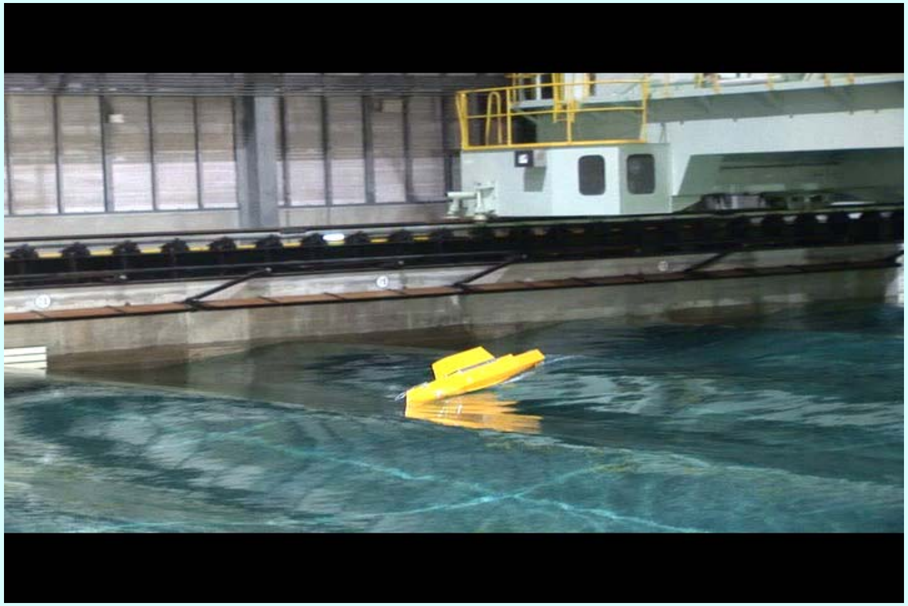
Specialist Committee on **Stability in Waves**

- Dr. N. Umeda (Chairman)
- Mr. A. J. Peters (Secretary)
- Prof. S. Fan
- Prof. A. Francescutto
- Dr. S. Ishida
- Dr. J. O. de Kat (until 2006)
  Dr. F. van Walree (from 2007)
- Prof. A. Papanikolaou
- Dr. A. M. Reed



Specialist Committee on **Stability in Waves**

• Dr. N. Umeda (Chairman)	Osaka Uni. (Pacific Isle)
• Mr. A. J. Peters (Secretary)	QinetiQ (C. Europe)
• Prof. S. Fan	MARIC (E. Asia)
• Prof. A. Francescutto	Trieste Uni. (S. Europe)
• Dr. S. Ishida	NMRI (Pacific Isle)
• Dr. J. O. de Kat (until 2006)	MARIN (C. Europe)
Dr. F. van Walree (from 2007)	MARIN (C. Europe)
• Prof. A. Papanikolaou	NTUA (S. Europe)
• Dr. A. M. Reed	NSWC (Americas)

Special Acknowledgements

Corresponding members

- Prof. K.J. Spyrou
- Prof. D. Vassalos (until 2006)

Supports to benchmark testing

SSRC (UK) ,TKK (Finland) , MARIC (China), MARIN (NL), MOERI (ROK), NTUA (Greece), OU (Japan), IST (Portugal), EU project SAFEDOR and US Office of Naval Research.

SiW Tasks from 24th ITTC

- **Develop** a **procedure** for **tank testing for parametric rolling.**
- **Revise the procedure** 7.5-02-07-04.1 **for intact stability testing**, to include extreme motions such as broaching and deck diving in irregular waves, wind and breaking waves.
- **Identify experimental techniques and data for validation of time-domain capsize codes**.
- **Assess the state of the art** for:
  – **Practical application of numerical methods** for the prediction of capsizing and **experiments** for assessment of safety/risk against capsize.
  – **Make recommendations** as to what scientific progress is required to move stability regulations from those based on hydrostatic calculations to those based on dynamic predictions, either using capsize codes or physical model experiments.

SiW Tasks (2)

- **Establish the importance of the** following **issues in predicting the dynamic behaviour of damaged vessels**, including sinking and capsizing, coupling between floodwater dynamics and ship dynamics, influence of flow coefficients for openings and flooding of complex spaces.
- **Review numerical methods for** assessing the **time to sink or capsize for damaged passenger ships** and associated validation techniques.
- Continue to **review** developments (to ITTC) in **stability safety assessment**, **with special attention on performance and risk-based approach** and relevant developments at IMO.

Additional Task from the IMO

- Assess and benchmark computer codes that simulate ‘time to flood’ and related damaged ship motion behaviour (SLF 48 in 2005) for the development of time-dependent survivability criteria of damaged passenger ships

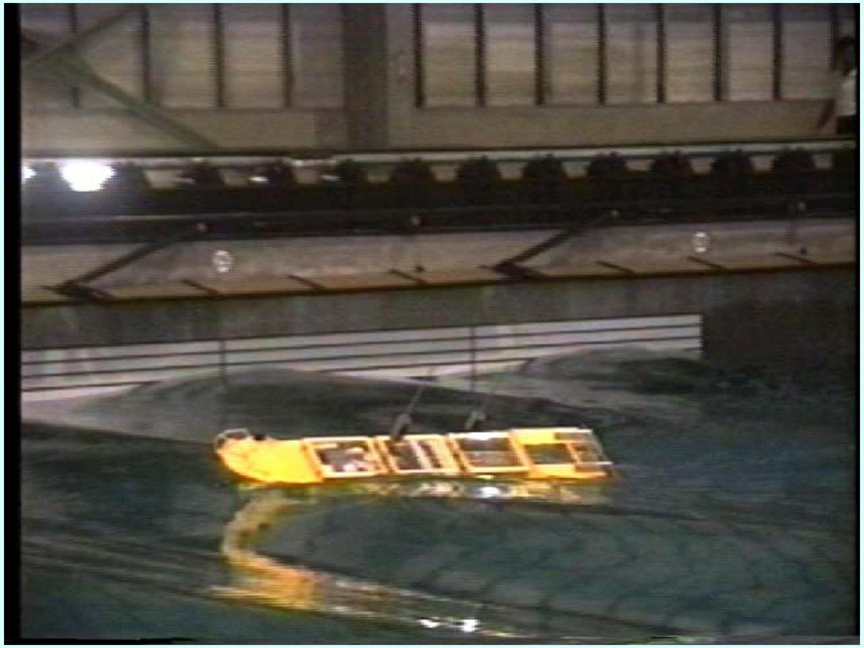
Organization of the Committee

- Experiment of parametric rolling (Ishida).
- Revision of the intact stability testing procedure (Fan & Ishida).
- Numerical prediction of damaged ship behaviour in waves (Papanikolaou).
- Time-to-Flood Prediction (de Kat / van Walree)
- Review of stability assessment (Reed & Francescutto).

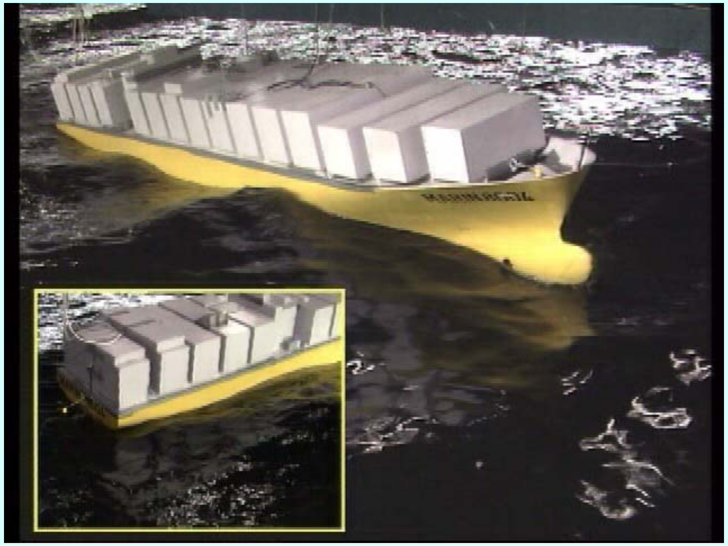
Committee Meetings

- Wageningen, NL - February 2006
- Rio de Janeiro, Brazil - September 2006
- Gosport, UK - May 2007
- Osaka, Japan - March 2008

1. Parametric Rolling Experiments



- Current procedure on 7.5-02-07-04.1 for intact stability testing covers parametric rolling in following and quartering waves.



- Recently several accidents due to head-sea parametric rolling have been reported so demands for model testing in head waves have increased.
- Thus, the existing procedure should be revised to include head-sea parametric rolling as well.

Items to be Added to the Existing Procedure

- Towing arrangement:

  Free-running test is desirable. In case of towing, the coupling with vertical motion and speed variation should be taken into account.

- Non-ergodicity in irregular waves:

  Ensemble average of multiple runs is recommended.

- Nonlinear feature:

  Parametric rolling can only exist within a certain wave height range.

