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INVESTIGATIONS ON THE WAVES TRANSFORMATIONS IN THE AREAS OF ROMANIAN MARITIME PORTS

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ABSTRACT

The sea wave in the Romanian coastal area generates the wave propagation patterns inside the Romanian sea ports, with specific dynamics influenced by the dominant wind directions and the configuration of the port basins. In this context, a Bousinesq-type numerical model application was considered appropriate to study the wave dynamics in Constanta seaport and also inside the entrance channel of Constanta-South port.

The hydrological processes in the internal access channels of a port may determine the need for a more detailed description of the hydrodynamic processes affecting the port operations. The results obtained as part of the simulations using BOUSS2D model on the waves propagation in the basin of the port of Constanta – South’s access channel, have been analyzed comparatively, against in situ video observations and UAV’s measurements.

The results of the present study include a complex research process, related to the numerical approach, as well as the approach related to filed measurements and observation activities, for an accurate knowledge of the hydrodynamic induced processes, given the considerable variability for the parameters involved. It also gives some recommendations for the use of technological solutions for the extension of the protected areas in the vicinity of sea ports, enclosed by breakwaters, and the front of the inner quays of the ports.

Keywords: ports hydrodynamics, waves propagation modeling, traped waves monitoring, port operations’ optimization.

AIMS AND BACKGROUND

The Black Sea basin is the main factor influencing regional shipping conditions in terms of sea surface roughness. Climate changes, mainly the atmospheric circulation and the recorded wind parameters (direction and speed), have a significant influence on the wave regime. Wind variability over the Black Sea generates wave fields that are closely related to local characteristics (direction, duration and intensity of local wind), especially in coastal areas. (Arsenie, 2008), (Omer, 2015).

In order to identify the hydrological data that are necessary for the expansion works of acces channel in the terminal port basin, in the development area of certain operational and multifunctional quays’platforms, and in the arrangement of several stage berths in the closest areas of the access channel coming from both, the main port entrance opening and from the north port jetty breakwater expansion of the Port of Constanta, it is necessary to develop a study using multi-year data considered based on statistical analysis methods and specific modeling programs in accordance with the availability of the data.

EXPERIMENTAL

The analysis of the multiannual data of waves recorded *in-situ* (by NIMRD) and modeled by the ECMWF, were considering the measurement point located near the shore, under the influence of the port adjacent bathymetry (Fig.1).

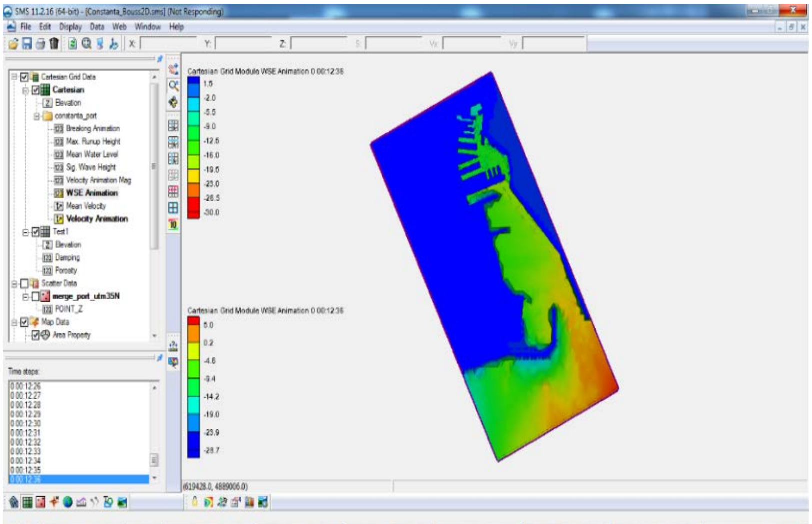

Fig. 1. Bathymetry of the seabed in the entrance area of Constanța port

Geometric model and computational grid were built by coupling all the mentioned digital extension data sets (Glover, 2005), (Korgen, 1995), in UTM35N projection (Fig. 2).

Also, the need for detail in the area of interest required the construction of local Cartesian computing networks with elements of 10x10m, origin point (632779.00, 4883580.00) and zero degree azimuths. Five characteristic sections were selected for the entrance channel in the Constanta South Port, and for determining the surface elevation profile variations.

