a turbulence model to account for the random behaviour of fluid particles that are important close to the hull surface. A "k-omega" model was chosen as this model is widely known to provide reliable results in most fluid flow modelling. In a k-omega model, two parameters are used to define the effect of turbulence, the first (denoted "k") is the kinetic energy of the turbulence, and the second (denoted by the Greek letter "omega" is the specific rate at which the turbulent kinetic energy dissipates.

A10.4 As is common with CFD calculations of vessels manoeuvring in confined waters, the so-called "Double-Model"[20] approximation was used for these calculations. This approach neglects the generation of waves by the moving vessel which is considered to be an

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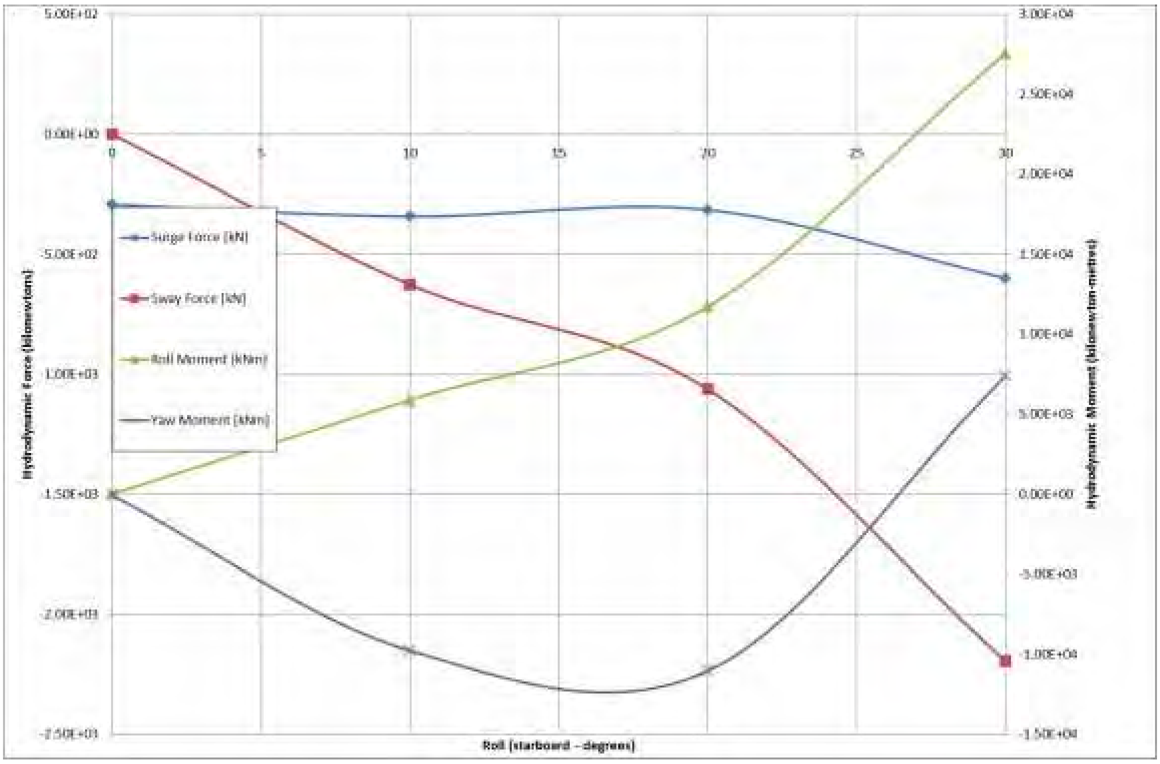
[19] Newton's second law states that the rate of change of momentum in time is equal to the net applied force.
[20] The double model approximation is a reference to a technique in wind tunnel testing of ship hulls in which the underwater shape and its mirror-image (in the waterline plane) is tested experimentally. As the tested body is symmetrical about the waterline plane, no air flow normal to the waterline is possible. This is analogous of applying a sheet of glass (or similar) over the waterline thereby restricting the formation of waves which is how the double-model approximation is applied in CFD. The advantage of this approach over the complete modelling of the water surface is that enhances the ease and speed of CFD computations.

