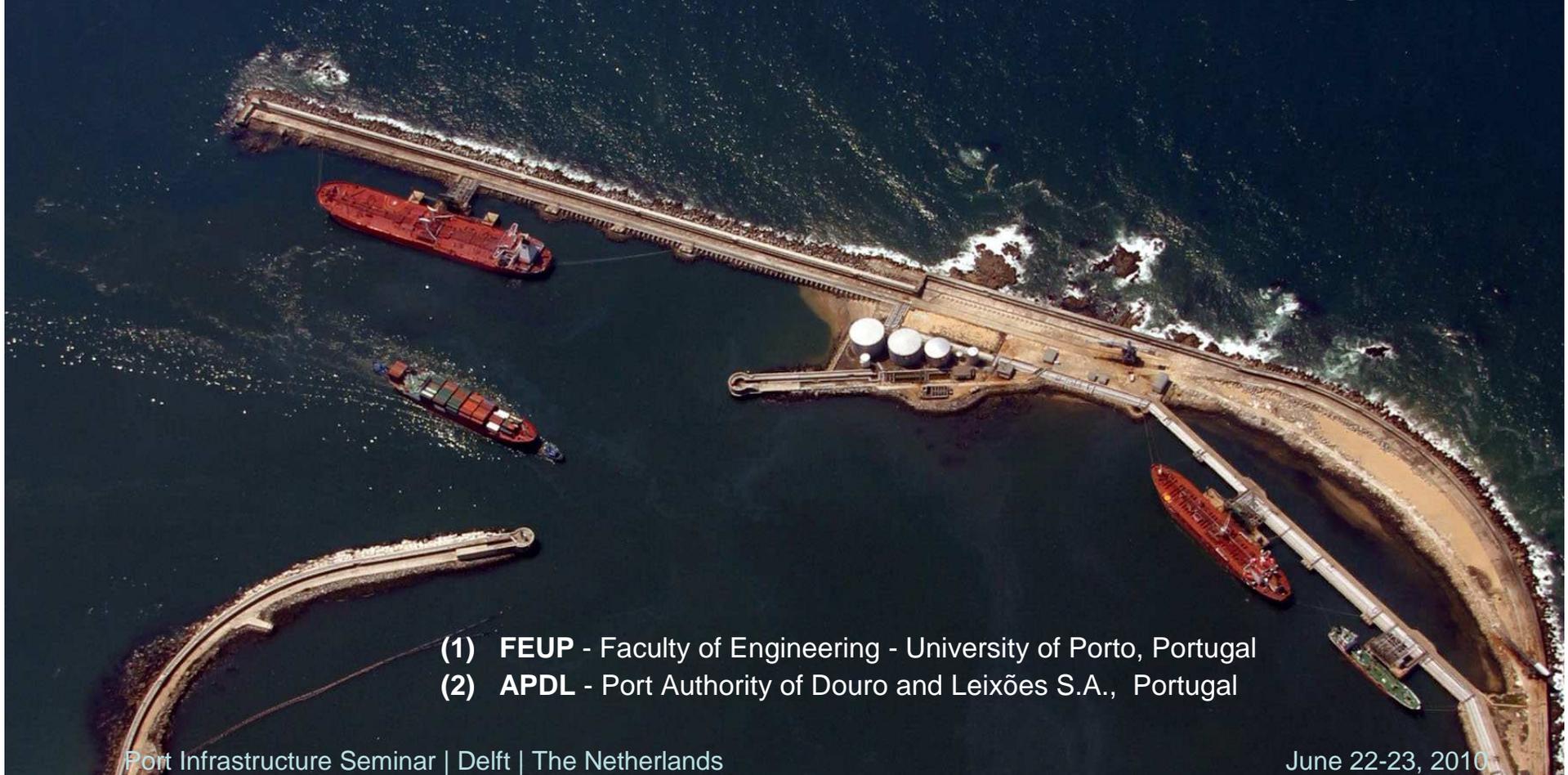


# PHYSICAL MODELLING OF LEIXÕES OIL TERMINAL - PORTUGAL

P. Rosa Santos<sup>1</sup> F. Veloso Gomes<sup>1</sup> F. Taveira Pinto<sup>1</sup> E. Brògueira Dias<sup>2</sup>

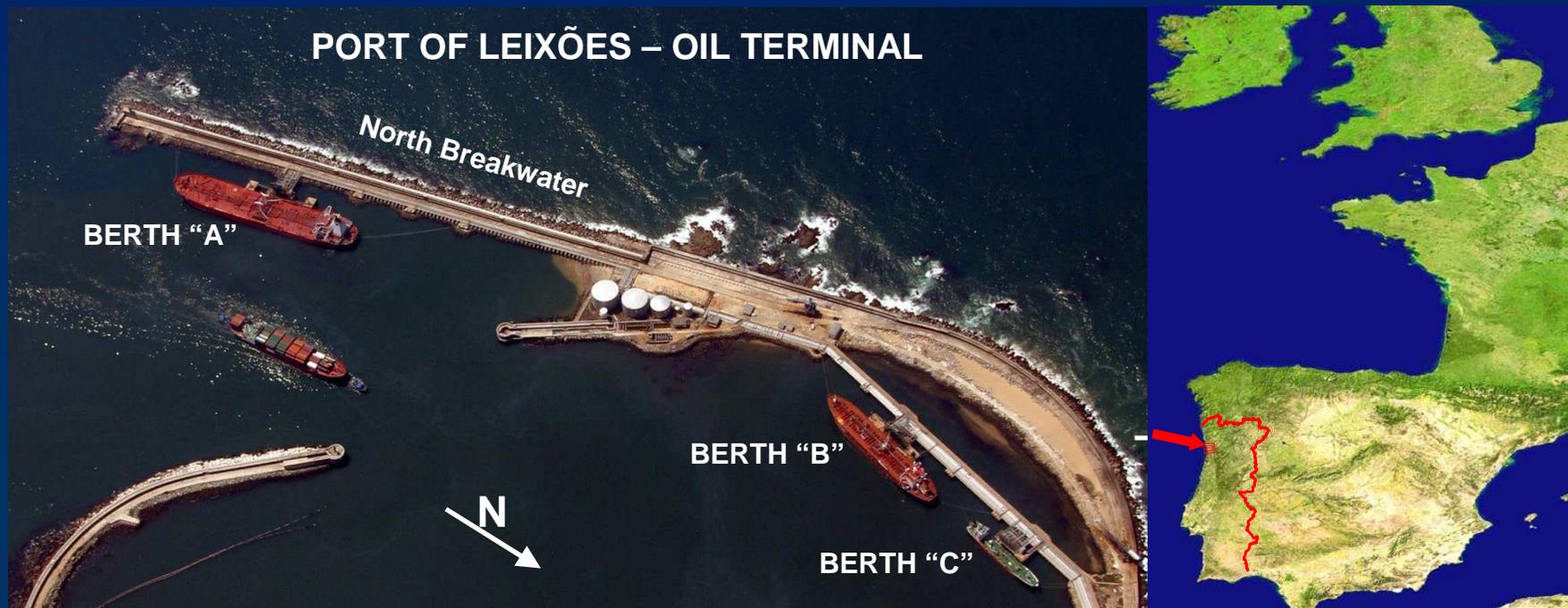


- (1) FEUP - Faculty of Engineering - University of Porto, Portugal
- (2) APDL - Port Authority of Douro and Leixões S.A., Portugal

## I – INTRODUCTION

### BERTH “A” OIL TERMINAL

- Located at the harbor entrance, parallel to the Leixões North breakwater;
- Exposed to rough environmental conditions (facing the North Atlantic):
  - During storms  $H_s$  exceed 8 m (about once per year) and  $T_p$  can be on the order of 16 to 18 s;
  - **W** and **NW** are the dominant wave directions;
- Berthing structure: Jetty with 2 breasting dolphins and a loading platform;
