REPORT

Subject	Report
MV Estonia Bow ramp flooding tests with complete car deck	4006 4100-2
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This report is a complement to SSPA report 4006 4100-1 that described manoeuvring tests in calm water and in waves as well as flooding tests through the bow ramp mainly carried out in SSPA's manoeuvring and seakeeping basin (MDL). In this report complementary bow ramp flooding tests with the ship model of M/V Estonia equipped with deck No. 2 (main car deck) were carried out in SSPA's towing tank.

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SUMMARY

Test in SSPA's towing tank was carried out to study the initial capsizing behaviour of M/V Estonia equipped with a complete deck No. 2 (main car deck).

Opening the ramp fully at 14.5 knots and letting the car deck be filled with water gives a very rapid start of a capsizing sequence.

In reality this could have been taken much longer time if the ramp got stuck in just a partially open condition when it was hit by big waves. Even if it opened immediately after it was closed by the waves, the effect of the ramp being closed now and then would significantly reduce the inflow rate.

If only the car deck is flooded the ship would stay in a stable condition at a heel angle of about 46-47 degrees, but some small amount of water would also flow in and out in this condition.

1 SHIP AND MODEL PARTICULARS

The hull model 3191-A was manufactured in carbon fibre according to information from the Joint Accident Investigation Commission final report and from Meyer Werft.

Model scale is 1:40.00. The model is shown in Figure 1 to 4 in Appendix C.

The length of the forward bilge keels is 35.2 m (#7.95 to #13.07) and the aft bilge keels 13.6 m (#5.38 to #7.36). The span of the bilge keels is 0.6 m.

The main data of the ship at the tests are given below.

Table 1: Main data of MV Estonia

		Ship	Model
Lbp	[m]	137.4	3.435
Beam	[m]	24.2	0.605
Draft, aft	[m]	5.61	0.140
Draft, fwd	[m]	5.17	0.129
Displacement	[tonnes]	12 046	0.1864
Block coefficient	[-]	0.683	0.683
LCB (fwd of Lbp/2)	[m]	-4.66	-0.116
LCB (% rel Lbp/2)	[%]	-3.39	-3.39
VCG	[m]	10.62	0.2655
GM (corrected)	[m]	1.17	0.0292
Radius of gyration (kxx)	[m]	8.954 (0.37*B)	0.224
Radii of gyration (kyy/kzz)	[m]	37.1 (0.27*Lbp)	0.928
Rudders:			
Area (one rudder), movable	[m^2]	8.75	
Area (one rudder), total	[m^2]	10.85	
Rudder height	[m]	4.00	
% of Lbp · T per rudder	[%]	2.93	
Rudder rate	[°/sec]	2.321	
Max rudder angle	[°]	35	

SSPA stock propeller models were used at the tests:

Table 2: SSPA stock propeller data

Diameter (model scale)	0.1044 m
Diameter (full scale)	4.18 m
No of blades, Z	4
Pitch P/D at 0.7R	0.806
Blade area ratio	0.611

The water depth corresponded to 102 m in full scale at the tests.

The model used in the previous tests had a height corresponding to the top of deck four of M/V Estonia. Not to risk that the ship model should capsize, an additional very simple superstructure was added to the ship model. The total height of the ship model was then representing roughly the real height of the ship. Since the part of the ship model representing the superstructure was water tight, it gave the ship model a substantial buoyancy in large heel angles.

2 TEST ARRANGEMENT AND INSTRUMENTATION

The ship model was self propelled and manually radio controlled (motor revs and rudder angle). The bow ramp was possible to open by a remote control. The model was following the carriage in the towing tank with an initial speed of 14.5 knots. Video recordings were made from a hand-held camera as well as from a stationary camera on the carriage.

The ramp was in this case free to move up and down with the waves after has been released from the closed position.

3 TESTS CARRIED OUT

Two runs in head sea were performed. In the first run an initial heel angle of 2.6 degrees to starboard was set by arranging ballast weights to simulate the heel from wind pressure.

After the first run an undesired shift of ballast weights occurred resulting in an additional permanent list of about 2 degrees. This is in fact what is assumed to be the heel angle due to the cargo shift onboard M/V Estonia. The second run had consequently an initial list of about 4.5 degrees.

4 RESULTS

In both test runs a heel angle of about 15 degrees to starboard occurred after just a few seconds after the ramp was opened corresponding to a full scale time of about half a minute. After about one minute full scale time the heel angle was in the order of 25 degrees. The ship model got a final heel angle of about 46-47 degrees after about 3-4 minutes.

It should be stressed that in both test runs the ramp, now and then when it was hit by big waves, closed but opened again at once. This has been observed before, also in low speeds. Even with this short time of closed ramp it was observed in the previous test that the reduction in inflow was in the order of 40 % when the ramp was allowed to close. This measurement was only carried out once at 5 knots and should therefore be taken with care. At higher speeds, 10-15 knots, the tendency of the ramp to close was less. In the initial inflow test (see SSPA report 40064100-1) the ramp was forced to stay open.

After that the model was filled with water on car deck it was let drifting in the waves. One could now see that water was going in and out of the ramp opening. The drift speed in the waves was measured to about one knot (full scale). It can be assumed that if wind had been added the drift speed would have been about the twice.

Since no more water could enter the ship model and stay there permanently, and the superstructure was intact, the ship model stayed in the 46-47 degree stable heeled position.

Ship model in a stable heeled position

5 CONCLUSIONS

Opening the ramp fully at 14.5 knots and letting the car deck be filled with water gives a very rapid start of a capsizing sequence.

In reality this could have been taken much longer time if the ramp got stuck in just a partially open condition when it was hit by big waves. Even if it opened immediately after it was closed by the waves, the effect of the ramp being closed now and then would significantly reduce the inflow rate.

If only the car deck is flooded the ship would stay in a stable condition at a heel angle of about 46-47 degrees, but some small amount of water would also flow in and out in this condition.