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Methodology for the inventory of coastal defences

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Abstract:
Inventories of shore protection structures and coastal facilities are regularly undertaken by French local authorities for public security matters, public maritime domain management or environmental concerns. However no standard inventory exists either for the applied method or for the structures' typology, so that present inventory results are not nationally compatible. The French institute for maritime and inland waterways (CETMEF) led in 2009 a large bibliography for inventorying all national and local studies dealing with coastal structures inventory, diagnosis or monitoring. Terms used for nominating the works are not homogeneous but the whole national territory is covered by an inventory and recent studies led to local GIS databases. The CETMEF then proposed a simple coastal structures' typology and an inventory methodology in order to achieve a national database of coastal protection.

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1. Introduction

In the early 70s, the French Ministry of territorial planning, equipment, housing and tourism, which was responsible for technical answers for sea defence, asked the National hydrological service to produce a guideline book for financial decisions. This book had to be based on both physical and economical aspects (SCHE, 1973a). The main objectives were to insure an indisputable and profitable decision answering a social necessity. The Service had to propose a unique method of evaluating benefits generated by the submitted sea defence projects and a methodology helping to define priorities. The necessity of standard data led the service to make a national inventory of basic data on sea defence. That inventory covered the whole existing structures or submitted sea defence projects and all the "other defending measures already taken or supposed to be taken soon" on the whole of metropolitan France. Collected data gave information about the location, nature, structure, size, construction date and status of the coastal works (SCHE, 1973b). That data was then mapped at 1/100000 scale (SCHE, 1973c).

Several national catalogues were led by the National technical service for maritime harbours and navigable waterways ("Catalogue des digues" and "Catalogue des défenses des côtes" in 1981; "Catalogues sédimentologiques des côtes françaises" between 1984 and 1995 – in 5 volumes –). However, no national inventory was undertaken since the 90s, and a national database is lacking today. Integrating local homogeneous data into a national GIS could facilitate the exchange, analysis and promotion of those existing local data at a national scale (LE BERRE & METZLER, 2008), which is not possible today. The French institute for maritime and inland waterways (CETMEF), historical legatee of this technical service, identified that lack in 2009 and proposed the definition of a national methodology for the inventory and the database development. Early 2010 the Xynthia disaster reminded people of the necessity of sound knowledge of coastal defences, clearly identifying potentially-complexed protection systems and their geotechnical characteristics in order to minimize breaching and breaking defence risks.

2. Current statement

Many local inventories exist. Often led by a decentralized government department, they are linked to needs in the management of the public maritime domain (DDE ALPES-MARITIMES, 1994; MALAFOSSE, 2006), in the increase of coastal risks knowledge (SOGREAH, 1995; PTOLEMEE, 2002; BONNOT COURTOIS & LANCON, 2004; LEVOY *et al*., 2004a, 2004b) or in the coastal structures diagnosis or monitoring (PIALLAT & LABEY, 2002; BREVIERE, 2004; BAVENCOFFE, 2005). Local public authorities also make coastal defence inventories when the defences management falls within their competence (LEVOY & LARSONNEUR, 1991; DDE SEINE-MARITIME, 1996). Latest inventories often led to the development of GIS maps linked

to local databases (MALAFOSSE, 2006; DHI, 2007; LE BERRE & HENAFF, 2009; Observatoire de la côte Aquitaine: *http://littoral.aquitaine.fr/*).

Initial goals for those local inventories and databases vary a lot from one agency to another. At a national scale, that kind of database would allow state agencies to evaluate political actions undertaken for developing soft coastal protection techniques, to quantify the increase of artificial surfaces in coastal zones and the French territory's vulnerability to coastal hazards. An analysis of past national inventories (STCPMVN, 1981a-1995; LCHF, 1986; LALAUT, 1992) was produced in the SAO POLO project from the French GICC 2008 program (for the management and impacts of climate change). The results give an estimated distribution of coastal protection types in the 80s: 80% of coastal protections are located on the upper foreshore, 16.5% are perpendicular to the shoreline and 3.5% are assimilated to detached breakwaters. Over the upper-foreshore located structures, 35% are made of rock, 22% are vertical and 43% concern masonry or concrete seawalls.

