
Towards a mobile monitoring tool for coastal structures inspection: The Ericeira rubble-mound breakwater test case

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Abstract

Rubble mound breakwaters (RMB) are the most common maritime structures in Portugal. Their main goal is to reduce the action of waves on the sheltered area of the structure to achieve safety conditions for ships, people and harbour activities.

To account and define the need for maintenance or repair works on such structures, it is necessary to evaluate its evolution along its expected lifetime. To predict damages that may occur in those structures and evaluate its importance in terms of structural safety and functionality, it is therefore of utmost importance to follow a monitoring program on such structures. For that purpose, a monitoring mobile tool to be used onsite by the observer would be very useful, adding in this way more efficiency to the existing traditional monitoring techniques used nowadays at LNEC, where visual, systematic, observations are made to attain relevant qualitative evaluation of those structures.

Hence, a responsive WebGIS system was developed (Maia *et al.*, 2017) for assisting the observation campaigns, enabling the introduction of photos and videos, their accurate geo-referencing, the automatic evaluation of the current, and evolutive, structural state of the structure, and also the checking of physical characteristics of the structure and materials.

Besides briefly describing the monitoring tool, this paper focuses primarily on demonstrating its application to a real case scenario of an inspection campaign to the RMB of Ericeira, Portugal, on the 20th of April 2017.

Key words: breakwaters, monitoring, inspection, WebGIS, mobile app, risk assessment.

1 INTRODUCTION

Breakwaters are constructed to create sufficiently calm waters for safe mooring and loading operations, handling of ships, and protection of harbour facilities. In Portugal, the most common breakwaters are the rubble-mound ones, which are usually composed by rock or artificial

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armour units. Its main function is to dissipate wave energy and/or to reflect wave energy back into the sea. Usually, rubble mound breakwaters consist of a core of fine material covered by an armour layer, made with stone or concrete blocks, together with filter layers as to avoid that fine material could be washed out through the armour layer (*Fig. 1a*).

For this type of structures, maintenance and repair works are normally needed during its whole lifetime not only because materials deteriorate over time but also when disasters occur, and they do occur sometimes. To determine the need for maintenance or repair works, it is therefore necessary to evaluate the evolution of the structure from a relevant earlier date, such as the last evaluation made on that structure or, when the latter is absent, the evaluation made when the structure was originally built (first evaluation).

Therefore, periodically, the structures are subjected to visual inspection, performed by the LNEC team, (*Fig. 1b*). In general, the structure is inspected yearly but additional inspections may be performed, especially after occurrence of notable storms. The data collected in each of those inspections refer to the current condition of the structure, namely its main components such as the armour layer, the superstructure and the inner filters.

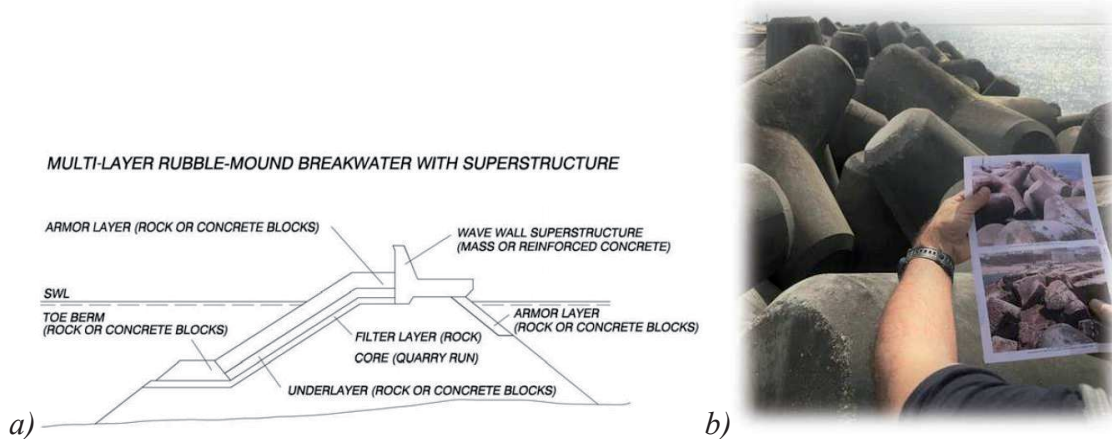


Fig. 1: a) A typical RMB with superstructure; b) Visual inspection (comparison of photos) in a point of section B of Ericeira's breakwater.

