OCEN 400 DESIGN PROJECT
FALL 1992

GALVESTON BREAKWATER

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1.0 INTRODUCTION

The report presented herein is an effort by the Fall 1992, Basic Coastal Engineering Class to complete a design project pertinant to the subject matter of the course. This project centers around a practical breakwater design to be implemented in front of the Galveston, Texas Seawall. The purpose of the breakwater design is to retain sand placed by the City of Galveston's Beach Renourishment Plan.

Statement of Engineering Problem

The exact location of interest to this project is a four-mile stretch of beach between 10th and 61st streets on Galveston Island. This area is a popular tourist spot along the Seawall, with several prominant hotels in near proximity. The cost, benefits, and logistics of replinishing this section of the beach have been established by the City of Galveston and the U.S. Army Corp of Engineers. Therefore, this class project assumes the Beach Renourishment plan inplace.

2.0 LITURATURE SURVEY

Liturature surrveyed for use in this report may be divided into two distinct parts; that is information pertaining to the study of local conditions and data used to design the breakwater system.

Local Conditions

Several different studies have been completed over the years encompasing the project area along with other portions of Galveston Island. Most of the studies pertain to either the structures already in place (Seawall and Groinfield)or to erosion control in the area. Information, from these studies, of interest to the project designed here includes type of sediment, the sediment budget, littoral transport, beach profile, and wind and wave data.

The beaches on Galveston Island are comprised of low, narrow, sand ridges perched on an extremely gentle slope of clay deposit. A large part of this sedimentary formation is clay derived from the Missisippi River and its tributary systems. Sand is a relatively minor part of this sedimentary composition and is found to have a median grain-size of 0.24 mm.

A comparison of beach profiles taken 1978-1980 to 1992 give a basis for sediment transport within the study area. It was concluded that in the area starting at 10th street has a tendency for beach profile loss at the western extremes of each groin cell with slight gains on the eastern portion. This trend continues to 37th street where gains occur more to the midpoint of the groin cell and at 61st street the western portion tends to gain.

A summary of sediment budget analysis, west of the Galveston Entrance Channel to 61st street shows an average accretion rate of 7.56 $yd^3/yr/ft$ of beach.

The wave clintate data in the area may be obtained from wave gage statictics, offshore wave statistics, refraction results, or LEO data. Due to the difficulty of obtaining any wave data for the Galveston area, the wave used in design the the breakwater system is a modification of LEO data from a previous project. Hurricane waves were used as a refernece during damage estimations to consider extreme condition.

The following is a list of references used throughout this design to for information pertaining to local conditions.

(1) "Galveston Beach Groinfield Maintenance Material Placement", Planning Assitance to States Programs, Section 22 Report, USAED, Galveston, Texas, August 1992.

(2) "Galveston County Shore Erosion Study: Feasilbility Report and Environmental Impact Statement", Gulf Study Site Report, Beach Erosion Control, USAED, Galveston, Texas, May 1985.

(3) "Sediment Budget and Coastal Process Analysis for the Upper Texas Coast", Tetra Tech submitted to USAED, Galveston, Texas, 1979.

3.0 SIZING & PLACEMENT OF BREAKWATER

GROINS:

The existing groins are approximately 500 feet long extending from the sea wall out into the Gulf. They extend into the existing surf zone approximately 300-400 feet. Existing beach is approximately 100 feet wide (on average). When the beach is replenished it will be approximately 350 feet wide. With the new fill the groins will extend out into the surf approximately 150 feet (see drawing BWPLAN2).

INFORMATION and CRITERIA:

The breakwater system will be designed so that tombolos will not form. The requirements used are from the SHORE PROTECTION MANUALS as follows:

1) Length (l) is less than or equal to X (not exceeding 2X).
2) Gap width/Wave length (B/L) is less than or equal to 2.

Data obtained from GALVESTON COUNTY SHORE EROSION STUDY:

- Waves are predominantly from the Southeast (26%).
- Most frequent wave height is 2.74 feet, with a period of 5.72 seconds.
- Predominant wave angle from beach _ = 89 degrees
- Water depth d = 5 to 10 feet (a value of 6 feet will be used in the calculations).
- Wave height frequencies:

Table 3.1 Wave Height Distribution

WAVE HEIGHT FROM SOUTHEAST (FT)	PERCENTAGE
0 - .82	2
.82 - 4.1	16
4.1 - 7.38	6
7.38 +	2
	26

PLACEMENT:

The placement of the breakwater was discussed amongst the sitting committee. It was decided that the breakwaters would be located approximately 50 feet out from the existing groins. By placing the larger gap near the end of the existing groins we hope to incorporate the effect of the breakwater's capability of decreasing perpendicular wave energy. And the groins ability to decrease longitudinal (or parallel) long shore transport. By applying both techniques we hope to decrease sediment accretion, and retain the flow of water reaching the beach (see PLAN drawings for layouts).