Those results will be compared to the new national inventory. This work will begin with the definition of a clear and precise typology of shore protections and of the expected level of detail. Those criteria will have to be primarily shared by all partners. The CETMEF proposes to work at a macro-scale allowing the inventory of the whole protection structures and coastal constructions over the public maritime domain, the foreshore and the supratidal zone. This inventory will not go into detail in the structural and mechanical diagnosis of the protection work. Complementary technical investigations would be conducted afterwards if needed. Defining structures called "shore protection works", which means constructed or unnatural objects with a primary aim of shore protection, remains the main difficulty. Coastal defences are indeed always more or less artificialized objects, as for example sand dunes reinforced by soft protection techniques (cf. figure 1).

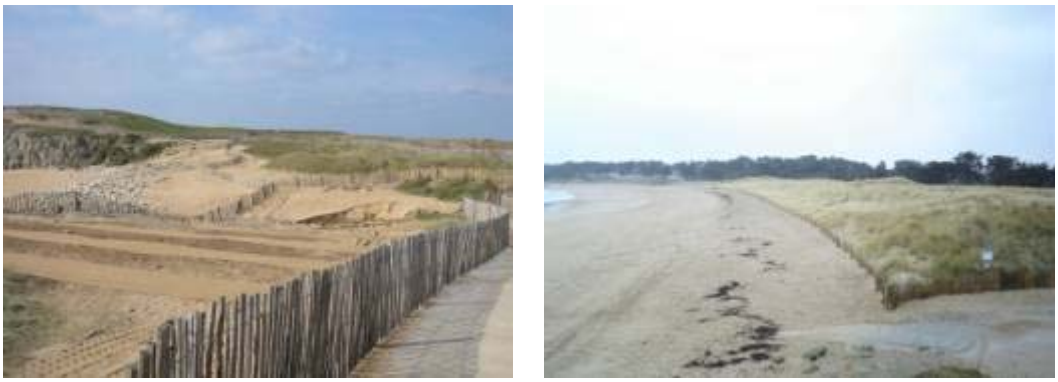

Figure 1. Examples of artificialized sand dunes: at Saint-Pierre-Quiberon (Morbihan, France – left) and the "Tombolo des Chevrets" (Ille-et-Vilaine, France – right) (© CETMEF).

3. A typology of coastal defences and constructions

3.1 Typology of "coastal structures"

The typology proposed by CETMEF (BOULLAY & VILLEMAGNE, 2009) is the result of a large bibliographical analysis of existing inventories over the whole French coast. "Coastal structures" relates to all the constructions, protection works and techniques which have an impact on hydrodynamics and morphological processes and modify coastal hazards. The proposed typology is based on a classification of the structure functions, completed by information related to its location (on the nearshore, foreshore, shoreline or ahead) and orientation to the shoreline (perpendicular or parallel). Coastal defence functions can be either protecting against coastal erosion, fixing the shoreline, dissipating wave energy, attenuating overtopping or wave overtopping processes. Functions are not unique for one structure and most coastal defences simultaneously hold several functions. Geometrical and mechanical characteristics and technical specificities such as materials, crest (crown wall) and/or toe (anti-scour) protection, have to be specified in order to make the structure denomination process easier. Coastal defence denominations and definitions are the proposed typology core and contain: walls and retaining walls, seawalls, coastal dikes, detached breakwaters and groynes. Names are completed with the main constituent materials: soil/sand/gravels, rocks, artificial rocks/gabions, concrete/armed concrete, masonry, bituminous bound materials, metal/wood, geotextile, etc.

Structures whose main function is not protecting against the sea are denominated "coastal constructions". Their proposed main purposes are giving an access (cf. roads liable to flooding, stairs, slipways...), the hydraulic regulation (cf. dams, tide gates, locks, outlets...), harbour facilities (quays, loading docks, jetties...), buildings (fortifications, leisure facilities, agricultural platforms...), security and signals. Coastal constructions' typology is not exhaustive as those structures are not the main purpose of the inventory. However, their existence and location may be interesting as they can have a significant impact on hydraulic processes such as wave propagation or on nearshore sediment transport.

"Protection techniques" refers more to methods for coastal protection than to constructions. They appear distinctly in the inventory methodology with, in particular, fascines for trapping of sand, experimental methods and soft techniques such as dune stabilisation, beach nourishment, beach drainage and by-passing process.

3.2 Typology of coastal defences

The proposed types of coastal defences have been defined from a simple geometrical description. Shore-parallel defences are the largest kind of structures and the most diverse (cf. figure 2).

