MV ESTONIA Accident 28.9.1994

Summary

- MV ESTONIA was on scheduled voyage from Tallinn to Stockholm, carrying 803 passengers and a crew of 186 people.

- The ship capsized and sank within about 40 minutes shortly after midnight due to water ingress on the open car deck through the open bow ramp.

- The ramp had been forces open by the detached bow visor whose attachments had failed due to wave impact loads about 10 minutes before the water ingress started.

- The significant wave height was about 4 m at the time of the accident, it grew to about 5.5 m later during the night.

- 852 people lost their lives, most of the dead were Swedish (501) and Estonian (285) citizens.

- Helicopters rescued 104 people, assisting vessels rescued 34.

- The joint Estonian/Finnish/Swedish Accident Investigation Commission was set up the day after the accident following a decision taken by the prime ministers of the three countries.

- A preliminary technical part report was released in April 1995, the final report was published in December 1997.

- The accident has resulted in significant changes in Codes, Rules and Regulations regarding passenger/ro-ro vessels.
M/V ESTONIA – GENERAL ARRANGEMENT
MV ESTONIA Building/Operating History

- The vessel “Viking Sally” was built by Jos. L. Meyer Shipyard October - 79 – June -80 for Sally, one of the partners in Viking Line.

- Its design was based on DIANA II, ordered by Slite, (the other partner in Viking Line), but was lengthened with a 18.4 m midship section. This was a condition for meeting the extraordinary short delivery time.

- Hoistable decks, ramps and manoeuvring/control equipment for ramps and visor was delivered by a subcontractor, von Tell AB.

- The ship was built to the rules of Bureau Veritas and to the rules and regulations of the Finnish Maritime Administration and applicable IMO-Codes.

- The vessel was at the time the second largest roro/pax ferry ever built for the Baltic Sea.

- Estline Marine Co Ltd registered in Cyprus controlled 50%/50% by Estonian State/Nordström & Thulin AB
  Crew management – Estonian Shipping Co Ltd
  Technical management – Nordström & Thulin AB

### Name Date Route
- **Viking Sally**
  - June 1980–
  - Stockholm–
  - Mariehamn–
  - Turku
  - Rederiaktie-
  - bolaget Sally

### Finnish flag 1980–1992
- **Silja Star**
  - April 1990–
  - Stockholm–
  - Turku
  - Effjohn Oy

- **Wasa King**
  - Jan 1991–
  - Vaasa–
  - Umeå and Sundsvall
  - Wasa Line

### Estonian flag 1993–1994
- **Estonia**
  - Jan 1993
  - Tallinn–
  - Stockholm
- **Estline Marine Co Ltd**
What initiated the accident?

- The accident was initiated by failure of the bow visor attachments under wave impact loads.

- The failure was primary due to local overload. The attachments were not designed to withstand even the rather moderate wave condition at the time of the accident.

- Bureau Veritas had no detailed rules for design of visor locking devices and hinges. BV requested the locking devices to be approved by Finnish Administration.

- The Finnish administration did not make any hull surveys because the ship was classed under the rules of an approved classification society.

- The shipyard made rough estimates of wave loads according to other guidelines and rules available at the time (but which later have been significantly strengthened up). The assumptions made did not reflect realistic load distributions.

- The locking devices were not manufactured properly according to the design intent.
What made the vessel capsize and sink?

- The forward ramp was integrated in the visor structure and was thus forced open when the visor attachments failed.

- There was no collision bulkhead extension in proper position according to SOLAS. The ramp was located too far forward to fulfil the requirements.

- The fully open car deck on these roro ferry designs makes them extremely sensible to water ingress.

- The officers did not reduce speed or change course when the first indications of something being wrong at the bow or the forward part of the car deck was given.

- The bow visor could not be seen from the conning position, and the indicator lamps for locked visor did not detect the failure of the locking devices.

- The ship was turned towards the waves when the ship started to heel over.

- The rapidly developed list to starboard could not be compensated by the heeling tanks since the port tank already was full at departure.

- The buoyancy reserve in the superstructure diminished when windows and doors broke and progressive flooding started from aft/above.
What made the outcome so serious?

- The list developed rapidly, it became 15° within only a few minutes and over 40° within 15 minutes.

- The narrow passages in accommodation areas and the staircases quickly became crowded with injured and panic-stroken people. It was almost impossible to reach open decks when the list was more than 30°. Only about 300 people reached outer decks.

- The lifeboat alarm was not given until about five minutes after the list developed. No information was given to passengers over the public address system.

- None of the lifeboats could be launched properly. It was difficult to launch life rafts and most of the rafts was water trapped or overturned at sea.

- Assisting vessels did generally not find it possible to rescue people from the sea.

