CHAPTER 95

THE INFLUENCE OF BREAKER TYPE ON RIPRAP STABILITY

by

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ABSTRACT

Test data related to the stability of dumped quarry stone riprap under wave action is presented The tests were conducted in the large 635-foot wave tank at the Coastal Engineering Research Center at near prototype scale The data indicate that the stability of the riprap is strongly influenced by the type of breaker The lowest riprap stability is associated with a breaker type intermediate between plunging and surging, sometimes referred to as a collapsing breaker

INTRODUCTION

From February 1969 to June 1970, tests were conducted in the large 635-foot wave tank at the Coastal Engineering Research Center (CERC) to determine the relation of stability of dumped quarry stone riprap to wave action During this period sixteen riprap protected earth embankments were subjected to progressively higher waves until the riprap failed The embankments were all constructed to have an initial slope of 1 on 2 5, with a median armor stone weight of 28 pounds for ten tests and 79 or 80 pounds for six tests The purpose of this study was to collect data related to riprap stability at nearly prototype scale so that current design criteria can be improved The scope of the study includes riprap stability for waves in reservoirs and coastal waters The sixteen tests described here represent all of the tests planned for a slope of 1 on 2 5, future tests will be conducted with slopes flatter than 1 on 2 5

TEST CONDITIONS

All of the sixteen tests described here were conducted in the 635-foot wave tank at CERC The width of this tank is 15 feet, the depth is 20 feet, the water depth used for all tests was 15 feet and the distance from the toe of the slope to the mean blade position was about 440 feet Sideboards were placed along the top of the tank wall near the crest of the embankment to allow the crest of the embankment to be built to a height of 24 feet above the bottom of the tank

The core of the embankment was composed of compacted earth, graded to a smooth 1 on 2 5 slope Between the core and the armor there was a layer of filter stone about half a foot thick The riprap was dumped on the filter bed from a skip, no water was in the wave tank during the dumping The riprap stone was quarry stone granite from near Occoquan, Virginia, with a specific gravity of 2 71 The median weight of the riprap stone was 28 pounds for tests SPL-1 through 10 and 79 or 80 pounds for tests SPL-11 through 16 The gradation of the riprap was measured by the ratio of the diameter of the 85% stone divided by the diameter of the 15% stone, D(85)/D(15), this ratio was about 1 7 for all tests The range in weights of the riprap stone was from about 4 times the median weight down to about 1/8 of the median weight The general shape of the stones could be described as blocky, almost none of the stones had a ratio of their longest axis divided by their shortest axis greater than 4 The porosity of the riprap was 37 4% for the 28 pound stone and 38 7% for the 79-80 pound stone

In order to include waves with characteristics similar to those observed on both reservoirs and in coastal waters, five wave periods were chosen for testing riprap stability Each of the tests in this study were run at one of the following wave periods 2 8, 4 2, 5 7, 8 5, and 11 3 seconds

TEST PROCEDURES

Waves were run in short bursts during the stability tests so that the generator would be shut off just before the wave energy reflected from the slope could reach the generator blade Between wave bursts there were brief interludes to allow reflected wave energy to dampen out Prior to the stability tests there was a calibration phase of this study to determine the proper wave height to assign to a particular combination of generator stroke and wave period During calibration waves were run in bursts with a wave absorber beach in the tank and the heights were recorded at several locations in the tank The wave heights used in this study were all obtained during calibration and, therefore, include almost no influence of reflection

A test was started by surveying the newly constructed slope on a square, 2 0 by 2 0-foot grid in the horizontal plane The initial survey was then used as a reference with which to compare subsequent surveys The slope was surveyed with a heavy, rigid sounding rod with a ball and socket foot, the foot was circular with a diameter of 0 5 feet The height of the first waves run on the newly constructed slope was chosen to be about 30% lower than the height which was expected to dislodge armor stones Waves were run, in bursts, on the embankment until it appeared that no further stones would be moved by waves of this height, in no case would less than 500 waves be run at a particular wave height and often over 1500 waves would be run before the slope was considered stable After the riprap was demonstrated to be stable at a particular height the slope would be resurveyed and the wave generator would be adjusted to generate waves approximately 10% higher The test procedure can then be summarized as, running enough waves at a given height until it appears that the slope is stable, then survey the slope and increase the wave height about 10% and repeat the cycle The cycle was repeated until enough armor stones were removed to constitute failure Failure, for these tests, was defined as having occurred when enough riprap stones were displaced so that the filter layer was exposed to wave action and core material was actually being removed through the filter layer

