Long-period waves and current variations in a port due to a passing vessel

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Highlights
Comparisons are made between the results of measurements of ship-induced long waves and current variations in a port and results of computations. The computations are based on a combination of potential flow calculations using the double-body assumption to determine the initial forcing due to the sailing ship and linear 3-d diffraction computations are used to determine the response of the port structure and a moored vessel to the forcing. In the process FFT methods are used to transform time-domain forcing to frequency-domain input for diffraction computations .RAOs generated by the 3d-diffraction are transformed to transient time-domain results which are directly comparable with measured data. Comparisons of wave elevations and currents are given for three port configurations.

Introduction
In this contribution results of model tests and computations on ship-induced long waves and current velocities will be presented. The model test program was part of the Joint Industry Project (JIP) ROPES, acronym for Research On Passing Effects of Ships. The objective of the ROPES JIP was to increase insight in the factors influencing forces on ships moored in ports caused by passing vessels. A review of this project may be found in Ref. (1). The objective of a part of the scale model tests carried out by Deltares was to investigate and to better understand the hydrodynamic forces on a moored ship due to a passing ship, especially related to the influence of (complex) harbour geometries. In complex harbour geometries, a large passing vessel will generate long waves consisting of so-called 'draw-down' which travel with the passing vessel and transient long period oscillatory waves in the form of standing waves or seiches. Such effects may also be of influence on the forces on moored vessels.The objective of the model tests carried out by Deltares was to produce a high-quality dataset, which included the effects of currents and the influence of harbour geometries on mooring forces , transient long waves and current effects.
The following sections describe briefly the model test set-up and the measurement set-up with respect to wave elevations and currents induced by a passing vessel. The results of the measurements are compared with the results of computations based on potential flow including free surface effects. The forces on the moored vessel are not treated.

Set-up of the model tests
The model tests were carried out in the Atlantic Basin at Deltares. An overview of these tests excluding comparisons with computed results is given in Ref. (2). The basin has a total length of 74.7 m which included , among others ,a dissipative beach at both ends. The effective length of the test section is 43.9 m with a width of 8.7 m. For the model tests , the basin was fitted with a towing carriage to which the a model of a Post-Panamax container vessel was connected. The vessel was captive in the surge, sway, roll and yaw directions while it was able to squat and trim freely. The model scale amounted to 1: 100.Several lay-outs of a straight channel with a width of 270 m with different basins to one side of the channel were modeled. The water depth in the channel and the basins amounted to 18 m full scale.

The vessels
The main dimensions of the passing Post-Panamax and the moored Panamax vessels are given below:

	Units	Post-Panamax	Panamax
Lpp	m	331.5	255.0
Beam	m	42.9	32.26
Draft	m	14.5	12.0
Displacement	m^3	127037	58660

Measurement equipment
A total of five capacitance type Wave Height Measurement (WHM) gauges were used to measure surface elevation at different positions in the basin. The measurement positions of the WHM gauges for each layout are indicated in the figures of the layouts. The WHM01 gauge was placed at the reference position x, y = (0 m, 12 m) for all tests.

The other WHM gauges were placed at strategic positions throughout the basin. In general, one gauge was placed in ahead , one aft, and one next to the mid ship position of the moored ship. In the test with a side basin, also two WHM gauges were placed in the corners of the basin to detect standing waves, since this is where the largest standing wave amplitudes are expected. In the tests of Layout 1 (straight channel), one wave gauge (WHM05) was placed outside the measurement channel on the other side of the channel wall. This was done to check the amount of wave penetration underneath or between the concrete building blocks of the channel wall (unwanted leakage).
The horizontal velocity components of the water was measured using five Electro Magnetic Velocity probes (EMS). A sample rate of 30 Hz was used. During the measurements, the signal was filtered by the data-acquisition software using a moving average filter with a window of 0.1 s (model scale). The measurement positions of the EMS probes for each layout are specified in the accompanying figures. EMS probes measure the flow velocity at a certain vertical position in the water column. In almost all cases the probes measured the flow velocity at a depth of 7 m under the water surface, which is approximately at half draught of the passing vessel. Only in Layout 1, EMS04 was positioned to measure at a water depth of z=-12 m, to check the variation of flow velocity over the draught of the passing vessel.

Test program
In this contribution some results of wave elevations and current velocities is shown for three port layouts. For all three cases the passing speed of the Post-Panamax vessel corresponded with 10.4 kn and the centerline of the vessel was 107 m from the bank nearest the side-basin. In the model tests the passing vessel started from X= +3000 m and slowly accelerated up to the required speed in order to minimize additional transient waves due to the start-up. Measurements were carried out with the vessel at a constant speed. At the end of the run the vessel was decelerated and stopped at about X= -1000m. The vessel was at 10.4 kn for the part of the channel shown in the layouts. In the computations a similar procedure was followed regarding the speed of the vessel.

