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NAS KEY WEST
5090.3a

INSTALLATION RESTORATION SITE 8 SHORELINE PROTECTION SYSTEM FLEMING KEY SOUTH LANDFILL NAS KEY WEST FL
12/17/1996
OCEAN BREEZE CONSTRUCTION

IR-8 SHORELINE PROTECTION SYSTEM

Fleming Key South Landfill

NAS Key West

DESIGN REPORT

December 17, 1996

Ocean Breeze Construction Co., Inc.
Delon Hampton & Associates, Chartered

22567-321-0248-0010-(1)-2

012145

Bechtel

Oak Ridge Corporate Center
151 Lafayette Drive
P.O. Box 350
Oak Ridge, Tennessee 37831-0350

Telephone: (423) 220-2000

FEB 10 1997

Commanding Officer
Southern Division
Naval Facilities Engineering Command
Attention: Dudley Patrick 1858
2155 Eagle Drive
North Charleston, SC 29406

SUBJECT: Bechtel Job No. 22567
Department of the Navy Contract No. N62467-93-D-0936
DO 0004, NAS KEY WEST, SHORE PROTECTION SYSTEM
Subject Code: 5040

Dear Mr. Patrick:

Enclosed are the final drawings and the design report for the Shoreline Protection System for IR-8 at Fleming Key. This final revision to the drawings includes all the changes necessary for the slope change to 3:1 and to allow the use of excavated material as backfill. A supplement to the design report is being prepared by Ocean Breeze to address the slope changes and will be forwarded to you as soon as it is available.

If you have any questions or comments, please feel free to give me a call at (423) 220-2745 or Roy Hoekstra at (423) 220-2271.

Sincerely,

O. N. McNeil, Jr.
Project Manager

REH:dcm:LR1091
Enclosure: As stated

cc: M. Ewing (ROICC) w/e
P. Williams (NASKW) w/e

IR-8 SHORELINE PROTECTION SYSTEM

Fleming Key South Landfill

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Introduction

The NAS Key West has used the southern portion of Fleming Key as a solid waste landfill for decades. Tidal fluctuations and wave action along the existing shoreline have caused significant erosion compromising the integrity of the solid waste landfill. The purpose of this project is to establish a shoreline protection system along 1,800 feet of the southwest portion of Fleming Key to protect the existing solid waste landfill from further degradation. See Attachments 1 and 1a for location of the project site.

The design of the shoreline protection system is based upon the RFP 22567-321-SC-0248, Addendum No. 5 and considers the following parameters:

- Cost effectiveness
- Longevity of the system
- Damage limitation
- Scour and flank protection
- Permeability
- Appearance
- Environmental criteria

Design Analysis

- Cost Effectiveness

  The baseline for cost comparison is stone fill (rip rap) over a geotextile liner keyed into the shoreline. Based upon previous correspondence between Ocean Breeze Construction Company and Bechtel Environmental, Armorflex articulated concrete block (ACB) was determined to be a cost effective alternative to the baseline stone fill over geotextile liner system. See Attachment 2 for information on the Armorflex ACB System.

- Longevity of the System

  The Armorflex ACB is comprised of a series of individual concrete blocks placed together to form a continuous embankment overlay. Concrete is a very durable material used extensively in saltwater environments. The 50-year design life specified is attainable with the use of concrete.

  For placement of the ACB mats, a flexible polyester cable will be inserted through the blocks to simplify the installation process. The cable is only needed for ease of installation and is not a factor in the design of the ACB system. See Attachment 3 for

22567-321-0248-0010-(1)-2

information on the polyester cable used for placement of the ACB mats. The Armorflex ACB shoreline protection system is designed in accordance with USACE Shoreline Protection Manual, Armorflex Design Manual, Nicolon Corporation "Armor" Wave Program, Mirafi Geotextile Filter Design, Application and Product Selection Guide, and sound engineering judgment. The Armorflex Wave program used to evaluate and size the Armorflex ACB System is provided as Attachment 11.

The design of the shoreline protection system considers the 50-year storm surge, the 50-year wave, and the 10 percent exceedence astronomical tide level. Based upon the Federal Emergency Management Agency Flood Insurance Study, Monroe County, Transect No. 1 in Man of War Harbor, Table 2, the 50-year storm surge still water elevation is +5.5 NGVD, as shown on Attachment 4.

Water surface elevations are based upon the National Geodetic Vertical Datum (NGVD) of elevation 0.0. The depth of water at the structure, considering the 50-year storm surge (+5.5 NGVD) and the 10 percent exceedence astronomical tide level (+0.55 NGVD) is equal to a still water elevation of +6.05 NGVD.

When a wave moves into increasingly shallow water, the limiting steepness which it can attain prior to breaking decreases. In other words, a wave will move toward a shore until the water becomes shallow enough to initiate breaking.

The existing grade at the proposed structure varies along the length of the project between elevation 0.5 NGVD near station 15+00 and elevation 3.0 NGVD near station 9+00. To be conservative, we have assumed the existing grade elevation at the structure is 0.5 NGVD. This means that at all other locations along this project the significant wave height is smaller.

It is common engineering practice to estimate that the significant wave height is no greater than 60 percent of the depth of the water at the structure. This design parameter of 60% is based upon a technical paper entitled "An Inside Look at Articulating Concrete Block Revetments" by Michael Koutsourias and Joel Sprague as presented at the International Erosion Control Association convention in 1992. Page 54 of the technical paper defines how to determine the design wave height. See Attachment 5 for a copy of the aforementioned technical paper.

Since the water depth was previously shown to be 6.05 feet and the existing grade elevation is 0.5 NGVD, then the significant wave height is no greater than 3.33 feet. The limiting steepness created by the wave moving into shallow water causes the wave to break prior to reaching the structure. Therefore, based upon the design parameters, there is no possibility of waves breaking over the top of the berm.

Another consideration for wave movement toward the shore is wave runup on the structure.

Wave runup calculations were developed for this project and are shown in the Appendix. The calculated runup value for the significant wave is 7.0 feet or elevation 12.55, which overtops the proposed berm with a top elevation of 10.0 feet. The calculated runup value is corrected for scale effects and for the estimated roughness and porosity of the Armorflex block. Since the Armorflex block was not in Table 7-2, a value for Gobi blocks was used. As noted in Table 7-2, the Armorflex block is rougher and more porous and the correction value was adjusted accordingly as shown in the calculations in the Appendix. A scouring protection and drainage system is provided in the form of a back of berm swale for a section of the shoreline protection system. The remainder of any wave runup which overtops the berm will infiltrate into the natural ground or flow back down the revetment into the ocean, as it does in the existing condition.

- Damage Limitation

The specified design parameter for estimated damage on this project is less than 10 percent as defined by the USACE SPM for multiple-layer Armor Stone Protection during a 50-year wave.

The Armorflex design program considers failure of the system as the loss of "intimate contact" between the most vulnerable individual block in the system and the subgrade. Therefore, the design of the Armorflex ACB allows zero damage which is well below the design parameter.

- Overtopping

The specified design parameter for overtopping rate for the 50-year design significant wave height and storm surge shall not exceed 200 liters/sec/meter unless a scouring protection and drainage system is included and is based upon the 50-year values.

Based upon the design calculations for overtopping rate including the effects of wind provided in the Appendix, the estimated rate of overtopping is 75 liters/second/meter, which is below the specified rate. As an extra safety measure, the top and backslope of the berm and the swale will be overlayed with the Pyramat permanent erosion and reinforcement matrix (PERM) to further reduce the potential for erosion along the backside of the berm and the swale. See Attachment 6 for information on the PERM. See the construction drawings for the proposed location of the PERM along the berm.

Overtopping of the berm that occurs between station 9+00 and station 14+00 will be contained in a small swale at the back of the berm and released onto the natural grade to be infiltrated into the ground as in the site's present condition.

Each end of the swale will have an erosion protection apron in the form of rip rap with a d_{50} of 0.40 feet. Each apron will be six feet wide at the end of the swale, 12 feet long, and 14 feet wide, at the end of the apron. The size of the rip rap and dimensions of the apron will allow for energy dissipation of the flow and protect the ends of the swales from erosion.

Calculations for the end of swale erosion protection are shown in the Appendix.

Overtopping of the berm between stations 0+00 to 9+00 and stations 14+00 to 18+00 will infiltrate naturally back into the ground as in the site's present condition.

- Scour and Flank

Scour and flank protection for the Armorflex ACB system is through the use of rip rap along the toe and edges of the revetment.

According to Technical Report CERC-93-8, U. S. Army Corps of Engineers, "Coastal Scour Problems and Methods for Prediction of Maximum Scour" by Jimmy E. Fowler (1993), the maximum scour depth can be estimated using the maximum wave height at the structure. Since the deepwater wave height calculated in the Appendix is 2.36 feet, the maximum depth of scour at the toe of the structure is no greater than 2.36 feet below the bottom. The elevation of the ground at the structure varies throughout the project limits, but is generally at elevation 0.5. In order to prevent scouring from the effects of wave action, the bottom of the revetment should be placed at elevation (-) 2.0 NGVD or the natural bedrock elevation, which is higher. Cover over the embedded toe of the revetment will be 125 pound rip rap between station 0+00 and 15+00 and 125 pound rip rap with sand between station 15+00 and 18+00. Design calculations for the rip rap coverage are shown in the Appendix.

Flank protection at each end of the revetment will encounter no more wave action attack than the toe of the revetment. Therefore, embedment of the flank 4.8 feet into the embankment to prevent the effects of scouring along the flanks of the revetment system will be provided. Cover over the embedded flanks of the revetment system will be 375 pound rip rap as shown in the calculations in the Appendix.

- Permeability

The Mirafi Filterweave 40/10 woven geotextile meets all of the requirements of the specifications for this project. No additional parameters were provided for the permeability of the geotextile fabric. Geotextile technical information is provided in Attachment 12.

- Appearance

The Armorflex ACB is a durable and stable alternative to conventional erosion control revetment systems (rip rap) as shown on the photographs in Attachment 2. The system will blend into the natural surroundings by allowing vegetation to grow into the system without damaging its structural integrity. In order to give mother-nature a head-start, the top three rows of the open-cell blocks will be planted with sea purslane. In addition, the bottom three rows of Armorflex will be planted with red mangroves starting at elevation 0.0 NGVD at the northernmost end of the project between station 15+00 and station 18+00 as the system transitions back to natural grade.

- Environmental Criteria

All environmental criteria within our project scope of work shall be obtained, evaluated and met.

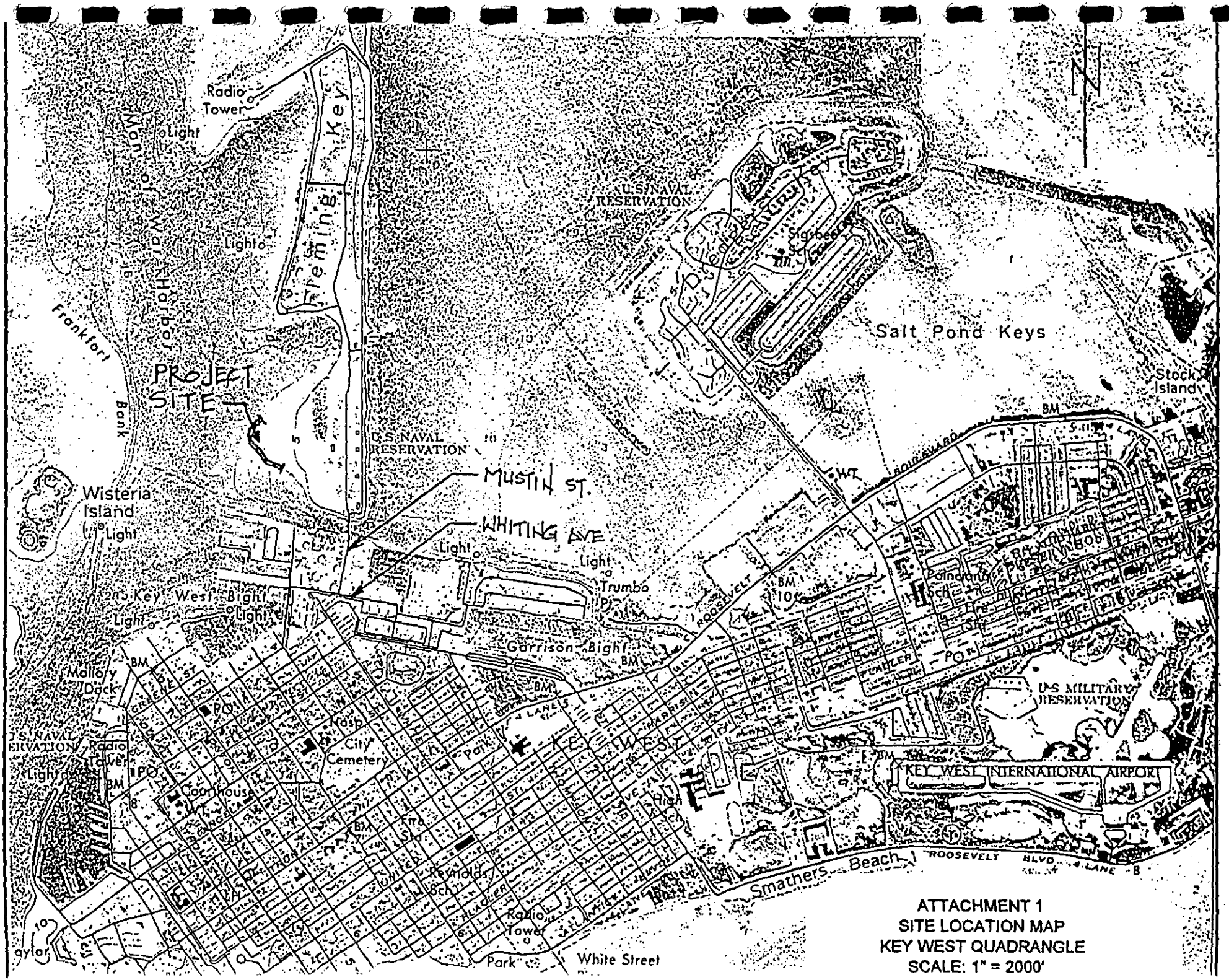
Limitations on erosion control and sediment disturbance will be accomplished during construction through the use of regularly maintained floating turbidity barriers in the disturbance area, minimizing the construction disturbance area to practical working areas, and revegetating disturbed areas as early as practical to reduce the erodible area available.

No alterations to the local littoral drift during the life of the shoreline protection system are expected.

ATTACHMENT LIST

Attachment	Description
1	Site Location Map
1a	Aerial Photo
2	Armorflex ACB System Technical Information
3	Polyester Cable Technical Information
4	FEMA 50-year Storm Surge Information
5	Technical Paper for Design Wave Reference
6	Pyramat PERM Technical Information
7	Preliminary Review Comments and Responses
8	Articulated Concrete Block Specification
9	Polyester Thread Technical Information
10	Construction Schedule
11	Armorflex Wave Calculation Program Printout
12	Geotextile Technical Information
	Appendix

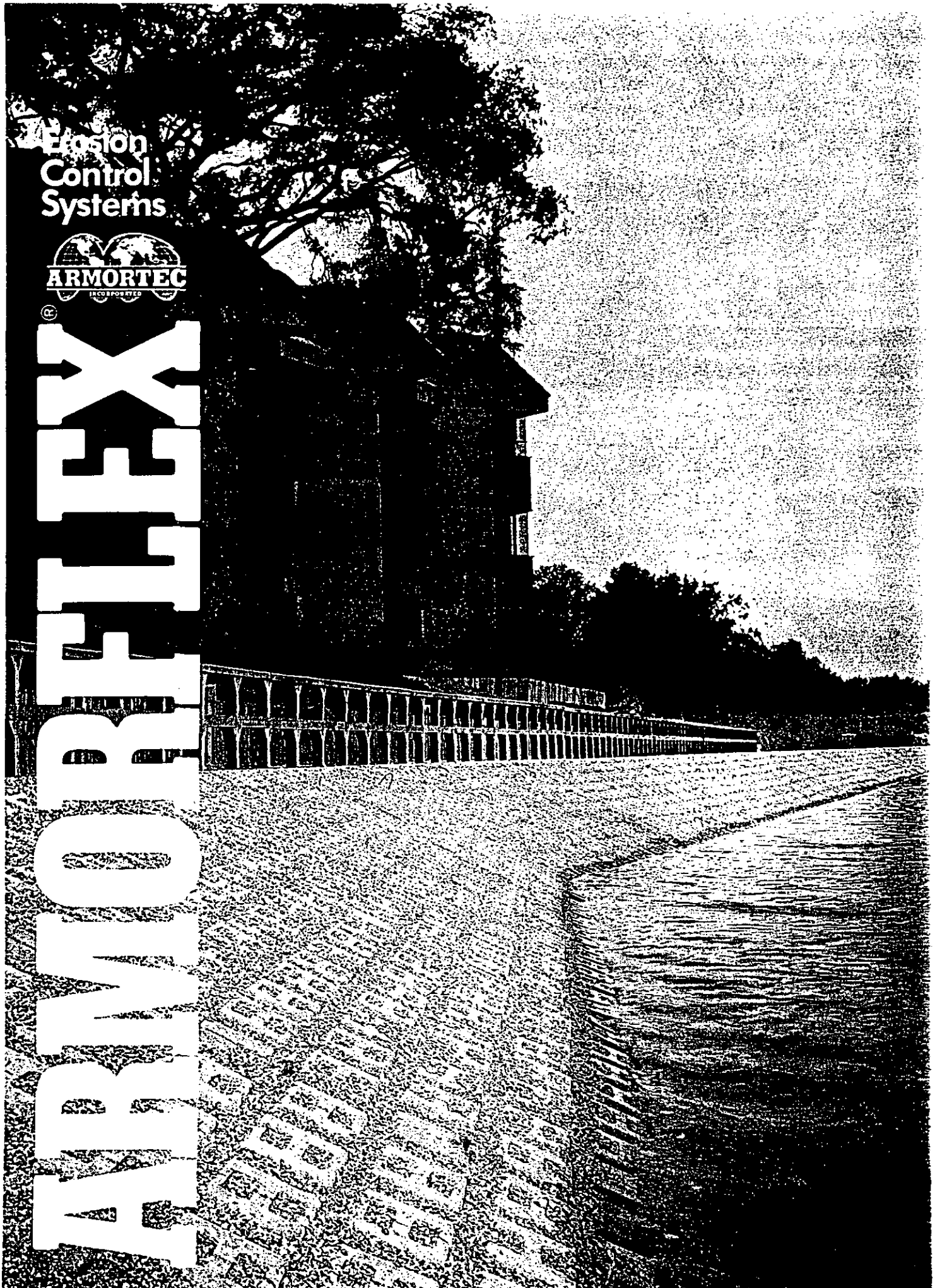
ATTACHMENT 1



ATTACHMENT 1
SITE LOCATION MAP
KEY WEST QUADRANGLE
SCALE: 1" = 2000'

ATTACHMENT 1a
AERIAL PHOTO
SCALE: 1" = 300'

ATTACHMENT 2



ARMOR FLEX®

Erosion Control Systems

ARMORTEC INCORPORATED

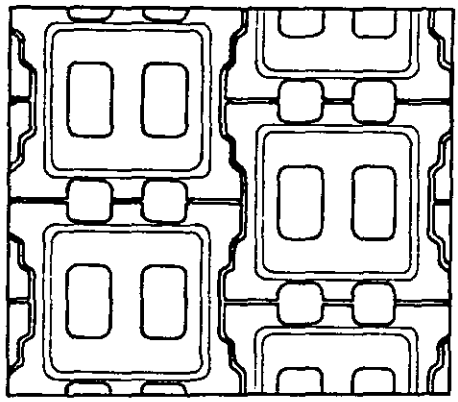
ARMORTEC

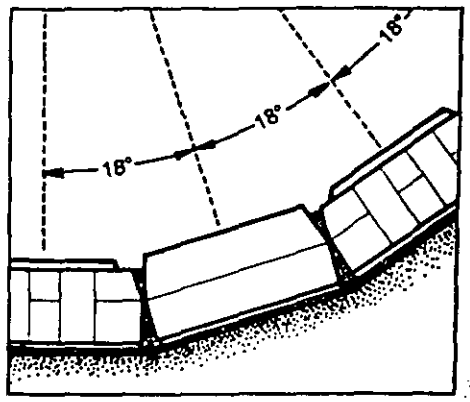
Backfill and compact the trenches as mat placement proceeds.

