TOOLS FOR FORECASTING AND EVALUATION OF STRUCTURAL RISK ON MARITIME WORKS

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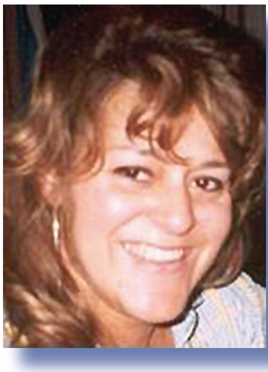

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1. INTRODUCTION

Emergency situations caused by sea waves hitting maritime structures are common along their whole lifetime, which will a) endanger the safety of people and goods (Figure 1), b) cause problems to the functionality of the structures (Figure 2) and c) have serious impact on the economy, society and environment (Figure 3). Storms and other extreme events, together with the accepted global warming, the rising sea levels and the recently observed increasing intensity of those storms, leads to greater and greater loads the maritime structures (natural or manmade) have to withstand.

In the case of Portugal, emergency situations on maritime structures caused by adverse sea conditions are quite recurrent all over the Portuguese coast. Usually, those structures, many times protecting important facilities, are located on the Atlantic Ocean open coast and therefore are subject to severe extreme wave conditions. Significant wave heights at the west coast of mainland Portugal can reach up to 15 m, with peak wave periods of 20-25 s, while in the Azores, significant wave heights

Figure 1: Storm and extreme events put in danger the safety of people

Figure 2: Overtopping affects buildings and goods. Porto da Vitória, Azores (left), Madeira (right)

Figure 3: Extensive overtopping of seawalls affects road and railway functionalities

may reach 12 m, with peak wave periods of 15-20 s, depending on the location on the archipelago.

Also, in the last 20 years, the number of maritime structures has increased significantly, both in mainland Portugal and it its islands, although that increase was most remarkable in the latter. Currently, there are broadly 20 main harbours and an extensive and increasing number of cruise terminals, marinas and optimised fishing harbours, all having a major relevance to the national economy, and almost all of them subjected, at least partially, to the above mentioned severe wave conditions.

From above, it is clear the need to protect maritime structures, to guarantee its safety and to minimise wave induced risks. In this framework, national and international regulators and civil society demand for:

- Improving the knowledge on the wave-structure interaction phenomena
- Increasing the maritime structure's reliability and safety
- Creating tools to prevent emergency situations
- Enabling a continuous monitoring/observation of structural behaviour
- Increasing the application of risk assessment techniques to support decision-making

LNEC has been working on the first four components by using physical and numerical tools to improve the knowledge on the wave-structure interaction phenomena, by developing and improving methodologies to increase the structure's reliability and safety, by developing and improving a forecast and warning system to prevent emergency situations and by running systematic inspection programmes to enable continuous monitoring/observation of the structural behaviour of a large number of existing maritime structures (see Figure 4).

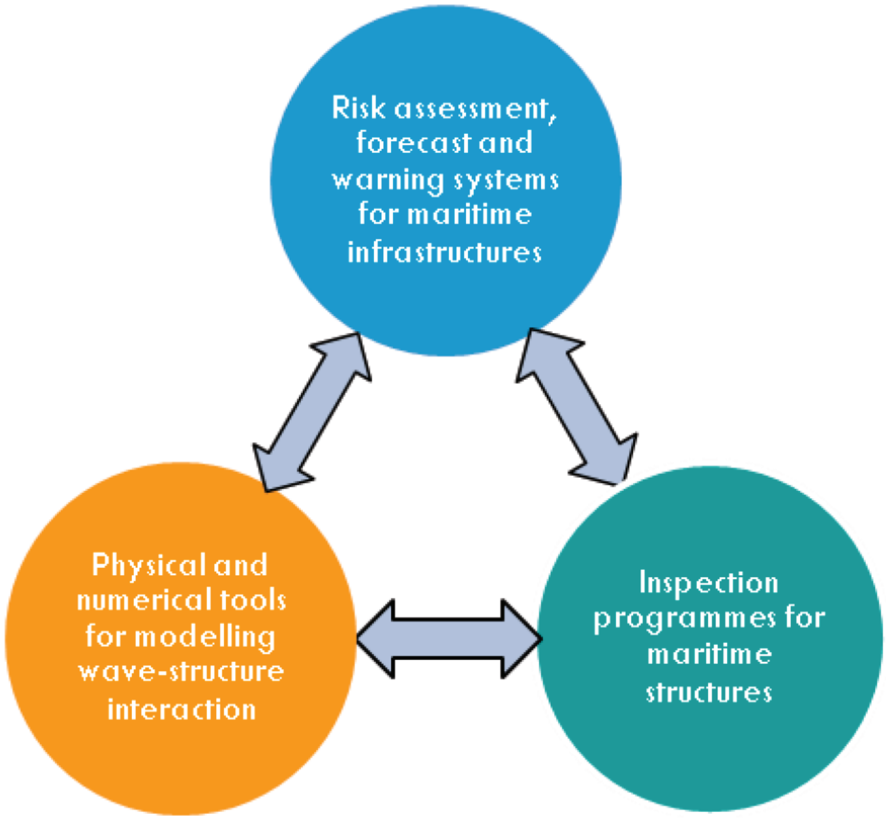

Figure 4: LNEC's tools for forecasting and evaluation of structural risk on maritime works

Since the physical and numerical tools have been described in several works [Reis et al., 2012 ; Fortes et al., 2012], this paper focuses on both the work performed on the forecast and warning systems to prevent emergency situations and on the monitoring of maritime structural behaviour. These are important aspects since: on the one hand, an adequate forecast and early warning system allows the identification of emergency situations due to wave action on the structure and enables authorities to take timely action to avoid loss of human lives and to minimise damages on goods; and, on the other hand, the monitoring of maritime structures behaviour allows the identification in time of their anomalous behaviour, enabling the authorities to take the measures necessary to maintain and repair those structures, therefore avoiding higher costs if failure, or even collapse, of the structures had occurred.

This paper presents an overview of the recent advances on the research project HIDRALERTA – 'Flood Forecast and Early Warning System in Coastal and Port Areas', of which the main objective is to develop a system for forecasting, warning and assessment of risks associated with wave overtopping and flooding in coastal and port areas, supported by measurements/predictions of waves and water levels. An overview of LNEC's experience on the systematic observation of maritime structure programmes, carried out in Portugal (in the mainland and in the Azores archipelago) and its associated database (ANOSOM) will also be described.

2. HIDRALERTA PROJECT – A FLOOD FORECAST AND WARNING SYSTEM IN COASTAL AND PORT AREAS

In the framework of the HIDRALERTA project [Fortes et al., 2014] a forecast and early warning system for maritime structures, named HIDRALERTA, is under development. This system allows the identification of wave-induced emergency situations and enables port authorities to take measures to avoid loss of lives and minimise damages.