Recently, a monitoring mobile tool to be used onsite by the observer was developed, adding efficiency to the existing traditional monitoring techniques (Maia *et al.*, 2017). The application enables the user to insert *in situ* relevant data of the structure's inspection (current location, photos, descriptions, video and surveying data) and on the current state of the structure. Other already existing data, regarding specific characteristics of the structure (for example, the width and length of the structure or the type and weight of materials of the structure being inspected), can also be viewed *in situ*. During the campaign, captured photos, recorded videos and other data are uploaded to the server, which may also be viewed on a specific web page. After data collection, the user can then access, *in situ*, the current state, the evolution state, and the risk state of the structure, to decide whether the structure needs repair or maintenance works.

The following chapters of the paper describe the system implementation and its application to Ericeira harbour.

2 SYSTEM IMPLEMENTATION

The mobile tool is an online geographic information system (WebGIS) that was developed by Maia *et al.* (2017). When the user accesses the platform, he needs to introduce his credentials on the login form. After login, the user is redirected to the map page, which is provided by OpenStreetMap. Once he accesses the map, the shapefile features (which represent breakwater's sections) are loaded. Each geographic feature is displayed on the map as a blue polygon. The breakwaters are divided into several sections and each of these sections has a unique code, which allows the connection of the feature with the information that is stored on an Oracle® MySQL™ database.

The system allows the user to access information on the evolution state of the structures, enabling the comparison of the Present Condition of one structure's section with its stored condition, determined at an earlier relevant date (5 years before or at a more recent date, if repairing works took place). Previous related work has been accomplished with the aim of collecting and storing, in Microsoft® Access® database format, the data collected in previous inspections.

The so-called ANOSOM database is a decision-making tool, as it is used to prioritize the breakwater repairing and maintenance works. Its first version (Reis and Silva, 1995) was developed with the double goal of storing all the information gathered in visual inspection campaigns on coastal structures carried out by LNEC and facilitating the diagnosis of the problems presented by each inspected structure. The collection of qualitative information related to the deterioration of the breakwater materials in profile elements, which can only be obtained through visual inspection, is of major importance in the evaluation of the condition of these structures. Currently, the ANOSOM database (Lemos and Santos, 2007) contains information collected in the visual inspection campaigns, as well as the general information and geometrical characteristics of the structure.

The present tool communicates in real-time with a database server (based on the ANOSOM database but containing additional tables). This database will be populated with data of each campaign: photos and video and associated metadata, such as position (latitude and longitude) and orientation of photo captures.

3 APPLICATION TO THE ERICEIRA'S BREAKWATER

To demonstrate the use of the monitoring tool, a campaign was set up for the 20th of April 2017 on the RMB of Ericeira harbour, Portugal. The Ericeira harbour is located on the west coast of Portugal, between cape Roca and cape Carvoeiro (*Fig. 2*) and its main function is to provide shelter for the local artisanal fishing fleet. With a small size, this port is made up of the breakwater, which also serves as berth, and a boat ramp. The breakwater had already been subjected to five repairing campaigns (1989, 1987, 2008, 2010 and 2015), because of local severe wave conditions. Its armour layer consists of rock, tetrapods and *Antifer* cubes units.

Fig. 2 shows the 4 sections (A, B, C and D, from the root to the head of breakwater) and a total of 17 observational points of the RMB of Ericeira used for the inspection campaign of 20th of April 2017. Sections were introduced for the first time using pre-defined shapefiles on the WebGIS platform, before the first inspection. For subsequent inspections, sections' inspection

data and recent photos and videos of each point were uploaded. Reference points are of utmost importance, as they are used to visually compare the damage occurred in each section between consecutive campaigns.