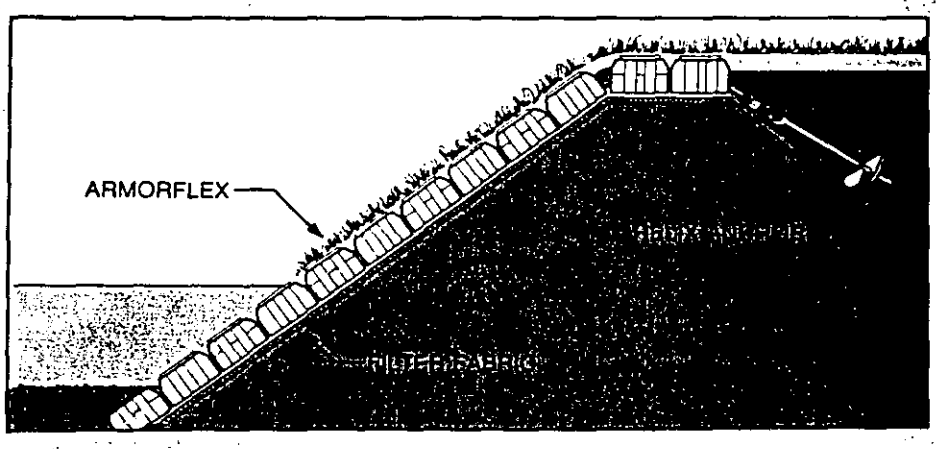
Additional sections of mats are placed and connected until the desired limits of protection are reached.

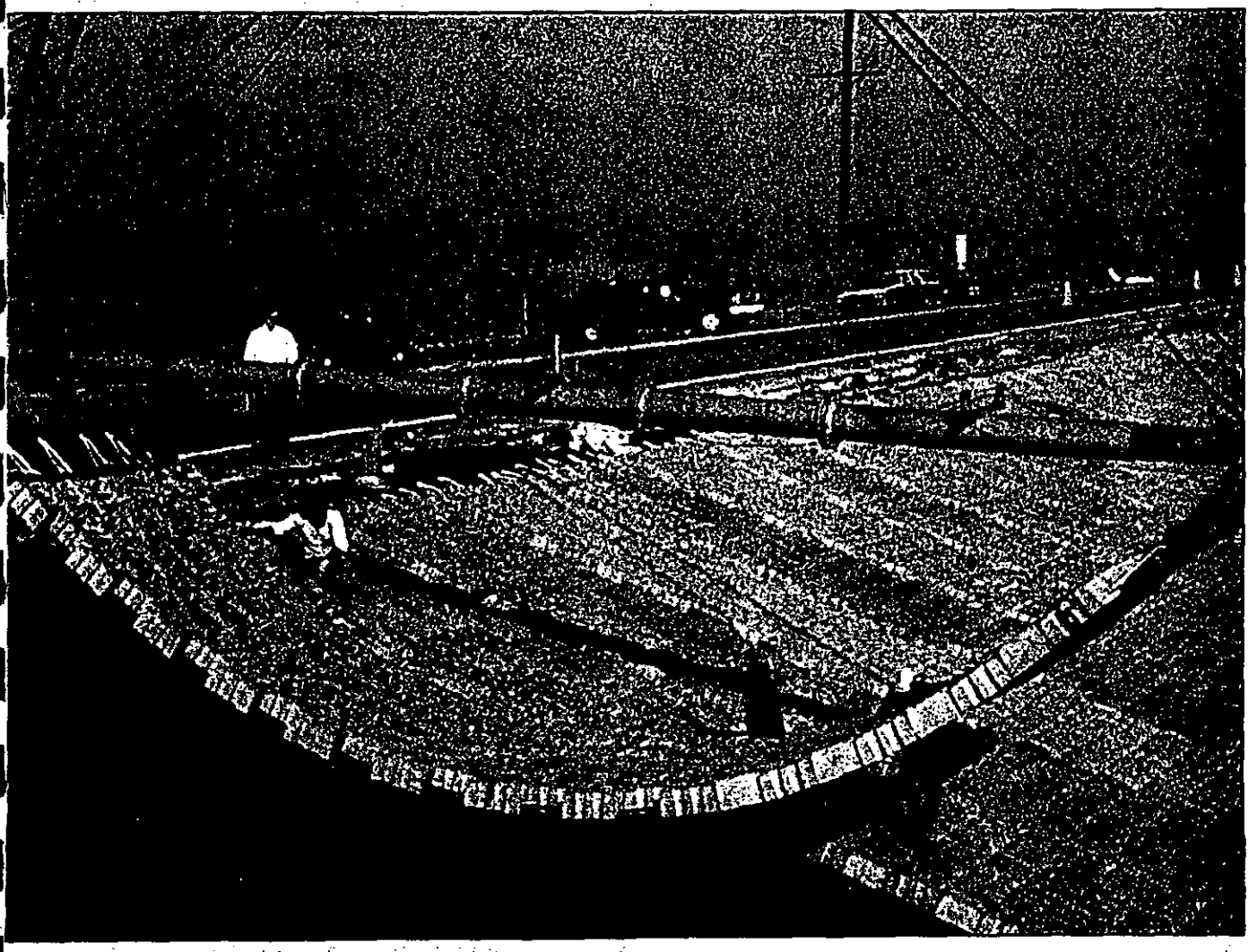
Backfill is spread over the mats and into the open cells, then sown or planted as desired.

RMORFLEX MATS CAN BE EASILY ISTALLED UNDERWATER. The ›reader bar can be fitted with ›ecial, remote release clamps, which low the mat to be released from the irface. There is no need to de-water e work area. The positioning of the ats can be done from the surface in allow water or by divers in deep ater. In addition, a structure can be sily built on a environmentally stricted site because there is no ed for expensive cofferdams that sturb the natural environment surunding the project site.

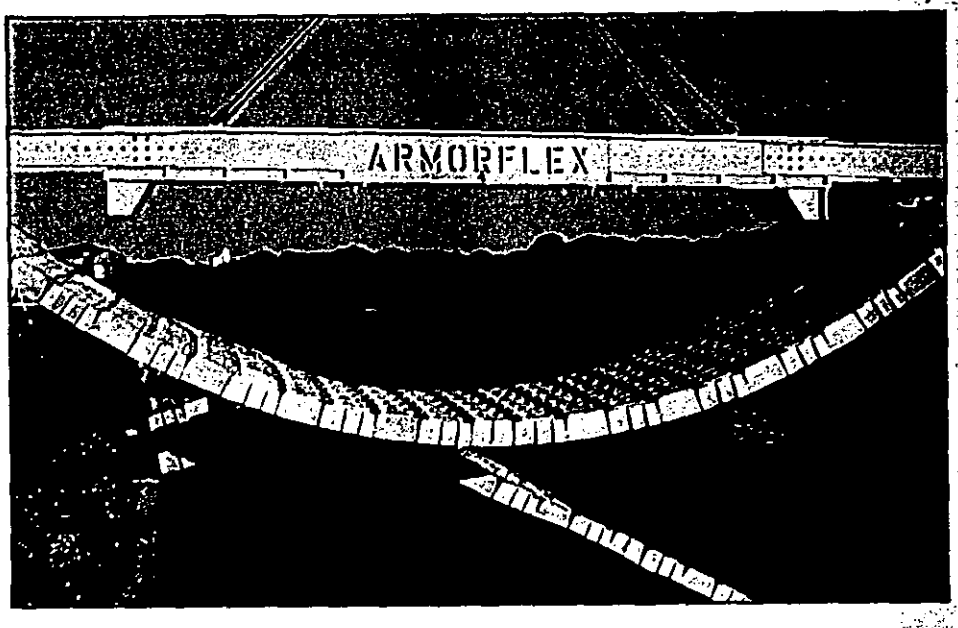








PERFORMANCE TESTED/COST EFFECTIVE ARMORFLEX® EROSION CONTROL SYSTEM



Armorflex articulating precast concrete mats erosion control system.

ARMORFLEX Erosion Control System provides the engineered alternative to conventional erosion control materials for revetment and channel protection.

ARMORFLEX combines its specially designed interlocking precast concrete grids, cables and filter system to provide stable, articulated and permeable erosion protection, which maintains its integrity in the event of subgrade deformation or severe dynamic loading.

ARMORFLEX is placed by conventional construction equipment directly on the prepared subgrade of the structure as a system of factory pre-assembled mats of interlocking grids interconnected with cables.

ARMORFLEX results in a stable erosion control system available in a range of classes to accommodate various wave climates and stream flow conditions with aesthetic and ecological advantages.

ARMORFLEX, whether vegetated or otherwise, provides durable, flexible and permeable erosion protection for:

- Coastal Shorelines
- Earthen Dams
- Storm Channels & Ditches
- Bulkhead, in lieu of
- Pipeline Crossings
- Lakes & Reservoirs
- Rivers, Streams, & Bayous
- Dikes & Levees
- Bridge Abutments
- Water Control Structures
- Ponds & Holding Basins
- Sand Dunes
- Embankments
- Spillways
- Subaqueous Pipelines
- Boat Launching Ramps

ARMORFLEX has been proven technically and economically superior to traditional protective materials. When conditions such as poor soils, limited access, aesthetic and environmental considerations or a short construction season or schedule are primary factors, ARMORFLEX has proven to be the design solution.

Characteristics.

STABILITY. ARMORFLEX provides a continuous erosion protection that acts as an articulated mattress to withstand the destructive forces of water. The proper ARMORFLEX class is determined by the design velocity or wave height to which it shall be subjected.

FLEXIBILITY. ARMORFLEX grids are interconnected by flexible cables which provide articulation between adjacent grids. The walls of the ARMORFLEX grid are designed with beveled relief to allow for flexibility in all directions.

PERMABILITY. ARMORFLEX is generally placed on filter fabric and/or conventional graded filter. The permeability of the filter system and grids relieves hydrostatic pressures while its capability for soil retention prevents leaching of subsoils through the installation.

FLOW RESISTANCE. ARMORFLEX is available with open cell grids or with closed cell grids to provide a combination of unit weight and surface roughness. The ARMORFLEX Manning Roughness Coefficient, "n", has a value ranging from 0.026 to 0.044, depending upon the grid used, material filling the cells, and vegetative cover.

VEGETATION. When vegetation is desired, ARMORFLEX's open cells are filled with soil, then sown or planted. The open cells provide a perfect environment for the establishment of vegetation. Even roots of grass and small shrubs can penetrate the filter system, providing a permanent anchor for the installation while beautifying the landscape. ARMORFLEX, with closed cells or open cells filled with stone, ($d_{50} < .75''$), precludes vegetative cover.

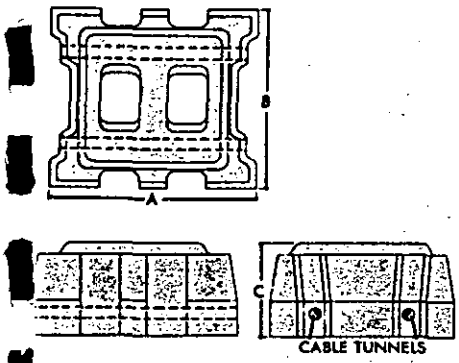
ACCESS. ARMORFLEX is free of dangerous projections thus providing safe access for pedestrians, animals, vehicles, boats, and other small craft to the water's edge.

Preparation and Installation.

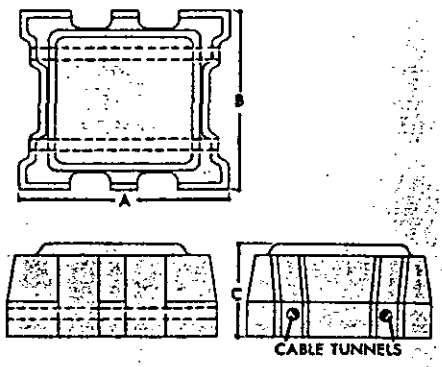
ARMORFLEX is delivered on trailers or barges as prefabricated mats, of up to 480 ft.^{2} per mat.

Construction begins with site preparation of the area to be protected. Vegetation and obstructions, such as roots and projecting stones are removed. Holes, soft areas and large cavities are filled and compacted with suitable materials.

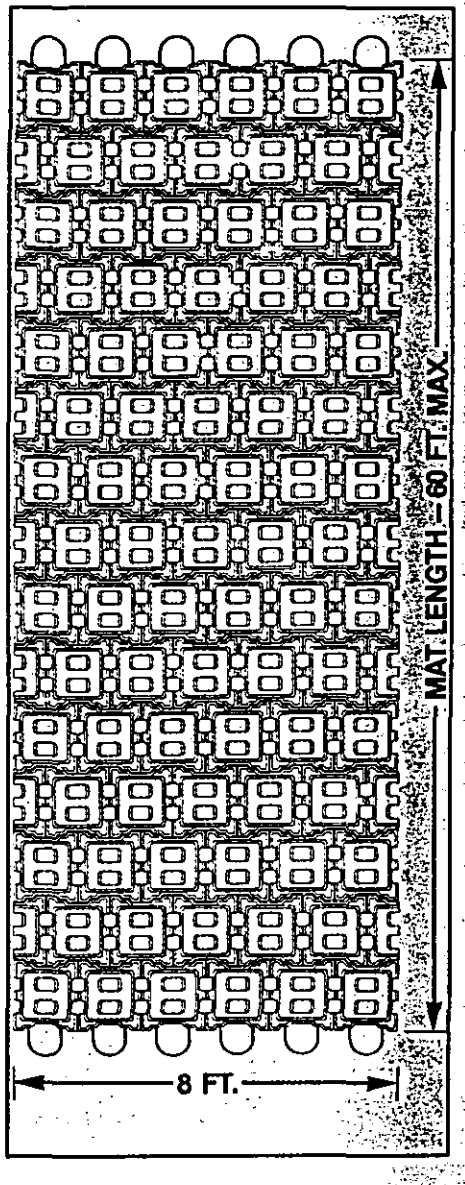
- Excavate toe, terminals and upper bank protection trenches as required.
- Filter fabric and/or graded filter material, is placed over the prepared subgrade.
- The first row of mats are placed side by side on the structure by attaching the cable loops at both ends of the mat to a spreader bar for placement by a crane or backhoe.
- Adjacent mats are connected by pouring side connecting keys and/or by fastening side connecting cables and end loops.
- Optional anchors are placed at the top of the slope.



OPEN CELL GRID



CLOSED CELL GRID



ARMORFLEX GRID SPECIFICATIONS

	CLASS	TECHNICAL DATA: SPECIFIC WEIGHT LBS./CU.FT.	COMPRESSIVE STRENGTH LBS./SQ.IN.	% MAXIMUM ABSORPTION	DIMENSIONS & WEIGHTS: NOMINAL DIMENSIONS IN. A	B	C	GROSS AREA/ GRID SQ.FT.	WEIGHT/ GRID LBS.	WEIGHT/ AREA LBS./SQ.FT.	OPEN AREA %
OPEN CELL	30	130-150	4000-5000	5	13.0	11.6	4.75	0.96	31-36	32-37	25
OPEN CELL	50	130-150	4000-5000	5	13.0	11.6	6.0	0.96	45-52	46-53	20
OPEN CELL	70	130-150	4000-5000	5	17.4	15.5	9.0	1.77	120-138	68-78	20
CLOSED CELL	45	130-150	4000-5000	5	13.0	11.6	4.75	0.96	39-45	40-46	10
CLOSED CELL	55	130-150	4000-5000	5	13.0	11.6	6.0	0.96	53-61	54-62	10
CLOSED CELL	85	130-150	4000-5000	5	17.4	15.5	9.0	1.77	145-167	82-95	10

›mponents.

IDS. The grids are precast concrete blocks, llable in a range of classes to accommodate ous applications. The range of classes allows selection of the proper combination of unit ght, surface roughness and open area for bility and hydraulic relief.

BLE & FITTINGS. Cables are galvanized steel raft cable or polyester; stainless steel has been d for special applications.

compression fittings used to make cable ces and to confine the grids are selected to ch the cable strength and are composed of erials suitable for the cable employed.

TER FABRIC. *The filter fabric is a pervious sheet* oven and/or nonwoven fabric selected in accor- ce to the gradation and permeability analysis of soil and/or fill material on which the mats are e placed. If a graded filter material is selected se, it must be carefully designed and installed revent movement of the gradation through the ection cover layer.

T ANCHORS. For structures with steep side es, helix type corrosion resistant anchors are alled at the top of the slope to provide addi- al stability.

Technical Assistance.

ARMORTEC is staffed by qualified civil engineers to aid in the preparation of designs and cost estimates for potential projects. If approved, *ARMORTEC's engineering department will prepare* shop drawings for the engineer's review and approval. Pre-bid and pre-construction conferences with contractors and on-site construction assistance are also provided by ARMORTEC's construction services group.

Manufacturer and Supply.

ARMORFLEX erosion control mats are available in six classes to accomodate the conditions prevailing in a given application. ARMORFLEX grids are manufactured on standard concrete block machines located around the world. ARMORFLEX mat cabling machines are portable and can pre-*assemble mats at the concrete block plants or on* the construction site. Mat dimensions are selected to meet the area required for the ARMORFLEX installation.

ARMORTEC Erosion Control Systems are currently in service around the world. Their uses range from channel linings to riverbanks and from subaqueous pipeline protection to major shoreline revetments. The positive results achieved by ARMORTEC in providing revetment and bank protection systems for civil engineering projects supply convincing proof of the benefits you may reap from ARMORTEC's broad spectrum of erosion control systems.

For further information on our erosion control systems and their varied applications, contact:

ARMORTEC INCORPORATED

A subsidiary of NICOLON, Corporation

3500 Parkway Lane
Suite 500
Norcross, Georgia 30092
(404) 447-6272
FAX (404) 242-3828
Telex: 804453

LOCAL REPRESENTATIVE

he best of our knowledge, the information contained herein is accurate. However, Armortec, Incorporated, cannot accept y of any kind for the accuracy or completeness thereof. Final determination of the suitability of any information or material for se contemplated, of its manner of use, and whether the suggested use infringes any patents, is the sole responsibility of the user.

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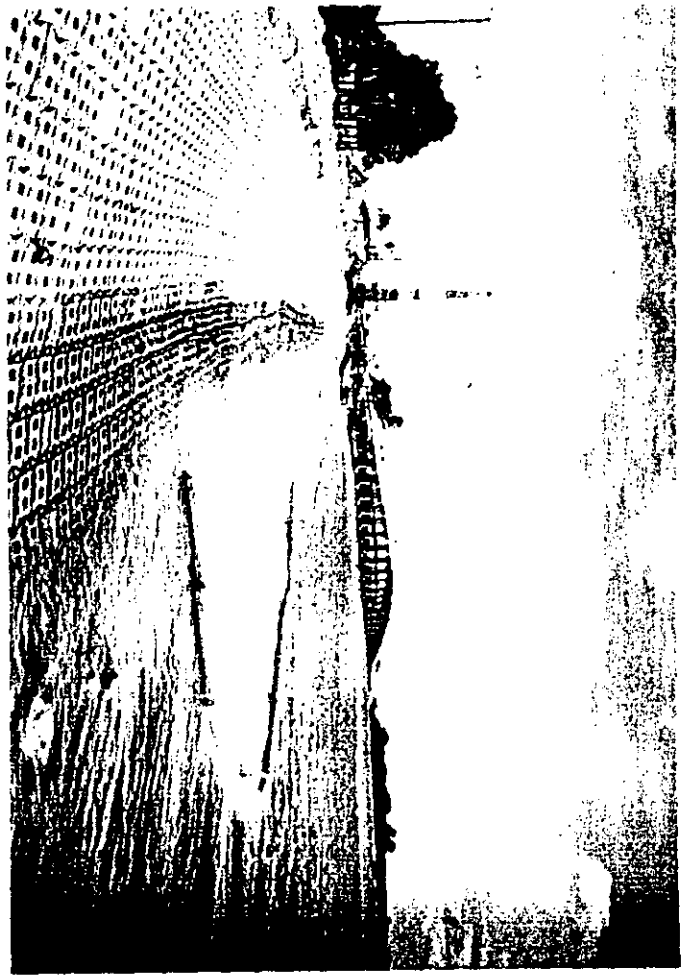
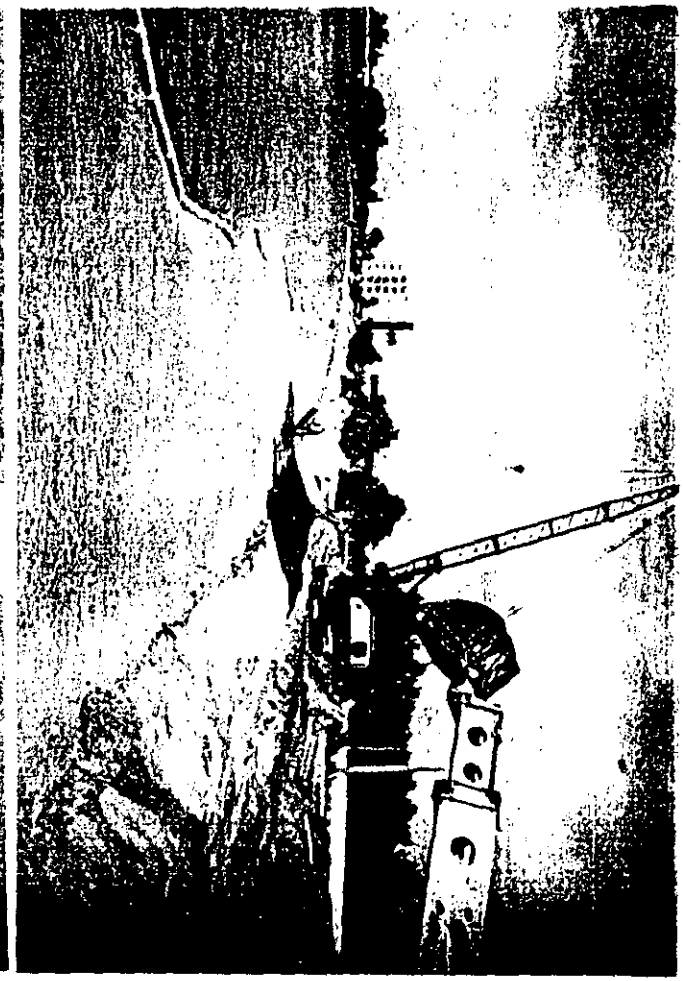
ARMORFLEX IS A NICOLON® PRODUCT

U.S. Patent No. 4,370,075 Canadian Patent No. 1,141,554 Other U.S. and foreign patents issued and pending





CAPE CORAL PARKWAY
CHARLOTTE HARBOR
ARMORFLEX CLASS 50

Attachment 13

ARMORFLEX CLASS 30 WITH RED MANGROVES

Attachment 14

ARMORLOC CLASS 3510 REVEGITATED WITH
SEED AND MULCH

ATTACHMENT 3

SPECIFICATION

DURAVET REVETMENT ROPE

SCOPE:

This specification pertains to Samson parallel core Duravet rope constructions.

