MR 79-1

An Annotated Bibliography on Detached Breakwaters and Artificial Headlands

by John R. Lesnik

MISCELLANEOUS REPORT NO. 79-1
FEBRUARY 1979

U.S. ARMY, CORPS OF ENGINEERS
COASTAL ENGINEERING
RESEARCH CENTER
Kingman Building
Fort Belvoir, Va. 22060

The QUARTERLY

KINGMAN BUILDING
FORT BELVOIR, VA. 22060

CERCular

INFORMATION BULLETIN

VOL. 4 NO. 2 APRIL 1979

COMMANDER AND DIRECTOR

Colonel Ted E. Bishop became Commander and Director of CERC on 30 April 1979. Colonel Bishop came from the Office of the Chief of Engineers where he was the Assistant Chief of the Planning Division, Directorate of Civil Works. Prior to that duty he was assigned to the Defense Special Projects Group at the Office of the Secretary of Defense.

Colonel Bishop has served in Europe, in Vietnam as an engineer battalion commander, and in Australia as an exchange officer with the Australian School of Military Engineering.

A 1955 graduate of the U.S. Military Academy at West Point, Colonel Bishop earned a master's degree in civil engineering from the University of Illinois in 1961. He is also a graduate of the Army War College.

Among his military awards are the Bronze Star with oak leaf cluster, Legion of Merit, and Air Medal. He is a registered professional engineer in the States of Virginia and Maryland.

Both the colonel and his wife, the former Nancy E. VanStrander, are natives of Findlay, Ohio. They have two daughters: Cynthia Bishop Horne of Springfield, Virginia, and Pamala A. Bishop, attending Mary Washington College in Fredricksburg, Virginia.

UNIVERSITY OF TOLEDO TO BE REPOSITORY FOR LAKE ERIE CORES

An agreement has been reached between CERC and the University of Toledo in Ohio that the sediment cores of the southern part of Lake Erie collected by CERC during the 1979 survey will be included in the collection of other Lake Erie beach and lake bottom samples that are part of the Subsurface Data Center within the Department of Geology. The 107 cores along with almost 860 kilometers of geophysical records were collected as part of a 2-year effort by CERC in cooperation with the U.S. Army Engineer District, Buffalo, Corps of Engineers, and the Ohio Geological Survey to conduct a comprehensive geologic study of the southern part of Lake Erie. The geographic region covered in the program extends from Erie, Pennsylvania, west to Toledo, Ohio. The main objective is to locate and assess sand and gravel resources that may be suitable as fill in Government-sponsored beach nourishment projects. The results will receive most immediate use in the Presque Isle Beach Erosion Study being conducted by the Buffalo District. In addition to assessing hard mineral resources the information lends itself to studies on sedimentation rates, changes in past lake level elevations, the history and evolution of the unique Presque Isle spit, as well as the geologic development of Lake Erie due to erosion and deposition by the thick continental glaciers that occupied the region until about 11,000 years ago.

As part of the University of Toledo's Subsurface Data Center, the cores will be readily available to industry, government, and academia for use in geologic, environmental, or engineering studies. The Center has designated storage areas for preservation of the samples and provides basic equipment, such as examination tables and binocular microscopes for use by researchers. To complement the physical samples, CERC will also provide ancillary information on the cores such as location, water depth, detailed geologic description, and grain-size analyses on selected samples.

This arrangement with the University of Toledo complements a similar one made several years ago with the University of Texas at Arlington where some 1,400 cores collected by CERC from Atlantic and Pacific shelf areas have been archived for use by qualified researchers. For additional information on the Lake Erie cores contact L. James Charlesworth (University of Toledo) at (419) 537-2398 or S. Jeffress Williams (CERC) at (202) 325-7445.

TWO NEW TECHNOLOGY TRANSFER ITEMS DEVELOPED FOR CORPS FIELD USE

● Field Guidance Letters

CERC is initiating an additional field information service by issuing Field Guidance Letters (FGL) to quickly transfer research results to Corps field personnel. FGL's will be based on technical reports and will call attention to field uses of the material in the report and provide brief guidance on how it is to be used. This will reduce the time required to get new technology to the field and have it applied there.

FGL's will be prepared when technical reports are in the final draft stage. They will include basic technical references and will provide the name and telephone number of a CERC staff member to call for further information.

● Coastal Engineering Technical Notes

In early fall of this year CERC will also issue a series of one- to four-page "Notes" on coastal engineering design criteria, intended primarily for Corps field personnel. These Notes will (a) clarify and call attention to coastal engineering criteria; (b) provide information on how to design with suggestions for better methods of design; (c) advise of criteria undergoing revision and identify problem areas; and (d) disseminate information on good designs developed for specific problems.

The design aids presented in these Notes are based on accepted theory, analysis of experimental investigations, model studies, and field observations and surveys.

SHORELINE EROSION CONTROL DEMONSTRATION PROGRAM

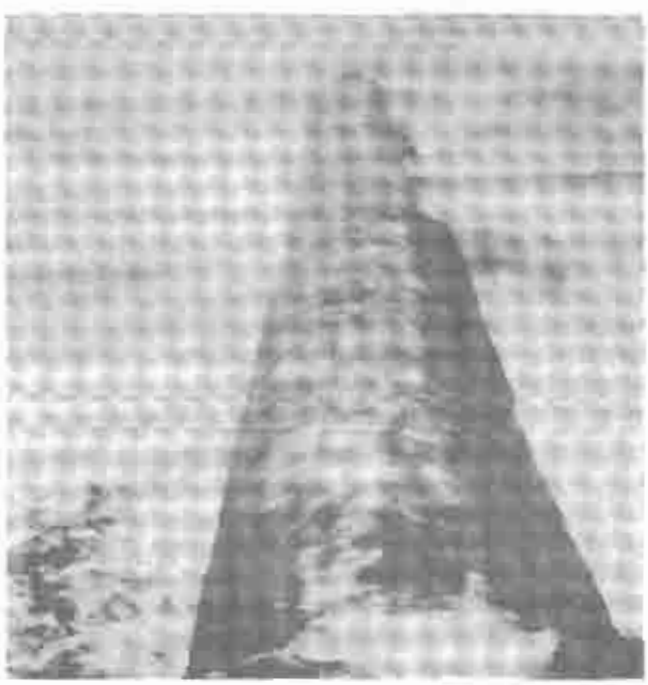
The 13th meeting of the Shoreline Erosion Advisory Panel (SEAP) was held in Fort Walton Beach, Florida, 4 and 5 April 1979. An important part of the agenda was an inspection of the demonstration project located at the Basin Bayou State Recreation Area on Choctawhatchee Bay, Florida.

The devices being tested at this site include a Sandgrabber, a Surgebreaker, a sandfilled bag offshore breakwater, a Longard tube offshore breakwater, and a hogwire fence-sandbag bulkhead. Vegetation will also be tested in concert with these structures. All devices have now been installed at the site except for the Surgebreaker and much of the vegetation.

The Sandgrabber, located at the western end of the project, is constructed of specially fabricated concrete blocks held together with steel rods to form a crescent-shaped breakwater, connected to shore at both ends. A typical Sandgrabber installation at a site on the Great Lakes is shown in the photo.

The Surgebreaker is a conventional offshore breakwater in plan but is constructed of a series of large precast concrete modules. A newly cast module for the Basin Bayou site is shown in the photo. (the module is shown lying on its side; however, the slots will be horizontal in the completed structure).

A Longard tube placed as a groin is shown in the photo. At Basin Bayou, a similar tube has been placed as an offshore breakwater. Installation involves layout of the tube on the bottom and then hydraulically filled with clean sand.



The hogwire fence-sandbag bulkhead was constructed by placing sandfilled acrylic and polyester bags behind a hogwire fence. There has been significant degradation of the bag materials under ultraviolet rays and many bags have ruptured.

A final report of this demonstration program will contain a complete analysis of the performance of all devices tested.

RECENT CERC PUBLICATIONS

NO.	TITLE, AUTHOR, AND DATE	AD NO.
	MISCELLANEOUS REPORTS (MR)	
79-1	**"An Annotated Bibliography on Detached Breakwaters and Artificial Headlands," John R. Lesnik, Feb. 1979.**	——[1]
	This annotated bibliography is presented to assist in the development of reliable design procedures for detached breakwaters. The references deal with topics which can be usefully applied to the design problem although many are not limited solely to the subject of detached breakwaters. Papers on wave diffraction, reflection, transmission, and overtopping are also included.	
	REPRINTS (R)	
79-1	**"Geologic Effects of Ocean Dumping on the New York Bight Inner Shelf," S. Jeffress Williams, Mar. 1979.**	——
	Evidence indicates the controlled ocean dumping of assorted solid materials in the New York Harbor over the past 85 years has significantly filled parts of the Hudson shelf channel and is an important geologic process. About 830 million cubic meters of liquid and solid wastes has been dumped since 1888. This has resulted in creation of several mounds with relief of about 15 meters spanning an area of about 9 thousand hectares. The calculated volume of anthropogenic solids filling the Hudson channel is 318 million cubic meters.	

[1] Not available at time of printing.

Copies of the above reports are obtainable by AD Number from National Technical Information Service, Springfield, Virginia 22151.

CURRITUCK SAND BYPASS STUDY, NEW RIVER INLET, NORTH CAROLINA (PHASE II)

When the U.S. Army Engineer District, Wilmington, acquired the split-hull barge *Currituck*, a three-phased experiment was planned to test and evaluate its use in inlet maintenance and sand bypassing at shallow-draft inlets. The first phase of the experiment was reported in the October 1976 issue of the CERCular (Vol. 2, No. 1).

Field monitoring associated with phase II of the *Currituck* sand bypass study should be completed by early summer of 1979. The effort began in June 1978 with monthly monitoring; results of phase II will determine whether a phase III is needed.

The results of phase I, conducted in the summer of 1976, are in the final review process for a CERC technical publication. Phase II is essentially a repeat of phase I with the exception that dredged material was placed in three different water depths to study the optimum dumping depth in terms of mechanical placement (time and cost) and bypassing benefits.

Since phase I, the *Currituck* has been modified by the Wilmington District with self-loading capabilities, allowing quicker loading and thus more material available for nearshore placement. Three separate mounds of sand (total of 53,000 cubic yards) were placed in 8, 10, and 12 feet of water over a 6-week period.

Another important difference between phases I and II was the monitoring technique. Phase I used a sea sled-mounted level rod towed by a LARC V along the profile and optical methods of positioning. For phase II, the Wilmington District developed a self-powered 24-foot tripod (see photo) called the CRAB (Coastal Research Amphibious Buggy) for surveying through the surf zone. An automated positioning system was incorporated with a minicomputer on shore and provided a real time tracking and data collecting means for carrying out the surveys. This provided a quick and accurate method of monitoring the placed material as well as rapid analysis of the collected data.

After an 8-week monitoring period (before, during, and after the initial placement), surveys have been collected monthly to the present time. When the monitoring is concluded in early summer, a CERC report is scheduled by fall or early winter of 1980.

COASTAL STRUCTURES 79

CERC was a cosponsor of the sixth specialty conference of the Waterway, Port, Coastal, and Ocean Division, American Society of Civil Engineers' *Coastal Structures 79*, held at the Ramada Inn in Old Town Alexandria, Virginia, on 14–16 March 1979. The U.S. Naval Facilities Engineering Command and the Permanent International Association of Navigation Congresses also cosponsored the event.

A total of 319 persons attended the conference, including 312 engineers and scientists, and 7 students. Sixty-five technical papers were presented during the 3-day conference. The keynote address was by E.M. Merrifield, from the Republic of South Africa, on "The Art of the Engineer." Dr. Bernard Le Mehaute was presented the Mauricio Porraz International Coastal Engineering Award for outstanding leadership and development in the field of coastal engineering. This award was endowed in 1977 in recognition of contributions of Mauricio Porraz in this area. The award was officially instituted by the Board of Direction on 15–16 October 1977. The conference was a great technical success.

A 1-day short course on "The Planning, Design, and Construction of Coastal Structures," was held on 13 March 1979 at the Ramada Inn. The course gave specialized attention to engineers and managers who were not experts in this field but who needed to deal with the planning, design, and construction of coastal structures on a realistic basis.

A special seminar was held Wednesday evening (14 March) on the Sines Portugal Breakwater. The speakers included J.H. Zwamborn, Daniel B.C. Vera-Cruz, John Mettam, W. Baird, and J. Ploeg. Approximately 150 people were in attendance.

COASTAL ENGINEERING COURSE

CERC has just conducted a 5-day course on coastal engineering in March 1979 at Oakland, California. The next scheduled coastal engineering course will be held at CERC in September 1979.

Technical articles on coastal engineering research achievements for highlighting in this CERCular should be submitted to the Commander and Director.

CERCular is published quarterly and prepared under the provision of AR 310-2 by the U.S. Army Coastal Engineering Research Center, Fort Belvoir, Virginia 22060. Material may be reproduced without permission although credit to the source is appreciated.

Comments on this CERCular may be addressed to the CERC Public Affairs Officer (Andre Szuwalski).

Ted E. Bishop

TED E. BISHOP
Colonel, Corps of Engineers
Acting Commander and Director

DEPARTMENT OF THE ARMY
COASTAL ENGINEERING RESEARCH CENTER
KINGMAN BUILDING
FORT BELVOIR, VA. 22060

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
DEPARTMENT OF THE ARMY
DOD-314
THIRD CLASS
BULK RATE
041110

U.S. MAIL

Reprinted from Shore and Beach, January 1979

The Effects of the 19 December 1977 Coastal Storm on Beaches in North Carolina and New Jersey

BY WILLIAM A. BIRKEMEIER
Coastal Engineering Research Center
Fort Belvoir, Virginia

INTRODUCTION

THOUGH BEACHES ARE CONSTANTLY BEING REMOLDED under the action of waves, winds and tides, the largest and most dramatic changes occur during storms. Because these storm-induced changes are important in coastal engineering projects, the Coastal Engineering Research Center and its predecessor, the Beach Erosion Board have a long history of interest in storm effects. In 1975, a field-oriented project was initiated to study coastal storms and to predict their effects. The field work concentrated on isolating the effects of individual storms through pre- and post-storm beach surveying and observations during the storm. This report discusses the results of a significant storm which occurred 19 December 1977 along the east coast of the United States.

The effect of the storm was monitored at the three localities shown in Figure 1. These beaches were selected because they had been included in a long-term program of monthly surveys providing a data base of long- and short-term profile line changes, and had well-established profile lines. Moreover, each locality has unique characteristics valuable in developing a general understanding of storm effects. Typical beach characteristics for each area are given in Table 1.

STUDY LOCALITIES

Long Beach Island, New Jersey.

This locality extends 32 km from Barnaget Inlet southward to Beach Haven Inlet and faces almost ESE. The entire length of beach is backed by a wide dune which averages 5.8 m in height. The dune has been stabilized with beach grass and sand fencing. The beach itself is protected by 110 rubble groins 100 m long spaced at about 300 m intervals. Beach cusps are common features as are ridge and runnel formations following storms. Everts and Czerniak[1] showed that between 1963 and 1972 the beach above MSL accreted at a rate of 1.8 m^3/m-yr. Net longshore transport is to the south, but reversals are not unusual.

Eight profile lines located along the southern two-thirds of the island were surveyed before and after the storm. Two of these profile lines (18 and 20) are within 100 m of groins and since they are on opposite sides, they are good indicators of longshore transport direction.

Ludlam Island, New Jersey.

The 12 km length of Ludlam Island is bordered by Corson Inlet on the north and Townsend Inlet on the south. The island faces SE and has finer sand and lower dunes than Long Beach Island. The foreshore slope is milder and features like cusps and berms are unusual during the winter. Outcrops of peat are frequently exposed along much of the beach providing a barrier to further lowering of the beach face. There are two groin fields along the island, an old permeable timber groin field along the north end of the island and a series of rock and timber groins backed by a seawall along the middle of the island fronting Sea Isle City. Net longshore transport is to the south. According to Everts and Czerniak[1] the long-term trend is erosional with the island losing an average −2.8 m^3/m-yr, above MSL, from 1963 to 1972. Thirteen profile lines along the entire island were surveyed before and after the December storm.

Dare County, North Carolina.

This site is located along a 100 km unbroken stretch of shoreline from Rudee Inlet, Virginia, to Oregon Inlet, North Carolina. Except for 6 piers, there are no coastal structures along the entire 100 km. Two reaches of beach, each with 5 profile lines and 2 piers were selected for study. The northern section extends 12 km from the recently completed CERC Field Research Facility (FRF) to the Kitty Hawk Pier. The second section located 22 km to the south, is 6 km long and includes Jeanette's Pier and the Outer Banks Pier. The beach is narrower and steeper with a higher

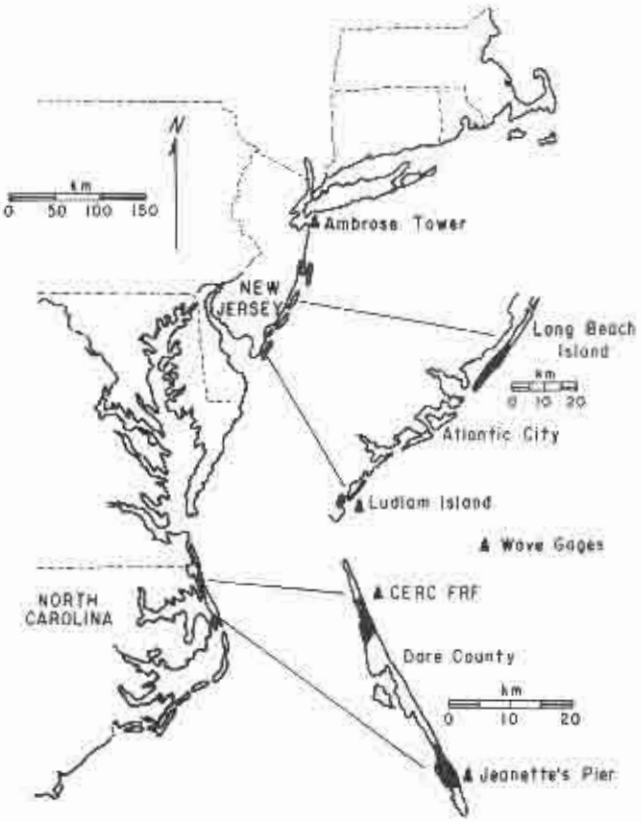


Fig. 1. Map showing the location of study beaches and wave gages.

dune and coarser sand than either New Jersey locality (see Table 1). Beach cusps are common. Net longshore transport is to the south.

FIELD DATA

Beach profile lines at each locality were surveyed from the dune to as close to mean sea level (MSL) as was possible by two-man crews using instrument and stadia surveying procedures. An analysis of these procedures has shown that the data represent the volume of each profile to an accuracy of approximately $\pm$ 0.6 m^3/m of beach front. The accuracy depends on the length and shape of the profile, on prevailing conditions and assumes that there are no totally erroneous data points. Each profile line is monumented by a permanent bench mark with one or two auxillary monuments to define the profile azimuth. As each profile line was surveyed, 4 to 6 photographs were taken to document any changes which may have occurred since the previous survey. Profiles along each of the piers were surveyed by lead line sounding the depth at regular intervals.

In order to examine the effect of the storm on sediment texture, the beach surface at representative profile lines at each locality, was sampled in 5 places during each survey. Samples were taken from the: dune crest, dune base, backshore, berm crest, and near the MSL contour.

Besides collecting the survey data, each field crew made frequent visual observations of wind, breaking wave characteristics and longshore currents. Wave characteristics were recorded by 5 wave gages located at the 4 locations shown in Figure 1.

STORM CONDITIONS

Weather and Tides.

According to the Mariners Weather Log,[5] the storm developed over North Carolina on 18 December 1977 at the intersection of a complex frontal system as shown in the synoptic weather maps in Figure 2.[6] By 19 December, the storm had intensified with the center of the low dropping to 989 mbs. Winds at sea were reported as high as 100 km/hr with waves up to 8 m. Because of blocking high pressure to the north and another frontal system moving in from the west, the storm moved almost due east, paralleling the 35° N line of latitude. By 0700 EST, 20 December, it was 1400 km offshore. This unusual track produced strong onshore winds of long duration over a long fetch.

Figure 3 shows hourly weather observations from the Atlantic City, New Jersey Marina (solid lines)

TABLE 1.

LOCALITY CHARACTERISTICS

Locality	Shoreline Orientation	Length of Study Beach (km)	Dune Height[1] (m above MSL)	Beach Width[1] (m)	Foreshore Slope[1]	Mean Sand Size (mm)	Mean Tide Range (m)	Profile Lines Surveyed
Long Beach Island, NJ	N29° E	18.5	5.8	52	1:12	0.33[2]	1.3	8
Ludlam Island, NJ	N34° E	8.2	4.6	76	1:43	0.23[2]	1.2	13
Dare County, NC	N22° W	17.9	6.3	42	1:11	0.45[3]	1.0	10 + 4 Piers

[1]Typical Winter Values, [2]Ramsey and Galvin,[2] [3]Headland[3]

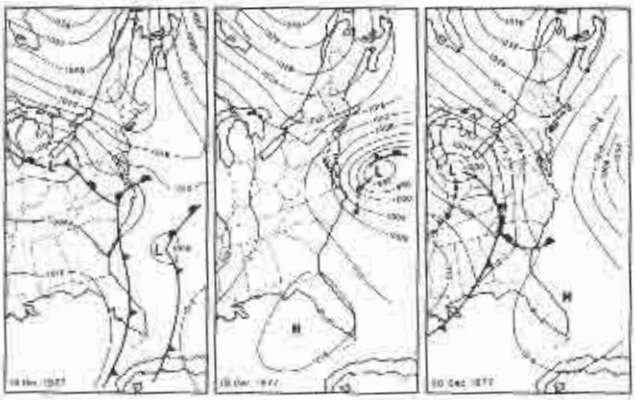


Fig. 2. Synoptic weather maps at 0700 EST showing movement of the storm from 18 to 20 December 1977 (Ref. 6).

and three-hourly measurements from Oregon Inlet, North Carolina (dashed lines). Because the storm did not follow a coastal track, the data from both areas are similar and generally in phase. This is most obvious in the plot of atmospheric pressure.

The pressure reached a lower value and the winds reached higher speeds in North Carolina, which was closer to the storm's center. The peak winds at Oregon Inlet and Atlantic City were 65 km/hr and 52 km/hr, respectively. However, the different orientations, and the difference in the weather preceding and following the storm caused the New Jersey area to sustain a longer period of significant onshore winds. In New Jersey onshore winds persisted for 88 hours and exceeded 35 km/hr for 38 hours. In North Carolina onshore winds lasted 51 hours with winds over 35 km/hr lasting 30 hours.

Approximate surge levels for Atlantic City and the CERC FRF are plotted at the bottom of Figure 3. The data were calculated by subtracting from the

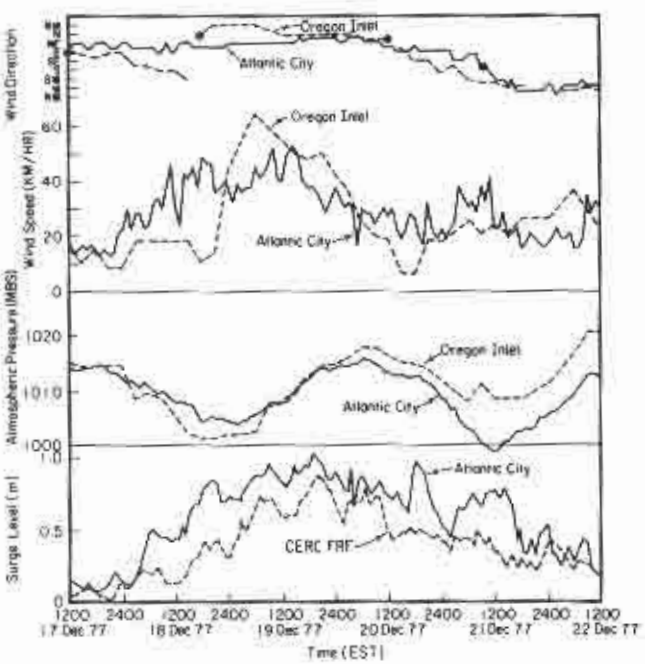


Fig. 3. Weather and surge data from Atlantic City, New Jersey and Dare County, North Carolina. Circles indicate periods of onshore winds.

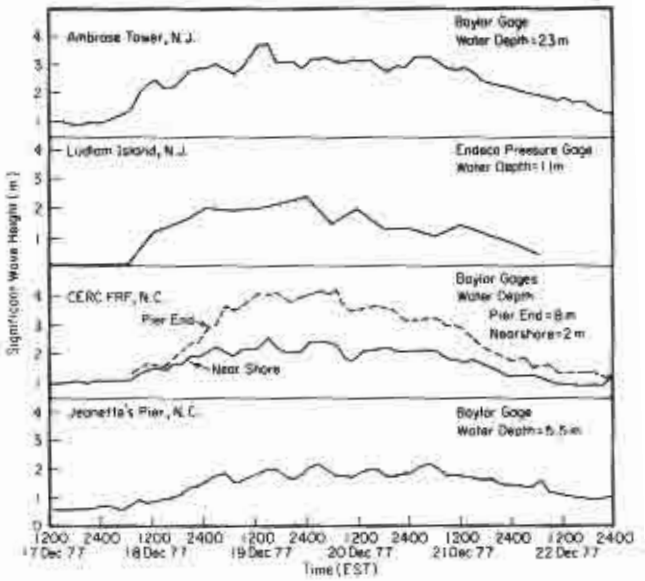


Fig. 4. Significant wave heights recorded during the storm at the four locations shown in Figure 1.

recorded tide data a cosine fit to each high and low tide predicted by the National Ocean Survey.[7] While this rough approximation does not remove all tidal components, it does illustrate the duration and magnitude of the storm surge. The long period of onshore winds forced the tide above the predicted level for 8 successive high tide periods starting 18 December. The peak surge which occurred during low tide at 2000, 19 December 1977 was 1.0 m at Atlantic City and 0.85 m at the CERC FRF. According to Ho and Tracey,[4] the surge level at the CERC FRF corresponds to a storm with a 2-year return period.

Waves and Currents.

Significant wave height data collected during the storm are plotted in Figure 4. All of the gages showed similar patterns of wave growth and decay, though significant wave activity began first in New Jersey. Significant wave heights in excess of 2 m were measured at all gages and a peak significant height of 3.8 m was recorded by the gage at the end of the FRF at 0600, 20 December. No gage records were available for Long Beach Island but visual observations indicated breaking waves 15–25% higher than those at Ludlam Island.

Figure 5, taken between 1000 and 1200, 19 December, illustrates the condition of the surf zone at the CERC FRF. Waves were breaking seaward of the pier suggesting the existence of a bar further offshore (Note: The pier extends 475 m from shore, seaward depth 20 December was 8 m below MSL). As can be seen in Figure 5, an occasional wave crested along the underside of the pier deck which was approximately 7 m above the mean water level at the time the photograph was taken.