The system can also act as a long-term management tool, since it can simulate the response to future scenarios related to climate changes, such as the increase of the mean sea level and/or of the storm severity, which will increase the probability of coastal flooding. Such a system may contribute to complying with the directive 2007/60/CE from the EU of 2007-10-23 in what concerns the preparation by the member states of risk management plans, including forecast, alert and warning systems, before December 22, 2015 (Chapter III – Art. 7-3). This framework does justify the HIDRALERTA project.

The HIDRALERTA system, implemented in a GIS environment, follows the basic idea of using wave forecasts (up to 180 hours) to calculate the effects of waves on the coast, particularly in terms of wave overtopping and flooding. Once wave overtopping/flooding are evaluated, they are compared with pre-defined thresholds, to build warning and risk maps and, if necessary, to issue warning messages.

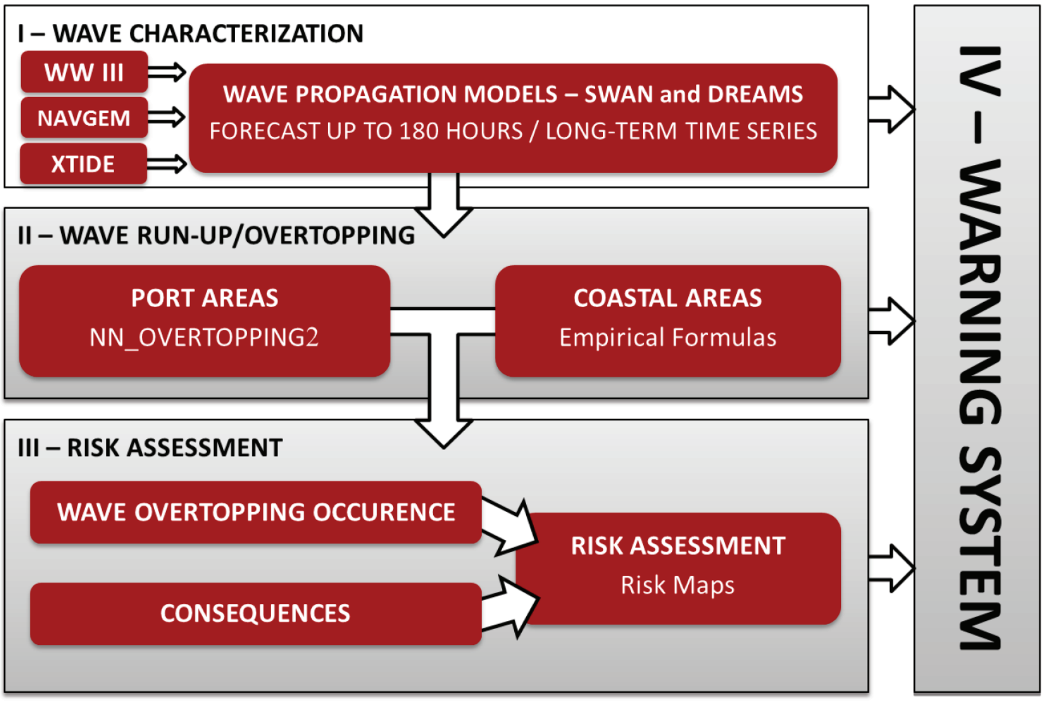

Figure 5: Schematic representation of the HIDRALERTA system

The system encompasses four main modules [Poseiro et al., 2013], see Figure 5: I – Wave Characterisation, II – Wave Run-up/Overtopping, III – Risk Assessment and IV – Warning System. The system is being developed in Python language, in a WebGIS platform.

Wave Characterisation Module

The objective of this module is to determine 180-hours-in-advance sea wave characteristics, to be used by the warning system. Sea wave characteristics may be computed inside a given port or at a certain location on the coast, by using numerical models for sea wave propagation. The use of one or more numerical models for the propagation depends on the study region characteristics and on the phenomena involved in the propagation. The system's currently used numerical models are the nonlinear spectral model of generation and propagation of waves in coastal areas, SWAN [Booij et al., 1999] and the linear mild-slope model of wave propagation in port areas, DREAMS [Fortes, 2002].

The following procedure was implemented: SWAN is forced by the sea wave characteristics estimated by WAVEWATCH III [Tolman, 1999], a numerical model for sea-wave prediction at a regional level, by the wind fields, also at a regional level, and by the tide levels. The wind fields are obtained from the model NAVGEM [Whitcomb, 2012] and the tide levels obtained from the XTide model [Flater, 1998]. XTide provides astronomical tide levels only, so a constant storm surge, defined by the maximum storm surge obtained with historical data from a buoy, is currently considered. WAVEWATCH III estimates of offshore wave conditions and the wind field obtained from NAVGEM are both provided through The Fleet Numerical Meteorology and Oceanography Center (FNMOC). FNMOC delivers forecast wave data from WAVEWATCH III up to 180 hours in advance and historical data since September 2003, with a 1° resolution. It also delivers wind data from NAVGEM up to 180 hours in advance and historical data since January 2004, with a 0.5° resolution. Then, these values are transferred to the coast using the SWAN model and finally into the harbour basins (where the reflection effects are important) with either DREAMS or BOUSS WHF models, depending on the need to consider a linear or a nonlinear model, respectively.

Wave Run-Up/Overtopping Module

The objective of this module is the determination of wave run-up/overtopping on coastal and port areas. In the HIDRALERTA system, wave run-up/overtopping determination follows two different approaches, depending on whether it is a coastal area or a port area.

For port areas, the NN_OVERTOPPING2 tool, based on artificial neural network modelling [Coeveld et al., 2005] is employed. This tool was developed as part of the CLASH European project (Crest Level Assessment of coastal structures by full-scale monitoring, neural network prediction and hazard analysis on permissible wave overtopping) to predict Froude-scaled mean wave overtopping discharges, q, and the associated confidence intervals for a wide range of coastal structure types (such as dykes, rubble-mound breakwaters and caisson structures). The input needed to run NN_OVERTOPPING2 includes the wave/water level conditions in front of each structure and its geometrical characterisation. For coastal areas (simple beaches or beaches with coastal defence structures), empirical formulas are applied to evaluate wave run-up/overtopping. The formulas for wave run-up evaluation are presented in Neves et al. (2013). The flood levels are obtained by adding the wave run-up estimation to the astronomical tide level and to the storm surge.

Warning System Module

The objective of this module is to assess and disseminate warnings of sea wave overtopping/ flooding to the responsible authorities. The system integrates all the information generated by the methodology components. It is made of two components: the data evaluation, which integrates the data from the remaining modules and the user interface. Whenever wave run-up/overtopping exceeds a pre-set threshold in a specific area, a warning message is sent to the authorities [Sabino et al., 2014].

The warning system deals with the following tasks: a) Data acquisition from the data sources, b) Trigger the wave run-up/overtopping determination component, c) Store risk assessment results, d) Disseminate current warning conditions through communication channels such as website, Twitter account and e-mail and e) Maintain the zone characterisation, using a map with the overtopping/flooding consequence layer and threatened areas.