DISCUSSION

The purpose of these tests was to determine the relationship of the stability of dumped quarry stone riprap to wave action on slopes of 1 on 2 5 The primary measure of stability for these tests was the zero damage wave height The zero damage wave height was estimated on the basis of the written notes made by observers of their impression of the damage occurring to the riprap during the tests, and from damage calculations obtained from the frequent surveys of the slope By comparing a survey associated with some wave height with the initial survey, the volume of armor displaced and the maximum penetration of damage into the riprap layer were calculated and used to help estimate the zero damage wave height Table I gives the estimated zero damage wave height for the various tests and also some other observed data Appendix II explains the meaning of all symbols used in this paper

Table I gives an average value of the runup ratio, R/H, for each test The runup ratio is the average of a number of observations made for waves lower than the zero damage wave height, while the slope was still in good condition Within the limited range of wave heights considered the runup ratio was approximately constant for each test The initial slope, shown in Table I, was calculated by fitting a least squares straight line through the initial survey points The initial slope was used as an estimate of how well the construction conformed to the planned 1 on 2 5 slope Table I also shows the average riprap layer thickness, $\bar{r}$, for each test

As the test series proceeded, the scatter in the zero damage wave height was greater than expected and appeared to be at least partly dependent on the wave period This was not completely unforeseen, however, since a previous study on riprap stability conducted at CERC seemed to show some influence of wave period The effect of the wave period was confused since these earlier tests were run in three different wave tanks at model scale ratios of from 1 to 30 to prototype In addition, the previous riprap tests did not generally test a wide range of depth to wave length ratios, d/L, as they were oriented towards some specific riprap problems on reservoirs

In Table II the stability number N_s, is defined and tabulated for each test by wave period and median armor weight The stability number shown in Table II is useful for intercomparing riprap tests, having the same slope but different median weights (Hudson (2)) Table II shows that the lowest stability is associated with the four tests with a wave period of 4 2 seconds and the two tests at a period of 5 7 seconds with the larger median weight There is relatively high stability for both the short period waves, T=2 8 seconds and for the long waves, T=8 5 and 11 3 seconds Table II suggests that the breaker type may influence the riprap stability since it is related to the incident wave height and period

TABLE I

OBSERVED TEST DATA

Test Designation	T (sec)	W_{50} (lbs)	$H_{D=0}$ (feet)	H(FAIL) (feet)	$\bar{r}$ (feet)	R/H	Initial Slope, 1/m
SPL-1	2 8	28	2 50	3 81	1 82	0 98	2 50
2	5 7	28	2 11	2 41	1 38	1 44	2 62
3	4 2	28	1 76	2 68	1 54	1 21	2 48
4	8 5	28	2 48	3 20	1 46	1 61	2 57
5	11 3	28	2 58	3 26	1 57	1 81	2 46
6	8 5	28	2 20	2 34	0 95	1 62	2 58
7	5 7	28	2 11	2 41	1 21	1 51	2 55
8	4 2	28	1 76	2 03	1 03	1 22	2 50
9	2 8	28	2 50	3 00	1 10	1 01	2 43
10	4 2	28	1 76	2 03	1 06	1 22	2 51
11	5 7	80	2 51	2 97	1 40	1 36	2 46
12	8 5	79	3 28	3 84	1 58	1 61	2 51
13	2 8	79	3 28	-	1 41	1 01	2 55
14	4 2	79	2 58	3 16	1 45	1 23	2 49
15	11 3	79	3 40	3 97	1 35	1 69	2 47
16	5 7	79	2 51	3 13	1 38	1 32	2 48

TABLE I

STABILITY NUMBERS BASED ON ZERO DAMAGE WAVE HEIGHTS

Median Weight	Wave Periods (seconds) 2 8	4 2	5 7	8 5	11 3
28	2 66	1 87	2 25	2 64	2 75
28	2 66	1 87	2 25	2 34	----
28	----	1 87	----	----	----
79	2 47	1 94	1 89	2 47	2 56
80	----	----	1 88	----	----

STABILITY NUMBER, $N_s = \dfrac{\gamma_s^{1/3} H_{D=0}}{W_{50}^{1/3}(S-1)}$

Table II also suggests that for the tests with the lowest stability the median armor weight is proportional to the cube of the zero damage wave height given by Hudson's (2) formula

