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Instructions for the benchmark study on flooding fundamentals

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1 INTRODUCTION

1.1 Background

Within the EU Horizon 2020 project FLARE, an extensive benchmark study on numerical simulation of flooding in simple geometries with fixed floating position. New dedicated model tests were performed at MARIN. The test cases involve up and down flooding, as well as extensive progressive flooding on a typical deck layout of a cruise ship.

In addition to the FLARE partners, also external participants with recent publications on flooding simulation tools were invited to contribute. The results of the benchmark study have been published in Ruponen et al. (2021).

The FLARE consortium has agreed to share the benchmark material to enable validation of new and improved simulation tools and further benchmarking in the future. This short document describes the available material.

1.2 Use of material

The provided material can be freely used for validation of flooding simulation codes, provided that:

- FLARE consortium and MARIN are acknowledged for sharing the data
- The following publication, presenting the benchmark study cases, is cited:

  Ruponen, P., van Basten Batenburg, R., Bandringa, H., Braidotti, L., Bu, S., Dankowski, H., Lee, G.J., Mauro, F., Murphy, A., Rosano, G., Ruth, E., Tompuri, M., Valanto, P., van't Veer, R. 2021. Benchmark Study on Simulation of Flooding Progression, *Proceedings of the 1st International Conference on the Stability and Safety of Ships and Ocean Vehicles*, 7-11 June 2021, Glasgow, Scotland, UK.

1.3 Summary of material

Geometry and definitions (all dimensions in model scale):

- drawing_box.dxf (geometry of box model for up and down flooding cases, including sensor locations).
  - Note that only the compartment with the tween deck (leftmost in the drawing) was used in the benchmark cases, and all openings in the deck were closed.
- drawing_deck.dxf (geometry of deck layout, including sensor locations)
  - Note that only the green and blue internal bulkheads were included in the model that was used for the benchmark study.
- deckmodel.3dm (Rhino 3D model of the deck layout)

Measurement data:

- up_flooding_measurements.csv (measured water levels in the up flooding case
- down_flooding_measurements.csv (measured water levels in the down flooding case
- deck_flooding_measurements.csv (measured water levels in the deck flooding case)

Videos of the model tests:

- up_flooding_video.mp4
- down_flooding_video.mp4
- deck_flooding_video1.mp4
- deck_flooding_video2.mp4

1.4 Contact information

The FLARE benchmark study was coordinated by NAPA, and general questions should be addressed to Dr. Pekka Ruponen (pekka.ruponen@napa.fi)

Model tests were conducted at MARIN, further information can be asked from Mr. Rinnert van Basten Batenburg (r.v.bastenbatenburg@marin.nl) and Dr. Riaan van't Veer (r.vantveer@marin.nl)

2 BENCHMARK MATERIAL

2.1 Test cases

This part of the FLARE benchmark study includes three flooding scenarios:

- Up-flooding in a box with opening in the tween deck
- Down-flooding in a box with opening in the tween deck
- Deck flooding

In all cases the model is captive (fixed floating position) and the focus is on the progress of flooding inside the model.

2.2 Geometry for up & down flooding cases

The up and down flooding cases use the same box-shaped model with a tween deck, the only difference is the location of in-flooding opening, as shown in Figure 1. It should be noted that the model contained also two other compartments that were not used in the benchmark study.

The detailed geometry and dimensions are presented in Figure 2 for the up flooding case and in Figure 3 for the down flooding case. Note that the size of the opening in the tween deck is different. Water level sensors 23 and 27 are the primary measurement signals, and the locations of these sensors are also shown in these figures.

Both flooded rooms are ventilated through large pipes, as shown in Figure 1, and thus full ventilation can be assumed in simulations. The volume of the ventilation pipes can be taken into account, but based on the published benchmark study results, the effect is marginal.