- Oil tankers up to 100,000 dwt (~ 250 m length overall).





## I – INTRODUCTION

### BERTH “A” DOWNTIME

#### BACKGROUND – PAST STUDIES

Breakwater overtopping | Water jets transmission through the breakwater core | Proximity to the breakwater’s head | Resonance near berth “A” | Characteristics of the mooring & fendering systems.

#### R&D PROJECT: DOLPHIN - PTDC/ECM/72835/2006

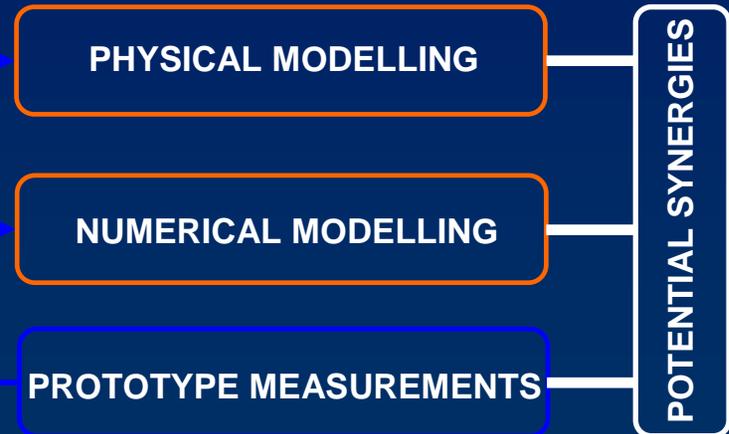


Started in – JAN 2008  
Duration – 3 years

#### CASE STUDY

Berth “A” of Leixões Oil Terminal

MODEL VERIFICATION  
& VALIDATION



#### DOLPHIN PROJECT: MAIN GOALS

- Clarify the contribution of some identified critical issues on Berth “A” Downtime;
- Analyse the efficiency of some solutions to reduce Downtime at Berth “A”.

