

## Dune Restoration and Requalification of the Main Avenue in Furadouro Beach, Ovar

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### ABSTRACT

Very early in time, man has chosen coastal areas due to its unique landscapes with wide and rich scenarios. The socioeconomic notability associated with leisure and tourism activities, as well as the environmental value of these areas, have led to the growing settling of the population at sea shore. The effects of human activities in association with natural factors has result in disastrous environmental impacts, such as loss of territory, destruction of natural sea defenses (usually dune systems) and the weakening protection capability, representing a growing danger to these ecosystems and ultimately to human life. Coastal dune system is a natural structure and represents space dynamic and defensive systems against sea attacks, but the instability of these natural structures, mainly due to anthropogenic pressure, has led to an intensive phenomenon of coastal erosion and its vast negative environmental and economic impacts. In the last decades, due to the anthropic pressures and climate changes, several damages have been registered in the urban coastline as well as a growing loss of coast dune fields, causing high destruction compromising the population safety in Furadouro Beach, located close to the city of Ovar, Aveiro district, in the Central Region of Portugal. In this context, with this work, we intend to understand coast degradation causes on furadouro beach; create management tools which may be applied in environmental planning; understand local natural and patrimonial facts, and to present an intervention proposal for these area combining the technical, science and art of space designing.

**KEY WORDS:** Coastal dune recovery, Furadouro beach, Coastal erosion, Bioengineering techniques.

### INTRODUCTION

While physical element of the natural landscape, coastal dunes act as a resilient barrier to the destructive force of the waves and wind (Gomez-Pina et al., 2002), protecting the continental shelf and constituting a sand reservoir that feeds the beaches affected by erosion and dune ridges, especially during storms (O'Connell, 2008).

Of all coastal ecosystems, the dune systems are most affected by human pressure (Carter, 2002). In this context, the Millennium Ecosystem Assessment (2005) has warned about the rapid changes in these ecosystems, particularly in the second half of the twentieth century, more than in other period of Human History. Moreover most of the Earth's ecosystems are significantly transformed by human actions.

The process of coastal erosion is a major problem affecting the Portuguese Coast, induced by anthropic and natural factors, including those generated as a result of climate change (EUROSION, 2004).

Facing this degradation scenario that has been occurred in the Portuguese coast there has been developed several recovery projects of coastal dunes using Natural Engineering Techniques, particularly in the Ria Formosa Cord Dune (Pereira et al., 2011) and Leirosa's Beach (Reis et al., 2008). The goal of this constructive measures of Natural Engineering, is the fulfilment of important functions - technical, ecological and aesthetic - including most importantly, protect the soil surface against erosion, soil stabilization, promotion of the mechanical condition of the soil, landscaping the structures and enrichment of the landscape by creating new elements, structures, shapes and colours of vegetation (H. Schiedtl in Zeh, 2007).

According to Fernandes & Freitas (2011), the Natural Engineering Techniques operate in line with Nature, prioritizing the use of systems, techniques and natural materials, or as close as possible to the natural systems -

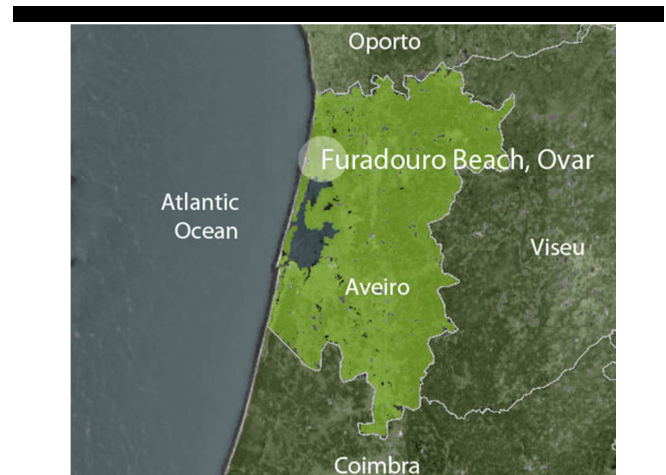


Figure 1. Furadouro Beach - location.

living and inert materials - being used in the recovery of the coastal areas to minimize the impacts of the pressures and the effects induced by climate change. The results have shown significant success rates towards the regeneration of ecosystems, protection of its habitats and erosion control.