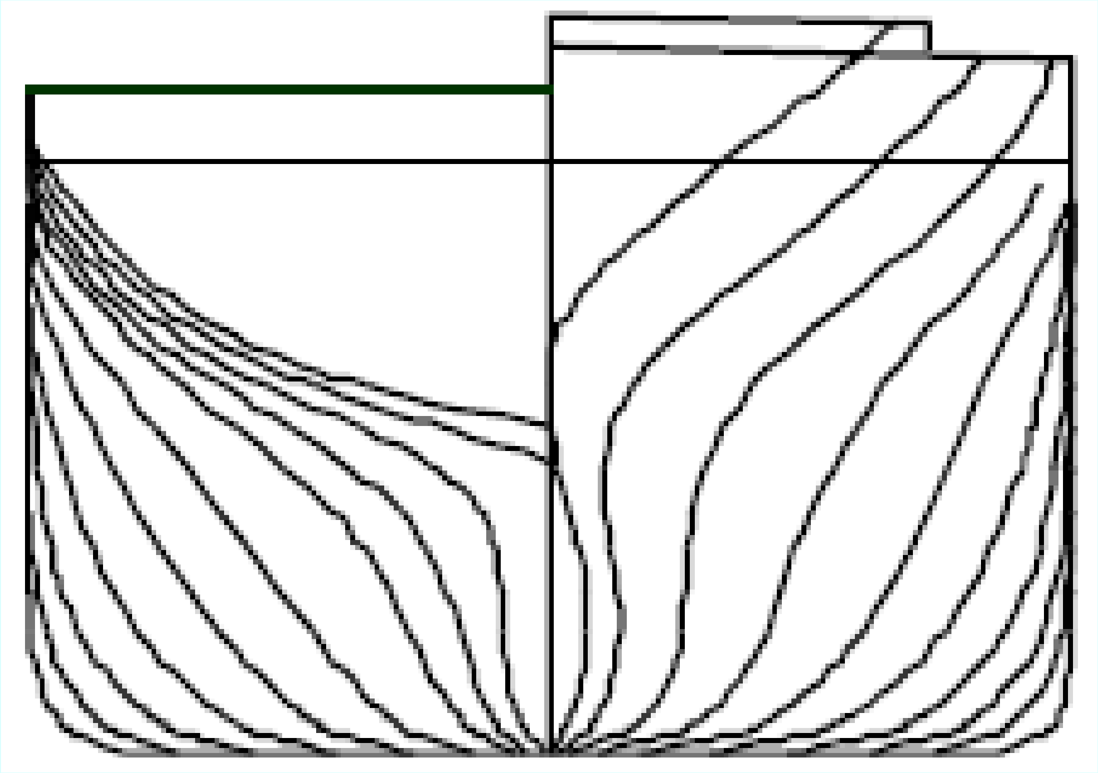
Experimental Data for Benchmark Testing of Head-Sea Parametric Rolling

- 23rd ITTC utilised data from a containership (A-1) for benchmark testing in following and quartering waves.
- Now three candidates have been identified and a benchmark testing plan has been proposed.

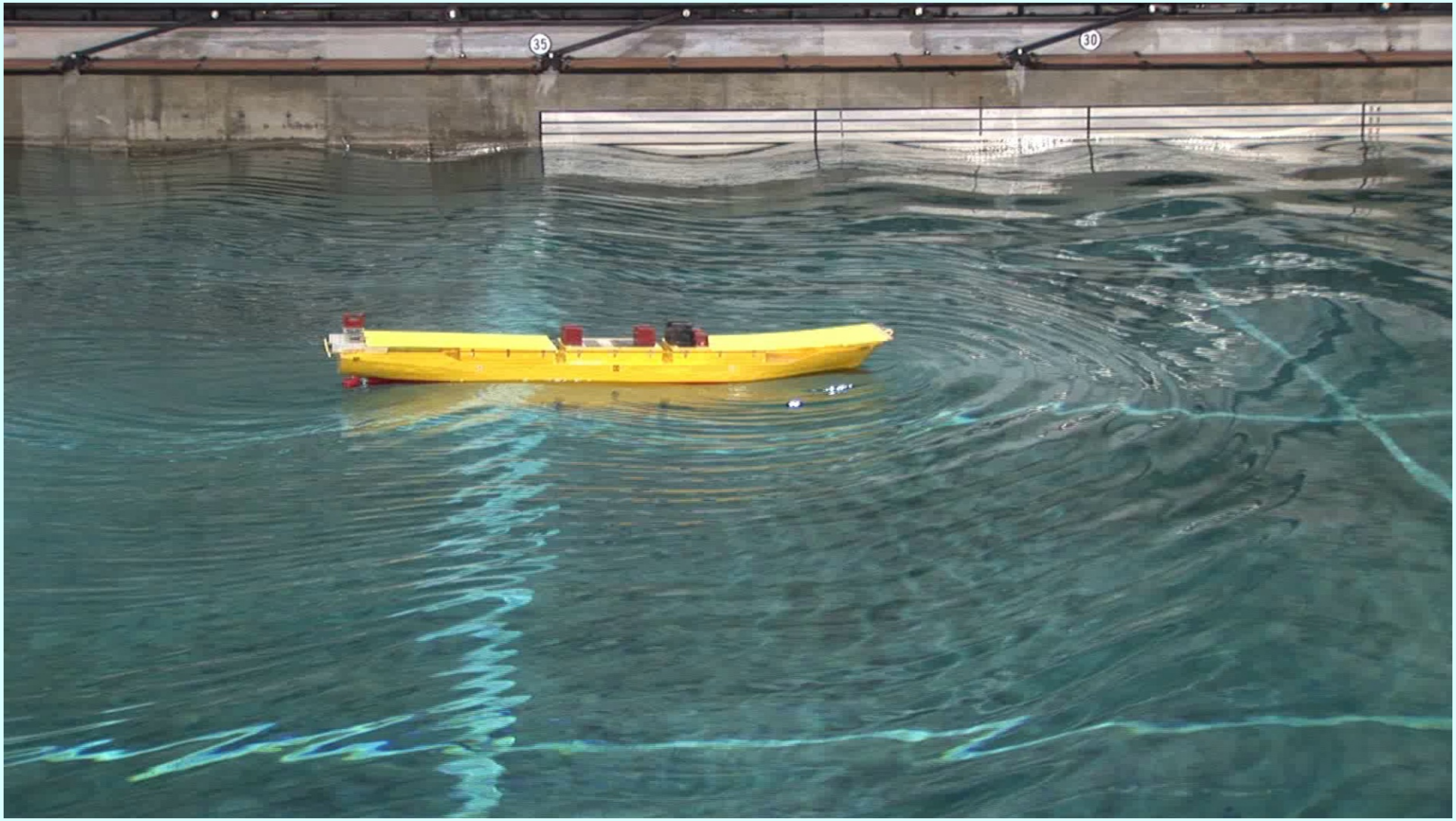
Experimental Data for Benchmark Testing of Head-Sea Parametric Rolling

- ITTC Ship A-1 Containership
  experiment at NRIFE (Japan)
- C11 class post-Panamax Containership
  experiment at MARIN (NL)
- MARIC Panamax Containership
  experiment at MARIC (China)

