

SUSTAINABLE SOLUTIONS FOR COASTAL ZONE MANAGEMENT OF LOWLAND AND RIVER DELTA COASTLINES

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Global Climatic Changes & Coastal Vulnerability

In recent years, the impacts of natural disasters are more and more severe on coastal and lowland areas. With the threats of climate change, sea level rise and potential subsidence, the reduction of natural disasters in coastal lowland areas receives increased attention. Moreover storm surges present a major natural hazard in coastal zones. At a global scale, an example of the effects of accelerated climate changes was demonstrated in autumn 2010 when the storm Becky reached the Santander Bay, Spain. As reported by THESEUS, the FP-7 EU project (2009-2013), the peak of nearshore significant wave height was about 8m, the storm surge reached 0.6m, with tidal level of 90% of the tidal range. This storm reflected at least a 20 years return period event. The recent coastal flooding in Alexandria on December 12, 2010, on the Nile Delta coastline was also a striking example of the severity of more progressive events. Egypt was hit by strong winds, exacerbated by heavy precipitation, up to 60km.hr with a 10 hrs duration. These weather conditions resulted in waves of more than 6.5m height with a surge of over 1.0m which forced the closure of Alexandria main harbor.

Many barrier islands and lowland in the world such as that in the US and lowland and deltas such as in Italy and the Nile Delta (Fig.1) are also experiencing significant levels of erosion and flooding. A prime example is the Rosetta headland of the Nile Delta, on the western coast of the Nile delta, which has been subjected to the most severe erosion of the delta coastline due to the absence of the Nile sediments since 1964 (Fig.1). The Rosetta seawalls are currently protected by two flanking seawalls since 1990. To its west, the protection of the lowland within Abu Qir bay against flooding and over-topping is achieved by M. Ali Seawall, placed at coastal site, within Abu Qir Bay, East of Alexandria along the Nile Delta coastline.

Objectives

Most modelling and design activities do not take into consideration the impact of the structure- ocean wave interaction on sediment transport rates. The modified rates are responsible for the observed accelerated shoreline erosion at seawalls and subsequent down drift sediment accretion at the end of seawall or breakwater trunk.

Coastal zone management of coastlines is of utmost significance under the current and progressive effects of climate change. This study was conducted to investigate hydrodynamic and sediment transport mechanisms induced by the interaction of seawalls or revetments and the incident wave field. These mechanisms modify longshore and cross shore sediment transport rates along the coastal structure.

Further aim of this research project is to determine the special extents, cross and long shore, of coastline modifications which are associated with the induced effects of seawall-hard structures. Such design data are prerequisite to successful coastal zone management under impacts of anthropogenic and natural factors. Such data will help the coastal designer to reduce wave overtopping on seawall structures. The third aim is to highlight the opportunities to use coastal soft defence measures.

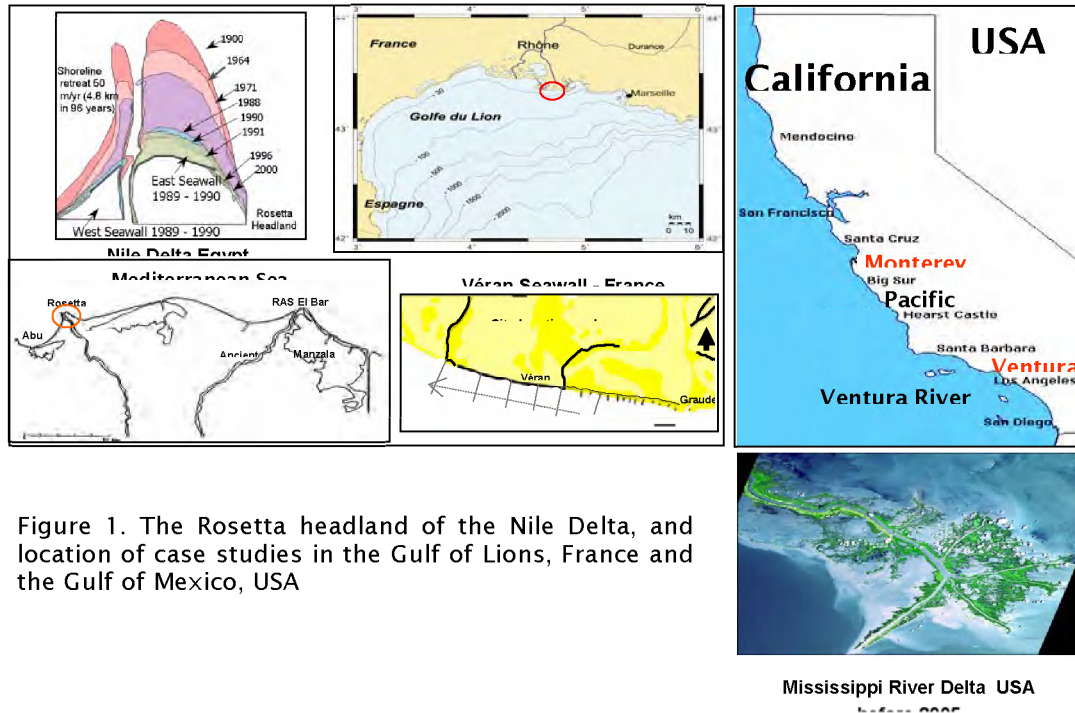


Figure 1. The Rosetta headland of the Nile Delta, and location of case studies in the Gulf of Lions, France and the Gulf of Mexico, USA