The case study presented, the Furadouro Beach in Ovar (Figure 1), is inserted in a highly dynamic coastline section - Northwest Portuguese Coast - affected by the process of coastal erosion (Polis Ria de Aveiro, 2010), rated "high erosion risk" and with a "high degree of vulnerability" (Veloso-Gomes et al., 2004). Moreover, Furadouro Beach is set in a coastal sector marked by the presence of an extensive and fragile dunes, sandy beaches of low quotas being considered the most dynamic type of coast (Coelho, 2005).

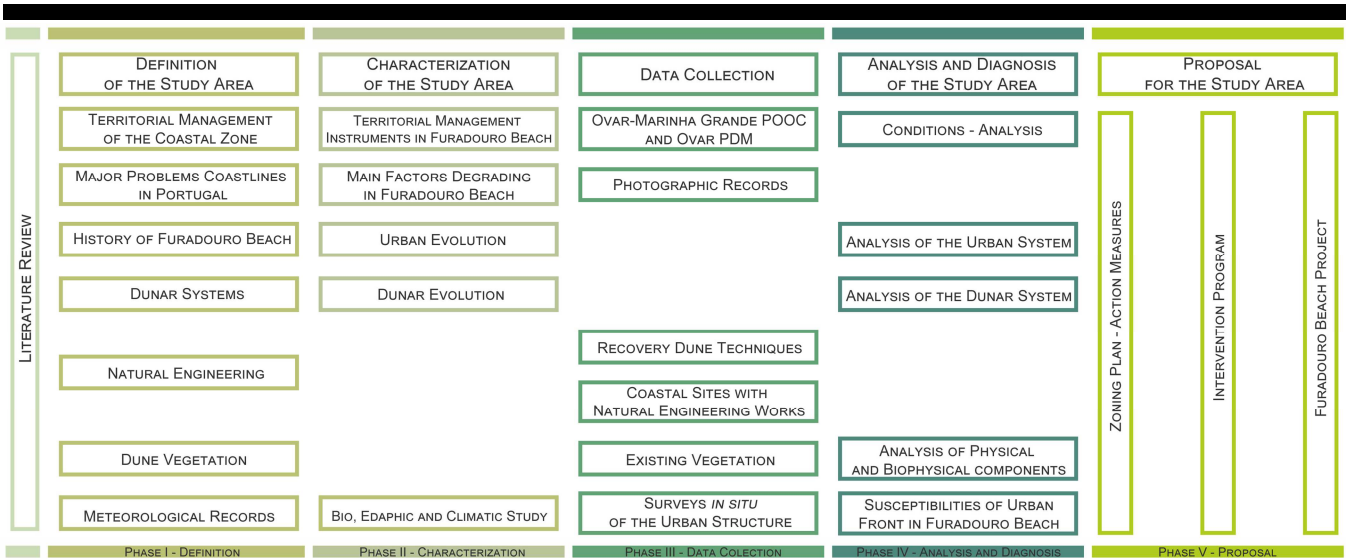


Figure 2. Methodology.

According to Dias et al. (1994), the main problems of Furadouro Beach are effective human occupation of coastal space, sediment supply deficiency, degradation of the dunes and tourism growth, which in turn are derived primarily to the serious problems in these region: the construction of coastal defence barriers, the expansion of the urban core and reduced sediment supply to the beach.

This study developed for Furadouro Beach allowed: (i) the identification of the factors degrading its urban and natural systems, and the main problems affecting it; (ii) the development of a specific analysis of its urban structure and its dune structure, integrating its History; (iii) presenting a solution for urban requalification and dune regeneration and recovery, for a reference beach Northwest Portuguese, considering its main characteristics and specificities.

## METHODS

The methodology was based on a deduction process beginning with more general studies and get into more specific studies (up down approach). The analytical process has five sequential phases and was performed under a pragmatic and deductive perspective, in a confrontation relationship of theoretical concepts and their practical applicability (Figure 2).

This study approaches the landscape as a whole, focused on its biophysical components, urban design and the methodology was developed based on the analysis layers method, whose origin dates back to McHarg (2000), complemented by an holistic method of valuing direct and subsequent analysis of its components (Asensio & Guerrero, 2001).

## DATA PROCESSING

### *Historical Evolution – Dunar System*

According to the analysis of the dune system evolution, it is verified that early, the beach-dune system was been affected by human activities intervention: the aggregates exploitation, the development of fishermen communities, the growing pressure in the urban front, the dunes destruction and the implementation of coastal defence barriers, showing gradually weakened its natural defence and the capacity to regenerate, leading to ecosystems fragility and vulnerability, essentially marked by sea “attacks”, affecting the population safety and the built

heritage.