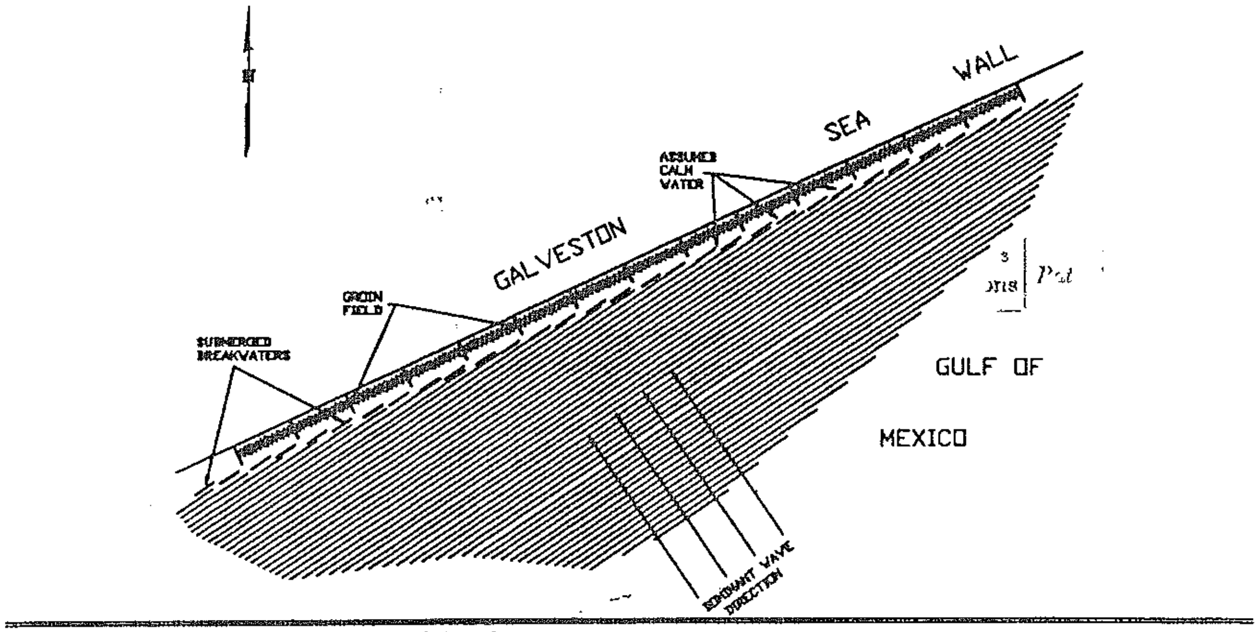


Figure 3.1 Plan View of Proposed Breakwater

CALCULATIONS:

SYMBOLS AS FOLLOWS:

l = BREAKER WATER LENGTH (FT)
L = WAVE LENGTH (FT)
B = BREAK WATER GAP (FT)
T = WAVE PERIOD (SEC)
d = WATER DEPTH AT SITE (FT)
X = DISTANCE FROM SHORE (FT)
α = ANGLE OF WAVE FROM SHORE LINE

Formulas used:

Wave length (L).

$$L = \frac{gT^2}{2\pi}\sqrt{\tanh(\frac{4\pi^2 d}{T^2 g})} = 78.8\,feet$$ (SPM 2-4b)

Breaker length (l) to distance from shore (X) ratio.

$$\frac{450}{532} \Rightarrow \ell = 0.846x$$

Gap width (B) to wave length (L) relationship.

$$\frac{B}{L} = \frac{140}{78.8} = 1.78$$

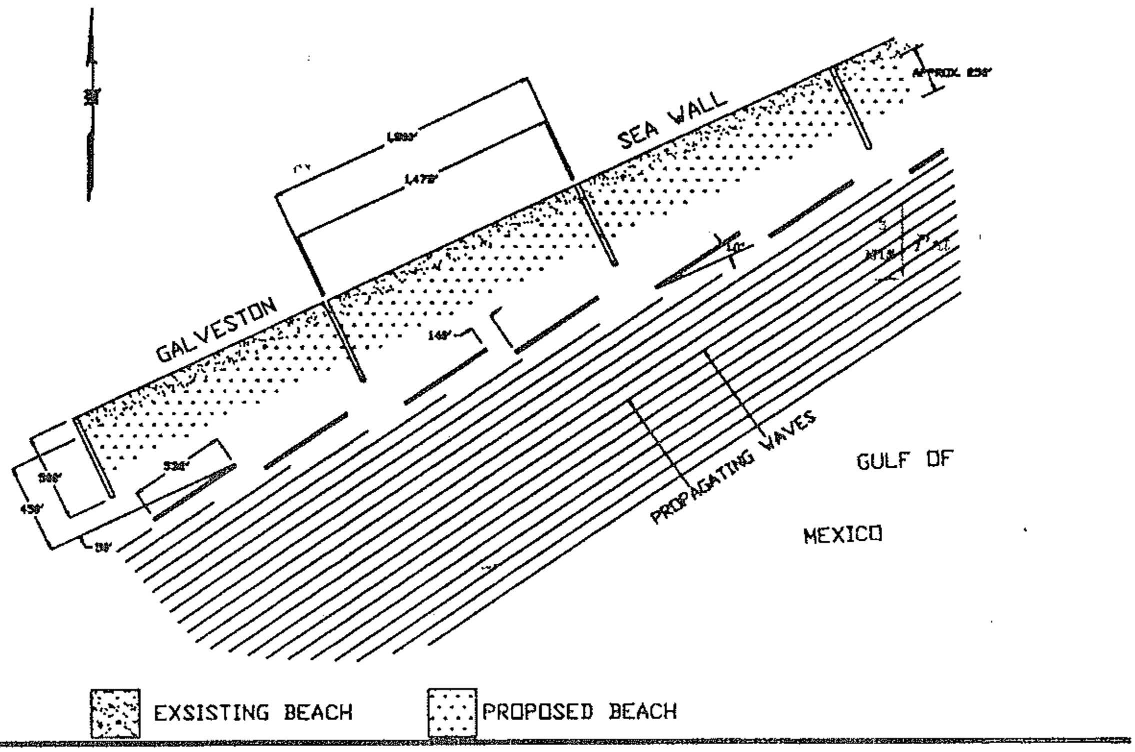


Figure 3.2 Typical Section of Breakwater

RESULTING CONDITIONS:

DIMENSIONS-

The length (l) of the breakwater will be 532 feet long with a middle gap width (B) of 140 feet. This will leave a gap between the breakwater and the groin of approximately 135.5 feet (271 feet between breakwaters). The near shore side of the breakwater will start 50 feet out from the end of the groin.