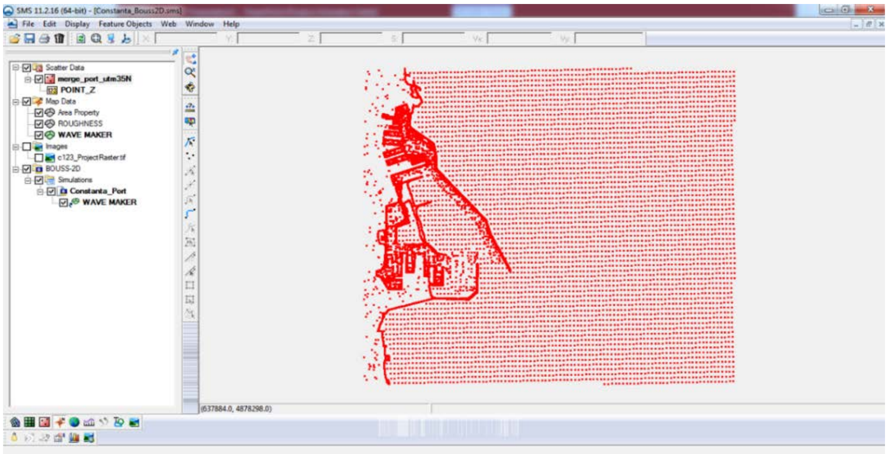

Fig. 2. Computational grid

Regarding the model initialization wind data, in addition to the historical wave data provided by various data bases, including data obtained from free sources such as https://gis.ncdc.noaa.gov/ from 1952 to the present, at Sulina and Constanta stations.

Thus, analyzing the data and comparing the wind roses of the three stations, a similar trend can be observed (Fig.3). But because Constanta station is surrounded by buildings, the distribution of wind directions may not clearly reflect the real situation (Lungu *et al.*, 2015).

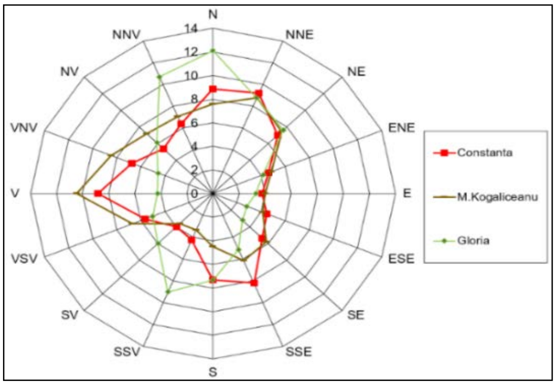

Fig. 3. Distribution of wind direction for the three stations over the entire period for each data set

In a tabular representation the used data provided by ECMWF, highlighting the predominance of wave's heights less than one meter (Fig. 4) in the location placed in front of Constanta area (29E, 44 N).

For the wave propagation it was selected BOUSS-2D model, as a suitable numerical model, for simulating the wave's propagation in a coastal port basins, based on a time solution for Boussinesq equations, including include friction with the solid seabed and the flow through permissive structures, including all main processes of the sea bottom friction, shoaling, refraction, diffraction and reflection.

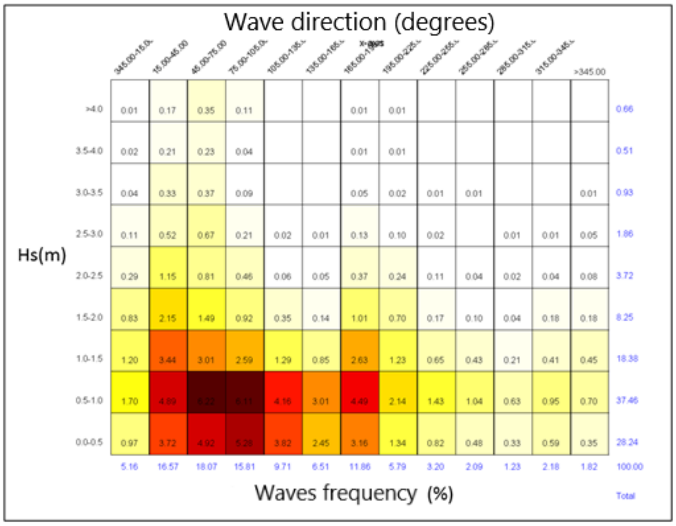

Fig. 4. The relative distribution of wave height by wave directions relative to the North direction, along the entire interval (WAM data, 1991-2002), expressed as specific frequency of occurrences.

Spatial discretization of the model was performed on a rectangular grid, the extreme and average annual wave conditions previously determined were considered as time series for model initialization, specified along the external wave generation limits, and wave propagation conditions were selected as periodic and unidirectional.

The maximum impact direction considered at the entrance of Constanta Port, are still representative/covering the entire coastal area between the entrance and the new quays close to the Constanta South Port entrance channel. The wave calculation was associated to the *Jonswap* spectrum, described by the parameters determined for certain previously extreme value statistics calculations (Oguz *et al.*, 2015), (Rusu, Soares 2011), (Van Vledder, Akpınar, 2015). For the hydraulic modelling of the Constanta-South access channel, the following parameters were set-up: Chezy roughness coefficient, the control time with the specification of the run time and the time step, as well as the desired output data type: sea surface height and wave propagation speed.