## II – EXPERIMENTAL FACILITY

### WAVE TANK

- 28.0 m long;
- 12.0 m wide;
- 1.2 m in depth.

### WAVE GENERATION SYSTEM

- Multi-element type -16 independent paddles;
- Developed by *HR Wallingford, UK*;
- Active Wave Absorption System (DWA).

### SHIP MOTIONS MEASUREMENT

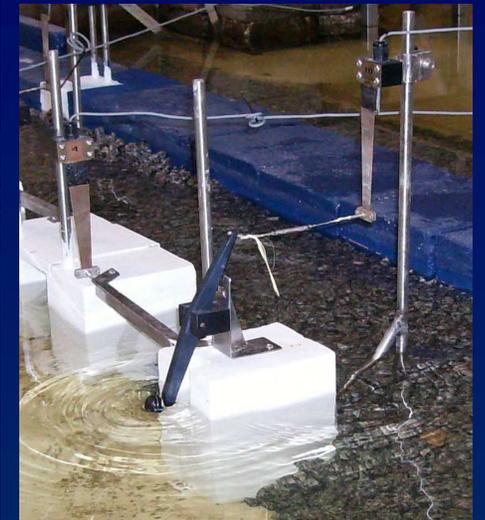
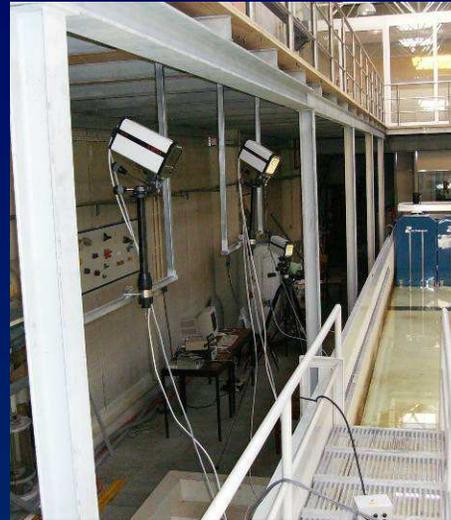
- Qualisys* – Motion Capture System:
  - 3 infrared cameras;
  - 6 degrees of freedom;
  - no contact with the ship model.

### FORCES ON MOORING LINES & FENDERS

- 10 Force transducers.  
(8 mooring lines and 2 fenders)

### SHIP MODEL

- 105,000 dwt oil tanker;
- Full loading condition.