The dune system of Furadouro's Beach was extent throughout the littoral, along the shoreline, but its permanence and spatial coherence were compromised since the time that human development began, namely because population setting occurred on top of the dunes, leading to the dune destruction in some sections and preserved in others.

Due to successive attacks from the sea and beach-dune system transformations, the replacement of a natural system with natural structures dissipative of energy - the dunes - for an artificial system consisting of rigid barriers structures has occurred. The implementation of coastal defense barriers have accelerated the process of destruction and extinction of the primary dunes, in the north due to the sediment transport and in the south, because of the seawall built, as evidenced by the disappearance of the first wall.

The pine forest areas appeared at the same time as the fisherman nuclei (seventeenth century) and remained up to this day, accompanying the urban sprawl, nevertheless some areas are threatened by the presence of invasive species (*Acacia longifolia* and *Carpobrotus edulis*).

### *Historical Evolution – Urban System*

The Furadouro Beach follows an orthogonal layout, typical model of a coastal town (Cullen, 1971), driven by two major power lines that define the urban agglomeration. This urban design model was based in spatial rectilinear planning of the fishermen core, imposed by hygiene and safety reasons. A proposition that later forms the guideline for urban expansion. The urban sprawl in Furadouro Beach follows



Figure 3. Urban agglomeration – density and growth.

the society evolution and its customs, resizing a reality primarily of a fishing beach for a reality of a residential, leisure and tourism area.

The biggest problem of this urban agglomeration relates to the strong pressures on the urban front over time, namely by the construction of urban structures with high proximity to the sea, since the formation of the cluster. This practice proved to common up to today, bringing an increasingly onerous consequences.

The urban and equipment expansion were developed in west to east direction, parallel to the coastline, according to the two main guidelines. The first buildings were developed on the streets of greater proximity to the sea extending its densification progressively inland (Figure 3).

The historical development is in line with the current reality of Furadouro Beach, given its geographical location - the northwest Portuguese coast, near by the Atlantic Ocean.

Table 1. Analysis and Diagnosis (Maps – Data – Results).

<b>Mobility</b>	Study of permanence and movement of people and vehicles.	Higher permanence in urban front and sand dunes.
<b>Land Use</b>	Study of the fragmentation of space and the relationship between urban space and the naturalized systems.	Urban space with predominance of buildings. Dunes planted with native vegetation and vast patch of pine forest with the presence of <i>A. longifolia</i> .
<b>People and Vehicles Flow and Concentration (synthesis)</b>	Identification of the main centers of concentration and flow of people and vehicles.	Highest concentration of pedestrians in urban front and the beach. Revealing more concentration during the summer (seasonal).
<b>Type of Green Spaces and Vegetation</b>	Identification of existing plant material and its spatial distribution in green spaces and areas - natural and naturalized.	Coating dominant in foredunes and secondary dunes with native vegetation and the presence of <i>C. edulis</i> . Tertiary dune with predominantly pine and punctual presence of <i>A. longifolia</i> . Two sectors (secondary dunes) dominance of invasive vegetation. Faced with a shortage of urban plant material.
<b>Dune Systems Conservation Status</b>	Check the conditions of the existing dune fields (anthropic pressures and natural causes).	North foredunes at high risk of erosion and secondary dune vulnerable with recovery works. Secondary dune recovered, to the south. Inland dunes stabilized by <i>P. pinaster</i> , threatened by invasive vegetation.
<b>Natural Systems Fragility (synthesis)</b>	Determination of areas with higher instability and higher state of disrepair.	High fragility: foredune and secondary dune pressure. Medium fragility: secondary and tertiary dune with invasive vegetation. Low fragility: inland dunes with predominantly <i>P. pinaster</i> .
<b>Natural and Naturalized Systems Occupation (synthesis)</b>	Check the loads exerted on different systems (urban and natural).	Higher loads on the beach and dunes secondary. Medium loads on the tertiary dunes with invasive vegetation. Seasonality of loads on the beach and in the secondary and inland dunes.
<b>Dominant Tide and Wind System</b>	Identification of the dominant direction of the wind and sea swell and correlation with rigid structures of coastal defense.	Advance of coastline, with beach profile transgressive. Wind regime with predominance of N and NW quadrant (summer) and the S and SW (winter).
<b>Littoral Fringe Transformation</b>	Analysis of changes in the physiography of the coastline.	Variation of shoreline physiography (advances and retreats).