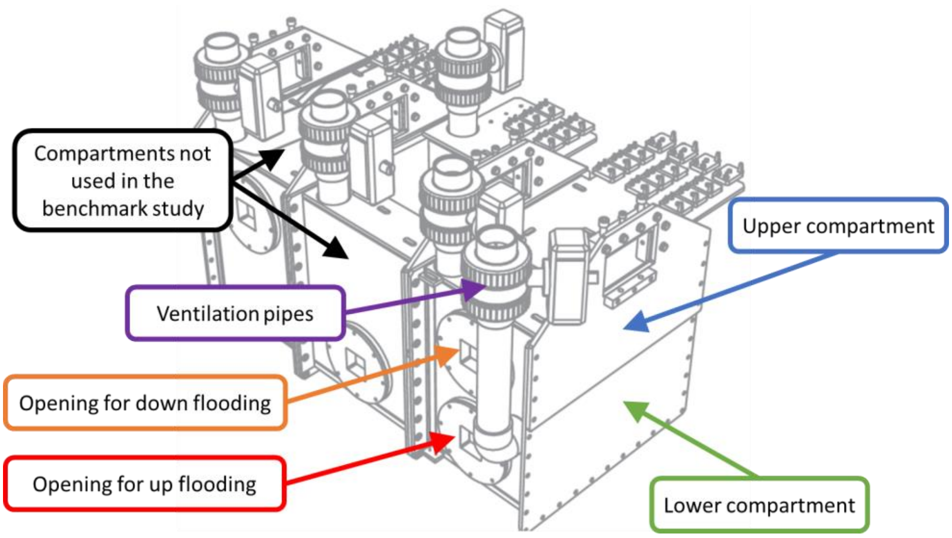

Figure 1 Visualization of the box-model used for both up and down flooding cases.

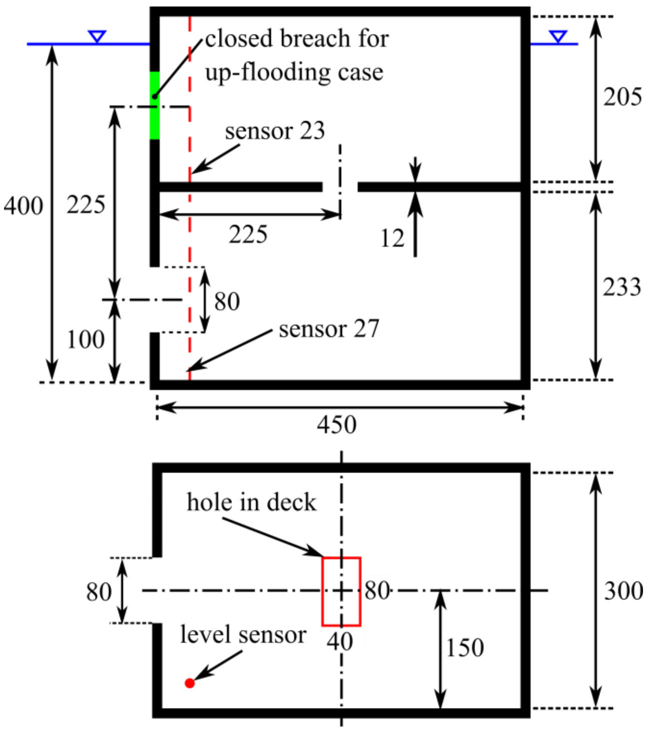

Figure 2 Box model with tween deck in the up flooding case.