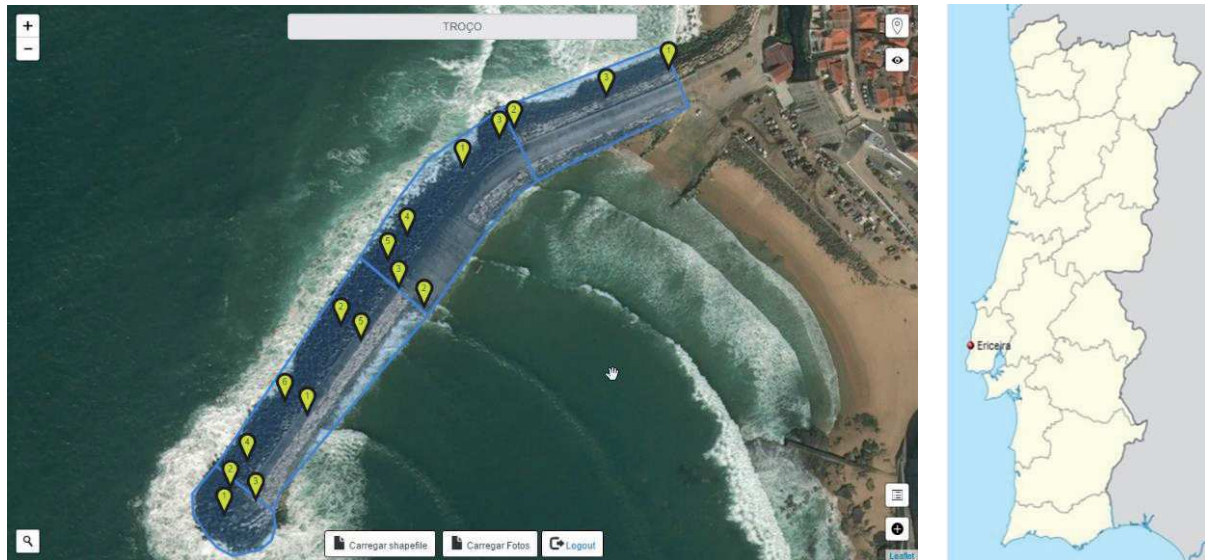


Fig. 2: Map showing sections and observational points of RMB of Ericeira used for the inspection campaign of 20th of April 2017.

3.1 BREAKWATER AND USER LOCATION

The user's current location is an important feature. A red marker is placed on it (using latitude and longitude) on the map interface. The system then associates the user's current position (if available) to a particular section of a structure. At this moment, the system knows which section is being inspected and will associate collected information to it. To speed up detection, only the structures that are visible on the map window, at the moment of detection, are considered for inspection. The time taken to detect the section chosen for inspection is important, as the number of structures to be added to the system is large and the search will be executed on a mobile device. The algorithm used for section detection is an adaptation of the *Point In Polygon algorithm* (Franklin, 2006).

Once the user's location has been detected, as the user walks on the structure, the system will associate the data he collects with one of its sections. In this context, the user can either add observations on that section or define new points of observation.

In Fig. 3, below, as an example taken on the 20th of April 2017 with a mobile phone (iOS 10.3.1, using Safari browser), one can see a point already pinpointed in section A of RMB of Ericeira (Fig. 3a) and the setup of a new point (red marker) on the same section (Fig. 3b).