Impact of Seawall and Ocean Waves Interaction

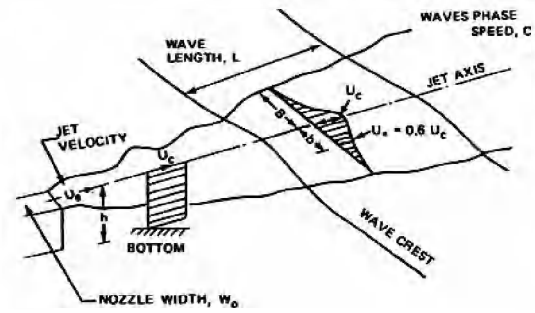
The prime case study addresses the seawalls constructed in 1990 at the Rosetta headland in response to the severe modifications and retreat of the Nile delta coastline after the operation of the Aswan High Dam in 1964 (Fig.1). The analysis was conducted on the basis of the extensive field work, performed by Egyptian government authorities. Use has been made of recent satellite remote sensing data for the Rosetta headland in 2005 and 2007 and the results of the numerical prediction of GENESIS coupled with an estimate of field data of the scour rate at the western seawall. It has been found that wave reflection and the generated wave pattern in front of the Rosetta headland seawall on the Nile Delta Coast enhance the rate of offshore sediment transport as well as the long shore transport rate. The obtained estimates of the alongshore and cross shore sediment transport rates agree with the corresponding values obtained from the results of fluorescent tracer experiments conducted at the Rosetta western seawall.

Review of field data published on other seawalls and coastal structures constructed in the USA and Europe confirms qualitatively the above results. Further the increased rates of sediment transport and reshaping of the coastline are strongly influenced by the cross-shore location of the seawall in the surf zone, the variability of wave climate and modifications of coastal circulation.

Longshore Modifications due to River Flow and Wave Interaction

The extent of the reshaping process of the Nile delta coastline due to the absence of the river Nile current, east of the Rosetta headland, is further explored from the work by Ismail and Wiegel (2003). The aim is to obtain the relation between the relative strength of waves to current momentum action and the alongshore distance where river flow was previously effective to entrain sediments. Based on the time and length scales and using the time average of the depth integrated conservation equations, as developed previously by Ismail and Wiegel (1983) for wave-current system on a smooth bottom. It is found that the relative strength of the wave action on the jet could be represented by the following dimensionless parameter; R_{sm}

$$R_{sm} \approx \frac{\frac{1}{2} \rho_s a_0^2 g \left(\frac{L_0}{h} \right) C_g}{(C_0 - U)} / \rho_0 U^2 w$$



Velocity and length scales of waves and opposing current system

The numerator of the above expression is proportional to the wave momentum action and the denominator is proportional to the initial momentum flux of the jet. In the above expression, ρ_s is the seawater mass density, ρ_0 is the river current mass density, a_0 is the deep water wave amplitude, g is the acceleration of gravity, C_g is the wave group velocity, L_0 is the deep water wave length, h is the average water depth near the river mouth, C_0 is the deep water wave phase velocity, U is the average jet exit velocity and w is the river mouth effective width. Confirmation of the above correlation was obtained using the experimental results of the extensive experiments which involved wave and current measurements as well as flow visualization techniques (Ismail and Wiegel, 1983, 2003). The obtained correlation is shown in Fig. (2). The figure shows that the expected length of coastline reshaping would be in the neighbourhood of 20 km east of Rosetta headland (1992-2007). This estimate would explain the continuous rates of erosion in the groin set segment of the coastline as could be seen in the satellite image of 2008 for Rosetta headland.

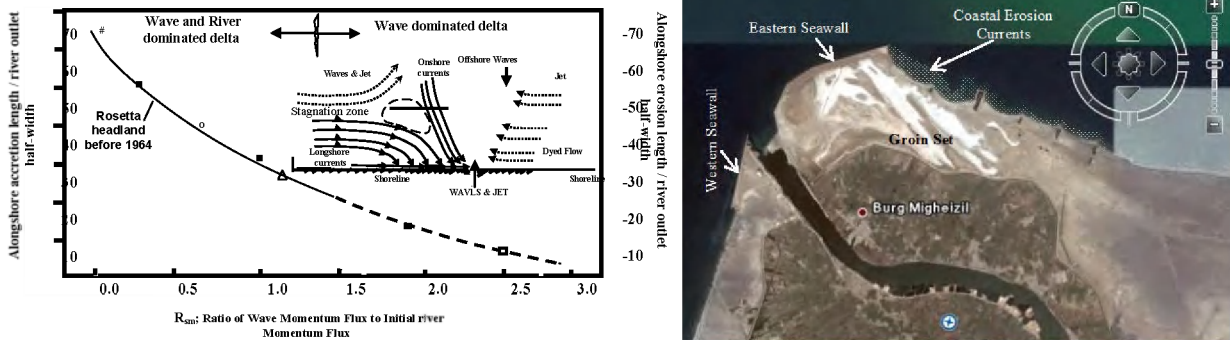


Figure 2. Correlation between wave-jet relative momentum thrust and length scale of the alongshore zone of accretion and erosion and Satellite image for Rosetta headland (2008)

Conclusions and Way Forward

The study concludes that new design alternatives to protect eroding lowland shorelines of deltas and barrier islands such as that implemented for Surfer's Point (CA, USA) should be explored. These managed retreat systems were adopted to restore coastal resources near the mouth of the Ventura River, Southern California (Fig.1). Furthermore other soft engineering alternatives such as beach nourishment, sand dunes stabilization and use of integrated barrier island and coastal lagoons would act as a buffer zone to defend main land. The sustainability of the integrated natural systems would require (1) barrier island and shoreline restoration and (2) hydrologic and vegetation restoration of coastal lagoons. Such restoration projects will require a major undertaking by national governments and international institutions.

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