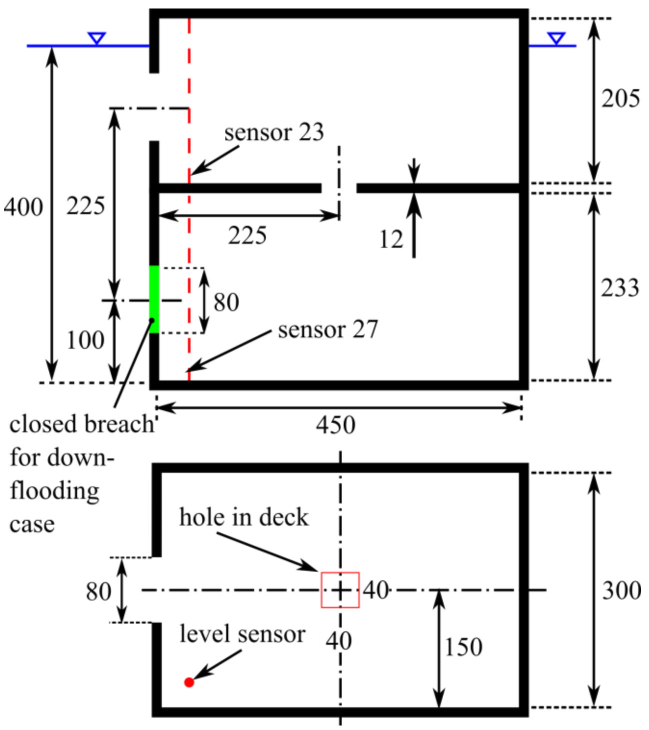

Figure 3 Box model with tween deck in the down flooding case.

2.3 Geometry for the deck flooding case

For the deck flooding case, a simplified geometry of part of the bulkhead deck of a cruise ship was used, Figure 4. The scale of the deck model is 1:60. The “breach” is between two partial transverse bulkheads. Detailed geometry (in model scale), including internal openings and locations of the water level sensors are presented in the file:

- drawing_deck.dxf

The model top is open, so all rooms are fully ventilated.

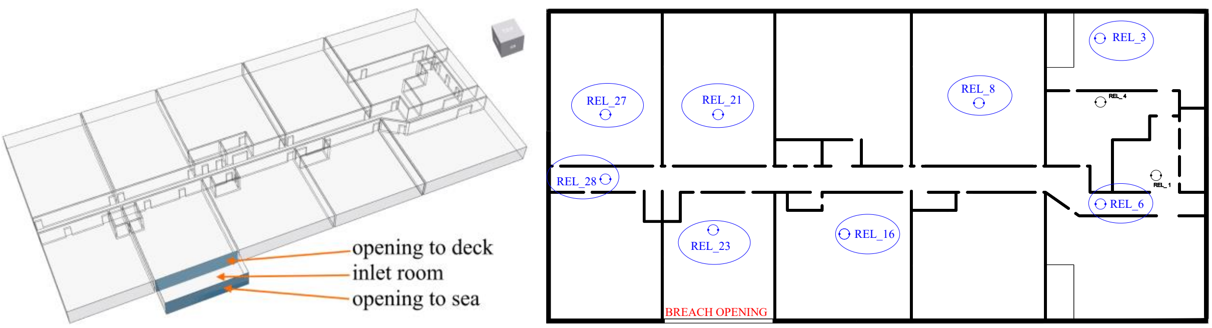

Figure 4 compartment arrangement in the deck flooding case, and the selected water level sensors.

2.4 Openings

For simulation codes based on hydraulic model and Bernoulli’s equation, the discharge coefficients of the openings in the models are provided below.

Case	**Opening**	**C_d**	**Explanation**
Up&Down	80 mm × 80 mm	0.65	Average from dedicated tests by MARIN
Up	80 mm × 40 mm	0.65	Same as for the inflow openings
Down	40 mm × 40 mm	0.70	Average from dedicated tests by MARIN
Deck	Narrow openings (width < 30 mm)	0.73	Based on test by MARIN with an opening size of 17 mm × 34 mm
Deck	Wide openings (width ≥ 30 mm)	0.70	Based on test by MARIN with an opening size of 47 mm × 34 mm
Deck	Breach	0.65	Same as for the inflow openings (80 mm × 80 mm)

3 TEST CASES

3.1 Up flooding

The inflow opening (size 80 mm × 80 mm) is in the side of the lower compartment of a box-shaped model. The flooded rooms are separated by a deck with a 40 mm × 80 mm hole in the middle of the deck. Draft is constant 400 mm throughout the test. For detailed dimensions, see Figure 2.

Measurement data for the water level sensors in both flooded rooms are given in the file:

- up_flooding_measurements.csv

Flooding is started at about 77.7 s.

For sensor locations, see the drawing:

- drawing_box.dxf

The progress of flooding can be seen in the left-hand side of the video:

- up_flooding_video.mp4

The timing of the video matches the measurement file.

3.2 Down flooding

The compartment geometry is the same as in the up-flooding case, but the breach opening (size 80 mm × 80 mm) is now located in the upper compartment and the hole in the deck is smaller, 40 mm × 40 mm, as shown in Figure 3. Also in this case the draft is constant 400 mm throughout the test.

Measurement data for the water level sensors in both flooded rooms are given in the file:

- down_flooding_measurements.csv

Flooding is started at about 74.7 s.

For sensor locations, see the drawing:

- drawing_box.dxf

The progress of flooding can be seen in the left-hand side of the video:

- down_flooding_video.mp4

The timing of the video matches the measurement file.

3.3 Deck flooding

The third case considers extensive progressive flooding along a typical deck layout of a cruise ship, including a long central service corridor, Figure 4. The scale of the model is 1:60, and the draft of the model is constant 0.03 m above deck level (in model scale). The breach on the side of one compartment is opened instantly, causing the flooding of the deck.

The measurement data file contains water levels at all sensors in the model, not only the ones that were used in the FLARE benchmark study. The sensor locations are marked in the file:

- drawing_deck.dxf

The 3D geometry is also provided in the file:

- deckmodel.3dm

Measurement data (in model scale) is in the file:

- deck_flooding_measurements.csv

Note that the flooding starts at about 36.6 s, and the openings in the deck were closed to prevent any down-flooding.

Flooding progression on the deck can be seen from the two videos:

- deck_flooding_video1.mp4
- deck_flooding_video2.mp4

The timing of the videos matches the measurement file.

Modelling guidance

In the FLARE benchmark study, Ruponen et al. (2021), for Bernoulli-based codes, a common modelling practice for the corridor was adopted, by dividing the long corridor into five adjacent rooms with division at the locations of the partial bulkheads, Figure 5. A discharge coefficient 1.0, i.e. no flow losses, was then applied for these artificial openings.

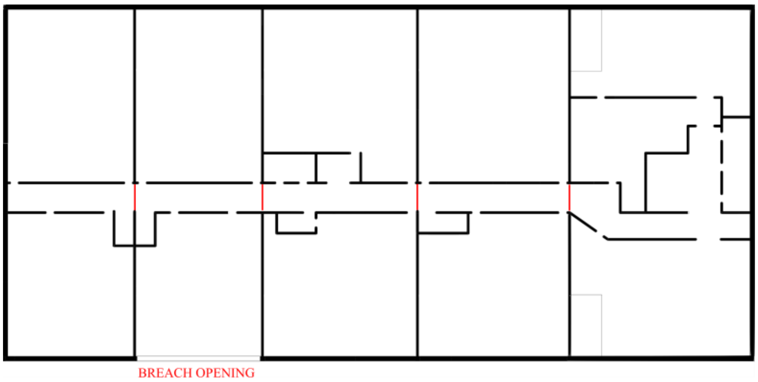

Figure 5 Recommended modelling of the long service corridor when using Bernoulli-based flooding simulation code: the room is dividing it into five parts, connected by four openings (marked with red).

4 REFERENCES

Ruponen, P., van Basten Batenburg, R., Bandringa, H., Braidotti, L., Bu, S., Dankowski, H., Lee, G.J., Mauro, F., Murphy, A., Rosano, G., Ruth, E., Tompuri, M., Valanto, P., van't Veer, R. 2021. Benchmark Study on Simulation of Flooding Progression, Proceedings of the 1st International Conference on the Stability and Safety of Ships and Ocean Vehicles, 7-11 June 2021, Glasgow, Scotland, UK.