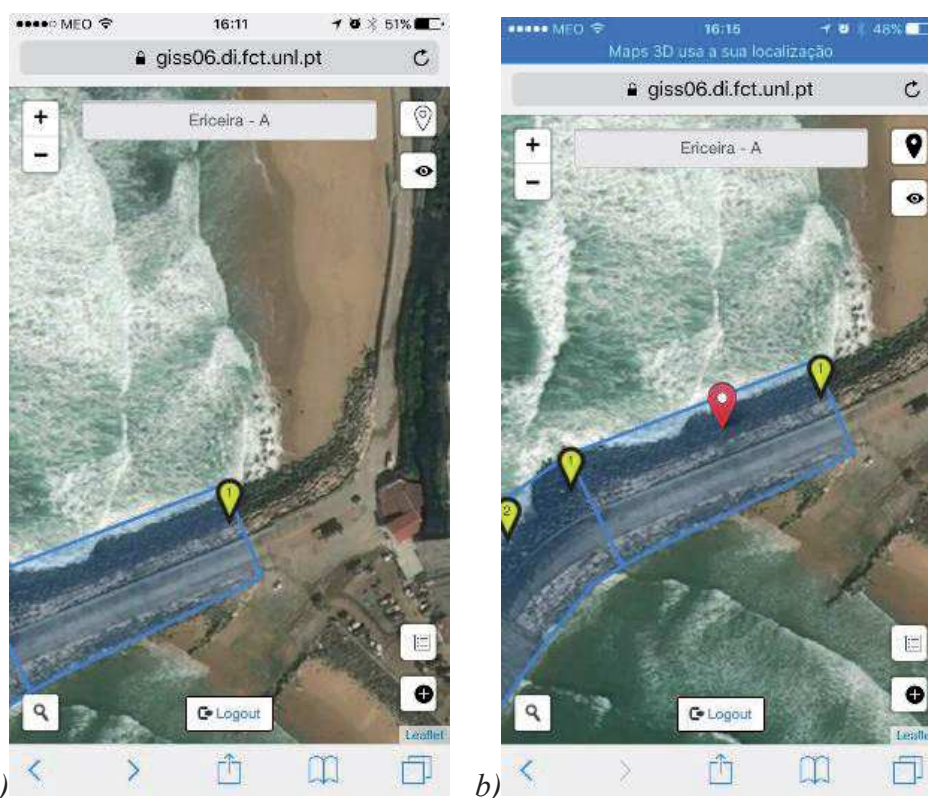


Fig. 3: a) Existing observational point (1, in yellow); and b) A new point (unnamed yet, in red), both in section A of RMB of Ericeira.

3.2 PHOTOS AND VIDEOS OF OBSERVATIONAL POINTS

Media data collection has been contemplated in the platform. For jpeg photos, it is possible to gather Exif (Exchangeable image file format) metadata from the file and directly add it to the system. When the user captures a jpeg photo, the system captures latitude, longitude, altitude and orientation of the photo from the file's metadata and associates the photo with a point that is created with the file's latitude and longitude metadata. If there is already a point very close to that captured latitude and longitude, instead of creating a new point, the photo is associated with the already existing point. This takes in to account the frequent error in GPS data collection. Afterwards, a request to view the photos gathered at this point of observation will include the corresponding photo. In fact, all the photos taken and collected on that point are presented to the user for viewing.

On the photos' page, the user has the chance to check the photos' metadata, with the help of a map, where the orientation of capture is displayed (Fig. 4a). With this feature, the user can capture photos using a particular camera instead of the mobile device camera. In this figure, note that the direction of the photo is indicated on the top image. On the left image on the bottom, one can observe the Exif data associated to that photo, namely the geographical coordinates, altitude and the direction of the captured photo.

The user can also capture and associate a video to a point of observation. However, in this case, only the date of upload is stored in the system. Uploading videos is similar to uploading photos. The user clicks on a point of observation, displayed on the map as a yellow marker, which causes a pop-up window to open. Next, the user presses the camera button icon (when using a

mobile device), takes the photo/video (or chooses a photo/video that has been previously captured) and the file upload starts automatically. After a few moments, the photo/video is stored in a folder on the server, becoming associated with the chosen point of observation. Consequently, the file also becomes part of the observation information associated with the section of the breakwater that owns the observation point.

One can access all photos and videos pertaining to each section of the RMB, that is, for all its points (Fig. 4b). In this figure, filenames include a "F" if they refer to the "front" of the RMB and "T" if they present the back, when referring to the direction of the photo.