Computations
The computational procedure was similar to that described in Ref. (3). The computations are based on potential flow which are solved using zero-order panel methods. The procedure is carried out in four phases : firstly the time-dependent flow due to the passing vessel is solved assuming double-body flow i.e. no free-surface effects. At each time-step the strengths of the sources on the passing vesssel are solved based on the near-field assumption i.e. both vessels and the fairway are modeled and included in the solution process. Secondly , the thus derived time-dependent source strengths on the passing vessel are used to compute the time-dependent velocity and pressure disturbances at the fairway boundaries and the moored vessel i.e. 'undisturbed' velocity components and pressure due only to the sources on the passing vessel. These time-dependent disturbances are transformed to frequency-domain vectors (FFT) which form the input to the third phase which consists of solving a zero-speed frequency-domain 3-d diffraction problem involving the fairway and the moored vessel but which excludes the passing vessel. Based on the frequency-domain solutions, RAOs of fluid velocity components , wave elevations and forces on the moored vessel are computed. Finally, the RAOs are transformed to transient time-domain results using Inverse FFT methods. These records are directly comparable with the measured time-records of velocity components and wave elevation.
In a previous IWWWFB workshop Ref. (4) some preliminary comparisons of results of measurements and computations of wave elevations were shown for a simple rectangular barge entering a restriction in a straight canal. In the contribution we are presenting new data for more realistic hull forms and port geometries and a more detailed flow analyses.

Results
In fig. 1 through fig. 6 the layout and comparisons of computed and measured results for three selected cases are shown. All data are for full scale. Computed results are given in red.
The results for Layout 1 show a lack of oscillatory waves and current variations compared to the results for Layout 2 which clearly shows strong seiching in the side basin. Layout 7 shows slightly more seiche effects than Layout 1 but clearly significantly less than Layout 2. Small, short secondary waves are discernable in the measured wave records only.

References
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3. Pinkster, J.A. ,“The Influence of a Free Surface on Passing Ship Effects,” Int. Shipbuilding Progress, 51, No. 4, 2004.
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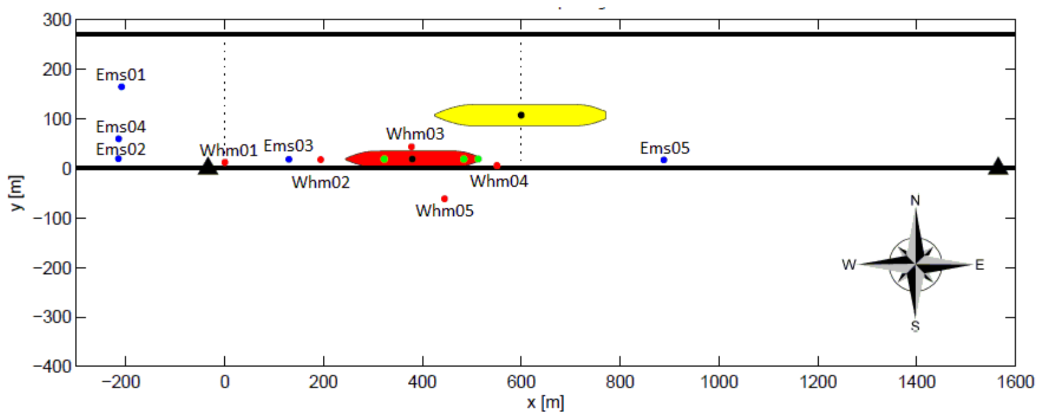