MATERIAL:

Duravet is constructed in high tenacity low elongation continuous filament synthetic fibers.

CONSTRUCTIONS:

a. Duravet consists of a core construction comprised of parallel fibers which is contained within an outer braided jacket or cover.

b. The cover shall be a 16-strand or 24-strand twill braid in which one strand of one direction of rotation about the axis passes over two strands of the opposite direction and then passes under the next two strands of opposite direction.

c. The weight of the parallel core shall be between 65% to 75% of the total weight of the rope.

d. Construction of the rope shall be such that the cover braid is non-load bearing and the rope is torque-free.

BREAKING STRENGTH AND WEIGHT:

The breaking strength of Duravet is determined by conduction capstan break tests. The test apparatus used is a Riehle geared screw machine fitted with two 9-inch diameter copper jacketed steel capstans. The test sample is wrapped twice around each capstan and the free ends of the sample are then tied off to pins. The sample is pulled to destruction at the head travel speed of 3 inches per minute and the resulting breaking strength is recorded autographically.

The breaking strength given below for Duravet is an approximate average strength. The average break strength is determined by conducting several tests and calculating the average of all the test results.

Nominal Rope Diameter	Circle	Approx. Avg. Strength	Minimum Strength*	Weight/100 Ft.-Lbs.	
				Minimum	Maximum
.187	(15mm)	1,800 Lbs.	1,620	1.24	1.37
.240	(19mm)	3,100 Lbs.	2,790	2.00	2.21
.255	(20mm)	3,700 Lbs.	3,330	2.47	2.74
.280	(22mm)	4,500 Lbs.	4,050	2.76	3.05
.295	(24mm)	5,200 Lbs.	4,680	2.95	3.26
.310	(27mm)	7,000 Lbs.	6,300	3.99	4.42
.380	(30mm)	10,000 Lbs.	9,000	4.75	5.26
.5	(40mm)	15,000 Lbs.	13,500	8.93	9.90
.63	(50mm)	23,000 Lbs.	20,700	13.02	14.42

** Above rope strengths are developed with a 98% confidence factor. Therefore, statistically we reserve the right that two (2) breaks out of 100 breaks may fall below stated minimums.*

ELONGATION DATA:

Elongation data specified in this section is based upon stabilized new, dry rope. Stabilization refers to a process in which the rope is cycled fifty times between a load corresponding to $200D^2$ and a load to 10%, 20%, or 30% of the rope's approximate average breaking strength. Relevant elongation values for Duravet are given in the table below. The tolerance on these values is ±5%.

	% - Breaking Strength		
	10%	20%	30%
Permanent elongation while working	.7%	1.8%	2.6%
Elastic elongation	.6%	1.4%	2.2%
Total stretch	1.3%	3.2%	4.8%

CHEMICAL RESISTANCE:

The material used in the construction of Duravet exhibits good to excellent resistance to most concentrated acids, alkalis and solvents.

ENVIRONMENTAL RESISTANCE:

Duravet is impervious to rot, mildew and degradation associated with marine organisms. The material used in the construction of the rope is not affected by continuous immersion in fresh or saltwater.

CRITICAL TEMPERATURE:

Critical temperature is defined as the point at which degradation of the rope occurs due to temperature alone. The critical temperature of Duravet is 350°F. The melting point of Duravet is 480°F.

QUALITY ASSURANCE:

Duravet is manufactured in accordance with product specification instructions which detail the construction particulars of the rope. During the manufacturing process, the rope is checked for compliance with these instructions by production supervision personnel. In addition, the strength of the finished product is verified by conducting one certified break test per 25,000 feet of finished rope.

WARRANTY:

All goods and materials manufactured by Samson are warranted free from defects in workmanship or material; consistent with established and generally acceptable standards of the type of product produced in accordance with Cordage Institute standards, testing and definitions.

STANDARDS FOR STRENGTH AND USAGE:

The improper use of rope may be dangerous. Use the right size for the job and do not overload, shock load or bend-over sharp corners. Information on standards for strength and usage are available from Samson, along with Guidelines for Inspection and Maintenance.

MANUFACTURER:

Duravet is manufactured by Samson Ocean Systems, Inc. for Nicolon Corporation.

COMPARATIVE CHEMICAL RESISTANCE OF "DACRON" AND DU PONT NYLON FIBERS

		Exposure Conditions	Per Cent of Original Strength Retained after Exposure: DACRON* polyester fiber	Per Cent of Original Strength Retained after Exposure: Du Pont nylon fiber
STRONG, MINERAL ACIDS				
1% Hydrochloric		70°F. (21°C.) for 1,000 hrs.	97	81
1% "		160°F. (71°C.) for 10 hrs.	103	90
10% "		70°F. (21°C.) for 10 hrs.	100	82
10% "		70°F. (21°C.) for 1,000 hrs.	87	—
37% "		70°F. (21°C.) for 100 hrs.	86	—
10% Hydrofluoric		70°F. (21°C.) for 10 hrs.	84	97
10% Nitric		70°F. (21°C.) for 10 hrs.	105	91
10% Phosphoric		70°F. (21°C.) for 10 hrs.	97	95
1% Sulfuric		70°F. (21°C.) for 1,000 hrs.	98	80
1% "		250°F. (121°C.) for 10 hrs.	92	11
10% "		70°F. (21°C.) for 10 hrs.	103	57
10% "		70°F. (21°C.) for 1,000 hrs.	103	—
70% "		70°F. (21°C.) for 100 hrs.	96	—
ORGANIC ACIDS				
98% Acetic		70°F. (21°C.) for 10 hrs.	89	88
3% Benzoic		210°F. (99°C.) for 10 hrs.	90	19
40% Formic		70°F. (21°C.) for 10 hrs.	103	99
90% "		70°F. (21°C.) for 10 hrs.	100	A
5% Oxalic		70°F. (21°C.) for 10 hrs.	90	82
3% Salicylic		210°F. (99°C.) for 10 hrs.	91	25
STRONG ALKALI				
1% Sodium hydroxide		210°F. (99°C.) for 10 hrs.	84	98
10% " "		70°F. (21°C.) for 10 hrs.	103	101
10% " "		210°F. (99°C.) for 10 hrs.	A	94
40% " "		210°F. (99°C.) for 10 hrs.	—	84
BLEACHING AGENTS				
3% Hydrogen peroxide	(pH-4)	70°F. (21°C.) for 10 hrs.	92	97
3% " "	(pH-10)	160°F. (71°C.) for 10 hrs.	105	76
2% Peracetic acid	(pH-4)	70°F. (21°C.) for 10 hrs.	103	94
2% " "	(pH-4)	210°F. (99°C.) for 10 hrs.	95	70
0.7% Sodium chlorite	(pH-4)	70°F. (21°C.) for 10 hrs.	106	93
0.7% " "	(pH-4)	210°F. (99°C.) for 10 hrs.	101	20
0.4% Sodium hypochlorite	(pH-11)	70°F. (21°C.) for 10 hrs.	97	94
0.4% " "	(pH-11)	160°F. (71°C.) for 10 hrs.	105	7
1% Sodium perborate	(pH-10)	70°F. (21°C.) for 10 hrs.	104	97
1% " "	(pH-10)	210°F. (99°C.) for 10 hrs.	110	95
REDUCING AGENTS				
1% Sodium bisulfite	(pH-4)	160°F. (71°C.) for 10 hrs.	102	97
1% Sodium hydrosulfite		160°F. (71°C.) for 10 hrs.	99	98

	Exposure Conditions	Per Cent of Original Strength Retained after Exposure: DACRON* polyester fiber	Per Cent of Original Strength Retained after Exposure: Du Pont nylon fiber
SCOURING COMPOUNDS			
1% Soap	210°F. (99°C.) for 10 hrs.	108	99
1% Sodium carbonate	210°F. (99°C.) for 10 hrs.	102	96
1% " "	250°F. (121°C.) for 10 hrs.	93	99
SALT SOLUTIONS			
3% Copper sulfate	70°F. (21°C.) for 1,000 hrs.	90	96
3% " "	210°F. (99°C.) for 10 hrs.	104	88
3% Ferric chloride	210°F. (99°C.) for 10 hrs.	112	56
3% Sodium chloride	70°F. (21°C.) for 1,000 hrs.	96	98
3% " "	210°F. (99°C.) for 10 hrs.	99	83
3% Zinc chloride	210°F. (99°C.) for 10 hrs.	99	103
ORGANIC SOLVENTS			
100% Acetone	70°F. (21°C.) for 1,000 hrs.	94	99
100% Amyl alcohol (normal solution)	70°F. (21°C.) for 1,000 hrs.	93	98
100% Benzene	70°F. (21°C.) for 1,000 hrs.	91	98
100% Carbon disulfide	70°F. (21°C.) for 1,000 hrs.	91	91
100% Carbon tetrachloride	70°F. (21°C.) for 1,000 hrs.	90	90
100% Chloroform	70°F. (21°C.) for 1,000 hrs.	90	95
100% Ether	70°F. (21°C.) for 1,000 hrs.	92	89
100% Ethyl acetate	70°F. (21°C.) for 1,000 hrs.	93	90
100% Ethyl alcohol	70°F. (21°C.) for 1,000 hrs.	95	90
100% Methyl alcohol	70°F. (21°C.) for 1,000 hrs.	90	98
100% Perchloroethylene	210°F. (99°C.) for 10 hrs.	104	99
100% Stoddard solvent	160°F. (71°C.) for 10 hrs.	96	101
100% Tetrachloroethane	70°F. (21°C.) for 1,000 hrs.	90	98
MISCELLANEOUS CHEMICALS			
10% Acetaldehyde (in water)	70°F. (21°C.) for 1,000 hrs.	84	96
28% Ammonia (in water)	70°F. (21°C.) for 1,000 hrs.	8	94
100% Benzaldehyde	70°F. (21°C.) for 1,000 hrs.	92	90
100% Cottonseed oil	70°F. (21°C.) for 1,000 hrs.	92	90
10% Formaldehyde (in water)	70°F. (21°C.) for 1,000 hrs.	91	89
100% Glycerine	210°F. (99°C.) for 10 hrs.	104	99
100% Glycol	210°F. (99°C.) for 10 hrs.	111	94
3.5% Iodine (in ethyl alcohol)	70°F. (21°C.) for 10 hrs.	103	95
100% Lard	70°F. (21°C.) for 1,000 hrs.	93	70
100% Linseed oil	70°F. (21°C.) for 1,000 hrs.	88	90
100% Mineral oil	210°F. (99°C.) for 10 hrs.	97	96
100% Nitrobenzene	70°F. (21°C.) for 10 hrs.	103	65
5% Phenol (in water)	70°F. (21°C.) for 10 hrs.	107	43

*Du Pont registered trademark A dissolved B degraded (brittle) — not tested

CHEMICAL ATTACK OF GEOTEXTILES

(POLYESTER)

CHEMICAL RESISTANCE DATA

Chemical attack of geotextiles is often difficult to clearly distinguish because of inherent product variability, the relatively small magnitude of degradation, and the concurrent non-chemical effects of water. For these reasons, chemical attack of geotextiles is best viewed with respect to trends rather than specific values, as well as with a preference for using high-temperature testing and baseline water exposure to magnify and isolate chemical effects.

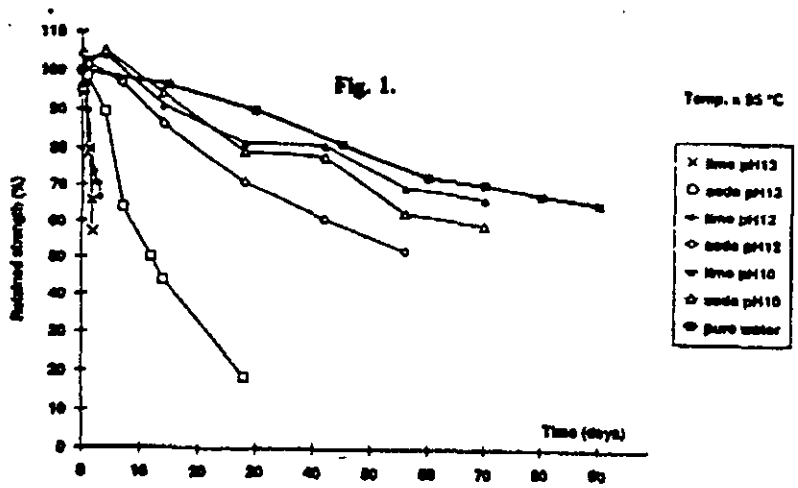
The most extensive study of polyester durability to date - a 3-phase research program formulated by Terre Armee Internationale & The Reinforced Earth Company, funded by Nicolon Corporation, and executed by TRI Environmental Inc. - properly incorporated all of these considerations. The program studied the degradation of poly(ethylene terephthalate), *commonly referred to as PET or, simply, polyester in the following three phases:*

- a comparative study of high-tenacity filaments in 27 media, at an elevated temperature (95°C in Phase 1), which was used to identify the most aggressive media;
- a comparative study of different yarns in the same selected media, at a lower temperature (Phase 2), which was used to compare yarn performance; and
- a comparative study of different products and coatings in the same media (Phase 3), which will be used to compare product performance.

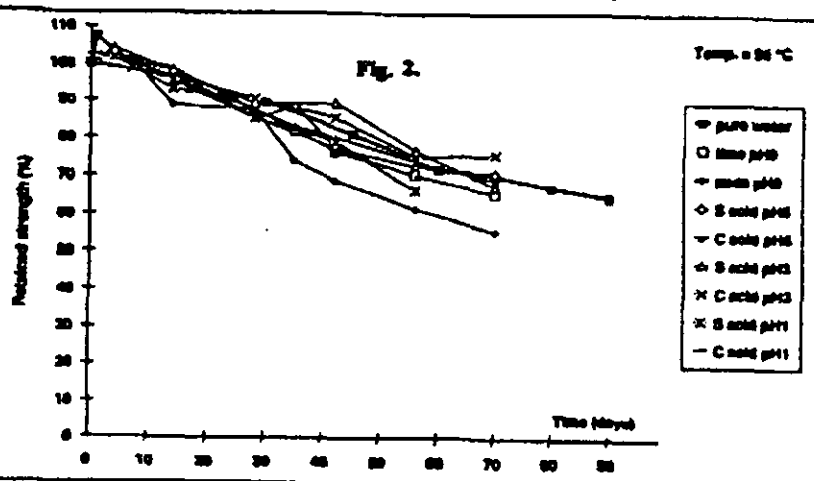
The results of Phase 1 have been reported by Jailloux et al (1992) and are summarized as follows:

- accelerated testing at high temperatures gives useful information, allowing for quick selection of media that are or are not prone to degrade polyester;
- typical chemicals found in soil have no significant effect (at 95°C) on the degradation rate of the filaments tested as compared with the behavior in water as long as the pH remains below 10;
- the filaments have lost a part of their matter.

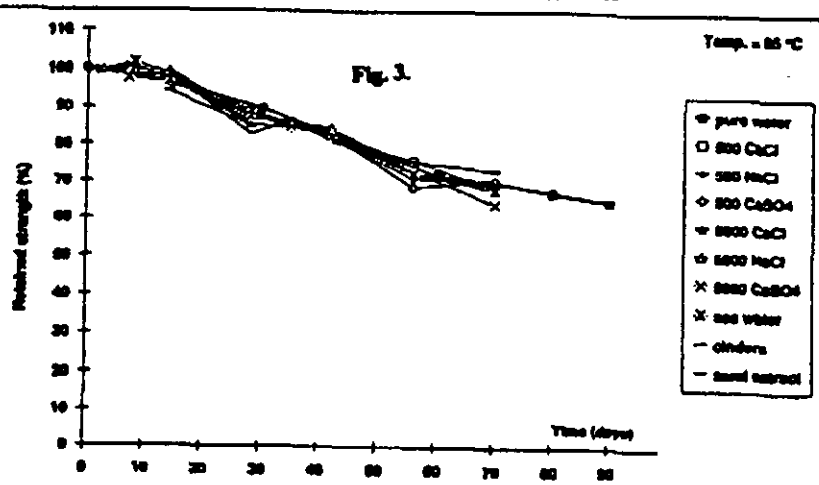
Supporting data follows . . .



Alkaline Media. It is well known that highly alkaline media will induce very rapid degradation of polyester. Figure 1 gives the results obtained in caustic soda and lime at different pH values. Degradation of filaments tested in lime or soda at a pH of 10 is close to the degradation evolution obtained in pure water.



pH less than 10. There was no observed difference between the behavior of filaments exposed to slightly alkaline media and that of those exposed in highly acidic media. As shown in Figure 2, the shapes of the curves are similar for sulphuric (S) and hydrochloric (C) acid. A pH of 1 does not damage the filament more than pure water.



Salty Media. These tests studied the behavior of high-tenacity PET in water with the addition of small or large quantities of the major salts encountered in soil, such as de-icing salts, gypsum, sea water, aggressive soil leachate, and ordinary soil. Figure 3 shows the curves all closely follow the pure-water line.