The data evaluation component assumes an emergency occurrence whenever the overtopping/flooding threshold is exceeded in one or more sections of the analysed structures. This identification leads to the generation of graphs, charts and reports, which are then transmitted to the interaction component and prompted to the user, who will evaluate the situation and act if necessary. The user interaction component is materialised in a web application, in which the whole warning system is parameterised. The application is designed for use in traditional and mobile web browsers, tailoring the information in accordance with the characteristics of the client's device.

Application of the System to Praia da Vitória

The port of Praia da Vitória is located on the east coast of the Terceira island in the Azores archipelago (Figure 6a). The two breakwaters that protect

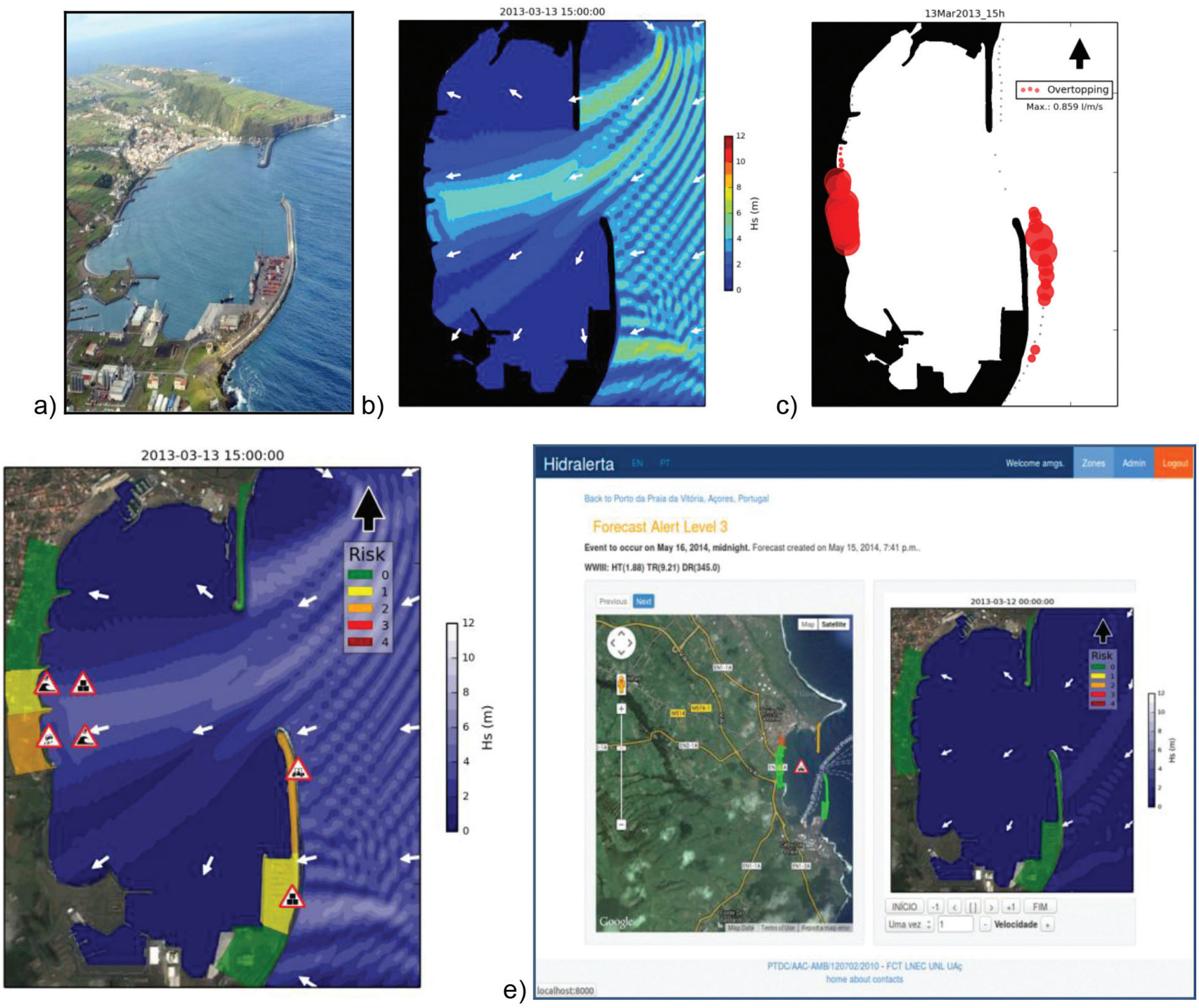

Figure 6: a) Praia da Vitória, Terceira, Azores, b) Module I: DREAMS, c) Module II: NN_OVERTOPPING2, d) Module IV – Generated warning map, e) WebGIS

the harbour define a roughly rectangular port basin with about 1 km x 2 km. For this port, the system is applied in two different approaches: warning (modules I, II and IV) and risk assessment (modules I, II and III), both for the overtopping phenomenon.

The warning system is running permanently for Praia da Vitória [Poseiro et al., 2013]. The sea wave characterisation module runs every day to predict, in advance, 180 hours of wave characteristics at the port entrance and inside the port, together with wind field and tide level predictions. The system creates a layout with significant wave height and angle of wave attack every three hours (Figure 6b). As soon as the wave characteristics in the port are available, the second module is applied, which predicts the run-up/overtopping levels associated with those wave characteristics. For each set of wave/water level characteristics, NN_OVERTOPPING2 provides, for each of the studied cross sections of the structures, information on mean wave overtopping discharge, q (Figure 6c). If the mean overtopping discharge exceeds the pre-defined (or pre-set) thresholds, a warning is issued (Figure 6d). Figure 6e shows an example of the WebGIS interface currently in development [Sabino et al., 2014].

3. LNEC'S INSPECTION PROGRAMMES FOR MARITIME STRUCTURES – OSOM

A programme of systematic inspections on selected maritime structures is being carried out by LNEC since 1985 for the mainland Portugal and since 2011 for the Azores archipelago [Lemos et al., 2002]. The importance of this programme is related with the fact that this kind of inspection programmes allows adequate planning of the maintenance and repair works, which is extremely important from management and planning standpoints. The timely identification of an anomalous behaviour of a maritime structure (e.g. an excessive movement of the armour layer), may allow for immediate or planned repair actions, avoiding further degradation of the structure, which could endanger people and goods and make a later repair much costlier, if not impossible, or even cause the collapse of the structure.

The established programme, named OSOM, encompasses visual inspections, surveys and photographic coverage, which are carried out every year and whenever a strong storm/typhoon hits the structure.