Contd/...

acceptable approximation for the expected passing speed of the HOEGH OSAKA (approximately 11.5 knots over ground and 12.5 knots speed over water).

A10.5 CFD calculations were performed for a heel angles of 0, 10, 20 and 30 degrees. The force in the surge (longitudinal) and sway (transverse) directions (were measured as were the roll and yaw moments. The forces and moments were calculated for 10 knots which is the approximate speed of the vessel as it navigated the Brambles turn. **Figure A4.1** shows forces and moments plotted against heel angle for zero drift angle.

<u>Figure A10.1 Forces and moments for 0-degree drift angle.</u>



A10.6 A Benchmark analysis against the general purpose CFD solver FLUENT was performed for the vessel in the upright position and with a 20 degree roll angle. A comparison of results is provided in **Table A10.1** below. As can be seen in this table the differences between the two CFD software codes are minor which indicates that the figures presented in **Figure A10.1** are an accurate solution of the RANSE equations.

Table 10.1 – Comparison of FLUENT and OPENFOAM results.

Solver	Surge Force (kilonewtons)	Sway Force (kilonewtons)	Roll Moment (kilonewtons –metres)	Yaw Moment (kilonewtons –metres)
OPENFOAM 0 Deg.	-292	0	2	-58
FLUENT 0 Deg.	-290	0	2	-38
OPENFOAM 20 Deg.	-314	-1062	11738	-11040
FLUENT 20 Deg.	-322	-1058	11779	-11859

Annex E

Estimated departure stability calculation

Hoegh Osaka estimation of departure condition

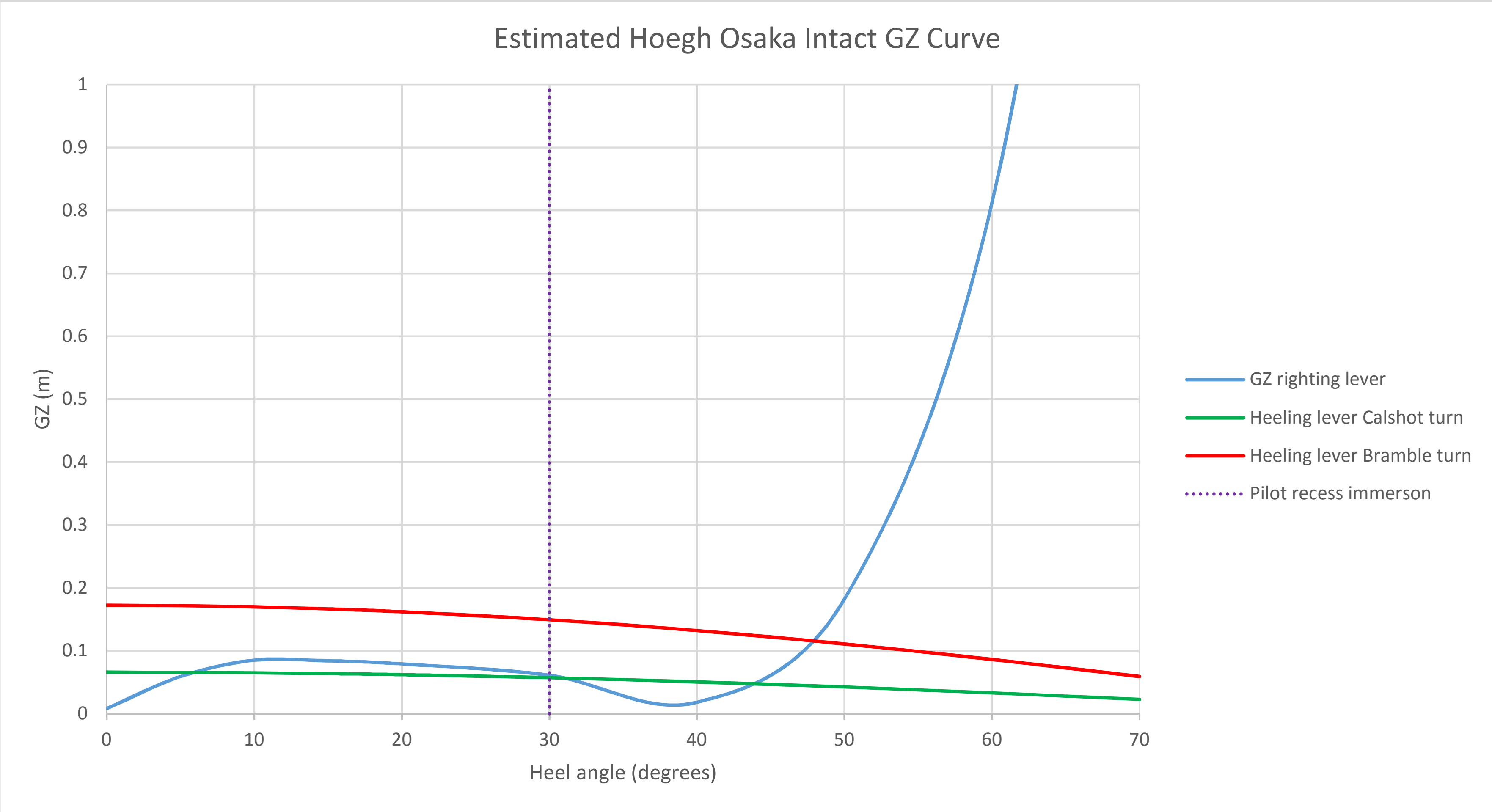
LCG positive fwd of midships
VCG positive above baseline
TCG positive to starboard