CHEMICAL DEGRADATION CONSIDERATIONS

ATTACHMENT 4

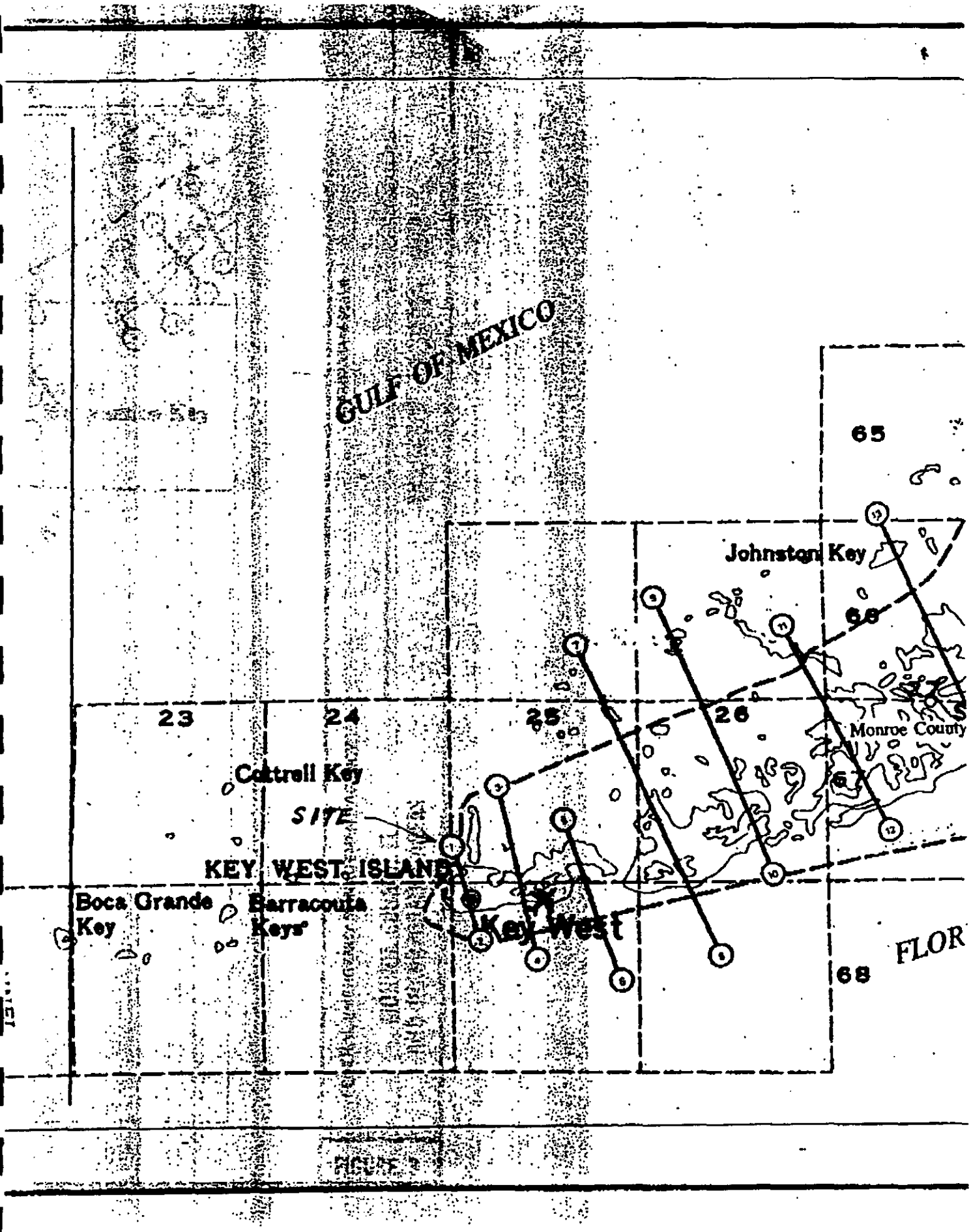

GULF OF MEXICO
65
Johnston Key
66
23
24
25
26
Monroe County
Cottrell Key
SITE
KEY WEST ISLANDS
Boca Grande Key
Barracouta Keys
Key West
FLOR
68

FIGURE 3

EXITING

FLOODING SOURCE AND TRANSECT	FLOOD INSURANCE RATE MAP PANEL	STILLWATER ELEVATIONS 10-YEAR	50-YEAR	100-YEAR	500-YEAR	ZONE	BASE FLOOD ELEVATIONS (FEET NGVD)
		STILLWATER ELEV					
GULF OF MEXICO		10Y	50Y	100Y	500Y		
	1708/1718	3.2	5.5	6.4	[illegible]	VE AE	11-13 8-10
		3.2	5.5	6.8	7.3	VE AE	9-11 7-9
ATLANTIC OCEAN 2	1718	2.7	4.8	7.6	8.4	VE AE	10-12 8-10
		2.7	4.8	8.0	8.4	AE	8-9
GULF OF MEXICO 3	1709	5.1	6.6	7.4	9.2	VE AE	9-11 7-9
ATLANTIC OCEAN 4	1709/1717	3.0	5.5	6.5	7.4	VE AE	11-13 9-11
		3.0	5.5	7.2	7.4	VE AE	9-11 7-9
GULF OF MEXICO 5	1728	4.7	7.6	8.4	10.4	VE AE	11-13 9-11

[1]ROUNDED TO THE NEAREST FOOT AND MAY INCLUDE EFFECTS OF WAVE ACTION
[2]DUE TO MAP SCALE LIMITATIONS, BASE FLOOD ELEVATIONS SHOWN ON MAP MAY REPRESENT AVERAGE ELEVATIONS FOR THE ZONES DEPICTED
[3]INCLUDE EFFECTS OF WAVE SETUP

TABLE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

MONROE COUNTY, FL
AND INCORPORATED AREAS

SUMMARY OF STILLWATER ELEVATIONS

GULF OF MEXICO—ATLANTIC OCEAN

ATTACHMENT 5

"The Environment Is Our Future"

Proceedings of Conference XXIII
INTERNATIONAL EROSION CONTROL ASSOCIATION
February 18-21, 1992
Reno, Nevada, USA

A NON-PROFIT ORGANIZATION TO PROVIDE OPPORTUNITIES
FOR THE EXCHANGE OF WORLDWIDE INFORMATION
AND IDEAS CONCERNING EFFECTIVE AND ECONOMICAL
METHODS OF EROSION CONTROL

AN INSIDE LOOK AT ARTICULATING CONCRETE BLOCK REVETMENTS

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Norcross, GA 30092

ABSTRACT

Civil Engineers throughout the world are continually faced with the problem of controlling erosion of coastal shorelines and inland waterways. Coastal areas frequently experience land loss and property damage resulting from the dynamic forces associated with wave attack, while inland waterways experience heavy currents which erode channel banks and beds, consequentially resulting in unfavorable environmental conditions.

The past decade has produced much needed research on articulating concrete revetment systems which has resulted in a more accurate prediction for the threshold of system stability, a better understanding for the most influential factors that affect system performance, and a growing demand for flexible, permeable, and environmentally desirable revetments that can be designed to withstand the forces associated with large waves and heavy currents. The purpose of this paper is to familiarize the design engineer with the design concepts and methodologies associated with resisting the forces of waves and currents. The manufacturing and installation processes of articulating concrete block revetments will also be presented.

INTRODUCTION

In the early stages of many new civil engineering technologies, practical application typically precedes, or at least coincides with, the research necessary for proper design. This is particularly true for articulating concrete block revetments. Although this technology and research dates back to the mid-1970's, nearly two decades have passed, and many of these systems are continually used without the limits of hydraulic stability clearly documented.

The past research has proven that the proper block selection to withstand unique hydraulic conditions for a particular application is more of a high-tech science than many people believe. The 1990's bring the civil engineer or designer of erosion control revetments to a crossroad. Do we continue to use the trial and error technique of the past to determine the proper system or block size to resist the hydraulic conditions unique to a particular site, or do we as professionals raise our standards to a higher level and require that the threshold of hydraulic stability be

determined and a design methodology provided before any particular system is approved for use?

The decade of the 1980's took a giant step in this latter direction with hydraulic research studies on articulating concrete revetments being performed nationally and internationally by the Delft Hydraulics Laboratory in Holland, the Construction Industry Research and Information Association (CIRIA) in Great Britain, and Simons, Li and Associates in Fort Collins, Colorado. Sponsoring of this research came from various government agencies such as the U.S. Bureau of Reclamation, U.S. Federal Highway Administration, Tennessee Valley Authority and the U.S. Soil Conservation Service. The commissioning of the Delft Hydraulics Laboratory and Simons, Li and Associates, Inc. by Nicolon Corporation, Atlanta, Georgia, has developed into a practical method for evaluating the stability of a unique block system under hydraulic conditions typically encountered in the field. A similar design methodology can be adapted to other articulating concrete block revetments once hydraulic data is acquired that documents the performance of these revetments under full-scale controlled testing. The net result is that the designer of the 1990's can now rely on practical design procedures, based on documented hydraulic research data, for protecting coastal shorelines and inland waterways from erosion damage due to the hydro-dynamic forces associated with either waves or currents.

DESIGN CONSIDERATIONS

Articulating concrete block revetments incorporate cellular concrete blocks, either open or closed, underlain with a properly designed filtration geotextile. The blocks are held on the slope by anchors placed at the top of the slope and/or by friction between the slope and the blocks. The blocks can be assembled into fabricated mats either at the factory or on site. Sections of precabled concrete blocks can be placed by using a special spreader bar, a procedure that may lower costs at large projects by reducing hand labor, or may be hand-placed with or without the cable subsequently installed.

The articulating concrete block family of revetment systems combines the favorable aspects of lightweight blankets and meshes, such as porosity, flexibility, vegetation encouragement and habitat enhancement, and ease of installation, with the nonerodibility, self weight, and high tractive force resistance of rigid linings. These specially designed interlocking precast concrete grids have proven to be a cost-effective, aesthetic, and functional alternative to dumped stone riprap, gabions, structural concrete, and other heavy-duty, durable channel protection systems. Additionally, these systems offer enhanced flow efficiencies, nurturing of vegetative cover and safe access.

Stability. Concrete block revetments provide a continuous articulating erosion protection mat to withstand the destructive forces of water. Proper block selection is based on the design velocity or wave height to which it shall be subjected and is product specific. The stability of articulating concrete block revetments is generally unquestioned. For instance, a 34 pound Armorflex block has a critical shear stress of 15 pounds per square foot, whereas a shear stress of only 10 pounds per square foot is required to initiate motion of a 24-inch diameter rock riprap weighing 1,200 pounds per stone (Clopper, 1991).

Through years of hydraulic research testing, Simons, Li and Associates, Inc. identified that each type of revetment system exhibited its own characteristic threshold failure point or critical shear stress level that the hydraulic forces must exceed to activate failure. It has been acknowledged that block weight, geometric proportion, and method of interlock all play important roles in overall system performance. Full-scale hydraulic testing under controlled conditions is the only proven reliable method of quantifying performance. From these tests, it is possible to extrapolate performance to larger or smaller blocks of the same "family", but not to different block types (Clopper, 1991). As a result, each articulating concrete block system manufacturer must provide hydraulic stability data for his product.

Flexibility. Another advantage of a cabled system is its flexibility. If an embankment settles unevenly, the revetment is able to conform to the distorted shape. Cabled preformed concrete blocks provide long-term articulating slope and channel protection. The primary difference between these systems and other materials commonly used to protect channel beds and banks from erosion scour and instability is their ability to accommodate minor changes in channel shape due to settlement, frost heave, slumping, and the like, while maintaining a nonerodible boundary between the channel subgrade and the potentially damaging flow of water.

Permeability. Articulating concrete block revetments are generally placed on a filter fabric and/or a conventional graded filter. The permeability of the

filter and revetment system relieves hydrostatic pressures while its capability for soil retention prevents leaching of sub-soils through the installation. The filtration geotextile must be properly designed according to the anticipated hydraulic flow conditions and the soil grain size distribution. An improper geotextile selection may lead to failure of the revetment by either not allowing the dissipation of excess hydrostatic pressure or not retaining the subgrade soils.

Flow Efficiencies. The Manning's roughness coefficient, n, is approximately constant, for a given channel lining, over the range of slopes and discharges typically encountered in channel design situations. The roughness coefficient tends to increase for very shallow flows where the height of the roughness elements comprising the lining is a significant percentage of the total depth of flow. For unvegetated revetment systems on mild channel slopes under uniform or near-uniform flow conditions, the Manning coefficient has been found to depend on the effective size of the individual blocks, and whether the blocks are of the open- or closed-cell configuration. Typical n values for Armorflex blocks range from 0.026 to 0.034

Vegetation. When vegetation is desired, open cell blocks are filled with soil, then sown or planted. The open cells provide a perfect environment for the establishment of vegetation. Even roots of grass and small shrubs can penetrate the filter system, providing a permanent anchor for the installation while beautifying the landscape.

Typical flood control improvements that protect development often do so at the expense of wildlife habitat, prompting agencies such as the Department of Fish and Game and the U.S. Fish and Wildlife Service to impose environmental mitigation requirements on the project. Articulating concrete block revetments have been well received by various agencies such as Corps of Engineers, Department of Natural Resources, Fish and Game, Fish and Wildlife Services and others who are well focused on the environmental problems faced by the entire country. In fact, the mat installation for the Serrano Creek flood control project in Orange County, California, qualified for a one-to-one habitat replacement since no mitigation requirements were imposed by the resource agencies.

Blocks with closed cells or open cells filled with stone (d_{50}<.75") precludes vegetative cover.

Access. Block mats are free of dangerous projections thus providing safe access for pedestrians, animals, vehicles, boats, and other small craft to the water's edge.

DESIGN APPROACH - CURRENTS

The analytical method for determining hydraulic stability was produced by Simons, Li and Associates, Inc., Fort Collins, Colorado. The method is aimed to ensure that each individual block within an articulating concrete block revetment maintain independent stability. The self weight of the most vulnerable individual block in the system must be large enough to maintain intimate contact with the subgrade when it is being subjected to the lift and drag forces associated with heavy currents or embankment overtopping. Failure, defined as the loss of "intimate contact" between a block (or group of blocks) and the subgrade, is the result of incipient overturning, when overturning moments equal resisting moments about the downstream edge of the block (Clopper, 1991).

By minimizing the potential resisting forces and maximizing, within reason, the potential forces that may act to cause displacement of an individual block, a sufficiently conservative design will result. In an attempt to minimize potential resisting forces, SLA's design methodology does not account for the potential ability of a subsystem drainage medium to conduct away uplift pressure, and does not consider any restraining force which can be attributed to the presence of cables, vegetation, or mechanical anchorage (Clopper, 1991). Furthermore, the interlocking nature of the mat system along with its permeability and flexibility is not analytically incorporated into the stability analysis. However, these unique parameters are key to the actual performance of the revetment, yet cannot be substantiated without conducting controlled hydraulic studies to determine the limits of hydraulic stability. For this reason, it is essential that articulating concrete block manufacturers provide unique design charts based on hydraulic performance as illustrated in Chart 1.

Under the action of flowing water, an individual block will be subjected to lift and drag forces. The lift force acts in a direction normal to the plane of the bed and is typically comprised of the buoyant force and differential pressure across the block due to local accelerations (Clopper, 1991).

The drag force acts in the direction of flow and is comprised of frictional and form drag. When a block

has the potential to be subjected to direct impingement by flow, which is possible when, due to irregular subgrade preparation or poor installation, an individual block protrudes vertically above its adjacent neighbor, it is necessary for the engineer to include this form drag force in the analysis (Clopper, 1991).

With the resistance to overturning provided by the submerged weight of the block acting through the center of gravity, and its moment arm, the lift and drag forces on the block produce overturning moments about the corner of the block. A "factor of safety" method is then utilized which incorporates the hydraulic conditions of flow, and the size, weight, and geometric characteristics of the block (Clopper, 1991). The equations used for this analysis are listed below.

Once one block within a certain "family" of revetments in terms of method of interlock, profile configuration, and characteristics and boundary roughness has been hydraulically tested resulting in a known critical shear stress, then the critical shear stress for other blocks within the same "family" can be determined through a balance of forces (Clopper, 1991).

$$l_2 W = F_L l_4 + F_D l_3$$

Conservatively assuming that the lift and drag forces are equal and designating subscripts t for the tested block and u for the untested block, then the critical shear stress for an untested block can be determined by:

$$\tau_{cu} = \tau_{ct} \frac{W_u}{W_t} \frac{l_{2u}}{l_{2t}} \frac{(l_{4t} + l_{3t})}{(l_{4u} + l_{3u})}$$

where: W = block weight
l_2, l_3, l_4, = moment arms

The critical shear stress τ_c is derived from physical model tests, and the bed shear stress τ_o is calculated from the equation $\tau_o = \gamma_w DS$

where: D = depth of flow
S = energy grade line (assumed equal to the bed slope, ft/ft)

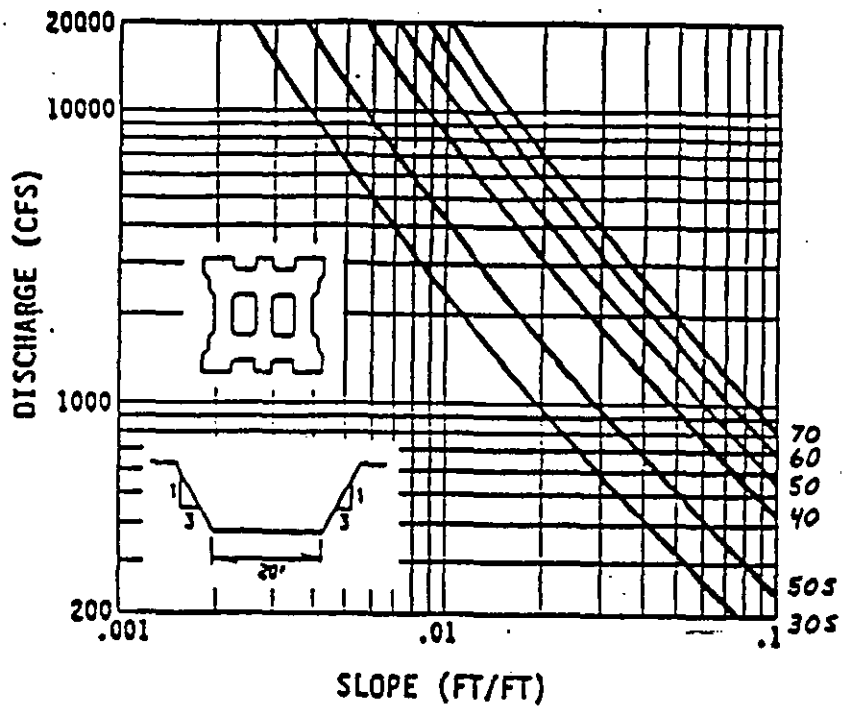


Chart 1. Armorflex stability.

$$\eta = \frac{\tau_o}{\tau_c}$$

$$\frac{M}{N} = \frac{l_4}{l_3}\frac{F_L}{F_D}$$

$$\beta = \tan^{-1}\frac{\cos\lambda}{\left(\frac{\frac{M}{N}+1}{\eta}\frac{l_1}{l_2}\right)\sin\theta + \sin\lambda}$$

Then the factor of safety can be determined as:

$$SF = \frac{\frac{l_2}{l_1}\cos\theta}{\sin\theta\cos\beta + \frac{l_2}{l_1}\left(\frac{\frac{M}{N}+\sin(\lambda+\beta)}{\frac{M}{N}+1}\right)\eta + \frac{l_3 F'_D\cos\delta + l_4 F'_L}{l_1 W_A}}$$

Where the additional drag force due to a vertically protruding block is proportional to the amount of protusion and the velocity of flow and is calculated as follows:

$$F'_D = c\,(\Delta\, Z\, \omega\, \rho\, V^2)$$

where:

λ	=	longintudinal bed slope
θ	=	bank side slope
F'_L	=	F'_D = lift and drag forces
l_1, l_2, l_3, l_4	=	moment arms
W_A	=	submerged weight of block
c	=	momemtum transfer coefficient assumed equal to 0.5
Δ	=	projection height
ω	=	width of projection
ρ	=	density of water
V	=	velocity of flow

DESIGN APPROACH - WAVES

The design criteria for articulating concrete block revetment systems under wave attack can be formulated by conducting hydraulic studies in a broad spectrum of wave environments. For instance, the Delft Hydraulics Laboratory tests confirmed the high stability of the Armorflex system, and a design criteria has been formulated from a report on model investigations. The objective of the study was to evaluate the behavior of the mat system and to determine the maximum limits of the application of Armorflex block protection mats. The characteristics of major importance are uplift of the mat system, length of uplifted area, deformation, and wave runup (Weckmann et al., 1983). Studying these parameters as a function of wave height, wave period, block size, and type of underlayer provides the necessary engineering data from which the operational limits of the concrete mats can be determined.

The forces resisting motion of the articulating block system are the submerged weight of the blocks, the downward force components of friction caused by contact with other blocks, and the systems' interlocking features. Stability may be considered of primary importance in revetment design. One may distinguish between external and internal stability. The former refers to the forces that act on the blocks themselves. The latter deals with the conditions of stability of the bedding construction supporting the blocks. With respect to external stability, the following forces are involved: (a) Various pressure forces perpendicular to the slope, which may be downward or upward; in the latter case, they may cause lifting of the blocks from the revetment; (b) inertia and drag forces caused by flow parallel or perpendicular to the slope; (c) friction forces between individual blocks and between blocks and the sublayer; and (d) forces in joints due to the effect of interlocking.

Because of the complexity of the problem, external stability has to be evaluated primarily by hydraulic model tests. In order to provide practical results, such tests must be based on a variety of realistic wave spectra.

Internal stability may be defined as the stability of the bedding underneath the revetment blocks. This implies that gravel must be stable against hydraulic gradients in the direction of the slope between the blocks and the filter, so that these parts do not move. The individual bedding material must not be sucked out through the joints by negative pressures. The size of the bedding material must therefore be in proper relation to the size of the joints so that loss of bedding material is largely or entirely prevented. In addition to the above criteria, which refer to the

possibilities of leakage of bedding material through the joints, it is also necessary for the original bank or core material below the bedding not to move into the pores of the bedding and finally to be lost through the joints. This requirement is typically met by designing a geotextile filter according to the filtered soil grain size distribution and the applicable hydraulic gradients.

The major parameters that effect the performance of an articulating concrete block revetment against wave attack are listed below.

