Journal of Coastal Research	SI 39	741 - 744	ICS 2004 (Proceedings)	Brazil	ISSN 0749-0208

Seawall Impacts on Adjacent Beaches: Separating Fact from Fiction

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ABSTRACT

BASCO, D.R., 2006. Seawall impacts on adjacent beaches: Separating fact from fiction. Journal of Coastal Research, SI 39 (Proceedings of the 8th International Coastal Symposium) 741 - 744. Itajai, SC, Brazil, ISSN 0749-0208.

The common perception in the US that seawalls ". . .increase erosion and destroy the beach" is examined by summarizing available field data including our own research efforts at Sandbridge, Virginia, beginning in 1990. Sand trapped behind seawalls is remove from the system, but is a relatively small fraction of the active sand volume across the entire profile to closure depth. End-of-wall or flanking effects may not be due to sand trapping but other mechanisms such as interior drainage, rip current formation, groin effect, and the seawall/adjacent beach system acting as a rocky headland/parabolic-shaped beach system. Suggestions are made for when seawalls are appropriate and when they are not, including methods to mitigate downdrift impacts, if appropriate. Many misconceptions, false assumptions and misleading statements have been made in the US literature. This paper begins to separate fact from fiction.

ADDITIONAL INDEX WORDS: *Hardened shorelines, beach erosion, environmental concerns, mitigation, coastal armoring.*

INTRODUCTION

Seawalls, revetments and dikes are considered the "hard" structural alternative for coastal, storm damage mitigation. Since antiquity, society has employed the hard alternative with little concern for environmental impacts on adjacent beaches. Today, coastal zone managers question how hardened shorelines interact with natural, sediment transport processes at the coast.

Nine possible effects have been cited in the literature, four verified by field data, but only one of interest here; namely, seawall impacts on adjacent beaches. We focus on the mechanism(s) for these adjacent impacts.

Hopefully, this paper will help to place the USA literature and experience in proper perspective for new developments along the world's coastal environments.

LITERATURE REVIEW

Beginning in the late 1970s, many allegations regarding the adverse affects of coastal armoring were presented, e.g. WALTON and SENSABAUGH (1979), KANA and SVETLICHNY (1982), PILKEY, HOWARD and KAUFMAN (1985). The claims were encapsulated by the phrase ". . .seawalls increase erosion and destroy the beach" as made popular in the US media by geology professor Orrin H. Pilkey, Duke University, to promote his retreat philosophy for solving coastal erosion problems (see e.g. PILKEY and WRIGHT, 1988).

DEAN (1987) critically examined all the commonly expressed concerns as summarized into nine possible effects in Figure 1 (adapted from BASCO, 1987). DEAN'S (1987) conclusions were (numbers coincide with Figure 1):

Amoring does NOT Cause
profile steepening (6)
delayed beach recovery after storms (5)
increased longshore transport (8)
sand transport far offshore (9)
increase in long-term average erosion rate (3)

Amoring CAN contribute to
frontal effects (toe scour, depth increases) (1a)
end-of-wall effects (flanking) (1b)
blockage of littoral drift when projecting in surf zone (groin effect) (4)
Beach width fronting amoring to diminish (2)

Space does not permit a full examination of these nine concerns. The interested reader should consult DEAN (1987), KRAUS and PILKEY (1988) and KRAUS and MCDOUGAL (1996) and the CEM (2000) and the many references cited for complete details.

Perhaps the key environmental concern is how a seawall impacts a neighbor beach with no armoring. Does the seawall create end-of-wall, flanking effects as illustrated in Figure 1 (Cause 1b).

Flanking Effects Field and Laboratory Data

WALTON and SENSABAUGH (1978) provide post-hurricane Eloise field observations of additional contour recession adjacent to seawalls at two sites in Florida. Figure 2 displays the data (14 points as excession erosion, r (meters) versus structure length, Ls (meters). For site1(Group I) data, r was between 3.5-13m for Ls from 30-70m. At site 2 (Group II), r ranged from 6-19 m for Ls from 116-123. Trends are difficult to determine. The excession erosion was attributed to the adjacent seawalls. No other possible mechanisms (see list below) were addressed.