Figure 1 Laout 1 ; Straight channel. Width 270 m, waterdepth 18.0 m

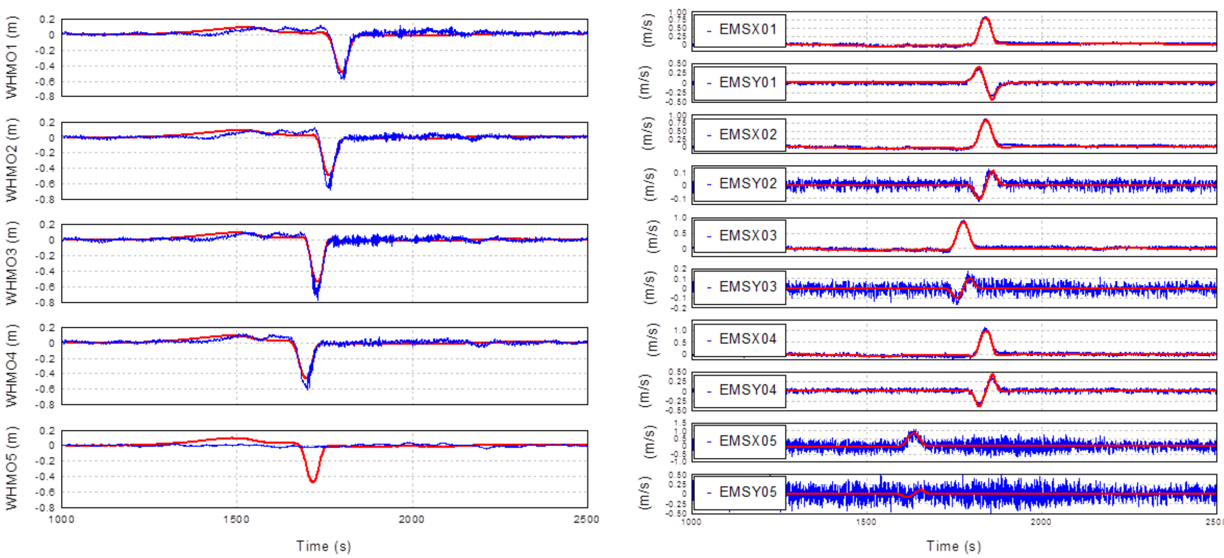

Figure 2 Results for Layout 1. Wave elevations left, X- and Y- Current velocity components right.

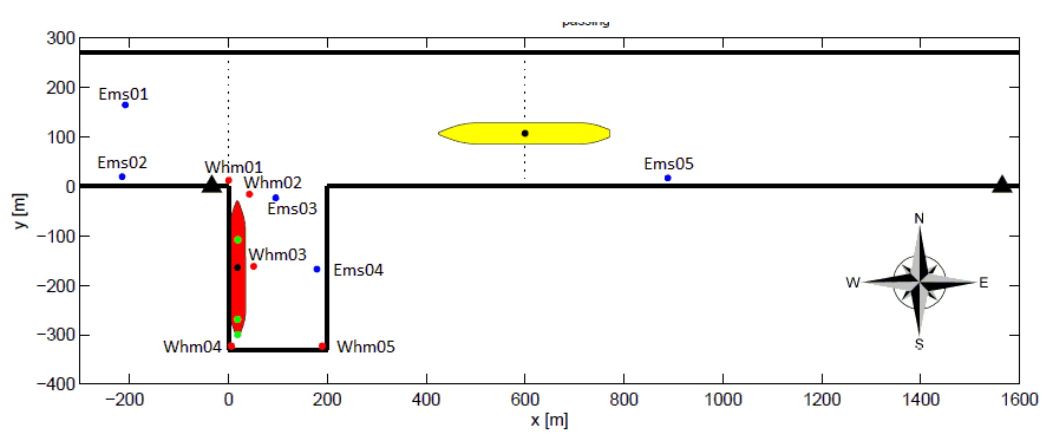

Figure 3 Layout 2 ; Narrow basin at right-angle to channel axis. Water depth in basin 18 m.