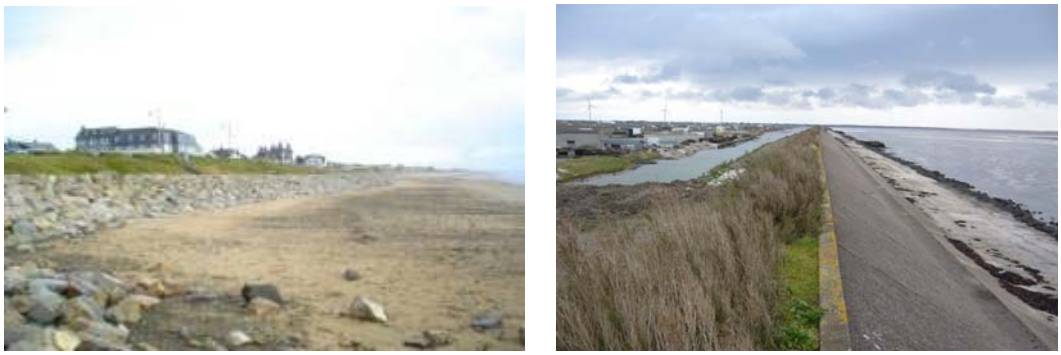

Figure 2. Examples of shore-parallel defences: rock-revetted seawall at Barneville (Calvados, France, left) and revetted dike at Beauvoir-sur-mer (Vendée, France, right) (© CETMEF).

On the shoreline stand mainly walls and retaining walls, characterized by a vertical front slope and their proper function, and also seawalls, characterized by a simple or multiple oblique front slope and mainly consisting in a revetted stable embankment. The latest are directly constructed on the natural topography. As highly-reflective structures, they often provoke foreshore lowering and have specific toe anti-scour protection. Coastal dikes or embankments are a part of those shore-parallel coastal protection and are usually located on the shoreline or inland. They are defined by an artificial bank raised above natural topography to redirect or prevent flooding. They are also characterized by a low permeability.

Detached breakwaters can be found on the foreshore or nearshore. They are mainly characterized by their function of modifying wave propagation in order to decrease their impact on the shoreline and to create thus a sheltered area in their lee. Their offshore location is also a criterion, even if they can be artificially linked to the land by a tombolo (cf. figure 3). Groynes are distinguished by their orientation perpendicular to the shore. They can present diverse geometrical configurations and be made of several materials.

Inventorying all coastal construction characteristics is not compulsory, whereas protection techniques have their own characteristics. There will still remain some flexibility in coastal structures database to make the field inventory easier. It is not rare, indeed, to have coastal structures along which geometrical characteristics or typology vary continuously.

Figure 3. Coastal structures (constructions and protection works) at Valras (Hérault, France): jetty, detached breakwaters and a groyne made of rock (from the background forwards) (© CETMEF).

4. Inventory organization

4.1 On-field inventory preparation

The on-field inventory efficiency entirely depends on preparatory investigations at the office. The on site inventory must be organized at a territorial scale related to French administrative departments or at least several coastal cities. Distances to consider may be long and the geographic area to cover has to be divided into "sites". Those sites may be defined by geomorphological or phenomenon exposition homogeneity considerations. All sites have to be clearly identified with their means of access to coast.

A primarily work consists in collecting all existing data and information: old inventories, existing databases, photographic sources (such as French coastal vertical views "Orthophotographie littorale" – *http://www.geolittoral.equipement.gouv.fr/*, IGN database "ORTHO", aerial oblique photographies, ...), administrative documents, maps, ... Those documents help defining the number of sites to visit and estimating the number of structures to inventory. They are also helpful for the identification of the means of access. It is then possible to estimate the time allowed for each site visit and if necessary to open procedures to have access to structures.

A planning is then defined, taking into account accessibility to structures, possible weather conditions, time slots related to tide, material availability, ... The direction and sense of visiting and inventorying the sites have to be fixed in advance. To help collecting on-field data two specific forms are proposed: one dedicated to the site and its environment and one to the inventoried structure and its technical and administrative information. Those forms can be filled in before going on field, depending on the detail of information raised. Before the visit, all the necessary material has to be checked: maps and photographs, adequate supply of forms, GPS, numeric camera, etc.

4.2 Inventory forms

BOULLAY & VILLEMAGNE (2009) proposed two inventory-helping forms. They specify environmental site characteristics and describe the physical and administrative context of the inventoried structures. They contain the least information necessary to a general and homogeneous view on coastal protection at a national scale and can be completed, if needed, with other scopes. Those forms have been tested on four sites, in four cities of Morbihan, France (Arradon, Banastère, Penvins and Séné). Those tests led to the forms' improvements and to recommendations in a methodological note to census takers.