- The first helicopter arrived about 90 minutes after evacuation had become impossible. The capacity of helicopters was limited as most of them could not land or lower survivors onto the surrounding ships. Only one helicopter managed to rescue more than 15 people in total.
Sequence of events

MV ESTONIA Accident, M Huss
Summary of damage to the bow area

Failed starboard hinge
Pounding marks

Twisted and broken parts

Scratch marks

Torn open

Ripped-out side locking lug in its recess (8.18)

Scratch marks

Torn open (8.2)

Impact hole

Failed bottom lock lugs (8.13, 8.14)

Deep indentations (8.12)

Preventer wires detached

Failed port hinge
Pounding marks (8.16)

Ripped-out side locking lug in its recess (8.17)

Failed port end hinge of ramp (8.11)

Ramp actuators broken

Damage

Broken rubber seal (8.3)

Damage
Analysis of visor design and strength

• Bureau Veritas had no rules for design of visor attachments, they made a note on the drawing that the locking devices should be examined and approved by the national authority. However the Finnish Maritime Administration did not examine the installation as the ship was built according to the rules of an approved classification society.

• The shipyard made hand calculations of required cross-sectional area of all attachment points (3 locks, 2 hinge points) assuming HT-Steel (St52-3) as requested by Bureau Veritas.

• The calculation was made similar to what was proposed by other class societies but the load distribution seems to have been misinterpreted.

A design wave pressure on projected areas of 54 kPa was used in shipyard calculations. (LR-78 would have given 30/60 kPa, GL: 157 kPa.) A resultant design load of 1 MN per attachment was calculated giving a required cross-sectional area of 6100 mm².

• The actual installation found was made of mild steel and the cross-sectional area of the bottom lock was significantly less than required.

• Analysis of the ultimate strength in the installation as found gives approx. 1.5 MN for the bottom lock, 1.2/1.6 MN for side locks and 5-7 MN per hinge point (dependent on the load direction).

Standard method found in the rules of Lloyds Register, Germanisher Lloyd, DNV and IACS-82.
Analysis of wave loads at the time of the accident - Model test results

Figure 12.3 Example of time series from model tests

MV ESTONIA Accident, M Huss
Analysis of wave loads at the time of the accident - Probability distributions

Y moment, [MNm]

150° Bow Sea

Mean exceedance period, [min]

Mean exceedance period, [min]

Y moment, [MNm]

180° Head Sea

Z force, [MN]

150° Bow Sea

Mean exceedance period, [min]

Mean exceedance period, [min]

Z force, [MN]

180° Head Sea

Mean exceedance period, [min]
Analysis of wave loads at the time of the accident - Extreme distributions

5-7 MN per hinge point (dependent on the load direction).
Example of load distribution for a possible failure condition

Failure example:

Wave Loads
Forces:
X  -5.4 MN
Y  2.0 MN
Z  -5.4 MN

Moments:
X  5.0/2 MNm
Y  15.5 MNm
Z  2.0 MNm

67% of net My taken by side locks

Mx and Mz shared equally by hinges and side locks
Analysis of the capsize – Intact stability

![Graph showing intact stability](image)

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<th>Heel a (°)</th>
<th>Gz (m)</th>
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- **Incl. superstructure**
- **Incl. deck 4**
- **Up to car deck only**

MV ESTONIA Accident, M Huss
Analysis of the capsize –
Stability during water ingress

Heel a (°)

GZ (m)

0 ton
400 ton
1000 ton
2000 ton
3000 ton
4000 ton

0° 10° 20° 30° 40°
Analysis of the capsize – Inflow simulations

Spectrum peak period $T_p$ (s)

Mean water inflow (ton/min)

Water on A-deck (ton)
Analysis of the capsize – Progressive flooding

Figure 4.16 Static stability curves, effect of damage stage, 3200 ton water on cardeck.
What could have been done to prevent the accident?

**Initiation**

- **Strict routines** for identification (FSA), design and inspection of vital safety components.
- **Upgrading** of existing vessels according to new requirements based on research and experience. (The strength of the visor locking devices would have been 5 - 10 times higher if 1994 rules would have been applied).
- **Learning by experience**: DIANA II suffered severe damage to the visor attachments after heavy weather in January 1993. More than 14 roro/pax ferries have had incidents or even complete failure of visors before the ESTONIA. A Swedish Maritime Administration surveyor have reported that the visor attachments are far too weak on many ferries already at the time of newbuilding of the ESTONIA.

**Capsizing**

- **Strict routines** for compliance with SOLAS.
- **Learning by experience**: The HERALD OF FREE ENTERPRISE accident highlighted the risk with water on deck on roro/pax ferries.
- **Training**: The crew should have been trained for immediate actions in case of possible water ingress. Correct actions at the time of the first indications (reported sounds from the bow) would have saved the ship.
- **Relevant alarm indicators** on the bridge would have showed when the visor was detached.

**Outcome in terms of lives lost**

- **Better conditions for evacuation** to open decks and to the sea.
- **Functioning life-saving equipment** would have saved many lives. Equipment for taking people from the sea on board other vessels.