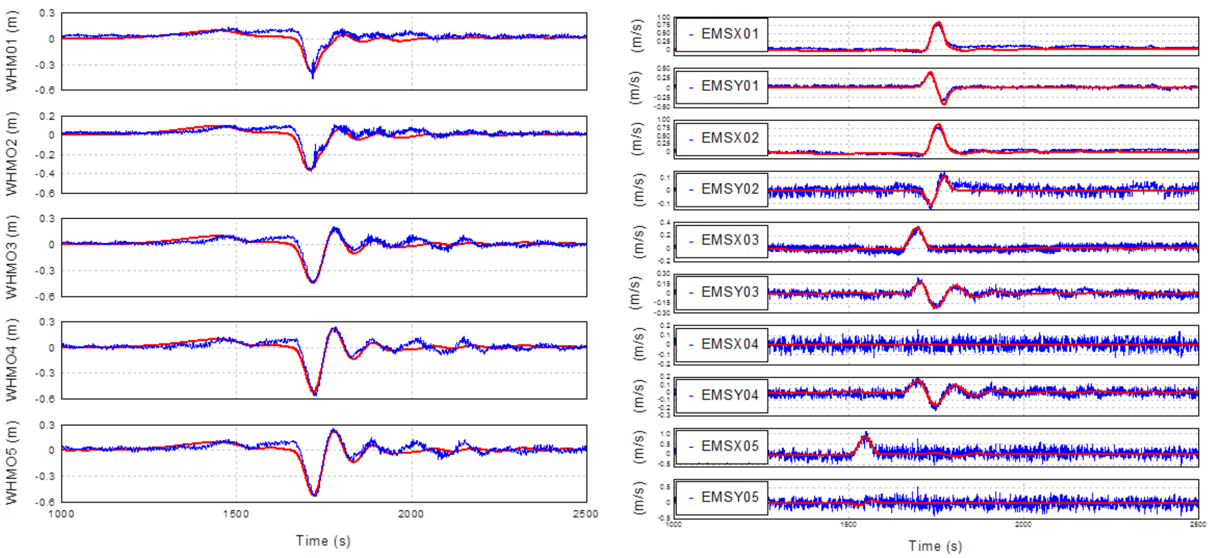

Figure 4 Results for Layout 2. Wave elevations left, X- and Y- Current velocity components right.

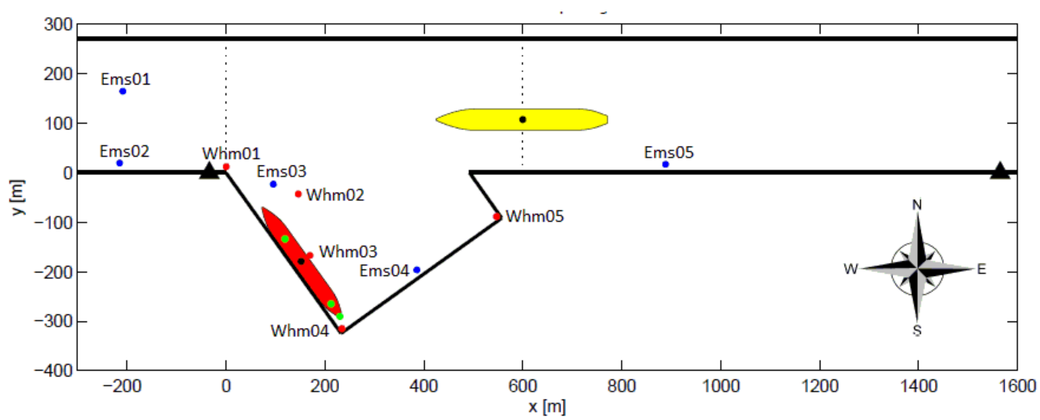

Figure 5 Layout 7 ; Basin at an angle to the channel axis. Water depth in basin 18 m.

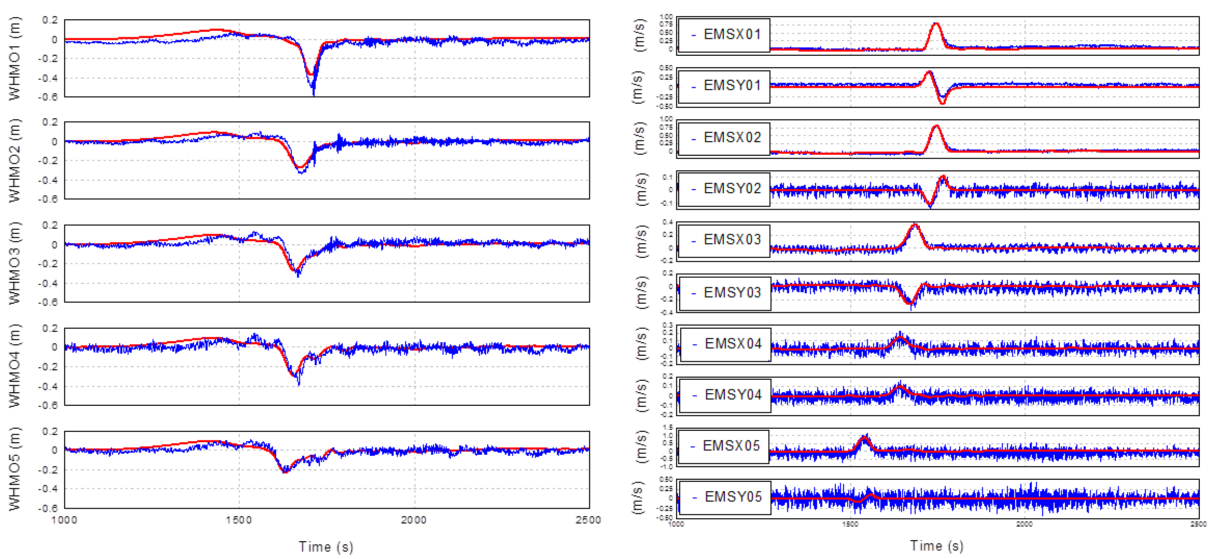

Figure 6 Result for Layout 7. Wave elevations left, X- and Y- Current velocity components right.