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SINES BREAKWATER HARBOUR: THE OSOM+ MONITORING PROGRAM

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EXTENDED ABSTRACT

Il National Laboratory for Civil Engineering (LNEC) ha sviluppato dal 1986 un programma per l'osservazione sistematica delle opere marittime (OSOM) per le strutture sotto la responsabilità dell'ex Istituto per i porti e il trasporto marittimo (IPTM). L'obiettivo di questo programma è valutare il rischio della struttura nel corso della sua vita utile, al fine di consentire tempestivamente i lavori di pianificazione, riparazione o manutenzione, ed evitare un deterioramento tale delle strutture da rendere necessari interventi di ripristino costosi o, addirittura, impossibili da realizzare. Attualmente, l'utilizzo dei droni (UAV), ha consentito di effettuare numerose indagini strutturali per integrare le informazioni ottenute durante i sopralluoghi. L'UAV oltre a fornire informazioni più dettagliate e accurate sullo stato delle strutture, consente la valutazione dell'evoluzione delle superfici delle strutture, nonché il rilievo di profili trasversali rappresentativi di tali strutture. Inoltre, è stata effettuata la migrazione del database ANOSOM esistente su una piattaforma online basata su WEB, completata da una applicazione mobile che consente durante i sopralluoghi di avere accesso online a tutte le informazioni relative a ciascuna struttura marittima. Tutte queste nuove funzionalità sono riunite nel nuovo OSOM+, le cui caratteristiche sono descritte nel presente lavoro, con particolare riferimento ad un caso studio: la diga frangiflutti lato ovest del porto di Sines. Le nuove funzionalità di OSOM + contribuiscono chiaramente a un programma migliore e più efficiente di osservazione sistematica delle opere marittime. Le campagne periodiche, integrate con i rilievi effettuati attraverso l'utilizzo dei droni, consentono di ottenere un quadro più chiaro sulle condizioni attuali, evolutive e di rischio delle strutture, fornendo dati più completi per popolare il database ANOSOM_WEB. Durante i sopralluoghi in campo, l'uso in situ di un'applicazione mobile, portatile, facilita l'analisi. Alla fine, sia il fornitore di queste informazioni (LNEC) sia gli utenti finali, come le amministrazioni dell'autorità portuale, beneficiano di informazioni più accurate sullo stato delle strutture di natura prevalentemente quantitativa.

ABSTRACT

The current program of Systematic Observation of Maritime Works (OSOM+), under development at the National Laboratory for Civil Engineering (LNEC), is essentially applied to rubble mound breakwaters. The OSOM's main objective is to monitor the behaviour of maritime structures under inspection and recommend timely interventions for their maintenance and/or repair as to properly maintain its function during its lifetime.

There are four main components of the OSOM+ program, namely: the periodic visual inspections made by a trained technician, where a set of photos and videos are taken at notable points along the structure and there is an identification of the main focuses of degradation of the structure; the periodic aerial inspections with an unmanned aerial vehicle (UAV) or drone, where individual aerial photographs are captured in a regular pattern and in the vertical direction, and from them orthomosaics, point clouds and/or profiles are obtained; the ANOSOM_WEB-based online platform, to store and/or query obtained information on the observation campaigns, as well as to diagnose present, evolution and risk conditions of the structure; and a mobile, portable, application for real-time input and visualization of the database information.

This paper presents an application of the OSOM+ program to the study case: the west breakwater of the port of Sines

Keywords: *rubble mound breakwaters, monitoring, maintenance, visual observations, drone.*

INTRODUCTION

In the design of maritime structures, in particular for rubble-mound breakwaters, it is assumed that, during the lifetime of the structure, damage may occur in some of its sections and therefore maintenance and repair works will be certainly needed.

However, to successfully carry out these interventions, in a timely and cost-effective manner, it is recommended that the structures are observed and monitored in a systematic way throughout their lifetime. This enables one to follow up their structural behaviour.