Design Wave Height. For critical structures where failure would be disastrous, and in the absence of reliable wave records, the design wave height should be the average height of the highest one percent of all waves expected during an extreme event, based on the deep water significant wave height. If early breaking might prevent this wave from reaching the revetment, the maximum wave that could reach the structure should be taken for the design value. For less critical structures, where some risk of exceeding design assumptions is allowable, the recommended design assumes that the design wave heights given are significant wave heights. In any case, the design wave height cannot exceed 60 percent of the water level during the extreme event.

Wave Period. As the wave period increases, the wave height that will cause erosion or probable dislodgement of uncabled blocks decreases. Further, for a given wave height, very large wave periods will result in greater uplift pressures behind the revetment and larger uplift lengths than that resulting from very small wave periods.

Block Selection. The stability of separate articulating concrete blocks on a slope being subjected to wave attack depends on block weight, permeability, and surface area. Block surface area relates to mat permeability in that a larger block surface area would result in a lower mat permeability due to longer drainage paths. For instance, a smaller, lighter, and more permeable block may actually outperform a larger, heavier block because of its ability to dissipate the excess hydrostatic pressures behind the revetment. In addition, joint filling and bedding material should be incorporated with block selection to produce the most economical design, however, without controlled hydraulic studies performed on the revetment system, it is difficult, if not impossible, to quantify any potential stability enhancement that may be provided by joint filling, bedding stone, or the unique interlocking features of a particular articulating concrete block revetment.

Joint Filling. Filling of the holes and tapered joints in and between an articulating concrete block revetment will result in erosion of the coarse material in the near-surface portion of the block during wave action. However, the finer material adheres within the narrow tapered joints between blocks to form an interlocking effect and a desirably more rigid system. The stability of the concrete block mats with gravel-filled holes is considerably greater than that of the non-gravel filled mats (Delft Hydraulics Laboratory, 1983).

Geotextile. A filtration geotextile design must consider the five criteria of filtration which include soil retention, permeability, anti-clogging, survivability, and durability. The geotextile selection is critical to the long-term performance of the system. Its selection is based on the site specific soil grain size distribution as well as the hydraulic flow conditions. The function of the geotextile is to prevent leaching of subsoils through the installation while permitting the dissipation of excess hydrostatic pressure behind the revetment.

Bedding Layer. The presence of a subsystem drainage medium will serve to conduct away uplift pressures that may otherwise cause dislodgement of uncabled blocks. For a given block size and design wave height, the presence of a bedding layer will improve block system stability. In some cases, the addition of this drainage medium may allow the use of a lighter block and prove to be more economical than a heavier block with no underlying drainage.

Base Material. An important aspect for overall stability is the relation between the revetment's armor layer and the condition of the core fill which it is placed upon. While a natural slope may be well consolidated, new fill may be loose and must be well compacted to serve as a foundation for a new revetment. In addition, blocks have to be placed accurately which, in turn, means that they must be cast within narrow limits of tolerance. Even the best design may fail as a result of poor workmanship.

The design method, which can incorporate all of the above parameters into a computer program, is based on the analytical model to predict the stability of block revetments as it is developed for the Dutch Ministry of Transport and Public Works. The original analytical model was developed for block revetments with blocks which are not interconnected by cables or

ATTACHMENT 6

SYNTHETIC INDUSTRIES

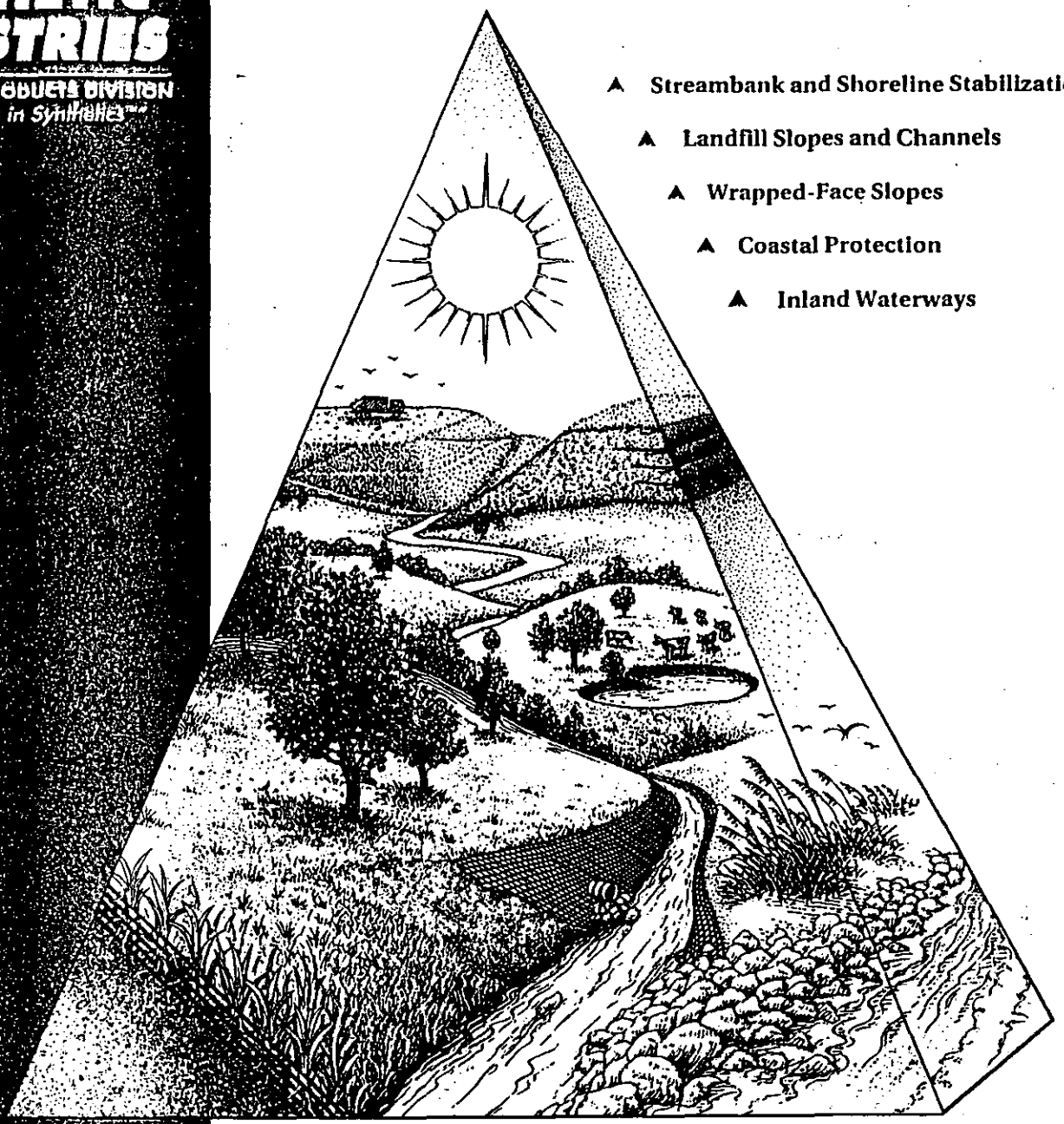
CONSTRUCTION PRODUCTS DIVISION

"Smart Solutions in Synthetics™"

PYRAMAT™

Permanent Erosion and Reinforcement Matrix

"The Fourth Dimension In Soft Armor"



- Streambank and Shoreline Stabilization
- Landfill Slopes and Channels
- Wrapped-Face Slopes
- Coastal Protection
- Inland Waterways

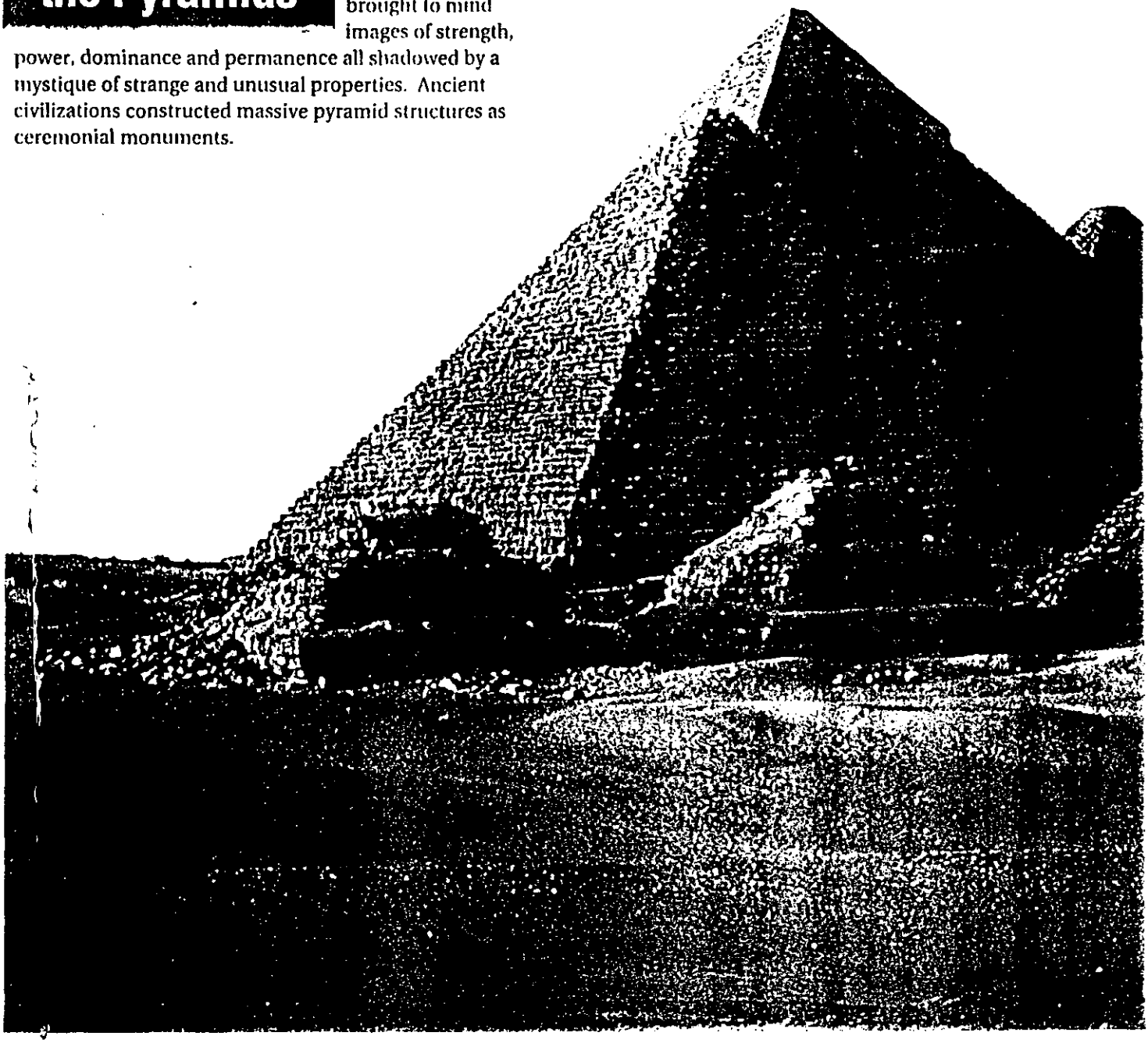
Pyr-a-mid \'pir - ∂ - mid \ n [L *pyramid -, pyramis,* fr. Gk. of unknown origin] (1549) 1 a : an ancient massive structure found esp. in Egypt having typically a square ground plan, outside walls in the form of four triangles that meet in a point at the top, and inner sepulchral chambers b : a structure or object of similar form.

The Mystery of the Pyramids

Throughout the sands of time, the word "pyramid" has brought to mind images of strength, power, dominance and permanence all shadowed by a mystique of strange and unusual properties. Ancient civilizations constructed massive pyramid structures as ceremonial monuments.

Thousands of years later, these structures remain intact. Scholars still attempt to comprehend and chronical the enigmatic history, construction, and often inexplicable properties of these highly efficient structures.

Pyramids have truly stood the test of time!



Bi-o-tech-ni-cal com-pos-ite \ bī-ō -'tek-ni-kəl Käm-'päz- ət \ n (1991) the synergistic, mutually beneficial union of living plant tissue and structurally integrated geosynthetic materials to provide permanently enhanced erosion protection and stability.

Through the years, flexible "soft armor" techniques have emerged as proven and preferred alternatives to traditional "hard" erosion control approaches emphasizing expensive and unattractive rock, concrete and structural materials. Yet many designers have been hesitant to employ environmentally superior soft solutions due to concerns regarding their retained strength, durability and performance through *time, the fourth dimension.*

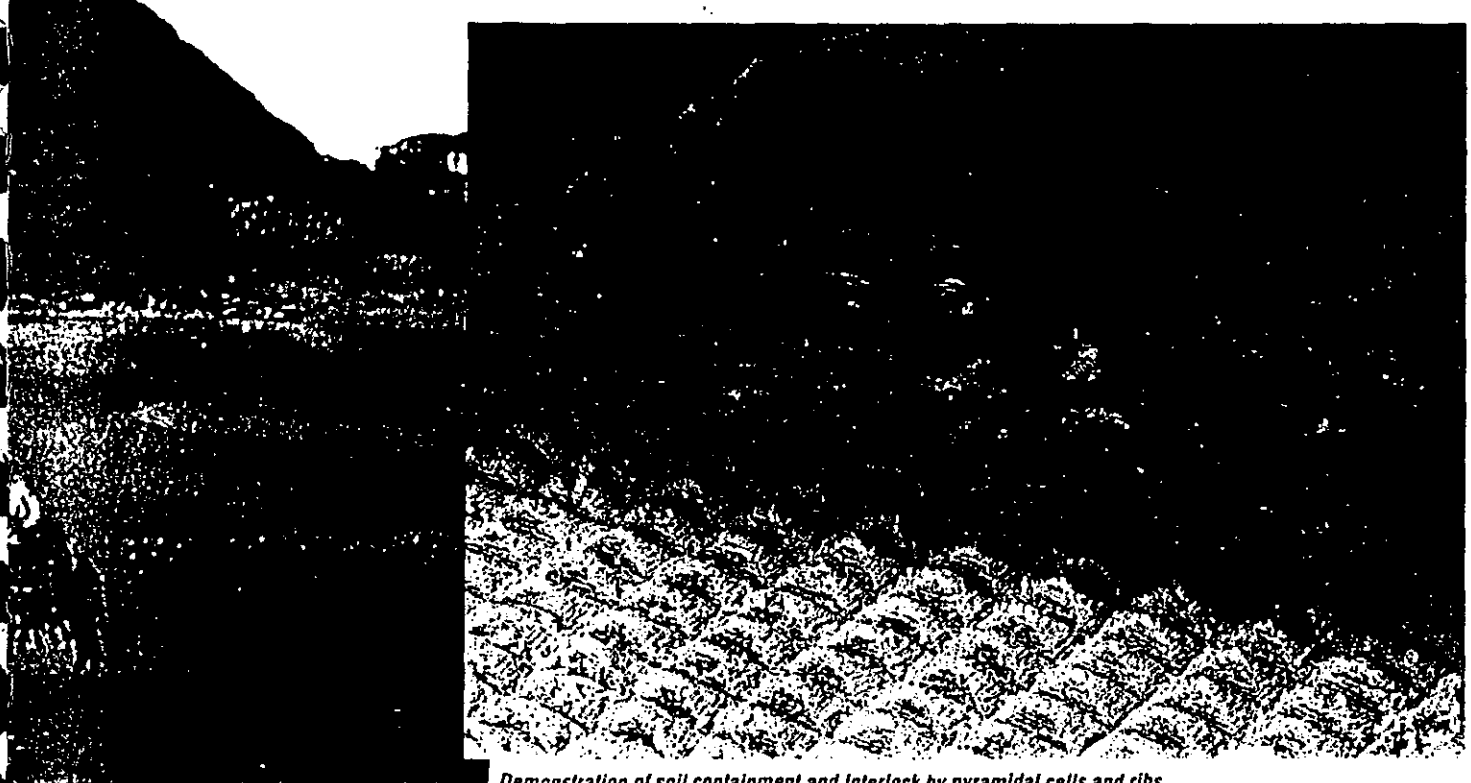
The Matrix of Pyramids

Focused on superior, long term performance, designers at Synthetic Industries have created PYRAMAT™ erosion matrix. This patent pending, *three-dimensional woven geotextile matrix* is composed of UV stabilized polypropylene monofilament yarns woven into a dimensionally stable, uniform configuration of resilient *pyramid-like projections.*

Using a novel and highly sophisticated weaving process all yarns are locked in place to create a **Permanent Erosion and Reinforcement Matrix (PERM)** which exceeds the vegetal reinforcement capabilities of conventional ***biotechnical composites*** ™ and combines the long- term strength, dimensional stability, durability and functional longevity of a ***high performance geotextile.***

The exceptionally efficient geometry of PYRAMAT™ erosion matrix helps stabilize soils and reinforce vegetation. Upward and downward protruding **"pyra-cells"** capture and contain soil while the multiple layers of grid-like "pyra-ribs" interlock with surrounding soils.

In addition, close inspection of the lofty, high modulus matrix will reveal **"hidden chambers"** which literally **entomb soils, even under high flow conditions!** PYRAMAT™ erosion matrix is the product for demanding erosion control applications – where reinforcement of vegetation is desired to replace hard armor and increase soil stability.



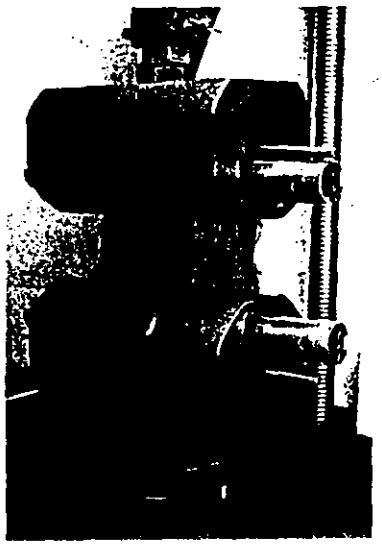
Demonstration of soil containment and interlock by pyramidal cells and ribs.

PYRAMAT™ permanent erosion and reinforcement matrix (PERM) is a precise, highly engineered product possessing the optimal qualities for *"geobotanical reinforcement"*. Unparalleled strength and dimensional stability in an open, three-dimensional geotextile designed to nurture and reinforce vegetation makes PYRAMAT™ the ultimate "new generation" erosion control matrix.

Pyramid Power!

PYRAMAT™ erosion matrix provides many times the strength of popular Turf Reinforcement Mats (TRMs) and Erosion Control Revegetation Mats (ECRMs) currently available. The tensile properties of PYRAMAT™ even exceed those of many conventional, two-dimensional geotextiles and geogrids. Moreover, the strength of PYRAMAT™ erosion matrix is distributed over three-dimensions!

Direct shear and pullout testing has demonstrated that PYRAMAT™ erosion matrix has a very high coefficient of friction with soils. A high interface shearing resistance makes PYRAMAT™ erosion matrix an ideal material to stabilize coast lines, embankments and landfill caps. Once emerging roots of the developing vegetation reach the zone of reinforcement, the resulting "revegetation platform" will provide increased slope stability and erosion control on critical sites.

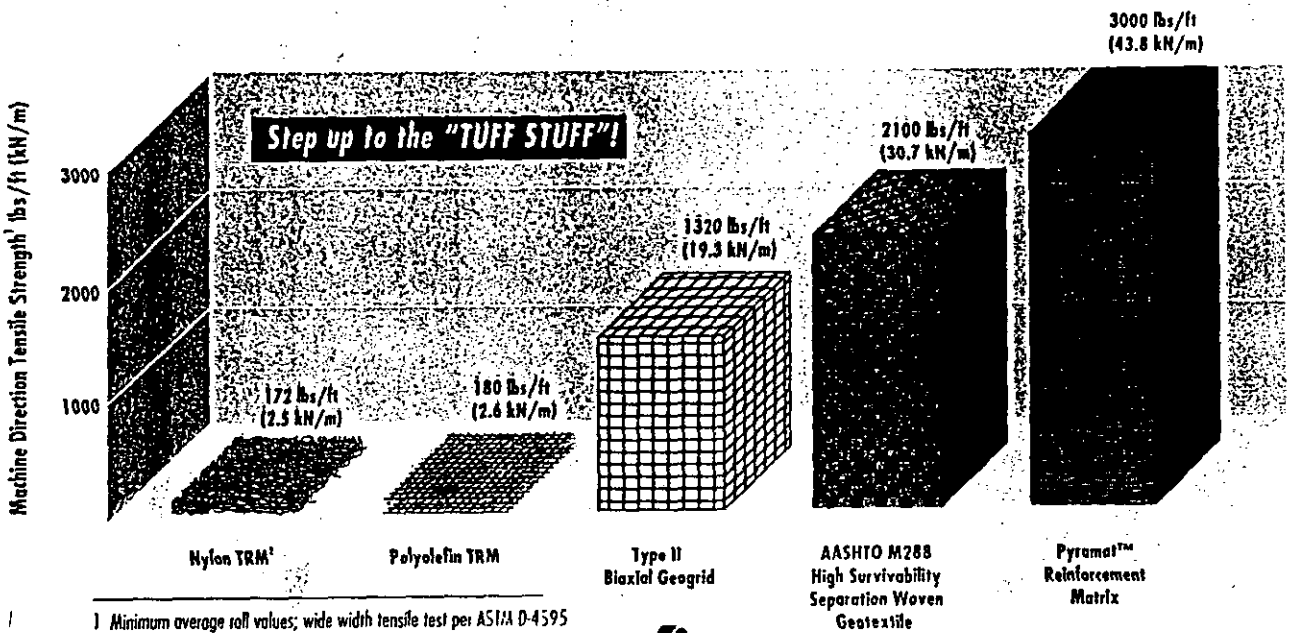


Wide width tensile testing of PYRAMAT™ Reinforcement Matrix.