Visual observations made during the storm at the three study beaches indicated wave angles of 10° to 20° (measured counterclockwise from shore normal) and southward longshore currents. The strongest longshore current measured (0.8 m/sec) occurred at Ludlam Island at 1525, 19 December. On the same day

Fig. 5. Waves breaking along the CERC research pier, 1000–1200, 19 December 1977. The storm surge level was 0.7 m above MSL and about 7 m below the pier deck.

a rate of 0.3 m/sec was recorded near the CERC FRF. No measurements were taken at Long Beach Island during the height of the storm but a rate of 0.6 m/sec was observed 20 December. No attempt was made to continuously measure longshore current speeds so these are only indicative of those that occurred. Currents were measured near the shoreline by tracking the movement of a patch of fluorescent dye.

BEACH CHANGES

Long Beach Island.

The 8 Long Beach Island profile lines shown in Figure 6a were surveyed 11, 20, and 22 December. The 20 December survey was completed at low tide during the waning stages of the storm and did not reach MSL. However, all of the profile lines reached to within 0.75 m of MSL close enough to extrapolate the distance to the MSL contour. Except for profile line 20, the beach at all profile lines eroded. Volume and MSL shoreline changes are shown in Figure 6b. The average volume change was -19.7 m^3/m which was in addition to -12.5 m^3/m removed since 13 October 1977 by early winter storms. Figures 7a and 7b, showing profile line 15, illustrates the profile modification caused by the storm. Profile line 20 located 44 m north of a groin eroded on the upper beach face and accreted on the foreshore for a net gain of 7.0 m^3/m, indicative of southerly longshore transport. The post-storm profile was featureless and slightly concave. The average extrapolated MSL position for all lines moved an average of 1.4 m seaward.

When the profile lines were resurveyed 22 December, a full day after the storm, the beach had accreted an average of 10.0 m^3/m, or 51% of the amount removed by 20 December. Of the 8 lines, only profile line 18, 100 m south of a groin, eroded further. At profile line 17, 0.6 m of sand was deposited at the base of the dune, reducing a 2.7 m scarp to 2.1 m. This rapid recovery supports the need for immediate post-storm surveying at least of beaches

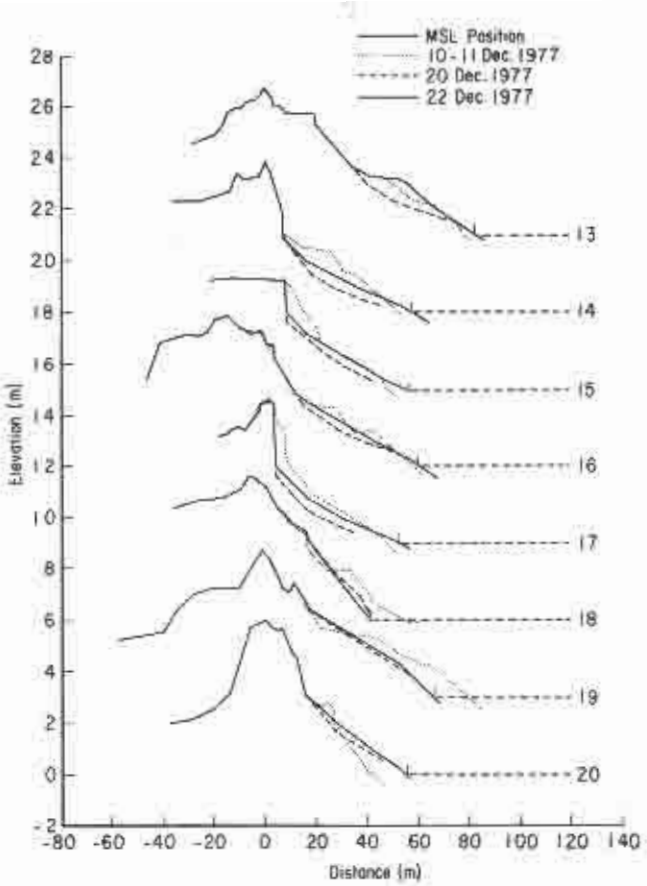


Fig. 6a. Pre and post storm surveys of Long Beach Island, New Jersey profile lines.

similar to Long Beach Island. As the sand moved ashore, the MSL shoreline position moved landward, back almost to its pre-storm location.

Ludlam Island.

The 13 profile lines which were surveyed on 10, 21 and 22 December are shown in Figure 8a. Every profile line eroded, losing an average of 16.9 m^3/m of material. The average MSL shoreline position retreated 10.3 m. Figure 8b shows the considerable variation between profile lines with volume losses

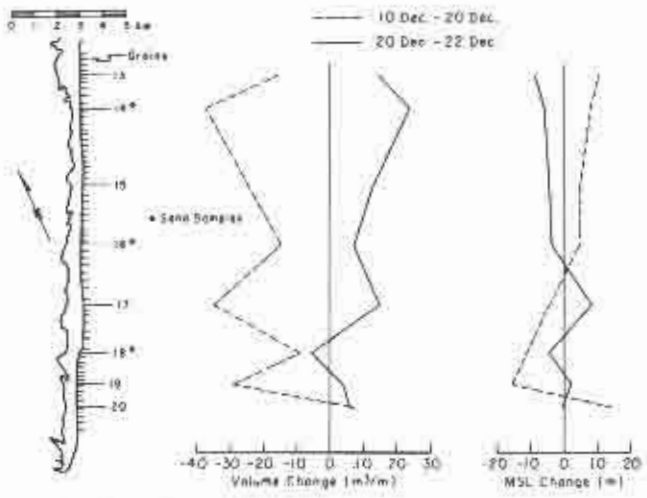


Fig. 6b. Volume and shoreline changes at Long Beach Island, New Jersey.

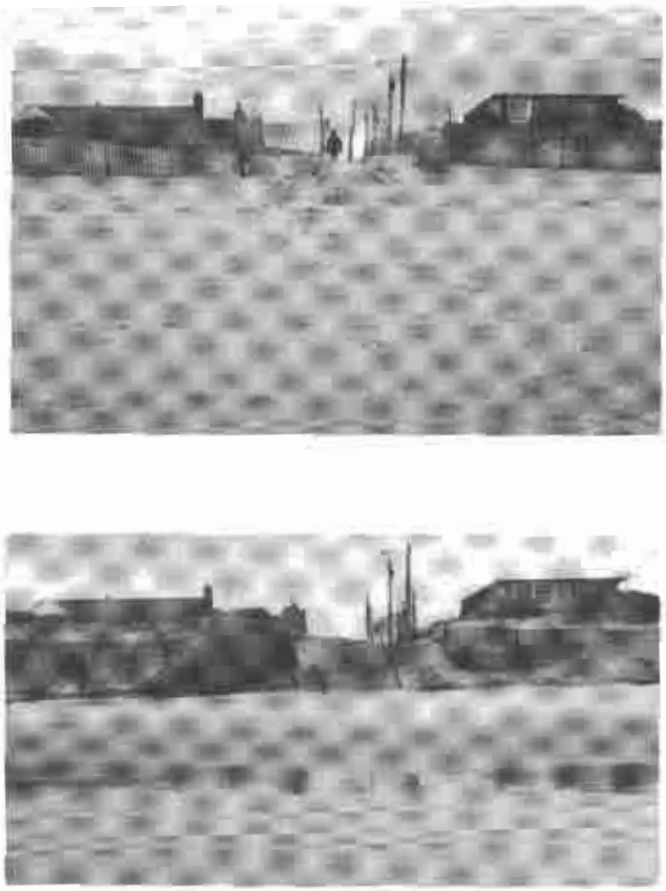


Fig. 7a, b. Pre and post storm condition of profile line 15 on Long Beach Island, New Jersey. Photographs were taken 26 November 1977 and 20 December 1977. Maximum scarp height in Figure 7b was 2 m.

ranging from -25.9 m^3/m at line 5 (shown before and after the storm in Figures 9a and 9b) to -9.8 m^3/m at line 18. The beach was described as the lowest it has been in 30 years by Mr. Howard Wright, a CERC visual wave observer for the past 10 years. This lowering of the beach face uncovered old debris, foundations, and seawalls. A sand fence was lost at line 17, a groin at line 11 was flanked and there was considerable dune loss especially at lines 5, 6, 17, and 19. Beds of peat were exposed at profile lines 5, 6, 7, and 9. These peat outcrops are indicated by the unusual beach face features seen on these lines in Figure 8a.

The groin field that fronts Sea Isle City effectively divides the island into three sections and it is useful to examine the beach changes in each section. Along the undeveloped section north of the groins between profile lines 4 and 10, the average beach change was -18.1 m^3/m with a landward MSL change of 11 m. Most of this loss resulted from a lowering of the beach face.

The volume change at profile lines 11, 14, and 16 within the groin field was similar, -18.3 m^3/m, however, the MSL position moved only 4 m landward. Downdrift of the groins (to the south) the beach is significantly narrower and the average change of -12.9 m^3/m was lower than for the other two sections. The change in MSL was -17 m due primarily to the removal of a bar at profile line 19.

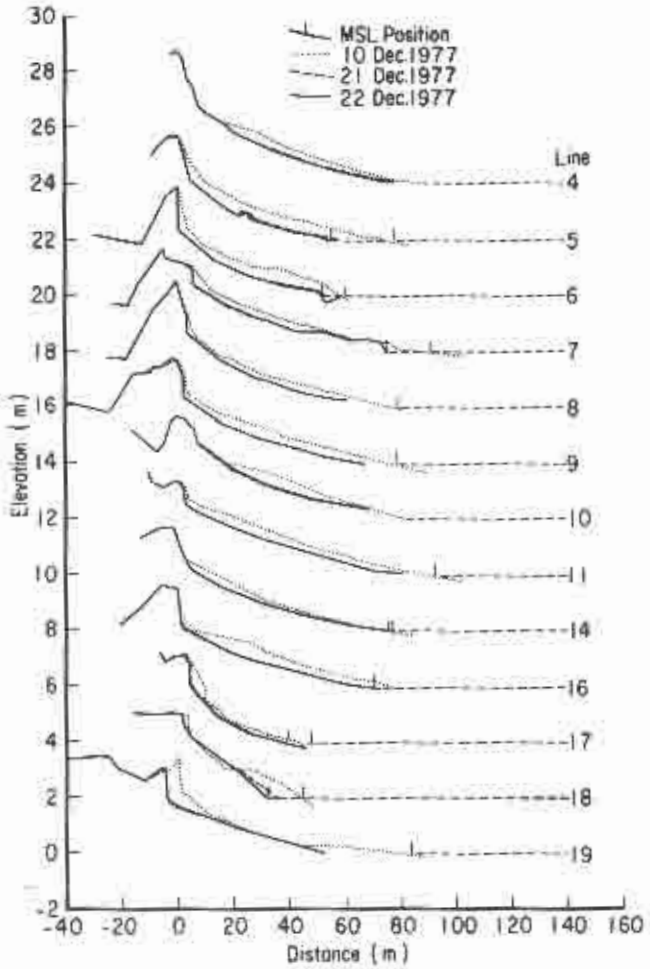


Fig. 8a. Pre and post storm surveys of Ludlam Island, New Jersey profile lines.

These results are interesting since measurements of longshore current at profile line 18 reached 0.8 m/sec toward the south. The expected result, increased erosion downdrift of the groins did not occur, at least on the beach above MSL.

A survey of the beach 22 December showed no significant recovery, in fact the average change was an additional loss of -1.1 m^3/m. This is typical of

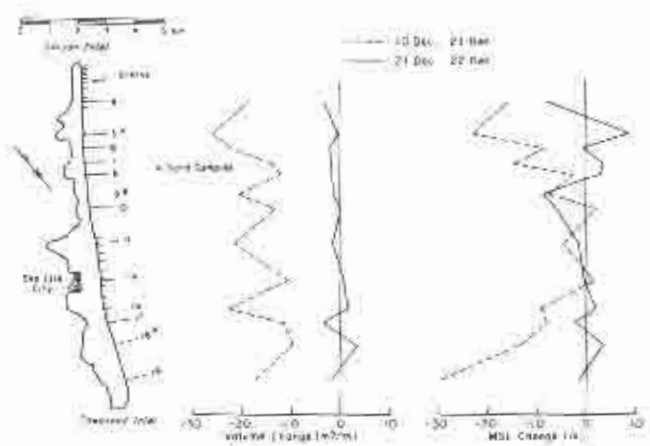


Fig. 8b. Volume and shoreline changes at Ludlam Island, New Jersey.

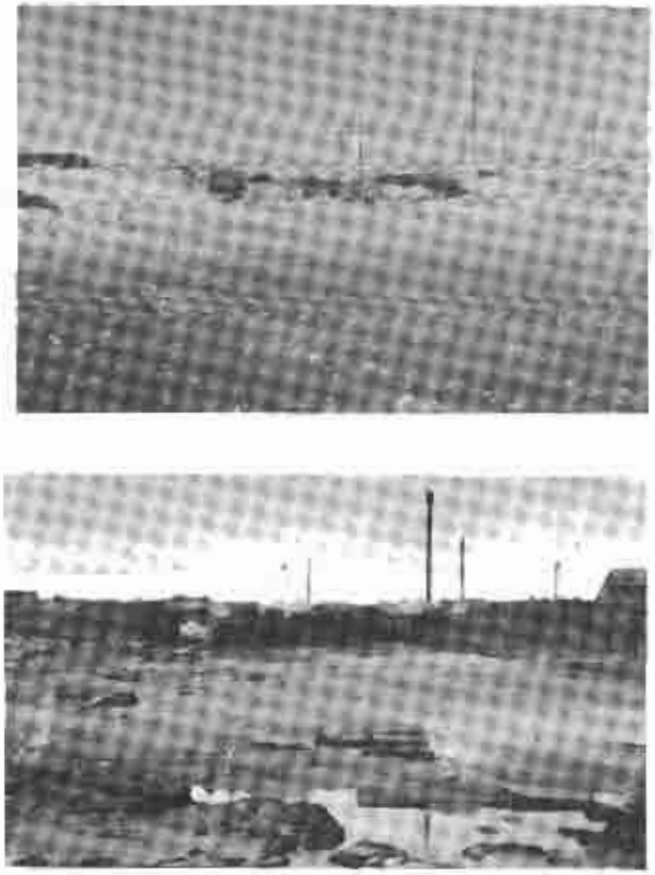


Fig. 9a, b Pre and post storm condition of profile line 5 on Ludlam Island, New Jersey. Photographs taken 10 December 1977 and 21 December 1977. Storm caused the backshore elevation to drop 0.5 m.

Ludlam Island which recovers slower than Long Beach Island.

Dare County, NC.

Since the 10 profile lines and 4 piers in Dare County were surveyed on 18 December as the storm was developing, they provide a better record of the pre-storm beach shape than was available for the New Jersey localities. The beach was resurveyed 20 December and 22 December. Because of high water and wave conditions, the 20 December survey did not reach MSL. Consequently, shoreline and volume changes are based on an extrapolated MSL position.

Figure 10a shows the 10 profile lines. Volume and shoreline changes are shown in Figure 10b. Average volume change between 18 and 20 December was $-12.0\ m^3/m$. The average MSL shoreline contour moved 3.3 m landward. Only profile line 20 had a net accretion, while the foreshore remained the same, the dune was slightly cut back, and the backshore built up. The most interesting change occurred at line 40 where the storm removed material from the foreshore and filled in a scarp above the 2 m contour. Beside the erosion, some low lying sections of beach (which were not studied) were overwashed, as shown in Figure 11. This area lies between the two surveyed sections and lacks a protective dune line. Buildings in the area have been built directly on the beach and are prone to frequent flooding.

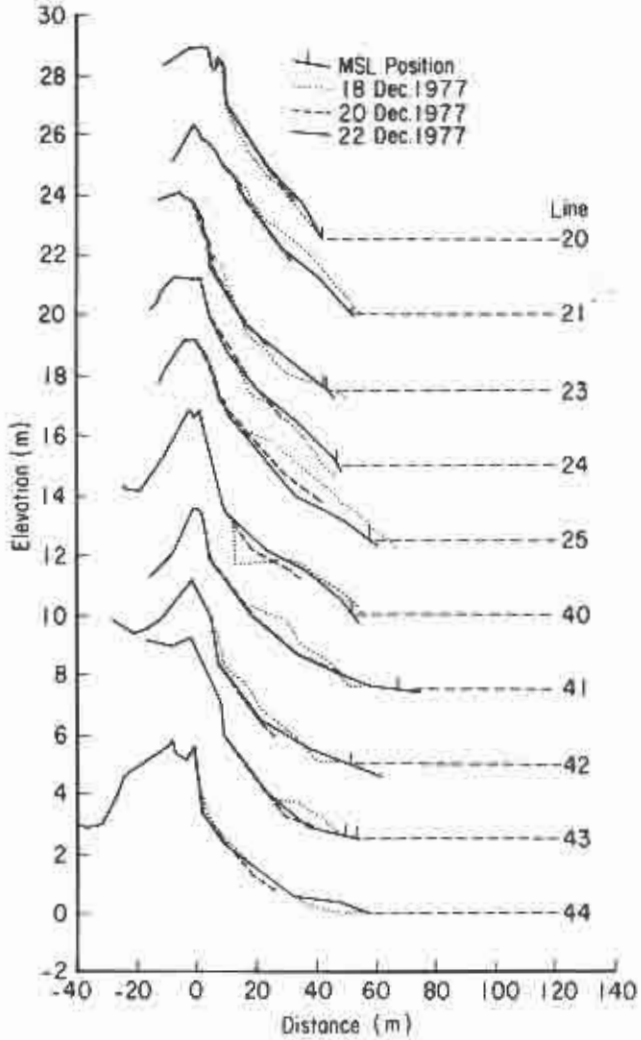


Fig. 10a. Pre and post storm surveys of Dare County, North Carolina profiles lines.

When the measured volume changes are examined by section, as shown in Figure 10b, the southern section eroded twice as much as the northern one with lines 40 to 44 losing $-16.0\ m^3/m$ versus the $-8.0\ m^3/m$ lost at lines 20 to 25.

The beach was surveyed again, 2 days later, and

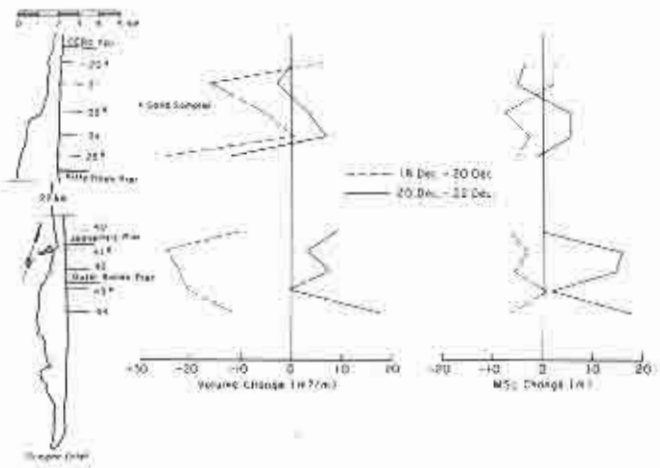


Fig. 10b. Volume and shoreline changes at Dare County, North Carolina.

Fig. 11. Overwash event occurring 1530 EST, 19 December 1977 in Dare County, North Carolina. Area shown is located between the two study sections shown in Figure 1.

the northern section showed an additional loss of −1.0 m^3/m, primarily due to further erosion at profile line 25. The other 4 northern profile lines showed evidence of accretion along the foreshore. The southern section showed significant accretion similar to that found at Long Beach Island, regaining 6.1 m^3/m. This accounts for 38% of the material removed by the storm.

Profiles along each of the piers before, during and after the storm are shown in Figure 12. Total volume changes for each pier are given in Table 2. The data indicate that each pier profile suffered a net loss of sand below MSL and in all cases, the first bar was removed.

If the changes, particularly along the CERC FRF, are examined according to distance from shore, the pre-storm profile shows 3 distinct humps including the beach berm and two offshore bars. By 21 December, these features had been removed leaving a long terrace at approximately −6 m depth from 90 to 290 m from shore. Some material located past the

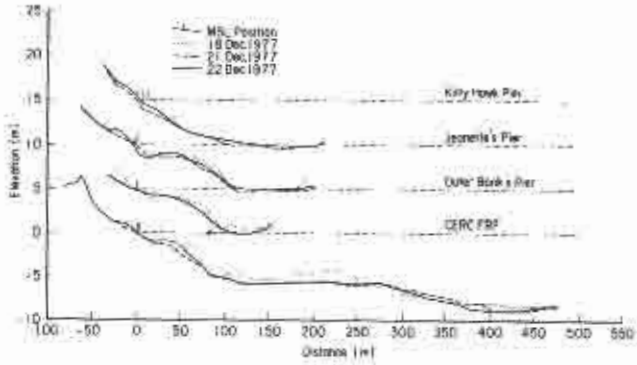


Fig. 12. Pre and post storm surveys of four Dare County, North Carolina piers.

400 m mark shown on Figure 12 also was removed. In terms of volume, the berm lost −8.2 m^3/m, while −197.9 m^3/m were removed between 0 and 270 m and −61.9 m^3/m were lost between 390 and 490 m. The only deposition, 25.5 m^3/m, occurred between 270 and 390 m. Looking at the seaward end of the profile, there is indication that some material moved offshore into water deeper than 8 m.

One day later, 22 December, the first bar had reformed slightly landward of its pre-storm position and the berm had rebuilt. Interestingly, the amount of material deposited in the berm (6.6 m^3/m) and in the bar (30.5 m^3/m) was only 12.2 m^3/m less than the material which was lost between 280 and 420 m, an indication of onshore transport. There was also a slight increase in the sand level at the end of the pier.

A similar response was found at the other piers with removal or modification of the berm and the first bar during the storm and rapid recovery of these features after the storm subsided.

Sand Samples.

All but 5 of the 130 samples collected were analyzed with CERC's Rapid Sediment Analyzer (RSA). The

TABLE 2

PIER VOLUME CHANGES m^3/m
(L = Pier Length)

Survey Dates	CERC FRF L = 555 m	Kitty Hawk Pier L = 251 m	Jeanette's Pier L = 277 m	Outer Banks Pier L = 198 m
18–21 Dec				
Above MSL	−8.2	−5.2	−11.6	
Below MSL	−234.3	−99.5	−80.4	
21–22 Dec				
Above MSL	6.6	11.0	10.0	
Below MSL	−11.9	48.9	36.4	
18–22 Dec				
Above MSL	−1.6	5.8	−1.6	−21.9
Below MSL	−246.2	−50.6	−44.0	−13.6

5 samples too coarse for the RSA were from Dare County. These were sieved to 1/4 phi intervals. Mean size and standard deviation were then determined by the method of moments.[2] Sieve results were converted to approximate RSA results using a conversion determined by Headland[3] based on results from 90 Dare County samples.

The mean size for each sample from the 5 positions across the beach, averaged by locality and date, are plotted in Figure 13. Since position on the beach was only approximately determined, samples from the dune crest and dune base are the most repeatable in terms of location. The most seaward samples were generally collected from the swash zone and were therefore taken near MSL. The only exceptions were the 20 December Long Beach Island samples where the final sample was taken in the swash, but near the pre-storm berm crest position.

All of the dune crest samples cluster around a mean size between 0.30 mm (1.73 ϕ) and 0.4 mm (1.32 ϕ). The finest sands were from Ludlam Island where the pre-storm beach face material collected at profile lines 5, 9, and 18, was finer than the dune sands. As the beach eroded during the storm, this fine material was removed leaving coarser sand across the entire beach, as shown by the samples collected on 21 December. This change is most apparent in the MSL samples where the average mean size almost doubled, changing from 0.21 mm to 0.39 mm (2.25 ϕ to 1.36 ϕ). This was primarily the result of the post-storm MSL sample from profile line 18 which had a mean size of 0.58 mm (0.79 ϕ). When the beach was resurveyed again 22 December, samples collected between the dune base and the berm crest exhibited an additional coarsening with dune and MSL samples becoming finer. The largest change was again at profile line 18 where the mean size of the MSL sample changed from 0.58 mm to 0.35 mm (0.78 ϕ to 1.5 ϕ). This is an indication of fine material beginning to return to the beach. In fact, the decrease in mean size at profile line 18 accompanied a rebuilding of the beach near the MSL intercept between 21 and 22 December, as shown in Figure 8a.

At Long Beach Island, samples were collected at lines 14, 16, and 18. The results indicate that except for a slight coarsening of sand on the berm crest, the material on the pre-storm beach was similar across the entire profile. The response due to the storm was similar to that found at Ludlam Island with the material coarsening as the beach eroded. The smallest change in mean size was found in the swash zone near the position of the pre-storm berm crest. Two days later, although the beach had recovered significantly, the material at the base of the dune and on the backshore had further coarsened, while the berm crest material was finer. Material near MSL, sampled for the first time after the storm was 0.15 mm coarser than on the pre-storm beach shifting from 0.30 mm to 0.45 mm (1.71 ϕ to 1.15 ϕ).

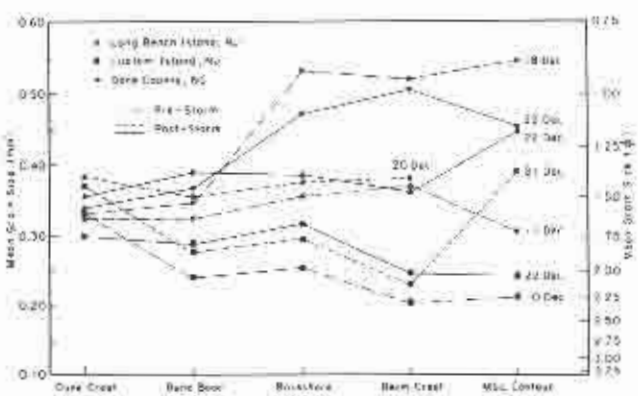


Fig. 13. Changes in mean grain size caused by the storm at the three study beaches.

The samples collected at lines 20, 21, 23, 41 and 43 in Dare County are most representative of the pre-storm beach since, unlike the New Jersey localities, they were collected just prior to the storm. Interestingly, the textural response due to the storm was opposite that of the New Jersey samples even though both localities experienced erosion. Samples collected from the backshore to MSL became finer after the storm while the samples from the dune crest and dune base showed little change. The largest shift was near MSL where the mean size changed from 0.55 mm to 0.45 mm (0.88 ϕ to 1.15 ϕ). Not included in the post-storm average for the MSL samples was a very coarse sample found at profile line 23 with a mean size of 1.27 mm (−0.34 ϕ) which was almost 3 times larger than the mean for the other 4 profile lines.

SUMMARY

A significant coastal storm developed over North Carolina, 18 December 1977, and moved almost directly offshore. Because of this track, similar wind and wave conditions occurred in New Jersey and northern North Carolina allowing the changes caused by the storm in these areas to be compared. The beaches at Long Beach Island, NJ; Ludlam Island, NJ; and Dare County, NC were surveyed before, just after and a day after the storm. Of the 32 profile lines surveyed, all but 2 eroded during the storm. This suggests predominantly offshore rather than alongshore movement of material. Sounding data collected along 4 piers in Dare County also indicates offshore movement with a net loss of −243 m^3/m of material from the dune to the −8 m contour at the CERC FRF.