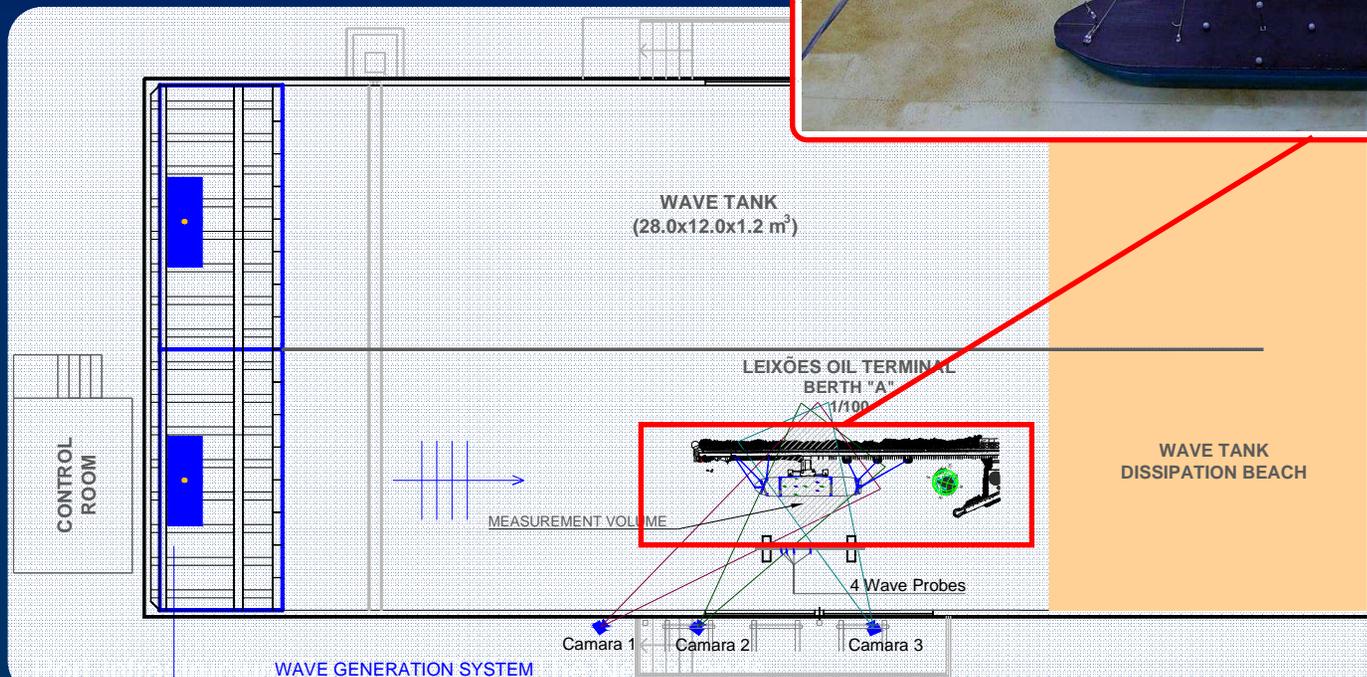
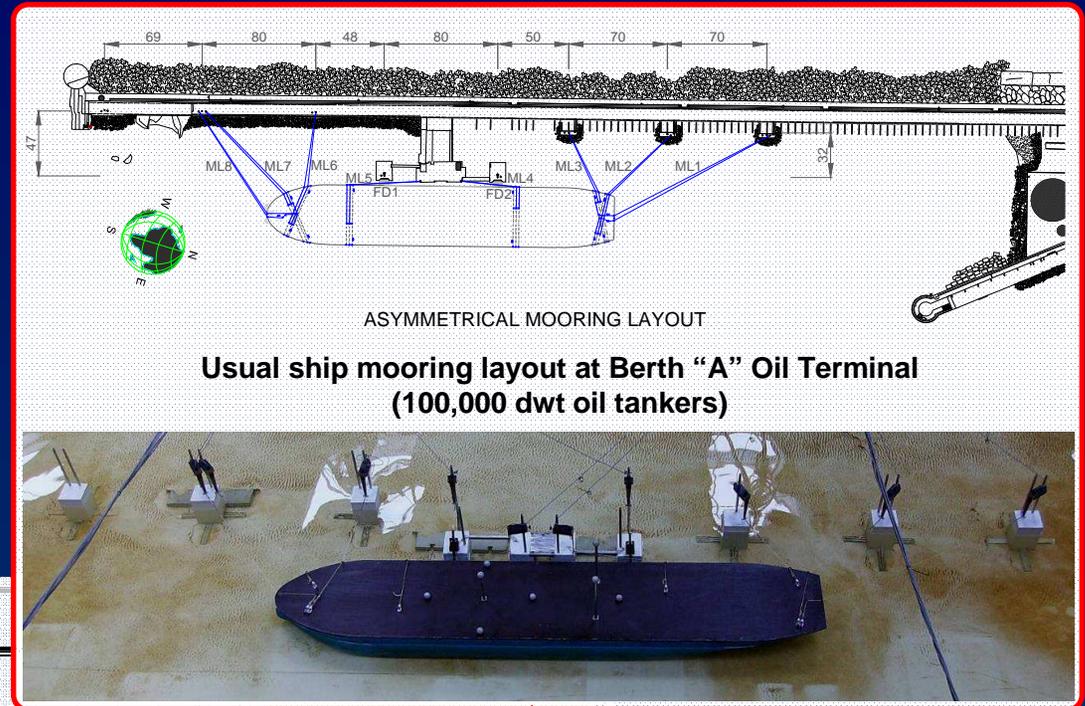


### III – PHYSICAL MODEL

#### 1<sup>st</sup> PHASE OF THE STUDY

Simplified physical model:

- Uniform water depth (-16 m CD);
- Accurate reproduction of the berthing structure and mooring system;
- No breakwater construction;
- Reproduction of the wave conditions expected to reach the Berth "A" area;