HST Loading condition data

Item	Weight	LCG	LMom	VCG	VMom	TCG	FSM
Water ballast	4893.164	9.086	44457.36	4.297	21023.78	-0.721	11548.82
Fresh water	253.309	-76.732	-19437	10.523	2665.47	3.443	651.188
Fuel oil	542.82	-36.826	-19990.1	6.217	3374.75	3.189	1371.773
Diesel fuel	22.755	-66.728	-1518.42	10.23	232.79	-5.868	7.435
Lub oil	62.242	-68.849	-4285.31	8.192	509.9	-7.405	58.697
Miscellaneous	41.167	-66.896	-2753.92	2.794	115.03	-0.532	17.997
Constants	320	2.078	665	19.55	6256	-1.181	0
No 1 car deck	114.84	-1.93	-221.64	2.82	323.85	-0.25	0
No 2 car deck	76.56	33.69	2579.31	4.8	367.49	-0.07	0
No 4 car deck	273.13	44.43	12135.17	12.69	3466.02	-2.65	0
No 6 car deck	1571	-2.86	-4493.06	17.1	26864.1	0	0
No 8 car deck	1047.27	31.86	33366.02	23.53	24642.26	4.2	0
No 9 car deck	124.27	46.7	5803.41	25.65	3187.53	-7.22	0
No 10 car deck	856.96	-5.08	-4353.36	27.99	23986.31	-0.36	0
No 11 car deck	910.06	5.44	4950.73	30.51	27765.93	-0.57	0
No 12 car deck	840.46	2.43	2042.32	33.01	27743.58	-0.24	0
Deadweight	11950.03	4.096	48947.01	14.437	172524.9	-0.017	13655.93
Lightship	15094	-6.89	-103998	16.9	255088.6	0	0
Displacement	27044.03	-2.036	-55050.7	15.812	427613.5	-0.008	13655.93

Draught	Aft	8.298	m
	Mid	8.62	m
	Fwd	8.911	m
Trim Between Marks		0.613	metres by the bow