Analysis and Diagnosis

The data for this study were obtained under a deductive and pragmatic perspective, using historic bibliography of Furadouro Beach and theoretical concepts related to the theme. In order to complement these theoretical data, was carried out a study of the dune system and urban core historical evolution to compare with the current state of Furadouro Beach. This study enclosed a review of different informative maps, with information organized in layers. Each information layer is a physic/biophysic territorial category essential to obtain the results that we pretend to answer (Table 1).

The information gathering was based in thematic maps created based in theoretical references, *in situ* data collection, on-site surveys (photographic records), aerial photographs of different dates, and orthophotomaps and digital mapping of the study area.

The analysis methodology was complemented with data obtained from expert interviews and comparative analysis of case studies: Natural Reserve of S. Jacinto Dunes and North Coast Natural Park, in Esposende (both located in the same geographic region, subject to similar environmental conditions).

RESULTS

Strategic Plan of Action

The Strategic Plan (figure 4) results from processing data (syntheses) during the Furadouro analysis process from, which data height requirements and potential intervention were determined. The content synthesis allows to define underlies action steps, configured in each outlined strategy.

The results indicate that the risk areas were located at the front of Furadouro Beach and include in the urban system, the Main Avenue and part of Central Avenue, and in the natural system, the North Dune Field (NDF) and South Dune Field (SDF). In the dune fields, the main influences are the presence of invasive species and the balance destruction of natural dune profile. In the Avenues the urban advancement to the beach and coastal defence structure artificialization generates contained dissipation power.

The Furadouro Beach has a vast pine forest area, in certain points threatened by invasive vegetation. Thus were planned: 1<sup>st</sup> - combat measures to *Acacia longifolia* using the manual cutting technique and subsequent overlay of



Figure 4. Strategic Plan of Action.



roots to dry, resulting in pine forest preservation; 2<sup>nd</sup> - manual removal of *Carpobrotus edulis* and replacement of native dune plant material according to each dune phase, to promote dunes stabilization; 3<sup>rd</sup> - demolition of structures/buildings, for safety and subsequent structural reinforcement of the urban front; 4<sup>th</sup> - rehabilitation of urban design, with receding the front line between the beach and Main Avenue; 5<sup>th</sup> - recovery techniques in dune fields.

#### Natural Engineering techniques applied in Furadouro Beach

The comprised areas within the limits of NDF and SDF were classified as naturalized systems with high fragility, subject to high pressure classified as nuclei with the high human occupation, adjacent to areas classified as natural system with high fragility and high quantity of invasive vegetation.

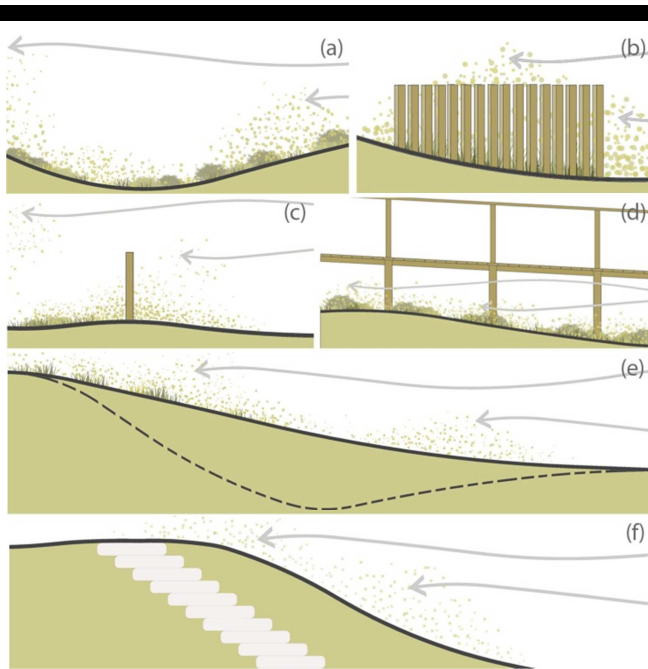


Figure 5. Natural Engineering techniques: (a) Planting native and pioneer vegetation; (b) Sand fences; (c) Palisades; (d) Walkways; (e) Morphological reconstruction; (f) Geotubes.