MCDOUGAL, STURTEVANT and KOMAR (1987) conducted small scale, "equilibrium" beach profile, laboratory experiments (9 data points) for regular waves with 7-14 cm wave heights at 1.1 sec wave period and medium, grain-sized beach materials. The excess erosion, r ranged from 3-10cm for seawalls 65-105cm long.

Unfortunately, these two data sets containing 23 data points have been erroneously combined in one plot that required logarithmic scales to capture the data. Figure 2 displays both the field (14 points) and laboratory (9 points) data as adopted from KOMAR and MCDOUGAL, 1988, except here, the trend line connecting the two data groups has been removed. When included, the incorrect correlation suggests that "excess" Flanking erosion, r due to the presence of the seawall is about 10 percent of the seawall length, Ls. In fact, no such relationship can be "proven" by this data because of the well-known and accepted "scale" effects of the laboratory data. For over 75 years, physical model investigations with natural sedimentshave been conducted, but the results only qualitatively

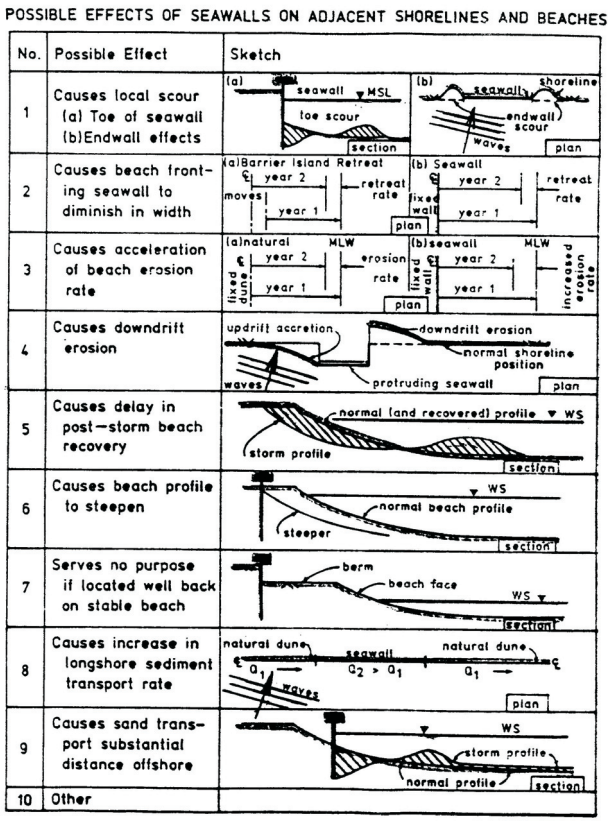

Figure 1. Possible effects of seawalls on adjacent shorelines and beaches (from DEAM, 1987)

Applied because of the great disparity between the Froude and Reynolds number scales for the sand particles. Simply put, if properly scaled, the sand particles would become silty, cohesive materials. However, Figure 2 with trend line continues to appear in the literature (KOMAR, 1998, 2nd Edition, Figure 12-22, p. 52) and to be accepted by the state agencies for permitting coastal structures.

Flanking Effects Possible Mechanisms

Table 1 lists the possible mechanisms for end-of-wall flanking effects of seawalls on adjacent beaches.

Sand Trapping

On historically erosional shorelines with no sediment source (river), DEAN (1987) argued that the structure denies sand to the littoral system during storm events resulting in excess erosion of unprotected adjacent properties. The magnitude of the excess was linked to the seawall length. However, only the data in Figure 2 exists and for very long seawalls, no correlation is physically plausible.

The proposed linkage between excessive erosion, r and seawall length, Ls ignores the importance of the location of the seawall on the beach. WEGGEL (1988) defined six types of seawalls depending on their location on the beach and water depth at the base. Walls further seaward were said to have an increasing effect on coastal processes, e.g. as more sand is trapped.