COMPARISON TO EXISTING DESIGNS

From model studies and past successful breakwater designs, it has been shown that the performance of an offshore breakwater is dependent upon the placement of the structure relative to the beach and the incident waves, the properties of those waves, and the sediment characteristics of the site. Through dimensional analysis, the following relationship can be derived:

$$\frac{Q_b}{XBD} = f\left(\frac{X}{B}, \frac{X_{br}}{B}, \frac{H_o}{L_o}, \frac{G}{B}, \alpha, \ldots\right)$$

where

Q_b = volume of sand transported into the shadow of the breakwater that is defined by (X)(B)(D)
X = distance from the original shoreline to the seaward edge of the breakwater
B = overall length of the breakwater
D = depth of the water on the seaward edge of the breakwater
X_{br}= the distance from the shoreline to the breaker line
G = the gap distance between successive breakwaters
α = the angle of incident wave crests

This expression shows a dependence of the sand deposited in the shadow of the breakwater on the geometeric parameters of the structure.

In 1986, Harris and Herbich examined the effects of G/B and X/B on Q_L. It was shown that generally, sand volume increases as G/B goes down. All the field data collected showed that tombolos formed in all instances when X/B was less than one. Not once did a tombolo form when X/B was greater than one. The relationship of Q_b to X/B is shown in Figure 3.3.

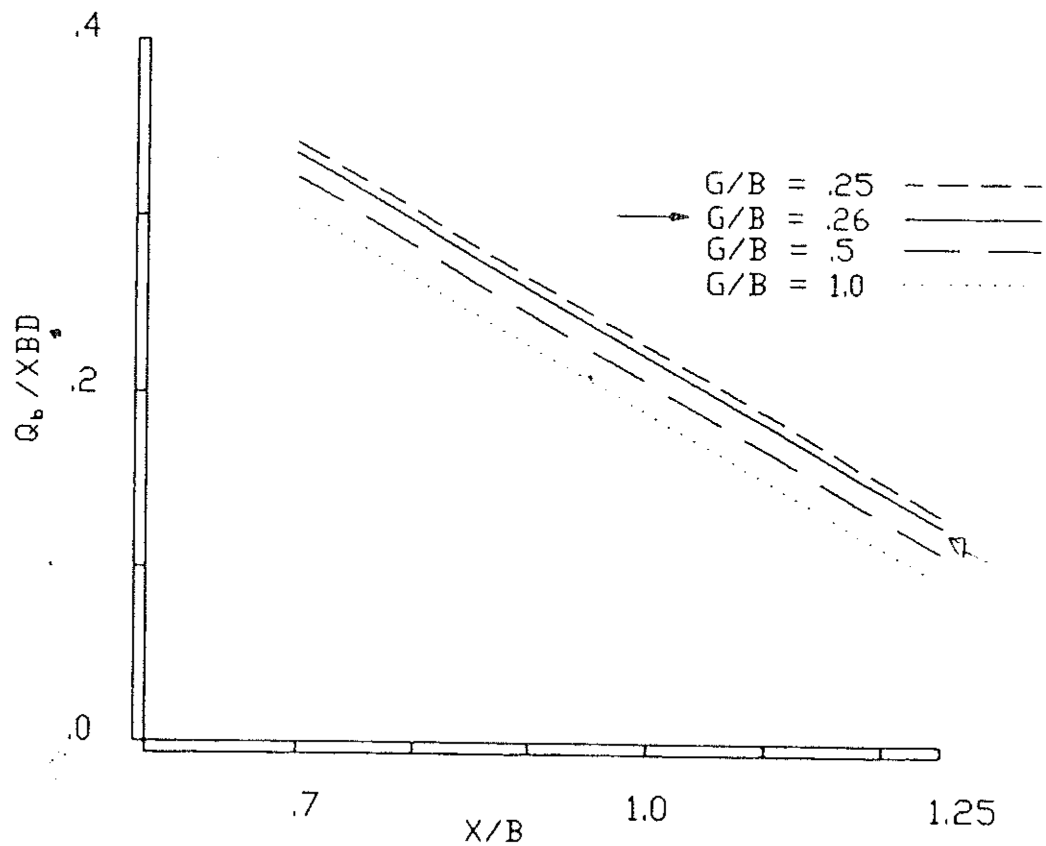


Figure 3.3 Effect of gap spacing on sand accretion behind each breakwater, (Galveston , G/B=0.26)

4.0 WAVE DIFFRACTION

Breakwaters have both detrimental and beneficial effects on the shore. The reduction of the incident wave action causes a subsequent reduction in the longshore transport. This reduction of the transport causes sand to accumulate behind the breakwater. The effects of the sand accretion are shallowing of the leeward side of the breakwater and creation of tombolos. Therefore, a good examination of the diffraction and reflection of the waves past the breakwater is essential to its design.

Diffraction is created by the energy transfer laterally along a wave crest. As the wave passes the breakwater its energy is transferred around the breakwater and into the leeward area. The wave height of leeward side wave is determined by a diffraction coefficient, K'. This coefficient is determined by the incident wave direction in relationship to the breakwater. Figure 4.1 shows the values for K' with respect to an incident wave at 90° (SPM, p 2-83). Each arc is spaced one radius-wavelength unit apart and rays are 15° apart. The scale of the hydrographic chart is 1:1600. This chart represents the diffraction past a typical groin along the Galveston seawall. Figure 4.2 represents the wave height past the groin by using the diffraction coefficient from Figure 4.1. The formula used to calculate the wave height:

$$H = K' H_i$$

Where H represents the wave height in the leeward area and H_i is the incident wave height, 2.74 feet for Galveston.