The results obtained for the test station located in front of the maneuvering basin, were relevant for the propagation of an incident wave of (Hsig =1.85m, Tp=12sec).

In the boundary diffraction coefficients, for a semi-infinite pier (Fig. 5), is included the calculated value of the diffracted wave, (Shore Protection Manual, 1984).

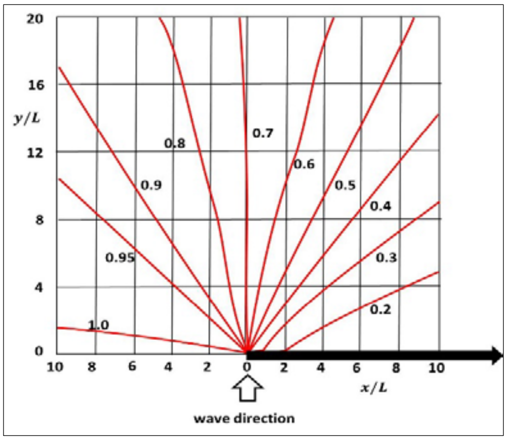

Fig. 5. Diffraction (ratio of diffracted wave height and incident wave height) of a normally incident directional random sea state for a semi-infinite barrier – adapted from Goda vs. ratio between diffracted waves high and incident wave high.

Taking into account the extreme conditions of the wind and waves propagated from the port sea entrance (Rusu *et. al.*, 2011), (Rusu, 2016), by refraction and diffraction calculations the extreme conditions of the waves near the the access channel entrance of the Port Constanta Sud - Agigea were determined (Fig. 6). These conditions have been applied to design the non-deformable structures for various boundary conditions and to establish the critical conditions for 100 years return periods with design purposes in the area of interest (Omer, 2014). Because the rectangular quays forming the channel twoard Constanta South Port are mainly from concrete walls, the imput datasets were use damping arcs and just few porosity arcs, as boundary conditions.

The model was run for a duration of 815.0 seconds, with a time-step 0f 0.25 seconds, a Courant number of 0.4, a constant Chezy coefficient for roughness type, and a Samagorinsky number of 0.2, for turbulent flow conditions.

Fig. 6. Calculus sections for significant parameters of waves field in the area of interest

RESULTS AND DISCUSSIONS

The results obtained based on modeling application of the BOUSS2D model shows the gradual decrease of the inner induced wave regime, respectively for the significant height of the wave propagated by diffraction and refraction in the area of interest - for regular long waves with a height of 1.85 m, a wave of 1.1 m propagates in the area of interest, revealed fact on the first (1) transversal section (Fig.7).

The highlight the changes of the wave field in the area of access channel in the Port of Constanta Sud-Agigea, including the decreasing of the waves in this area of interest, daily transited by conttaineriers or cargo ships.

The waves described by water surface elevation (WSE/Water Surface Elevation) and Significant Height (Hs) shows relatively high values in the case of the waves incidence from quadrant 2/SE-S sector. Concerning the areas of interest from which the port development started, the gradual decreasing of waves'highs in the direction of propagation are present, a fact followed in the transversal profile set on the calculation grid (Fig. 7).

Due to a reduced fetch (Fig.8) in the area of Constanta South basins, wind-induced currents, or jet currents, produced by maneuvering ships are limited, but the configuration of the port, allows the installation of the resonance phenomenon between the basins with vertical quay, as well as the rapid installation of some situations with modified wave regime at the storm, due to the sepatation produced by the position of the central island within the Constanta maritime port.