The National Laboratory for Civil Engineering (LNEC) has developed a program for Systematic Observation of Maritime Works (OSOM+) for a set of rubble-mound breakwaters along the Portuguese coastline (Capitão *et alii*, 2018) and abroad. This monitoring program follows a previous one, named OSOM, that was developed in the early 80's, upgraded during the following years (Lemos *et alii*., 2002; Santos *et alii*, 2003; Silva & Capitão, 2015).

The OSOM+'s main objective is to monitor the behaviour of maritime structures under inspection and recommend timely interventions for their maintenance and/or repair as to properly maintain its function during its lifetime.

The importance of this program is related with the fact that this kind of inspection programs 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.

For each structure, the OSOM+ program is carried out every year plus whenever a strong storm/typhoon hits the structure.

Risk evaluation status is periodically reported to port authorities in order to give information for enabling the prioritization 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, according with the risk level, which depends on the present condition and on the condition evolution level:

- Level 1: Urgent repairing and 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 programs in Portugal only include the inspection of the emerged part of the breakwater. Nevertheless, the database structure, which may be customized according to different inspection programs 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.

The basic version of OSOM+ program, without aerial inspections of a drone, has been applied to 28 rubble-mound breakwaters in mainland Portugal (1986 - to present). In addition to this program, LNEC had already implemented inspection programs for the 19 rubble mound breakwaters in the Azores (2001-2002), the main breakwater protection of the Macau International Airport Earthfill (2000 - 2005), for the Oeiras Marina (2001-2008) and for the Nador, Al Houceima and Tan Tan breakwaters in Morroco (Lemos *et alii*, 2014).

Recently, the OSOM+ program was applied to the five breakwaters of the port of Sines, located at the west mainland coastline, and to four breakwaters in the Algarve region, in the south mainland coast of Portugal: two breakwaters of the Faro-

Olhão's harbour entrance and two breakwaters of the Portimão harbour. All this work has been pursued under the framework of a research contract between LNEC and the APS - Ports of Sines and the Algarve Authority S A.

OSOM+ currently comprises the following four main components below (with features recently introduced underlined):

- Periodic visual inspections by a trained technician, supported by systematic photos and video taking, all GPS-tagged;
- Periodic aerial inspections, through vertical-oriented photographs with a drone;
- The ANOSOM_WEB interface platform to collect campaign data and to perform the diagnosis analysis of each section of the structures, namely its present, evolution and risk conditions. Based on this information, it is then possible to establish when, where and under what circumstances maintenance or repair works should be carried out;
- A mobile, portable, application associated with the ANOSOM_WEB platform, for real-time input and visualization of the database information obtained during visual and aerial inspections.

The above components will be detailed in the next sections. The rest of present article describes the main features of the OSOM+ methodology and its application to the Sines west breakwater.

Visual inspection

The visual inspection allows, in a fast and intuitive way, to follow the structural behaviour of the breakwaters. The visual inspection of the structure (Santos *et alii*, 2003) is made usually every year and whenever a strong storm/typhoon hits the structure.

The main objective is to better characterize the present condition of the structure. For that purpose, the structure is firstly divided into sections, according to their different physical and functional characteristics. In general, each section corresponds to a different cross-section along the breakwater, with the head of the breakwater always considered as a section. For each section, a set of notable points is established where photos and/or videos are taken in every campaign, with the same photo view parameters (notably the same camera focal length and view angle and the same photo framing). These points are ink-marked on the breakwater in order to be used in subsequent campaigns.