The breaker types for the six tests with low stability noted above (tests SPL-3, 8, 10, 11, 14 and 16) were all intermediate between surging and plunging Galvin (1) calls this transitional type of breaker a collapsing breaker Apparently collapsing breakers have characteristics which yield low riprap stability Table III places each test into a breaker category based on the wave conditions observed for the test before and just after the zero damage wave height Table III shows that the average stability number for the tests with collapsing waves is considerably lower than tests in the plunging or surging breaker category Galvin's definitions of breaker types have been used throughout this study

In order to more clearly show the effect of breaker type on riprap stability Figure 1 shows the riprap stability coefficient, K_{RR}, plotted versus the offshore breaker parameter $H_o/L_o m^2$ The riprap stability coefficient is equal to the product of the cube of the stability number and the tangent of the slope angle, it is similar to the stability coefficient, K_Δ, which is frequently used in evaluating the stability of armor units in rubble-mound breakwaters The offshore breaker parameter is useful for predicting the breaker type on a known slope for waves with known deep water steepness The offshore breaker parameter for Figure 1 was computed by converting the zero damage wave height for each test to their equivalent deep water height Figure 1 clearly shows the low stability associated with collapsing breakers For these tests the transition between surging and collapsing breakers occurred between values of 0 08 and 0 10 of the offshore breaker parameter and the transition between collapsing and plunging occurred between values of 0 20 and 0 25 of the offshore breaker parameter

CONCLUSION

Intuitively it seems reasonable that the manner in which the waves break on a slope will influence the stability of the armor protecting the slope When a plunging breaker hits the armor stones with great impact, the impact has only a small component which is tangential to the slope, so that it takes a surprisingly large wave to dislodge armor stones The uprush following the plunge is a turbulent, spongy mass of water with a great quantity of entrained air and has little impact against the stones The return flow of the uprush appears to lack the volume, elevation and time to develop the strength to overturn the armor stones In the case of a surging breaker the runup travels rather gently up the slope and the impact against the armor stones is slight When riprap stones are removed by surging waves, it is by the return flow of the runup through, out of, and over the armor layer The flow out of the armor layer tends to lift the stones and the return flow over the surface tends to overturn them The breaker type transitional between plunging and surging, referred to as a collapsing breaker, has an uprush which seems to have significant impact against the stones and is directed approximately tangential to the slope The uprush of the collapsing wave

TABLE 11

INFLUENCE OF BREAKER TYPE ON STABILITY NUMBER, N_s, FOR

DUMPED QUARRY STONE RIPRAP ON A SLOPE OF 1 ON 2 5

TEST	WAVE PERIOD	SURGING	COLLAPSING	PLUNGING	SPILLING
SPL-1	2 8 sec	----	----	2 66	----
2	5 7	2 25	----	----	----
3	4 2	----	1 87	----	----
4	8 5	2 64	----	----	----
5	11 3	2 75	----	----	----
6	8 5	2 34	----	----	----
7	5 7	2 25	----	----	----
8	4 2	----	1 87	----	----
9	2 8	----	----	2 66	----
10	4 2	----	1 87	----	----
11	5 7	----	1 88	----	----
12	8 5	2 47	----	----	----
13	2 8	----	----	2 47	----
14	4 2	----	1 94	----	----
15	11 3	2 56	----	----	----
16	5 7	----	1 89	----	----
Average		2 47	1 89	2 60	