The effect of wave diffraction past a breakwater water gap is dependant on the gap to width ratio. The gap between the breakwaters is 140 feet and the design wave length is 78.8 feet. Therefore, the gap to width ratio is determined to be 1.77. Using Figure 4.3 , for a 90° incident wave passing a gap of width less than 1.78 wavelengths, leeward side wave heights are calculated. This information is useful in determining the wave climate in the leeward area of the breakwater and the expected amount of longshore transport.

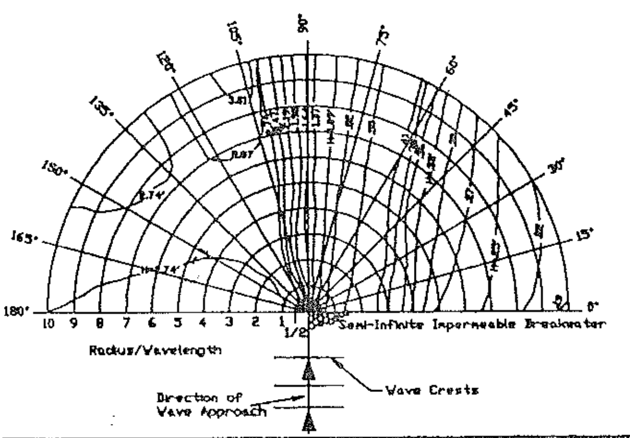


Figure 4.1 Diffracted Wave Height
90 degree angle
H_i=2.74 ft

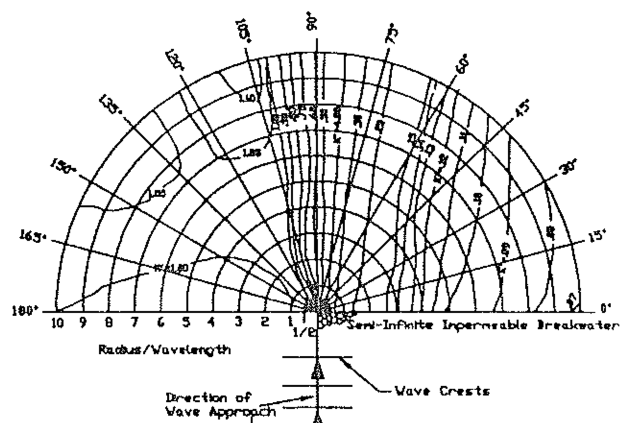


Figure 4.2 Diffraction Coefficient
90 degree angle
H_i=2.74 ft

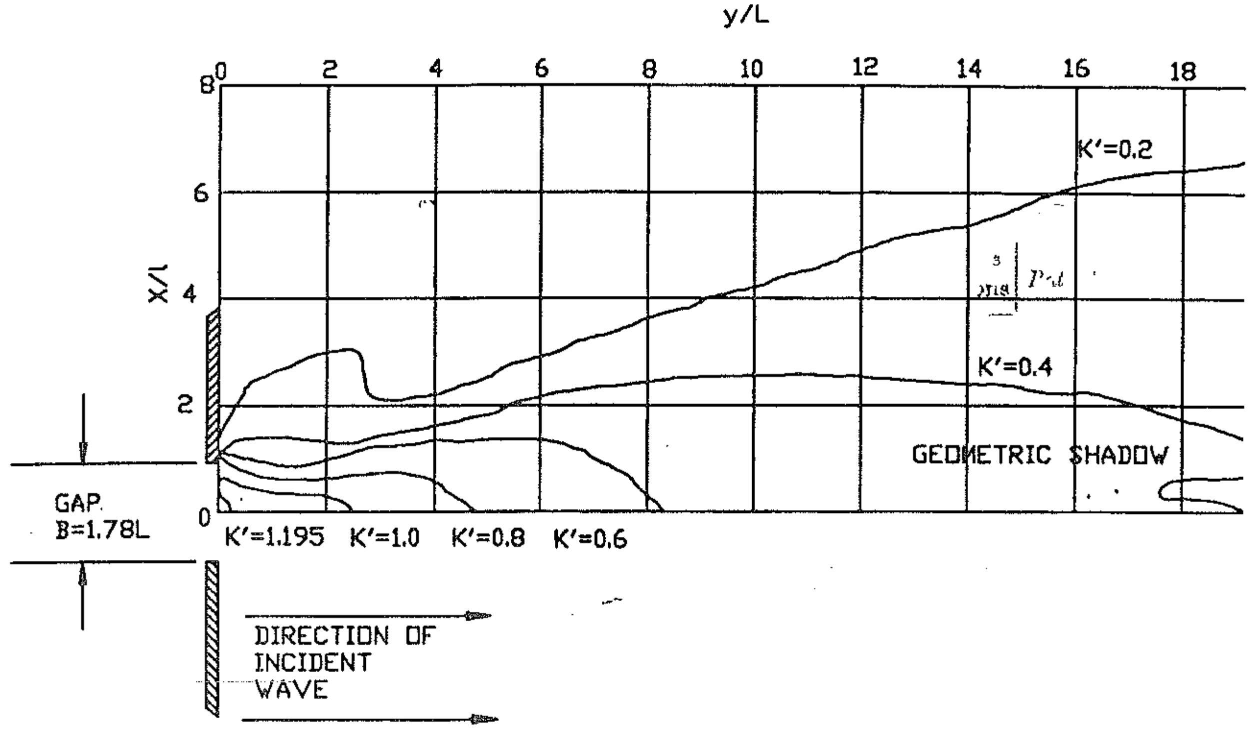


Figure 4.3 Contours of equal diffraction coefficient gap width = 1.78 wavelengths (B/L=1.78)

5.0 BREAKWATER CROSS SECTION DESIGN

The design of the breakwater will proceed as stipulated for rubble structures in the SPM. The cross section determination will assume the following:

- 1 on 1.5 slope
- nonbreaking waves
- no overtopping, except in severe storms

The slope of cotθ=1.5 is recommended as the angular limit for a breakwater. Nonbreaking waves are assumed because the data available for the stability coefficient is not reliable for breaking conditions. The requirement for no overtopping combined with low transmission through the structure allow the designers to neglect shoreside effects in preliminary design.