The proposed linkage between r and Ls also neglects the magnitude of the sand volume that is "active" in the cross-shore profile, and its distribution. BASCO (2000) and OZGER (2002) discuss a wall trap ratio, WTR, as the ratio of actual volume removed to that active in the cross-shore volume during storm events. When the active volume is large, the tapped volume may only be a small percentage of the total, active sand volume in the coastal zone.

A few US states (Florida, California) have adopted mitigation policies and procedures to permit seawall construction and maintain a healthy beach. Formulas attempt to deterministically estimate the wall trap volume, but do not take into account the active sand volume so that the importance of the relative trapped volume is unknown. Property owners annually replace the beach materials trapped behind the structure by placing new sand on the beach. Clearly, stochastic methods are needed to account for the statistical distribution of high water and wave energy events.

Rip Currents and Seaward Return Flows

MCDOUGAL, STURTEVANT and KOMAR (1987) observed rip currents in their model tests and also field evidence to conclude that this mechanism may be more responsible for end-of-wall effects, than trapping. Similar observations of rip currents and return flows in the field were made by PLANT (1990) and PLANT and GRIGGS (1992) at the interior and ends of armored sections. They were attributed to wave overtopping, elevated beach water tables, and seaward, return flows.

Figure 3 displays dune recession over 13-14 years for a 365m section at the south end of Sandbridge Beach, Virginia, US. The data was taken from a series of aerial photographs by the Virginia Institute of Marine Science (WRIGHT, 2003). The top curve (24 March 1987) was before a wall was constructed in the winter of 1988/89 to the left (north) of zero. Beach access around the wall required sand fence removal and lowered the local elevations to permit storm flooding and ebbing at the end of the wall. After 13.4 years, the entire dune toe has receded a similar distance landward, over the shoreline south of the wall end (zero). No discernable, end-of-wall effect is evident from the data. The evidence in Figure 3 was employed to overturn the State of Virginia's denial of a permit application to extend the seawall approximately 100m further south (2002).

Blockage of Littoral Drift (Groin Effect)

GRIGGS and TAIT (1988) found significant, long-term flanking effects at one site on the California coast that lowered the beach profile over 150m downcoast. It was proven that the upcoast end of this protruding wall produced sand impoundment, i.e. a groin effect. TOVE and WANG (1990) conducted laboratory experiments with waves attacking walled and non-walled beaches at angles and concluded that downdrift impacts were a groin effect.

Headland, Parabolic Bay Beaches

Wave refraction, diffraction, shoaling and breaking transformation processes create parabolic or crenulated-shaped beach planforms adjacent to rocky headlands (SILVESTER and LIN, 1993). For waves from a dominant direction, the planform evolves and reaches an equilibrium shape where all waves break normal to the beach, hence longshore transport ceases. Methods exist to predict the equilibrium planform shape, hence maximum indentation of the shoreline position for design (e.g. CEM, 2000).

Seawalls and adjacent beaches could be considered as headland, bay beach systems. Note that this analogy means a

Table 1. *Possible Mechanisms for Flanking Effect.*

Possible Mechanism	References
Sand trapped behind wall	DEAN (1987)
Rip currents and seaward return flows	MCDOUGAL, *et al.* (1987), PLANT (1990), PLANT and Griggs (1992)
Blockage of littoral drift (groin effect)	GRIGGS and TAIT (1988), TOVE and WANG
Headland, parabolic bay system	This paper

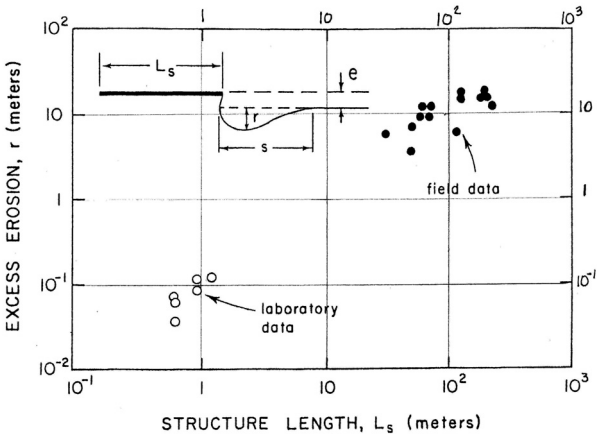

Figure 2. Structure length versus excess erosion for 23 data points (modified from KOMAR and MC DOUGAL, 1988).

maximum indentation, not connected with the "length" of the headland. And, for waves from many directions, the adjacent beach can fill with sand and the headland act as a groin. Not all seawalls are constructed at sites with eroding shorelines, but the excessive erosion misconception is unfortunately applied to many non-eroding situations.