**SCALE 1/100**

June 22-23, 2010

## IV – RESULTS & DISCUSSION

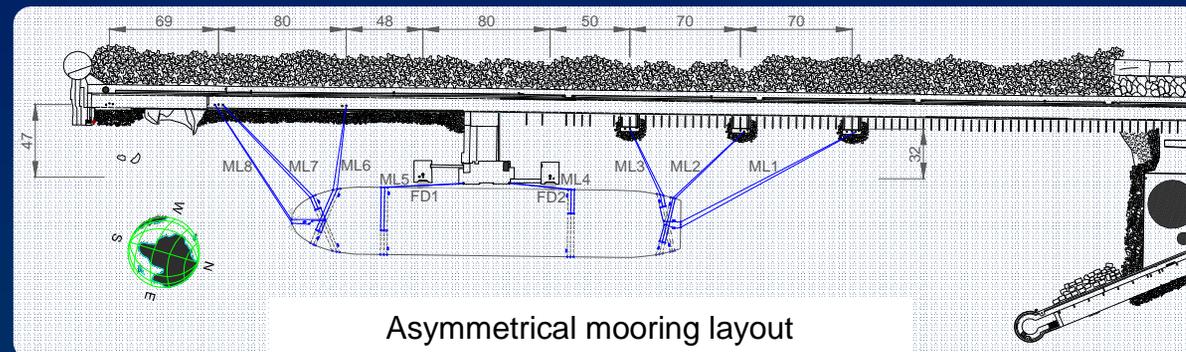
### MOORING LAYOUT

#### Asymmetrical *versus* Symmetrical mooring layout

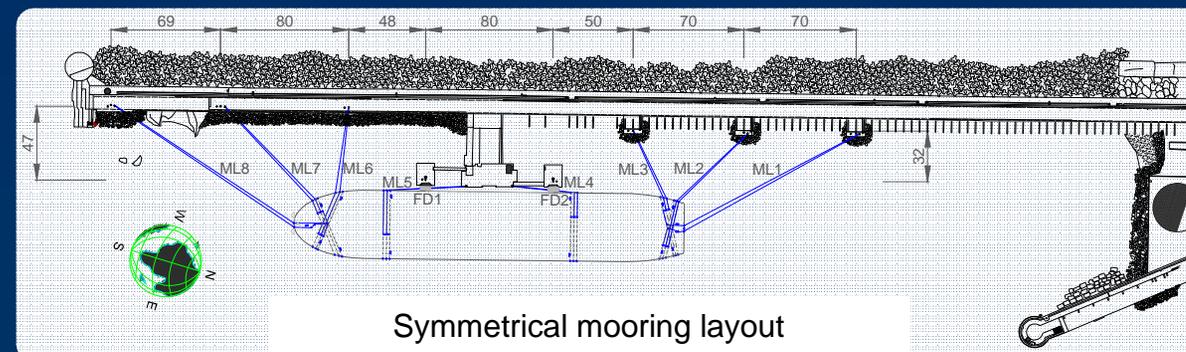
##### Test conditions

- Irregular long crested waves (JONSWAP):  $H_s=2.0$  m and  $8 s < T_p < 14$  s;
- Water depth of 20 m (high tide water level);
- Pre-tension forces ~ 100 to 120 kN;

**USUAL  
LAYOUT**



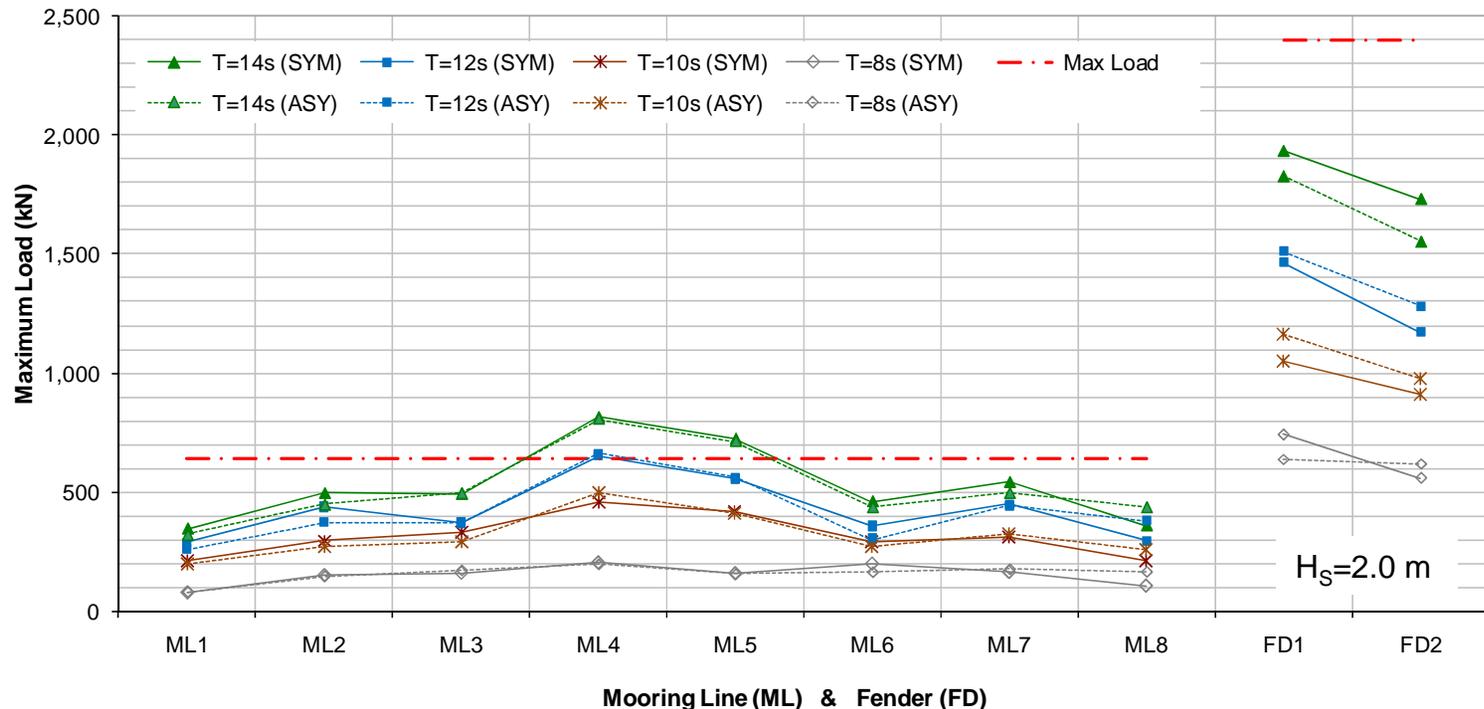
**ALTERNATIVE  
LAYOUT**



## IV – RESULTS & DISCUSSION

### Asymmetrical (ASY) versus Symmetrical (SYM) mooring layout

- Small differences between the two mooring layouts;
- Smaller loads on FD1 & FD2 for SYM layout at intermediate wave periods;
- Spring lines (ML4 & ML5) were the most loaded ML and would be the first ML to break;
- Tested mooring layouts differ only in the position of one double head line.