Before further estimations of the breakwater design can be made, the wave characteristics for the area must be determined. Wave data values are found in a recent document prepared by Romeo Garcia (21 Nov 1991). His data reflects monthly measurements for wave height, period, and tidal levels. Garcia's information is based on LEO data. The LEO Program, conducted by the Corps of Engineers, provides the following data for the Galveston area:

Table 5.1 LEO DATA

MONTH	# OF VALUES	Hs (ft)	BREAKER PERIOD (sec)	BREAKER STEEPNESS (ft/ft)	BREAKER ANGLE	LONGSHORE ENERGY FLUX (ft/sec)	MEASURED CURRENT VELOCITY (ft/sec)
January	36	2.79	6.61	0.032	88	10.36	0.3
February	21	2.98	5.63	0.038	89	6.11	0.3
March	31	3.32	5.37	0.042	87	23.97	0.1
April	28	3.31	5.59	0.041	88	15.88	0.2
May	19	3.11	5.86	0.039	87	20.21	0
June	13	3.36	5.98	0.038	92	-16.49	-0.2
July	19	1.67	6.25	0.026	94	-5.73	-0.6
August	17	2.11	5.51	0.033	91	-2.58	-0.3
September	21	2.31	5.55	0.034	88	6.46	0.4
October	21	2.81	5.03	0.042	86	21.04	0.5
November	23	2.65	5.66	0.036	85	22.67	0.6
December	26	2.46	5.63	0.035	89	3.78	0
ANNUAL	**275**	**2.74**	**5.72**	**0.036**	**89**	**8.81**	**0.1**

Based on the assumptions and the provided wave data, the design can continue. The calculations describing the cover layers follow the stability formula. This formula, generated after experimentation by Iribarren, Nogales Y Olano, and Hudson, determines the stability of armor units on rubble structures. The expression allows empirical estimations of the breakwater cross section. The stability formula can be represented by

$$W = \frac{w_r H^3}{K_D (S_r - 1)^3 \cot\theta}$$

where

$W=$ weight in pounds of an individual armor unit in the primary cover layer

$w_r=$ unit weight of armor unit in lb/ft3

$H=$ design wave height at the structure site in feet

$S_r=$ specific gravity of the armor unit, relative to the water at the structure

$\theta=$ angle of structure slope measured from horizontal in degrees

$K_D=$ stability coefficient

Using the stability formula, the assumptions made previously, and the wave data, the weight of an individual armor unit was determined. A decision was made to concentrate on using Quadripod armor units weighing 162 lb/ft^3. The stability coefficient for a Quadripod on a 1.5 slope is given as 6.0 (SPM, p.7-206). The design wave height H was determined from the LEO data and factored to a H_1 wave, where $H=H_1=1.667H_s$. The individual weight was as follows:

<u>ARMOR WEIGHT DETERMINATION</u>

$$W = \frac{w_r H^3}{K_D (S_r - 1)^3 \cot\theta}$$

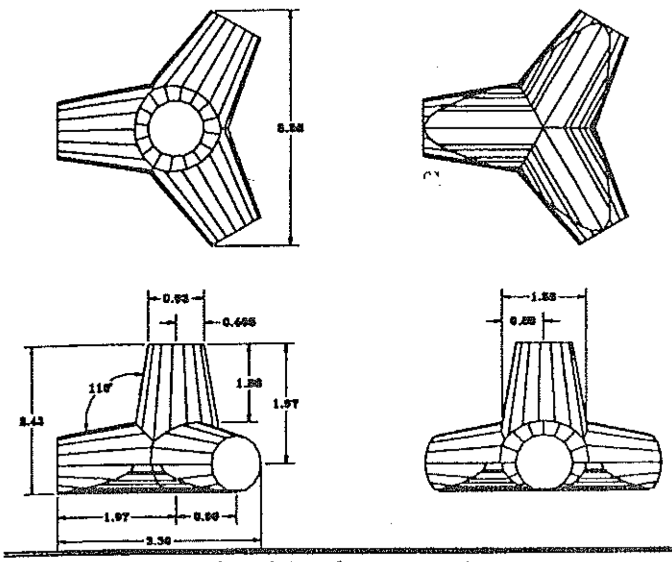
$$W = \frac{(162\frac{lb}{ft^3})(1.667 \cdot 2.74 ft)^3}{(6.0)[(\frac{162\frac{lb}{ft^3}}{64\frac{lb}{ft^3}}) - 1)^3 (1.5)}$$

$$W = 1074.93 lb$$

$$W = 0.537 tons$$

The calculated weight of the individual armor unit drives the size selection for the Quadripod. Our values require the use of the smallest available Quadripod armor unit at the 162 lb/ft^3 level. The rest of the cross section material weights is based on the initial value determined for the armor unit. The tabulated information on the armor (SPM, p.7-219) is summarized in Figure 5.1.