Natural Beach Recovery after Storms

Most beaches in the world naturally recover after erosional storm events. The wave characteristics (height, period) return to levels that cause the onshore direction of sand transport, and the wave direction may also change. Flanking effects, if any, due to the above cited mechanisms, or combinations, disappear as the sand returns from offshore or the longshore transport direction changes toward the walled section. WALTON and SENSABAUGH (1978) did not return to the field sites in Florida (Figure 2) to determine the natural, post-hurricane Eloise recovery of the beach. MCDOUGAL, STURTEVANT and KOMAR (1987) did not modify the wave conditions in the laboratory to determine the recovery of the beach in their laboratory investigations (Figure 2).

No field or laboratory studies and measurements of the coastal processes (waves, wave-induced currents, sediment transport, and bathymetric change) have been made at time scales (hours, days) relevant to document end-of-wall flanking effects of seawalls on the adjacent beach. The very recent development of numerical modeling tools (e.g. CAMS, 2003) to study the seawall-adjacent beach physics will help to sort out the true answer in the near future.

APPLICATION OF HARD STRUCTURES

Migrating Barrier Islands

Every coastal site is unique. Barrier islands are one of eleven types of land/water interfaces found on earth (Shepard, 1976). Barrier beach systems make up about 35 percen of the United States coastline. They are naturally dynamic systems and landward migration due to sea level rise is the common perception. A 1-2 mm/yr rise in sea level translates at most to a 0.05 0.2m/yr shoreline retreat rate. However, at most coastal locations, the overall, local sediment transports and budget produce far greater erosion and accretion rates (KOMAR *et al.* 1991).

Man enters the picture by constructing a road to visit the beach. The road fixes a reference line to quantify shoreline movement and if the shoreline is retreating landward, to quantify "erosion". The distance from the shoreline to the road decreases each year but no one claims the road increases erosion and destroys the beach (see Figure 1, No. 2).

The perception of a barrier island "moving" as the cause of all erosion; the incorrect combination of 23 data points from the field and laboratory (Figure 2, see e.g. KOMAR, 1998); the sand trapping theory as the cause of end-of-wall, flanking effects; and an intensive, well-financed media campaign has enabled the anti-seawall establishment in the US to convince some state legislatures (North Carolina, South Carolina), Maine to pass laws banning the use of all hard shoreline structures including groins and breakwaters for shore protection.

Every coastal site is unique and most are not "moving" barrier islands.

Sandbridge, Virginia, USA

BASCO *et al.* (1977) summarize results based on subaerial beach profiles taken at Sandbridge, Virginia, USA. The shoreline has been eroding on average about 2m/yr long before seawall construction began in 1987. The study focus is on 10 full wave years of monthly and post-storm profile data taken at 28 locations (16 walled, 4720m, 62% and 12 non-walled, 2950m, 38%) since October 1990. A weighted-average method calculated total sand volume seaward of the walls, or partition at non-walled, i.e., dune locations. The initial volume seaward was the regression line intercept at October 1, 1990 and the seaward volume *difference* determined over time. It has been concluded that the volume erosion rates over ten years (negative regression slopes) are *not higher* in front of seawalls.

The seasonal variability of sand volume in front of walls is slightly greater than at non-walled locations. Winter season waves drag more sand offshore in front of walls but summer swell waves pile more sand up against walls in beach rebuilding. Walled beaches were found to recover about the same time as non-walled beaches for both seasonal transitions (winter to summer) and following erosional storm events.

In general, the study confirms all the conclusions of DEAN (1987), KRAUS (1988) and KRAUS and MCDOUGAL (1996) except the end-of wall, flanking effect caused by sand trapping. There has never been evidence of flanking effects after storms on adjacent beaches at Sandbridge, Virginia. On the other hand, many times a short section of beach at an interior wall location experienced excessive scour. This occurred where wave overtopping ponded water behind the wall so that a strong return current flowed beneath the wall to locally lower the beach.