ITTC Ship A1 Containership

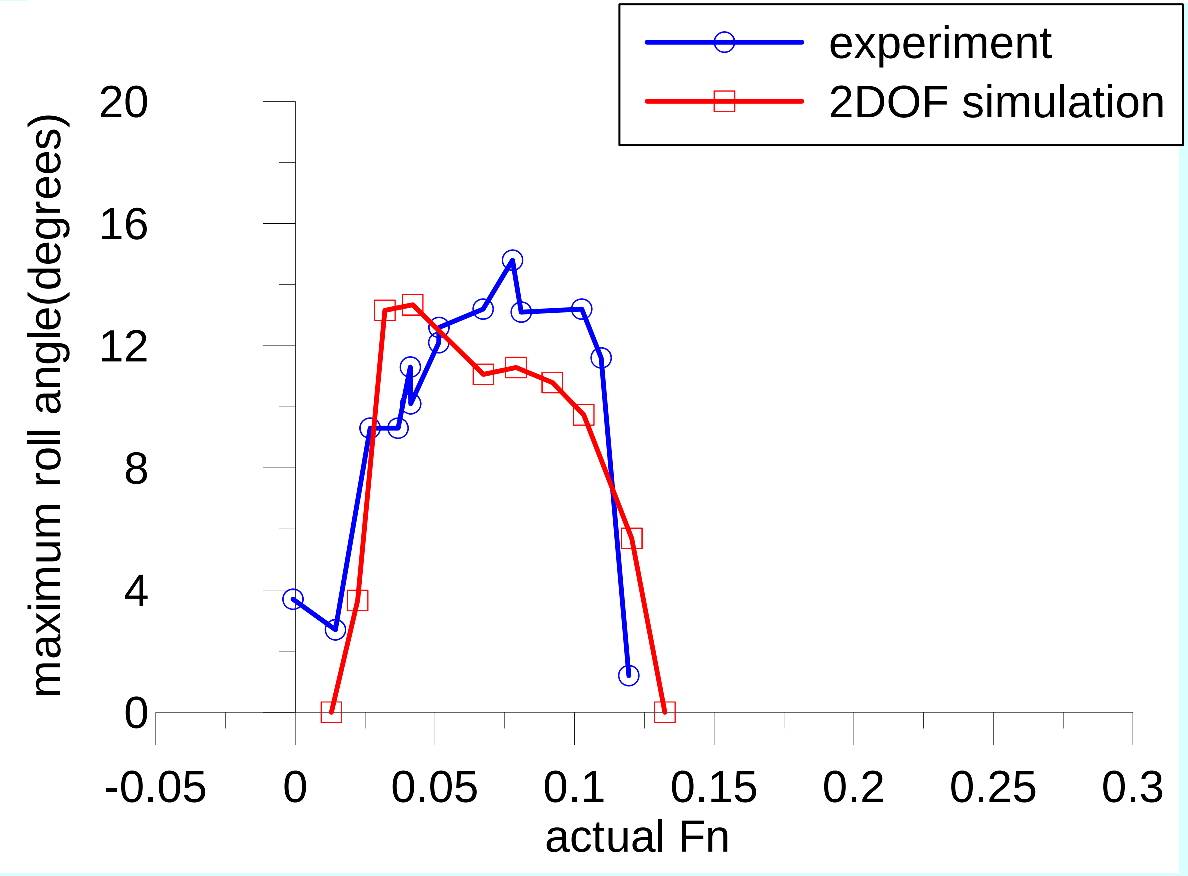


ITTC Ship A1 Containership

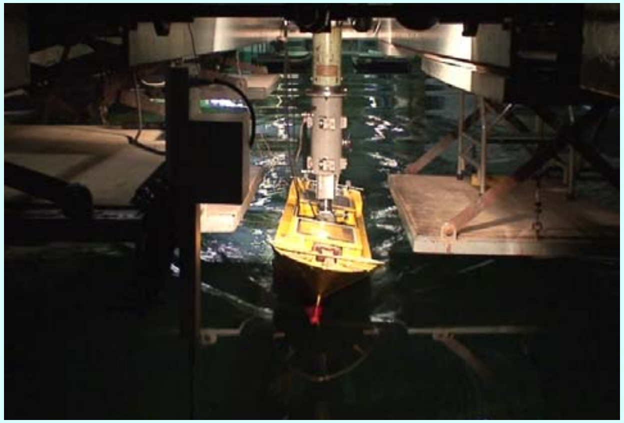


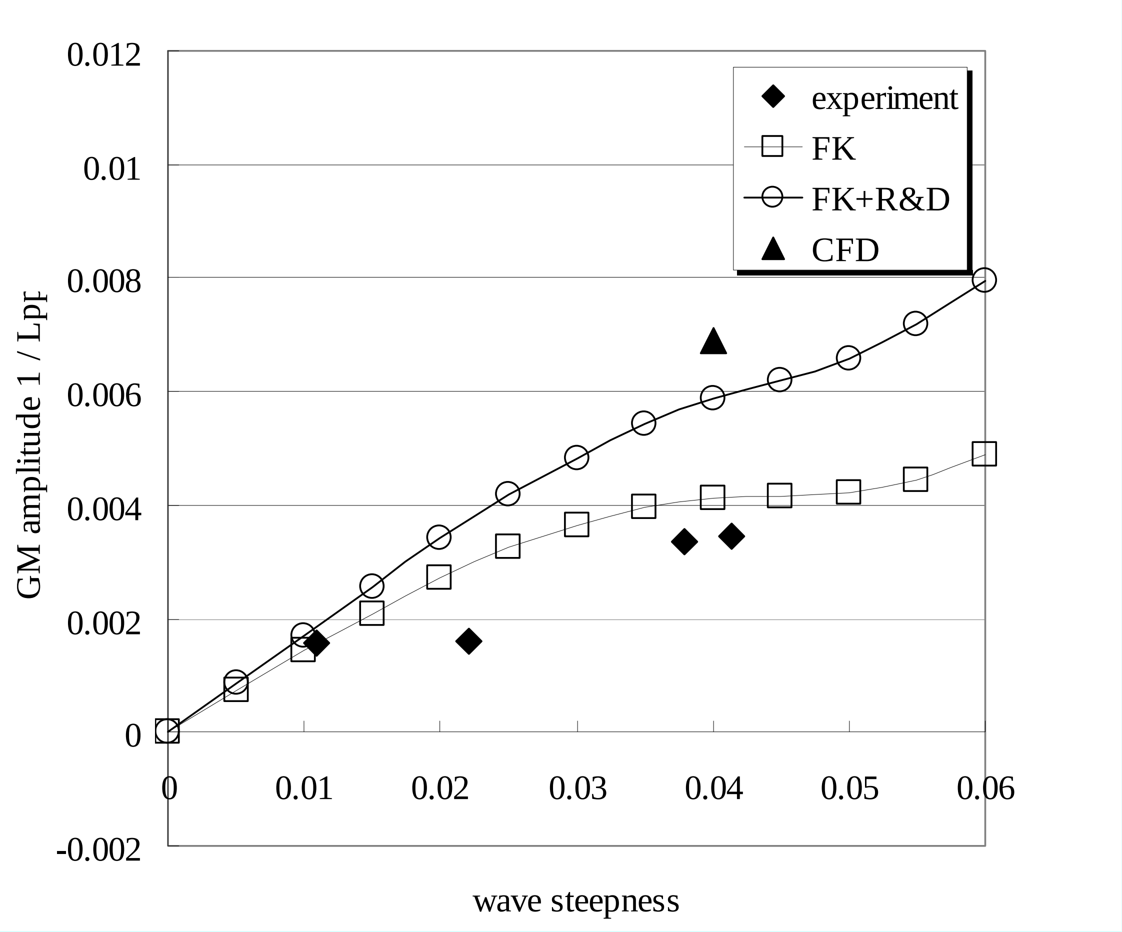
Head-Sea Parametric Rolling of ITTC A1 Containership

$\lambda/L=1.25$ $H/\lambda=0.03$



Restoring Variation of ITTC A1 Containership





C11 Class Post-Panamax Containership

MARIC Containership

Benchmark Testing Plan

Comparative numerical simulations together with experiments

- Roll decay test as a function of forward speed
- Roll and pitch responses in head waves
- Hydrodynamic forces and moment in waves

2. Intact Stability Testing Procedure

- Task : revision “Model Tests on Intact Stability” Procedure 7.5-02.07-04.1
- Literature & expert opinion survey
- Major Extensions:
  - Head-sea parametric rolling
  - Modelling wind loads
  - Generation of transient waves
  - Roll decay test (based on IMO guidelines)
  - Formula of confidence interval for capsizing experiment

3. Damage Stability

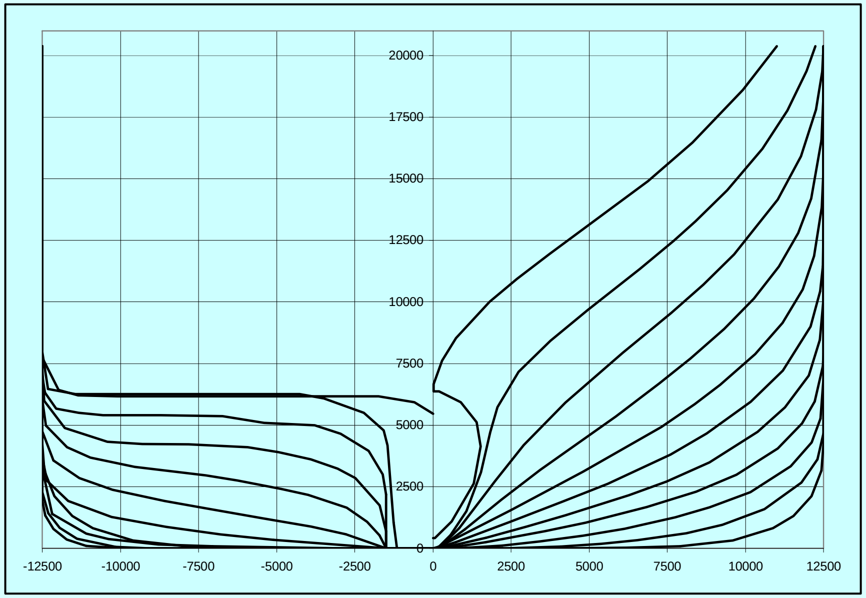
- Literature survey
- Benchmark study of numerical modelling within the European project SAFEDOR
- Benchmark testing of numerical codes for Time-to-Flood for the IMO

3.1 SAFEDOR Benchmark Study on Numerical Prediction of Damage Ship Stability in Waves

Institute	Acronym	Country
National Technical University of Athens, Ship Design Laboratory	NTUA-SDL	Greece
Ship Stability Research Centre, Universities of Glasgow and Strathclyde	SSRC	United Kingdom
Maritime Research Institute Netherlands	MARIN	The Netherlands
Instituto Superior Tecnico, Lisbon	IST	Portugal

Supported by the ITTC SiW committee

Passenger/Ro-Ro Ferry (PRR02)

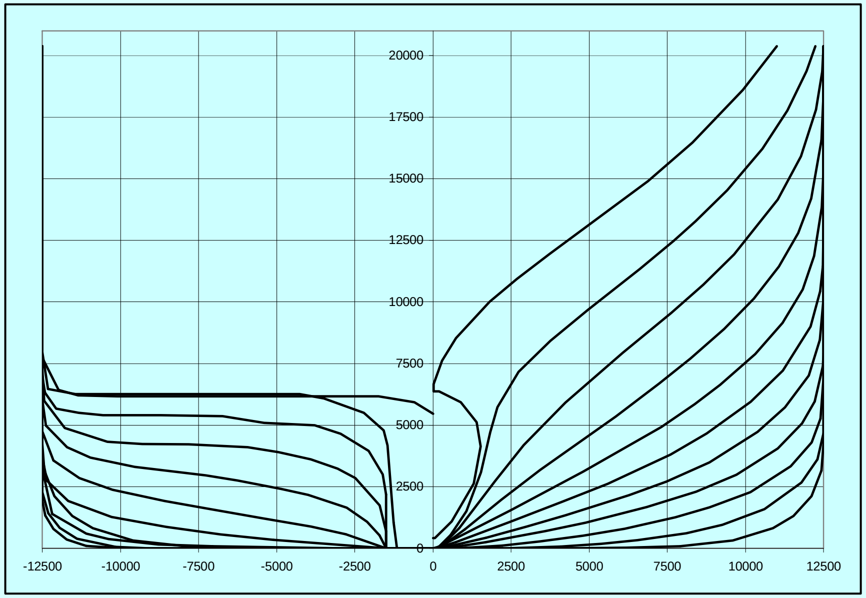


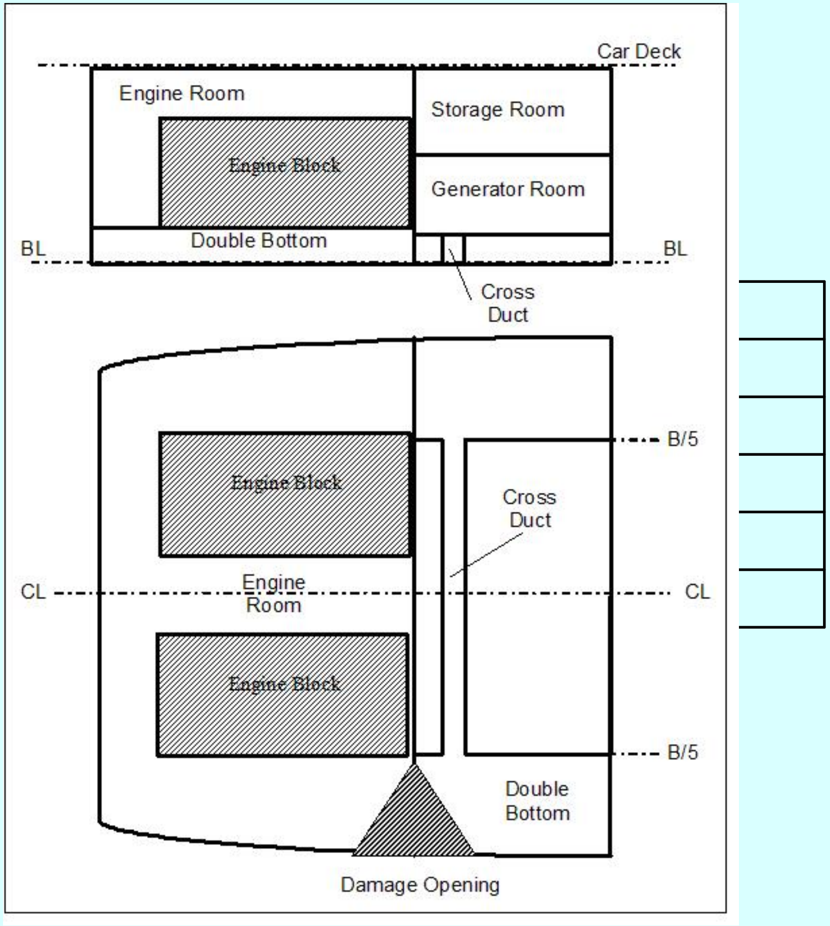
Main Particulars

Length Lpp (m)	174.800
Beam, B (m)	25.000
Draft, T (m)	6.40
Car deck (m)	9.10
Center of gravity above baseline, KG (m)	12.300
Model scale	1:38.25

- Experimental Data: HARDER E.C. project, (2000). "Harmonization of Rules and Design Rational". DG XII-BRITE, 2000-2003. Data provided by MARIN, July 2004.

Passenger/Ro-Ro Ferry (PRR02)





- Experimental Data: HARDER E.C. project, (2000). “Harmonization of Rules and Design Rational”. DG XII-BRITE, 2000-2003. Data provided by MARIN, July 2004.

Benchmark Test Condition

- The damaged Ro-Pax ferry is assumed to be adrift in irrregular beam waves.
- Survival wave height, $H_{s.surv}$ is to be assessed.

Anonymous participant	$H_{s,surv}$ (m)	Mean (m)	Differ. from mean (m)	Exp. (m)
P1	3.23	3.00	+0.23	≤ 3.00
P2	1.75		-1.25	
P3	4.00		+1.00	
P4	3.00		+0.00	

Key Results

- Two codes provided successful predictions of the survival wave height.
- Numerical estimation is most sensitive to KG and wave peak period.
- It is less sensitive to discharge coefficient.
- Effect of roll damping is small. But it is different from the 24th benchmark test results.
- Final results will be reported to the IMO by SAFEDOR.

3.2 Benchmark Study of Numerical Codes for Time-to-Flood

Purpose: Assessment of the state-of-the-art of numerical codes for estimating time-to-flood of a large passenger ship after damage (to contribute to the IMO's work programme titled "time-dependent survivability criteria of passenger ships").

Phase I: A benchmark based on a barge for which detailed model test data (TKK) are available.

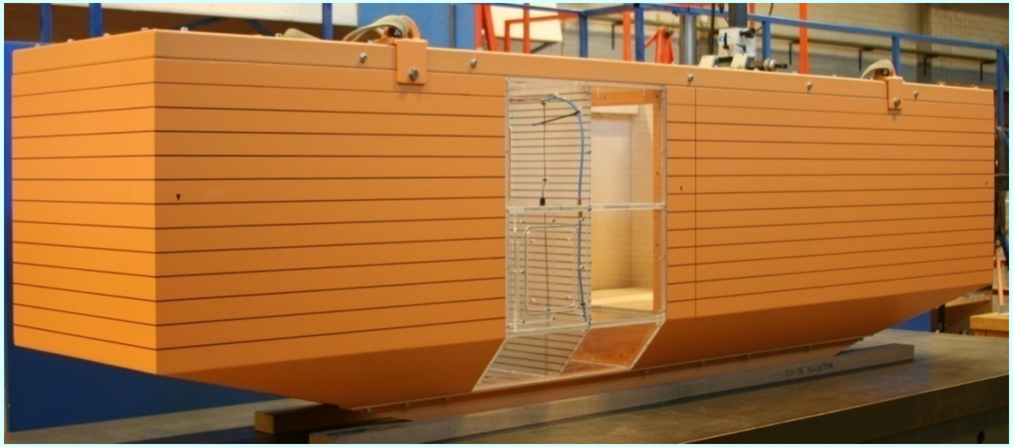
Phase II: A benchmark based on a realistic passenger ship (designed by SSRC) with complex internal geometry. No model test data is available.

Participants in Phase I

- Ship Stability Research Centre (SSRC), United Kingdom.
- Helsinki University of Technology (TKK), Finland.
- Maritime Research Institute Netherlands (MARIN), The Netherlands.
- Maritime and Ocean Engineering Research Institute (MOERI), Korea
- National Technical University of Athens (NTUA), Greece.

Barge Model Used in Phase I

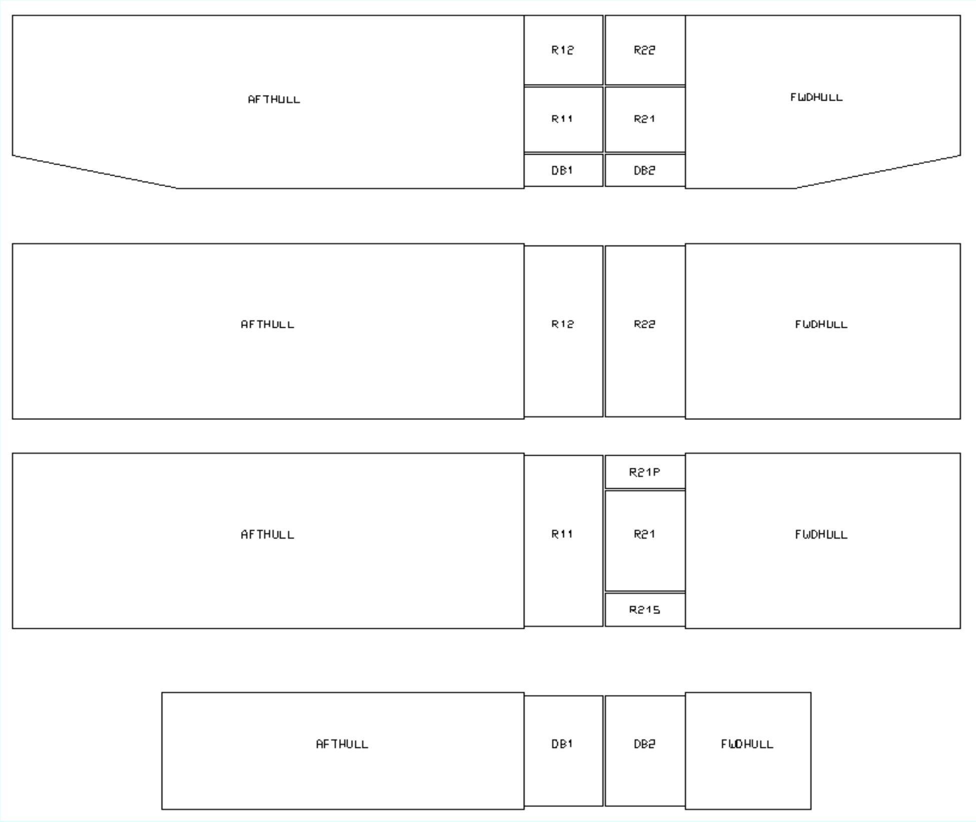
Main Particulars

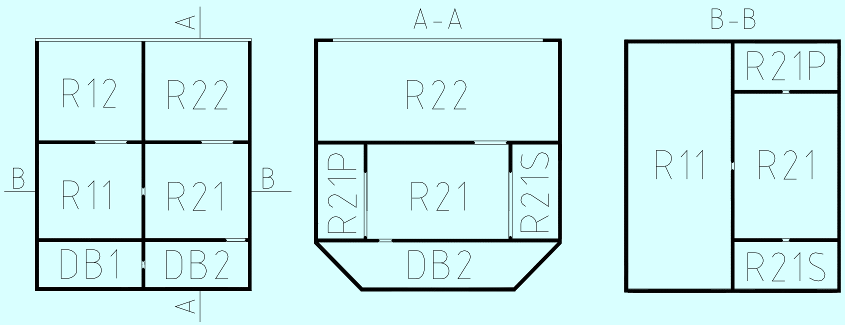


Length over all	4.000 m
Breadth	0.800 m
Height	0.800 m
Design draft	0.500 m
Block coefficient	0.906
Volume	1.450 m^3

Model experiment at the Helsinki University of Technology (TKK) by Dr. Ruponen (2006)

Barge Model Used in Phase I

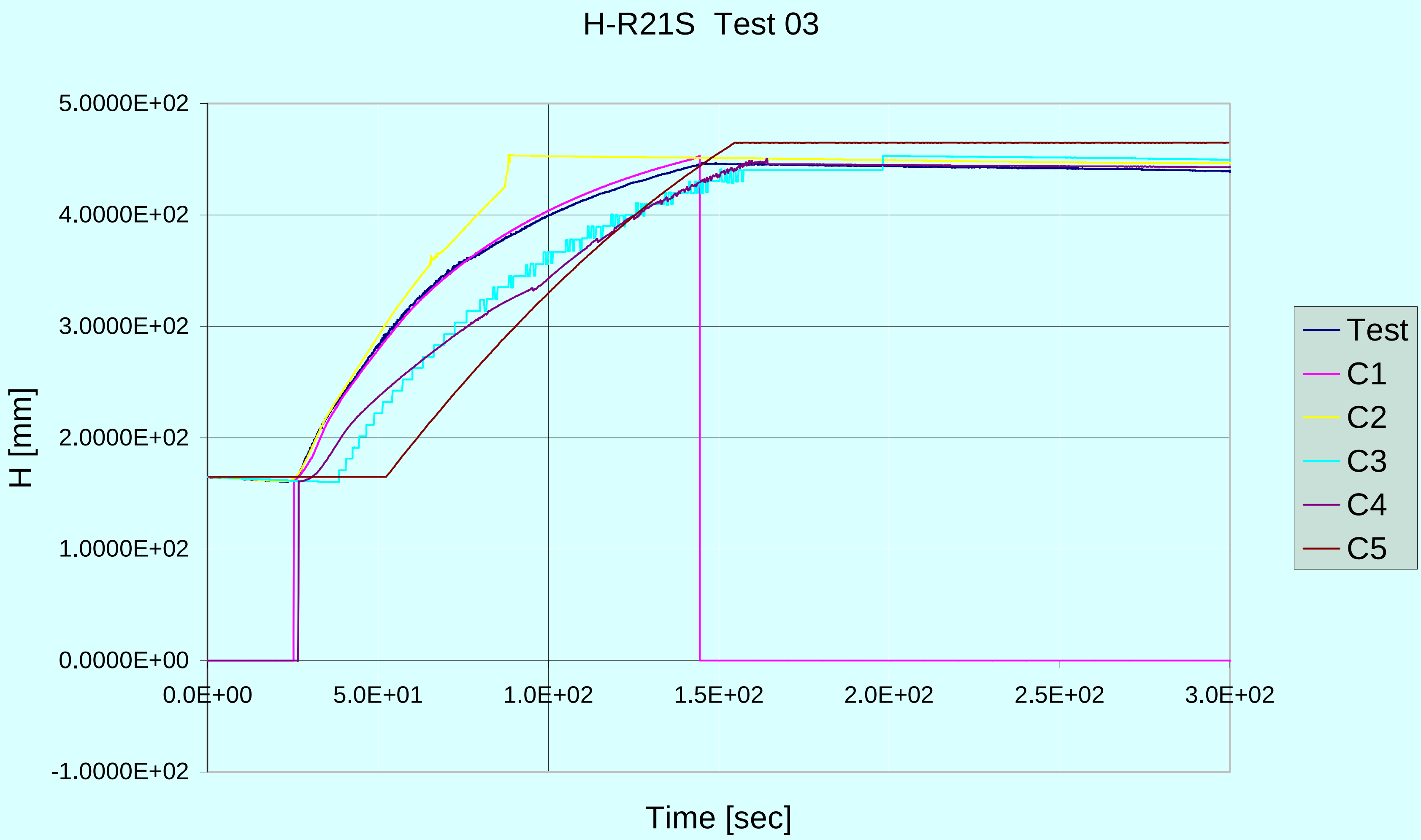




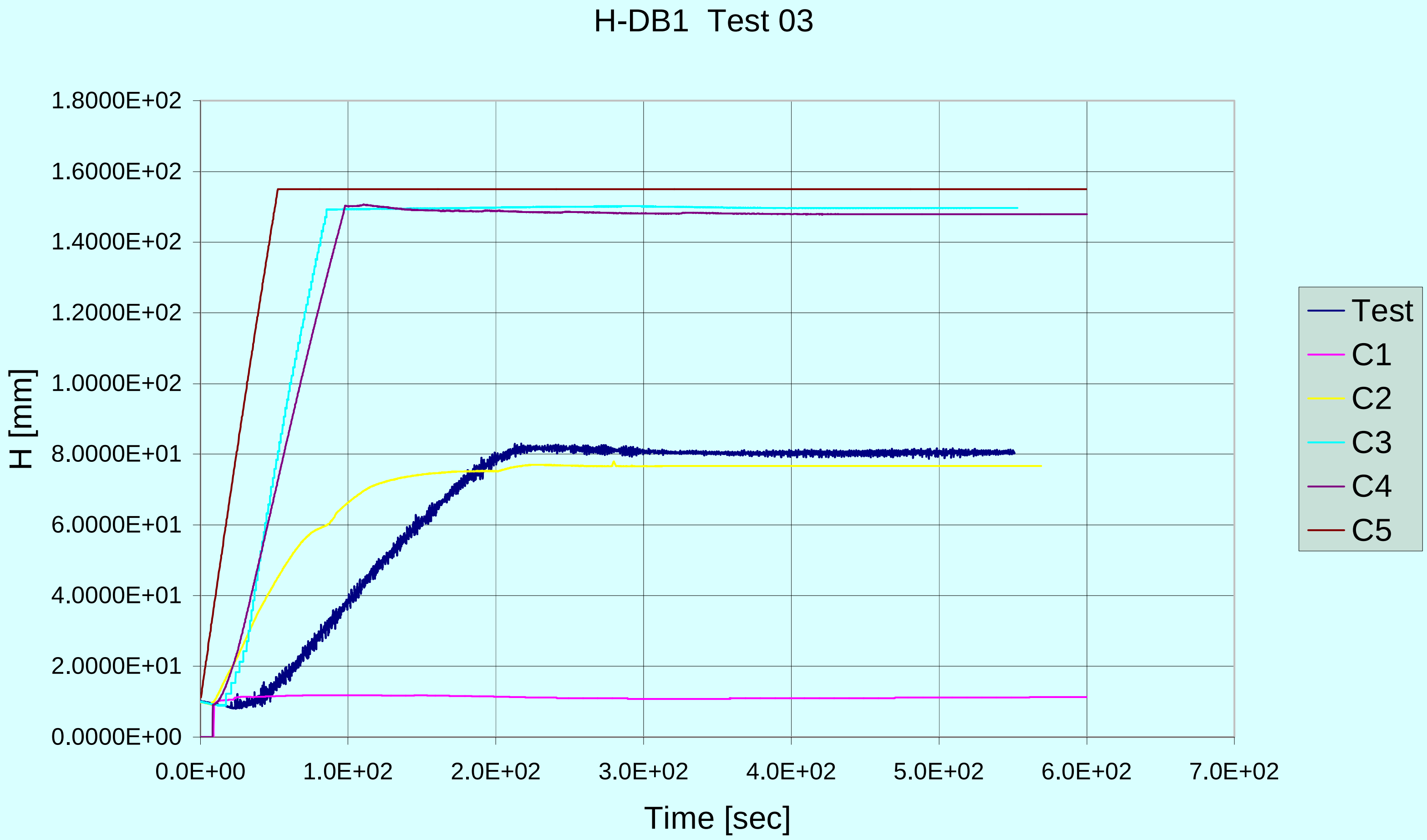
Four different flooding cases [Test 03]