GM Solid	1.2	m
GM Fluid	0.695	m
Effective VCG	16.317	m
Moulded Displacement	27007.06	tonnes
Waterline at LCF referred to hull definition datum	8.581	m
LCF referred to hull definition datum	-10.955	m
Heel Angle	0.64	degrees to port


Estimated Hoegh Osaka Intact GZ Curve
GZ (m)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
Heel angle (degrees)
GZ righting lever
Heeling lever Calshot turn
Heeling lever Bramble turn
Pilot recess immerson

Stability result

Accident condition

Displacement	27044.03	tonnes
Longitudinal Centre of Gravity	-2.036	m
Vertical Centre of Gravity	16.317	m
Transverse Centre of Gravity	-0.008	m
Equilibrium GM	0.695	m
Equilibrium Heel Angle	0.638	degrees to port
Equilibrium Draught	8.621	m
Equilibrium Trim Between Marks	0.616	metres by the bow

Angle of Vanishing Stability	148.9 degrees to stbd	147.0 degrees to port
Maximum GZ	4.162 metres to stbd	4.466 metres to port
Maximum GZ Angle	101.7 degrees to stbd	102.4 degrees to port

Heel Angle degrees	Righting GZ metres	Lever KN metres	Waterline metres	Trim metres	VCB metres	GZ Curve Area metres.rad
0	0.008	0	8.62	-0.613	4.893	0
5	0.059	1.474	8.641	-0.768	4.939	0.003
10	0.085	2.911	8.705	-1.15	5.071	0.01
15	0.084	4.3	8.812	-1.637	5.287	0.017
20	0.079	5.652	8.955	-2.137	5.585	0.024
30	0.061	8.212	9.317	-2.923	6.422	0.037
40	0.018	10.501	9.694	-3.132	7.546	0.042
50	0.182	12.676	10.019	-2.957	9.077	0.055
60	0.812	14.939	10.251	-2.75	11.241	0.133
70	2.19	17.52	10.173	-2.338	14.335	0.385
80	3.444	19.511	9.955	-1.941	17.57	0.89
90	3.98	20.297	9.913	-1.258	20.297	1.545

Downflooding and Margin Line Points

X	Y	Z	Freeboard metres	Stbd Angle degrees	Port Angle	Type	Description
80	14	34.5	25.744	71.9	162.4	Downflood	Fan room vent
80	-14	34.5	25.433	163.1	71.1	Downflood	Fan room vent
-20	13.5	15.07	6.672	30	Exposed	Downflood	Pilot boarding recess
-20	-13.5	15.07	6.372	Exposed	30.1	Downflood	Pilot boarding recess

Calshot turn

Heeling lever	0.07	cos(theta)		
Speed V	10.0	knots	5.1	m/s
h (KG -1/2T)	11.45	m		
KG (vertical centre of gravity)	15.8	m		
T (draught)	8.7	m		
R (radius of steady turn)	0.43	nm	796.36	m
g	9.81	m/s		

Theta	0	5	10	15	20	30	40	50	60
Heel on turn	0.065851	0.065600063	0.064850226	0.063607	0.061879	0.05702833	0.050445	0.042328	0.032925

Bramble turn

Heeling lever	0.17	cos(theta)		
Speed V	11.8	knots	6.1	m/s
h (KG -1/2T)	11.45	m		
KG (vertical centre of gravity)	15.8	m		
T (draught)	8.7	m		
R (radius of steady turn)	0.27	nm	500.04	m
g	9.81	m/s		

Theta	0	5	10	15	20	30	40	50	60
Heel on turn	0.17231	0.171654413	0.169692327	0.166439	0.161919	0.14922493	0.131997	0.110759	0.086155