At the field, the following main tasks are performed:

a) visual observations are made by a technician who walks along the crest of the breakwater and looks at, at least, the following three main components of the breakwater: the outer armour layer, the superstructure and the inner armour (sometimes the filters may be seen). For each of these components, the observer is able to detect possible changes in the breakwater and its armour units, namely broken elements, changes in their placement, their relative location within the armour layers, etc., Figure 1;

b) a simple characterization is made by the technician. This characterization involves observing the deterioration of the breakwater elements due to the natural physical and chemical processes that is likely to occur in the harsh sea environment where these structures are located. All this information is filled into a paper or electronic (or using a mobile app) form, Figure 2. Each form usually corresponds to a single section of the structure and enables characterization of all its main components;

c) a set of photos (and videos, if necessary) is taken at notable, predefined, points. These photos are taken systematically, at exactly the same predefined locations and directions, through use of GPS-tagging provided by the GPS equipment. Also, the observer compares, in situ, the present condition of the section at that location/direction and compares with previous photos taken in the last campaign, if available, Figure 1. In addition, 360° handheld videos may be made for selected points that, during the course of the campaign, are somewhat considered relevant to better illustrate and characterize the present condition of the observed component, section or even the whole structure. In order to have the maximum depth of the armour slope visible to the observer, the visual inspections should be carried out preferably during low tide. Also, it is important to guarantee the security of the observer, so that the inspections should be performed under good weather conditions and preferably under calm sea wave conditions.

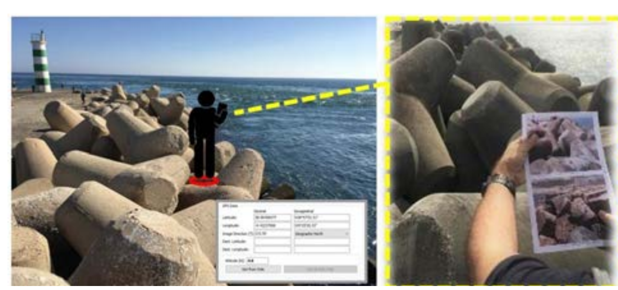
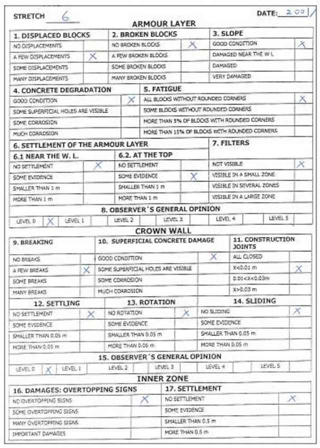


Fig. 1 - Visual observation technique used in each breakwater.

Aerial surveys

The use of a drone (Henriques *et alii*, 2014, 2016), provides more detailed and accurate information on the condition of the structures, but it also allows a better assessment of the evolution of the structures' surface as it produces more relevant representative profiles of the structures.

The main results of observation campaigns using these vehicles are the individual aerial photographs used to create the point cloud, the numerical surface model and the orthomosaic of the structure. This complements the information obtained in the visual observation campaigns by providing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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	

Fig. 2 - Structure´s observation paper form.

substantially more detailed information on the structure, as it covers hidden perspectives from a human observer walking on the structure.

Currently LNEC uses a DJI Inspire 1 V2.0 drone, equipped with a 12 Mpixel ZENMUSE X3 camera, Figure 3. This UAV performs aerial photographic surveys of the maritime structures, being the flight plan established a priori, usually at office.

Conducting a drone observation campaign, however, requires particularly favourable weather conditions, namely no precipitation and fog, and also restricted wind conditions. To maximize the visible structure area to be monitored, the aerial footage should also be carried out at low tide conditions.

The results of these observation campaigns are the individual aerial photographs, captured in a regular pattern and in the vertical direction (nadir), and, after processing, a point cloud from which the numerical surface model of the structure is derived, and an orthomosaic (here, each photo is corrected from geometric distortions and is orthorectified; then sections of these are stitched, forming the orthomosaic).

In order to georeference the obtained models and to allow comparisons between surveys or models taken in different campaign dates, it is always necessary to obtain data pertaining to specific positions on the structure called ground control points (GCP), by using high-resolution positioning equipment (a pair of GNSS receivers and/or a total station, with sub-centimetre accuracy). When the total station is used, which allows a higher internal accuracy, it is necessary to complement the observations with the coordination of two points by GNSS (static mode, more accurate than RTK) for transformation of the coordinates in the National reference frame. Usually, the GCP are located in the superstructure (the crown wall), and sometimes also on the units of the armour layers. Note that it is mandatory that all GCP must be recognizable in the photos.