When Seawalls are Appropriate

We agree with HOUSTON (1988) that seawalls should neither be banned nor used in all situations. In analogy with the medical profession, a seawall is likened to penicillin as one of several possible treatments for a diagnosed illness. Penicillin is prescribed selectively because some people are allergic to it. Similarly, hardened shorelines protect infrastructure, property, and human life, but must not degrade the environment and recreational resources. They can and are being applied selectively (e.g. Corps of Engineers, 2000) in the United States.

Coastal engineering considers both hard structures, shoreline modifying structures (groins, breakwaters), soft beach nourishment "structures" and non-structural alternatives for coastal damage mitigation. The five design constraints are (1) knowledge of science and engineering, (2) economics, (3) the environmental impacts, (4) social, political, institutional, and (5) aesthetics. Engineering is design under constraint. The new, political/institutional constraint in the US could be termed environmental law when politicians and management agencies pass and apply "laws" that bar the use of the hard, seawall alternative for shore protection. The situation already exists in the US where these blanket policies are administered to sites where none of the reasons for the regulations exist (see BAER-VS-WISCONSIN, 2003).

New studies for coastal damage mitigation along the coastlines of Brazil will benefit from a factual understanding of how seawalls and beaches interact. Many misconceptions exist, and false assumptions and misleading statements made in the US literature. Hopefully, this paper will help to begin to separate fact from fiction.

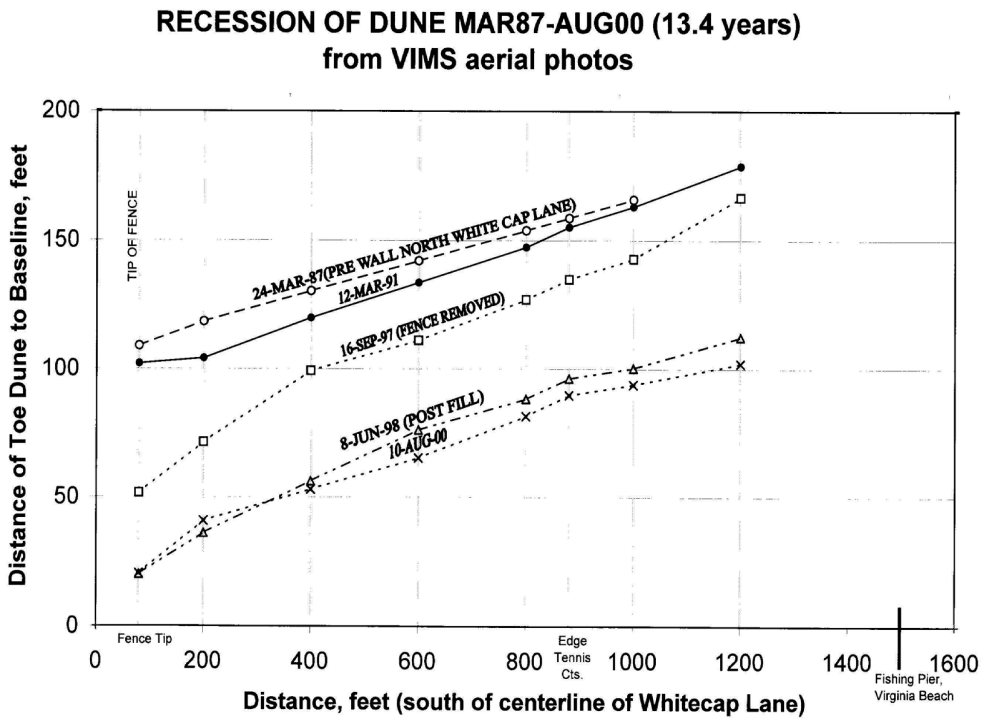

Figure 3. Dune recession south of end seawall (Whitecap Lane) at Sandbridge, Virginia from VIMS aerial photographs.

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