Maximum Loads (Prototype) - Asymmetrical (ASY) versus Symmetrical (SYM) mooring layouts

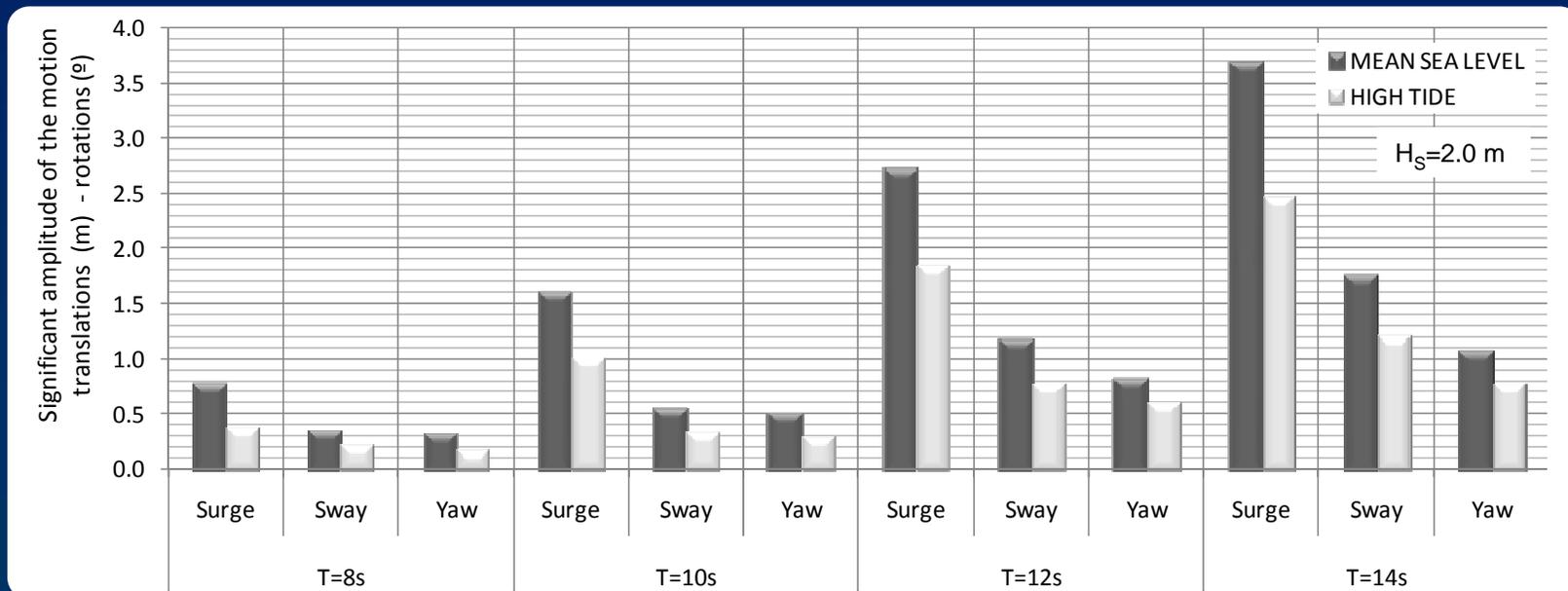
## IV – RESULTS & DISCUSSION

### WATER DEPTH – SHIP UNDERKEEL CLEARANCE

Mean sea level *versus* high tide water level

#### Test conditions

- Irregular long crested waves (JONSWAP):  $H_s=2.0$  m and  $8 \text{ s} < T_p < 14 \text{ s}$ ;
- Water depth near the berth: 20 m (high tide) and 18 m (mean sea level);
- Symmetrical mooring layout;
- Pre-tension forces ~100 to 120 kN.



The increase of the water depth results in an important reduction of the amplitude of the horizontal motions!



**V – PHYSICAL MODEL  
2<sup>nd</sup> PHASE OF THE STUDY**

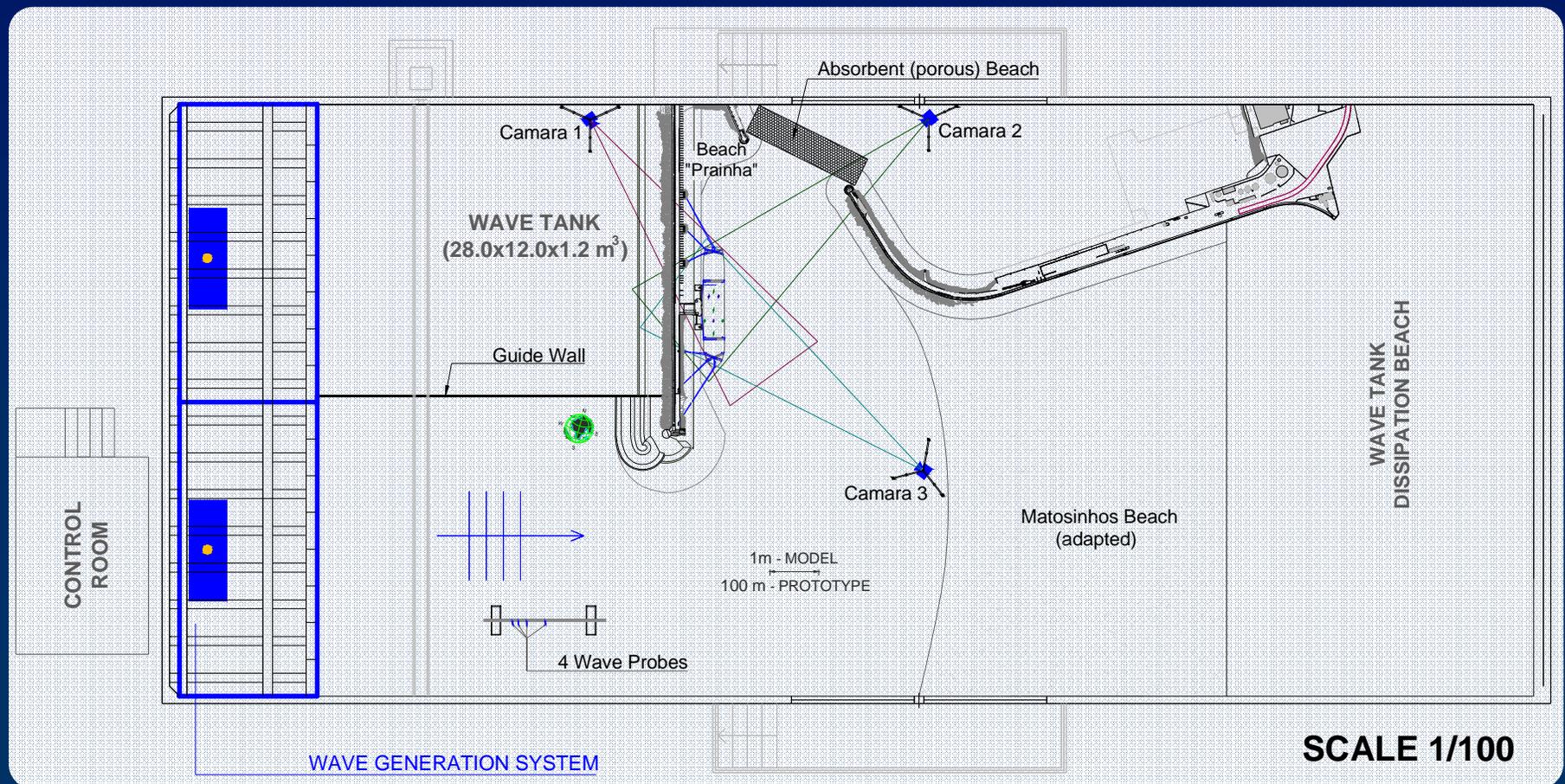


Port of Leixões and its surrounding area, delimitation of the area reproduced in the physical model [source: *Google Earth*].

## V – PHYSICAL MODEL

### 2<sup>nd</sup> PHASE OF THE STUDY

- || Wave direction: W-20°S – perpendicular to the north breakwater (most problematic wave conditions)
- || Uniform water depth (-16 m CD)





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Port Infrastructure Seminar 2010  
22 and 23 June 2010

## V – PHYSICAL MODEL

### 2<sup>nd</sup> PHASE OF THE STUDY

Wave conditions near Berth “A” depend on the diffraction of incident waves around the head of the north breakwater, and on the reflections on the south breakwater and Matosinhos Beach.



## VI – RESULTS & DISCUSSION

### FRICION FORCES AT THE SHIP-FENDERS INTERFACE

Mooring line pre-tension and friction coefficient at the ship-fenders interface

#### Test conditions

- Sea states reproduced at the wavemaker boundary correspond to wave conditions outside the port;
- Irregular long crested waves (JONSWAP):  $H_s=3.0$  m and  $10 \text{ s} < T_p < 20$  s;
- Water depth of 20 m (high tide water level);
- Asymmetrical mooring layout;
- Theoretical set-down compensation;
- 2 Pre-tension conditions;
- 2 Types of interface between the ship hull and the fenders.