The main objectives of an inspection programme are:

- To evaluate the structure's risk during its lifetime
- To allow planning repair or maintenance works timely
- With proper repair or maintenance works, to avoid the deterioration of the structure to a point where works become too expensive or even impossible to proceed

The current two programmes encompass 28 rubble-mound breakwaters in Mainland Portugal and 19 rubble mound breakwaters in the Azores (Figure 7). In addition to these programmes, LNEC had already implemented inspection programmes for Macau International Airport Earthfill (2000-2005) and for Oeiras Marina (2001-2008).

Each programme includes systematic observation with two main steps:

- The field campaigns, to verify the structures' status and evolution, made every year or whenever a strong storm/typhoon hits the structure.

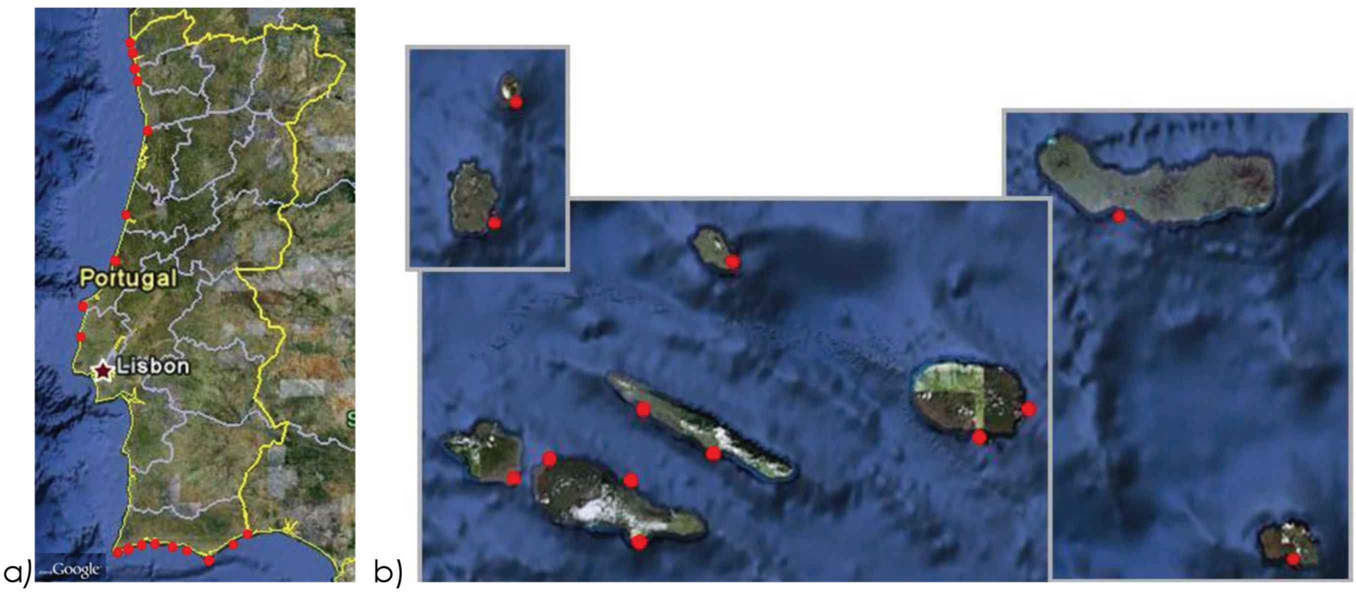

Figure 7: Current inspection programmes for maritime structures implemented by LNEC at: a) mainland Portugal, b) the Azores archipelago

- The use of the ANOSOM database, Lemos & Santos (2007), to evaluate the evolution of the structure conditions and to establish a risk level, therefore storing both the breakwater's historical data and the results obtained in the field campaigns.

Field Campaigns

The field campaigns consist of visual inspection of the rubble-mound breakwaters made from the structure's crest and, occasionally, from the sea. With this inspection any changes in the breakwater slopes, namely broken elements, change in the placement of those elements (Figure 8) or the deterioration of the armour elements due to the natural physical and chemical processes that occur at the sea, are observed and noted.

The visual inspection is always complemented with photographs of the inspected structure according to a plan of viewpoints and angles established for each breakwater. During the inspection, a structure observation form is filled in and results are introduced into ANOSOM database (Figure 9).

Figure 8: Nazaré (Portugal). Images of two consecutive field campaigns

STRETCH 6 DATE: 2001/

ARMOUR LAYER

1. DISPLACED BLOCKS		2. BROKEN BLOCKS		3. SLOPE	
NO DISPLACEMENTS		NO BROKEN BLOCKS	X	GOOD CONDITION	X
A FEW DISPLACEMENTS	X	A FEW BROKEN BLOCKS		DAMAGED NEAR THE W L	
SOME DISPLACEMENTS		SOME BROKEN BLOCKS		DAMAGED	
MANY DISPLACEMENTS		MANY BROKEN BLOCKS		VERY DAMAGED	

4. CONCRETE DEGRADATION		5. FATIGUE	
GOOD CONDITION	X	ALL BLOCKS WITHOUT ROUNDED CORNERS	X
SOME SUPERFICIAL HOLES ARE VISIBLE		SOME BLOCKS WITHOUT ROUNDED CORNERS	
SOME CORROSION		MORE THAN 5% OF BLOCKS WITH ROUNDED CORNERS	
MUCH CORROSION		MORE THAN 15% OF BLOCKS WITH ROUNDED CORNERS	

6. SETTLEMENT OF THE ARMOUR LAYER				7. FILTERS	
6.1 NEAR THE W. L.		6.2. AT THE TOP			
NO SETTLEMENT	X	NO SETTLEMENT		NOT VISIBLE	X
SOME EVIDENCE		SOME EVIDENCE	X	VISIBLE IN A SMALL ZONE	
SMALLER THAN 1 m		SMALLER THAN 1 m		VISIBLE IN SEVERAL ZONES	
MORE THAN 1 m		MORE THAN 1 m		VISIBLE IN A LARGE ZONE	

8. OBSERVER´S GENERAL OPINION

LEVEL 0	X	LEVEL 1		LEVEL 2		LEVEL 3		LEVEL 4		LEVEL 5	

CROWN WALL

9. BREAKING		10. SUPERFICIAL CONCRETE DAMAGE		11. CONSTRUCTION JOINTS	
NO BREAKS		GOOD CONDITION	X	ALL CLOSED	
A FEW BREAKS	X	SOME SUPERFICIAL HOLES ARE VISIBLE		X<0.01 m	X
SOME BREAKS		SOME CORROSION		0.01<X<0.03m	
MANY BREAKS		MUCH CORROSION		X>0.03 m	

12. SETTLING		13. ROTATION		14. SLIDING	
NO SETTLEMENT	X	NO ROTATION	X	NO SLIDING	X
SOME EVIDENCE		SOME EVIDENCE		SOME EVIDENCE	
SMALLER THAN 0.05 m		SMALLER THAN 0.05 m		SMALLER THAN 0.05 m	
MORE THAN 0.05 m		MORE THAN 0.05 m		MORE THAN 0.05 m	