Water Ballast Breakdown

Name	Weight	LCG	VCG	TCG	FSM	% full
FPT	542.774	80.204	9.735	0	1068.065	56
Fore Deep Tank	139.005	71.146	3.845	0	59.993	39
No 1 WBT (P)	442.178	53.413	2.408	-2.533	604.755	61
No 1 WBT (S)	442.178	53.413	2.408	2.533	604.755	61
No 2 WBT (P)	721.083	21.916	2.063	-8.558	1938.462	85
No 2 WBT (S)	735.502	21.916	2.063	8.558	1977.226	85
No 3 WBT (P)	343.927	-7.311	2.561	-12.665	339.41	90
No 3 WBT (S)	38.214	-6.335	1.059	11.764	83.964	10
No 4 WBT (P)	162.814	-26.579	2.693	-10.394	270.568	90
No 4 WBT (S)	170.912	-26.581	2.708	10.36	277.535	90
No 5 WBT (P)	212.986	-39.227	2.525	-6.845	561.718	90
No 5 WBT (S)	224.821	-39.237	2.605	6.9	601.692	95
APT (C)	136.261	-80.592	8.588	0	1160.3	35
APT (P)	294.492	-83.424	10.185	-9.64	1126.959	40
APT (S)	286.027	-83.108	10.333	10.218	873.445	60

MAIB safety flyer

MAIB
MARINE ACCIDENT INVESTIGATION BRANCH

SAFETY FLYER

Hoegh Osaka: Listing, flooding and grounding on 3 January 2015

Hoegh Osaka

Narrative

At 2109 (UTC) on 3 January 2015, the pure car and truck carrier (PCTC) *Hoegh Osaka* was departing Southampton, UK, and turning to port around the Bramble Bank when the vessel developed a significant starboard list. As the list increased in excess of 40º the ship lost steerage and propulsion, and subsequently drifted aground on Bramble Bank. A cargo shift as the vessel listed resulted in breaches to the hull and consequent flooding. All crew were safely evacuated from the ship and surrounding waters. There was no resulting pollution, and the ship was later successfully salvaged.

Hoegh Osaka was employed to move vehicles between Europe and the Middle East. European ports were usually visited in the order Bremerhaven, Hamburg and, finally, Southampton; fuel was normally embarked in Hamburg. On this occasion, due to New Year holidays, the cycle was changed with Southampton being the first European port visited, but the cargo loading plan was not adjusted.

Findings

Stability modelling and analysis following the accident show that *Hoegh Osaka* heeled heavily to starboard while turning as a result of having departed port with inadequate stability. Cargo distribution was such that the upper vehicle decks were full while the lower vehicle decks were lightly loaded. *Hoegh Osaka* was low on bunker fuel oil, which was stored low down in the ship, and the ship's overall vertical centre of gravity (VCG) was relatively high.

Hoegh Osaka's inadequate stability had not been identified prior to departure. The figures in the pre-stowage plan were significantly different to the final cargo tally; the estimated weight of many items of cargo was less than their actual weight; and no allowance was made for the VCG of the cargo loaded being above deck level. Finally, it was onboard practice to alter the ballast tank quantity readings on the loading computer so its output would match the observed draught readings. It would have been possible to embark additional ballast prior to departure to reduce the ship's VCG as necessary, but as the shortcoming in stability had not been identified this was not done.

Witness and anecdotal evidence, and the findings of other investigations, suggest that it is a general practice in the car carrier industry for ships to sail before an accurate departure stability condition has been calculated, on the assumption that their stability condition is safe.

Safety Lessons

- Assessing a ship has adequate stability for its intended voyage on completion of cargo operations and before it sails is a fundamental principle of seamanship that must not be neglected. Sufficient time must be made before departure for an accurate stability calculation to be completed.

- A loading computer is an effective and useful tool for the safe running of a ship. However, its output can only be as accurate as the information entered into it.

- The master has ultimate responsibility for the safety of his/her ship. This responsibility cannot be delegated to shore-based managers or charterers' representatives.

This flyer and the MAIB's investigation report, which identifies a number of further contributing factors to the accident, are posted on our website: www.gov.uk/maib

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