The abrasion resistant, resilient PYRAMAT™ structure also provides maximum resistance to construction and maintenance induced stresses. Field surveys have demonstrated that low strength mattings may sustain mechanical damage and rutting from passes of maintenance (mowing), emergency, service and recreational vehicles.

Powerful PYRAMAT™ reinforcement matrix provides greater tensile properties than an AASHTO M288, high survivability woven separation geotextile, insuring protection from both anticipated and unanticipated abuse.

PUBLISHED TENSILE STRENGTHS FOR GEOSYNTHETIC MATERIALS



1 Minimum average roll values; wide width tensile test per ASTM D-4595

2 Manufacturer only publishes typical values

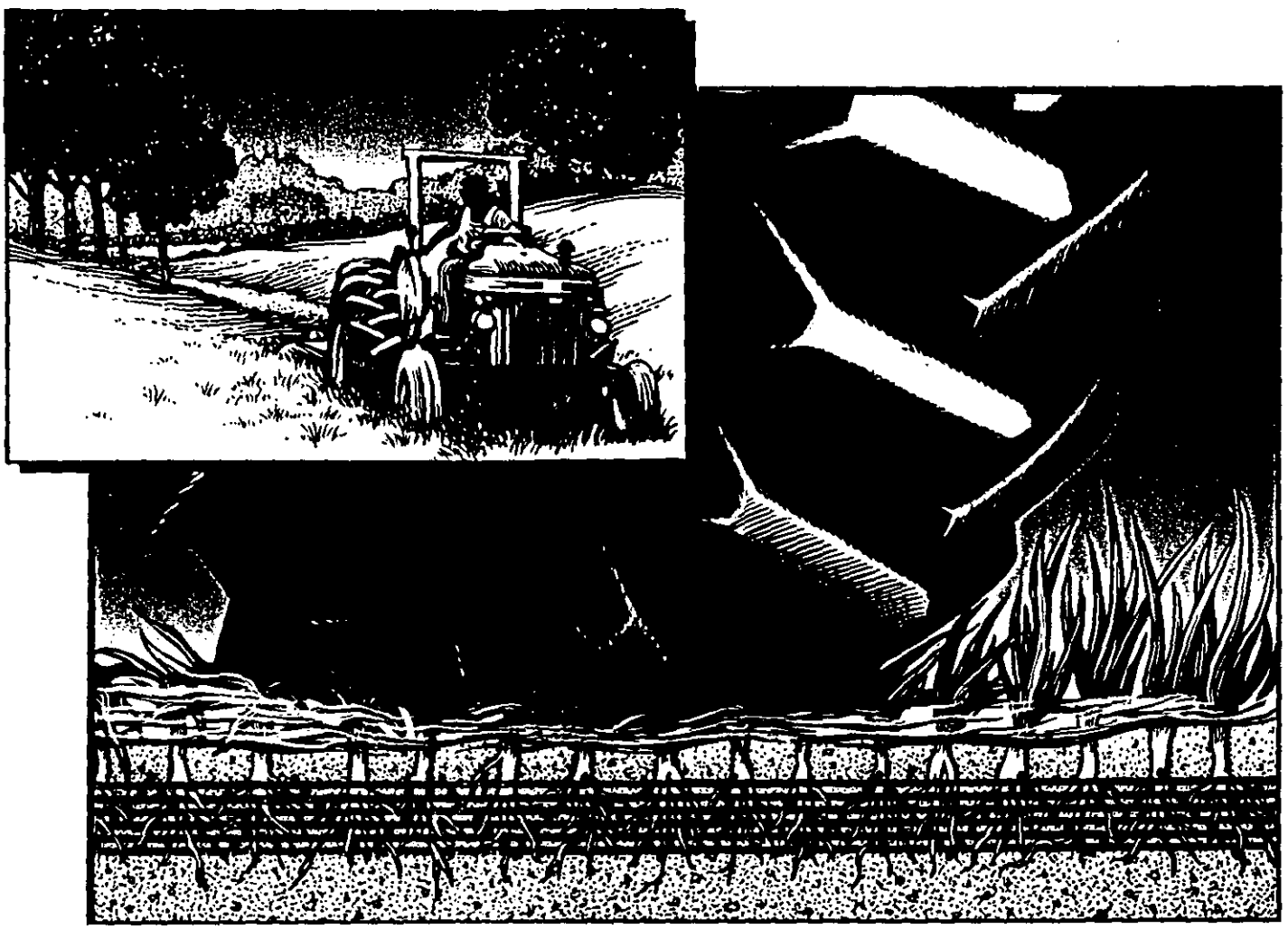
Reinforcement matrices must provide long term performance under adverse conditions. In arid to semi-arid regions or sites where establishment of vegetation is slow, inadequately stabilized TRMs may undergo significant UV degradation prior to performing their primary function.

The durable PYRAMAT™ erosion matrix is designed to withstand prolonged exposure in the challenging conditions of demanding jobsites or inhospitable climates. Ultraviolet stabilizers assure functional longevity when vegetative establishment is delayed or the matrix is otherwise exposed to extended periods of sunlight.

Functional Longevity For The Ages!

The polypropylene yarns of PYRAMAT™ erosion matrix are resistant to biodegradation and unaffected by chemicals normally found in soils. Some polymers, such as moisture absorbing polyamides (nylon), may be subject to temporary and permanent loss of strength from both chemical and hydrolytic attack. Because polyolefins (polypropylene) absorb negligible amounts of water, PYRAMAT™ erosion matrix will maintain its tensile properties under saturated conditions with no long term loss of strength via hydrolysis.

This corrosion resistant matrix will endure as a key component of a shoreline protection system, even in brackish or salt water conditions. Careful polymer selection, high strength/tensile modulus, resiliency, abrasion and puncture resistance and unsurpassed dimensional stability insure *these pyramids will also stand the test of time!*



PYRAMAT™ reinforcement matrix provides "rebar for root systems".

Performance of PYRAMAT™ erosion matrix has been extensively evaluated at a renowned hydraulics testing laboratory in the western United States.

Establishing a flow rate versus time continuum, performance (see graph below) has been quantified using vegetated and non-vegetated mattings versus non-reinforced vegetation and bare soil. These studies identify the "design window", which provides performance guidelines from time of installation, transitioning to a mature vegetated condition for the long-term design life of the project.

Peak Performance!

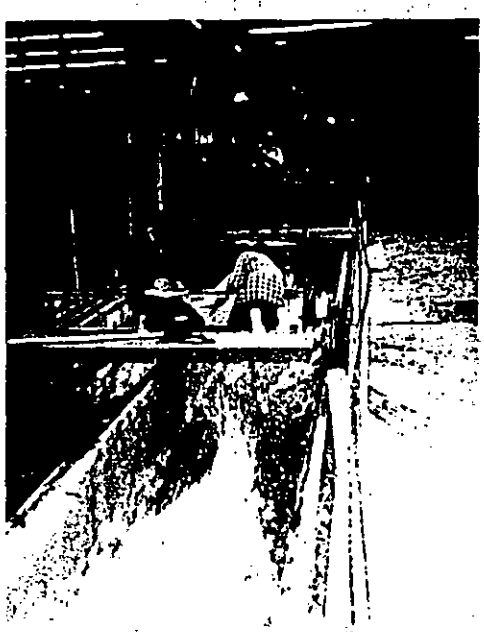
Maximum recommended permissible velocities and shear stresses for PYRAMAT™ erosion matrix are presented in the table above. Vegetated, PYRAMAT™ erosion matrix will resist flow velocities of up to 25 ft/sec at shear stresses up to 10 lbs/ft²!

Additionally, the resistance of unvegetated PYRAMAT™ erosion matrix to directly applied high velocity shear stresses was measured using a specially designed flume. The PYRAMAT™ erosion matrix structure resisted the maximum shear developed at full-flume capacity with no deformation whatsoever. Maximum shear stress developed was approximately 8 lbs/ft² at a velocity of 27 ft/sec!

PYRAMAT™ MAXIMUM PERMISSIBLE DESIGN VALUES

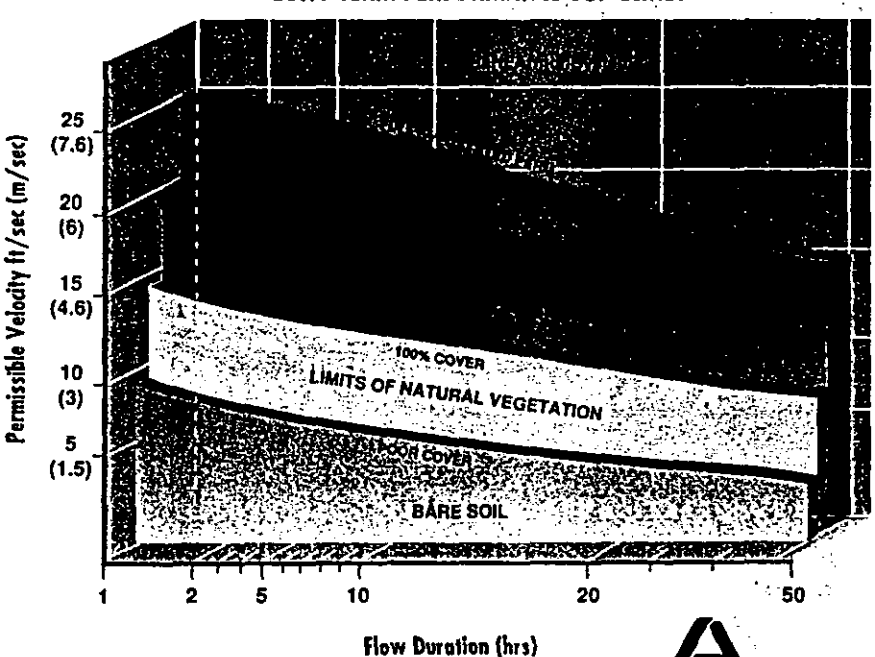
PERFORMANCE	SHORT TERM (1/2 hr)	LONG TERM (50 hrs)
VELOCITY		
Vegetated	25 ft/sec (7.6 m/sec)	14 ft/sec (4.3 m/sec)
Unvegetated	20 ft/sec (6.1 m/sec)	10 ft/sec (3.0 m/sec)
SHEAR STRESS		
Vegetated	10 lbs/ft² (48.9 kg/m²)	6 lbs/ft² (29.3 kg/m²)
Unvegetated	8 lbs/ft² (39.2 kg/m²)	3 lbs/ft² (14.7 kg/m²)

The graph below illustrates the enhanced performance of PYRAMAT™ permanent erosion and reinforcement matrix above that of conventional *Biotechnical Composites*™ and natural vegetation.



High velocity hydraulic flume testing.

LONG TERM PERFORMANCE GUIDELINES



PYRAMAT™ erosion matrix takes "geobotanical reinforcement" to unprecedented levels.

The erosion and sediment control industry has rapidly evolved into a diverse hierarchy of cost effective methods and techniques. The adjacent *"Performance Pyramid"* highlights the four primary divisions of vegetated erosion control techniques.

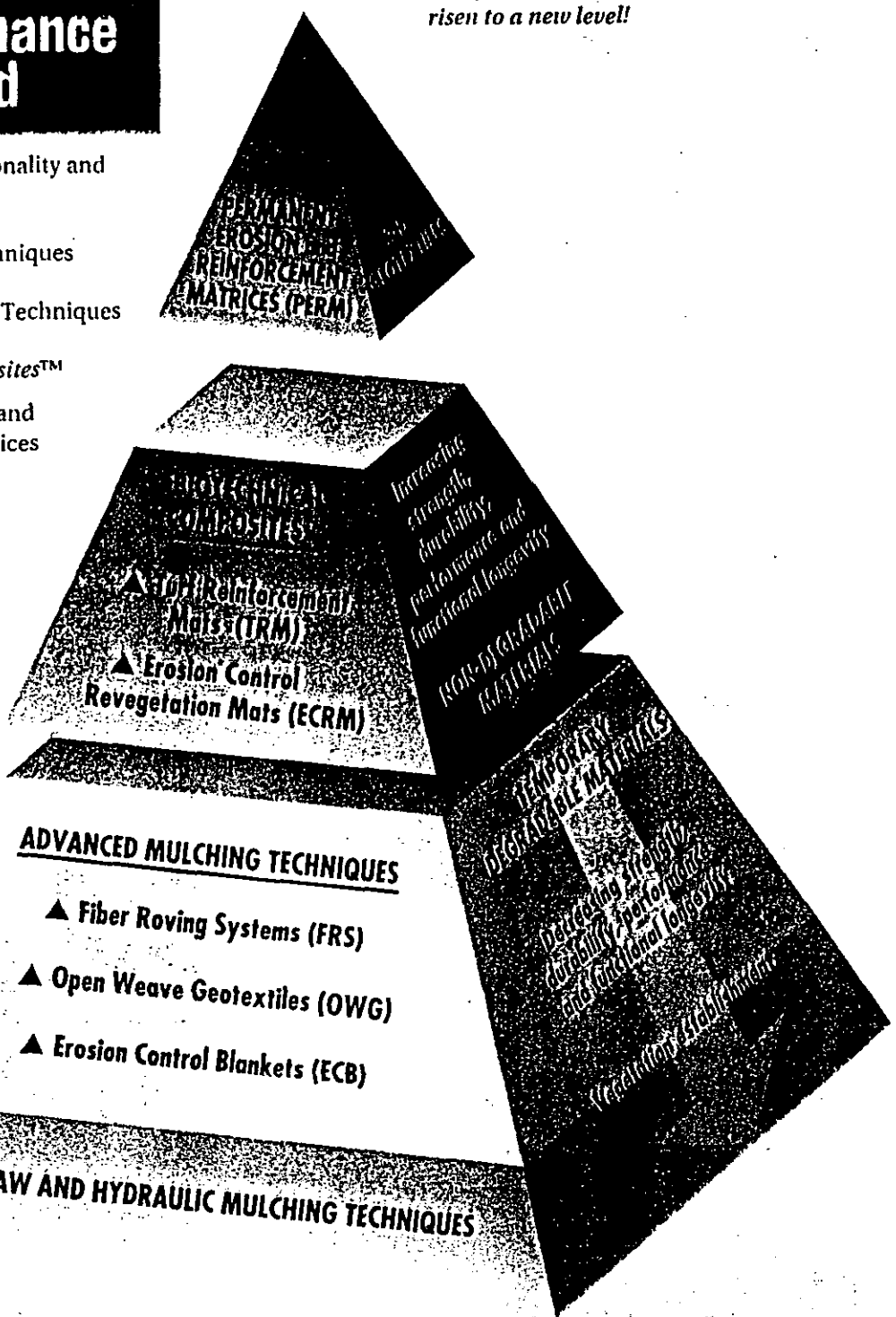
Superior tensile properties combined with rugged construction, durability, proven performance and unsurpassed functional longevity clearly separate the high survivability PYRAMAT™ PERM from existing TRMs and ECRMs.

Geosynthetic erosion control materials have risen to a new level!

The Performance Pyramid

In order of increasing functionality and performance are:

- ▲ Basic Mulching Techniques
- ▲ Advanced Mulching Techniques
- ▲ *Biotechnical Composites*™
- ▲ Permanent Erosion and Reinforcement Matrices



PYRAMAT™ erosion matrix handles a broad range of discriminating biotechnical applications requiring vegetated soil reinforcement and stabilization including:

PYRAMAT ™ Applications

- Landfill Caps, Slopes & Diversion Structures
- Dam, Dike & Levee Protection
- Bank & Shoreline Stabilization
- High Flow Channels
- Geosynthetic Reinforced Earth Structures
- Vegetated Geotextile Slope Facings
- Veneer Cover Soil Stabilization

Other potential applications include :

- Grassed Access Roads/Temporary Parking Areas
- Pre-grown Reinforced Vegetated Carpets
- Bioengineered "GeoLogs"
- Sports Turf Protection
- High Friction/High Flow Geotextile Beneath Hard Armor
- Grout Filled Transitional Matrix for:
  - Low Flow, Pilot or Trickle Channels
  - Outfall Protection
  - Pond & Lagoon Shorelines

The rugged PYRAMAT™ matrix will also absorb considerable installation stress permitting the use of mechanical equipment. The matrix will perform best when installed beneath the soil surface.

PYRAMAT ™ Installation

- When used as a vegetative reinforcement matrix the product should be installed first, seeded, then a 1/2" - 1" veneer of soil placed and compacted into the "pyra-cells".
- Light weight wheeled equipment or vibratory tampers may be carefully utilized to facilitate compaction.
- Refer to the Synthetic Industries LANDLOK® Erosion Mat Installation Guidelines for specific installation instructions as a soil filled matrix.
- For other installation requirements please contact Synthetic Industries for prompt recommendations and on-site construction assistance at (800) 621-0444, extension 2.

Coastal dredge spoil stabilization - Houston, Texas

Channel Protection - Indianapolis Airport

Engineering Specifications

The PERMANENT EROSION AND REINFORCEMENT MATRIX (PERM) shall be a three-dimensional, lofty, woven polypropylene geotextile specially designed for erosion control applications on steep slopes, water containment structures and vegetated waterways. The matrix shall be composed of polypropylene mono- filament yarns woven into a uniform, dimensionally stable configuration of resilient pyramid-like projections. The material shall exhibit very high interlock and reinforcement capacity with both soil and root systems and demonstrate high tensile modulus. The PERM shall conform to the property values listed below under dry or saturated conditions.

MINIMUM AVERAGE ROLL VALUES (MARV)

PROPERTY	TEST METHOD	ENGLISH	METRIC
MECHANICAL			
Tensile Strength[2]	ASTM D-4595	3,000 X 2,200 lbs/ft	43.8 X 32.1 kN/m
	ASTM D-5035	4,000 X 3,500 lbs/ft	58.4 X 51.1 kN/m
Tensile Elongation[2]	ASTM D-4595	45% (max)	45% (max)
	ASTM D-5035	50% (max)	50% (max)
Tensile Strength[2] @ 10% Elongation	ASTM D-4595	1,850 X 1,600 lbs/ft (typ)	27.0 X 23.4 kN/m (typ)
ENDURANCE			
UV Resistance @ 1000 hours	ASTM D-4355	80%	80%
PHYSICAL			
Thickness	ASTM D-1777	0.5 in	12.7 mm
Resiliency[3]	ASTM D-1777	80%	80%
Mass Per Unit Area	ASTM D-5261	14 oz/yd²	475 g/m²
Ground Cover Factor[4]	Light Projection Analysis	75%	75%

PERFORMANCE	MAXIMUM PERMISSIBLE VALUE[5]			
	Short Term (1/2 hr)		Long Term (50 hrs)	
Velocity				
Vegetated	25 ft/sec	7.6 m/sec	14 ft/sec	4.3 m/sec
Unvegetated	20 ft/sec	6.1 m/sec	10 ft/sec	3.0 m/sec
Shear Stress				
Vegetated	10 lbs/ft²	48.9 kg/m²	6 lbs/ft²	29.3 kg/m²
Unvegetated	8 lbs/ft²	39.2 kg/m²	3 lbs/ft²	14.7 kg/m²

NOTES:

1. All published values are Minimum Average Roll Values (MARV) unless otherwise indicated, yielding a 95% confidence level. Additional property values available upon request.
2. Values for both machine and cross machine directions under dry or saturated conditions.
3. Resiliency defined as percent of original thickness retained after 3 cycles of a 100 psi load (690 kPa) for 60 seconds followed by 60 seconds without load...thickness measured 30 minutes after load removed in accordance with ASTM D-1777.
4. Ground Cover Factor represents "% shade" from Lumite Light Projection Test.
5. Values obtained at an independent hydraulics testing laboratory.

