Secondary Flows and Sediment Transport due to Wave - Current Interaction

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Objectives:

The purpose of this study is to define the modifications of coastal processes driven by wave-current interaction and thus to confirm hydrodynamic mechanisms associated with morphological changes at river mouths and tidal inlets. Further, the aim of the work has been to obtain the effect of the relative strength of waves to current momentum action and the alongshore distance where river flow was previously effective to entrain sediments. Thereby more effective coastal defense structures are designed.

Methodology and Analysis:

Use is made of an earlier study reported by the authors(1983) on the interaction of horizontal momentum jets and opposing shallow water waves at a shore, and of an unpublished later laboratory study. The turbulent horizontal discharge was shore-normal, directed offshore, and the incident wave direction was shore-normal, traveling toward shore. Flow visualization, velocity and water surface elevation measurements were used to determine wave, current modifications as well as the flow pattern in the jet and the induced circulation on both sides of the jet, for a range of wave and jet characteristics.

The experimental data showed several distinct flow pattern regimes. The observed flow regimes were found to depend on the ratio of the wave momentum action on the jet to the jet initial momentum.

Based on the time and length scales of wave and current parameters and using the time average of the depth integrated conservation equations, it is found that the relative strength of the wave action on the jet could be represented by a dimensionless expression; $R_{sm}$

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

In the above dimensionless expression, $\rho_s$ is the seawater mass density, $\rho$ 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, $L$ 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 or the tidal inlet effective width. The values of the above number were found to be in the range between 1.0 and 6.0-8.0 for the examined laboratory and field case studies for non-buoyant jets. Upper bound corresponds to cases of higher wave activity on the coast while the lower bound corresponds to cases of tidal currents with minimum wave activity.

Coastal Processes Modifications due to River and Ebb Current Interaction with Opposing Waves:

Confirmation of the obtained theoretical expression was obtained by comparison with field data for the formation of accretion shoals and erosion spots near river mouths and tidal inlets in the USA and on the Nile delta coastline. The extent of the reshaping process due to the absence of the river Nile current, east of the Rosetta headland, was confirmed using the above correlation and showing that the expected length of coastline reshaping would be in the neighborhood of 20 km east of Rosetta headland (1997-2010). The results of the present work were well compared to the data on Fort Pierce Inlet, Florida, where severe erosion is known to exist on both sides of the inlet (Joshi, 1983). The current results are in parallel to that obtained recently by the numerical model Delft3D coupled to the wave model SWAN (Nardin, et al, 2013) on wave-current interaction at river mouths and
the formation of mouth bars.

Further analyses were also conducted to test the validity of the derived expression to the cases of wave interaction with buoyant currents in shallow waters. The buoyant jets represent the thermal discharges from power plants on coastlines of Diablo Canyon cove in CA at the Pacific Ocean (Ismail, et al, 1988) and at the northern coast of Egypt at Al-Arish. The comparison showed higher values range of $R_{sm}$ for the cases of buoyant jets.

References:


