



## REMR TECHNICAL NOTE CO-RA-1.1

### CONDITION SURVEY OF CONCRETE ARMOR UNIT BREAKAGE ON EXISTING CORPS OF ENGINEERS' BREAKWATERS AND JETTIES

PURPOSE: To summarize and update a survey of existing Corps of Engineers' breakwaters and jetties containing concrete armor units. The original survey was conducted by the Waterways Experiment Station (WES) during the period June 1980 to February 1981 (Ref m). Since that time, WES has obtained additional information on more recent armor unit breakage on a few structures and additional repair and rehabilitation work that have been carried out on two structures.

BACKGROUND: During the original survey, nine Corps structures were found that had one or a combination of weights and types of concrete armor units. In 1981, Hilo Breakwater was added to the list when a portion of the sea-side slope was repaired with one layer of tribars. Additional rehabilitation work using tribar armor units was completed on the Kahului Breakwaters in 1984. Of these ten structures, only three were originally constructed with concrete armor units. The remaining seven were old armor stone structures on which concrete armor units were used during the repair, rehabilitation, or extension.

Since completion of the 1981 survey, some additional reported breakage has occurred on a few structures and where new data are available, they have been incorporated into Table . 1, which summarizes the locations, types and weights, and existing reported breakage of concrete armor units used by the Corps of Engineers.

- REFERENCES:
- a. Design of tetrapod cover layer for a rubble-mound breakwater, Crescent City Harbor, Crescent City, California; hydraulic model investigation. R. Y. Hudson, R. A. Jackson. US Army Engineer Waterways Experiment Station, Vicksburg, MS, Jun 1955. Technical Memorandum 2-413.
  - b. Stability of Crescent City Harbor Breakwater, Crescent City, California. R. Y. Hudson, R. A. Jackson. US Army Engineer Waterways Experiment Station, Vicksburg, MS, Apr 1956. Miscellaneous Paper 2-171.
  - c. Designs for rubble-mound breakwater repairs, Nawiliwili Harbor, Nawiliwili, Hawaii. R. A. Jackson, R. Y. Hudson, J. G. Housley. US Army Engineer Waterways Experiment Station, Vicksburg, MS, Feb 1960. Miscellaneous Paper 2-377.
  - d. Designs for rubble-mound breakwater repair, Kahului Harbor, Maui, Hawaii; hydraulic model investigation. R. A. Jackson. US Army Engineer Waterways Experiment Station, Vicksburg, MS, Feb 1964. Technical Report 2-644.

- e. Stability of quadripod coverlayers. O. F. Weymouth, O. T. Magoon. In: Proceedings, Eleventh Conference on Coastal Engineering, American Society of Civil Engineers, 1969, Chapter 51, pp 787-796.
- f. Proposed jetty--head repair sections, Humboldt Bay, California; hydraulic model investigation. D. D. Davidson, US Army Engineer Waterways Experiment Station, Vicksburg, MS, Nov 1971. Technical Report H-71-8.
- g. Design and construction of Humboldt Jetties, 1880 to 1975. O. T. Magoon, R. L. Sloan, N. Shimizu. In: Proceedings, Fifteenth Coastal Engineering Conference, American Society of Civil Engineers, 1976, Chapter 143, pp 2474-2498.
- h. Waianae Small-Boat Harbor, Oahu, Hawaii, design for wave protection; hydraulic model investigation. R. R. Bottin, Jr., C. E. Chatham, R. D. Carver. US Army Engineer Waterways Experiment Station, Vicksburg, MS, May 1976. Technical Report H-76-8.
- i. Kahului Breakwater stability study, Kahului, Maui, Hawaii. D. G. Markle. US Army Engineer Waterways Experiment Station, Vicksburg, MS, Jul 1982. Technical Report HL-82-14.
- j. Stability tests of Nawiliwili Breakwater repair. D. D. Davidson. US Army Engineer Waterways Experiment Station, Vicksburg, MS, Jan 1978. Miscellaneous Paper H-78-4.
- k. Crescent City Harbor, California - 20 August 1982 inspection of outer breakwater dolos section. J. R. Edmisten. US Army Corps of Engineers, South Pacific Division, San Francisco, CA, Sep 1982. Memorandum for Record.
- l. Nawiliwili Breakwater stability study, Nawiliwili Harbor, Kauai, Hawaii. D. G. Markle, C. R. Herrington. US Army Engineer Waterways Experiment Station, Vicksburg, MS, Sep 1983. Technical Report HL-83-21.
- m. Breakage of concrete armor units; survey of existing Corps structures. D. G. Markle, D. D. Davidson. US Army Engineer Waterways Experiment Station, Vicksburg, MS, Mar 1934. Miscellaneous Paper CERC-84-2.

Table 1  
Summary of Armor Unit Breakage in Prototype Survey

Location	Type of Unit and Date of Placement	Armor Unit Size, tons	Was Reinforce-ment Used?	Total No. of Units Placed	Units Broken To Date		Design Wave Height, ft	Has Structure Experienced Design Wave?
					No.	%		
<u>San Francisco District</u>								
Crescent City Breakwater Crescent City, CA	Tetrapods (1957): Sta 41+20 to 46+70	25	No	1,836	3	0.2	21	Yes
	Tetrapods (1957): Sta 37+00 to 39+00	25	No	140	70	50.0	21	Yes
	Dolosse (1974): Sta 34+70 to 37+100	40	No	246	70+	>28.5	35	Yes
Humboldt Jetties Eureka, CA	Dolosse (1971): South Jetty	42-43	Yes (2513) No (22)	2,535	22	0.9	40	Probably
	Dolosse (1972): North Jetty	42-43	Yes (2255) No (4)	2,259	12	0.5	40	Probably
Santa Cruz Jetties Santa Cruz, CA	Quadripods (1963): West Jetty	28	No	900	0	0	21	No
<u>Honolulu District</u>								
Pohoiki Breakwater Pohoiki Bay, Hawaii, HI	Dolosse (1979)	6	No	210	5	2.4	12	Yes
Kahului Breakwaters Kahului, Maui, HI	Tetrapods (1956): West Breakwater	33	No	400	9	3.2	34	Probably
	East Breakwater	33	No		4 (13)			
	Tribars (1966): West Breakwater	35 50	Yes Yes	181 173 (354)	2	0.6	34	Probably
	East Breakwater	35 50	Yes Yes	827 43 (870)	4	0.4	34	Probably
	Tribars (1969): West Breakwater	19	Yes	260	5	1.9	(Depth-limited)	Probably
	Tribars (1973): West Breakwater	19 35	Yes Yes	80 25	0 0	0 0	(Depth-limited)	Probably
	Dolosse (1977): West Breakwater	20 30	Yes Yes	291 257 (548)	14	2.0	(Depth limited)	Probably
	East Breakwater	6	No	455	6	1.3	(Depth-limited)	Probably
		20 30	Yes Yes	164 610 (774)	2	0.3		
		Tribars (1984): West Breakwater	6.5 (Harbor side) 11.0 25.0	No No Yes	540 170 10	1 0 0	0.2 0 0	25.6 21.5 21.5
	East Breakwater	9.0	No	755	0	0	30-34	
Waianae Breakwater Waianae, Oahu, HI	Dolosse (1979)	2	No	6,633	170	2.6	11.8	No
Nawiliwili Breakwater Nawiliwili, Kauai, HI	Tribars (1959): Head	17.8	Yes (351)	351 (598)	99	16.5	24	Probably
	Trunk	17.9	No (247)	247			19	Probably
	Dolosse (1977): Trunk	11	No	485	0	0	19	Probably
Hilo Breakwater Hilo, Hawaii, HI	Tribars (1981)	7.5			0	0	13.5	Probably
<u>Philadelphia District</u>								
Manasquan Jetty Point Pleasant, NY	Dolosse (1980): South Jetty	16	Yes	680	1	0.1	25.0	Yes
	Dolosse (1982): North Jetty	16	Yes	646	4	0.6	25.0	Yes
<u>Buffalo District</u>								
Cleveland Breakwater Cleveland, OH	Dolosse (1980)	2	No	29,700	659	2.2	13.4	No