The site form contains all the geomorphological, sedimentary and stakes aspects of the site environment with the possibility of indicating the existence of particular natural structures such as sand dunes or rocky forms, etc. Sand dunes status can be described in detail thanks to a specific box with the general shape of their base ("triangular", "trapezoid" or "eroded", cf. figure 4). The triangular shape corresponds to a relatively narrow dune compared to its height, and the dunes stability is not insured, particularly during severe marine erosion phases. The trapezoid shape describes a more aerodynamic dune profile, often man-made, and is supposed to be generally more stable. The eroded shape is indicated in order to mention the existence of a former dune when it has partially or completely disappeared.

The coastal defence form completes the site one with specific information on defences, constructions or protection techniques that may be on site. That form recaps the typological elements presented above. Some boxes give census takers the possibility of drawing schemata of the inventoried structures.

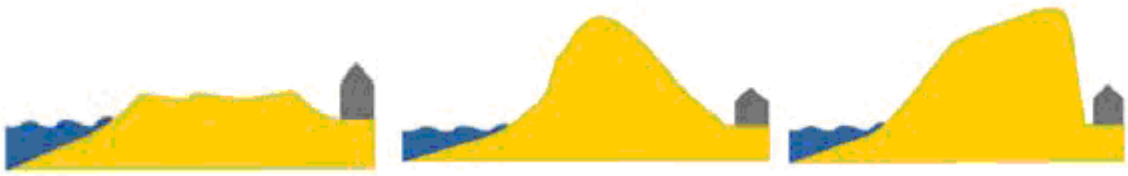

Figure 4. Illustration of dune base shapes (from left to right: eroded, triangular and trapezoid) (© ONF).

Both forms will also be available in a numerical format in order to help gaining time on field and at the office by easily filling in the forms and the database. A PDA prototype is also under consideration. To make the on site inventory even easier and guaranteeing the homogeneity of GPS precisions taken and of photograph sizes registered in the future database.

5. Integrating field data into a national database

The national database on coastal protection has to be entirely structured as no such database already exists in France. The CETMEF works at the moment on the definition of its structure and on the associated GIS mapping characteristics. A report has been written in 2010 in order to propose a simple architecture saving all the collected data and permitting the mapping of inventoried structures with a GIS (SENHOURY, 2010). Some critical elements have already been identified to facilitate the upcoming integration into the database: it is highly recommended to give a unique identifying number to each object and to register some characteristic points with a GPS (for instance both ends). The precision and the quality of the database is dependent on the precision of the inventory and of the notes taken on field. Filling the database and mapping the structures is supposed to be as time consuming as half the time spent on field (LE BERRE & HENAFF, 2009). The mapping scale of the GIS is not defined yet but will strongly be related to the database utilized. The French vertical photographs "Ortholittorales", which cover the whole Atlantic and Channel coasts at a very low tide and are considered as a national geographical mapping reference, will certainly be used as background of the GIS mapping.

6. Conclusion

This study launched by the CETMEF in 2009 has led to a proposal of coastal defences typology and of recommendations for a national homogeneous inventory with two forms (BOULLAY & VILLEMAGNE, 2009). This work has been continued in 2010 with a national technical group and it was divided into two phases: the practical organization of that inventory, given to the decentralized government departments as a result of actions taken after disaster Xynthia, and the construction of the national GIS database, containing in particular the status, type and location of inventoried coastal structures. The national group and the decentralized government department of Côtes d'Armor, which tested the forms on field, contributed to the improvement of the recommendations in the methodological note and in the forms. The collected data will be one element of the updated documents "Catalogues sédimentologiques des côtes de France" and will contribute to an improvement in the knowledge of coastal phenomenon.

The evaluation of the protected stakes and of the structural status of sea defences will then help to define priorities of protection and of strategies for a sustainable management of the shoreline. A methodological report on the monitoring and diagnosis of coastal defences will complete this primary work of inventory. It will be inspired by the already developed methods called "Simplified and compared visits" (BREVIERE, 2004; BAVENCOFFE, 2005).

7. Acknowledgements

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The recommendations for the inventory of coastal protection structures have been possible thanks to the field collaboration of the decentralized government departments of Morbihan and Côtes d'Armor.

The national technical group gathers general directions and decentralized government departments of the ministry MEEDDM, the national technical support services CETE, the national "Observatoire du Littoral", public establishments such as Conservatoire du Littoral, Cemagref, ONF and BRGM, and universities such as the University of Western Britanny, University of Caen Basse Normandie and University of Nantes.

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