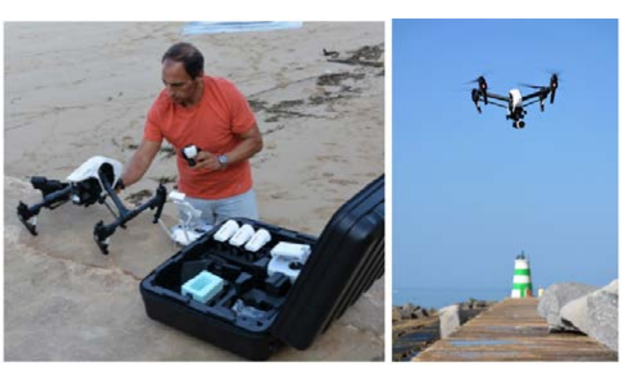
Fig. 3 - Preparing and flying the DJI Inspire V1 Pro UAV.

The ANOSOM_WEB PLATFORM (desktop and mobile)

An important part of the OSOM+ methodology is its database. This is based on a previous ANOSOM database (Reis & Silva, 1995; Santos *et alii*, 2003, Lemos & Santos, 2007). In 2016 and 2017, this database was enhanced with more powerful technologies, notably in terms of functionalities provided by geographic information systems (GIS) (Lemos *et alii*, 2016) and web technologies (PHP/Laravel, Javascript, Bootstrap/jQuery e Leaflet) (Maia *et alii*, 2017). Those technologies enabled one to include, among other assets, data georeferencing (based on spatial features do SGBD MySQL), shapefiles import, cartography (ESRI/ArcGIS maps), mapping and information visualization. It also enabled monitoring data to be included into a web mapping platform accessible by any mobile device (smartphone, tablet) or PC equipped with web connection.

Recently, the new ANOSOM_WEB platform, Figure 4, was revised and improved enabling monitoring data to be included. Also the user interface was improved to provide easier and more intuitive navigation on the new platform. A side navigation tree, user profiles, logging and administration capabilities have been added.

The platform allows:

a) the storage and analysis of the information collected for the observed breakwaters, in particular visual inspection and drone campaigns' data, or other information (e.g. surveys of submerged and submerged parts of structures);

b) the diagnosis of the structure, i.e. the levels of the present, evolution (corresponding to the degree of evolution over a certain period of time) and risk (associated with lack of intervention) conditions of each section or component of the breakwater. This calculation is performed by applying pre-specified, properly calibrated criteria (Santos et *alii*, 2003);

c) searching the structure history, based on the information on the structure available at LNEC (e.g., historical data, interventions carried out, project drawings, existing hydrographic surveys, underwater inspections, aerial photographs, etc.);

d) the physical characterization of the sections, e.g. their physical limits, geometry, materials used and standard profiles.

On this platform, one may calculate the present condition of the structure in real time using the available data. The user can thus access, in situ, the structure's conditions (present, evolution and risk levels), and assess on site whether the structure needs repair or immediate maintenance work.

All navigation and interaction in ANOSOM_WEB has been rethought in a mobile first logic, and to be usable on small devices with limited bandwidth.

The mobile, portable, application associated with the ANOSOM_WEB platform, allows: a) real-time or deferred filling and uploading of visual observations (photographs, videos, characterization of breakage components, etc.). Information obtained during campaigns (photos, videos and other data such as damage information) is thus immediately uploaded to the server and viewed on the device in situ; b) consulting in-situ information from previous campaigns, including the location of the points and characteristics of the associated photos and videos; the respective photos and videos; and information on the physical characteristics of the breakwater sections and their components; c) consultation of present, evolution and risk conditions, if any.