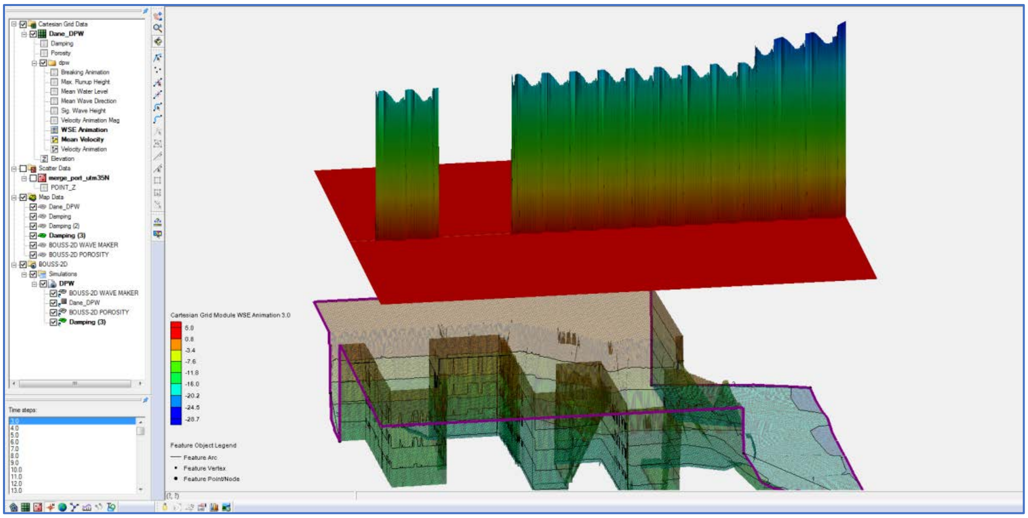

Fig. 7. Significant wave height vs. average sea level in the entrance channel of the Constanta South Port - transversal section following the main direction of propagation.

For certain values of the inner fetch between 3 and 6 km, for ENE and ESE incidence winds, waves up to 1.5-2 m can develop (Fig. 9), (Shore Protection

Manual, 1984), as well as average currents up to a value of 70cm/s (Omer, 2014), (Vlasceanu, 2015), in case of winter storms. For the situation, encountered in the transition area of the Romanian coast, for the development of sea thunderstorms, the wind speed at gust can exceed 55 m/s.

Fig. 8. Interior fetch of 6.1 and 3.3 km, with impact in the area of interest

Thus, there are situations in which a port hydrological regime can be installed under the combined effect of the action of waves in areas with currents from the opposite direction, generated especially by the level elevations of coastal water masses in storms (storm surges), when due to excess water accumulated in the port basin, a reverse current is formed, on the corridor bordered by the White Lighthouse towards the barge port, the access corridor in the Constanta South - Agigea port (Fig. 10), which creates conditions for breaking and raising the waves propagated in the South Constanta port.

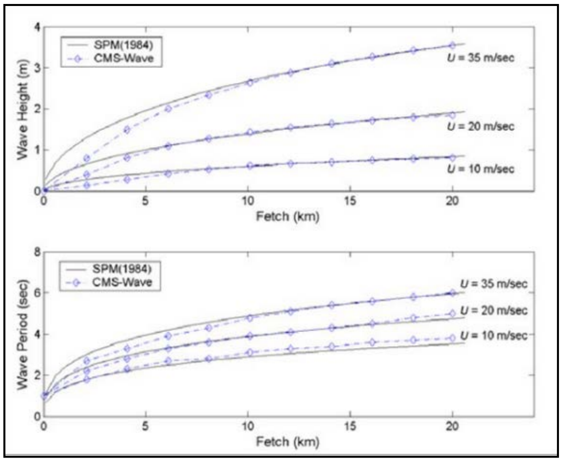

Fig. 9. Waves development inside seaports
(SPM 1984 / Shore Protection Manual,’84 reports)

The observed situations for the model results estimations occurred when the wind blows in the direction of the maximum fetch, along the northern dam of the Constanta port, and respectively, for the SSE incident wind.

In this way the model results were validated by local observations which were carried out at 26.06.2020, 16:42, but also for 18,10.2023, 11:20 for an averaged measured incident wave high of 1,5m from SE direction, at the entrance of the Port of Constanta, the high of the propagated wave at the entrance of the port of Constanta – South was of 0.7m.

Fig. 10. Aerial observation over the ports' entrance and access channels for the Port of Constanta and the Port of Constanta – South (date: 26.06.2020)

CONCLUSIONS

The hydrodynamics of the maritime portuary areas is an actuale topical problem in the new climate change context (Vlasceanu *et. al.*, 2015). It is a problem difficult to solve, because of a lack of systematic measurements carried for the processes that generate the emergent combination of all sorts of processes related to the traped waves, but also the complex hydrodynamics induced in basins with a complex basins' configuration.

The study of the types of interaction between various chracteristics of wave and current patterns in coastal ports areas can entail the understanding of the phenomena in their entirety. On the other hand, the obtained results can thus contribute to an enhanced control and optimization of the ways to design the structural and functional new extensions of the ports. By the same token, the results may contribute to the safety of the maritime navigation and the specific operations in ports and its adjacent areas.

Methods of data collection and analysis of information in the marine and coastal environment, as well as the automated calculation methods included in the new ways of integrative approach of the involved processses may generate the understanding of the ways to appropriately manage the characteristics of the ports' shelter areas.

Certain natural or constructive causes can be understood and managed correctly, apart from the great variability of the marine hydrological induced by the regional changed climate and/or technological risk phenomena.

Even though, after the extension of the harbour jetties, an intensified hydrological regime is maintained in the sub-basins of the South Port of Constanta in case of storms, this is a factor for achieving and maintaining some characteristics in relation to the water quality parameters of coastal ports, which are described in the Marine Spatial Planning objectives for "green ports".

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