FENDER  
S

FD-LF | Low friction |  $0.11 < \mu < 0.13$

FD-HF | High friction |  $0.45 < \mu < 0.48$  (pneumatic fenders installed at Berth "A")

PRE-  
TENSION  
CONDITION

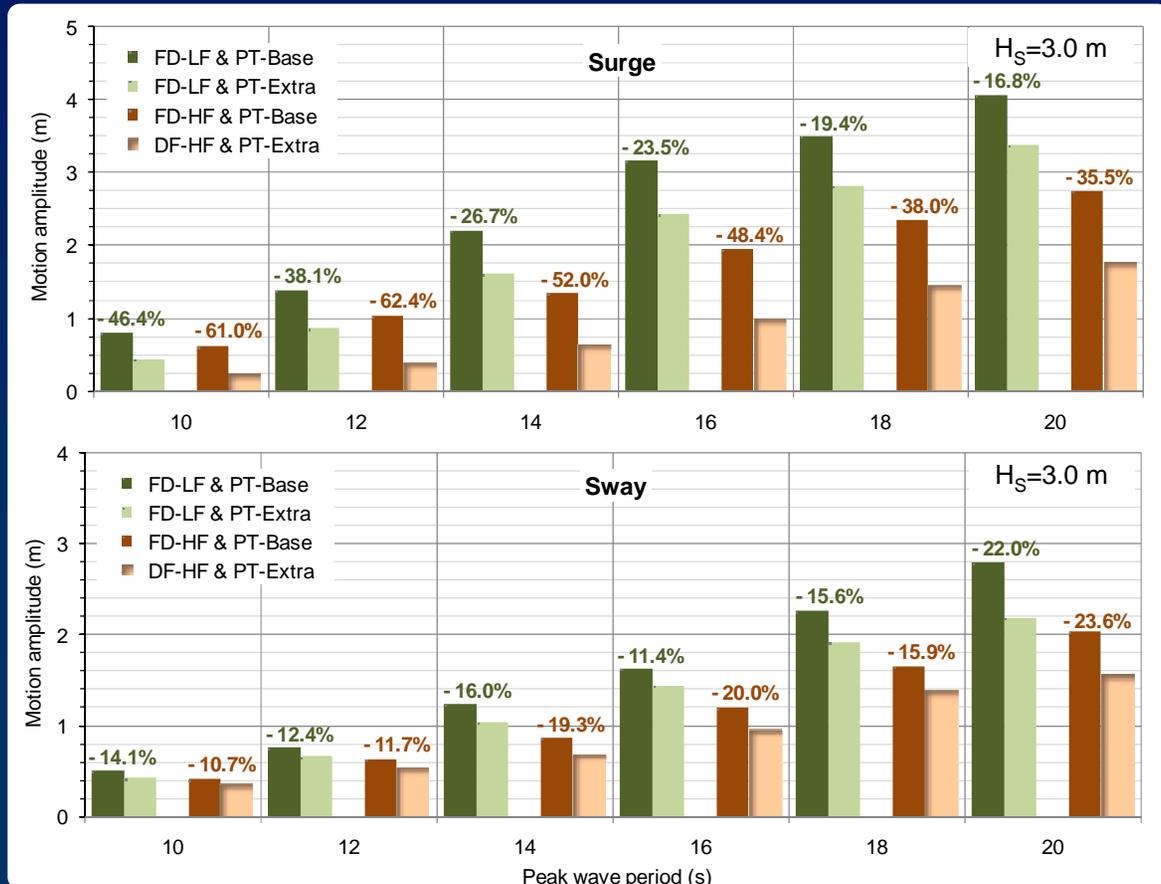
PT-Base | 100 - 120 kN in all the ship mooring lines

PT-Extra | 245 - 265 kN in the breast lines & 100 - 120 kN in the remaining mooring lines

## VI – RESULTS & DISCUSSION

### Friction forces at the ship-fenders interface

- Pre-tension forces and the type of interface between the fenders and the ship have a significant effect on the horizontal motions of a moored ship;
- The best results are always associated with high friction forces at the ship-fenders interface;
- Reductions of the surge motions are higher than those of sway;
- The increase of the breast lines' pre-tension is more effective when high friction fenders are installed on the berth (35 to 60% reduction of surge against 17 to 46%);
- In the case of the sway, differences are less significant (reductions up to 24%),
- The high friction forces at the ship-fenders interface may well require a more frequent and rigorous control of the ship mooring conditions.





## VII – CONCLUSIONS

- The behaviour of a ship moored at Berth “A” of the Leixões Oil Terminal was analyzed based on the results of two physical models.
- The modifications introduced in the mooring layout more common at Berth “A” had only a small influence on the moored ship response; nevertheless the increase of the breast lines’ pretension can effectively reduce the moored ship motions, particularly if high friction fenders are installed on the berth. The water depth near the berth was identified as an important factor controlling the behaviour of the moored ship.



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## ACKNOWLEDGEMENTS

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# FCT

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# THANK YOU FOR YOUR ATTENTION

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