15. OBSERVER´S GENERAL OPINION

LEVEL 0	X	LEVEL 1		LEVEL 2		LEVEL 3		LEVEL 4		LEVEL 5	

INNER ZONE

16. DAMAGES: OVERTOPPING SIGNS		17. SETTLEMENT	
NO OVERTOPPING SIGNS	X	NO SETTLEMENT	X
SOME OVERTOPPING SIGNS		SOME EVIDENCE	
MANY OVERTOPPING SIGNS		SMALLER THAN 0.5 m	
IMPORTANT DAMAGES		MORE THAN 0.5 m	

Figure 9: Structure observation form

ANOSOM

ANOSOM (Figure 10) is a decision-making database that, by combining the results from the several observation campaigns, it determines the Present Condition, the Evolution and the Risk according to revised and corrected criteria based on LNEC's experience. This database stores both the historical information relative to the structure and the results of each of the observation campaigns [Lemos et al., 2002 ; Reis et al., 2003 ; Lemos & Santos, 2007]. Figure 11 presents the pre defined criteria, for a) Present Condition, b) Evolution and c) Risk of a breakwater stretch, as well as the diagnosis of the risk condition of stretches, taking in account its evolution during the last five years (Figure 11d).

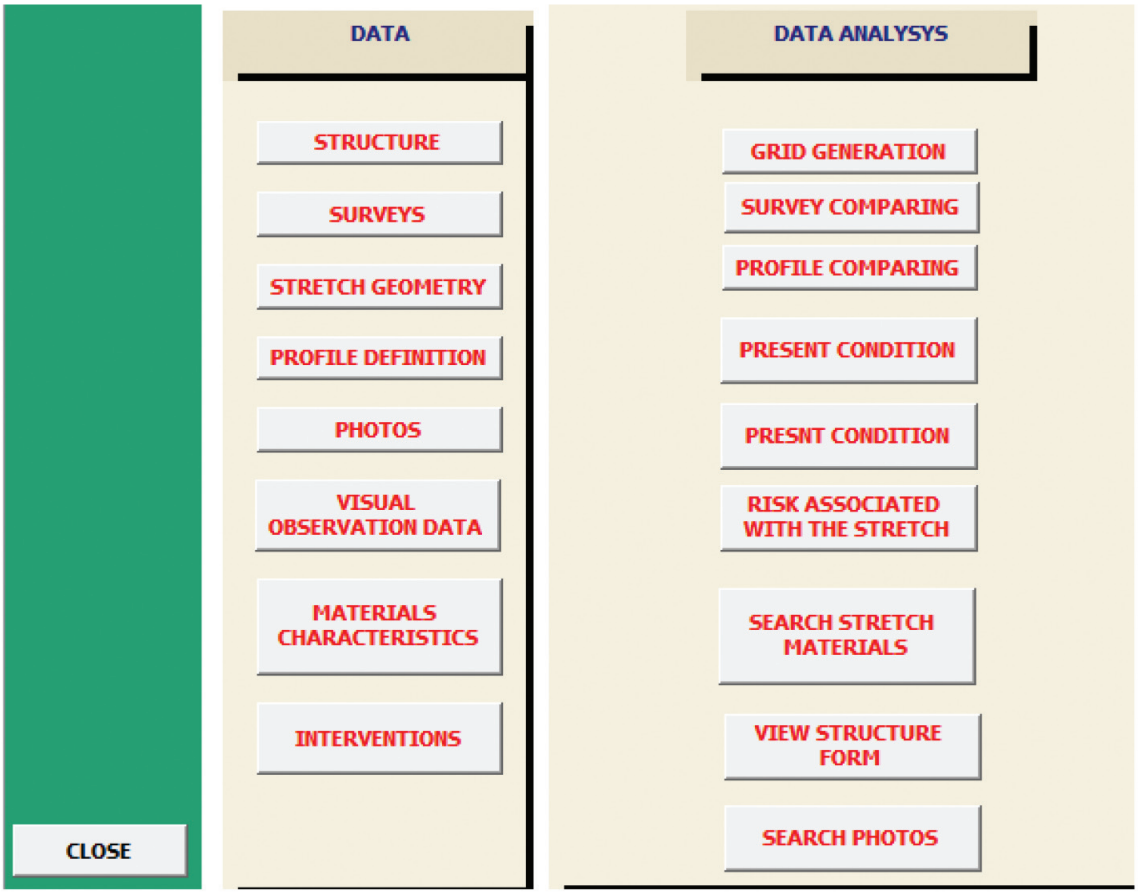

Figure 10: ANOSOM database main query form

a)

PRESENT CONDITION	DESCRIPTION
0	THE ARMOUR LAYER/CROWN-WALL IS IN GOOD CONDITION
1	THE ARMOUR LAYER/CROWN-WALL IS IN GOOD CONDITION BUT THERE ARE SIGNS OF SLIGHT LOCALIZED DETERIORATION
2	THE ARMOUR LAYER/CROWN-WALL HAS SLIGHTLY DETERIORATED
3	THE ARMOUR LAYER/CROWN-WALL HAS DETERIORATED
4	THE ARMOUR LAYER/CROWN-WALL HAS HEAVILY DETERIORATED
5	THE ARMOUR LAYER/CROWN-WALL HAS PARTIALLY COLLAPSED

b)

EVOLUTION	DESCRIPTION
0	NO EVOLUTION: THE CONDITION OF THE ARMOUR LAYER/CROWN-WALL IS UNCHANGED BETWEEN THE TWO CAMPAIGNS
1	SIGNS OF VERY SLIGHT EVOLUTION: THE CONDITION OF THE ARMOUR LAYER/CROWN-WALL HAS CHANGED VERY SLIGHTLY BETWEEN THE TWO CAMPAIGNS
2	SLIGHT EVOLUTION: THE CONDITION OF THE ARMOUR LAYER/CROWN-WALL HAS CHANGED SLIGHTLY BETWEEN THE TWO CAMPAIGNS
3	CONSIDERABLE EVOLUTION: THE CONDITION OF THE ARMOUR LAYER/CROWN-WALL HAS CHANGED CONSIDERABLY BETWEEN THE TWO CAMPAIGNS
4	STRONG EVOLUTION: THE CONDITION OF THE ARMOUR LAYER/CROWN-WALL HAS STRONGLY CHANGED BETWEEN THE TWO CAMPAIGNS
5	THE ARMOUR LAYER/CROWN-WALL HAS PARTIALLY COLLAPSED BETWEEN THE TWO CAMPAIGNS

c)

RISK	DESCRIPTION
0	THE ARMOUR LAYER/CROWN-WALL IS WITHOUT ANY APPARENT RISK
1	THE ARMOUR LAYER/CROWN-WALL IS AT LOW RISK (CAREFUL OBSERVATION IS REQUIRED)
2	THE ARMOUR LAYER/CROWN-WALL IS AT MODERATE RISK (REPAIR IS ADVISED)
3	THE ARMOUR LAYER/CROWN-WALL IS AT HIGH RISK (URGENT REPAIR)

d)

STRETCH	COMPONENT	PRESENT CONDITION (2005)	EVOLUTION (2000-2005)	RISK CONDITION (2005)
1	Armour Layer	1	0	0
	Crown-Wall	0	0	0
	Inner slope	0	0	0
2	Armour Layer	1	0	0
	Crown-Wall	0	0	0
	Inner slope	0	0	0

Figure 11: Pre-defined criteria for a) Present Condition, b) Evolution, c) Risk and d) Diagnosis of a breakwater stretch

The ANOSOM database enables:

- The storage of the data concerning the physical and geometrical characterisation of each one of the breakwater stretches.
- The storage of both the data and the photographs taken during the visual observation campaigns of rubble mound breakwaters.
- The prioritisation of the structure stretches that require immediate repair and/or maintenance.