STABILITY NUMBER, $N_s = \dfrac{\gamma_s^{1/3} H_{D=0}}{W_{50}^{1/3}(S-1)}$

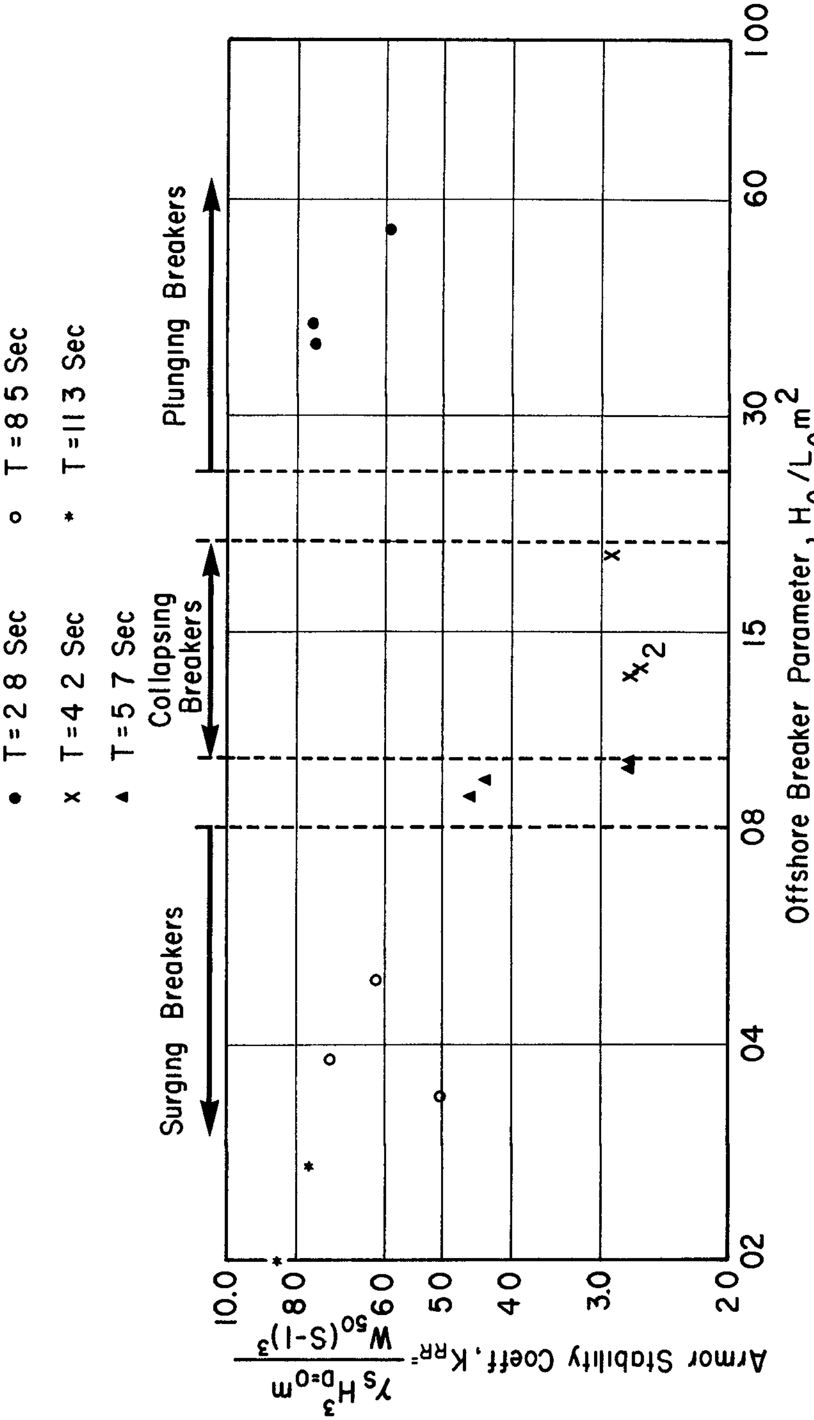

FIGURE I ARMOR STABILITY COEFF VS OFFSHORE BREAKER PARAMETER also has dynamic properties which tend to lift the stones The return flow of the runup can then dislodge or overturn stones which have been momentarily placed in a less stable position by the uprush Since the return flow of the collapsing breaker seems to be significantly stronger than that of the plunging breaker it is possible that even stones which were not made unstable by the uprush could be dislodged by the downrush It seems as if the physical characteristics of collapsing breakers have combined in an optimum way to yield low riprap stability

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APPENDIX 1 - REFERENCES

1 Galvin, Cyril J , Jr , "Breaker Type Classification on Three Laboratory Beaches", Journal of Geophysical Research, Vol 73, No 12, June 15, 1968, p 3651-3659

2 Hudson, R Y , "Laboratory Investigations of Rubble-Mound Breakwaters", ASCE, Journal of the Waterways and Harbors Division, Vol 85, No WW3, Paper 2171, September, 1959

APPENDIX II - NOTATION

The following symbols are used in this paper

d = water depth

H = wave height

H_o = deep water wave height

$H_{D=0}$ = zero damage wave height

$H(FAIL)$ = failure wave height

K_{RR} = stability coefficient for riprap

K_{Δ} = stability coefficient for rubble-mound breakwaters

L = wave length

L_o = deep water wave length

m = tangent of slope angle

N_s = stability number

$\overline{r}$ = average riprap layer thickness

R = runup

S = specific gravity of riprap stone

T = wave period

W_{50} = median armor weight

γ_s = specific weight of riprap stone