STUDY CASE – THE SINES' WEST BREAKWATER

Brief description of the case study

The port of Sines is the largest artificial port of Portugal, a deep water port with natural bathymetries up to -28 m (CD), see Figure 5. Besides being the main port of Portugal, due to its geophysical characteristics, it is the main gateway to the energy supply of Portugal: container, natural gas, coal, oil and its derivatives. It owns specialized terminals that allow the movement of different types of goods, all protected by rubble-mound breakwaters, including the west breakwater, mentioned in this paper as a case study.

The Sines west breakwater is the biggest maritime structure in the port of Sines, a breakwater that houses the Liquid Bulk Terminal (TGLS), the largest liquid bulk terminal in the country. With six jetties and natural beds down to -28 m (CD), it has the capacity to receive vessels up to 350,000 tonnes DWT, and allows the simultaneous handling of different products (crude, refined products, liquefied gases and other liquid bulks).

This breakwater has an initial section about 250 m long protected with rockfill blocks. The next section, which is about 500 m long, is part of a superstructure whose crown is at +16.0 m (CD), at the nearest point of the breakwater rooting and with crown at +19.0 m (CD) at the end of the section.

This change in elevation is gradual and proceeds over approximately 30 m (Abecasis & Pita, 1993). Along all extent where the crowning dimension is higher, the superstructure incorporates a wave deflector. The outer slope of the root portion is protected by 400 kN Antifer cubes. In the initial section only one layer of blocks is used with a slope of 2:1. At +14.0 m (CD) there is a 15 m wide berm, consisting of rock of 10 to 30 kN. In the intermediate section, two layers of 900 kN Antifer cubes placed regularly are used, extending the slope to a height of +17.5 m (CD), where there is a 15 m wide berm. The head section comprises 1050 kN Antifer cubes.

Inspection campaigns

The (visual and drone) inspections campaigns of this breakwater were carried out on November 13th, 2018.

For the visual inspection campaign, the structure was divided into nine sections (A to I), according to its different physical and functional characteristics, Figure 6.

Also, notable points considered for each section are marked in this structure. These points (37 points) were ink-marked on the breakwater in order to be used in subsequent campaigns.

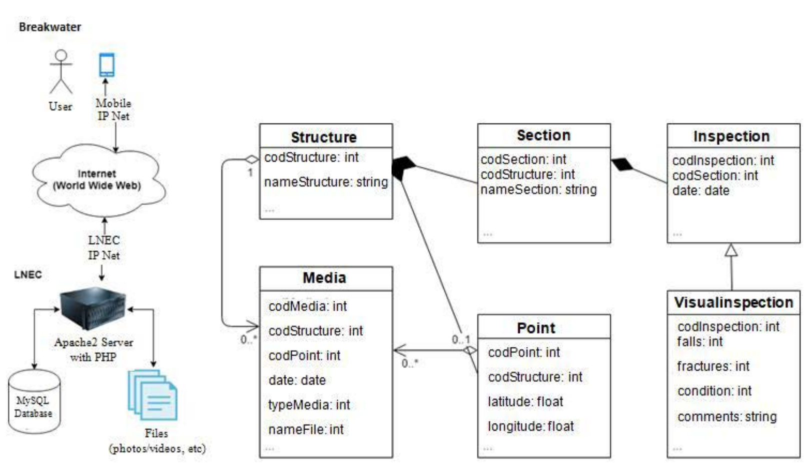

Fig. 4 - Schematic representation of ANOSOM-WEB platform; Simplified UML diagram of the OSOM+ data model.

Fig. 5 - Left: The Sines port area. Right: The Sines west breakwater.

Figure 7 shows a photograph taken at a predefined point of Sines west breakwater (point 27, located in the seaward side of section G). Also Figure 8 shows one output of the visual observation in the Sines west breakwater (Point 30).

For each section, a paper form (as seen before, see Figure 2) was filled to characterize the breakwater condition.

For the aerial campaign, the flights were automatic, programmed to be performed at an altitude of 30 m and with a photo taking overlapping of 80%. They were made during low tide to maximize the visible area above water. During the flights, 751 photos were taken by the drone, see Figure 9-left, for a number of 8 flight missions, Figure 9-right.