Further design of the cross section consists of the crest elevation and width. It has been decide to have a crest on the rubble structure that will prevent overtopping except in the case of waves during severe storms or with long return periods. The selection of the size for the crest width and the breakwater height must adhere to this criteria. Overtopping of the structure relies upon the wave runup, R. Runup depends on the wave characteristics, structure slope, porosity, and roughness of the cover layer. For estimation purposes, our structure is considered as a rubble slope; this leads to lower values for the crest elevation than if model testing of the armor unit slope was performed. Also, for the purpose of the calculations, the water depth at the lowest elevation of the breakwater is taken as 9 feet. After allowing for tide, the water depth can then be modified to 12 feet. Given these assumptions, the wave height, wave period, and the graph of R/H_0'(SPM, Fig. 7-20,p.7-31), the runup can be calculated.



VOLUME	7.14 ft^3
WEIGHT	0.58 tons
THICKNESS OF TWO LAYERS PLACED PELL-MELL	3.66 ft
# PER 1000 FT^2	261.05

Figure 5.1 Quadripod armor unit
SOURCE: SHORE PROTECTION MANUAL, FIGURE 7-110.
**NOTE: The Quadripod is patented, but the U.S. patent has expired. Patents may still be in force in other countries however; payment of royalties to the holder of the patent is required.*

RUNUP CALCULATIONS
For a 1 on 1.5 slope:

$$\frac{H_o'}{gT^2} = \frac{2.74\,ft}{(32.2\frac{ft}{s^2})(5.72s)^2}$$

$$\frac{H_o'}{gT^2} = 0.002601$$

using the graph and 0.002601

$$\frac{R}{H_o'} \approx 1.04$$

$$\therefore R = 1.04 \cdot 2.74\,ft = 2.85\,ft$$

So, say the runup R is 3.00 feet. This provides for a breakwater height of 15 feet (12 feet + 3 feet). At low tide, 6 feet of the breakwater will be exposed subaerially.

The crest width is calculated on the basis of the general guide presented in the SPM. Consider for overtopping conditions that the minimum crest width should be equal to the combined widths of three armor units. This can be shown by

$$B = nk_\Delta\left(\frac{W}{w_r}\right)^{1/3}$$

where

B=	crest width, ft
n=	number of stones(n=3)
k_Δ=	layer coefficient
W=	weight of armor unit in primary armor layer, lb
w_r=	specific weight of armor unit. lb/ft^3

The calculations based on this expression deliver a crest width value of approximately 6 feet. This same value is used for the total layer thickness on the sloping face of the breakwater. Our simplified breakwater consists of two layers of primary armor (3.66 feet), a layer of W/10 cover (2.44 feet), and a graded underlayer estimated at a stone size of W/500. The primary armor and secondary layer add up to 6 feet in thickness. The W/500 underlayer extends from that level to the filter blanket. The position for the filter blanket and the structure toe are determined as stipulated in the SPM (pp.7-233 to 7-248). The use of a filter blanket is not required if small currents are expected around the footing of the breakwater. To account for possible irregularities in current velocities, the structure protrudes 3 ft below the mudline, and the filter blanket is placed 1 ft above the bedding layer. (See figure 5.3).

The wave height of 2.74 feet is assumed as a no damage wave height. To account for seasonal exceedence of this limit and storm action, calculations have been made to determine wave heights associated with percentages of damage. The determination is based on tabulated values provided (SPM, Table 7-9, p. 7-211).

Table 5.2 Damage Wave Height (Based on $H_{D=0}$ = 1.66(2.74 ft))

% of Damage	H/H_D	H (ft)
5 to 10	1.09	4.97
10 to 15	1.17	5.33
15 to 20	1.24	5.70
20 to 30	1.32	6.02
30 to 40	1.41	6.43
40 to 50	1.50	6.84

For aesthetic and economic reasons, it has been decided to not extend the armor units along the entire 532 foot length of the breakwater. Instead, both ends will be rounded and constructed of quarry stone matching the appearance of the groins. This reduces the amount of Quadripods that must be purchased, avoids the troublesome placement on the rounded surfaces, and adds a visible similarity between the new structure and the existing groins.