The database is composed by three main information groups (Figure 12):

- The first includes the tables where visual observation dates, breakwater name and stretches names are listed.
- The second contains historical information, as the physical and geometrical characterisation of each one of the breakwater stretches.
- The third contains the information collected during visual observation campaigns, used to produce reports about:

    o The stretch condition during a campaign
    o The evolution of a stretch condition between two campaigns
    o The risk associated with the stretch

Risk evaluation status is periodically reported to port authorities in order to give information that enables the prioritisation of repair or maintenance works.

Based on the previous experience with the behaviour of the structures under observation, it was possible, after 2007, to make a prediction of the period from which any structure needs repair and/or maintenance works. This prediction should obviously be adjusted every year.

The information provided to port authorities comprises four levels of repair urgency:

- Level 1 – Urgent repairing works needed now
- Level 2 – Repairing works to be done during the next 1-5 years
- Level 3 – Repairing works to be done during the next 5-10 years
- Level 4 – Repairing works not needed

Current programmes in Portugal only include the inspection of the emerged part of the breakwater. Nevertheless, the database structure, which may be personalised according to different inspection programmes and to different breakwater layouts, enables the storage of both emerged and submerged parts, allowing surface and profile representations, according to the surveys, as well as the representation of surface differences between two different surveys (Figure 13).

Figure 14 shows the visual observation form and the breakwater geometrical characteristics form, resulting from the database personalisation for Nador Harbour principal breakwater (Morocco).