- External opening is in the bottom of DB2 and progressive flooding is allowed.
- Except for DB1, all compartments are ventilated.

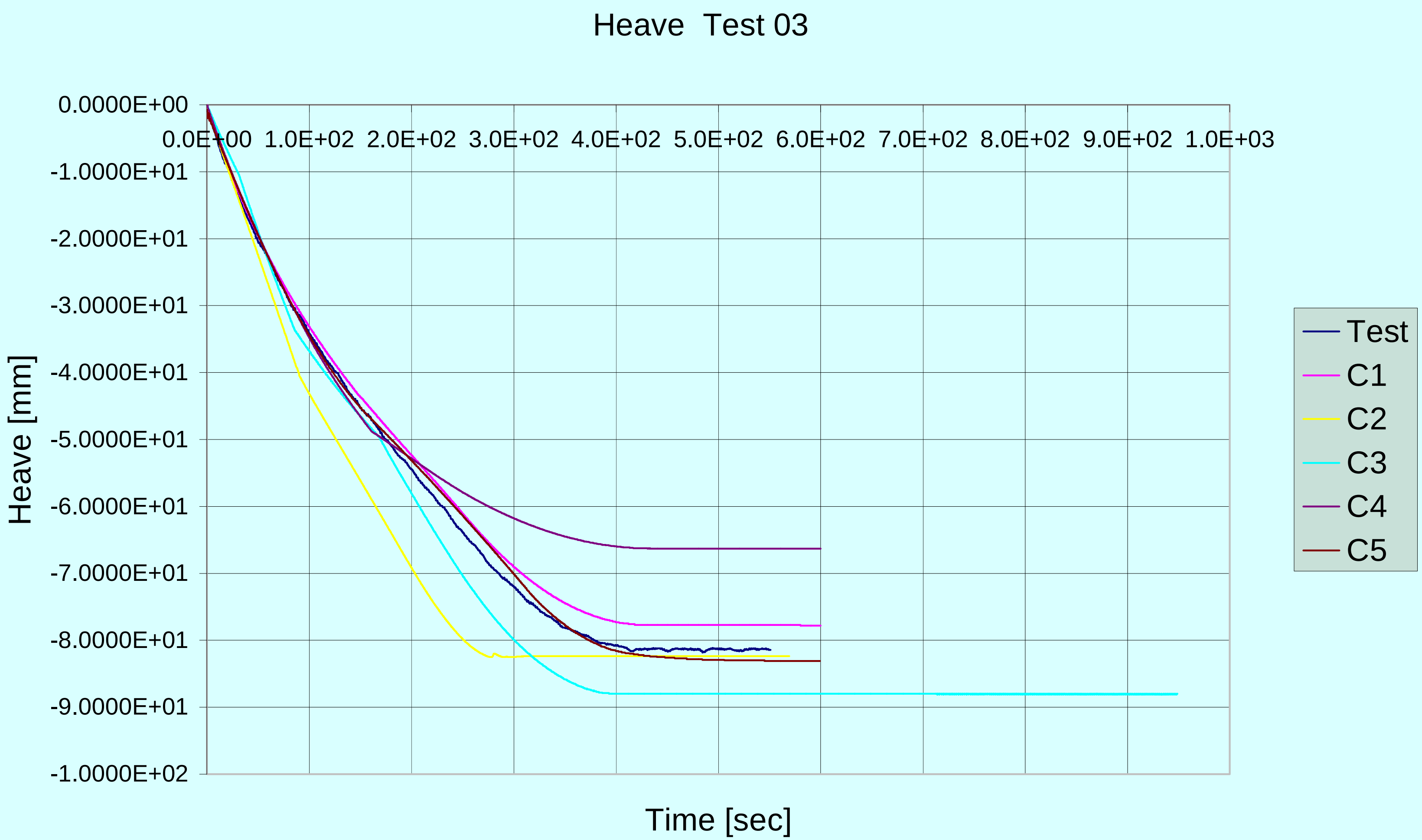
Water Level for Compartment R21S



Water Level for Compartment DB1



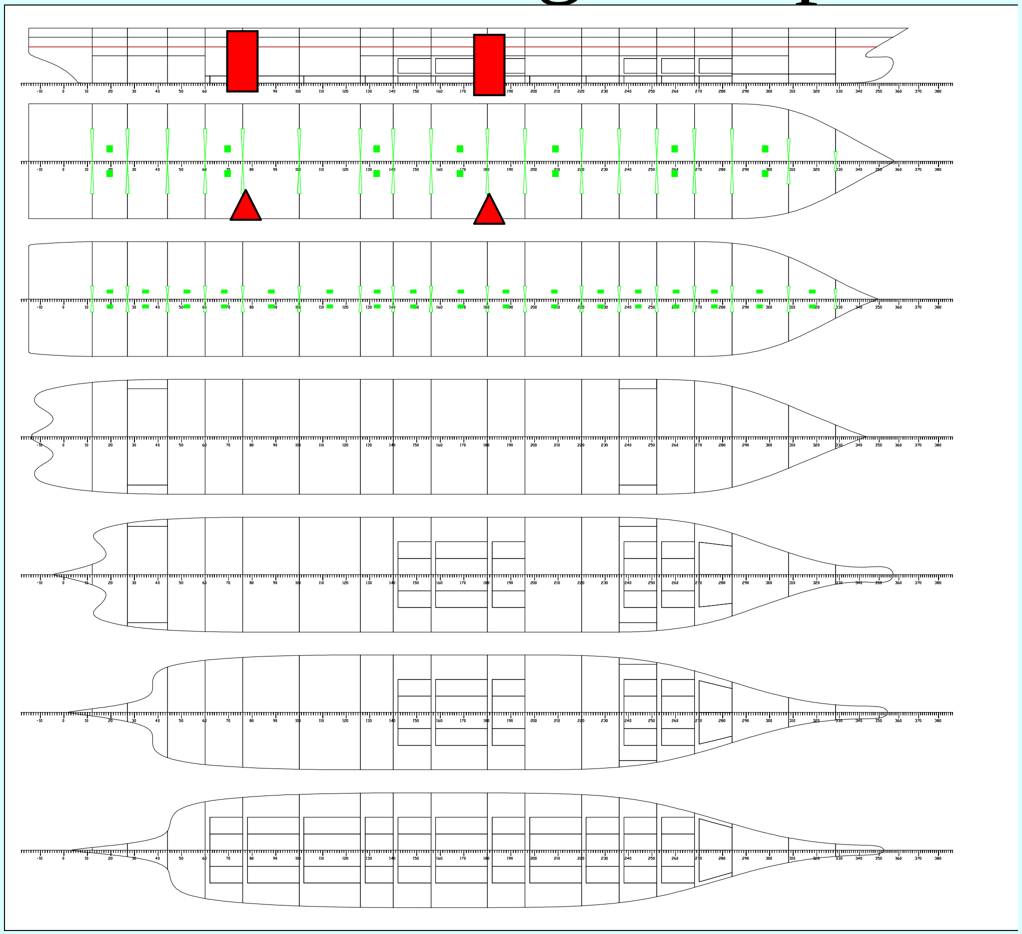
Sinkage of the Barge



Conclusions from Phase I

- Prediction of flooding rates, especially for unventilated compartments shows large variations.
- Differences in local flooding rates on the total flood water mass apparently cancel out, since the equilibrium position is reasonably well predicted by most codes.
- Reasonable time-to-sink predictions appear feasible by most of the present codes, at least for ships having a relatively simple internal geometry and interconnection between flooded compartments under calm water conditions.