DATA PROCESSING

The photogrammetric software Agisoft Metashape® was used to produce the photogrammetric products previously referred. Figure 10 illustrates the orthomosaic of the breakwater´s head and adjacent trunk – which has a pixel size of around 1.5 cm. Figure 11 shows, as an example, a detail (with a 40% zoom) of the orthomosaic of the head of the west breakwater, where one can attest the excellent resolution attained by the drone. Figure 12 shows the contour maps generated from the point cloud.

To monitor the breakwater evolution, point clouds or numerical surface models of different campaigns may be compared and areas and volumes of changed sections may be computed.

Also, profiles at more vulnerable points of the structure may be produced: Figure 13 shows profiles P62 and P63 of Sines west

Point	Coordinates (PT-TM06/ETRS89)	
1	-66238.75	-190100.79
2	-66335.17	-190209.07
3	-66352.57	-190200.94
4	-66407.15	-190299.58
5	-66425.85	-190292.85
6	-66448.42	-190384.94
7	-66465.70	-190378.50
8	-66473.60	-190507.84
9	-66502.00	-190504.32
10	-66472.24	-190601.88
11	-66504.41	-190598.92
12	-66463.94	-190815.56
13	-66504.28	-190815.24
14	-66459.17	-190939.64
15	-66495.18	-190942.29
16	-66456.00	-190970.74
17	-66455.52	-191027.01
18	-66480.48	-191035.73
19	-66430.93	-191093.34
20	-66444.61	-191093.47
21	-66482.59	-191092.45
22	-66415.31	-191160.89
23	-66439.96	-191160.57
24	-66482.24	-191165.00
25	-66412.47	-191247.20
36	-66437.59	-191246.41
27	-66478.88	-191245.95
28	-66410.65	-191370.79
29	-66432.71	-191371.08
30	-66461.14	-191371.31
31	-66409.49	-191402.80
32	-66431.30	-191401.22
33	-66461.67	-191436.74
34	-66409.29	-191464.94
35	-66432.06	-191464.76
36	-66462.02	-191450.12
37	-66434.79	-191482.19

Fig. 6 - Sines west breakwater with division into sections (A to I) and visual observational points (1 to 37), with corresponding coordinates.

Fig. 7 - Systematic photos took during visual observation in the Sines west breakwater (Point 27).

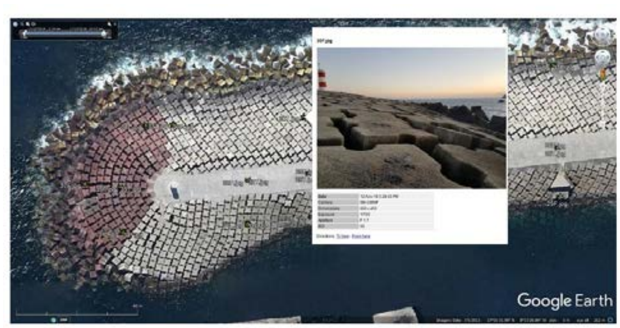

Fig. 8 - Output of the visual observation in the Sines west breakwater (Point 30).