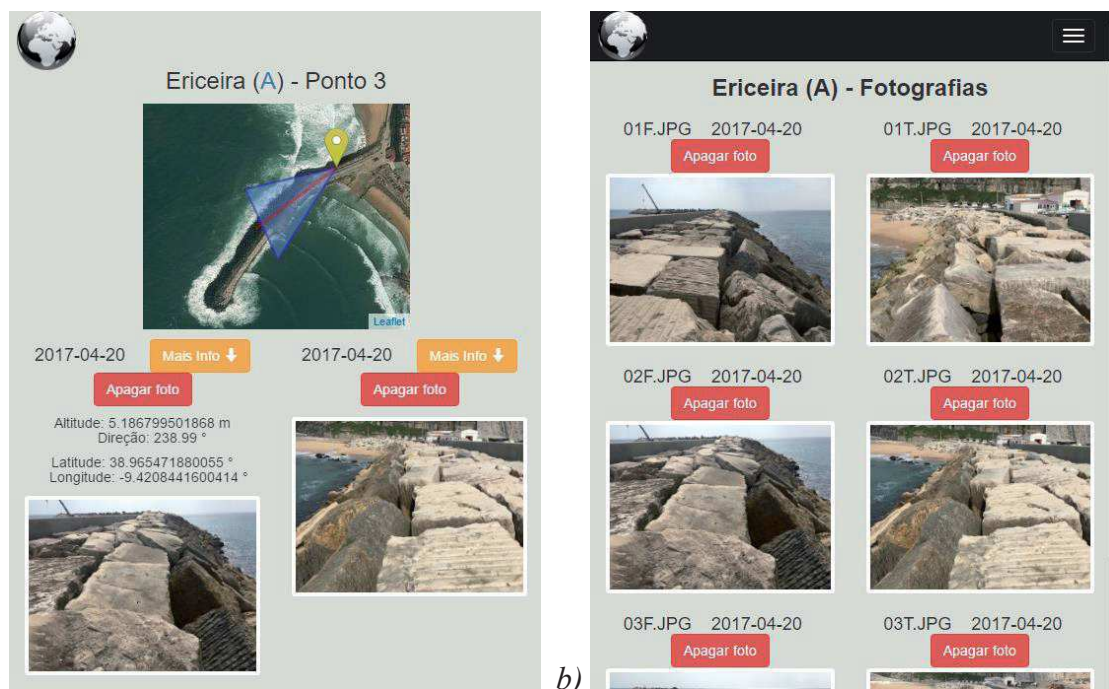


Fig. 4: a) Photos from point 03, section A; and b) All photos from section A (only points 01 and 02 are shown in figure), of RMB of Ericeira.

3.3 INFORMATION ABOUT THE SECTIONS OF THE BREAKWATER

Each structure's section has very specific characteristics, as shown in Fig. 5, such as its length and width, information about the superstructure/crown, the armour layer, the outer crest berm, the inner crest berm, and so on. This information essentially relates to the slope of the outer armour layer, the width, the values of the maximum and minimum dimensions and their materials (the type of blocks, the weight, the layout, etc.). To facilitate information viewing and analysis, the section interface page includes an interactive drawing of a breakwater, enabling viewing of a particular part of the information by clicking on the structure's relevant part.

The interface has also been structured with several tabs and a navigation bar (at the top of the page), allowing the user to navigate to other pages to view the section's photos and videos, to access section observations (according to the selected date), and to analyse the characteristics of other sections belonging to the same structure.