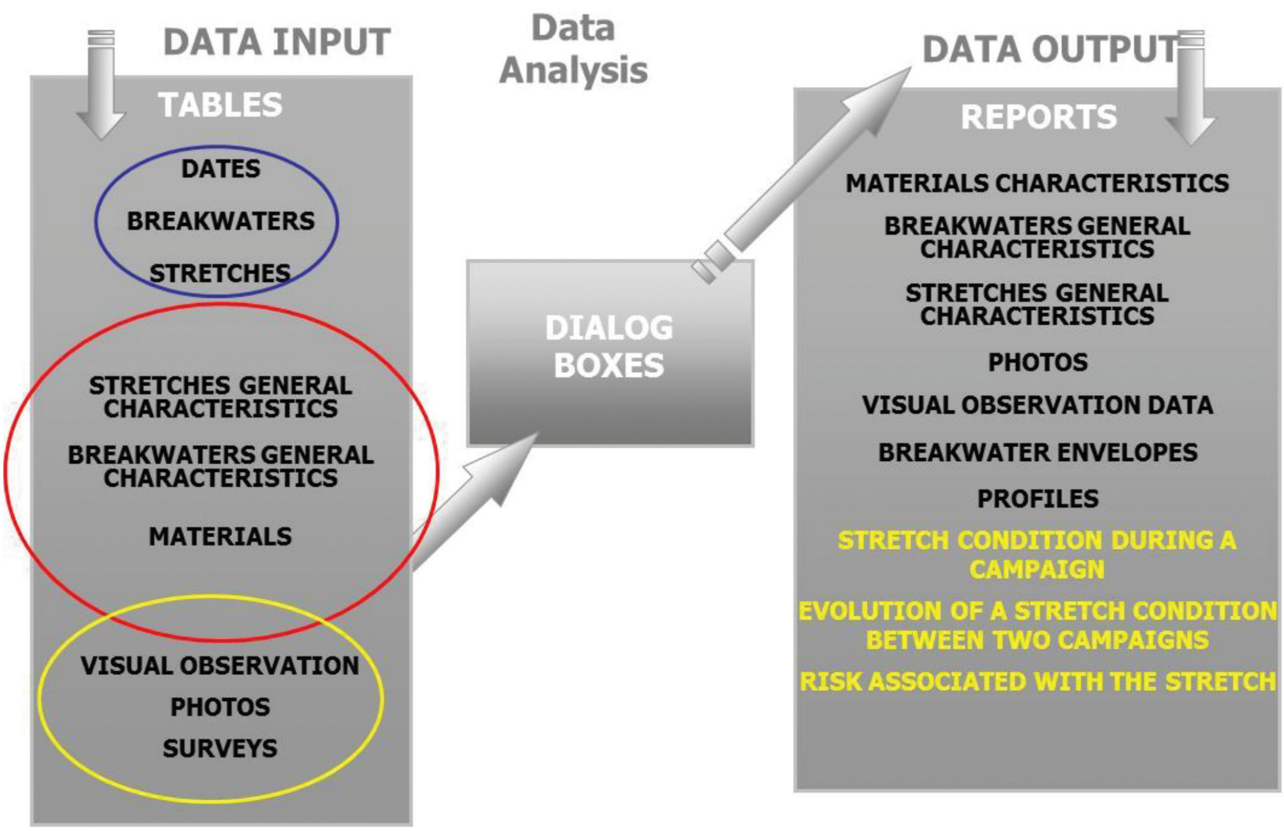

Figure 12: ANOSOM database structure

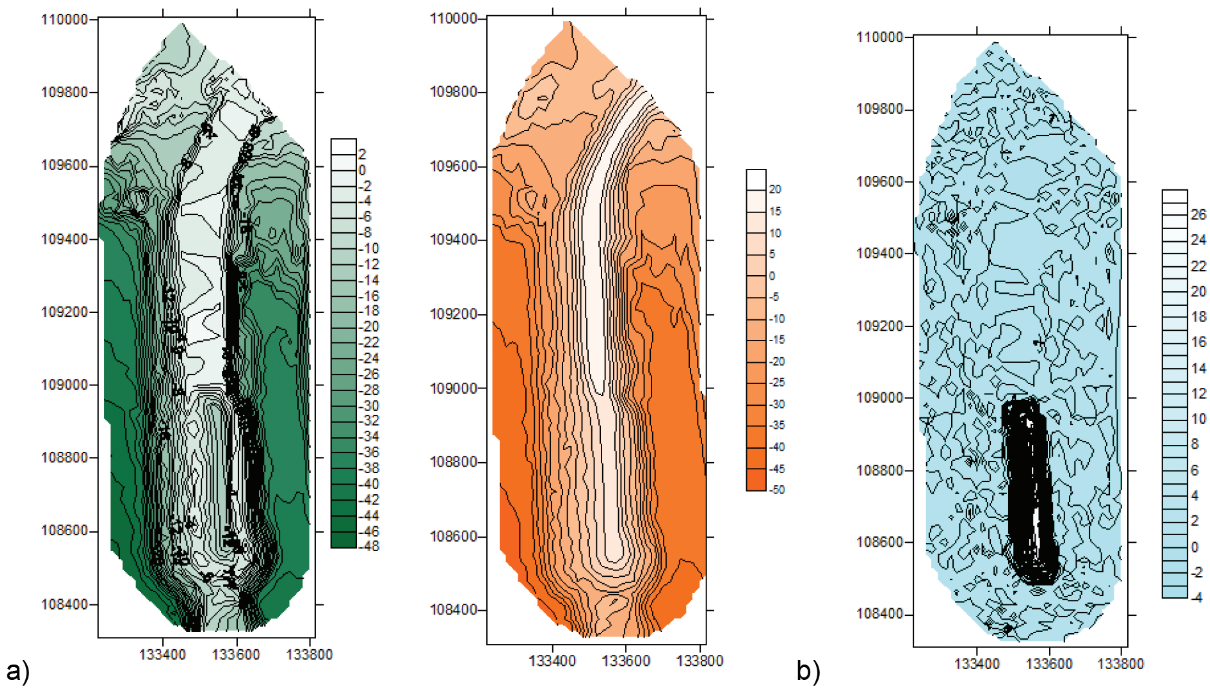

Figure 13: Surface representation:
a) Two different surveys, b) Elevation differences between both surveys

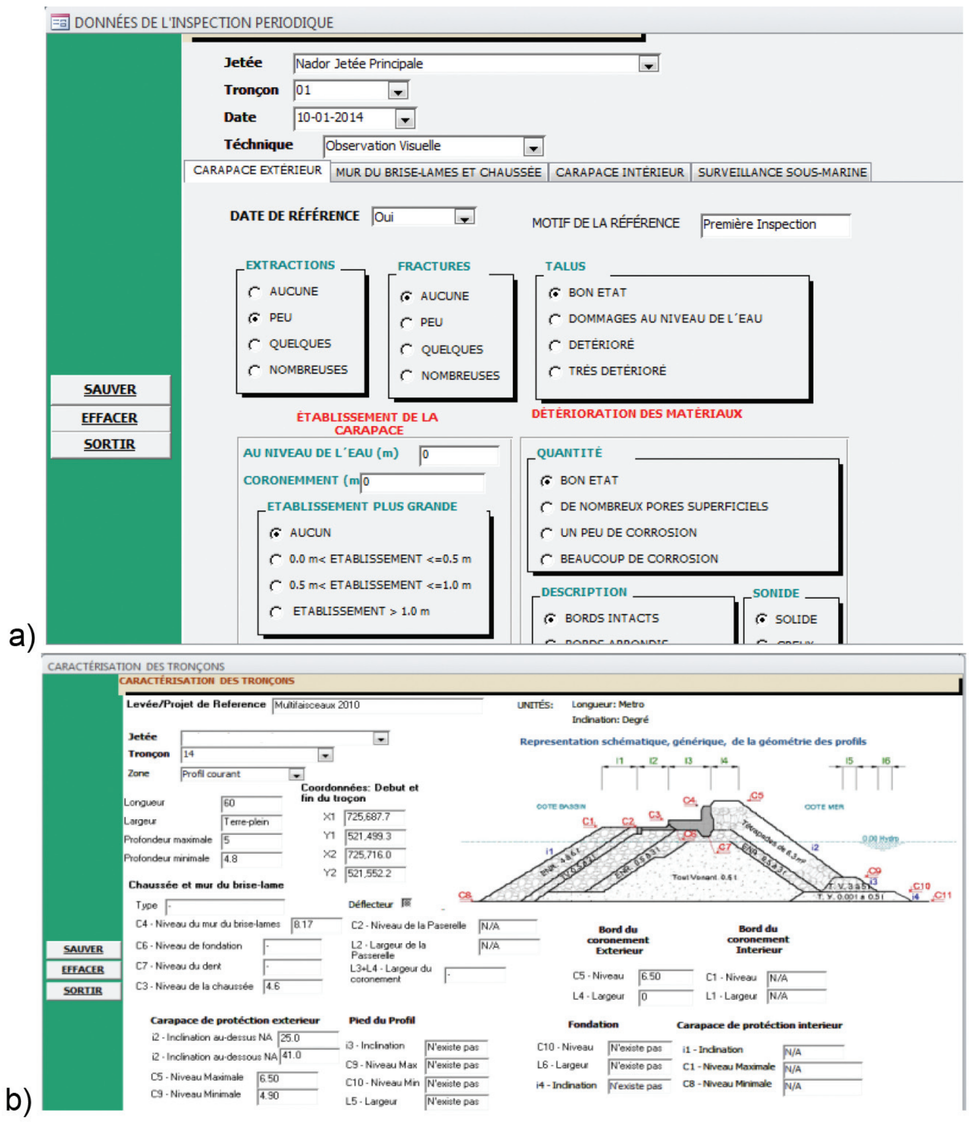

Figure 14: a) Visual observation form and b) breakwater geometrical characteristics form resulting from the database personalisation for Nador Harbour principal breakwater (Morocco)