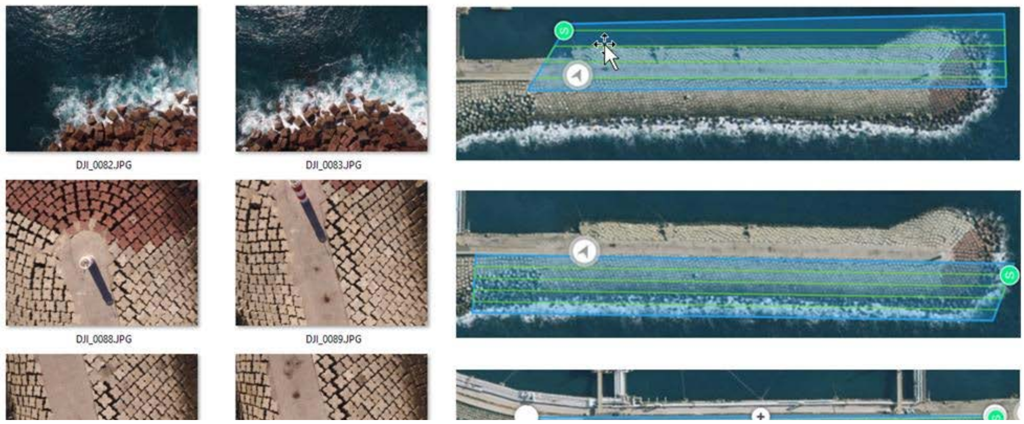

Fig. 9 - Left: examples of six (out of 751) aerial photos; Right: example of three (out of eight) flight plans of drone campaigns.

breakwater for current campaign of November 13th 2018.

Figure 14 and Figure 15 illustrate operations on the database regarding the view of a photo associated to a certain point and inspection.

The ANOSOM_WEB database, which was initially fed with info related to the structure's project design only (project drawings, existing hydrographic surveys, underwater inspections, aerial photographs, historical data, etc.) was then fed with information collected in the observation campaigns.

To date, since only a first campaign is available for the Sines west breakwater, it is not possible yet to determine the evolution and risk conditions of the structure, being only possible to determine the present condition of each section.

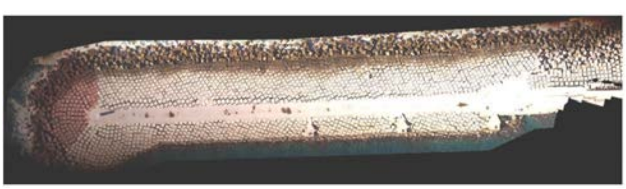

Fig. 10 - Orthomosaic (with detail) of the head of the west breakwater.

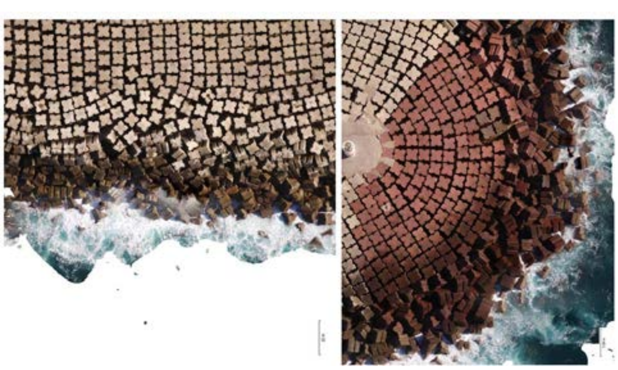

Fig. 11 - A detail (40%) of the orthomosaic of the section D and the head of the west breakwater.

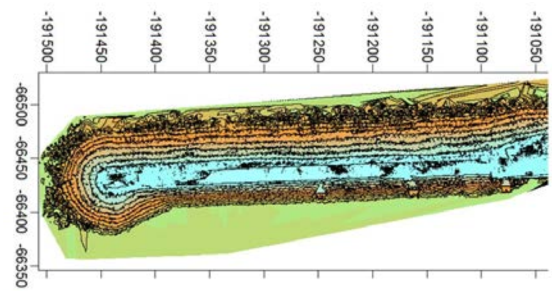

Fig. 12 - Contour maps of the head and adjacent trunk of Sines west breakwater

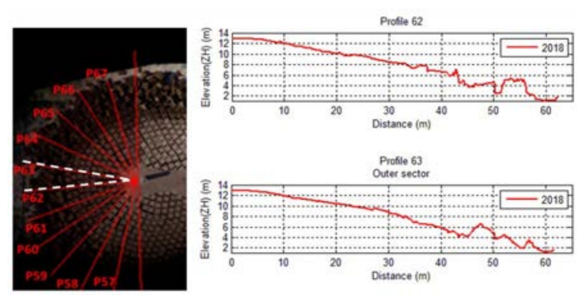

Fig. 13 - Profiles (P62 and P63) of Sines west breakwater.