Passenger ship used in Phase II

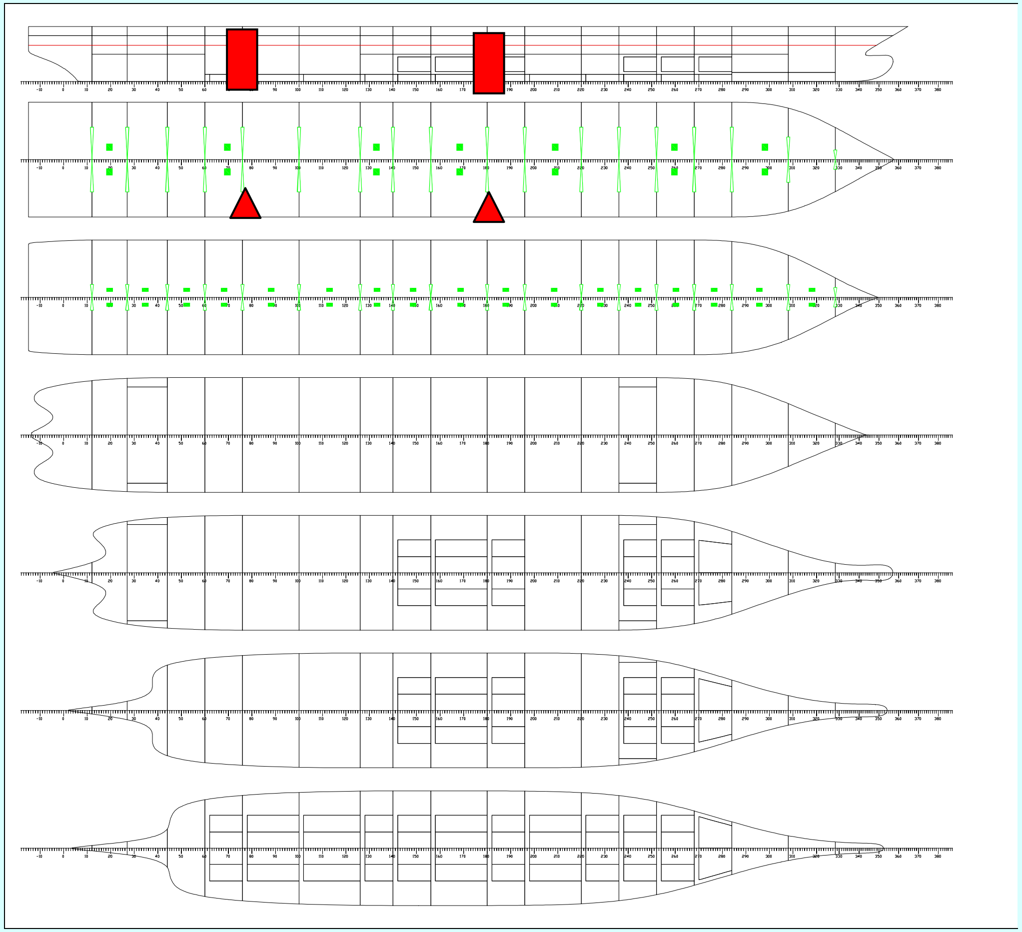


Main Particulars

Mass	56542	[ton]
Lpp	247.7	[m]
B	35.5	[m]
T	8.3	[m]
GM	2.0	[m]

- 142 compartments with 84 openings.
- Ship geometry data were kindly provided by SSRC (UK).

Damage in Phase II



Two damage cases:

•Two-compartment damage aft of amidships.

•Two- compartment damage at amidships

Benchmark Condition

- The ship is freely drifting in irregular waves.
- Survival time should be identified .
- Two damage positions.
- Five sea states per damage case.
- Ten wave realizations per sea state.

Participants in Phase II

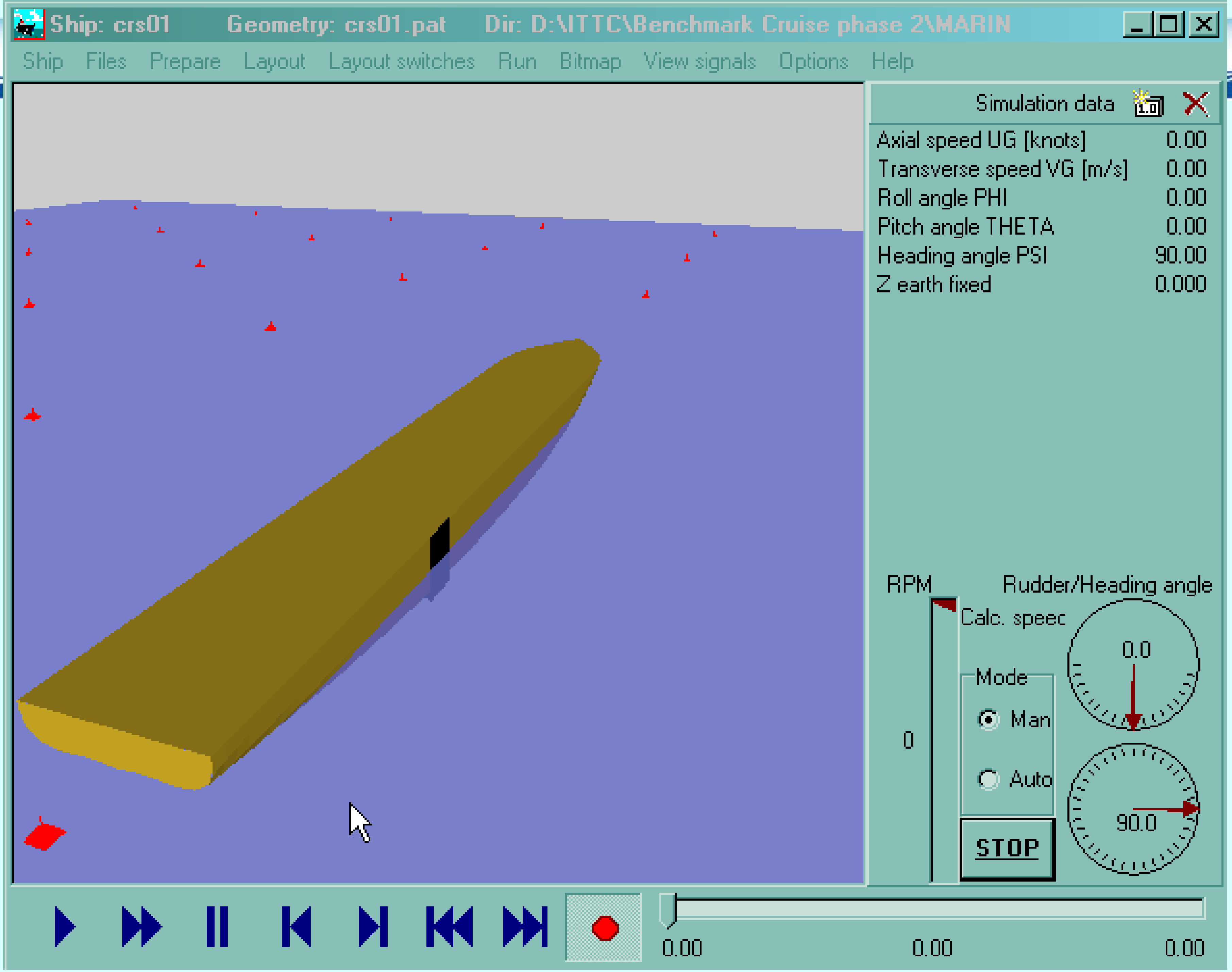
- Ship Stability Research Centre (SSRC), United Kingdom.
- Maritime Research Institute Netherlands (MARIN), The Netherlands.

Numerical Codes Used in Phase II

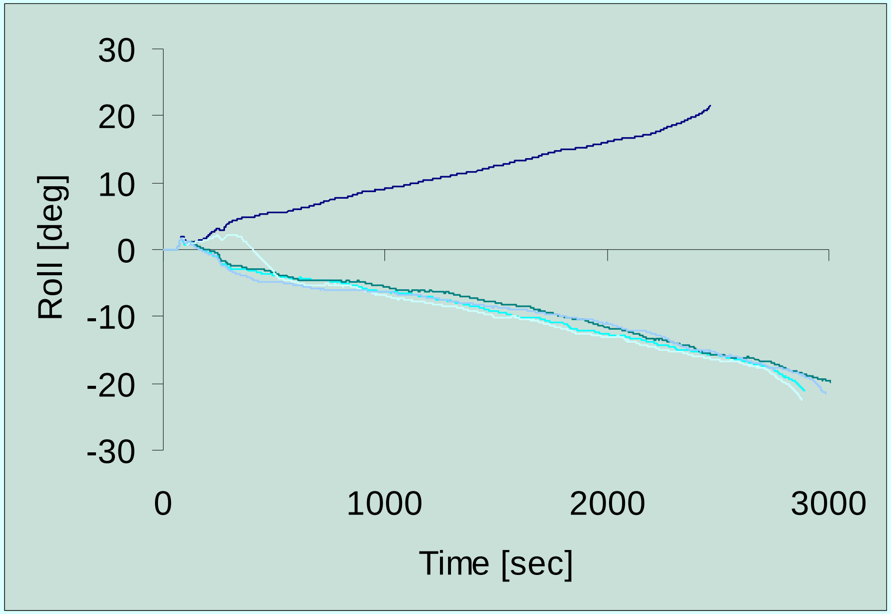
- 6 DOF time-domain simulation
- Nonlinear Froude-Krylov and restoring forces
- Radiation & diffraction forces by strip theory or 3D panel method
- Memory effect is included.
- Viscous forces are semi-empirically estimated.