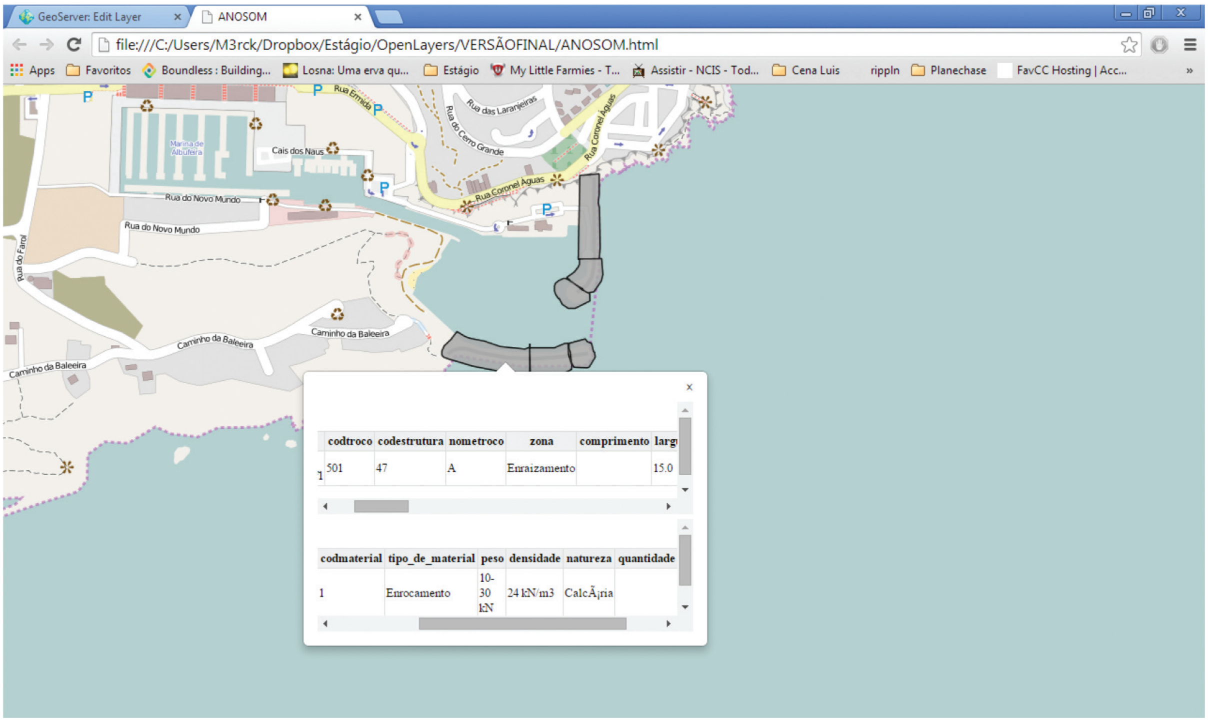

Figure 15: ANOSOM database – WebSIG interface for Albufeira Harbour, Portugal

Aiming to make the ANOSOM more user-friendly and interactive, the database is recently being migrated to a WebSIG platform (Figure 15), Domingos (2014).

4. FINAL REMARKS

This paper described LNEC's tools for forecasting and evaluation of structural risk on maritime works.

A system for forecasting, warning and assessment of risks associated with wave overtopping and flooding in coastal and port areas is a tool of upmost importance nowadays, mainly for a country with such a long coastline and such a severe wave climate like Portugal. The HIDRALERTA system is such a tool. The system was applied to the Praia da Vitoria bay, in Terceira Island, Azores and it has demonstrated the potential to become a useful tool for the management of coastal and harbour areas, due to its fast and efficient capabilities to effectively issue warnings and to evaluate risks. It has also been applied to Costa da Caparica, either as a warning system or as a risk evaluation tool, although it can be easily extended to other locations. The methodology is also currently being applied to other Portuguese locations, such as the ports of Ponta Delgada (Azores) and Sines, at the Praia da Galé coastal area.

Also an important tool to prevent high costs of maintaining and repairing maritime structures is the inspection programme for maritime structures that LNEC has been undertaken in the last 25 years – the OSOM programme – that greatly contributed for the risk assessment of maritime structures, allowing immediate or timely planned actions that avoided foreseen degradation or even collapse of the scrutinised structures. The ANOSOM database, a decision-making tool of the OSOM programme, has been recently upgraded (now including underwater surveys) and tailored in a way to be applied on inspection programmes for foreign countries. A WebSIG interface is currently being developed to make it more user-friendly.

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SUMMARY

This paper describes recent advances on forecasting and evaluation of structural risk on maritime structures. An integrated set of tools and methods that constitutes the HIDRALERTA system is described. This system makes it possible to forecast, warn and assess risks associated with wave overtopping and flooding in coastal and port areas, on the basis of measurements and/or predictions of waves and water levels. A case study of the port and bay of Praia da Vitória, at Terceira Island, Azores, demonstrates these capabilities. Moreover, the importance of LNEC's inspection programme for maritime structures, as a tool for adequate planning of the maintenance and repair works, is highlighted in this paper. This enables timely identification of anomalous behaviour of maritime structures, which prevents high economic costs on maintenance/repair works due to failure or collapse of those structures.

RÉSUMÉ

L'article décrit les avancées récentes dans la prédiction et l'évaluation des risques structurels sur les infrastructures maritimes. La chaine intégrée d'outils et de méthodes qui constitue le système HIDRALERTA est décrite. Le système permet de prédire, alerter et évaluer les risques associés avec les franchissements de vague et la submersion dans les zones côtières ou portuaires, sur la base de mesures et/ou de prédictions de la houle et des niveaux de la mer. Une application à l'étude du port et de la baie de Praia da Vitória sur l'île de Terceira, aux Açores, démontre ces performances. L'article met également en évidence l'importance du programme d'inspection des structures maritimes du LNEC. Ce programme permet d'identifier en temps utile des pathologies des structures maritimes, en économisant des coûts importants de réparation à la suite d'une défaillance ou d'une destruction de ces structures.

ZUSAMMENFASSUNG

Dieser Artikel beschreibt die jüngsten Fortschritte in der Vorhersage für maritime Bauwerke und in der Bewertung von strukturellen Risiken bei maritimen Anlagen. Das eingebundene Handwerkszeug und die Methoden, aus denen das HIDRALERTA System aufgebaut ist, werden beschrieben. Dieses System ermöglicht es, auf der Basis von Messungen und/oder der Vorhersage von Wellenhöhen und Wasserständen Risiken, die mit Überströmungen und Überflutungen in Küsten- und Hafenbereichen verbunden sind, vorherzusagen, davor zu warnen und zu bewerten. Eine Fallstudie für den Hafen und die Bucht von Praia da Vitória, auf der Insel Terceira, Azoren, demonstriert diese Fähigkeiten. Ebenso wird in diesem Beitrag die Bedeutung des LNEC Inspektionsprogramms für maritime Bauwerke herausgestellt, als ein Werkzeug für adäquate Planung der Unterhaltungs- und Reparaturarbeiten. Dieses ermöglicht eine rechtzeitige Erkennung von normabweichendem Verhalten maritimer Bauwerke, was hohe ökonomische Kosten für Unterhaltungs-/Reparaturarbeiten wegen Versagen oder Zusammenbruch dieser Bauwerke verhindert.

RESÚMEN

Este artículo describe los recientes avances en la predicción y evaluación de riesgos estructurales en obras marítimas. Se describen un conjunto de métodos y herramientas que constituyen el sistema HIDRAELECTRA. Este sistema permite predecir, alertar y gestionar riesgos asociados a rebases del oleaje e inundaciones en áreas portuarias y costeras, basándose en mediciones y/o predicciones del nivel del mar y del oleaje. El caso del puerto y la bahía de Praia da Vitoria servirá para ilustrar sus posibilidades. Adicionalmente, este artículo resaltará la importancia del programa de inspección LNEC para estructuras marítimas como herramienta para una adecuada planificación y gestión de los trabajos de reparación. Este sistema permite identificar a tiempo comportamientos anómalos de estructuras marítimas, lo que ayudará a evitar la aparición de costes asociados a operaciones de mantenimiento/reparación debidos a fallos en este tipo de estructuras.