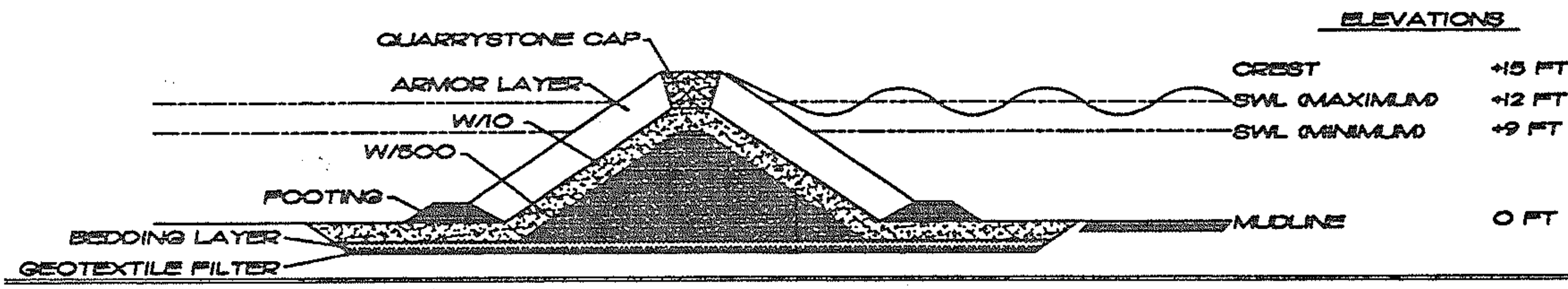


Figure 5.2 Typical Breakwater Cross Section

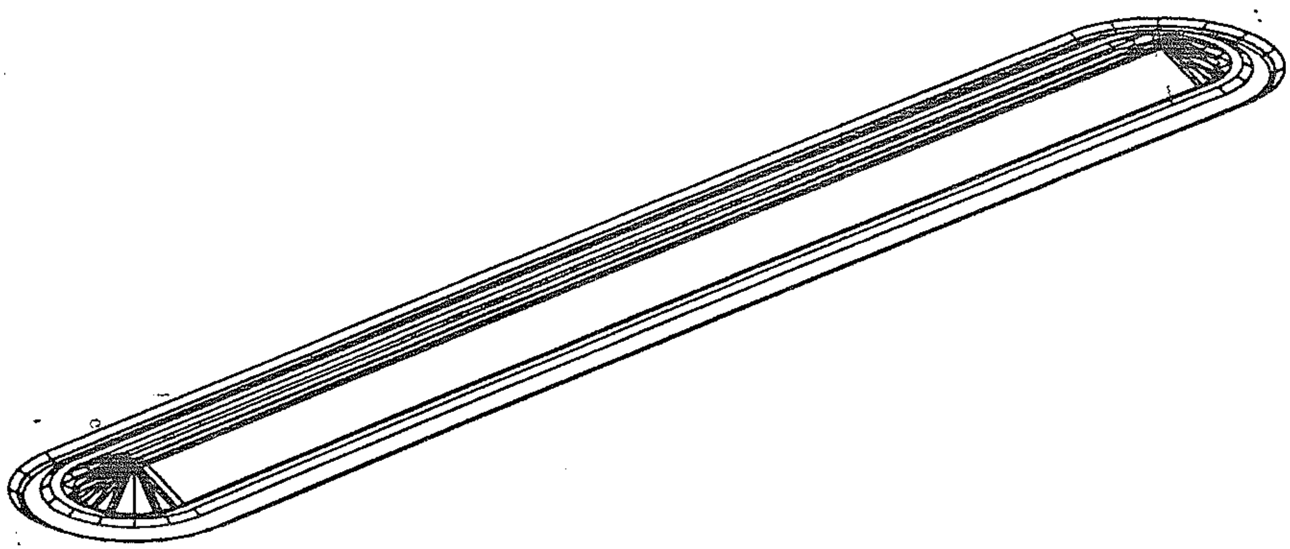


Figure 5.3 3-D Perspective of Typical Breakwater

6.0 ECONOMIC BENEFITS

The Galveston County Parks board estimates that just over six million tourists visit Galveston beaches annually. Most of these visits occur in the summer months from April to September. Several holidays such as Labor Day, the Fourth of July, and Memorial Day occur in this prime tourist season. The proposed beach renourishment project is hoped to give the area increased tourism profits. Is this assumption accurate?

Preliminary research done by the Park Board estimates an increase of about 10 percent in the number of tourists that will visit the beaches. This means an additional six hundred thousand people will come to Galveston over a year's time. Whether or not this increase will provide substantial additional income to the area depends on several factors. These factors include the following:

1. Amount of money spent during the average trip.
2. Percentage of tourists that remain overnight.
3. Number of people that return for future visits.
4. Overall cost of renourishing the beaches.

The amount of money spent in Galveston depends on the type of trip. For example, Galveston sees approximately one hundred thousand visitors on an average summer weekend. Most of these tourists are day visitors, but some will stay overnight. Galveston has an estimated 4000 hotel and motel rooms available with and additional 200 or so in the form of boarding houses and rental beach property. Estimating 85 percent occupancy with two people per room, just over seven thousand people stay in Galveston hotels. According to the Park Board, the average overnight visitor spends $125/day. This gives a daily income to the city of $892500/day for overnight visitors. The rest of the beachgoers visit for the day only. These visitors come from nearby areas and spend an average of $25/day. With approximately 43000 day visitors, $1,075,000/day can be generated. The numbers proposed above are for one day in the average summer weekend. The total amount of money generated in a weekend would be about $3,935,000. NOTE: These numbers are the amount **spent** in Galveston and should not be considered profits made by Galveston merchants.

The increase of ten percent would mean that almost eight thousand visitors would stay overnight giving the hotels a 95 percent occupancy rate. Also, the number of day visitors would increase to about 47000 people a day. This increase would give an increase of $125,000 for overnight guests, and $100,000 for day visitors. The net increase of money flowing into Galveston would be about $450,000 per summer weekend.

Looking at the whole summer as an economic period, we can estimate the total revenue generated by the tourism industry. The number of rooms available in Galveston translates to about 14 percent of the visitors being able to stay overnight at 85 percent occupancy. This means that 840,000 people will stay in hotels during the tourist season. Making the assumption that these people stay for just one night, the income from these guests is about $105 million dollars a year. If the remaining 5.16 million people are day visitors only, they bring approximately $129 million to the area annually. The estimated ten percent increase will bring an additional $23 million annually.

The goal of the beach renourishment project is to make the beaches more enjoyable for the tourists who frequent them. The additional beach area proposed will provide a more aesthetically pleasing beach with greater space allotments for each visitor. This strategy is aimed at visitors who will have opportunity for future visits to the area. The good beaches also provide for "word of mouth advertising" of the area that may increase the number of visitors in the off-season months.

How much will the renourishment cost? The current plan for funding the beach renourishment has two main points. First, one cent is to be taken from the hotel, motel room tax. This one cent should provide the city with about 2.4 million dollars. Second, bonds are proposed to raise any additional money needed for the project. The current cost estimate for the project is in the neighborhood of 4 million dollars.