STANDARD ROLL SIZE INFORMATION = 6 ft x 90 ft = 540 ft² = 60 yd²
1.83 m x 27.4 m = 50 m²

FABRICATED DOUBLE WIDE ROLLS = 12 ft x 90 ft = 1080 ft² = 120 yd²
3.66 m x 27.4 m = 100 m²

Take the mystery out of designing and specifying erosion control products. Now you can cost effectively specify modern materials using the new EC-DESIGN™ computer aided design (CAD) software program. In minutes, you can calculate and select the most appropriate geosynthetic erosion control product for a variety of channel and slope applications.

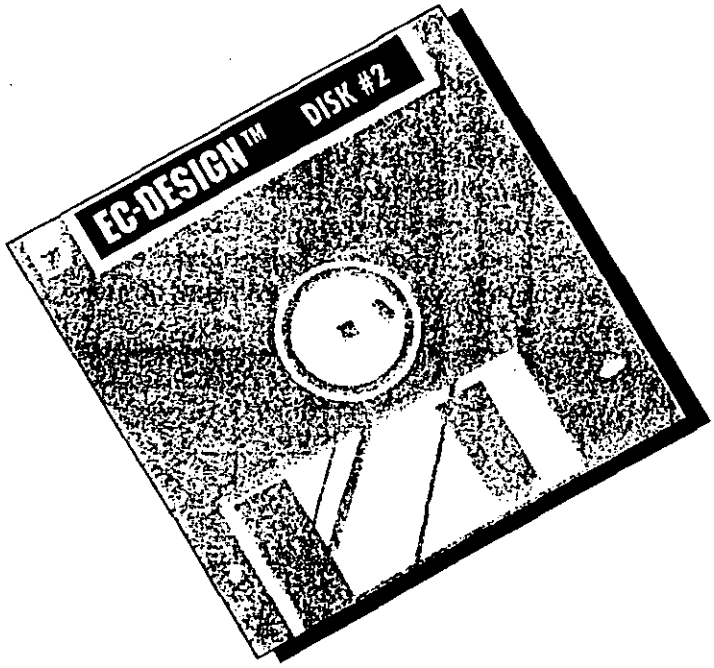
EC-DESIGN ™

EC-DESIGN™ calculations use state-of-the-practice Federal Highway Administration procedures. Once a product is selected, you can print out the calculations, specifications and manipulate CAD drawings to suit project needs.

EC-DESIGN™ offers these important features:

- ▲ Channel lining design
- ▲ Slope protection design analysis
- ▲ Maximum permissible velocity and shear stress approaches
- ▲ Integration of compound flexible channel lining systems
- ▲ Mouse driven pull down window screens

Specify the best with total confidence!



Smart Solutions

Addressing and solving construction end-user challenges is why we're the leader in Geosynthetic technology today. We're here to assist you.

FOR ADDITIONAL INFORMATION PLEASE CALL:

Synthetic Industries
Construction Products Division
4019 Industry Drive
Chattanooga, TN 37416 USA
TOLL FREE: (800) FIX-SOIL or (800) 621-0444
(615) 899-0444
FAX: (615) 899-7619

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IFAI INDUSTRIAL FABRICS ASSOCIATION INTERNATIONAL
ECTC
ifs International geotextile society

A FULL LINE OF GEOSYNTHETIC PRODUCTS AVAILABLE

Synthetic Industries manufactures a full line of high quality geosynthetic materials including woven and non-woven geotextiles, SILT CHECK®, silt fences, FIBERGRIDS® 3-dimensional soil reinforcement fibers, LANDSTRAND® fiber roving system, POLYJUTE® open weave erosion control geotextile, and LANDLOK® erosion mats.

For additional information on any of our engineered geosynthetic materials –
Call us or our distributor today!

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CONSTRUCTION PRODUCTS DIVISION
"Smart Solutions in Synthetics™"

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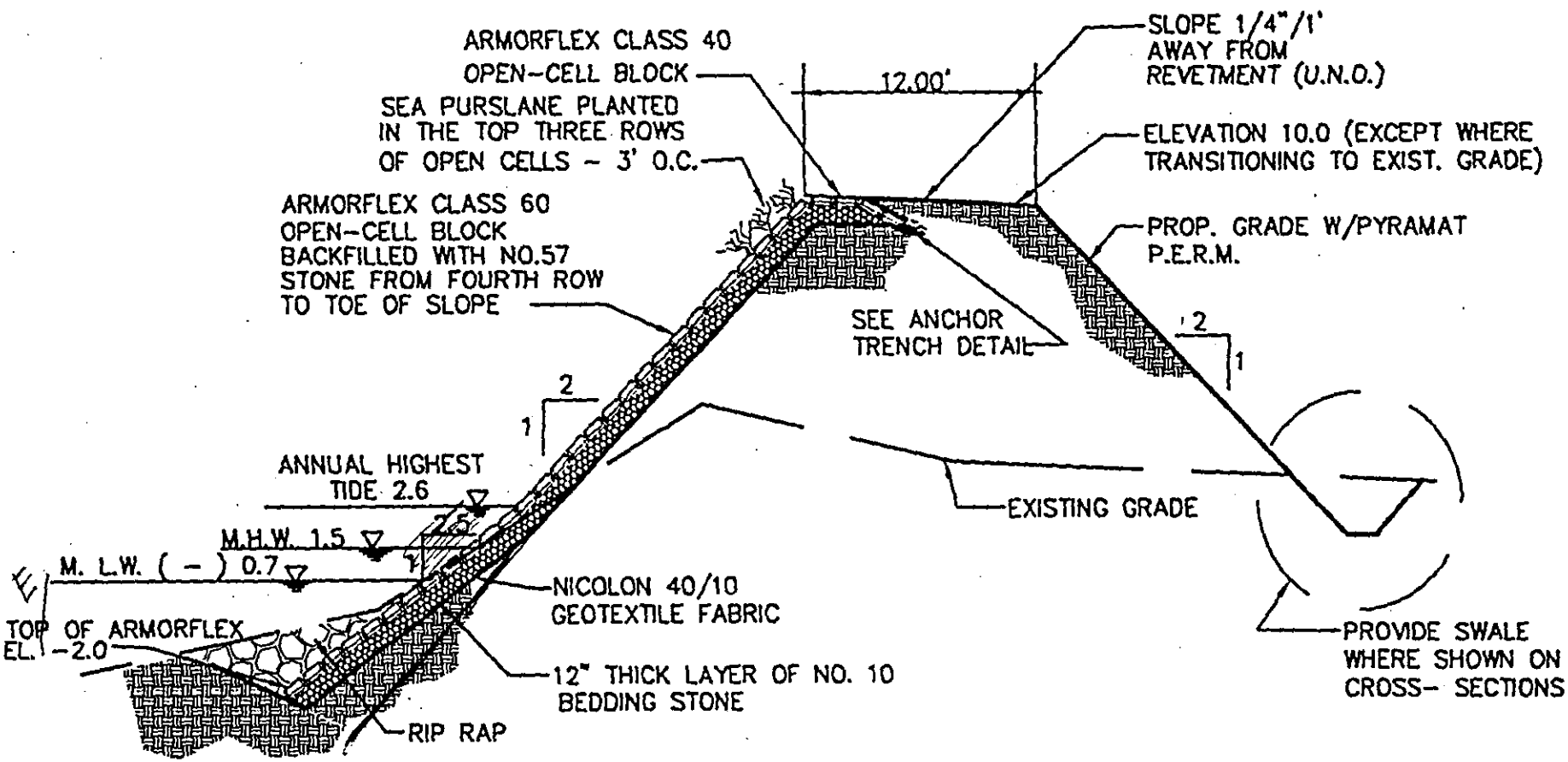


TYPICAL ARMORFLEX CROSS SECTION

N.T.S.

~~ATTACHMENT 6a~~

ATTACHMENT 7

010718

Bechtel

Oak Ridge Corporate Center
151 Lafayette Drive
P.O. Box 350
Oak Ridge, Tennessee 37831-0350

Telephone: (423) 220-2000

AUG 13 1996

Mr. Andrew Hackett, President
Ocean Breeze Construction Company, Inc.
01276 Riverside Drive
Palm Beach Gardens, FL 33410
2155 Eagle Drive, P.O. Box 190010
North Charleston, SC 29419-9010

Post-it® Fax Note 7671	Date 8/14	# of pages ▶ 4
To ANDY HACKETT	From MAC	
Co./Dept.	Co.	
Phone #	Phone # McNEIL	
Fax # 407-627-4408	Fax #	

SUBJECT: Bechtel Job No. 22567
Department of the Navy Contract No. N62467-93-D-0936
Subcontract No. 225567-321-SC-0248
Shoreline Protection, Fleming Key, NAS Key West, FL
PRELIMINARY DESIGN REPORT REVIEW COMMENTS
Subject Code:

Dear Mr. Hackett:

I am enclosing Bechtel's review comments concerning the preliminary design report of the subject contract. The preliminary design has been reviewed by Pat Ryan in our San Francisco office.

The preliminary design is acceptable, and you may proceed to final design, subject to incorporation of the enclosed comments in the final design or other resolution.

We appreciate your spirit of cooperation.

Sincerely,

O. N. McNeil, Jr.
Project Manager

ONM:cw:LR0854

Enclosure: As stated

Bechtel Environmental, Inc.

010718

PRELIMINARY DESIGN REVIEW COMMENTS
BECHTEL SUBCONTRACT 22567-321-SC-0248
SHORE PROTECTION SYSTEM, FLEMING KEY, NAS KEY WEST, FL
13 August 1996

1. Typical Cross Section - Indicate basis for the elevations shown on drawing. "NGVD" 0.0 = MLW

2. Swale and Sediment Basins. Ponding of the water in the basins could provide a source of water to leach into the landfill. Provide reason for using this design feature, including what it accomplishes, any alternatives and cost impact, etc. Describe "ditch checks." ← Deleted

3. Calculations. All calculations need to be finalized and include all assumptions, sources of data, references, etc. Identify (title/purpose) all calculation sheets. The Preliminary Design package contained two separate ARMORFLEX analyses--please explain the difference. Program cannot test A 6' wave if Depth is too low. Mike's = Max. 6' wave. Andy's = Max. wave with water elev. Surge

4. Drawings. Identify drawings to be provided with final design. These should include plan views, layouts, surveys and additional details and sections as required.

5. The following are comments on specification, "Articulated Concrete Block Systems."
Paragraph No.

2.3 Provide a copy of all test results and specifications of all materials to be used in installation of the system to Bechtel. = Normal submittals

2.4 Provide cable specifications, including materials, lifespan, vendor's data for strength (taking into account the weakness of the splice and the required factor of safety) and chemical resistance of the cable. Need Copy of "Canadian" Test and Specs for Simpson.

3/8" ± 1/2" slit

3.3.2 This section requires the toe to be buried to 1m deep; however, the Key West design doesn't have the required depth. – Unknown existing Rock strata Elev. ⇒ Rock Rubble Toe Backfill for added stability and Resistance for Scour

3.3.3 Provide details of side terminations and materials to be used. "Key Block"

5.1 Describe how the foundation at the lower end (below water) will meet the 95% compaction criteria and how will you determine that compaction is satisfactory. – Compaction Testing on a 2/1 slope is not possible. → Subgrade Limerock is being over Filled in Compacted Lifts. Excavator compacts the slope with Back of Bucket → Settling Time approx. 1 week. Rock is basically self Compacting. The overfill is Excavated back To solid compacted Fill Prior to Bedding Stone/Fabric Placement.

5.3 Do all of the grade changes meet the 1m minimum radius at all points?
Check @ Top of Bank Crest and Flank.

Any deviations from the specification should be adequately described and reasons given, so that Bechtel and the Navy can evaluate the proposed materials and methods to be employed.

6. Construction phase comments

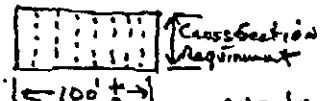
Daily Inspections by Bechtel Inspector

a) At what points will Ocean Breeze provide an inspection by the design engineer? Note that the specification specifically mentions prior to placement of the geotextile. Prior to 1st Mats, 2nd Middle of Job, 3rd End of Job

b) Describe your quality control checks and testing to meet specification and design requirements. Geotextile Certification → Test → Delivery sampling to match Blocks, Installation, Rinker, Concrete Cylinder, etc.

c) Describe how you will protect the geotextile and pyramat from UV damage. Key West is a high UV environment. – Topsoil Cover and planting

d) Describe the field cutting, sewing, and overlapping of the geotextile. Provide a specification on the sewing material.



overlap 3' per specs.

010718

e) The 32 ton limit for the bridge cannot be waived. Potential areas for laydown on the Key West side of the Fleming Key bridge are the area in front of Bldgs C59 and C60, the area near the swimming pool at the road intersection, or the sea plane ramp. A decision will be made in conjunction with you and the ROICC.

f) Update equipment list as discussed during meeting 31 July. Rollers Grader All

g) Describe how revegetation will be accomplished, including mitigation measures as discussed in my letter of 6 August (minutes of meeting with state permitting agencies).

h) Note that substantial completion approval will occur after mitigation planting rather than after final dressing as indicated on preliminary construction plan.

i) Identify source of fill material and provide testing and other data.

7. Permit Application:

Ocean Breeze will prepare and submit to Bechtel the following sections of the Florida Department of Environmental Protection Joint Application for Environmental Resource Permit / Authorization to Use State Owned Submerged Lands / Federal Dredge and Fill Permit.

- Sections A, part 6; C; and E
- Tables 1, 2, 3, and 5

8. Schedule:

Update schedule.

9. Comments on geotechnical calculations (Richard Kulesza) are attached:

010718

8/9/96

R. KULESZA'S COMMENTS ON THE PROPOSED SHORE PROTECTION SYSTEM, FLORIDA

1. The configuration of the materials involved in the slip circle stability diagrams is not clear because of the small scale of the computer printout diagrams that show the slip circles. Suggest showing the critical slip circle on a copy of the typical slope protection cross-section, so that it is clear what length of the slip surfaces passes through each material.

2. The basis for the adoption of the shear strength parameters (cohesion and friction angle) should be explained for each material. The values shown on the stability analysis diagrams are quite high, and need to be justified for each material. Post-peak shear strength, rather than peak shear strength, needs sometimes to be considered (a reduced value), because of significant strains that may develop in the system. Note that the factors of safety are not very high, so that lower strength values would have a significant unfavorable impact on the factors of safety.

3. Only results of circular slip surface analysis are shown. It should be checked, and documented, that plane slip surfaces paralleling the slope are not more critical. The appropriate strength parameters along the contacts between the various materials should be examined.

4. If plane slip surfaces paralleling the slope are found to be more critical in an analysis that neglects the end restraint at the top of the slope (tension), and bottom of the slope (compression), then proper account should be taken of these end restraints in the stability analysis, to show that, if the end restraints are taken into account, the factor of safety is satisfactory.

5. Consideration should be given to checking that the factor of safety against slope failure is at least, say, 1.2 in the event of erosion at the top of the slope reducing the effectiveness of the anchorage.

RESPONSES TO
PRELIMINARY DESIGN REVIEW COMMENTS

1. Done. Basis for elevations is National Geodetic Vertical Datum (NGVD) - 0.0.

2. This requirement was deleted from the design during discussions at the preliminary design review meeting at the NAS Key West on July 31, 1996 and subsequent telephone conversations.

3. All calculations are finalized and include assumptions, sources of data, references, etc. All calculation sheets have been identified for purpose. The final design package includes the final ARMORFLEX analysis used in this report. All calculations are included in the Appendix.

4. The drawings provided in the final design package include:

   - Site Layout
   - Cross-Sections (station 0+00 to station 18+00)
   - Details

5. A revised specification is provided as Attachment 8.

   Paragraph 2.3 - Test results and product data of materials to be used will be provided during the normal submittal process during construction.

   Paragraph 2.4 - Information on the polyester cable is included as Attachment 3.

   Paragraph 3.3.2 - As outlined in the design report, the toe of the Armorflex ACB system will be placed 3.3 feet (1 meter) below the existing bottom to prevent scouring from wave action.

   The ACB will then be backfilled with 125 pound rip rap between station 0+00 and 15+00 and 125 pound rip rap and sand between station 15+00 and 18+00.

   In the event natural bedrock is encountered above the 3.3 foot depth, then the ACB will be placed on the bedrock and backfilled with rip rap.

   Paragraph 3.3.3 - Details of the side terminations and connection of adjoining mats are provided in the construction drawings.

Paragraph 5.1 - Compaction testing on a 2:1 slope is not possible. The limerock used in the subgrade will be overfilled in compacted lifts. The backhoe/excavator compacts the slope with the back of the bucket. Experience has shown that the limerock material is self-compacting. After approximately one week, the overfill is excavated to the solid, compacted fill level necessary for bedding stone/geotextile fabric placement.

Paragraph 5.3 - The details show a 3.3 foot (1 meter) minimum radius for all grade changes for the Armorflex ACB.

6. a) The design engineer will provide the first site inspection of the construction during the installation of the geotextile prior to the placement of the first mat of ACB. The second site inspection by the design engineer will be approximately during the middle of the project. The third site inspection by the design engineer will be at the end of the project.

b) All materials will be certified in writing by the manufacturer of the material for conformance with the Specifications. Actual test reports will be submitted for the concrete blocks, geotextile, and poured-in-place concrete in accordance with the appropriate ASTM standard. Embankment fill and bedding stone will have gradation test done at the quarry.

c) The Pyramat will be protected from Ultra Violet (UV) damage by placing a one-inch layer of topsoil cover and seeding the topsoil. The geotextile will be protected from UV damage by covering the material as quickly as practical with the Armorflex ACB and backfilling the voids.

d) Field fabricated panels will be constructed by cutting pieces from the bulk rolls equal to the total section length required. Approximately eight pieces will be sewn side-to-side, "accordian style," to form a panel covering approximately 96 linear feet along the embankment. The seams will be sewn in a "J" seam, double-stitched. See Attachment 9 for information on the 12/4 polyester thread. All overlays of panels will be a minimum of three feet.

e) The 32 ton limit for the bridge is not waived. A material laydown area will be provided by NAS Key West on the south side of the bridge.

f) The equipment to be utilized on this project includes:

Loader	Dozer	Note: Items with an (*) asterisk
Rake	Chipper	were added after the Preliminary
Excavator	Jobsite Office/ Storage Trailer	Design Review meeting.
Crawler Crane	*Single-drum motorized roller	
	*Gradall	

g) Revegetation will be accomplished as described on the construction plans and specifications. Mitigation will be accomplished according to the permit application currently before the Florida DEP.

h) Noted that substantial completion approval will occur after mitigation planting rather than after final dressing.

i) Fill bedding stone and rip rap will be provided by CSR-Rinker Materials, Aggregate Division, from the Krome Quarry in Southwestern Dade County (Miami), Florida. See design calculations for sliding analysis in the Appendix for gradation graph of a representative sample of the fill bedding stone material. Actual material to be used will be tested prior to shipment.

7. Permit application complete.

8. Construction schedule is updated and included in the Design Report as Attachment 10.

9. Response to R. Kulesza's comments are as follows:

   1. *The critical failure circle for the normal, long-term condition is plotted on the* typical Armorflex Cross-Section Detail in the construction drawings.

   2. The basis for the strength parameters is the embankment soil is classified as a well-graded gravel-sand-mixture-GW (see gradation curve in Appendix for calculations of Sliding Analysis). An effective friction angle of 38 degrees was assigned based on the following reference for compacted materials:

      Soil Mechanics and Foundation and Earth Structures, NAVFAC DM-7.1 and 7.2, Dept. of Navy, 1982.

      This reference suggests that for a compacted well-graded clean gravel-sand mixture, an effective friction angle of 38 degrees is a lower bound value (see chart in Appendix for calculation of Sliding Analysis). Further, a unit weight of 125 pcf was assigned based on inspection of the same reference and experience with Florida soils and aggregate.

   3. The following plane slip surfaces were considered:

      a. Geotextile slippage along embankment soil. This is not possible since the geotextile will be embedded in a non-erodible, concrete trench at the top of the slope.

b. Bedding stone sliding along geotextile interface. This is the only practical consideration and has been addressed by the calculations in the Appendix.

The most critical time for this type of failure will be during and immediately after placement, at which time no buttressing effect is provided by the rock rip rap proposed to be placed at the toe of slope. Therefore, two analyses are provided, 1) for an infinite slope which considers zero buttressing effect (i.e., during construction), and 2) a finite slope analysis (i.e., immediately after construction). The analyses show a factor-of-safety of 1.25 and 1.36, respectively for the two cases. These values are considered acceptable for short-term conditions as intended. For long-term conditions, the mat and rock rip rap at the toe will provide additional stability. Therefore, this condition was not analyzed based on inspection of the factors-of-safety for the short-term conditions.