Thus, the Natural Engineering techniques selected were:

- Planting native and pioneer vegetation [figure 5(a)], aiming to maximize its functionality to capture and fixation of sand dunes:  
NDF and SDF: in both cases, their replacement is related to the existing copies and with the combination of new native species. The selection of this technique arises from the functional and aesthetic properties of vegetation for dune system. The application of this technique works in combination with other techniques to assist the retention, uptake and accumulation of sandy sediments;
- Sand fences (boxes) [figure 5(b)] with *A. arenaria*, located in areas with higher sediment deficit, in order to capture and accumulate sand that helps in the process of stabilization and consolidation of the dunes. The use of *A. arenaria* relates to their ability to anchor the sand:
  - NDF: the vast area of the dune field can be installed in strategic locations to increase the volume of sandy sediments captured. The topography proposal incorporates spaces interdune deep, where the

accumulation of the sand becomes crucial for the stabilization of sand;

- SDF: the topography of the dunes does not require the application of this technique since, in this situation, the palisades in association with pioneer vegetation and indigenous meets the intended purpose;
- Fences/palisades for protection [figure 5(c)] and delineation of routes and areas to stay, in order, to interdict the public passage whose intends to conserve, defining the areas for recreation and leisure:
    - NDF: the direct contact with the sand dunes and patent confusion regarding appropriate uses of the spaces shows that is necessary to distinguish the open access areas and areas barred to the public, both on the beach and in the dunes. In addition to defining areas, the palisades will allow the retention and accumulation of sand for the dunes;
    - SDF: despite the separation between the beach and dunes, this technique allows the delineation of pathways to mark up the areas of protection and interdiction to the public, while also acting as pickup sands of the dunes;
  - Walkways on high-beach access [figure 5(d)] in order to set up a network of footpaths, widening and extension in the existing number:
    - NDF: this zone presents conflict in distribution and access paths to the beach, so that the application of this technique allows public access, so careful, allowing mobility between the beach, the avenue and the car parks without damage the dune ridges. Through these high structures, on-users continue to have access to this area of the beach which access involves crossing the dunes, while it induces the uptake and stabilization of sand beneath them;
    - SDF: this area provides access to an area of Furadouro Beach, south, little visited by the previous lack of access, so the network of pathways is elevated walkways over-extended facilitating the mobility of users between the beach, the pinewoods, Main Avenue and car parks;
  - Morphological reconstruction of coastal sand dune [figure 5(e)] with artificial feeding, to (re)shaping the profile of the dunes in equilibrium:
    - NDF: in this area, there is a foredune set a high cliff and the subsequent dunes are degraded. Applying this technique, the dunes are able to return to work as natural barriers dissipating energy, with a profile in equilibrium. The height of the dune crests is important for the performance of their functions of protection and defense. Therefore, it is necessary a sufficient volume of sediments to perform this assumption;
    - SDF: remodeling the sandy terrain to a dune profile at equilibrium is fundamental to the fulfillment of their functions of protection and defense. However, it is crucial create conditions for their self-sustaining development, once, at the time of intervention, are created the basic conditions for the system acquires autonomy, for his self-regulatory functions;
  - Geotubes [figure 5(f)], aimed at halting the sand dunes of the front rebuilt in a wide expanse of dune field and protect him from attacks from the sea, avoiding the use of rigid defense works and maximizing the capabilities of the geotextile. This option is discreet, once it is installed inside the dune, and assists the installation of native and pioneer vegetation, enhancing their development and give stability to the sandy substrate:
    - NDF: this technique complements other techniques selected once it confers stability to the sandy soil and provides for the consolidation of sand dunes structure. It

is used because this area of dunes will help rebuild the dune morphology and fulfill functions of defense and coastal protection;

- SDF: in this area, exists a structure of longitudinal defense serving the purposes immediately set out for what is not needed this type of intervention, but in the future will be able to replace the defense structure.

This work fulfils the intended purposes: to allow public accessibility to places of interest and help to regenerate the ecosystem.

## CONCLUSION

The methodology applied in this study allows a pragmatic approach, with direct and reliable results essential for the development of the work.

The interventions based on Natural Engineering Techniques have gathered consensus about its effectiveness, increasing its application, since discreetly, effectively and economically its possible to use in dune restoration projects with very positive results.

The Natural Engineering Techniques selected for the Beach Project were the most suitable because they will allow coastal defence natural structures to recovery, minimizing degradation problems and their negative impacts.

The minimization and mitigation success of the main causes of degradation of this natural ecosystems involves the implementation of recovery projects and landscape requalification, in cooperation with landscape enhance measures and to raise awareness of its importance from the conservation, preservation and environmental education.

Nature and Society must act in consonance and harmony.

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