On the beach above MSL, Long Beach Island eroded the most, losing −19.7 m^3/m. It also recovered the most, regaining 10.0 m^3/m just one day after the storm. Ludlam Island eroded an average of −16.9 m^3/m and showed a slight additional loss of −1 m^3/m after the storm. Profile lines within and updrift of the Sea Isle City groin field eroded more than downdrift ones. The least affected locality was Dare County where the average change for the 10 profile lines was −12.0 m^3/m. A day after the storm, the beach had regained 2.5 m^3/m. There was considerable variation in volume changes among profile lines. The largest change (−37.0 m^3/m) occurred at line 14 on Long Beach Island while line 20 on Long Beach Island accreted 7.0 m^3/m. The results of analysis of surface sediment samples collected before and after the storm at each locality indicate that the New Jersey beaches became coarser

due to the storm while the beach face in Dare County became finer. Again there was considerable variation among samples.

The data presented here are being combined with similar data from recent and historic storms in order to develop a general model for predicting storm losses based on the relationships between beach and storm characteristics. Such a model would be useful in the design of beach nourishment projects and for classifying beaches according to the maximum storm they could withstand.

ACKNOWLEDGEMENTS

Charley Judge, Gene Bichner, Mike Leffler, Lin Tornese, and Frederick Weinmann assisted in data collection. All data were analyzed at CERC by the Coastal Processes Branch with assistance from the ADP office and the Research Support Division. Reviews by Rudolph Savage, Robert Hallermeier, Craig Everts, Allan DeWall, and Marilyn Fleming, all of CERC, were appreciated.

Approval for publication is appreciated. The analysis presented in this paper, unless otherwise noted, was based on research conducted at the Coastal Engineering Research Center under the Coastal Engineering Research Program of the U.S. Army Corps of Engineers.

REFERENCES

1. Everts, C. H. and Czerniak, M. T., *Spatial and Temporal Changes in New Jersey Beaches*. The Proceedings of the Conference on Coastal Sediments '77, ASCE, Charleston, South Carolina, 1977.
2. Folk, R. L., *Petrology of Sedimentary Rocks*. Hemphill's, Austin, Texas, 1965.
3. Headland, J. R., *Sand Size Trends Along and Across North Carolina Beaches*, Unpublished Report, U.S. Army Coastal Engineering Research Center, 1977.
4. Ho, F. P., and Tracey, R. J., *Storm Tide Frequency Analysis for the Coast of North Carolina, North of Cape Lookout*, NWS HYDRO-27, National Oceanic and Atmospheric Administration, 1975.
5. Mariners Weather Log, *Smooth Log, November and December 1977*, May 1978, Vol. 22, No. 3, p. 194.
6. National Oceanic and Atmospheric Administration, *Daily Weather Maps*, 18–20 December 1977.
7. National Ocean Survey, *Tide Tables, High and Low Water Predictions, East Coast of North and South America*, 1977.
8. Ramsey, M. D. and Galvin, C. J. Jr., *Size Analysis of Sand Samples from Three Southern New Jersey Beaches*, MR 77-3, U.S. Army Coastal Engineering Research Center, 1977.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER MR 79-1	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AN ANNOTATED BIBLIOGRAPHY ON DETACHED BREAKWATERS AND ARTIFICIAL HEADLANDS		5. TYPE OF REPORT & PERIOD COVERED Miscellaneous Report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) John R. Losnik		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of the Army Coastal Engineering Research Center (CEREN-CD) Kingman Building, Fort Belvoir, Virginia 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS F31234
11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Army Coastal Engineering Research Center Kingman Building, Fort Belvoir, Virginia 22060		12. REPORT DATE February 1979 13. NUMBER OF PAGES 79
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Annotated bibliography
Artificial headlands
Detached breakwaters
Ocean engineering

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This annotated bibliography is presented to assist in the development of reliable design procedures for detached breakwaters. The references deal with topics which can be usefully applied to the design problem although many are not limited solely to the subject of detached breakwaters. Papers on wave diffraction, reflection, transmission, and overtopping are also included.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

PREFACE

This report provides coastal engineers a bibliography of references which could potentially be applied to the design of detached breakwaters. The bibliography is published under the coastal construction research program of the U.S. Army Coastal Engineering Research Center.

The report was prepared by John R. Lesnik, Hydraulic Engineer, under the general supervision of R.A. Jachowski, Chief, Coastal Design Criteria Branch.

The author gratefully acknowledges the following people who made contributions to this effort: F. Biesel, Directeur Scientifique, Laboratoire Central d'Hydraulique de France; S.Y. Chew, Housing and Development Board, Republic of Singapore; D.P. Dodge, Public Works Canada, Vancouver, B.C.; I. Fried, Civil and Marine Engineering Co., Ltd., Haifa, Israel; O.T. Magoon, U.S. Army Engineer Division, South Pacific; M. Porraz, Control de Erosion, S.A., Mexico City, Mexico; R. Silvester, University of Western Australia.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

JOHN H. COUSINS
Colonel, Corps of Engineers
Commander and Director

CONTENTS

AN ANNOTATED BIBLIOGRAPHY ON DETACHED BREAKWATERS AND ARTIFICIAL HEADLANDS

by
John R. Leenik

1. INTRODUCTION

In recent years there has been a growing awareness of the potential use of detached breakwaters for shore stabilization. However, lack of design experience with these structures has hindered their widespread application in beach erosion projects. Engineers are often uncertain about how to approach the design problem because of the many unknowns involved. In addition, there are few existing structures that can be studied to provide prototype data.

This annotated bibliography is presented to assist in the development of reliable design procedures for detached breakwaters. The references deal with topics which can be usefully applied to the design problem although many are not limited solely to the subject of detached breakwaters. For instance, the wave dissipation characteristics of submerged breakwaters are discussed in several papers. An understanding of these characteristics would be necessary for the design of some detached breakwaters. Papers on wave diffraction, reflection, transmission, and overtopping are also included. The bibliography is not comprehensive in these areas but an attempt has been made to identify some significant works with potential applications.

Several papers describe the use of detached breakwaters as sand traps for navigation projects. Although this use does not fall within the realm of shore protection, these structures do affect the coastal processes in the same way as shore protection breakwaters.

In compiling this bibliography a decision had to be made concerning exactly what constitutes a detached breakwater. The usual shore-parallel structures obviously fit this category but there are other types of construction which could be included. Among these are T-groins where the length of breakwater section is much longer than the groin, submerged sills of timber, steel-sheet piling, rubble or other materials, and artificial headlands used to form crenulate-shaped bays.

The bibliography includes several foreign language papers that have been independently translated. These translations are in the U.S. Army Coastal Engineering Research Center (CERC) library; however, the accuracy of the translations has not been verified. Some foreign language papers were not translated but keywords were deduced from identifiable figures, photos, and illustrations within the text.

Copies of some references were not reviewed but were included in the bibliography because of their titles. Abstracts and keywords are not given for these publications.

II. SUBJECT AND LOCATION HEADINGS

As an aid to the user the references are keyworded by subject headings and, if appropriate, by geographical location. Alphabetical indexes by subject headings and locations are in Sections IV and V.

1. Subject Headings.

Accretion
Aesthetics
Akmon armor unit
Armor stability
Armor units
Artificial headlands
Beach fill
Bibliography
Bolsacreto ® concrete bag
Compartmented breakwater
Composite structures
Concrete blocks
Concrete structures
Construction procedures
Continuous breakwater
Crenulate-shaped bay
Currents
Design guidelines
Detached breakwater
Downdrift beaches
Economic analysis
Environmental concerns
Foundation design
Gabions
Grout-filled bags
Hexaleg blocks
Hollow tetrahedron
Hydraulic model (two-dimensional)
Hydraulic model (three-dimensional)
Impermeable breakwater
Littoral transport
Local scour
Movable bed
Numerical model
Offshore island
Perched beach
Permeable breakwater
Pile arrays
Recreation
Rubble mound
Sand mound
Sand tracer study
Sand trap
Sandbags
Sediment gradations
Sediment sizes
Segmented breakwater
Ship hulls
Shipwrecks
Steel-sheet piling
Structural dimensions
Structural stability
Structure settlement
Submerged breakwater
Tetrapods
Timber bulkhead
Tombolo
Tribars
Vertical breakwater
Wave attenuation
Wave diffraction
Wave overtopping
Wave pressure
Wave reflection
Wave refraction
Wave setup
Wave transmission

2. Locations.

Australia
  Kirra Beach-Queensland

Brazil
  Ceara

California
  Channel Islands
  Imperial Beach
  Newport Beach
  Santa Monica
  Venice

Canada
  High Park-Toronto

Cyprus
  Kiti Beach
  Larnaca

Denmark
  Arnager
  Hundested
  Snogebaek

Florida
  Broward County Beach
  Palm Beach
  Singer Island

France
  Anse des Huttes
  Arros
  Beaulieu
  La Bocca
  La Bravette
  Carnon
  La Croisette
  Ete
  Golfe Juan
  Grau du Roi
  La Gravette
  Mourillon Beach-Toulon
  Pen Bron
  Pointe de Grave
  Port Canto
  Prado Beach-Marseilles
  La Ragne
  Sablettes-Menton
  Toulon

Hawaii
  Ala Wai Peninsula
  Haleiwa Beach
  Kaimu Beach
  Magic Island
  Waikiki

Illinois
  Chicago
  Lincoln Park-Chicago

India
  Cochin
  Visakhapatnam
  Vypeen

Israel
  Achziv
  Bat-yam
  Caesarea
  Carmel Beach
  Manshiah-Tel-Aviv
  Nahariya
  Netanya
  Tel Baruch-Tel-Aviv
  Tel-Aviv

Italy
- Bagnoli
- Ceriale
- Chiavari
- Corroglio
- Lido of Rome
- Ligure
- Loano
- Ostia
- Porto S. Giorgio
- Posillipe
- Salerno
- Sanremo
- Taggia
- Vecchio
- Viserba

Japan
- Aomori
- Atsumi
- Fuya
- Hakahama
- Hamada
- Ishiji
- Ishizaki
- Iwafune
- Kaike
- Kaizaka

Japan--Continued
- Kanzaki
- Kineichiyo
- Kitaebisu
- Maizuru
- Maji
- Miyazu
- Nakahama
- Neya
- Niigata
- Niishiki Beach
- Nishikihama
- Nishikinohama-Kaizuka
- Onejime
- Seppu
- Shinmatsubara-Okagakicho
- Toban
- Toyama Bay
- Zenigamezawa

Massachussetts
- Dennis Shore
- Vineyard Haven
- Winthrop Beach

Mexico
- Salina Cruz

Monaco
- Larvotto Beach-Monte Carlo

Morocco
- Agadir

New Jersey
- Asbury Park
- Sandy Hook

Nicaragua
- Paso de Caballos

Ohio
- Lakeview Park-Lorain

Puerto Rico
- San Juan

Singapore

South Africa
- Durban

Sri Lanka

U.S.S.R.
- Crimea
- Odessa

III. ANNOTATED BIBLIOGRAPHY

1. ADACHI, S., and KOAI, A., "Experimental Studies on Shoaling of Harbor Areas," *Proceedings of the Fifth Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1958, pp. 81-86 (in Japanese--translation available in CERC library).

Keywords: Accretion, Detached breakwater, Hydraulic model (three-dimensional), Littoral transport, Tombolo

This paper presents an experimental study of changes of the shoreline in a sheltered area behind a detached breakwater constructed at right angles to the direction of the incident waves.

2. ADACHI, S., SAWARAGI, T., and OGO, A., "The Effects of Coastal Structures on the Littoral Sand Drifts," *Coastal Engineering in Japan*, Tokyo, Japan, Vol. 2, 1959, pp. 85-98.

Keywords: Detached breakwater, Hydraulic model (three-dimensional), Japan (Miyazu), Littoral transport, Movable bed, Tombolo, Wave diffraction, Wave refraction

This report discusses the estimated shoreline deformation of sand beaches by the variation of longshore current velocity when an offshore breakwater is constructed. The developing and stabilized forms of tom-

bolos resulting from the construction of an offshore breakwater are experimentally analyzed in terms of the influence of the breakwater length, water depth at the structure, and the deepwater wave steepness. These basic experimental results are used to estimate formation of shorelines at the Miyazu coast, Kyoto Prefecture, where an offshore breakwater is planned.

3. ANONYMOUS, "A Round-Table Discussion of Shore and Beach Protection," *Shore and Beach*, Vol. 2, No. 4, Oct. 1934, pp. 139-140.

Keywords: Accretion, Detached breakwater, New Jersey (Sandy Hook), Shipwrecks, Tombolo

Two instances of detached breakwaters formed from shipwrecks are recounted. In 1876, a 600-foot-long French liner grounded in about 28 feet of water at Low Moot and formed a tombolo out to the hull before it was removed. The *Kate Harding*, which grounded near Sandy Hook, New Jersey, around 1894, also formed a tombolo.

4. ANONYMOUS, "The Burning of the *Minnie A. Caine*," *Shore and Beach*, Vol. 8, No. 3, July 1940, pp. 93, 71.

Keywords: Accretion, California (Santa Monica), Detached breakwater, Downdrift beaches, Littoral transport, Shipwrecks, Tombolo

The grounding of the *Minnie A. Caine*, an 880-ton, four-masted schooner, on the Malibu coast on 24 September 1939, is discussed. The hull acted as a detached breakwater and formed a tombolo. Because erosion occurred on the downdrift beaches, the wooden hull was burned on 22 December 1939, thereby reestablishing natural conditions.

5. AVERIN, V.Z., and SIDORCHUK, V.N., "The Effect of Permeability of Breakwaters on the Suppression of Waves," *Wave Mechanics and Circulating Flow*, Academy of Sciences of Ukrainian SSR, No. 2, 1967, pp. 49-52.

Keywords: Composite structures, Concrete structures, Detached breakwater, Hydraulic model (two-dimensional), Rubble mound, Wave attenuation, Wave transmission

A series of model tests identified the wave dissipation characteristics of various types of permeable and impermeable breakwaters. The impermeable breakwaters had 2 on 1 slopes on the seaward side and either a 2 on 1 slope or a vertical wall on the landward side; the permeable breakwaters had 2 on 1 rubble slopes. A curve was developed which shows the transmitted wave heights for both types of structures as a function of the incident wave conditions.

6. BEACH EROSION BOARD, "Beach Erosion Control Study, Winthrop Beach, Massachussetts," H. Doc. 764, 80th Cong., U.S. Army, Corps of Engineers, Washington, D.C., Sept. 1947.

Keywords: Accretion, Downdrift beaches, Littoral transport, Massachusetts (Winthrop Beach), Rubble mound, Segmented breakwater, Structural dimensions, Wave attenuation

The existing Winthrop Shore Drive Seawall at Winthrop, Massachusetts, was found to provide inadequate protection to the developed area behind it except for the part which lies in the lee of the offshore breakwater constructed opposite the south part of Winthrop Beach in 1931-1933 by the Massachusetts Department of Public Works. To prevent further erosion, stabilize and improve the beach, and protect the existing Winthrop Drive Seawall, the study recommended placement of 385,000 cubic yards of sand-fill, construction of eight stone groins with an aggregate length of 3,400 feet, and raising the top elevation of the existing seawall 2 feet for a length of 3,200 feet.

7. BEACH EROSION BOARD, "Beach Erosion Control Study, Illinois Shore of Lake Michigan," H. Doc. 28, 83d Cong., 1st sess., U.S. Army, Corps of Engineers, Washington, D.C., Oct. 1952.

Keywords: Economic analysis, Illinois (Chicago), Littoral transport, Rubble mound, Steel-sheet piling, Submerged breakwater

Report recommends the placement of beach fills to be retained by submerged breakwaters as one solution to beach erosion problems along Lake Michigan. The breakwaters would be constructed of steel-sheet piling or rubble mound.

8. BEACH EROSION BOARD, "Beach Erosion Control Study, Point Mugu to San Pedro Breakwater," H. Doc. 277, 83d Cong., 2d sess., U.S. Army, Corps of Engineers, Washington, D.C., Nov. 1953.

Keywords: Accretion, California (Santa Monica and Venice), Detached breakwater, Downdrift beaches, Littoral transport, Structural dimensions, Wave diffraction

This report reviewed masterplans, prepared by local authorities, of shoreline improvement projects to determine the most suitable means of providing shoreline stability. The effects of existing structures on the shoreline and the effect of proposed shoreline improvements on existing flood control outlet works were also studied. The history of shoreline changes associated with the Santa Monica and Venice detached breakwaters is outlined.

9. BEACH EROSION BOARD, "Beach Erosion Control Study, Haleiwa Beach, Oahu, Hawaii," H. Doc. 107, 89th Cong., 1st sess., U.S. Army, Corps of Engineers, Washington, D.C., Feb. 1963.

Keywords: Armor stability, Beach fill, Detached breakwater, Economic analysis, Hawaii (Haleiwa Beach), Littoral transport, Rubble mound, Structural dimensions

This report describes the causes of beach erosion at Haleiwa Beach. The recommended plan of restoration includes a beach fill, detached breakwater, and one groin.

10. BERRIOLO, G., and SIRITO, G., *Spiagge e Porti Turistici* (Beaches and Marinas), Ulrico Hoepli, Editore, Milan, 1972 (in Italian).

Keywords: Accretion, Detached breakwater, Italy (Ceriale, Ligure, Loano, Porto S. Giorgio, Sanremo, and Viserba), Offshore island, Segmented breakwater, Tombolo, Wave diffraction

Textbook discusses Italian experiences with coastal structures, particularly detached breakwaters and artificial offshore islands used for shore protection, and includes various photos and figures.

11. BERRIOLO, G., and SIRITO, G., "Essais Sur Modele Reduit de L'Action de Guides Submerges Sur le Movement Littoral du Sable," *Bulletin of Permanent International Association of Navigation Congresses*, Vol. II, No. 15, 1973, pp. 91-99 (in French).

Keywords: Hydraulic model (three-dimensional), Littoral transport, Movable bed, Offshore island

Report discusses a series of model experiments on an expedient for controlling littoral draft, developed at Grenoble, France. This expedient is formed by thin, underwater separating walls properly fixed in the sandy sea bottom. The experiments considered two possible applications in placing the separating walls normal or parallel to the bottom contour lines. Interesting results were obtained in both cases.

12. BERRIOLO, G., and SIRITO, G., "Le Cause Determinanti della Situazione di Erosione della Coste Dell'Alto Tirreno e Cenni Sui Possibili Interventi," *L'Ingegnere*, Vol. 51, No. 3, Mar. 1976, pp. 81-98 (in Italian).

Keywords: Detached breakwater, Italy, Offshore island

13. BERRIOLO, G., GALLARETO, E., and SIRITO, G., *Le Nostre Spiagge, Situazoine e Provvedimenti Necessari* (Our Beaches, The Situation and the Necessary Improvements), Ente provinciale per il tourismo di Savona, 1968 (in Italian).

Keywords: Accretion, Detached breakwater, Italy (Loano), Segmented breakwater, Tombolo

14. BERRIOLO, G., GALLARETO, E., and SIRITO, G., *Studio per il Miglioramento ed Incremento Degli Arenili*, Ente provinciale per il tourismo di Imperia, 1968 (in Italian).

Keywords: Accretion, Detached breakwater, Italy (Loano, Taggia, and Vecchio), Segmented breakwater

15. BIXBY, W.H., "Notes on the Pointe de Grave, River Gironde, France, and the Works for the Protection of its Shore Against Encroachments of the Sea," U.S. Army, Engineer Department, Washington, D.C., 1881.

Keywords: Accretion, Armor stability, France (Anse des Huttes and Pointe de Grave), Rubble mound, Segmented breakwater, Structural dimensions, Wave attenuation

Notes discuss Pointe de Grave, located at the mouth of the Gironde River in France. From 1817 to 1830, the point eroded about 15 meters per year; from 1830 to 1842, the rate increased to 30 meters per year. In spite of stabilization attempts by the government, the rate increased to 48 meters per year from 1842 to 1846. Beginning in 1854, a segmented, detached, rubble-mound breakwater was constructed about 150 meters from shore. The breakwater extended 1,300 meters with a crest elevation of 1.5 meters below the high water line (HWL). The breakwater successfully protected the beach at Anse des Huttes and caused a considerable accretion of littoral materials in its lee.

16. BLUE, F.L., Jr., and JOHNSON, J.W., "Diffraction of Water Waves Passing Through a Breakwater Gap," Report HE-116-299, Department of Engineering, Fluid Mechanics Laboratory, University of California, Berkeley, Calif., Mar. 1949.

Keywords: Hydraulic model (three-dimensional), Wave diffraction

This investigation experimentally identified wave patterns and comparative wave heights due to diffraction of water waves entering a gap in a breakwater normal to the incident wave direction in water of uniform depth, and compared these results with approximate theoretical solutions. Both deepwater and shallow-water waves were studied. Oblique incidence and varying depths were not investigated, but approximate methods of considering their effect are suggested. The results verified the general form of the wave diffraction theory for breakwater gaps with gap-width and wavelength ratios as small as 1.41 in water depths as small as 0.14 wavelength. The theory and computation methods considered in the investigation form a usable basis for estimating the effect on diffraction of waves at a breakwater gap.

17. BONNEFILLE, R., and ALLEN, H., "Study of Mourillon Beach," Report T373, Laboratoire National d'Hydraulique, Electricite de France, 1964.

Keywords: France (Mourillon Beach-Toulon)

18. BRATER, E.F., et al., "The Michigan Demonstration Erosion Control Program in 1976," Technical Report No. 55, Michigan Sea Grant Program, Coastal Zone Laboratory, University of Michigan, Ann Arbor, Mich., Feb. 1977.

Keywords: Hydraulic model (three-dimensional), Movable bed, Submerged breakwater, Wave attenuation

A series of small-scale laboratory experiments was conducted to test the effectiveness of three methods of protection against bluff erosion: groins with and without sandfill and a parallel seawall 20 feet (prototype) from shore. A submerged sill with height equal to 0.4 d_s was also tested. Results are presented in graphical form.

19. BREBNER, A., and KENNEDY, R.J., "Littoral Drift in Lake Ontario Harbors," *Annual Meeting of the Engineering Institute of Canada*, June 1959.

Keywords: Accretion, Canada (High Park-Toronto), Littoral transport, Segmented breakwater

The littoral drift problem for the north shore of Lake Ontario is examined. Sources of littoral material are identified and the mechanisms of their movement are reviewed. Remedial measures for erosion problems, such as groins and beach fills, are discussed. The report includes a photo of the use of detached breakwaters at High Park, Toronto. Necessary considerations for harbor construction and operation are also presented.

20. BRISTOW, R.C., "Cochin Harbour Works," *Proceedings of the Institution of Civil Engineers*, Vol. 230, Pt. II, 1929-1930, pp. 40-71.

Keywords: Accretion, India (Cochin and Vypeen), Segmented breakwater, Structural dimensions

The construction of a deepwater port at Cochin is discussed. Part of that work involved the use of segmented breakwaters for stabilizing eroding shores at Vypeen. The performance of the breakwaters was satisfactory and after 8 years the erosion problem was claimed to have been completely solved.

21. BRUNO, R.O., and GABLE, C.G., "Longshore Transport at a Total Littoral Barrier," *Proceedings of the 15th Conference on Coastal Engineering*, American Society of Civil Engineers, 1976, pp. 1203-1222 (also Reprint 77-6, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., NTIS AD A042 473).

Keywords: Accretion, California (Channel Islands), Detached breakwater, Littoral transport, Sand trap

An analysis of longshore transport at a littoral barrier is presented. Channel Islands Harbor, California, was selected as the study site because its offshore breakwater and jetties form a unique complete littoral barrier. Repetitive surveys accurately determined that longshore transport rates in one direction ranged from 160,000 to 1,284,000 cubic meters per year. Using visual observations of surf parameters, the range of longshore wave thrust was computed as 145 to 1,988 newtons per meter. A comparison was made of the relation of wave thrust and longshore sediment transport. This study indicates that in an environment of high

transport, nearly twice as much transport is predicted under corresponding wave thrust as that of the data summarized in CERC's Shore Protection Manual.

22. BRUNO, R.O., WATTS, G.M., and GABLE, C.G., "Sediments Impounded by an Offshore Breakwater," *Coastal Sediments 77, Fourth Annual Symposium of the Waterways, Port, Coastal and Ocean Division*, American Society of Civil Engineers, 1977, pp. 1006-1025 (also Reprint 78-8, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., NTIS AD A051 577).

Keywords: Accretion, California (Channel Islands), Detached breakwater, Littoral transport, Sand trap, Sediment gradations

This paper discusses patterns of sediment deposition behind an offshore breakwater at Channel Islands Harbor, California. Data were collected to determine if the deposition observed agrees with that predicted before construction. Both the geometry and size distribution of the deposition sediment are examined. Three-dimensional computer plots illustrate filling patterns. Sediment-size and sorting distribution which occur during filling are investigated. The data were used to evaluate predicted versus actual filling patterns, and sediment distribution in the impoundment area.

23. CAMANZI, A., and STRONGOLI, G., Untitled Report to SII-QI (New Designs of Breakwaters with Vertical Sides and of Structures with Sloping Faces: (a) for Port Protection, (b) for Shore Protection), *XVIIIth International Navigation Congress*, Rome, 1953, pp. 111-150 (in French).

Keywords: Accretion, Design guidelines, Detached breakwater, Italy (Bagnoli, Lido of Rome, Loano, and Ostia), Littoral transport, Rubble mound, Structural dimensions, Tombolo, Wave attenuation

This report deals, in part, with the use of detached breakwaters for shore protection in Italy. Segmented breakwaters have been built for this purpose at the Lido of Rome, Loano, and Bagnoli. Design considerations are presented, based on the experience with these structures.

24. CAREY, A.E., "The Sanding Up of Tidal Harbours," *Proceedings of the Institution of Civil Engineers*, Vol. 156, Pt. II, 1903-1904, pp. 215-302.

Keywords: Accretion, Brazil (Ceara), Construction procedures, Currents, Detached breakwater, Downdrift beaches, Littoral transport, Wave attenuation

The paper includes case histories of several notable harbor constructions in the late 19th century. Discussed in detail is the example of Ceara, Brazil, where a detached breakwater connected to shore by an open viaduct was constructed in 1885. The harbor quickly shoaled and

had to be abandoned. Further discussion gives an interesting insight to the understanding of littoral processes as it then existed.

25. CASSIDY, W.F., "The Trend Toward Dual Purpose Inlet Control," *Shore and Beach*, Vol. 29, No. 4, Oct. 1961, pp. 22-26.

Keywords: Accretion, California (Channel Islands), Detached breakwater, Littoral transport, Sand trap

The relationship between littoral barriers formed by improved inlets and the adjacent beaches is examined. The need for bypassing is established and present trends in bypassing techniques are discussed. Special note is given to the sand trap method used at Ventura County Harbor (Channel Islands) in southern California. This sand trap is formed by a detached breakwater protecting a jettied entrance.