Table 6.1 Tourist Statistics

	CURRENT		WITH 10% RISE	
	ANNUAL	WEEKEND	ANNUAL	WEEKEND
TOTAL VISITORS	6000000	100000	6600000	110000
OVERNIGHT GUESTS	840000	14280	924000	15708
DAY VISITORS	5160000	85720	5676000	94292

Table 6.2 Commerce Statistics

	CURRENT ANNUAL	WITH 10% RISE ANNUAL	NET INCREASE IN EXPENDITURES
TOTAL VISITORS	234000000	257400000	23400000
OVERNIGHT GUESTS	105000000	115500000	10500000
DAY VISITORS	129000000	141900000	12900000

7.0 COST ESTIMATION

As a source of information on this project, Mr. Carl Wiles was used. He has held the position of project manager on many similar projects, both for the Corps of Engineers and private individuals. His previous experience include the Municipal Breakwater for the city of Cleveland, and the breakwater at the mouth of the Clombia River.

One of the first tasks is to determining the type of equipment to be used. Due to the small size of the armor stones, a rig capable of handling a 3 cubic yard bucket was chosen. Along wiht the rig, a tow boat, spud barge, and 3 material barges will be neede. The estimated cost for the equipment is 17,100 dollars per month, see table.

The office personnel is estimated to be 3 persons earning managerial wages of 20 dollars and one assistant earning 10 dollars per hour. There will be three 8 hour shifts for this crew.

Material quantities are next to be calculated. The ends of the individual breakwaters do not have the armor unit covering. The total quantity of stone is estimated to be 281,687 cubic yards(see table). The stone is estimated to cost 15 dollars per ton (average for the several sizes). The stone is also estimated to occupy 1.5 cubic yards per ton. Utilizing these values, the total cost of the stone material is estimated to be 6,330,750 dollars (see table).

The armor units themselves weigh approximately 1000 pounds per unit. The total number of units required, using a 261 per 1000 square feet of coverage, is estimated at 230,707 units. These units contain approximately .25 cubic yards of concrete each. The cost per unit is estimated to be 25 dollars (see table).

The next step is to estimate the time required to complete the job. It is estimated that the rig, with a competent perator, can make one lift of 3 cubic yards in 1.5 minutes. For the armor units it is estimated at one lift per 1.1 minutes. Utilizing a 50 minute work hour and a 24 hour work day, it is estimated that 2400 cubic yards of stone can be placed per day. Utilizing this and the 30 percent downtime, it is estimated to take 168 days to place the stone. Utilizing the same information it is estimated to take 302 days to complete the placement of the armor stone.

The office crew is considered to work on all days, even blowouts (470 days). The labor crew is considered to work only on the days that material is placed (329 days). The labor cost over the time period of the job is next considered. Now with this information the total net line cost for the job is calculated. Multiplying this by 15 percent profit and miscellaneous ratio, a final total for the job is estimated at 16,175,385 dollars.

ESTIMATION OF COSTS

TOTAL LENGTH OF BREAKWATERS	15,960 ft
LENGTH OF ARMOR UNIT PROTECTED SURFACE	13,620 ft

MATERIAL	AREA	LENGTH(ft)	CUBIC ft	CUBIC yds
W/10	154.40	15690	2457840	91032
W/500	194.94	15690	3111242	115232
BEDDING	94.00	15690	1500240	55565
CAP & ENDS	12.96	13620	527515	19538
	150.00	2340		

261 ARMOR UNITS PER 100 sf WALL: 883937 sf WALL, 230707 ARMOR UNITS
COST OF 25$ PER UNIT **TOTAL = 5,767,688**

CAN PUT 1200 TON OR 1800 cy ON BARGE (1.5 T/cy) STONE ON AVG. 15$
281,376 TOTAL cy OF STONE OR 422,050 TON **TOTAL = 6,330,750**

TIME ASSUMPTIONS: EQUIPMENT USES 3 cy BUCKET 50 min hrs
CAN MAKE LIFT EVERY 1.5 min 30% downtime

STONE:
IN ONE DAY MAKE 800 LIFTS OR 2400 cy (3,8 hour shifts)
TAKE 118 DAYS + DOWNTIME 168 days
ARMOR UNITS: ASSUME 1 LIFT PER 1.1 min
IN ONE DAY MAKE 1090 LIFTS
TAKE 211 DAYS + DOWNTIME 302 days

TAKE A TOTAL OF 329 WORD DAYS OF 470 TOTAL DAYS

EQUIPMENT:

PIECE	RATE PER MONTH
SPUD BARGE	3500
CRANE	7500
TOW BOAT	5000
3 MATERIAL DECK BARGES	1080

TOTAL (x470/30) 267900

OFFICE LABOR:

# OF PEOPLE	PAY RATE	HOURS	PLUS 30$ RENT
3	20$	8	
1	10$	8	
x470 DAYS		277300	

CREW LABOR:

7	20$	(3x8),24	
x329 DAYS		1105440	

COST TOTALS:

STONE	6330750
ARMOR	5767688
EQUIPMENT	267900
CREW LABOR	1105440
OFFICE LABOR	277300
TOTAL	13749088
15% PROFIT & MISC.	$16,175,385

8.0 CONCLUSION AND RECCOMMENDATIONS

This design project represents a great deal of hard work in a short period of time. The work presented on the configuration of the breakwater is purely empirical, and, like most coastal structures, should be re-analyzed and model tested. If time permitted, we would have liked to generate a two-dimensional model in our wave basin for more reliable design results. Nonetheless, this project follows the design process presented in the SPM, and is comparable to other projects.

The proposed plan for renourishing the beach in front of the Seawall raises some interesting questions. Unfortunately, this breakwater is not an answer to any of them. The high cost and length of time required to implement make this project impractical. The new beach face is purely recreational in nature, and protection of something that is of no environmental importance to the coastal zone is not worth 16 million dollars. If the present conditions required that sand be placed as protection for some hazard to the seawall - undermining of the toe, pile exposure - then protection of the replaced beach might warrant a project on the grand scale of an offshore breakwater. Until such problems arise, the City of Galveston will just have to hope their recreational beach does not wash away.

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