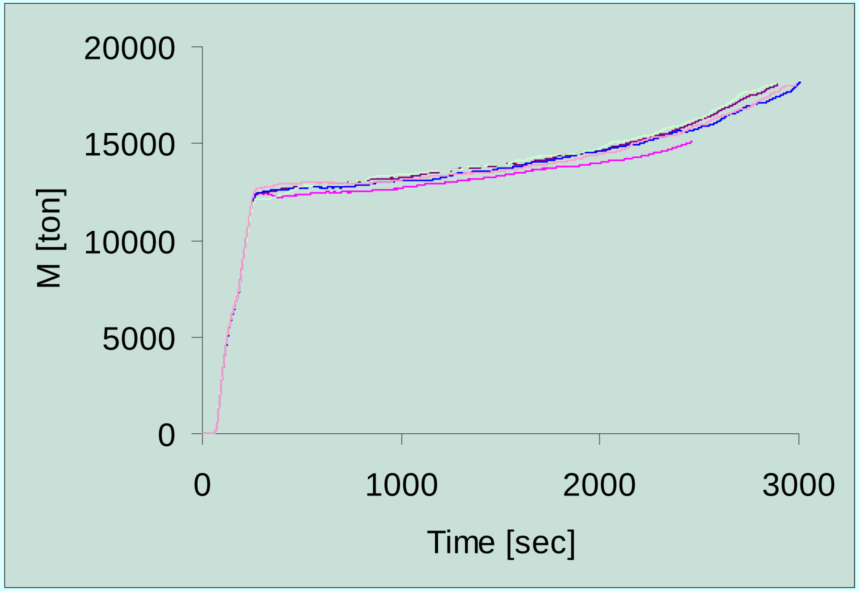
Numerical Codes Used in Phase II

- Flooding model: modified Bernoulli equation with semi-empirical discharge coefficients.
- Internal water surface is planar but horizontal or coupled with ship motion.
- Air compressibility effects were taken into account.


Ship: crs01 Geometry: crs01.pat Dir: D:\ITTC\Benchmark Cruise phase 2\MARIN
Ship Files Prepare Layout Layout switches Run Bitmap View signals Options Help
Simulation data
Axial speed UG [knots] 0.00
Transverse speed VG [m/s] 0.00
Roll angle PHI 0.00
Pitch angle THETA 0.00
Heading angle PSI 90.00
Z earth fixed 0.000
RPM
Rudder/Heading angle
Calc. speec
0.0
Mode
Man
Auto
0
STOP
90.0
0.00
0.00
0.00

Code B for Hs=4m with 5 Realisations





But, other code estimates a constant roll with smaller flooded water mass (M) for H_S=4m.

Conclusions from Phase II

For a large passenger ship with complex interior layout

- For the most severe flooding and sea conditions there were considerable differences in the results from the two codes for the time-to-flood.
- The true performance of the current codes can only be evaluated when accurate experimental model benchmark data are available for comparison.

Reports to the IMO

- SLF 49 (2006): ITTC provided a **plan** for benchmark testing of time-to-flood. (SLF 49/4/2)
- SLF 50 (2007): ITTC provided a **report on Phase I** benchmarking. (SLF 50/8)
- SLF 51 (July 2008) ITTC provided a **report on Phase II** benchmarking. (SLF 51/8)
- IMO has invited member states and NGOs to submit proposals based on the reports from the ITTC.

4. Stability Safety Assessment

- During this term, application of performance-based approaches can be found mainly in intact stability .
- US Navy developed dynamic stability criteria because the conventional criteria do not explain the safety margin of tumblehome ship designs. The new criteria are based on a relative capsizing risk assessment . (US Navy 2002 & 2003b)
- At the IMO, alternative way of assessment of weather criterion using model experiments at a towing tank and/or wind tunnel is permitted with guidelines. (MSC.1/Circ. 1200, 2006)

- Under a revision of the Intact Stability Code, new-generation intact stability criteria are now under development at IMO.
  - –They will cover three major phenomena:
    - a) Stability variation problems such as parametric rolling,
    - b) Stability under dead ship conditions
    - c) Manoeuvring-related problems such as broaching.
  - –Vulnerability criteria and direct stability assessment methodology are required to be developed .
  - –ITTC is now invited to take part in the correspondence group on this task.

5. Conclusions and Recommendations

- Procedure 7.5-02-07-04.1 “Model Tests on Intact Stability” has been updated and extended to cover head-sea parametric rolling.
- Experimental data of head-sea parametric rolling for benchmark tests are identified.
- Responding to requests from IMO, prediction capabilities of numerical codes for time-to-flood have been investigated through benchmark studies.

Recommendations to ITTC

- Adopt:

  Revised Procedure 7.5-02-07-04.1

  “Model Tests on Intact Stability”.

Thank you for your kind attention.

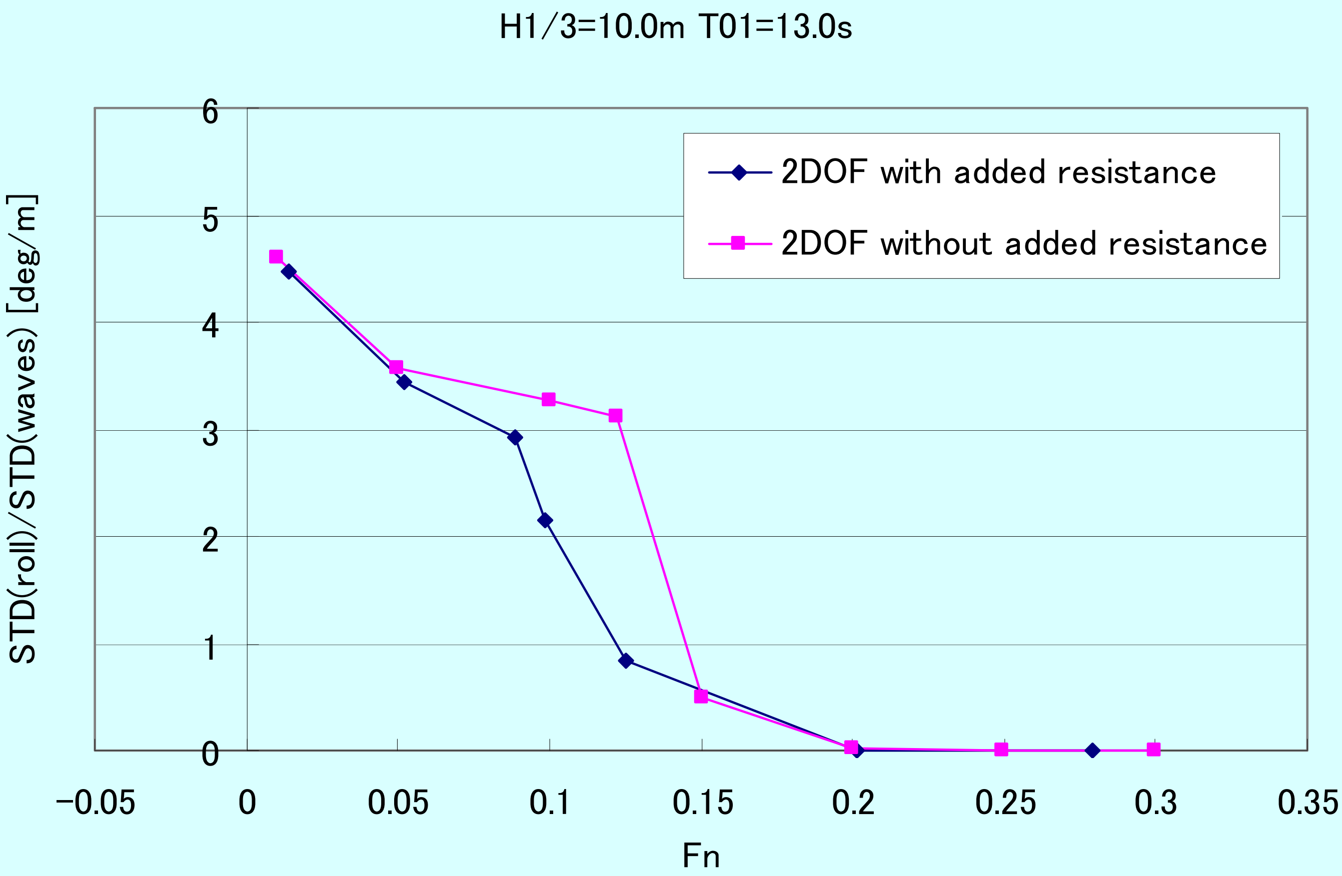


Figure 1 Effect of added resistance on parametric rolling in head waves in the light of numerical simulation I
n the time domain. (Umeda and Francescutto, 2008)