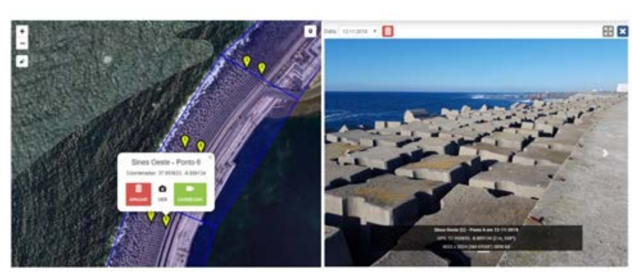

Fig. 14 - ANOSOM_WEB interface. Searching photos in real-time. Example of a photo from campaign of 12th November 2018, at Point 6 (Section C).

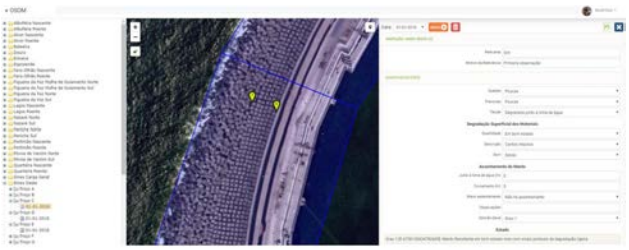

Fig. 15 - ANOSOM_WEB interface. Form inspection of the section C of Sines west breakwater.

ANALYSIS

The present condition of Sines west breakwater shown here was based on both visual and aerial monitoring campaigns.

From the results of the visual and drone inspections, it can be concluded that the breakwater is currently in good conditions, although with local signs of degradation, namely:

• In a few sections, the randomly placed armour units of the armour layer, at the seaward side, suffered some displacements and movements near the waterline level. In the vicinities of this waterline level area, there is lack and some dispersion of the armour units;

• The armour layer of sections D and E (and even section C) showed some sliding/settling in the area where regularly placed armour units exist, mainly in the rows closer to the waterline. A spacing between the crest level and the first row of cubes is also apparent, although this behaviour is not uniform across the sections;

• At the leeward side of the armour layer of section G, significant cracks are found on the bollard of the stairs nearby;

• At the breakwater head area, some lack of units is visible on the randomly placed armour units, due to displacements and movements, as well as some armour unit's dispersion at waterline level. The slope of the armour layer varies also.

Although the west breakwater does not show evidence of existing high risk and the risk analysis carried out is only indicative, since it is the first observation (visual and drone), the sections mentioned above should deserve special attention during future inspections to infer on the evolution of those anomalies. These concerns are quantified in the levels shown in Table 1.

Structure/ Section	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*
Armour layer	*1*	*1*	*1*	*2*	*1*	*2*	*2*	*2*	*1*
Super-structure	*1*	*2*	*1*	*1*	*1*	*1*	*1*	*1*	*-*
Lee side	*-*	*-*	*-*	*-*	*-*	*0*	*1*	*0*	*1*

0 Element in good condition
1 Element in good condition but has signs of slight degradation
2 Element slightly degraded
3 Element degraded
4 Element much degraded
5 Element in ruin

Tab. 1 - Present condition of the west breakwater.

FINAL REMARKS

In this paper, the OSOM+ methodology was applied to Sines west breakwater, describing some of the main new features of the methodology and the obtained results for that real case.

The new features of OSOM+ described in this paper clearly contribute to a better and more efficient program of systematic observation of maritime works. Periodic visual observation campaigns complemented with drone observations allow a sounder determination of the present, evolution and risk conditions of the structures and a more complete fill of the ANOSOM_WEB database.

During campaigns, the in-situ use of a mobile, portable, application also streamlines the process.

In the end, both the provider of this information (LNEC) and the end-users, namely Port Authority Administrations, benefit from more accurate information on the state of the structures in a predominantly quantitative nature.

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