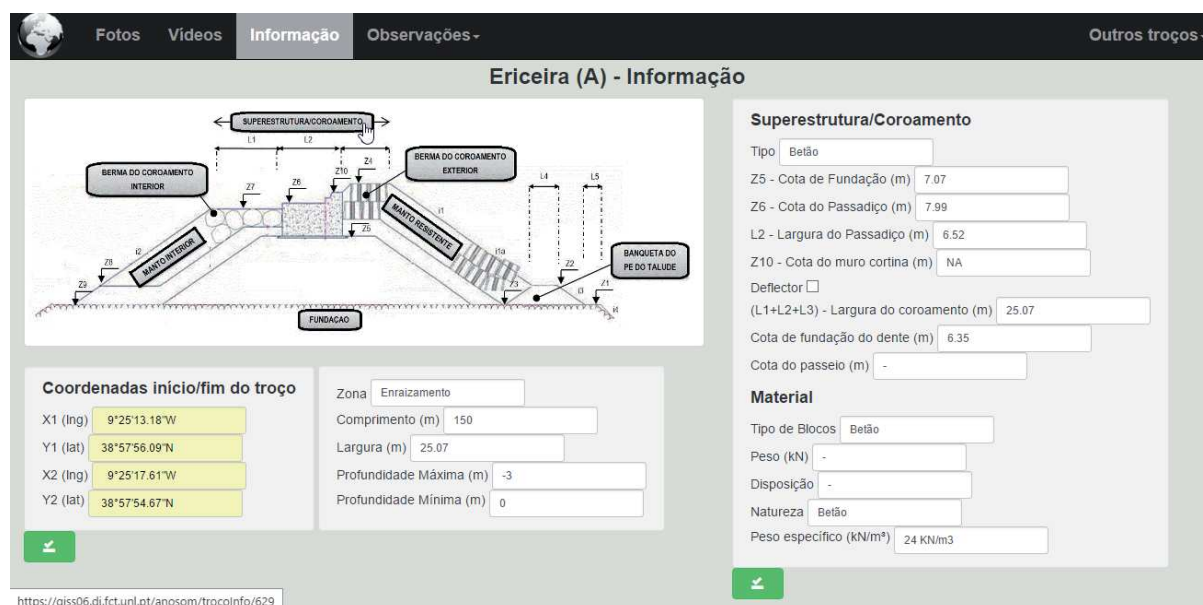


Fig. 5: The interactive interface includes clickable drawings and alphanumeric information of the elements of the section (in this case, section A of RMB of Ericeira).

To make the data gathering process easier, most of these data are entered into the inspection forms via radio buttons. Predefined, qualitative, values scales have been defined as, for example, in the case of the number of unit displacements that may have occurred, where values can be 0 (None), 1 (Few), 2 (Some) or 3 (Many). These and other values contribute to calculate the Present Condition of that part of the structure's section, and these range between 0 and 5. LNEC researchers have developed a methodology that enables the evaluation of the Present Condition of the structure and its evolution (Santos *et al.*, 2003). If at least two visual inspections have been performed, it is possible to calculate the Evolution Condition. The Risk Condition associated with the structure can be calculated from existing information on the Present Condition and the Evolution Condition.

During this campaign, all captured photos, recorded videos, and other data were successfully uploaded to the server, making it able to be viewed later on the system's webpage. The tool has clearly increased productivity and efficiency in the inspection reported in this paper. Increase in productivity has been evaluated in Maia *et al.* (2017) and Maia (2016).

4 CONCLUSIONS

In this paper, the use of a mobile monitoring tool is demonstrated in an application to a real case scenario of a monitoring/inspection campaign of RMB. This tool takes the form of a WebGIS platform that enables the geographic visualization of coastal structures on mobile devices and lets the user collect new observations, when located on the structure. Geo-referencing of the structure, its sections and observation points are displayed on a map. Photos, videos and other related information about a given section can be uploaded to the site and also to the ANOSOM database, through the use of this tool. The collected information is used to calculate the Present Condition of each structure's section. The tool was used to upload relevant data *in situ* (current location, photos, descriptions, video and surveying data) on the current state of the structure on an inspection made recently, on 20th of April 2017, on the Ericeira's breakwater.

During the demonstration, the system was used to retrieve existing data regarding specific characteristics of this structure such as, for example, the width and length of the structure, the type and weight of materials of the structure, etc.. During the campaign, captured photos, recorded videos and other data were successfully uploaded to the server, enabling access to them later on the system's webpage. At a later stage, and after data collection, the user can then access *in situ* the current state, the evolution state, and the risk state of the structure, to decide whether repair or maintenance works on the structure were necessary. She can also upload a batch of photos and/or videos, and other rubble mound breakwaters related data, to the WebGIS platform, in an automated fashion.

The developed tool has clearly increased productivity and efficiency in the inspections made so far. However, it is the authors' opinion that there is some room for improvement. As coastal structures largely differ, one would like to update the platform to enable administrative configuration of the information viewed on the interface, so that the researchers could, by themselves, change and evolve the structure of the database. Also, an offline version, which would not require internet connection (supported by GSM data) on location, would be most welcomed and should be considered in a future upgrade of this tool.

Finally, one cannot forget that this system can only operate when good meteorological conditions exist, as the wind and waves may harm these mobile devices, and when the safety of the observer is not at stake, as manoeuvring these devices hinders equilibrium on top of blocks.

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