26. CHATHAM, C.E., Jr., DAVIDSON, D.D., and WHALIN, R.W., "Study of Beach Widening by the Perched Beach Concept, Santa Monica Bay, California," Technical Report H-73-8, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss., June 1973.

Keywords: Beach fill, California (Santa Monica), Currents, Hydraulic model (two-dimensional), Hydraulic model (three-dimensional), Littoral transport, Movable bed, Perched beach, Rubble mound, Submerged breakwater

Hydraulic model studies were conducted at the U.S. Army Engineer Waterways Experiment Station to determine the technical feasibility and optimum design factors of the perched beach concept for widening an existing beach along part of the Santa Monica Bay coastline. The following three models were studied: (a) An undistorted, three-dimensional, fixed-bed model (scale 1:100) was used to determine the effect of the perched beach on rip currents; (b) a distorted-scale (1:100 horizontal, 1:50 vertical), two-dimensional, movable-bed model was used to estimate the amount of sand which might be lost seaward over the toe structure due to normal and storm wave actions and to determine the optimim crown elevation of the submerged structure and the length of stone riprap apron required to reduce the seaward migration of sand to a minimum; and (c) an undistorted, two-dimensional model (scale 1:30) was used to determine the structural design of the proposed rubble-mound toe structure for various depths. The report describes the testing and results up to the premature termination of the model studies.

27. CHEW, S.Y., "Processes and Beach Development Between Headland Breakwaters, South-East Coast of Singapore," Masters Thesis, University of Singapore, 1976 (available in CERC library).

Keywords: Artificial headlands, Crenulate-shaped bay, Sand tracer study, Sediment gradations, Sediment sizes, Singapore

An analysis of the beach development around the Singapore headland breakwaters is presented. Among the processes studied are: sediment-size changes, size and sorting relationships, beach profile changes, bay shape changes, sand movement by sand tracer studies, alongshore variation of maximum beach heights, offshore topographic changes, and the stages of beach development.

28. CHEW, S.Y., WONG, P.P., and CHIN, K.K., "Beach Development Between Headland Breakwaters," *Proceedings of the 14th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. II, 1974, pp. 1399-1418.

Keywords: Artificial headlands, Beach fill, Construction procedures, Crenulate-shaped bay, Currents, Gabions, Rubble mound, Sediment sizes, Singapore, Structural dimensions

Breakwaters in a series are used to protect newly reclaimed land along the southeast coast of Singapore, acting as headlands for the formation of sand beaches. The development of these beaches occurs under conditions of low-energy waves, a predominant wave direction from the southeast, and an east-west littoral drift. The characteristics and development of three beaches over a 1-year period are presented. Surveys of the reclaimed land show various beach types between the headland breakwaters. A relationship exists between berm orientation and the headland breakwater orientation. Beach stability is tentatively indicated by the formation of a wide berm.

29. CIVIL AND MARINE ENGINEERING COMPANY, LTD., Company Brochure, Consulting Engineers, Haifa, Israel, undated (circa 1976).

Keywords: Beach fill, Cyprus (Kiti Beach and Larnaca), Detached breakwater, Israel (Caesarea, Carmel Beach, Manshiah-Tel-Aviv, Nahariya, and Netanya), Segmented breakwater, Tombolo

A company brochure outlining the capabilities and past achievements of the Civil and Marine Engineering Company. Photos and brief descriptions of detached breakwater projects at Tel-Aviv Jaffa, Nahariya, Carmel Beach (Haifa), and Netanya are presented.

30. CORINTO PORT AUTHORITY, REPUBLIC OF NICARAGUA, "Design of Coastal Protection at Paso de Caballos, Corinto Island, Nicaragua, Using Bolsacreto ®," Control de Erosion, S.A., Oct. 1972.

Keywords: Bolsacreto ® concrete bag, Detached breakwater, Grout-filled bags, Hydraulic model (two-dimensional), Nicaragua (Paso de Caballos)

The report presents a solution to the shore erosion problem at Paso de Caballos by using Bolsacreto ® elements to form a detached breakwater. The weight of the elements was determined from standard design methods, and a series of two-dimensional laboratory tests was conducted to verify the stability of the structure.

31. CORNEJO VELAZCO, J., and CADENA CALZADA, J., "Contribucion al Estudio de Formacion de Tombolos," *Proceedings of the Fourth Congreso Nacional de Hidraulica*, Mexico, 1976 (in Spanish--translation available in CERC library).

Keywords: Accretion, Detached breakwater, Hydraulic model (three-dimensional), Littoral transport, Movable bed, Tombolo

The use of a tombolo in controlling littoral transport on a beach has many advantages; however, there must be a clear understanding of the mechanisms of its formation. Using physical model experiments, the parameters involved in the formation of a tombolo were considered and a number of practical laws governing the development of tombolos were established.

32. COX, D.C., GERRITSEN, F., and LEE, T.T., "Proposed Improvement of Kaimu Beach, Hawaii," *Proceedings of the 15th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. II, 1976, pp. 1552-1571.

Keywords: Aesthetics, Beach fill, Environmental concerns, Hawaii (Kaimu Beach), Recreation, Submerged breakwater

This paper discusses the proposed plans to improve Kaimu Beach, Hawaii. The beach, which is famous for its jet black color, has been receding for at least a century. The plans called for an enlargement of the beach and protection by an offshore breakwater. Although the advantages of a larger beach area and the improvement of swimming conditions are acknowledged, a serious question is raised as to whether the project would result in an overall improvement.

33. CURREN, C.R., and CHATHAM, C.E., Jr., "Imperial Beach, California - Design of Structures for Beach Erosion Control," Technical Report H-77-15, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss., Aug. 1977.

Keywords: California (Imperial Beach), Compartmented breakwater, Continuous breakwater, Currents, Hydraulic model (three-dimensional), Littoral transport, Segmented breakwater, Structural dimensions, Submerged breakwater

A 1:75-scale (undistorted) hydraulic model, reproducing approximately 2.6 miles of shoreline and sufficient offshore area to permit generation of the required test waves, was used to investigate the arrangement and design of alternative proposed structures to prevent erosion of the Imperial Beach shoreline. The proposed structures consisted of (a) continuous breakwaters at the -15- and -10-foot contours, (b) segmented breakwaters at the -15- and -5-foot contours, (c) stepped breakwaters at the -10- and -5-foot contours, (d) a system of five groins, and (e) a system of nine groins. A 115-foot-long wave generator, crushed coal tracer material, and an automated data acquisition and control system (ADACS) were used during model operation. Test results are given.

34. DELAGE, G., "L'Utilisation d'un Brise-Lames Pour La Defence d'Une Plage" (Breakwaters Used for Beach Protection), *Proceedings of the Fifth Conference on Coastal Engineering*, American Society of Civil Engineers, 1954, pp. 479-494 (in French).

Keywords: Accretion, Currents, Detached breakwater, Hydraulic model (two-dimensional), Hydraulic model (three-dimensional), Littoral transport, Submerged breakwater, Wave attenuation, Wave transmission

This study consists of two parts. The first part discusses the effect of the presence of a breakwater on the profile of a beach. The tests were preceded by a study of the kind of disturbance arising behind a breakwater, which causes the occurrence of harmonics of the incident wave. The different types of breaking over the structure resulting from the characteristics of the incident wave and the layout of the structure were also observed; three typical types were noted: a horizontal jet of water, a descending jet, and partial breaking.

The second part discusses the layout of an immersed breakwater intended for local beach protection. The characteristics of the protection were studied to find the most favorable compromise between the protection desired and the danger of erosion. The influence of the duration of wave action from different directions plays an important part in determining the characteristics of the structure.

35. DICK, T.M., and BREBNER, A., "Solid and Submerged Breakwaters," *Proceedings of the 11th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. II, 1968, pp. 1141-1158.

Keywords: Hydraulic model (two-dimensional), Impermeable breakwater, Permeable breakwater, Submerged breakwater, Wave reflection, Wave transmission

This paper reexamines the behavior of thin and rectangular solid submerged breakwaters. Dean's theory is found to be correct for a thin barrier in infinitely deep water. An empirical and theoretical relationship for the reflection coefficient of a thin breakwater across the wave number spectrum is proposed. Rectangular solid breakwaters have a maximum reflection when the incident wave has the same period as a standing wave on top of the breakwater and with a wavelength equal to the crest width. A submerged permeable breakwater for depths of submergence greater than 5 percent of the total depth transmits less wave energy than the solid over a certain frequency range. The minimum is transmitted when the criterion above for solid breakwaters is also met. Both permeable and solid rectangular breakwaters cause a substantial loss in wave energy and at least 50 percent of the incident energy is lost to turbulence. A substantial proportion, 30 to 60 percent, of the energy transmitted is transferred to higher frequencies than the incident wave.

36. DISKIN, M.H., VAJDA, M.L., and AMIR, I., "Piling-Up Behind Low and Submerged Permeable Breakwaters," *Journal of the Waterways and Harbors Division*, Vol. 96, No. WW2, May 1970, pp. 359-372. Discussions by M.R. Gourlay, Feb. 1971, pp. 219-222; R.A. Dalrymple and R.G. Dean, May 1971, pp. 423-427; Closure, Feb. 1972, pp. 74-78.

Keywords: Detached breakwater, Hydraulic model (two-dimensional), Submerged breakwater, Wave setup

Wave setup was experimentally studied using two trapezoidal breakwater sections. Maximum setup values were observed when the breakwaters protruded above the mean water level a distance equal to 50 to 90 percent of the incident deepwater wave height. The amount of setup decreased for lower structures.

37. DOLAN, R., "Coastal Problems in Israel," ESN-29-4, European Scientific Notes, Office of Naval Research, London, Apr. 1975, pp. 164-166.

Keywords: Detached breakwater, Israel

Report briefly describes shoreline erosion problems in Israel. The use of detached breakwaters is mentioned.

38. EATON, R.O., "Some Examples of Large Scale Shore Protection Projects," *Shore and Beach*, Vol. 27, No. 1, June 1959, pp. 8-13.

Keywords: Accretion, California (Santa Monica), Detached breakwater, Downdrift beaches, Littoral transport

The shore erosion problems experienced in the Los Angeles area and the Santa Monica offshore breakwater and its effect on adjacent shores are discussed. Case histories are also briefly outlined for Playa del Rey, Ballona Creek, and Redondo Beach.

39. EVANS, D.V., "Water Wave Transmission Through Barriers with Small Gaps," *Journal of Engineering Mathematics*, Vol. 11, No. 1, Jan. 1977, pp. 1-10.

40. FEVE, M., Untitled Report to SII-S4 (Coastal Regime. Carriage of Material by Swell and Currents. Model Studies and In Situ Observations. Influence of Port Structures. Coastal Defense Works. Breakwaters), *XXIId International Navigation Congress*, Paris, 1969, pp. 63-109 (in French).

Keywords: Compartmented breakwater, France (Mourillon Beach-Toulon), Submerged breakwater

The report describes French research dealing with sediment transport by waves and currents including the initiation of transport, beach profiles, and scale effects. Also considered were methods of determining transport direction and quantities using heavy minerals, limestone content,

grain-size parameters, radioactive tracers, experimental groins, and repetitive beach surveys. The use of alveole or compartmented detached breakwaters at Mourillon Beach, Toulon is described.

41. FISCHER, J.A., and LU, B.T.D., "Evaluation of Offshore Breakwater Stability Under Wave Action," *Proceedings of the Offshore Technology Conference*, Vol. 3, 1975, pp. 579-590.

Keywords: Armor stability, Detached breakwater, Foundation design, Structural stability

Attacking storm waves affect the overall design of any offshore breakwater used as a protective structure. This paper describes the methods and considerations required to evaluate the stability of an offshore breakwater under design storm wave action. The following storm wave effects are of concern:

(a) The possibility of wave forces physically causing damage to the breakwater embankment materials;

(b) the stability of the breakwater against horizontal sliding;

(c) the stability of the breakwater embankment against slope failure; and

(d) the effect of continuing storm waves on the strength and stability of the foundation soils.

The procedures described in this paper are part of the necessary stability considerations in the design of a breakwater to protect a floating nuclear generating plant (FNP). Although developed for a floating nuclear powerplant, the concepts presented are considered applicable to the stability evaluation of any major offshore breakwater-foundation soil system. They also represent an advance in the state-of-the-art of stability analyses for offshore structures.

42. (a) FLORES LIRA, M.A., and MAZA, A.J.A., "New Type of Structures for Littoral Drift Control," *Proceedings of the 14th Congress of the International Association for Hydraulic Research*, Vol. 4, 1971, pp. 177-182.

(b) FLORES LIRA, M.A., and MAZA, A.J.A., "Estudio de estructuras para el control del arrastre litoral" (Study of Structures for the Control of Coastal Erosion), *Coastal Engineering in Mexico, Proceedings of the Fourth Latin-American Congress of Hydrology*, 1971 (in Spanish--translation available in CERC library).

Keywords: Accretion, Detached breakwater, Hydraulic model (three-dimensional), Littoral transport, Movable bed, Tombolo

When continuous wave action strikes the beach at an angle, transport of the beach material occurs along the entire length of the littoral. On occasion, this may cause serious problems in some maritime structures or in natural river mouths such as silting of harbors, the formation of sandbars in river mouths and inlets. To avoid or at least reduce this type of problem, the Hydraulic Laboratory of the Secretaria de Recursos Hidraulicos executed a series of studies to find a structure that may permit a control on the longshore transport produced by wave action. Based on these studies, a new type of structure was developed and tested on hydraulic models; the structure permits the accumulation of littoral material in volumes up to 30 times as large as the volume retained by conventional breakwaters and spur dikes or jetties. This paper deals with the definition of the size of breakwaters depending on wave characteristics and the slope of the beach. The experiments leading to the recommendations given in the paper were conducted on estuaries with and without sediment transport.

43. FOSTER, D.N., "Breakwater Stability: Kirra Beach," Technical Report No. 72/13, Water Research Laboratory, University of New South Wales, New South Wales, Australia, 1972.

Keywords: Armor stability, Australia (Kirra Beach-Queensland), Foundation design, Hydraulic model (two-dimensional), Local scour, Rubble mound, Wave overtopping, Wave reflection, Wave transmission

Model tests have been undertaken to investigate the stability, wave transmission, and wave overtopping for the proposed offshore breakwater at Kirra Beach, Gold Coast, Queensland. The results indicate that the breakwater will be effective under all wave conditions. Some damage which will require maintenance occurs when high waves are superimposed on high storm surge.

44. FRIED, I., "New Coastal Works at Nahariya (Israel) - Beach Protection and Development," *The Dock and Harbour Authority*, Vol. XLV, No. 532, Feb. 1965, pp. 323-326.

Keywords: Accretion, Armor stability, Compartmented breakwater, Currents, Gabions, Israel (Nahariya), Local scour, Recreation, Rubble mound, Segmented breakwater, Structural dimensions

The coastal installation at Nahariya, which consists of a low breakwater and a central groin, proved successful from the stability viewpoint and for the purpose of creating a stretch of protected sandy beach and foreshore. Two shallow-water basins, protected from wave action and easily accessible to bathers, were formed in the lee of the breakwater; these basins also served as terminals for small craft and cruising launches during the summer season, thus supplying additional attraction to vacationers.

The rubble-mound breakwater has withstood storm wave onslaughts and requires only slight periodical maintenance, mainly at the heads. Its

inner slope, protected by a gabionade, has also proved to be stable. The concrete cap on top of the breakwater has not shown any signs of subsidence during the past 4 years. Moreover, considerable quantities of valuable sand are being extracted from the central area each year.

45. FRIED, I., "Protection by Means of Offshore Breakwaters," *Proceedings of the 15th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. II, 1976, pp. 1407-1424.

Keywords: Compartmented breakwater, Hydraulic model (three-dimensional), Israel (Tel Baruch-Tel-Aviv), Littoral transport, Movable bed, Recreation, Segmented breakwater, Structural dimensions, Tombolo

Many factors are involved in the reproduction of natural sedimentological processes in a wave basin with a movable bed, and a misinterpretation of some of them may lead to erroneous conclusions. The exact definition of the sedimentological time-scale is less important than the reproduction of the seabed configuration or representation of sand grain particles and wave spectra.

Little is known about the exact full-scale sedimentation processes in the prototype. However, it is assumed that the formation of tombolos in the lee of offshore breakwaters results mainly from the interception of littoral drift. Some of the sand enters directly into the shadow zone behind the breakwater; other sand particles bypass the breakwater on the seaward side and are then directed by diffraction into the shadow zone. The accelerated sedimentological process in the model reproduces the natural development of tombolo formation in the prototype, which, in order to reach a state of equilibrium, requires a considerable period of time.

46. GELINEAU, V., "Evolution in Design and Construction of Coast Protection Works in the United States," *Shore and Beach*, Vol. 3, No. 2, Apr. 1935, pp. 53-58.

Keywords: Accretion, Downdrift beaches, Littoral transport, New Jersey (Asbury Park), Shipwrecks, Tombolo

Report describes the grounding of the ship, *Morro Castle* at Asbury Park, New Jersey, in 1934. Because of its final position parallel to shore, it acted as a detached breakwater and resulted in the rapid growth of a tombolo.

47. GODA, Y., YOSHIMURA, T., and ITO, M., "Reflection and Diffraction of Water Waves by an Insular Breakwater," *Report of the Port and Harbor Research Institute*, Yokosuka, Japan, Vol. 10, No. 2, 1971, pp. 4-51 (in Japanese).

Keywords: Detached breakwater, Hydraulic model (three-dimensional) Wave diffraction, Wave reflection

Although insular breakwaters are often constructed in harbors, the interaction between an insular breakwater and water waves has not been clearly defined. This report presents the exact solution of wave reflection and diffraction by a vertical, elliptical cylinder with a series of Mathieu functions. The solution coincides with the solution for a circular cylinder when the circle is taken as an asympotic figure of an ellipse. The exact solution for a straight insular breakwater is derived from the deformation of the elliptical cylinder into a plate of infinitesimal thickness. Wave height ratios of scattered waves to incident waves have been calculated near insular breakwaters, and the application limit of the approximate solution is determined from the comparison between the exact and the approximate solutions.

48. GRANGE, M.A., Untitled Report to SII-CI (Protective Works Adopted to Limit Erosion Along the Open Coast; How They Work. Reference to Model Experiments), *XVIIth International Navigation Congress*, Lisbon, 1949, pp. 63-74 (in French).

Keywords: Accretion, Compartmented breakwater, France (Anse des Huttes, Arros, and Pointe de Grave)

This paper refers to a report on the principles adopted for protection of coasts against erosion and practical considerations for construction of such works, presented by M. Kauffman at the Congress of Venice in 1931. The conclusions of that report remain valid. The paper discusses several works created on French coasts:

(a) Prefabricated, reinforced concrete structures built on the channel coasts;

(b) the replacement of framework structures by masonry structures in Normandy, especially at St. Valery en Caux;

(c) the use of openwork groins of reinforced concrete stakes, braced longitudinally and transversally by wooden joists, in the Basse-Camargue region on the Mediterranean coast; and

(d) the construction of a groin made of natural rock blocks at Hendaye.

The second part of the paper is a historical survey of the works undertaken during the last 100 years around the Pointe de Grave, which borders the outlet of the Gironde to the south.

49. GRANT, U.S., and SHEPARD, F.P., "Shallow-Water Sediment-Shifting Processes Along the Southern California Coast," *Proceedings of the Sixth Pacific Scientific Congress*, Vol. 2, 1939, pp. 801-805.

Keywords: California (Santa Monica), Littoral transport, Sediment sizes

From several years of qualitative and quantitative study of the shore processes effective along the southern California coast, wave turbulence was found to be the most important factor in making sediment with a grain size larger than 125 micrometers (0.125 millimeter) available for transportation along the coast. In the certain constricted tidal inlets, at the shoulders of submarine platforms, and at the summits of submarine ridges and divides, currents are sufficiently accelerated at times to transport sand of a substantial grain size, but the magnitude of such sediment shifting is probably inconsequential compared to that which occurs along most beaches and the adjacent sea floor. This paper briefly discusses where and how littoral drifting occurs in this region and gives an example of the relative effectiveness of the various transporting processes as illustrated by the changes which occurred in and near the Santa Monica breakwater.

50. HABER, D., "Velocity Field and Wave Regime Behind a Low Detached Breakwater," Thesis, Technion-Israel Institute of Technology, Haifa, Israel, 1970.

51. HAFERKORN, H.E., *Sand Movement, Beaches and Kindred Subjects: A Bibliography*, The Engineer School, Fort Humphreys, Va., 1930.

Keywords: Accretion, Bibliography, Detached breakwater, Littoral transport

An annotated bibliography containing numerous references on the effects of offshore breakwaters on littoral processes.

52. HAFERKORN, H.E., *Breakwaters: A Bibliography*, Engineer School Library, Army War College, Washington, D.C., May 1932.

Keywords: Accretion, Bibliography, Detached breakwater, Littoral transport

An annotated bibliography that deals primarily with breakwaters constructed for navigation purposes. Many of the citations have shore protection applications. Keywords are also provided.

53. HALE, R.K., "Symposium of Coast Protection Problems," *Shore and Beach*, Vol. 3, No. 3, July 1935, pp. 94-95.

Keywords: Accretion, Detached breakwater, Massachusetts (Dennis Shore, Vineyard Haven, and Winthrop Beach), Segmented breakwater

The construction of three offshore breakwaters in Massachusetts is discussed. The Winthrop Beach breakwaters were constructed for shore protection between 1933 and 1935. At Dennis Shore, a harbor of refuge, a detached breakwater completed earlier had totally shoaled by 1935. A detached breakwater constructed at Vineyard Haven caused the shoreline to advance 300 to 400 feet.

54. HALE, R.K., "Shore Protective Work at Winthrop, Massachusetts," *Shore and Beach*, Vol. 6, No. 3, July 1938, pp. 92-95 (also appears in *Civil Engineering*, Vol. 8, No. 6, June 1938, pp. 388-390).

Keywords: Accretion, Downdrift beaches, Massachusetts (Winthrop Beach), Segmented breakwater

The history of the shoreline development at Winthrop, Massachusetts, is discussed. Before construction of a segmented detached breakwater between 1933 and 1935, the beaches were primarily shingle and badly eroded. Between 1931 and 1937, there was a net accretion of 50,000 cubic yards of sand in the area behind the breakwater.

55. HALL, W.C., "A Model Study of the Effect of Submerged Breakwaters on Wave Action," TM-1, U.S. Army, Corps of Engineers, Beach Erosion Board, Washington, D.C., May 1940.

Keywords: Florida (Palm Beach), Hawaii (Waikiki), Hydraulic model (two-dimensional), Illinois (Lincoln Park-Chicago), Steel-sheet piling, Submerged breakwater, Timber bulkhead, Wave attenuation

This was a general model study to determine the effect, under varied conditions, of underwater sills upon wave heights and the power of waves. General conclusions regarding shape and effectiveness of such structures are presented.

56. HALL, W.C., "Beach Protection Measures," *The Military Engineer*, Vol. 34, No. 200, June 1942, pp. 292-296 (also appears in *Shore and Beach*, Vol. 10, No. 2, Oct. 1942, pp. 60-66).

Keywords: Florida (Palm Beach), Hawaii (Waikiki), Illinois (Lincoln Park-Chicago), Submerged breakwater

The following elements of beach protection are discussed: beach erosion studies, sources of beach sand, causes of erosion, restoration methods, protective structures, typical problems, and recreational areas. Among the structures described are submerged, shore-parallel sills used for shore protection at Honolulu, Chicago, and Palm Beach.

57. HAMADA, T., "Several Problems Concerning the Beach Erosion at Niigata," *Disaster and Countermeasure*, Tokyo, Japan, Aug. 1956.

58. HANDIN, J.W., and LUDWICK, J.C., "Accretion of Beach Sand Behind a Detached Breakwater," TM-16, U.S. Army, Corps of Engineers, Beach Erosion Board, Washington, D.C., May 1950.

Keywords: Accretion, California (Santa Monica), Detached breakwater, Littoral transport, Sediment sizes, Structural dimensions, Wave attenuation, Wave diffraction, Wave refraction

The problem of sand transport by a longshore current is clarified by observing the effect of a breakwater on the current. Sand samples were collected on a network from the beaches near the breakwater at Santa Monica, California. The distribution of median grain sizes indicates a reduction of the competence of the longshore current. The history of shoreline changes discloses an accompanying reduction in the capacity of the current. A decrease in transporting power of the longshore current is correlated with a decrease of Q, the littoral drift factor; Q can probably be used as a qualitative measure of the sand-transporting power of longshore currents.

The history of accretion indicates that a shoreline changes position in a direction toward equilibrium with respect to the forces acting on a beach. Given enough time, it is probable that the breakwater will become connected to the mainland.

59. HARUTA, T., "Recent Coastal Processes in Niigata Prefecture," *Coastal Engineering in Japan*, Tokyo, Japan, Vol. IV, 1961, pp. 73-83.

Keywords: Accretion, Detached breakwater, Downdrift beaches, Japan (Fuya, Hakahama, Ishiji, Iwafune, Kitaebisu, Nakahama, and Neya), Littoral transport, Structural dimensions, Tombolo

The exposure of the coast of Niigata Prefecture to the winter monsoon of the Sea of Japan, which has the predominant direction from northwest to north, is the most important factor affecting the beach erosion or sand transport on this coast. Most of the coast has sandy beaches nourished by sediment from rivers. There are some harbors and a number of small fishery ports. The construction of breakwaters, groins, or jetties in the harbors or ports caused certain changes in the patterns of waves, currents, and littoral transport; thus, beach erosion or sand deposition occurred in many parts of the coast. This paper presents several examples of such coastal processes with a description of the protection works applied.

60. HASHIMOTO, H., "A Model to Predict the Influence of Erosion on Neighboring Beaches Due to Detached Breakwaters," *Proceedings of the 21st Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1974, pp. 181-186 (in Japanese).

61. HASHIMOTO, H., "Application of a Beach Deformation Model to Fuji Coast," *Proceedings of the 23d Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1976, pp. 218-222 (in Japanese).

62. HASHIMOTO, H., and UDA, T., "A Method of Numerical Prediction of Nearshore Currents and its Applications," *Proceedings of the 21st Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1974, pp. 355-360 (in Japanese).

63. HAYASHI, T., HATTORI, M., and SHIRAI, M., "Closely Spaced Pile Breakwater as a Protection Structure Against Beach Erosion," *Proceedings of the 11th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 1, 1968, pp. 606-621.

Keywords: Hydraulic model (two-dimensional), Local scour, Pile arrays, Wave reflection, Wave transmission

A theory for wave transmission and reflection at a closely spaced pile breakwater was developed, using the shallow-water wave theory of small amplitude. An experiment on the hydraulic characteristics of the breakwater was conducted in a two-dimensional wave flume. The agreement between the theory and the experiment is good with respect to the coefficients of transmission and reflection of waves, and also to the shoreward velocity of the jet discharged from a space between two adjacent piles.

An experiment was also conducted on the local scouring at the foot of the closely spaced pile breakwater. The maximum scouring depth at the foot of the breakwater relates closely to the velocity ratio of the jet to the mean fall velocity of bed material. The relationship between the maximum scouring depth and the power of the jet is discussed.

64. HAYASHI, T., KANO, T., and SHIRAI, M., "Hydraulic Research on the Closely Spaced Pile Breakwater," *Proceedings of the 10th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 2, 1966, pp. 873-884.

Keywords: Hydraulic model (two-dimensional), Pile arrays, Wave attenuation, Wave reflection, Wave transmission

Hydraulic properties of a row of closely spaced circular piles as a breakwater have been studied both theoretically and experimentally. A theory is presented for the transmission of waves past the breakwater and also for the thrust and bending moment exerted by the waves on each pile in the breakwater. A laboratory experiment was conducted on a model structure. Close agreement is shown in the comparison between the theory and the experiment with respect to the transmission coefficient and the bending moment distribution.

65. HAYES, M.O., HUBBARD, D.K., and FITZGERALD, D.M., "Investigation of Beach Erosion Problems at Revere, Winthrop and Nantasket Beaches, Massachusetts," Contract No. 2229, Metropolitan District Commission, Boston, Mass., Oct. 1973.

Keywords: Accretion, Massachusetts (Winthrop Beach), Sediment gradations, Segmented breakwater

Over the past 15 years the beaches in Boston Harbor have undergone intensive erosion, particularly the popular sandy beaches of Revere, Nantasket, and Winthrop. This project was undertaken to gain a better understanding of the natural processes that cause this erosion and to consider ways to accommodate the natural processes in dealing with the problem. The study is a combination of short-term studies designed to

provide basic data on wave action, tides and tidal currents, and wind action for comparison with those processes acting on other Massachusetts beaches previously studied.

66. HERRON, W.J., Jr., and HARRIS, R.L., "New Methods of Conserving Beach Sand," *Shore and Beach*, Vol. 30, No. 1, Apr. 1962, pp. 34-37.

Keywords: Accretion, California (Newport Beach), Detached breakwater, Littoral transport

Since the 1940's, the beaches between the Surfside Beach Colony and Newport submarine canyon have experienced progressive erosion caused by the loss of sand supply to the beach because of flood control reservoirs and the improper placement of harbor structures on the shore. The most economical proposed solution for this problem would require construction of a 2,600-foot-long detached breakwater to act as a sand trap on the 24-foot contour immediately updrift of the Newport canyon. At 5-year intervals, 1,500,000 cubic yards would be dredged from this sand trap and backpassed to renourish updrift beaches.

67. HERRON, W.J., Jr., and HARRIS, R.L., "Littoral Bypassing and Beach Restoration in the Vicinity of Port Hueneme, California," *Proceedings of the 10th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 1, 1966, pp. 651-675.

Keywords: Accretion, Armor stability, California (Channel Islands), Detached breakwater, Downdrift beaches, Littoral transport, Rubble mound, Structural dimensions, Wave diffraction

The construction of Port Hueneme Harbor, California, in 1940, resulted in an average annual erosion of 1,200,000 cubic yards from the shoreline downcoast of the harbor. The cause was diversion by the north jetty of the harbor of littoral sand movement into the Hueneme canyon. A sand-bypass system was established in 1960-61 by the construction, 1 mile upcoast, of Channel Islands Harbor fronted by a 2,300-foot-long offshore breakwater located in the 30-foot depth contour. The breakwater serves a dual function of sheltering the harbor entrance and acting as a littoral sand trap. Three cycles of biennial littoral sand bypassing were successfully completed. Comparison of the design of the structure with the impounding characteristics experienced during the three cycles indicates that the dimensions and capacity of a sand trap formed by an offshore breakwater can be based on the diffraction patterns of prevailing wave trains at the two ends of the structure and is independent of the depth and dimensions of the entrapment area.

68. HIRANANDANI, M.G., COLE, C.V., and PENDSE, Y.D., "Strengthening Breakwater at Visakhapatnam," *Journal of the Waterways and Harbors Division*, Vol. 88, No. WW3, Aug. 1962, pp. 139-158. Discussions by R.Q. Palmer, May 1963, pp. 93-96; L. Barailler and L. Greslou, May 1963, pp. 96-98.

Keywords: Armor stability, Armor units, Concrete blocks, Construction procedures, Economic analysis, Foundation design, Hydraulic model (two-dimensional), India (Visakhapatnam), Local scour, Rubble mound, Ship hulls, Structural dimensions, Tetrapods, Tribars, Wave overtopping

The island breakwater at Visakhapatnam, consisting of two scuttled ships filled with small stones, was protected by 2- to 6-ton stones on the weather and lee sides. However, the weather side was damaged by storms, exposing the ships' plates to wave action, thus warranting action for reinforcing the breakwater. Tests were conducted in a wave flume with various types of armor units, such as stones, tetrapods, and tribars, to evolve a suitable protective layer for the breakwater and to study the relative merits of various armor units.

69. HO, S.K., "Crenulate Shaped Bays," Thesis No. 346, Asian Institute of Technology, Bangkok, Thailand, 1971.

Keywords: Artificial headlands, Crenulate-shaped bay, Hydraulic model (three-dimensional), Littoral transport, Movable bed, Numerical model, Wave diffraction, Wave refraction

Where headlands are spaced along a sedimentary coast, the shoreline between the headlands assumes a crenulate shape. If the most persistent or predominant waves have a resultant direction which is oblique to the headland alinement, a shape is gradually reached which is in equilibrium with the waves. The eventual development of such an equilibrium-shaped bay, starting with an initial straight-line coast, was studied by means of a model in which wave directions and heights were the sole variables. The curved part of the equilibrium-shaped coastline was then analyzed by fitting log-spiral curves.

A typical prototype bay in fully developed condition, derived from hydrographic charts, was analyzed by computer to verify that diffraction and refraction combined to form the log-spiral part of the coastline.

70. HOM-MA, M., and HORIKAWA, K., "Experimental Study of a Submerged Breakwater (2nd Report) - Mechanism of Its Slumping and Maintenance Measures of the Structure," *Proceedings of the Sixth Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1959, pp. 114-120 (in Japanese).

Keywords: Hydraulic model (two-dimensional), Local scour, Structure settlement, Submerged breakwater

71. HOM-MA, M., and HORIKAWA, K., "Coastal Protection Works and Related Problems in Japan," *Proceedings of the Seventh Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 2, 1960, pp. 904-930.

Keywords: Compartmented breakwater, Japan (Kaike, Niigata, and Toban), Littoral transport, Submerged breakwater

This paper introduces the general factors affecting the coastal problems in Japan and discusses the patterns with which some of these factors were linked to produce particular coastal problems. The efforts and contributions made by the Japanese engineers to solve such problems are discussed. The coastal protection works and practices are presented with some representative examples.

72. HOM-MA, M., and HORIKAWA, K., "A Study on Submerged Breakwaters," *Coastal Engineering in Japan*, Tokyo, Japan, Vol. IV, 1961, pp. 85-102.

Keywords: Accretion, Compartmented breakwater, Concrete structures, Foundation design, Hydraulic model (two-dimensional), Japan (Niigata), Local scour, Movable bed, Structure settlement, Submerged breakwater, Tetrapods, Wave overtopping, Wave transmission

The functions and maintenance devices of submerged breakwaters, using tetrapods, were studied through the comparison of experimental results and field data from the Niigata west coast. Since one of the most important functions of a submerged breakwater is the damping action, the structure has played an important role in protecting the Niigata west coast. The slump of the structure, which was overlooked at the early stage of construction, has become an important and difficult problem.

73. HOM-MA, M., and SAKOU, T., "An Experimental Study on the Submerged Breakwater," *Coastal Engineering in Japan*, Tokyo, Japan, Vol. 2, 1959, pp. 103-109.

Keywords: Accretion, Hydraulic model (two-dimensional), Local scour, Movable bed, Submerged breakwater, Vertical breakwater

The two principle functions of a submerged breakwater are (a) to attenuate waves by causing premature breaking and partial reflection, and (b) to bar seaward movement of bed materials in the surf zone. Most studies of these functions deal with the effects of the height, shape, width, location, etc., of the breakwater on the transformation of passing waves. However, the effect on the sand movement and deformation of the beach due to the existence of the breakwater has not been sufficiently studied. This study presents the basic information needed to predict the possible change in beach profiles after the construction of a breakwater and to estimate the amount of scour around the structure. This was accomplished with a study of the two-dimensional deformation of a beach in an experimental wave flume.

74. HORIKAWA, K., and KOIZUMI, C., "An Experimental Study on the Function of an Offshore Breakwater," *Proceedings of the 29th Annual Convention*, Japan Society of Civil Engineers, 1974, pp. 85-87.

75. HORIKAWA, K., and SONU, C., "Experimental Study of a Submerged Breakwater," *Proceedings of the 12th Annual Convention*, Japan Society of Civil Engineers, June 1957.

76. HORTON, D.F., "An Engineer Looks at Waikiki Beach," *Bulletin of the Beach Erosion Board*, Vol. 2, No. 2, Apr. 1948, pp. 1-7.

Keywords: Accretion, Beach fill, Compartmented breakwater, Concrete structures, Hawaii (Waikiki), Littoral transport, Structural dimensions, Submerged breakwater

This report describes an inspection of Waikiki Beach during December 1947. The inspection was made prior to developing a study program for a cooperative study of erosion at the beach. Some of the features noted are described and illustrated.

77. HORTON, D.F., "Shore Effects of Coastal Structures," *The Military Engineer*, Vol. XL, No. 275, Sept. 1948, pp. 402-405.

Keywords: Accretion, California (Santa Monica), Detached breakwater, Downdrift beaches, Massachusetts (Winthrop Beach), Segmented breakwater, Structural dimensions

This report discusses the natural forces and the structures, such as jetties, that affect coastal inlets and the adjacent shorelines. The design of navigation improvements on ocean coasts requires consideration of the natural forces and the effect of proposed structures on adjacent shorelines.

78. HOSOI, M., and TOMINAGA, M., "Wave Height Reduction by Offshore Breakwaters," *Proceedings of the Sixth Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1959, pp. 121-123 (in Japanese).

Keywords: Hydraulic model (two-dimensional), Submerged breakwater, Wave attenuation, Wave transmission

Offshore breakwaters are structures built away from the beach, parallel to the shoreline, for shore protection. The effectiveness of such structures has become widely recognized. In designing offshore breakwaters, various complex factors such as the choice of height, width, location and structure suitable for the intended use, and preventive measures against settling, must be considered. This report presents experimental results of the effect of offshore breakwaters in reducing wave heights.

79. HOTTA, S., and MARUI, N., "Local Scour and Current Around a Porous Breakwater," *Proceedings of the 15th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 2, 1976, pp. 1590-1604.

Keywords: Currents, Detached breakwater, Hydraulic model (two-dimensional), Local scour, Movable bed, Wave attenuation, Wave setup, Wave transmission

Scour at the foot of vertical homogeneous crib-style walls, which were used as models for detached breakwaters, and the rise of mean water level in the shoreside region of the breakwaters were experimentally investigated. The results were compared to some field data.

80. INCE, S., and JAMIESON, W.W., "Field and Model Studies for Visakhapatnam Harbor." *Proceedings of the 14th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 2, 1974, pp. 1503-1523.

Keywords: Accretion, Currents, Detached breakwater, Downdrift beaches, Hydraulic model (three-dimensional), India (Visakhapatnam), Littoral transport, Movable bed, Ship hulls

Model studies and analyses of oceanographic and littoral drift data were undertaken to advise Howe India (Private) Ltd. on littoral drift, siltation, and shore erosion problems to be encountered during and after the construction of Visakhapatnam outer harbor project. Distorted fixed- and movable-bed models with a horizontal scale of 1:300 and a vertical scale of 1:80 were calibrated to reproduce the integrated net effect of an average southwest and northeast monsoon season. Experiments were conducted to assess and predict seasonal changes resulting from the construction of breakwaters under normal and extreme conditions. Recommendations were made concerning breakwater and sand-trap location, shore protection, dredging, and disposal of dredged material.

81. INGLE, J.C., Jr., "Tracing Beach Sand Movement by Means of Flourescent Dyed Sand," *Shore and Beach*, Vol. 30, No. 4, Oct. 1962, pp. 31-36.

Keywords: California (Santa Monica), Currents, Detached breakwater, Littoral transport, Sand tracer study

Sand tracer studies were conducted at five locations along the southern California coast (Goleta Point, Trancas, Santa Monica, Huntington, and LaJolla). Tests were conducted at 4- to 6-week intervals at each site for 1 year. Additional tests were conducted on the prograding shoreline behind the detached breakwater at Santa Monica. Contour maps of tracer movements are given for each significant test.

82. INMAN, D.L., and FRAUTSCHY, J.D., "Littoral Processes and the Development of Shorelines," *Proceedings of the Santa Barbara Specialty Conference on Coastal Engineering*, American Society of Civil Engineers, Oct. 1965, pp. 511-536.

Keywords: Accretion, California (Venice), Detached breakwater, Littoral transport, Structural dimensions, Tombolo

Basic principles of the nature of beaches and processes that act to modify them are considered for the present coastal development demands. A working hypothesis is developed that applies the principle of the

conservation of mass to the mechanics of granular-fluid media. This hypothesis appears to have general application to transport processes in the littoral zone.

83. IWASAKI, T., and NUMATA, A., "Experimental Studies on Wave Transmission of a Permeable Breakwater Constructed by Artificial Blocks," *Coastal Engineering in Japan*, Tokyo, Japan, Vol. 13, 1970, pp. 25-29.

Keywords: Hydraulic model (two-dimensional), Permeable breakwater, Wave attenuation, Wave transmission

When a breakwater is composed of artificial blocks, waves can pass easily through it. However, wave energy is dissipated and the wave height is decreased. This paper deals with the transmission rate of wave height, i.e., the ratio of the transmitted wave height H_t to the incident wave height H_i, and the rate of energy dissipation. It was found by experiments that H_t/H_i depends only on incident wave steepness for the breakwater when the crest height above the stillwater level h_c is larger than H_i. However, when h_c is smaller than H_i, H_t/H_i depends on both the incident wave steepness and the Reynolds number defined by $U_{max}h_c/\nu$, where U_{max} is the maximum horizontal velocity at the stillwater level. The energy dissipation is expressed as a function of the incident wave steepness, but its expression is different for the above two cases.

84. JAPAN MINISTRY OF TRANSPORT, PORT AND HARBOR BUREAU, "Kowan Kozobutsu Sekkei Kijun" (Design Standard for Port and Harbor Structures), Sept. 1968, pp. 11-13 (in Japanese).

Keywords: Local scour, Vertical breakwater

85. JAPAN SOCIETY OF CIVIL ENGINEERS, *Design Manual for Shore Protection*, Sec. 3, June 1957, pp. 199-219 (in Japanese).

Keywords: Accretion, Armor units, California (Santa Monica), Composite structures, Concrete structures, Detached breakwater, Downdrift beaches, Foundation design, Italy (Loano and Posillipe), Littoral transport, Local scour, Permeable breakwater, Rubble mound, Segmented breakwater, Structural dimensions, Structure settlement, Submerged breakwater, Tombolo, Wave attenuation, Wave diffraction, Wave overtopping, Wave transmission

Various aspects of the design of detached breakwaters are discussed. Among these are the spacing, length, crest height, and offshore distance. Construction precautions are outlined and descriptions are given of the various structural types that can be used. Two design examples are provided for a vertical concrete structure and a rubble-mound structure.

86. JAPAN SOCIETY OF CIVIL ENGINEERS, *Kaigan Hozen Shisetsu Sekkei Benran* (Handbook for Coastal Protection and Facility Designs), Tokyo, Japan, July 1969, pp. 102-106, 241-249 (in Japanese).

Keywords: Accretion, Beach fill, Concrete structures, Design guidelines, Foundation design, Japan (Niigata and Nishikihama), Littoral transport, Structure settlement, Submerged breakwater, Wave attenuation, Wave transmission

This general coastal engineering handbook offers advice on the positioning and height of detached breakwaters. Case histories are studied of installations near Niigata and at Nishikihama, Japan.

87. JOHNSON, A.G., "Beach Protection and Development Around Los Angeles," *Shore and Beach*, Vol. 3, No. 4, Oct. 1935, pp. 110-112.

Keywords: Accretion, California (Santa Monica and Venice), Detached breakwater, Downdrift beaches, Littoral transport, Structural dimensions

The natural topography and meteorological conditions of the shoreline of Santa Monica Bay are discussed. Serious erosion problems were caused by the construction of detached breakwaters at Venice in 1905 and Santa Monica in 1934.

88. JOHNSON, A.G., "A Report on Erosion of the Beaches in the Venice District," Department of Public Works, City of Los Angeles, Los Angeles, Calif., Apr. 1940.

Keywords: Accretion, California (Santa Monica and Venice), Downdrift beaches, Littoral transport, Sediment gradations, Shipwrecks, Structural dimensions

The Bureau of Engineering, City of Los Angeles, has prepared studies of beach protection and development for the past 10 years. Many surveys have been made along most of the shore of Santa Monica Bay, in part with the cooperation of the County Surveyor and the City Engineer of Santa Monica. Reports, as long as 6 years ago, predicted the present severe erosion of the beaches at Venice, and a program was outlined which, if carried out, would not only have prevented the erosion, but would have added considerably to the width of the beaches.

This report evaluates the natural conditions that affect the beaches, discusses the effect of the various structures which have been constructed along the beaches, and outlines the steps necessary and the costs to prevent further erosion, and the possibilities of development of the Venice beaches.

89. JOHNSON, A.G., "A Report on Protection and Development of the Beaches in the Westgate Addition and the Santa Monica Canyon Addition," Department of Public Works, City of Los Angeles, Los Angeles, Calif., Aug. 1940.

Keywords: Accretion, Beach fill, California (Santa Monica and Venice), Detached breakwater, Downdrift beaches, Littoral transport, Ship hulls, Structural dimensions, Submerged breakwater

This report discusses the development of a stretch of beach along the shore of the Santa Monica Bay by artificial widening. The report takes into consideration the source of the sand on these beaches, the movement of sand along the beaches, the effects of the ocean waves and currents, the tides, natural and artificial obstructions along the shore, and rainfall, erosion and flood conditions in the tributary watersheds. Much of the data on waves, currents, tides, winds, sand movement, and rainfall and flood conditions in the tributary watersheds, contained in the April 1940 report on Venice Beach, are pertinent to this report, and are repeated herein with the necessary modifications.

90. JOHNSON, A.G., "Southern California Beach Erosion - Problems Aggravated by Unwise Man-Made Structures and Lack of Centralized Control," *Shore and Beach*, Vol. 8, No. 4, Oct. 1940, pp. 106-109, 120.

Keywords: Accretion, California (Santa Monica), Detached breakwater, Downdrift beaches, Littoral transport

This article discusses new shore structures and further erosion, emphasizing the necessity for proper planning, and the preservation and development of shorefronts in the interests of an entire area, not just one locality.

91. JOHNSON, A.G., "Beach Protection - Erosion, Pollution Mar Shores," *Western Construction News*, Vol. 18, No. 6, June 1943, pp. 259-262, 279.

Keywords: Accretion, California (Santa Monica and Venice), Detached breakwater, Downdrift beaches, Littoral transport, Structural dimensions

The most difficult problem in shoreline planning is that of beach erosion, largely caused by haphazard and ill-advised developments by local coastal communities. Control of pollution by oil and sewage is also troublesome. The need for a greater extent of publicly owned ocean frontage has been recognized for years, and is largely a matter of financing. Development and improvement of public ocean frontage is also largely a matter of financing, plus proper planning. This article presents a brief outline of most of these problems.

92. JOHNSON, A.G., "The Beaches Are Born Again," *Western City*, Vol. 22, No. 5, May 1946, pp. 24-31.

Keywords: Accretion, California (Santa Monica), Detached breakwater, Downdrift beaches, Littoral transport

In the May 1940 issue of *Western City*, an article by this writer entitled "The Vanishing Beaches of Southern California" described the serious beach erosion which had been caused by construction of breakwaters and jetties along the southern California coastline, particularly at Santa Barbara, Santa Monica, Venice, Redondo Beach, and Long Beach.

This article describes the progress that has been made in the intervening 6 years toward correcting the beach erosion problems and evolving long range, coordinated plans for the best use of the shoreline.

93. JOHNSON, J.W., "Model Studies Made at the University of California, River and Harbor Laboratory," *Transactions of the American Geophysical Union*, Vol. 29, 1948, pp. 107-116.

Keywords: Accretion, California (Santa Monica), Detached breakwater, Downdrift beaches, Hydraulic model (three-dimensional), Littoral transport

Since establishment of the River and Harbor Hydraulic Laboratory at the University of California at Berkeley, approximately 10 years ago, numerous model studies have been made in connection with a variety of engineering problems. Some of the data obtained in the model studies had not been published previously. This paper briefly describes a few of the important investigations.

94. JOHNSON, J.W., "Dynamics of Nearshore Sediment Movement," *Bulletin of the American Association of Petroleum Geologists*, Vol. 40, No. 9, Sept. 1956, pp. 2211-2232.

Keywords: Accretion, California (Santa Monica), Detached breakwater, Downdrift beaches, Littoral transport

Considerable research on the basic mechanics of shoreline processes has been done over the last 15 years by geologists and engineers. Much of this research was done during World War II, but in more recent years numerous investigations have been made in connection with the qualitative and quantitative effects of shoreline structures on nearshore sediment movement. This paper summarizes some of the more important investigations that have been made on the many phases of this phenomenon.

95. JOHNSON, J.W., "The Littoral Drift Problem at Shoreline Harbors," *Journal of the Waterways and Harbors Division*, Vol. 83, No. WW1, Apr. 1957, pp. 1211-1--1211-37. Discussion by R. Silvester, Jan. 1958, pp. 13-17; Closure, May 1958, pp. 3-9.

Keywords: Accretion, Brazil (Ceara), California (Channel Islands and Santa Monica), Detached breakwater, Downdrift beaches, Littoral transport

A harbor which fronts directly on an open shoreline and has a relatively small flow into and out of it is defined as a shoreline harbor. The littoral drift, which occurs along the shoreline, causes certain design, construction, and maintenance problems. This paper summarizes some of these basic considerations in generalized terms and presents a few case histories of typical shoreline harbors for which operational information extending over a long period of years is available.

96. JOHNSON, J.W., "Lessons in Coastal Engineering Gained from California Projects," *Symposium on Coastal Engineering*, Stellenbosch, South Africa, June 1969.

Keywords: Accretion, California (Channel Islands and Santa Monica), Detached breakwater, Downdrift beaches, Littoral transport, Structural dimensions

Experience gained at coastal engineering projects on the California coast has led to a better understanding of littoral processes. Detached breakwaters, constructed earlier at Santa Barbara and Santa Monica, have had disastrous effects on the downdrift beaches. Lessons learned from these projects have been applied to the Channel Islands-Port Hueneme area where a detached breakwater serves as a sand trap. Material dredged from this trap is bypassed to beaches downdrift of Port Hueneme.

97. JOHNSON, J.W., FUCHS, R.A., and MORISON, J.R., "The Damping Action of Submerged Breakwaters," *Transactions of the American Geophysical Union*, Vol. 32, 1951, pp. 704-718.

Keywords: Hydraulic model (two-dimensional), Submerged breakwater, Wave attenuation, Wave reflection, Wave transmission

The results of an experimental investigation on the damping action of submerged rectangular breakwaters are presented. The experimental data are compared with published theories. A new theory is presented which compares more favorably with the experiments than the previous theories. Also given is a summary of the published theoretical and experimental information on the damping action of trapezoidal and triangular breakwaters, reefs of various configurations, and plane barriers of various orientations.

98. JORDAAN, J.M., Jr., "Study of Durban Harbor Silting and Beach Erosion," *Proceedings of the 12th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 2, 1970, pp. 1097-1116.

Keywords: Accretion, Hydraulic model (three-dimensional), Littoral transport, Movable bed, Segmented breakwater, South Africa (Durban), Structural dimensions

A 1:300 vertical, 1:100 horizontal scale model of 7 miles of coastline, including the major area of the port limits and the inner harbor, was constructed to study combined wave, tide, and wind action on transport of sand along the coast. The model study attributed the cause of beach erosion to the existence of an offshore shoal produced by the localized dumping of sand dredged from the harbor approaches. This shoal caused selective wave action along the coastline, which was reproduced to scale in the model. Wind and tidal action had a major effect on the redistribution of sand on the beaches as modeled but a minor effect on the permanence of the harbor entrance channel. The model study was conducted by the South African Council for Scientific and Industrial Research for the South African Railways and the City Council of Durban.

99. KABELAC, O.W., "Model Tests of Coastal Protective Structures in USSR," *Journal of the Waterways and Harbors Division*, Vol. 89, No. WW1, Feb. 1963, pp. 21-34.

Keywords: Hydraulic model (two-dimensional), Submerged breakwater, Wave attenuation, Wave reflection, Wave transmission

Model tests of underwater coastal protective structures that were performed by A.I. Lyzlov in the laboratory of the Institute of Engineers of Maritime Fleet in Odessa are presented and results are compared with natural conditions. The tests are based on the Froude similarity principle. The results are compared with those of preceding investigations of coastal phenomena by members of the Institute of Oceanology: B.A. Popov, N.A. Aybulatov, E.N. Egorov, and others. These model studies are part of an extensive Soviet program of coastal research and engineering, initiated in 1955 by the Oceanographic Commission of the Academy of Sciences, U.S.S.R.

100. KATAYANA, T., IRIE, I., and KAWAKAMI, T., "Performance of Offshore Breakwaters of the Niigata Coast," *Coastal Engineering in Japan*, Vol. 17, 1974, pp. 129-139.

Keywords: Accretion, Compartmented breakwater, Continuous breakwater, Currents, Detached breakwater, Hydraulic model (two-dimensional), Japan (Niigata), Littoral transport, Local scour, Permeable breakwater, Rubble mound, Structural dimensions, Structure settlement, Submerged breakwater, Tetrapods, Wave attenuation, Wave overtopping, Wave reflection, Wave setup, Wave transmission

This paper reviews the effect of offshore breakwaters on the Niigata coast utilizing survey maps collected over 20 years. The offshore breakwaters have been found to be successful in checking the beach erosion onshore of these structures in spite of steady erosion of the seabed offshore.

101. KAWAGUCHI, T., and SUGU, M., "Study of the Arrangement of Detached Breakwaters," *Proceedings of the 19th Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1972, pp. 77-81.

102. KUBO, T., and YAMAMOTO, T., "An Experimental Research of the Section of Submerged Barrier for Protection of Beach Erosion," *Journal of the Japan Society of Civil Engineers*, Vol. 39, No. 10, Oct. 1954, pp. 54-59 (in Japanese).

Keywords: Hydraulic model (two-dimensional), Submerged breakwater, Wave attenuation, Wave transmission

Submerged barriers, which are constructed for shore protection, must have a dampening effect on incident waves. Model tests on several types of barrier sections were performed to determine the section of the

barrier which is effective for damping action. A barrier with a wave deflector was found especially effective for high steepness waves.

103. KUBO, M., et al., "Changes in a Beach Caused by Detached Breakwaters," *Proceedings of the 23d Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1976, pp. 223-228 (in Japanese).

Keywords: Accretion, Detached breakwater, Segmented breakwater, Tombolo

104. KURODA, S., "The Coastal Protection Works in the Port of Niigata," Report to SII-QI (New Designs of Breakwaters with Vertical Sides and of Structures with Sloping Faces: (a) for Port Protection, (b) for Shore Protection), *XVIIIth International Navigation Congress*, Rome, 1953, pp. 151-167.

Keywords: Accretion, Concrete structures, Currents, Detached breakwater, Foundation design, Gabions, Japan (Niigata), Littoral transport, Local scour, Permeable breakwater, Structural dimensions, Structural stability, Structure settlement, Submerged breakwater, Wave pressure

The shoreline near the Shinano River at Niigata has retreated as much as 10 meters per year for the last 25 years. This has necessitated the development of a system of combined protective works instead of individual structures placed in an uncoordinated manner. Because of unsatisfactory performance of groins, prototype tests on detached submerged breakwaters were conducted using gabionlike, wire-cage breakwaters, hollow concrete structures, and cellular concrete caissons filled with rock. Results of these tests are presented.

105. LABORATOIRE CENTRAL D'HYDRAULIQUE DE FRANCE, "Plages et Littoraux Artificiels" (Artificial Beaches and Littorals), 1972.

Keywords: Beach fill, Compartmented breakwater, Currents, Detached breakwater, Downdrift beaches, Environmental concerns, France (Beaulieu, La Bocca, La Bravette, Carnon, La Croisette, Ete, Golfe Juan, Grau du Roi, La Gravette, Mourillon Beach-Toulon, Pen Bron, Pointe de Grave, Port Canto, Prado Beach-Marseilles, La Rague, and Sablettes-Menton), Hydraulic model (three-dimensional), Littoral transport, Monaco (Larvotto Beach-Monte Carlo), Morocco (Agadir), Movable bed, Sediment sizes, Structural dimensions, Submerged breakwater, Tombolo, Wave attenuation, Wave diffraction

A manual dealing with the engineering considerations involved in creating and retaining sand beaches. Littoral processes are reviewed and possible structural alternatives to be used in conjunction with or without beach fills are described. These structures include groins, T-groins, alveolar (compartmented) beaches, diffraction cones, and detached breakwaters. Numerous case histories are illustrated.

106. LARSEN, O.J.F., "Large Scale Coastal Protection or (Headland Protection)," Noble Engineering Company, Newport Beach, Calif., May 1960.

Keywords: Artificial headlands, Economic analysis, Littoral transport, Wave diffraction, Wave refraction

The present way of maintaining the beaches by artificial supply of material should include an investigation of the possibility of decreasing, without adverse effects, the transport of material away from the beaches. An idea of coastal protection called "Headland Protection" is presented. This is a systematic, possibly improved, application of the principle after which most coastlines are more or less protected naturally. The economical feasibility depends on measures to decrease the costs involved in construction of structures in deeper water. Two different ideas for such measures are presented. A research program is also suggested.

107. LE BLOND, P.H., "On the Formation of Spiral Beaches," *Proceedings of the 13th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 2, 1972, pp. 1331-1345.

Keywords: Crenulate-shaped bay, Currents, Littoral transport, Numerical model

The theory of wave-induced longshore currents is applied to problems of beach erosion. An erosion equation is derived, relating the local erosion (or deposition) rate to the form of the beach and to the characteristics of the incoming wave field. A numerical integration technique of the erosion equation is discussed. A specific example, that of a linear coastline which has gradually eroded into a spiral-shaped beach in the lee of a headland, is examined.

108. LEEDS, C.T., "Shore Protection at Venice, California," *Professional Memoirs*, U.S. Army, Corps of Engineers, Washington, D.C., Vol. 8, No. 27, 1916, pp. 42-58.

Keywords: Accretion, California (Venice), Currents, Detached breakwater, Downdrift beaches, Environmental concerns, Littoral transport, Segmented breakwater, Wave attenuation

The problem of beach erosion at Venice is examined and structural solutions are suggested. The historical causes for the problem are outlined and existing structures which have worsened the situation are identified. Of particular interest is the Windward Avenue pier which is protected by a detached breakwater. Segmented, detached breakwaters were rejected as a possible solution because of aesthetic and economic reasons. Groins and a seawall were selected as the best engineering alternative.

109. LEPETIT, J.P., and MOREAU, S., "Study of an Artificial Island," *Proceedings of the 15th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 4, 1976, pp. 3526-3535.

Keywords: Accretion, Currents, Downdrift beaches, Environmental concerns, Hydraulic model (three-dimensional), Littoral transport, Numerical model, Offshore island, Tombolo, Wave attenuation, Wave diffraction, Wave refraction

The location of large surface industrial zones along seashores often competes with other coastal activities, such as recreational pursuits, fishing, nature reserves, etc. The construction of an artificial island, near the shore, poses many problems particularly with its impact on the environment. The results of a study examining this aspect include (a) the influence of the island on local wave climate or swell, consequent shoreline changes, tidal currents, and the resulting evolution of the sandy seabed; and (b) the dispersion of industrial effluents.

The effect of the island on swell and on shore stability and the calculation of pollutant dispersion are approached by the use of mathematical models; the effect of the island on tidal currents is analyzed on a reduced-scale physical model.

110. LEYPOLDT, H., "Shoreline Formation by Currents," *Shore and Beach*, Vol. 9, No. 1, Jan. 1941, pp. 14-17, 29-31. Discussions by M.P. O'Brien, Apr. 1941, p. 46; O.F. Evans, Apr. 1941, pp. 46-47; Closure, Apr. 1942, p. 21.

Keywords: Accretion, California (Santa Monica), Crenulate-shaped bay, Currents, Downdrift beaches, Littoral transport, Shipwrecks, Tombolo

Littoral oceanic currents induce eddy currents in the lee of promontories, either natural or artificial, and thereby shape the shoreline to some form of the logarithmic spiral, $r = e^{a\theta}$. Construction of jetties or breakwaters extending into the currents causes the spiral shoreline to form, resulting in beach erosion and prograding. The severe erosion of southern California beaches is discussed. Beach changes are independent of size of sand, beach slopes, depths in the foreshore, prevailing winds, or other causes, except for currents--littoral, eddy, or estuarial.

111. LIU, P.L.F., and MEI, C.C., "Effects of a Breakwater on Nearshore Currents Due to Breaking Waves," Report No. 192, Ralph M. Parsons Laboratory, Massachusetts Institute of Technology, Cambridge, Mass., Sept. 1974.

Keywords: Accretion, Currents, Detached breakwater, Littoral transport, Numerical model, Tombolo, Wave diffraction, Wave refraction

This study provides a semiempirical theory of nearshore currents due to breaking waves in the presence of (a) a shore-connected breakwater or (b) an offshore breakwater. The effects of diffraction and refraction by shoaling waters are studied. Sample results for stream functions and mean sea levels are plotted for various beach profiles or incidence angles.

For the offshore breakwater, the predicted current pattern is consistent with available laboratory observations and the known tendency of tombolo formation. For the shore-connected breakwater, the computed flow pattern exhibits cells in both down-wave and up-wave regions.

112. LIU, P.L.F., and MEI, C.C., "Water Motion on a Beach in the Presence of a Breakwater, 1. Waves, 2. Mean Currents," *Journal of Geophysical Research*, Vol. 81, No. 18, June 1976, pp. 3079-3094.

Keywords: Accretion, Currents, Detached breakwater, Littoral transport, Numerical model, Tombolo, Wave diffraction, Wave refraction

For a long breakwater on a slowly varying bottom, an asymptotic theory is given which accounts for the combined effects of refraction and Fresnel diffraction of water waves. Numerical examples are given for an offshore breakwater and an isolated jetty.

A semiempirical theory of breaking-induced mean currents on a beach is developed to study the combined effects of refraction and diffraction. With the omission of convective inertia and lateral turbulent diffusion, the resulting averaged equations are solved by finite differences. The case of an offshore breakwater is studied in detail, and the predicted current pattern is consistent with laboratory observations and the known tendency of tombolo formation near sandy beaches. Numerical results for an isolated breakwater extending from the shore are also presented.

113. LO GATTO, D., "Construction of Ports on Sandy Shores," Report to SII-Q3, *XIth International Navigation Congress*, Saint Petersburg, U.S.S.R., 1908.

Keywords: Accretion, Detached breakwater, Downdrift beaches, Italy (Chiavari and Salerno), Littoral transport, Segmented breakwater, Tombolo

The construction of ports on sandy coasts presents serious problems to the designer. Provision must be made for dealing with the littoral materials moving down the coast. Port structures can be either perpendicular to shore as jetties or parallel to shore as detached breakwaters. Detached breakwaters at Salerno and Chiavari have been used to protect eroding shorelines where the use of groins had previously failed. The placement of harbor structures must be planned to eliminate or reduce required maintenance dredging. To achieve this end, the idea of a "neutral axis" is presented. Seaward of the neutral axis no material can be moved to the shore.

114. LOGACHEV, L.A., LYZLOV, L.A., and MIROSHNICHENKO, V.G., Untitled report to SII-S2 (Means of Controlling Littoral Drift to Protect Beaches, Dunes, Estuaries, and Harbor Entrances. Establishment of Artificial Beaches), *XXIIId International Navigation Congress*, Ottawa, 1973, pp. 259-275.

Keywords: Beach fill, Concrete structures, Continuous breakwater, Currents, Foundation design, Hydraulic model (two-dimensional), Structural dimensions, Structural stability, Submerged breakwater, U.S.S.R. (Crimea and Odessa), Wave attenuation, Wave pressure, Wave setup

The knowledge of the nature of currents in the coastal zone is important for the successful completion of many design problems. The choice of approach channel tracks and the drifting of those channels are typical problems that require an understanding of coastal currents. Artificial beaches have been maintained along the Black Sea coast through the use of submerged, concrete breakwaters constructed parallel to shore. Design considerations are outlined.

115. LONGUET-HIGGINS, M.S., "On the Trapping of Wave Energy Round Islands," *Journal of Fluid Mechanics*, Vol. 29, Pt. 4, Sept. 1967, pp. 781-821.

Keywords: Offshore island, Wave setup

Islands can trap long-wave energy in a way similar to the capture of a particle of an atomic nucleus. The frequencies of the captured waves form a discrete set and are determined by the shape of the island and the contours of the surrounding seabed. If the depth at great distances tends to a constant value, the trapped modes leak some energy to infinity, though the consequent rate of decay may be exceedingly small. The initial energy of the trapped modes may be absorbed from incident radiation of the same frequency or from a sharp pulse. The particular example of a rectilinear pulse incident on a circular island is discussed in some detail.

116. LONGUET-HIGGINS, M.S., "On the Wave-Induced Difference in Mean Sea Level Between the Two Sides of a Submerged Breakwater," *Journal of Marine Research*, Vol. 25, No. 2, Feb. 1967, pp. 148-153.

Keywords: Submerged breakwater, Wave reflection, Wave setup, Wave transmission

Simple formulas are derived for the difference in mean level between the two sides of a submerged breakwater when waves are incident at an arbitrary angle. The formulas apply also to waves undergoing refraction due to changes in depth and to waves in open channel transitions.

117. LYZLOV, L.A., "Experimental Investigations of Various Types of Coastal Protective Underwater Breakwaters," Trudy Okeanograficheskoi Komissii, Vol. 12, 1961.

118. LYZLOV, L.A., "Sea Submerged Breakwaters," Transportnoe Stroitstvo, No. 5, 1962, pp. 42-44 (in Russian).

Keywords: Concrete structures, Submerged breakwater

119. LYZLOV, L.A., "Calculation of Underwater Coast Reinforcement Breakwaters for Wave Damping," Trudy Akademiianauk, Estonskoi, U.S.S.R., 1966.

120. LYZLOV, L.A., "Design of Submerged Shore-Protection Breakwaters for Wave Suppression," *Transactions of the Scientific Coordinating Session*, Oceanographic Commission of the Academy of Sciences, U.S.S.R., 1966.

121. MAGOON, O.T., "Offshore Breakwaters at Winthrop Beach, Massachusetts, *Shore and Beach*, Vol. 44, No. 3, Oct. 1976, p. 34. Discussion by P.S. Rosen, Apr. 1977, p. 37; Closure, Apr. 1977, p. 37.

Keywords: Accretion, Massachusetts (Winthrop Beach), Segmented breakwater, Structural dimensions, Tombolo

Paper gives a brief history of the segmented detached breakwaters at Winthrop Beach.

122. MAGOON, O.T., and EDGE, B.L., "Stabilization of Shorelines by Use of Artificial Headlands and Enclosed Beaches," *Coastal Zone '78*, 1978, pp. 1367-1370.

Keywords: Artificial headlands, Compartmented breakwater, Crenulate-shaped bay, Detached breakwater

Paper presents a brief overview of the current use of coastal structures, particularly enclosed beaches, detached breakwaters, and artificial headlands.

123. MANOHAR, M., "Sediment Movement at South Indian Ports," *Proceedings of the Sixth Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 1, 1957, pp. 359-405.

Keywords: Accretion, Currents, Detached breakwater, Downdrift beaches, India (Visakhapatnam), Littoral transport, Sand trap, Ship hulls, Structural dimensions, Structure settlement

The mechanism of littoral transport is examined along with the effect of structures on the littoral environment. The case histories of several harbors are outlined. Visakhapatnam harbor has been improved using a detached breakwater which acts as a sand trap to impound the northerly moving littoral drift. The detached breakwater was formed by sinking two ships and armoring them with rubble.

124. MARCONSULT/STUDIO VOLTA, "Interventi di Costruzione e Ricostruzione di Spiagge in Liguria" (Beach Construction and Reconstruction Operations in Liguria), *La Marina Mercantile*, Vol. 29, No. 3, Mar. 1976, pp. 11-17 (in Italian--translation available in CERC library).

Keywords: Beach fill, Italy (Amelia, Ceriale, Imperia, Ligure, and Loano), Offshore island

This study examines several case histories in which artificial offshore islands, or island platforms, were used to stabilize eroding beaches in Italy, along with beach fills.

125. MARKLE, D.G., and CARVER, R.D., "Breakwater Stability Study, Imperial Beach, California," Technical Report H-77-22, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss., Dec. 1977.

Keywords: Armor stability, California (Imperial Beach), Hydraulic model (two-dimensional), Rubble mound, Structural stability, Submerged breakwater, Wave overtopping

A 1:16-scale, undistorted hydraulic model was tested to determine stable rubble sections to protect a beach fill at Imperial Beach. Four adequate plans were selected out of 21 tested for structure sites at the -5 and -10 mean lower low water contours. One plan at each site was for a continuous high-sill structure and the other was for an alternating high- and low-sill structure.

126. MASHIMA, Y., "Stable Configuration of Coast Line," *Coastal Engineering in Japan*, Tokyo, Japan, Vol. 4, 1961, pp. 47-59.

Keywords: Crenulate-shaped bay, Littoral transport

The beach prism consists of many kinds of materials ranging from soft clays to durable rocks. These are arranged according to the severity of the local wave climate. If the coastal material is uniform, the shoreline will maintain a stable configuration and slope. Capes, headlands, or strong groins resist wave action and influence neighboring coastlines. They are the fixed points on the configuration of the shoreline. Between the adjoining fixed points, the beach materials are usually uniform so that the coast maintains its shoreline configuration and slope. The supply of materials around these fixed points will be related to the depth adjacent to the fixed points and to the approaching directions of the coastlines. This report describes the configurations of the coastline between fixed points.

127. MINIKIN, R.R., "Fundamentals of Coast Erosion and Defence," *Proceedings of the Fifth Conference on Coastal Engineering*, American Society of Civil Engineers, 1954, pp. 448-470.

Keywords: Accretion, Armor stability, Compartmented breakwater, Construction procedures, Detached breakwater, France (Anse des Huttes, Arros, and Pointe de Grave), Italy (Chiavari), Littoral transport, Rubble mound, Segmented breakwater, Structural dimensions, Wave attenuation

The difficulties of hydrodynamic studies are too well known to emphasize except to underline the fact that most popular quantitative formulas are of a semiempirical nature. This paper briefly examines beach behaviour subjected to complex sea action, and the reasons and the remedies usually proposed, or executed, for given conditions in various countries.

128. MONTEFUSCO, L., "The Diffraction of a Plane Wave By an Isolated Breakwater," *Meccanica* (Journal of the Italian Association of Theoretical and Applied Mechanics), Vol. 3, 1968, pp. 156-166.

Keywords: Detached breakwater, Wave diffraction

The diffraction of a plane wave incident on an isolated breakwater was studied, and the exact solution of the problem is briefly reported. A general method involving energies is used to determine comparative importance of the terms in the series which appear in the solution. Numerical calculations were done for 12 different cases, with the wavelength of the incident wave comparable to the length of the breakwater.

129. MORISON, J.R., "Model Study of Wave Action on Underwater Barriers," Report No. HE-116-304, Fluid Mechanics Laboratory, University of California, Berkeley, Calif., July 1949.

Keywords: Hydraulic model (two-dimensional), Submerged breakwater, Wave attenuation, Wave transmission

The results of experiments in connection with submerged barriers in the path of model waves indicate that the most effective position of the barrier would be in shallow water of d/H = 2.0 to 2.5; i.e., directly at the breaking point. Indications are that the most effective heights of the barrier are more than two-thirds of the water depth. This condition gives less than a wave height of water over the barrier. From the standpoint of the waves, the relatively long-period waves have more transmission than do shorter waves. How far this analogy of model waves can be carried with regard to ocean waves has not been demonstrated.

130. MORROW, C.T., "Diffraction of Ocean Waves About a Breakwater," *Journal of the Waterways and Harbors Division*, Vol. 92, No. WW3, Aug. 1966, pp. 25-44. Discussions by J. Miles and W. Munk, Feb. 1967, p. 111; R.B. Loudon and J.W. Dunham, May 1967, pp. 266-270; Closure, Nov. 1967, pp. 237-240.

Keywords: Detached breakwater, Wave diffraction

The diffraction about the end of a one-arm or detached breakwater is analyzed here in such a way as to yield the total wave power entering the mouth and measure the performance of a breakwater-marina system. A formula, derived from the Kirchhoff theory of diffraction, is used to obtain the total wave power entering the marina mouth. A comparison is made of the overall performances of the marina with and without the breakwater.

131. NAGAI, S., and KUBO, N., "Studies on Detached Breakwaters," *Proceedings of the 17th Conference on Coastal Engineering in Japan*, 1970, pp. 317-322 (in Japanese).

Keywords: Accretion, Compartmented breakwater, Continuous breakwater, Currents, Hydraulic model (three-dimensional), Littoral transport, Movable bed, Segmented breakwater, Tombolo, Wave attenuation

The two major purposes of an offshore breakwater are to prevent erosion and to protect structures on the shore. Studies on offshore breakwaters have included experiments in two dimensions, monitoring of existing breakwaters, and determinations of transmitted wave heights on submerged breakwaters. There are few studies on the three-dimensional effects of offshore breakwaters on shore processes.

This study determines the design and positioning of offshore breakwaters not only to prevent shore erosion, but to promote an accumulation of littoral material to lessen the nearshore slope and to maximize the area of the sandy beach. The model chosen for the study was Kasumi Bay, northern Hyogo Prefecture, facing the Sea of Japan. Waves on this coast occur mainly during the winter, caused by seasonal winds. When winter storms pass through, the coast is subjected to continuous waves with heights of several meters for periods of 2 to 3 days.

132. NAGAI, S., and SEO, G., "Constructions of Small Commercial and Fishery Harbours on Sandy Coasts in Japan," Report to SII-S2 (Means of Controlling Littoral Drift to Protect Beaches, Dunes, Estuaries, and Harbor Entrances. Establishment of Artificial Beaches), *XXIIId International Navigation Congress*, Ottawa, 1973, pp. 97-119.

Keywords: Accretion, Hydraulic model (three-dimensional), Japan (Seppu), Littoral transport, Sand trap, Tombolo

This report discusses Japanese fishery, one of Japan's primary industries. Subjects of discussion include: Japan's geographical and environmental conditions, the outline of the fishing industry and fishing ports, a general idea of the fishing port construction on Japanese sandy beaches, and two fishing ports as examples in recent constructions with littoral drift problems and their countermeasures.

133. NAKAMURA, M., SHIRAISHI, H., and SASAKI, Y., "Wave Damping Effect of Submerged Dike," *Proceedings of the 10th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 1, 1966, pp. 254-267 (also appeared in *Proceedings of the 13th Conference on Coastal Engineering in Japan*, 1966, pp. 76-79).

Keywords: Hydraulic model (two-dimensional), Submerged breakwater, Wave attenuation, Wave transmission

Wave energy is dissipated by a submerged breakwater when waves break on the structure. Some of the remaining energy is dissipated by reflection and friction on the crown of the submerged breakwater and some is transmitted shoreward. In previously published reports, the

transmission coefficient has been obtained mainly by the observation of wave reflection from the submerged structure. The theoretical analysis of wave breaking is very difficult because of its complexity. However, the wave energy dissipation by a submerged breakwater is maximized by inducing the wave breaking on the structure.

This report mainly deals with energy dissipation due to breaking on a submerged breakwater and offers experimental data for practical use. To investigate the scale effect of the experimental results, a comparison between experimental data and field data is presented.

134. NANCE, T.F., and HIROTA, P.M., "Magic Island . . . Ten Years After," *Shore and Beach*, Vol. 42, No. 2, Oct. 1974, pp. 19-22.

Keywords: Armor Stability, Beach fill, Environmental concerns, Hawaii (Ala Wai Peninsula, Magic Island, and Waikiki), Littoral transport, Rubble mound, Segmented breakwater, Structural dimensions, Wave diffraction, Wave overtopping

In 1964 the Ala Wai Peninsula was completed as the first phase of the Magic Island complex. The rest of the project was never constructed because of environmental objections. The project utilizes a series of detached breakwaters to retain a recreational beach. The performance of the project after 10 years is evaluated.

135. NATAL' CHISHIN, G.D., "Determination of Wave Forces on Submerged Shore Protection Breakwaters in Shallow Waters," *Gidrotekhnicheskoe Stroitel'stvo*, No. 4, Apr. 1974, pp. 42-44 (in Russian--translation available in CERC library).

Keywords: Concrete structures, Hydraulic model (two-dimensional), Structural stability, Submerged breakwater, U.S.S.R. (Odessa), Wave attenuation, Wave pressure, Wave setup

The use of submerged concrete breakwaters has become widespread in the Odessa region of the Black Sea coast. Investigations were made and results are presented on the wave suppression effect, wave pressures, wave setup, and maximum bed velocities to be used for design of these structures.

136. NIHON TETRAPOD CORPORATION, "Nihon No Uni To Riku" (Sea and Land of Japan), Tokyo, Japan, 1976.

Keywords: Armor units, Detached breakwater, Japan (Hamada, Nishikinohama-Kaizuka, and Shinmatsubara-Okagakicho), Segmented breakwater, Structural dimensions, Tetrapods

A company brochure with illustrations of coastal projects in Japan. Numerous color photos, maps, and figures are included. Several detached breakwater installations are presented.

137. O'ROURKE, J.J., "Discussion on Beach Erosion Studies," *Transactions of the American Society of Civil Engineers*, Vol. 105, 1940, pp. 895-898.

Keywords: Beach fill, Compartmented breakwater, Illinois (Lincoln Park-Chicago), Structural dimensions, Wave attenuation

Unusually high Lake Michigan levels in 1929 caused erosion and destruction of parts of Outer Drive in Chicago as it passed through Lincoln Park. In 1930, a series of groins were constructed to protect this section of beach. They were ineffective because of a lack of littoral transport in this area. Submerged bulkheads were constructed in 1939 to retain a bathing beach fill. Their effectiveness is assessed.

138. OSADA, T., "Variation of Shorelines in the Vicinity of Harbors in Niigata Prefecture," *Proceedings of the Fifth Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1958, pp. 123-136 (in Japanese).

Keywords: Detached breakwater, Segmented breakwater

139. OZAKI, A., "On the Effect of an Offshore Breakwater on the Maintenance of a Harbor Constructed on a Sandy Beach," *Proceedings of the Ninth Conference on Coastal Engineering*, American Society of Civil Engineers, 1964, pp. 323-345.

Keywords: Accretion, Currents, Detached breakwater, Hydraulic model (three-dimensional), Japan (Seppu), Littoral transport, Movable bed, Sand trap

This paper describes an experimental attempt to prevent the rapid blocking of a harbor entrance caused by littoral transport in the summer period. This work was conducted at Seppu, a fishing harbor constructed on a sandy beach in Hokkaido, Japan. This investigation was originally sponsored by the Harbor Section of the Hokkaido Prefectural Office. One of the top priority objectives, at that time, was to determine the efficiency of two jetties constructed on the updrift side to counter the littoral transport. Detailed observations, including preliminary model experiments, were made from 1961 to 1963 on the general aspects (i.e., condition and phenomena) of the coast. Meterological data were also compiled.

Based on the above, this paper suggests the utilization of natural forces, i.e., waves, offshore currents, etc., by constructing an offshore breakwater to curb the blockage of the harbor mouth.

140. PALA, F. and D'ARRIGO, A., Untitled report to SII-Q2 (Protection of Coasts Against the Sea, With or Without Preponderating Coastal Drift of Materials), *XVth International Navigation Congress*, Venice, 1931.

Keywords: Accretion, Detached breakwater, Italy (Posillipe and Salerno), Segmented breakwater

Italian uses of detached breakwaters for shore protection are discussed. Segmented structures at Salerno and a single detached breakwater at Posillipe have been effective. The growth of tombolos is apparent at both locations.

141. PERAINO, J., et al., "Features of Various Offshore Structures," MP 3-75, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., Apr. 1975.

Keywords: Accretion, Aesthetics, Armor stability, Beach fill, California (Venice), Detached breakwater, Downdrift beaches, Littoral transport, Massachusetts (Winthrop Beach), Rubble mound, Segmented breakwater, Structural dimensions, Tombolo

The classification and identification of some existing offshore structures are presented as a means of comparison for various structures from the technical, environmental, and economic aspects. A bibliography follows each structure description.

142. PERLIN, M., "Predicting Beach Planforms in the Lee of a Breakwater," *Proceedings of the Coastal Structure '79 Specialty Conference*, American Society of Civil Engineers, 1979, pp. 792-808.

Keywords: Accretion, Detached breakwater, Numerical model, Tombolo

A numerical model is developed which predicts beach planforms in the lee of a shore-parallel structure. Diffraction and refraction are included in the implicit finite-difference scheme. Three physical models and several dimensionless cases are presented.

143. RAMAN, H., JOTHI SHANKAR, N., and DATTATRI, J., "Submerged Breakwaters," *Journal of the Central Board of Irrigation and Power*, New Delhi, India, Vol. 34, No. 2, Apr. 1977, pp.205-212.

Keywords: Submerged breakwaters, Wave attenuation

The mechanism of the damping action of a submerged breakwater and a critical evaluation of the various theoretical and experimental studies regarding submerged breakwaters are presented.

144. RAO, S.A.R., SOMAYAJULU, S.K., and SHANMUGHAM, A.T., Untitled report to SII-S2 (Means of Controlling Littoral Drift to Protect Beaches, Dunes, Estuaries, and Harbor Entrances. Establishment of Artificial Beaches), *XXIIId International Navigation Congress*, Ottawa, 1973, pp. 83-96.

Keywords: Accretion, Downdrift beaches, India (Visakhapatnam), Littoral transport, Sand trap, Segmented breakwater, Ship hulls

This paper presents a study of the sand drift pattern along the east coast of India with particular reference to harbor structures and

the protection measures adopted to restore the waterways and adjoining beaches.

145. RAO, S.S., et al., "Island Breakwater at Visakhapatnam Port (India)," Report to SII-S1 (Breakwaters With Vertical and Sloping Faces. Measurement of Waves. Study of Wave Forces. Methods of Calculations), *XXIst International Navigation Congress*, Stockholm, 1965, pp. 77-92.

Keywords: Accretion, Armor stability, Armor units, Construction procedures, Downdrift beaches, Hydraulic model (two-dimensional), India (Visakhapatnam), Littoral transport, Rubble mound, Sand trap, Segmented breakwater, Ship hulls, Structural dimensions, Structure settlement, Tetrapods, Tribars, Wave pressure

The port of Visakhapatnam is protected from shoaling problems by an offshore breakwater that acts as a sand trap and forms a sheltered dredging basin. The breakwater is constructed of rubble armor over two sunken ship hulls. The heavy wave conditions have necessitated extensive rehabilitation efforts, the most recent of which was tested in a hydraulic model.

146. REA, C.C., and KOMAR, P.D., "Computer Simulation Models of a Hooked Beach Shoreline Configuration," *Journal of Sedimentary Petrology*, Vol. 45, No. 4, Dec. 1975, pp. 866-872.

Keywords: Crenulate-shaped bay, Littoral transport, Numerical model, Wave diffraction, Wave refraction

Computer simulation models are developed to investigate the formation of a hooked-beach shoreline shape in the lee of a rocky headland. The modeling technique combines two one-dimensional cell systems alined at right angles to each other so that beach erosion can proceed in two directions. In the hooked part of the beach, the shape of the refracted-diffracted wave front is an arbitrary function of the offshore wave approach angle. The results indicate that the shape of the hooked beach is dependent on the direction of wave approach, and the shape of the refracted-diffracted wave front.

147. RIPLEY, H.C., "Beach Erosion: Its Causes and Cure," *Transactions of the American Society of Civil Engineers*, Vol. LXXXVII, 1924, pp. 589-594. Discussions by C.W. Staniford, pp. 595-598; V. Gelineau, pp. 598-601; E.J. Dent, pp. 601-604; M.C. Collins, pp. 604-605; C.S. Riche, pp. 605-606; and H.J. Sherman, pp. 606-608; Closure, pp. 608-610.

Keywords: Accretion, Aesthetics, Brazil (Ceara), Concrete structures, Currents, Detached breakwater, Downdrift beaches, France (Anse des Huttes and Pointe de Grave), Littoral transport, Structural dimensions, Submerged breakwater, Wave attenuation

This paper specifically explains the principal causes of beach erosion and accretion and determines the principles which control these actions. Two examples are given, one in France and the other in Brazil, where works have been constructed that fully illustrate the principles enumerated, confirming the conclusion.

148. SAKURAMOTO, H., HORIKAWA, K., and SASAKI, T., "Prediction of Shoreline Changes Due to Coastal Structures," *Proceedings of the 32d Annual Convention*, Japan Society of Civil Engineers.

149. SASAKI, T., "Simulation on Shoreline and Nearshore Current," *Proceedings of the Conference on Civil Engineering in the Oceans III*, American Society of Civil Engineers, 1975, pp. 179-196.

Keywords: Accretion, Currents, Detached breakwater, Downdrift beaches, Littoral transport, Numerical model, Tombolo, Wave diffraction

Two simulation models on nearshore environments were developed. The first model is for predicting shoreline deformation behind a detached breakwater placed parallel to the shoreline, and the second is for simulating currents in the nearshore zone under the influence of an arbitrary bottom topography. The former model was tested by laboratory experiments (Horikawa and Koizumi, 1974), and the latter was verified by field observations.

150. SASAKI, T., "A State-of-the-Art Summary of Techniques for the Prediction of Beach Changes Due to a Breakwater," Report No. 1, Nearshore Environment Research Center, Tokyo, 1976 (in Japanese).

151. SASAKI, T., and SAKURAMOTO, H., "Field Verification of a Shoreline Simulation Model," *Proceedings of the International Conference on Water Resources Engineering*, Bangkok, Thailand, 1978.

Keywords: Detached breakwater, Littoral transport, Numerical model, Tombolo, Wave diffraction

Several numerical treatments have been presented to predict shoreline changes under natural conditions such as at river deltas and around headlands, as well as the changes brought about by the erection of man-made structures such as groins, jetties, and breakwaters. However, few discussions concerning the validity of these models have been made except those based on laboratory data. This paper presents a verification of the shoreline simulation model of Sasaki (1975), using very precise field data regarding the shoreline and wave conditions, particularly those on wave direction. Satisfactory agreement is found for engineering purposes in predicting shoreline changes near a breakwater.

152. SATO, N., and MITSUHASHI, H., "A Means of Preventing Filling of a Harbor Entrance Along a Coast With Alongshore Sand Transport," *Proceedings of the 16th Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1969, pp. 125-130 (in Japanese).

Keywords: Accretion, Currents, Detached breakwater, Hydraulic model (three-dimensional), Littoral transport, Movable bed, Tombolo, Wave attenuation

The article discusses experimental data for a harbor where offshore dikes and training levees are combined to counteract filling of the harbor entrance on a coast with longshore littoral transport. Included is an experimental study of the possibility of preventing filling of the harbor entrance through use of different harbor shapes.

153. SATO, S.I.I., and HORIE, T., "Study of Coastal Erosion of Inner Bay," Report No. 28, *Studies of the Erosion on the Coast of Toyama Bay*, Reports of Cooperative Research for Disaster Prevention, National Research Center for Disaster Prevention, Japan, Feb. 1972, pp. 87-112 (in Japanese).

Keywords: Accretion, Currents, Detached breakwater, Hydraulic model (three-dimensional), Japan (Toyama Bay), Littoral transport, Movable bed, Sand tracer study, Sediment gradations

Field observations and model experiments were conducted to clarify the characteristics of erosion in Toyama Bay, one of the most eroded coasts in Japan. Some countermeasures for preventing coastal erosion are offered.

The results from observations of longshore current by floats and of longshore drift by fluorescent tracers, topographic survey, sediment analysis, nearshore scour measurements, and model experiments (in both fixed and movable beds) are given. The characteristics of coastal erosion in Toyama Bay were found to be well associated with the irregular distributions of waves and longshore currents due to topographical complexities.

154. SAUVAGE DE SAINT MARC, M.G., and VINCENT, M.G., "Transport Littoral Formation de Fleches et de Tombolos" (Littoral Drift Formation of Spits and Tombolos), *Proceedings of the Fifth Conference on Coastal Engineering*, American Society of Civil Engineers, 1954, pp. 296-328.

Keywords: Currents, Detached breakwater, Hydraulic model (three-dimensional), Littoral transport, Movable bed, Tombolo

This paper is devoted to the study of phenomena connected with the evolution of sandbanks (littoral spits and tombolos). These formations are of interest to the engineer responsible for the construction of ports on sandy coasts.

An attempt was made to determine the influence on littoral drift of such factors as: wave characteristics, wave steepness, the inclination of the wave crests breaking on the beach, and the nature of the beach material. The formation of certain types of tombolos found in nature is also described.

155. SAVILLE, T., Jr., and WATTS, G.M., Untitled report to SII-S4 (Coastal Regime--Carriage of Material by Swell and Currents. Model Studies and In-Situ Observations. Influence of Port Structures. Coastal Defense Works. Breakwaters), *XXIId International Navigation Congress*, Paris, 1969, pp. 249-271.

Keywords: Accretion, California (Channel Islands), Detached breakwater, Downdrift beaches, Littoral transport, Sand trap

This paper discusses recent laboratory and field studies in the United States which are considered pertinent to development of a better understanding of the interaction of the beach and the littoral zones with and without manmade structures.

156. SAXENA, P.C., VAIDYARAMAN, P.P., and SRINIVASAN, R., "Design and Behavior of Sandtraps in Regions of High Littoral Drift," *Proceedings of the 15th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 2, 1976, pp. 1377-1393.

Keywords: Accretion, Detached breakwater, Hydraulic model (three-dimensional), India (Visakhapatnam), Littoral transport, Movable bed, Sand trap

The use of sand traps to contain littoral transport at several Indian ports is illustrated. The port of Visakhapatnam is served by a sunken ship detached breakwater which has acted as a sand trap. Expansion of the port facilities has required model testing and construction of a new detached breakwater and sand trap seaward of the original one.

157. SHINOHARA, K., and TSUBAKI, T., "Model Study on the Change of Shoreline of Sandy Beach by the Offshore Breakwater," *Proceedings of the 10th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 1, 1966, pp. 550-563.

Keywords: Accretion, Detached breakwater, Hydraulic model (three-dimensional), Littoral transport, Movable bed, Structural dimensions, Tombolo, Wave diffraction

This paper presents the results of an experiment to clarify shoreline changes caused by the construction of offshore breakwaters, the amount of sand deposits within the region sheltered by the breakwater, and sand movements on the beach as it deforms to an equilibrium profile. Initial profiles were made by the waves of steepness, δ_o = 0.0192 and δ_o = 0.0461, and then new equilibrium profiles were formed with waves of the same steepness with an offshore breakwater present.

158. SHIRAISHI, N., NUMATA, A., and HASE, N., "The Effect and Damage of Submerged Breakwater in Niigata Coast," *Coastal Engineering in Japan*, Vol. 3, 1960, pp. 89-99 (also appeared in *Proceedings of the Fifth Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1958, pp. 189-195) (in Japanese).

Keywords: Accretion, Armor units, Compartmented breakwater, Downdrift beaches, Littoral transport, Local scour, Rubble mound, Structure settlement, Submerged breakwater, Wave attenuation, Wave transmission

Beach erosion is a serious problem on the Niigata Coast where the shoreline has receded more than 300 meters during the past 50 years. This tendency was accelerated after the completion of a floodway on the Shinano River which caused a considerable decrease of sediment supply to this coast. A submerged breakwater was constructed about 500 meters from the shoreline to protect the eroded coast. This paper discusses the effect of the breakwater on wave transmission and on the deposition of sand, using the results of field observations by the Office of Shinano River Works, Niigata Prefecture.

159. SHIRDAN, L., Untitled report to SII-S1 (Breakwaters With Vertical and Sloping Faces. Measurement of Waves. Study of Wave Forces. Methods of Calculation), *XXIst International Navigation Congress*, Stockholm, 1965, pp. 101-109.

Keywords: Accretion, Armor stability, Composite structures, Construction procedures, Detached breakwater, Gabions, Israel (Nahariya and Tel Baruch-Tel-Aviv), Local scour, Rubble mound, Structural dimensions, Wave attenuation, Wave overtopping

Failures of low breakwaters are often induced by washouts of the landward slopes by overtopping waves. A low breakwater at Nahariya, Israel, was damaged on numerous occasions and a successful treatment for the landward slope was not found until PVC-coated gabions were tried. The results have been promising. The use of gabions on the landward slope has been introduced into the design of a similar structure at Tel Baruch.

160. SILVESTER, R., "Offshore Breakwaters," *Journal of the Waterways and Harbors Division*, Vol. 83, No. WW3, Sept. 1957, pp. 1368-1--1368-15.

Keywords: Accretion, Detached breakwater, Hydraulic model (three-dimensional), Littoral transport, Tombolo, Wave attenuation, Wave diffraction

The determination of wave heights and patterns for waves diffracted by an infinitely long breakwater, or by a breakwater gap, has been based on the theoretical solution for optical diffraction. Correct results are obtainable at distances in the shadow zone many wavelengths from the breakwater, but within an area of three wavelengths the results are erroneous. Offshore breakwaters of limited length must be studied if their use in preventing beach erosion is to be successful. The main factor to be considered is the wave pattern close to the breakwater. Model tests for wave patterns with two different lengths of breakwater and waves of different steepnesses are described and results presented in a form suitable for application.

161. SILVESTER, R., "Stabilization of Sedimentary Coastlines," *Nature*, Vol. 188, No. 4749, Nov. 1960, pp. 467-469.

Keywords: Accretion, Artificial headlands, Crenulate-shaped bay, Hydraulic model (three-dimensional), Littoral transport, Movable bed, Tombolo

A sedimentary coastline with a predominant direction of swell tends to develop crenulate-shaped bays between adjacent headlands. This has been verified by model experiments described here. The use of artificial headlands would stabilize eroding shorelines by promoting growth of miniature crenulate-shaped bays, providing wide beaches to protect backshore areas.

162. SILVESTER, R., "Sediment Movement Around the Coastlines of the World," *Proceedings of the Conference on Civil Engineering Problems Overseas*, Institution of Civil Engineers, 1962, pp. 14-1--14-15.

Keywords: Artificial headlands, Crenulate-shaped bays, Hydraulic model (three-dimensional), Littoral transport, Movable bed

Ocean waves and their action on beaches are discussed with emphasis on the two classifications, storm and swell, and on the repetitive nature of their occurrence. Discussion of beach processes explains the importance of the persistent swell in sediment movement.

A model investigation is described in which waves from an oblique direction eroded a straight sedimentary coastline until a stable bay shape was formed about fixed headlands. A similar shape was seen to occur in nature as is observed, for example, on Admiralty Charts. The orientation of these bays was related to the direction of the predominant swell and hence of the net sediment movement along the coast. Sediment movement for the coastlines of the world was determined from the Admiralty Charts. The significance of such data for the design of maritime structures is discussed.

163. SILVESTER, R., "Beach Profiles and Littoral Drift Assessment," *La Houille Blanche*, Grenoble, France, Vol. 24, No. 6, 1969, pp. 615-621.

Keywords: Artificial headlands, Crenulate-shaped bay, Littoral transport, Sand tracer study, Wave refraction

Typical or standard beach profiles, if established for a given wave climate and sediment characteristic, could be useful for measuring stability. The balance of volumes in a storm and swell profile would permit the assessment of imminent beach degradation. The many formulas derived for littoral current and littoral drift need attention as also the many practical variables involved in their measurement. Greater cognizance should be taken of sediment transport offshore from the surf zone.

164. SILVESTER, R., "Coastal Defense," *Proceedings of the Institution of Civil Engineers*, Vol. 45, 1970, pp. 677-682.

Keywords: Accretion, Artificial headlands, Beach fill, Crenulate-shaped bay, Littoral transport, Wave diffraction, Wave reflection, Wave refraction

Coastal defense incorporates the results of sediment motion (erosion or accretion) along the shore. Although much of this activity is in the surf zone, the ultimate stability of the shoreline is determined by tendencies seaward of the zone. The effectiveness of groins depends on their location within bays formed between headlands. Such naturally formed bays indicate a beach control system by headland-type structures. The natural bypassing of sediment across harbor and river mouths might be achieved by promoting wave reflection. Short-crested waves could maintain the sediment in quasi-suspension during passage across the entrance channel. Seawalls and revetments constructed on sedimentary coasts only aggravate the erosion problem they are designed to mitigate, because of the influence of wave reflection. Hence, the influence of reflected waves in the near and offshore zone is of great importance. Causes of erosion should be determined before beach renourishment is undertaken on a large scale. All factors combine in an estuary to produce siltation.

165. SILVESTER, R., "Growth of Crenulate Shaped Bays to Equilibrium," *Journal of the Waterways and Harbors Division*, Vol. 96, No. WW2, May 1970, pp. 275-287.

Keywords: Artificial headlands, Crenulate-shaped bay, Hydraulic model (three-dimensional), Littoral transport, Movable bed, Sand tracer study, Wave diffraction, Wave refraction

Crenulate-shaped bays are prominent coastal features. If sediment supply is not available, an equilibrium shape is reached. The shape and orientation of the bays is a function of the persistent swell. The final shape is independent of scale and depends only on the wave approach angle.

166. SILVESTER, R., "Coastal Engineering, I - Generation, Propagation and Influence of Waves," *Developments in Geotechnical Engineering*, Vol. 4A, Elsevier Scientific Publishing Company, Amsterdam, The Netherlands, 1974, pp. 217-260, 301-366.

Keywords: Pile arrays, Submerged breakwater, Wave diffraction, Wave reflection, Wave refraction, Wave transmission

A textbook of coastal engineering with an emphasis on the needs of the practicing design engineer. This volume concentrates on wave theory and wave-related subjects such as diffraction, refraction, etc.

167. SILVESTER, R., "Coastal Engineering, II - Sedimentation, Estuaries, Tides, Effluents and Modeling," *Developments in Geotechnical Engineering*, Vol. 4B, Elsevier Scientific Publishing Company, Amsterdam, The Netherlands, 1974, pp. 71-100, 127-148.

Keywords: Accretion, Artificial headlands, Beach fill, Crenulate-shaped bay, Currents, Detached breakwater, Downdrift beaches, Hydraulic model (three-dimensional), Littoral transport, Movable bed, Wave diffraction, Wave reflection, Wave refraction

A textbook on coastal engineering with an emphasis on the needs of the practicing design engineer. This volume deals mostly with shoreline processes, coastal defense, and hydraulic modeling.

168. SILVESTER, R., "What Makes A Good Surfing Beach," *Proceedings of the Second Australian Conference on Coastal and Ocean Engineering*, The Institution of Engineers, 1975, pp. 30-37.

Keywords: Crenulate-shaped bay, Recreation

From all aspects of surfing, a mildly sloped beach produces better waves than a steeply sloped beach. The extra demand for board riding in plunging breakers is for a reasonably slow-peeling rate, which requires an extreme approach angle of breaking waves to bed contours. The crenulate-shaped bay, either as a natural or manmade feature, can supply the variety of conditions demanded by the body or board surfer. Thus, stabilization and recreation might be served by the same headland approach.

169. SILVESTER, R., "Comments to Article: Sands Protect Sea Walls at Bournemouth Resort," *World Dredging and Marine Construction*, Vol. 12, No. 4, Mar. 1976, pp. 36-37.

Keywords: Artificial headlands, Beach fill, Crenulate-shaped bay, Sandbags, Singapore, Structural dimensions

An appeal is made for consideration of the use of artificial headlands to form crenulate bays which would stabilize an eroding coast. The headlands would protect a new beach fill and could be constructed of massive polyethylene sandbags.

170. SILVESTER, R., "Headland Defense of Coasts," *Proceedings of the 15th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 2, 1976, pp. 1394-1406.

Keywords: Accretion, Aesthetics, Artificial headlands, Crenulate-shaped bay, Design guidelines, Detached breakwater, Economic analysis, Environmental concerns, Littoral transport, Sandbags, Structural dimensions, Tombolo

Crenulate-shaped bays are ubiquitous and constitute the largest proportion of coastline length. The characteristics of stable bays (i.e., no littoral drift) are known and realistic encroachment limits can be defined. Allowances should be made for long-term changes in direction of persistent swell and annual attack from multidirectional storm waves. The exposure of a rock outcrop during an erosive sequence will create a new fixed point on the coast and hence a new system of bays.

An existing nonstable bay can be prevented from indenting to its equilibrium shape by the construction of one or more fixed points around its periphery. Research should be conducted to minimize the cost of headlands which might start as offshore breakwaters, even mobile units.

171. SILVESTER, R., and HO, S.K., "Use of Crenulate Shaped Bays to Stabilize Coasts," *Proceedings of the 13th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 2, 1972, pp. 1347-1365.

Keywords: Artificial headlands, Crenulate-shaped bay, Design guidelines, Gabions, Littoral transport, Recreation, Rubble mound, Sand tracer study, Singapore, Structural dimensions, Wave diffraction, Wave refraction

Crenulate-shaped bays are common on coastal margins of oceans, inland seas, or lakes where sedimentary beaches exist between headlands. They have a particular orientation to the swell or resultant wave energy vector, such that the straight tangent section is downcoast and the curved part upcoast. The latter is a logarithmic spiral at all stages of development of the bay. When fully stable, i.e., no littoral drift occurring, the constant of the logspiral equation has a specific relationship to the approach angle of the waves to the headland alinement. In this condition it is known that diffraction and refraction are involved when waves sculpture the curved beach in the lee of the upcoast headland. A further ratio to identify stable bays appears to be the ratio of indentation length to clearance between headlands. The application of crenulate-shaped bays to stabilization of a reclaimed shoreline suffering strong littoral drift on Singapore Island is described.

172. SILVESTER, R., and HO, S.K., "New Approach to Coastal Defense, *Civil Engineering*, Vol. 44, No. 9, Sept. 1974, pp. 66-69. Discussions by G.A Soucie, "Cape Hatteras, a Real Problem?" Nov. 1975, pp. 62-63; C.W. Nelson, "Destroy Barrier Dunes," Nov. 1975, pp. 63-64. Reply by R. Silvester, Nov. 1975, p. 64.

Keywords: Accretion, Aesthetics, Artificial headlands, Beach fill, Construction procedures, Crenulate-shaped bay, Design guidelines, Environmental concerns, Gabions, Littoral transport, Recreation, Rubble mound, Sandbags, Ship hulls, Singapore, Structural dimensions, Tombolo

The standard structures for shore protection, seawalls and groins, do not always perform as desired. They may fail to stop erosion of the beach. Seawalls are sometimes undermined and fail. The concept of "artificial headlands" appears generally to cost less and to perform better. The idea was suggested by observation of natural headlands and bays on the seacoasts of the world.

173. SILVESTER, R., and LIM, T.K., "Application of Wave Diffraction Data," *Proceedings of the 11th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 1, 1968, pp. 248-270.

Keywords: Hydraulic model (three-dimensional), Wave diffraction, Wave reflection

By considering separately the two terms of the Sommerfield solution of wave diffraction behind a semi-infinite breakwater, the influence of the wave reflection from the structure can be evaluated. The diffraction coefficient at any point can be obtained from a graph or table for full, partial, or no reflection by the addition of two coefficients. Wave heights were found to decrease consistently along the near-circular crests for all distances from the breakwater tip. For a workable range of incident angle and distance from the breakwater, wave heights could be defined by this arc distance from the shadow line expressed in wavelengths. These relationships have been verified experimentally for all but the smallest incident angle in proximity to the breakwater.

Several theoretical solutions for the breakwater gap are shown to be very similar, diverging only for small incident angles. New parameters are provided which greatly simplify the presentation of information. The scatter of past experimental data precludes the verification of this theory and indicates the need for further tests.

174. SIVARD, F.L., "Building a Beach With an Offshore Sill, Singer Island, Florida," *Shore and Beach*, Vol. 39, No. 1, Apr. 1971, pp. 42-44.

Keywords: Accretion, Compartmented breakwater, Construction procedures, Florida (Singer Island), Littoral transport, Sandbags, Wave attenuation

The use of a sill constructed parallel to the shoreline to assist in building and stabilizing a beach is not new; however, this type of structure has not been as accepted as groins, bulkheads, and seawalls. This paper discusses the dramatic success of one particular installation constructed of sandfilled nylon bags.

175. STIASSNIE, M., and DAGAN, G., "Wave Diffraction by Detached Breakwater," *Journal of the Waterways, Harbors, and Coastal Engineering Division*, Vol. 98, No. WW2, May 1972, pp. 209-225. Discussion by Y. Goda and T. Yoshimura, May 1973, pp. 285-288.

Keywords: Detached breakwater, Permeable breakwater, Wave diffraction

A thin barrier of finite length in water of finite depth and infinite extent is considered. An incident gravity wave, attacking an obstacle from infinity, is diffracted and scattered by the thin barrier (this represents a detached breakwater of large length to thickness ratio). The potential wave energy (i.e., the wave height) in the region surrounding the obstacle was computed. Maps of the state of the sea near the barrier were used to evaluate the breakwater performance, therefore, improving the design. Computations are carried out for a monochromatic incident wave and an impervious obstacle. The solution is extended to the cases of a pervious barrier and a random incident wave.

176. SUGAWARA, T., "Relationship Between the Height of Detached Breakwater and the Beach Profile," *Proceedings of the 23d Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1976, pp. 229-233 (in Japanese).

Keywords: Accretion, Detached breakwater

177. SUGIYAMA, M., "Beach Erosion at Niigata West Coast," *Proceedings of the Sixth Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1959, pp. 36-44 (in Japanese).

Keywords: Currents, Japan (Niigata), Littoral transport

An analysis of the results obtained for winter surveys during fiscal years 1956, 1957, and 1958 on the problem of erosion and washout of the Niigata coast is presented. The paper includes a description of the data, and the mechanism of erosion and washout on the west coast of Niigata, which was the main objective of the survey.

178. SWAN, B., "The Coast Erosion Hazard, Southwest Sri Lanka: A Reconnaissance Study," No. 40, New England Research Series in Applied Geography, Department of Geography, University of New England, New Armidale, Australia, Dec. 1974.

Keywords: Detached breakwater, Sri Lanka

Coastal retreat due to erosion by the sea is experienced along several segments of Sri Lanka's coastline. This report discusses the erosion experienced on a section of the southwest coast, between Colombo and Dondra Head. Here, dense human inhabitance compounds the gravity of the problem as settlements, cultivable land, public installations, and scenic tourist beaches are threatened by the sea.

179. TAKAHASHI, A., "The Wave Sheltering Effects for Fishing Harbors Created by Using Offshore Breakwaters," *Proceedings of the 17th Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1970, pp. 91-96 (in Japanese).

Keywords: Hydraulic model (three-dimensional), Segmented breakwater, Wave diffraction

180. TAKIUCHI, T., and ARAKI, H., "Coastal Erosion and the Secular Change of Coastal Structures on the Coast of Toyama Bay (Final Report)," No. 28, *Studies on the Erosion of the Coast of Toyama Bay (Report II)*, Reports of Cooperative Research for Disaster Prevention, National Research Center for Disaster Prevention, Science and Technology Agency, Tokyo, Feb. 1972 (in Japanese).

Keywords: Hexaleg blocks, Japan (Toyama Bay), Segmented breakwater, Tombolo

A series of studies were conducted from 1968 to 1971 on the process of erosion and the variation of function of coastal structures on the coast of Toyama Bay. An analysis of the coastline changes which have occurred during the past 10 years is made by comparing the shoreline plan (scale: 1/5,000) drawn in 1957 with the plan made during the past 3 years (1968-1971). The analysis revealed that the coastline on the east coast, in particular, had receded by 50.0 to 70.0 meters. Research was conducted to determine if there was a connection between the recession and the location of rivers. Most of the recession occurred at the mouth of rivers. Because of steep slopes at the mouth, most rivers flow rapidly into the bay.

Based on the results of studies about the secular change of coastal structures, types of shorelines and shore protection structures were classified.

181. TANAKA, N., "Wave Damping and Beach Protection by a Submerged Breakwater with a Wide Crest," *Proceedings of the 23d Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1976, pp. 152-170 (in Japanese).

Keywords: Submerged breakwater, Wave transmission

182. TAUMEN, J., "Enclosing Scheme for Bathing Beach Development," *Proceedings of the 15th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 2, 1976, pp. 1425-1438.

Keywords: Accretion, Compartmented breakwater, Environmental concerns, Israel (Achziv and Bat-Yam), Littoral transport, Recreation, Structural dimensions, Submerged breakwater, Wave attenuation

This paper presents a method for beach design which provides both coastal protection for the beach and protection for the bathing public. Reasons are given as to why the open sea foreshores are, in many cases, unsuitable for recreation.

The method uses an enclosed submerged breakwater coupled with short groins to provide a bathing beach with a safe swimming area and a controlled sand plaza. Economical in execution and maintenance, the method can be used for sandy or rocky coasts.

183. TOMINAGA, M., "Field Observation of Wave Absorption by Offshore Breakwaters," *Proceedings of the 18th Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1971, pp. 149-154 (in Japanese).

184. TOMINAGA, M., and SAKAMOTO, T., "Studies on Wave Deformation Due to Permeable Coastal Structures (1) - On the Movement of Coastal Ground Water and Wave Deformation Due to a Vertical Riprap Dike," *Journal of Research*, Tokyo, Japan, Vol. 15, 1972, pp. 65-96.

Keywords: Hydraulic model (two-dimensional), Permeable breakwater, Vertical breakwater, Wave reflection, Wave transmission

Wave motion through a permeable coastal structure such as a riprap dike or a permeable breakwater is subject to resistance. If the flow in a permeable structure is laminar, it is treated by considering linear resistance. Such treatment is effective in the analysis of the fluctuations of coastal ground water caused by the ebb and flow of tides, and has produced satisfactory results in field tests for permeability measurement.

If the flow is turbulent due to short-period waves such as wind waves, the resistance is a function of Reynolds number. The analysis of such a flow can be made by approximating the nonlinear resistance term with a linear relationship. A typical example of nonlinear resistance, the wave motion in a vertical riprap dike, was adopted and a theoretical study was made on the ratios of wave transmission and reflection due to the structure. Experiments were also conducted to determine transmission and reflection characteristics of a riprap dike constructed in a wave channel. The results of these experiments show a good fit between experimental and theoretical values.

185. TOMINAGA, M., and SAKUMA, N., "Wave Overtopping on Coastal Dikes," Report of the Public Works Research Institute, Ministry of Construction, Tokyo, Japan, Vol. 143, Sept. 1972, pp. 59-94 (in Japanese).

Keywords: Concrete structures, Hydraulic model (two-dimensional), Vertical breakwater, Wave overtopping

Wave overtopping of breakwaters has been investigated experimentally to obtain data to be used in the design of the height of these structures. Various models of breakwaters were set on a beach with a slope of 1:30, and the volume of wave overtopping was measured. Wave overtopping on vertical walls was studied in detail; the effects of the front slope, parapet wall, and wind were determined by comparisons with the results of the vertical wall tests.

The relationship between wave runup and wave overtopping was investigated, and a method of estimating wave overtopping was established. The overtopping volume of the existing structure was calculated by this method. It was found that wave absorbers should be placed seaward of structures when the volume of wave overtopping is large.

186. TOURMEN, L., "The Creation of an Artificial Beach in Larvotto Bay-Monte Carlo, Principality of Monaco," *Proceedings of the 11th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 1, 1968, pp. 558-569.

Keywords: Beach fill, Compartmented breakwater, Monaco (Larvotto Beach-Monte Carlo), Structural dimensions, Submerged breakwater, Wave attenuation, Wave diffraction

One of the features of a recent Monaco Government modernization scheme was an artificial beach in Larvotto Bay at Monte Carlo, which was to offer first-class bathing and amenities matching the very high standard of urban development planned for the area. Most of the Monaco coast is rocky and very steep, and the only places with a gradual slope down to the sea were a few very inferior beaches the waves had formed with widely varied materials from local builders' rubble dumps.

187. TOYOSHIMA, O., "A Method for Constructing a Breakwater Away From Shore," *Proceedings of the 15th Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1968, pp. 169-174 (in Japanese).

Keywords: Accretion, Detached breakwater, Foundation design, Segmented breakwater

188. TOYOSHIMA, O., "On the Height of Offshore Breakwaters," *Proceedings of the 16th Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1969, pp. 247-252 (in Japanese).

Keywords: Foundation design, Segmented breakwater

189. TOYOSHIMA, O., "Statistical Considerations of Detached Breakwaters," *Proceedings of the 17th Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1970, pp. 323-330 (in Japanese).

Keywords: Detached breakwater, Japan, Segmented breakwater

190. TOYOSHIMA, O., "Detached Breakwaters," *Coastal Engineering for the Practicing Engineer: Erosion*, Chapter 8, 1972, pp. 227-317 (in Japanese).

Keywords: Accretion, Akmon armor units, Composite structure, Concrete structures, Continuous breakwater, Design guidelines, Detached breakwater, Downdrift beaches, Environmental concerns, Foundation design, Hexaleg blocks, Hollow tetrahedron, Hydraulic model (three-dimensional), Japan (Aomori, Atsumi, Ishizaki, Kaizaka, Kanzaki, Kineichiyo, Maizuru, Maji, Niigata, Niishiki Beach, Onejime, and Zenigamezawa), Littoral transport, Local scour, Movable bed, Rubble mound, Segmented breakwater, Structural dimensions, Structure settlement, Submerged breakwater, Tetrapods, Tombolo, Wave attenuation, Wave diffraction, Wave setup, Wave transmission

The chapter gives a comprehensive look at beach erosion, its causes and possible countermeasures, and examines in detail the use of detached breakwaters. Topics discussed include wave attenuation effects and sand-trapping mechanisms of these structures. The dimensions and effectiveness of the existing detached breakwaters in Japan are listed in tabular form. Design guidelines are given and case histories are described.

191. TOYOSHIMA, O., "Design of a Detached Breakwater System," *Proceedings of the 14th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 2, 1974, pp. 1419-1431.

Keywords: Accretion, Armor units, Design guidelines, Detached breakwater, Environmental concerns, Hexaleg blocks, Japan (Ishizaki and Niigata), Littoral transport, Segmented breakwater, Structural dimensions, Tombolo

As a countermeasure against beach erosion, a serious problem in Japan, many preventive works, such as seawalls and groins, have been constructed during the past 20 or more years. However, seawalls and groins are not always effective in preventing beach erosion; in some cases they accelerate erosion.

Based on the above, detached breakwater systems were tried as a measure against beach erosion for the last 8 years. The purpose was to develop sand deposition behind the structures. Several experimental works were carried out and most of the tests were successful. The design method of this system was based on the results of field investigations conducted for more than 8 years.

192. (a) TOYOSHIMA, O., "Changes of Sea Bed Due to Detached Breakwaters," *Proceedings of the 15th Conference on Coastal Engineering*, American Society of Civil Engineers, Vol. 2, 1976, pp. 1572-1583.

(b) TOYOSHIMA, O., "Countermeasure Against the Beach Erosion on the Kaike Coast," *Civil Engineering in Japan*, Japan Society of Civil Engineers, Vol. 15, 1976, pp. 26-37.

Keywords: Accretion, Detached breakwater, Japan (Ishizaki and Kaike), Littoral transport, Segmented breakwater, Structural dimensions, Tombolo, Wave attenuation

The coastlines of the Japanese Island predominantly face the open sea and are subject to attack by severe wave action. Beach erosion has increased since the 1950's due to decreased sediment supply from rivers and from interference with longshore sediment transport by manmade structures.

The shoreline at Kaike has receded about 200 meters since about 1920. Attempts to stabilize the beach using groins and seawalls was largely unsuccessful during the period from 1947 to 1971. In September 1971, the first of a series of segmented, detached breakwaters was constructed. These have caused the accretion of sediment and several tombolos have formed. The article describes the development of the Kaike project and presents results of field surveys.

193. TRAITMAN, E.E.R., "Submerged Barriers for Shore Protection," *The Engineer*, Mar. 1940, pp. 226-228.

Keywords: Beach fill, Construction procedures, Illinois (Lincoln Park-Chicago), Steel-sheet piling, Structural dimensions, Submerged breakwater, Timber bulkhead, Wave attenuation

Severe beach erosion along the Lake Michigan shores at Chicago, Illinois, was counteracted through the use of a submerged sill. The timber structure had a crest elevation 3 feet below normal water level and it successfully retained a beach fill.

194. U.S. ARMY ENGINEER DISTRICT, BUFFALO, "Cooperative Beach Erosion Control Project at Lakeview Park, Lorain, Ohio, General Design Memorandum, Phase II - Project Design," Buffalo, N.Y., June 1975.

Keywords: Accretion, Armor stability, Beach fill, Construction procedures, Economic analysis, Environmental concerns, Foundation design, Littoral transport, Ohio (Lakeview Park-Lorain), Recreation, Rubble mound, Sediment gradations, Segmented breakwater, Structural dimensions, Structural stability, Wave attenuation, Wave diffraction, Wave overtopping, Wave refraction, Wave transmission

This memorandum details the design of a beach fill at Lorain, Ohio. The best alternative solution to stabilize the fill involved the construction of a three-segment, detached breakwater. The structures are situated in accordance with a diffraction analysis discussed in this report. Other design values are also determined.

195. U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE, "Beach Erosion Control Report on Cooperative Study of San Juan, Puerto Rico," Jacksonville, Fla., Apr. 1961.

Keywords: Detached breakwater, Puerto Rico (San Juan)

An investigation of the causes and possible solutions of beach erosion problems in the San Juan area is discussed. A detached breakwater for shore protection at the La Concha Hotel, San Juan, is mentioned.

196. U.S. ARMY ENGINEER DIVISION, PACIFIC OCEAN, "Hawaii Regional Inventory of the National Shoreline Study," Honolulu, Hawaii, Aug. 1971.

Keywords: Beach fill, Detached breakwater, Hawaii (Haleiwa Beach)

A brief history is given of the erosion problems at Haleiwa Beach which led to the construction of a detached breakwater in 1965.

197. U.S. ARMY ENGINEER DIVISION, PACIFIC OCEAN, "Water Resources Development in Hawaii," Honolulu, Hawaii, Jan. 1975.

Keywords: Beach fill, Detached breakwater, Hawaii (Haleiwa Beach)

A brief history is given of the offshore breakwater used for shore protection at Haleiwa Beach, Hawaii.

198. UNIVERSITY OF FLORIDA, "Coastal Engineering Evaluation of Planned Offshore Breakwater at Broward County Beach," Department of Coastal and Oceanographic Engineering, Gainesville, Fla., June 1971.

Keywords: Accretion, Currents, Detached breakwater, Downdrift beaches, Florida (Broward County Beach), Hydraulic model (three-dimensional), Littoral transport, Segmented breakwater, Submerged breakwater, Wave overtopping, Wave setup

Model tests to determine the quantity of littoral drift for various crest elevations of an offshore breakwater at the Broward County Beach were conducted. Wave heights on the lee side of the breakwater were measured by theoretical and empirical methods, and the capacity of sand transport for each breakwater height was determined. Four specific cases were tested in detail: sand transport capacity without a breakwater (i.e., the existing conditions) and sand transport with breakwater crest elevations of +2, -2, and ±0 feet above MSL. The range of wave heights and water levels in the model tests covered the corresponding parameters in nature.

199. UNIVERSITY OF MICHIGAN, "Bibliography on Beach Erosion and Related Subjects," Research Pub. No. 1, Department of Civil Engineering, Lake Hydraulic Laboratory, 1950.

Keywords: Bibliography, Detached breakwater

A bibliography with abstracts.

200. VAJDA, M.L., DISKIN, M.H., and COHEN, A., "Manshiah Shore Development, Breakwater and Seawall Model Investigation," Project No. 2926, Technion-Israel Institute of Technology, Hydraulic Laboratory, Haifa, Feb. 1966.

Keywords: Accretion, Armor stability, Beach fill, Detached breakwater, Hydraulic model (two-dimensional), Israel (Tel-Aviv), Local scour, Movable bed, Rubble mound, Sediment sizes, Submerged breakwater, Wave setup

Model studies of a seawall structure and of low and submerged breakwaters were carried out in the Hydraulics Laboratory of the Technion for Hasmareng, Joint Consulting Engineers, for Manshiah Shore Development, Tel-Aviv, on behalf of Achuzot Hachof Company Ltd. The object of the studies was to determine experimentally the suitability of the various shore protection structures proposed by Hasmareng engineers, as a part of the feasibility study carried out by them for Achuzot Hachof Company, and to recommend improvements.

201. VASCO COSTA, F., and FIUZA PERESTRELO, J., "Modification of the Sea Bed With a View to Concentration and Dispersal of Sea Waves," *The Dock and Harbour Authority*, London, Vol. 39, No. 460, Feb. 1959, pp. 305-306.

Keywords: Wave attenuation, Wave refraction

If a submerged dam or raised area on the seabed is built, shaped in plan like a prism, a wave traveling across it will undergo two deviations: one when entering the prism and one when leaving it, just as with a light ray passing through a prism of glass. In a similar way submerged dams could be built having a plan the shape of a lens, thereby affecting the wave orthogonals as glass lenses affect light rays.

202. VEDEL, P., "Island Harbors and the Accumulation of Material Caused by Detached Works," *Transactions of the American Society of Civil Engineers*, 1905, pp. 139-158. Discussions by L.M. Haupt, pp. 351-352; W.H. Hunter, pp. 354-355; A.E. Carey, pp. 380-381; Closure, pp. 384-385.

Keywords: Accretion, Denmark (Arnager, Hundested, and Snogebaek), Design guidelines, Littoral transport, Offshore island, Sediment sizes

An outline is given for a method of estimating (without a claim of accuracy) approximate limits for accumulations which may form behind a detached solid work, before a stable equilibrium is established, provided the movement of material is due only to wave action. Such an estimate will be necessary for forming an opinion of how far out from the shore a given structure should be placed to ensure against its becoming land-connected in time.

203. VERA-CRUZ, D., "Ondas Na Rebentacao," Memoria No. 199, Laboratorio Nacional de Engenharia Civil, Lisbon, 1962 (in Portuguese).

Keywords: Submerged breakwater, Wave attenuation

Laboratory tests for determining the height of reformed waves after breaking on gentle slopes belonging to submerged obstacles are described. The measured values of the ratio of the breaking depth to breaking wave height are presented and compared with values already published. The results tend to confirm the mathematical theories which consider solitary waves to be the limiting case of an oscillatory wave.

204. VERGARA, M.A., and CORNEJO, J., "Tombolo Formation Controlling Littoral Drift," *Coastal Sediments '77, Fourth Annual Symposium of the Waterways, Port, Coastal and Ocean Division*, American Society of Civil Engineers, Nov. 1977 (not published in proceedings).

Keywords: Detached breakwater, Hydraulic model (three-dimensional), Littoral transport, Mexico (Salina Cruz), Movable bed, Ship hulls, Tombolo

For controlling littoral drift, the location of a structure near the shore which causes tombolo formation, is more effective than other systems more frequently used. An experimental study carried out in a physical sedimentological model, using bakelite, was developed to find

tombolo formation limits, as well as accumulation percentages in total or partial tombolo formation. Most of the parameters prevailing in tombolo formation were varied--the length of the obstacle, the gap between the beach and the obstacle, the angle formed between the long axis of the structure and the incident wave, the wave height and its period.

Several observations on the nature of shoreline movement near three old sunken ships on the coast of Salina Cruz, Oaxaca, Mexico, were compared with the experimental results; these showed great similarity. Comparative tests with groins and tombolos were made in the same model to define the order of effectiveness.

205. VICHETPAN, N., "Equilibrium Shapes of Coastline in Plan," Masters Thesis, Asian Institute of Technology, Bangkok, Thailand, 1969.

Keywords: Crenulate-shaped bay, Hydraulic model (three-dimensional), Littoral transport, Movable bed, Wave diffraction, Wave refraction

If a straight sedimentary coastline with headlands suffers persistent waves from an oblique direction and no replenishment is provided for material removed downcoast, it will assume a crenulate shape which becomes progressively more indented. Finally, a shape is reached which is in equilibrium with the waves. The development of such equilibrium-shaped bays was studied by means of a model in which wave direction and wave periods were the sole variables. Thus, the wave height, water depth, beach height, and sedimentary material were the same throughout.

The shape of the bay at various stages from straight line to fully stable was measured after various wave durations. It was found that the major curved part of the waterline was a logarithmic spiral, the constant of which varied throughout. A consistent pattern was observed for this constant for the three wave approach angles of 30°, 45°, and 60°, and the three wave periods of 0.6, 1.0, and 1.4 seconds.

206. VISENTINI, M., PANCINI, G., and TEUSCHL, E., Untitled report to SII-CI (Protection Works Adopted to Limit Erosion Along the Open Coast, How They Work, Reference to Model Experiments), *XVIIth International Navigation Congress*, Lisbon, Portugal, 1949, pp. 105-134 (in French).

Keywords: Detached breakwater, Italy (Corroglio), Segmented breakwater, Tombolo

This report discusses general considerations in the selection and the construction of protective works on an open shore to prevent erosion of alluvial beaches. The conditions that exist on the Venetian coastline are discussed, taking into account the various protective works used to protect the lagoons that lie behind the beaches. The causes of beach erosion in Venetia are briefly recounted, as well as the localities where such erosion is most marked. Other Italian beaches are also reviewed.

207. WADA, A., "On a Method Of Solution Of Diffraction Problems," *Coastal Engineering in Japan*, Tokyo, Japan, Vol. 8, 1965, pp. 1-19.

Keywords: Detached breakwater, Wave diffraction

The technique presented here provides a significant extension of the range of diffraction problems that can be solved by the use of a Fourier transform; e.g., the problem of diffraction of sea waves by an insular breakwater is treated. Approximate expressions, taking into account the interaction between the edges, are derived. Some numerical results are also presented in which the interaction solution significantly improves the noninteraction approximation.

208. WADA, Y., NISHIMURA, H., and NIREI, Y., "Scour Around Breakwaters and Erosion of Adjacent Beaches," *Proceedings of the 17th Conference on Coastal Engineering In Japan*, Japan Society of Civil Engineers, 1970, pp. 311-316 (in Japanese).

209. WALKER, J.R., PALMER, R.Q., and DUNHAM, J.W., "Breakwater Back Slope Stability," *Proceedings of Civil Engineering in the Oceans III*, American Society of Civil Engineers, 1975, pp. 878-898.

Keywords: Armor stability, Armor units, Design guidelines, Hydraulic model (two-dimensional), Local scour, Rubble mound, Wave overtopping

This paper summarizes factors governing the stability of low-crest breakwaters subjected to overtopping waves. Both model experiments and prototype experience indicate that the backslope armor units of such breakwaters may be more susceptible to damage than those on the seaward slope. It is often desirable to lower the crest elevation to reduce the first cost where partial protection from the incident waves is required. Such applications occur in water intakes for powerplants, small-craft harbor entrance channels, beach protection projects, and hard-surfaced offshore fills.

210. WALTON, T.L., Jr., "Equilibrium Shores and Coastal Design," *Coastal Sediments '77, Fourth Annual Symposium of the Waterways, Port, Coastal and Ocean Division*, American Society of Civil Engineers, 1977, pp. 1-16.

Keywords: Crenulate-shaped bay

Logarithmic spiral curves approximate equilibrium shoreline shapes for areas of Florida's coast which are sheltered by natural reefs and capes. However, the log spiral curve lacks physical justification for describing the phenomena of an equilibrium coast. A model is postulated for an equilibrium coast which uses a continuous wave height energy distribution from visual ship wave observations to predict the stable, sheltered shoreline and is found to provide shoreline shapes similar to the logarithmic spiral shape for sheltered coasts in Florida. The method

can also be used in the design of coastal structures for prediction of erosion-accretion zones in stable areas.

211. WATTS, G.M., "Field Inspection of Erosion Problems in India," *Shore and Beach*, Vol. 37, No. 2, Oct. 1968, pp. 34-60.

Keywords: Accretion, Detached breakwater, Downdrift beaches, India (Visakhapatnam), Littoral transport, Sand trap, Ship hulls

Numerous coastal projects were inspected in October and November 1963, as a technical service to the Government of India. Visakhapatnam harbor was visited on 20-21 September. An account is given of the history of the harbor and its maintenance operations. Special emphasis is given to the detached breakwater sand trap.

212. WATTS, G.M., VALLIANOS, L., and JACHOWSKI, R.A., Untitled report to SII-S2 (Means of Controlling Littoral Drift to Protect Beaches, Dunes, Estuaries, and Harbor Entrances. Establishment of Artificial Beaches), *XXIIId International Navigation Congress*, Ottawa, 1973, pp. 233-257 (also Reprint 25-73, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., NTIS AD A773 930).

Keywords: California (Channel Islands and Venice), Detached breakwater, Illinois (Chicago), Littoral transport, Massachusetts (Winthrop Beach), Sand trap, Segmented breakwater, Submerged breakwater

A summary of techniques used in the United States for controlling littoral drift to stabilize beaches, dunes, and entrances to harbors and estuaries is presented. The use of detached breakwaters for shore stabilization and as sand traps for harbor entrances is discussed briefly.

213. WONG, P.P., "Beach Formation Between Breakwaters, Southeast Coast of Singapore," *Journal of Tropical Geography*, Vol. 37, 1973, pp. 68-73.

214. YAMADA, S., "On the Beach Erosion at Niigata Coast," *Proceedings of the Second Conference on Coastal Engineering in Japan*, Japan Society of Civil Engineers, 1955, pp. 174-186 (in Japanese).

Keywords: Compartmented breakwater, Concrete structures, Foundation design, Japan (Niigata)

215. YASSO, W.E., "Plan Geometry of Headland Bay Beaches," Technical Report No. 7, Office of Naval Research, Geology Branch, Washington, D.C., 1964.

Keywords: Crenulate-shaped bay, Littoral transport, Sediment sizes, Wave diffraction, Wave refraction

A headland-bay beach is defined as a beach lying in the lee of a headland subjected to a predominant direction of wave attack. Such

beaches characteristically have a seaward-concave plan shape resulting from erosion caused by refraction, diffraction, and reflection of waves into the shadow zone behind the headland. Increasing radius of plan curvature with distance from the headland suggested testing the logarithmic spiral, $r = e^{\theta \cot \alpha}$, as an approximation to the shape of headland-bay beaches. Four natural beaches were selected for testing goodness of fit to the log-spiral approximation: Spiral Beach, Sandy Hook, New Jersey; Halfmoon Bay Beach, California; and Drakes Beach and Limantour Spit Beach lying along the Drakes Bay shoreline to the north of San Francisco, California. Results range from excellent to good with the best fit being the Spiral Beach curvature for which the mean squared error in length of the log-spiral radius vector is only 0.82 foot squared.

216. ZENKOVITCH, V.P., "Formation of Accumulative Shore Forms in the Case of Blocking of the Shore from Outside," Comptes Rendus (Doklady) de l'Academie des Sciences de l'URSS, U.S.S.R., Vol. LIV, No. 4, 1946, pp. 317-319.

Keywords: Artificial headlands, Crenulate-shaped bay, Detached breakwater, Littoral transport, Ship hulls, Tombolo, Wave diffraction, Wave refraction

A discussion of the processes involved in the growth of tombolos behind natural or manmade offshore structures.

217. ZWAMBORN, J.A., FROMME, G.A.W., and FITZPATRICK, J.B., "Underwater Mound for the Protection of Durban's Harbor," *Proceedings of the 12th Conference on Coastal Engineering*, Vol. 2, 1970, pp. 975-994.

Keywords: Hydraulic model (three-dimensional), Movable bed, Sand mound, Sand tracer study, Sediment sizes, South Africa (Durban), Submerged breakwater

The construction of an underwater mound of sand for the protection and improvement of Durban's beaches has been recommended on the basis of intensive investigations. Those investigations included prototype measurements of beach changes as related to recorded sea conditions, basic scaling tests in which these beach changes were reproduced to scale in movable-bed models, and tests of the proposed underwater mound in models, using different scales in order to eliminate possible scale effects.

IV. SUBJECT HEADING INDEX

V. LOCATION INDEX

Lesnik, John R.

An annotated bibliography on detached breakwaters and artificial headlands / by John R. Lesnik. – Ft. Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1979.

79 p. (Miscellaneous report – U.S. Coastal Engineering Research Center ; no. 79-1)

This annotated bibliography is presented to assist in the development of reliable design procedures for detached breakwaters. The references deal with topics which can be usefully applied to the design problem although many are not limited solely to the subject of detached breakwaters. Papers on wave diffraction, reflection, transmission, and overtopping are also included.

1. Breakwaters – Design – Bibliography. 2. Ocean engineering – Bibliography. 3. Ocean waves – Bibliography. I. Title. II. Series: U.S. Coastal Engineering Research Center. Miscellaneous report ; no. 79-1.

TC203 .U581mr no. 79-1 627

Lesnik, John R.

An annotated bibliography on detached breakwaters and artificial headlands / by John R. Lesnik. – Ft. Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1979.

79 p. (Miscellaneous report – U.S. Coastal Engineering Research Center ; no. 79-1)

This annotated bibliography is presented to assist in the development of reliable design procedures for detached breakwaters. The references deal with topics which can be usefully applied to the design problem although many are not limited solely to the subject of detached breakwaters. Papers on wave diffraction, reflection, transmission, and overtopping are also included.

1. Breakwaters – Design – Bibliography. 2. Ocean engineering – Bibliography. 3. Ocean waves – Bibliography. I. Title. II. Series: U.S. Coastal Engineering Research Center. Miscellaneous report ; no. 79-1.

TC203 .U581mr no. 79-1 627

Lesnik, John R.

An annotated bibliography on detached breakwaters and artificial headlands / by John R. Lesnik. – Ft. Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1979.

79 p. (Miscellaneous report – U.S. Coastal Engineering Research Center ; no. 79-1)

This annotated bibliography is presented to assist in the development of reliable design procedures for detached breakwaters. The references deal with topics which can be usefully applied to the design problem although many are not limited solely to the subject of detached breakwaters. Papers on wave diffraction, reflection, transmission, and overtopping are also included.

1. Breakwaters – Design – Bibliography. 2. Ocean engineering – Bibliography. 3. Ocean waves – Bibliography. I. Title. II. Series: U.S. Coastal Engineering Research Center. Miscellaneous report ; no. 79-1.

TC203 .U581mr no. 79-1 627

Lesnik, John R.

An annotated bibliography on detached breakwaters and artificial headlands / by John R. Lesnik. – Ft. Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1979.

79 p. (Miscellaneous report – U.S. Coastal Engineering Research Center ; no. 79-1)

This annotated bibliography is presented to assist in the development of reliable design procedures for detached breakwaters. The references deal with topics which can be usefully applied to the design problem although many are not limited solely to the subject of detached breakwaters. Papers on wave diffraction, reflection, transmission, and overtopping are also included.

1. Breakwaters – Design – Bibliography. 2. Ocean engineering – Bibliography. 3. Ocean waves – Bibliography. I. Title. II. Series: U.S. Coastal Engineering Research Center. Miscellaneous report ; no. 79-1.

TC203 .U581mr no. 79-1 627