The critical parameter in these analyses is the interface friction angle between the bedding stone and the geotextile. The value chosen of 32 degrees is based on a coefficient of interaction of 0.80 and assuming that the bedding stone has an internal friction angle greater than the embankment fill itself, 38 degrees. This is a reasonable assumption as a result of the coarseness and angularity of the proposed bedding stone. The coefficient of interaction is based on available data developed from pullout and direct shear testing on similar materials. A compilation of such data is available and a summary is included herein as support.

c. Sliding of the mat on the bedding stone. In any past research conducted and experience with similar projects, mat sliding has never been a mode of failure, probably due to the end-restraints. Since in this case, the mat will be embedded in concrete along the slope crest, erosion is not likely to occur and negatively effect the anchorage. Therefore, this consideration has been made and deemed unlikely to occur.

4. Previously discussed in #3.

5. Previously discussed in #3.

ATTACHMENT 8

Section 02130

ARTICULATED CONCRETE BLOCK SYSTEMS

PART 1 - GENERAL

1.01 Scope

A. The work specified in this Section consists of providing an articulated concrete block system (ACB) as shown on the Drawings.

B. An articulated concrete block system is comprised of a series of individual concrete blocks placed together to form a mattress overlay with specific hydraulic performance characteristics. The blocks within the mattress shall be dense and durable, and the mattress shall be flexible and porous. Articulated concrete block systems are used to provide erosion protection to underlying materials from the forces of waves and/or flowing water.

PART 2 - PRODUCTS

2.01 Concrete

A. Concrete shall conform to the following applicable ASTM specifications:

Portland Cements - Specification C 120, for Portland Cement.
Blended Cements - Specification C 595, for Blended Hydraulic Cements.
Hydrated Lime Types - Specification C 207, for Hydrated Lime Types.
Pozzolans - Specification C 618, for Fly Ash and Raw or Calcined Natural Pozzolans for use in Portland Cement Concrete.

Aggregates shall conform to the following ASTM specifications, except that grading requirements shall not necessarily apply:

Normal Weight - Specification C 33, for Concrete Aggregates.

B. Strength and Durability Requirements. At the time of delivery to the work site, the units shall conform to the physical requirements prescribed in Table 1 below.

TABLE 1. PHYSICAL REQUIREMENTS			
Minimum Compressive Strength MPa (psi)		Maximum Water absorption kg/m^3 (lb/ft^3)	
Avg. of 3 units	Individual Unit	Avg. of 3 units	Individual Units
27.6 (4,000)	24.1 (3,500)	10 (16)	12 (18.2)

In severe weathering regions, where the weathering index exceeds 500 per ASTM C-62 Figure 1, the manufacturer shall meet one of the following requirements in addition to the requirements of Table 1:

1. Prescriptive Requirement: Average net area compressive strength of the units shall be not less than 5,000 psi, with no individual unit less than 4,500 psi.

2. Performance Requirements: Freezing and Thawing testing, conducted on units representative of those intended for the project, performed in accordance with the requirements of ASTM C67, shall show no breakage of weight loss greater than 1% after 50 cycles.

C. Sampling and Testing. Sample and test units in accordance with the requirements of ASTM C120, except as modified below:

1. Test full size units whenever possible. If coupons must be cut, maintain the same ratio of height to thickness and length to thickness in the saw cut coupon as in the original specimen, if possible. In no instance shall the ratios exceed 1 to 1.

2. Coupons shall be 100% solid, and shall not contain cable holes or other voids.

3. The compressive strength of the coupon shall be considered to be the net area compressive strength of the full size unit.

2.02 Revetment Cable and Fittings

A. The revetment cable and fittings shall provide adequate strength and durability characteristics to facilitate lifting and placing of large mattresses.

B. Revetment cable shall be constructed on high tenacity, low elongating, continuous filament synthetic fibers. Fittings, such as sleeves and stops, shall be aluminum or copper and washers (as required per manufacturer) shall be galvanized steel or plastic. Revetment cable and splicing fittings shall be selected so that the resultant splice provides a minimum factor-of-safety of 5.0 with respect to lifting of mattresses from both ends to form a catenary.

C. For applications in which the cable is deemed necessary for long design lifetimes, the revetment cable shall exhibit good to excellent resistance to most concentrated acids, alkalis and solvents. Cable shall be impervious to rot, mildew and degradation associated with marine organisms. The materials used in the construction of the cable shall not be affected by continuous immersion in fresh or salt water.

2.03 Geotextile Filter

A. A geotextile filter shall have adequate strength to survive the handling and installation conditions of the revetment system. Based on AASHTO M288-96 guidelines, Table 2 provides strength properties for three geotextile classes. The geotextile shall conform to the properties of Table 2 based on the geotextile class required in Table 3, for the indicated applications.

B. All numeric values in Table 2 represent MARV in the weaker principal direction. The geotextile properties required for each class are dependent upon geotextile elongation.

Table 2. Geotextile Strength Property Requirements

	Test Methods	Units	Class 2	
			Elongation <50%(2)	Elongation ≥ 50%(2)
Grab Strength	ASTM D 4632	N	1100	700
Sewn Seam Strength	ASTM D 4632	N	990	630
Tear Strength	ASTM D 4533	N	400(4)	250
Puncture Strength	ASTM D 4833	N	400	250
Burst Strength	ASTM D 3786	kPa	2700	1300
Permittivity	ASTM D 4491	sec1	Minimum property requirements for permittivity, AOS and UV stability are based on geotextile application. Refer to Table 3 for permanent erosion control.	
Apparent Opening Size	ASTM D 4751	mm		
Ultraviolet Stability	ASTM D 4355	%		

Notes for Table 2:

1. As measured in accordance with ASTM D 4632.
2. The required MARV tear strength for woven monofilament geotextiles is 250 N.

Table 3 Permanent Erosion Control Geotextile Requirements

	Test Methods	Units	Requirements		
			Percent In-Situ Soil Passing .075 MM(1)		
			< 15	15 to 50	> 50
Geotextile Class Woven Monofilament Geotextiles All other Geotextiles			Class 2 from Table 2(2)		
Permittivity	ASTM D 4491(4)	sec1	0.7	0.2	0.1
Apparent Opening Size	ASTM D 4751(4)	mm	0.43 max. avg. roll	0.25 max. avg. roll value	0.22 max avg. roll value
Ultraviolet Stability (Retained Strength)	ASTM D 4355	%	50% after 500 hours of exposure		

Notes for Table 3:

1. Based on grain size analysis of in-situ soil in accordance with AASHTO T88.

2. Armor layer stone weights exceed 100 kg, stone drop height is less than 1 m, and the geotextile is protected by a 150 mm (minimum) thick aggregate bedding layer designed to be compatible with the armor layer.

3. These default filtration property values are based on the predominant particle sizes of the in-situ soil.

PART 3 - INSTALLATION

3.01 Foundation Preparation

A. The slope should be graded to a smooth plane surface to ensure that intimate contact is achieved between the slope face and the geotextile, and between the geotextile and the bottom surface of the articulated concrete blocks. All slope deformities, roots, grade stakes, and stones which project normal to the local slope face must be regraded or

removed. Holes, "pockmarks," slope board teeth marks, footprints, grooves, depressions or other localized voids should also be removed, filled and compacted. The slope and slope face should be uniformly compacted to 95% standard proctor (ASTM D698).

B. The anchor trench at the top of the slope should be uniformly graded to facilitate the development of intimate contact between the articulated concrete blocks and the underlying grade at the transition between the embankment crest and the slope face. Immediately prior to placing the geotextile filter and articulated concrete blocks, the prepared area should be inspected and approved by the Engineer. The slope must be geotechnically stable in the absence of erosive forces. The revetment must be considered to provide stability to an otherwise unstable slope.

3.02 Placement of Geotextile

A. The geotextile should be placed directly on the prepared area, in intimate contact with the subgrade, and free of folds or wrinkles. The geotextile shall be placed in such a manner that placement of the overlying materials will not excessively stretch so as to tear the geotextile. The geotextile should not be walked on or disturbed when the result is a loss of intimate contact between the articulated concrete block and the geotextile or between the geotextile and the subgrade. The geotextile should not be left exposed for more than 14 days to minimize damage potential due to ultraviolet radiation exposure.

B. The geotextile should be placed so that the upslope strip of fabric overlaps the downslope strip. The longitudinal and transverse joints should be overlapped at least 1m (3 ft.). If a sewn seam is to be used for the seaming of the geotextile, the thread used shall consist of high strength polypropylene, or polyester and shall be resistant to ultraviolet radiation. The geotextile should extend at least 0.3m (1 ft.) beyond the top toe, and side termination points of the revetment. In certain applications to expedite construction and to maintain the recommended overlaps, 450m (18 inc.) anchoring pins placed on 600 mm (24 in.) to 1,800 mm (72 in.) centers, depending on the slope of the covered area, may be used.

3.03 Placement of Articulated Blocks/Mats

A. The articulated concrete blocks should be placed on the geotextile in such a manner as to produce a smooth plane surface in intimate contact with the geotextile. Care shall be taken during installation so as to avoid damage occurring to the geotextile as a result of the installation process. Should the geotextile be damaged during installation, a geotextile patch shall be placed over the damaged area extending 1 m (3 ft.) beyond the perimeter of the damage. Placement shall take place so as to avoid stretching and subsequent tearing of the geotextile. Individual blocks

within the plane of placed articulated concrete blocks should not protrude more than what was accounted for in design of the blocks, typically 12.5 mm (0.5 in.) for cable-tied systems. To facilitate the development of a flush block surface and intimate contact with the subgrade, it is suggested that the blocks be "seated" with a roller or otherwise positioned until a flush surface exists.

B. If assembled and placed as large mattresses, the articulated mats can be attached to a spreader bar to aid in the lifting and placing of the mats in their proper position with a crane. The mats should be placed side by side and/or end to end, so that the mats abut each other. Mat seams or openings between mats greater than 50 mm (2 in.) should be filled with grout. Whether placed by hand or in large mattresses, distinct grade changes should be accommodated with a well-rounded transition (i.e., minimum radius of 1 m (3 ft.).

C. Anchor trenches and side trenches should be backfilled and compacted flush with the top of the blocks. The integrity of a soil trench backfill must be maintained so as to ensure a surface that is flush with the top surface of the articulated blocks for its entire service life. Top, toe and side termination trenches should be backfilled and compacted immediately with suitable material.

5.04 Finishing

A. The open area of the articulated concrete block system is to be backfilled with No. 57 stone or with suitable soil for revegetation as shown on the construction drawings. Backfilling and compaction should be completed in a timely manner such that the system is not left exposed for a long period of time.

B. Dispose of all excess materials in a manner satisfactory to the Owner.

ATTACHMENT 9

POLYESTER

THREAD SIZE	12/4	12/5	12/4	13/4	13/5	13/6	20/4	20/5	20/6
Tensile Strength	15.0	19.8	23.1	14.6	19.4	22.6	13.4	16.7	16.6
Feet Per Pound	7,560	6,048	5,040	8,190	6,552	5,460	12,900	10,080	8,400

POLY / COTTON BLEND

THREAD SIZE	12/3	12/4	12/5	12/6
Tensile Strength	9.3	12.4	15.5	17.4
Feet Per Pound	10,080	7,560	6,064	5,040

100 % COTTON

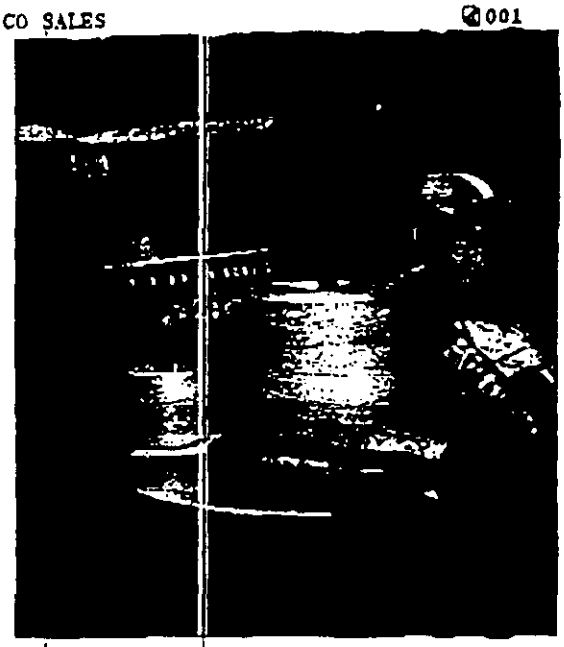
THREAD SIZE	12/4	12/5	12/6
Tensile Strength	7.6	9.4	11.2
Feet Per Pound	7,560	6,048	5,040

POLY / RAYON BLEND

THREAD SIZE	12/4	12/5	12/6
Tensile Strength	14.2	18.8	21.9
Feet Per Pound	7,560	6,064	5,040

CONTINUOUS FILAMENT THREAD

DENIER	Tensile Strength	Feet Per Pound	Cone Size	Case Size
1050 Polypropylene	16.4	12,755	6 Lb.	300 Lbs.
1000 Polyester	19.1	13,392	6 Lb.	300 Lbs.



OUR THREADS ARE ENGINEERED AND PRODUCED FOR BAG MANUFACTURERS AND BAG CLOSERS...

ALL THREADS ARE SPUN WITH THE HIGHEST QUALITY FIBERS FOR SUPERIOR SEWING RESULTS AND MAXIMUM TENSILE/SEAM STRENGTHS.
ALL PACKAGES ARE WOUND ON PRECISION KNOTLESS CONES... WITH HIGH SPEED PROTECTIVE FINISH... AND TRANSFER TAILS...
ALL CONES ARE PACKED IN INDIVIDUAL PLASTIC BAGS... PLACED IN CASES THAT ARE SHRINK WRAPPED... AND PALLETIZED FOR PROTECTION...

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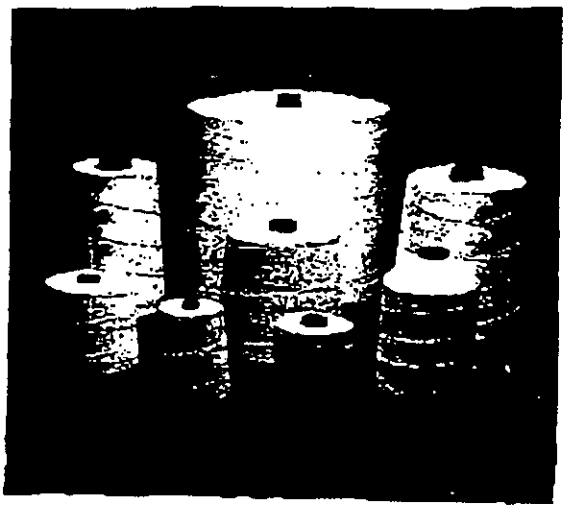
DYED COLORS ... PRIVATE LABELING... AND PACKAGING... TO YOUR SPECIFICATIONS... AND NEEDS...
PLUS CUSTOM ENGINEERED THREADS ARE AVAILABLE FOR YOUR IMPOSSIBLE TASKS...



PACKAGING SPECIFICATIONS FOR OUR PRODUCTS

CONE SIZE	Individual Cone: Cones	Individual Cone: Pounds	Full Pallet: Cases	Full Pallet: Pounds
8 Oz. Cone	32	16	64	1,024
2.5 Lb. Cone	16	45	16	810
5.0 Lb. Cone	12	60	18	1,060
20 Lb. Cone	2	40	32	1,280
20 Lb. Cone	4	80	16	1,280
20 Lb. Cone	8	160	8	1,280

This Information is Offered without Warranty. Due to the Manufacturing Process of Staple Spun Threads, it is impossible to Guarantee Exact Specifications, Yields... Or Tensile Strengths... All Of Our Testing Methods... And Procedures... Conform to Industry Standards...

BAG CLOSING MATERIALS

Ply	FILLER CORD 1.0/2	TEAR STRING 8/8	TEAR STRING 8/10	HAND SEWING 4/12
Cone Size	8 Lbs.	15 Lbs.	15 Lbs.	50 Lbs. Many Ends
Feet Per Pound	1,260	2,520	2,016	840
Cone Weight	64	120	120	As Specified

(1) Dyed Thread Is 12/4 Poly
(2) White Thread You Get Is 13/4 Poly

Ocean Bags & Cons.

ATTACHMENT 10

PROJECT: NAS - KEY WEST, FLEMING KEY LANDFILL REVETMENT, # 22567-SC-1248 SCHEDULE A

PROJECT SCHEDULE FLOW CHART			1996 (Months / Weeks)												1997 (Months / Weeks)											
		DATES	O C T				N O V				D E C				J A N				F E B				M A R			
DESCRIPTION	DAYS	START - FINISH	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Permitting	60 - 90	10/2/96 - 1/2/97																								
Final Design	15	10/10 -11/1																								
Notice To Proceed	1	12/2																								
Final Submittals	2	12/3 -12/6																								
Pre-Con Meeting	1	12/5 - 12/6																								
Safety Training	1	12/9 - 12/11																								
Mobilization	2	12/11 - 12/13												H												
Turbidity Controls	1	12/12 / 12/13												O												
Clearing of Vegetation	7	12/12 -12/20												L												
Debris Removal	7	1/2 - 1/17												I												
Fill & Compaction	15	1/2 - 3/7												D												
Armorflex Fabrication	16	1/20 - 2/7												A												
Geotextile & Bedding	9	1/27 - 2/21												Y												
Final Grading	6	2/3 - 2/28																								
Mat Installation	12	2/3 - 2/28																								
Rock Rip Rap "Toe"	2	2/24 - 2/28																								
Concrete Anchor	2	2/24 - 2/28																								
Backfill Open Cells	2	2/24 - 2/28																								
Berm & Swales Grading	3	3/3 - 3/7																								
Pyramat Installation	1	3/3 - 3/7																								
As-Built Survey	1	3/10 - 3/11																								
Mangrove Planting	2	3/10 - 3/12																								
Sea Purslane Planting	1	3/12 - 3/14																								
Clean-up & Demob.	2	3/10 - 3/14																								
Seed & Mulch	1	3/17 - 3/21																								
Punch List	2	3/17 - 3/21																								
Remove Turbidity Controls	1	3/24 - 3/26																								
Final Acceptance Meeting	1	3/26 - 3/27																								

NOTES:

1. The above dates are contingent upon the issuance of the Notice To Proceed (NTP).
2. No work below the mean high waterline will commence until receipt of the environmental permits from the FDEP & COE.
3. Normal weather and equipment downtime is built-in.
4. Holidays, 11/28, 11/ 29, 12/25, 1/6, 2/24
5. Christmas Holiday, no work between 12/24/96 thru 1/1/97 = 9 calender days.
6. Total days, 12/2 thru 3/27 = 116 calender days less 11 holidays = 105 days.

ATTACHMENT 11

A R M O R F L E X calculation program

(C) NICOLON B.V. 1988, 1989; version 1.20

calculations : DELFT HYDRAULICS
user interface: BEIAERD PRODUCTIONS

NICOLON B.V.
PostBox 236
7600 AE Almelo
The Netherlands

I N D U S T R I A L T E X T I L E S

tel: ..31 5490 44247 fax: ..31 5490 44490

G E N E R A L P R O J E C T I N F O R M A T I O N

DESIGN CALCULATIONS FOR

PROJECT Identification: NAS Key West, Fleming Key Landfill Revetment

CLIENT Name.....: Ocean Breeze Construction Co., Inc.
Adress.....: 10276 Riverside Drive
City.....: Palm Beach Gardens, FL 33410
Phone.....: 561-627-4407
Fax.....: 561-627-4408

Contact.....: Andrew K. Hackett, CPESC
Date.....: September 25, 1996

FROM Company.....: Delon Hampton & Associates, Chartered
Contact.....: Stephen W. Murray, P.E., CPESC

by Mike

S U M M A R Y O F I N P U T D A T A

CALCULATION	identification.....:	NAS Key West, Fleming Key Shoreline
STRUCTURE	slope angle (vert.= 1 : hor.= ?).:	2.0
	water depth at toe of structure..:	1.8 m
	hight of structure.....:	3.0 m ?
WAVE CHARAC.	significant wave height.....:	1.08 m → (max = 7')
	wave period (peak spectrum).....:	10.0 s
ARMORFLEX TYPE	.....:	alternative
	block thickness.....:	203 mm
	density of concrete.....:	2100 kg/m3
JOINT FILLING	.....:	ordinary (D 15v: 5mm) WASHED 89 ?
GEOTEXTILE	between ARMORFLEX and filter/base:	present
	potential head over geotextile...:	50.0 mm] permeability
	at specific discharge.....:	0.03 m/s
FILTER LAYER	.....:	present
	thickness.....:	0.20 m 6" bedding stone
	grain size.....:	10.00 mm ½"
	porosity.....:	0.40
BASE MATERIAL	grain size.....:	0.35 mm fine "105"

no Ø used

R E S U L T S O F C A L C U L A T I O N S

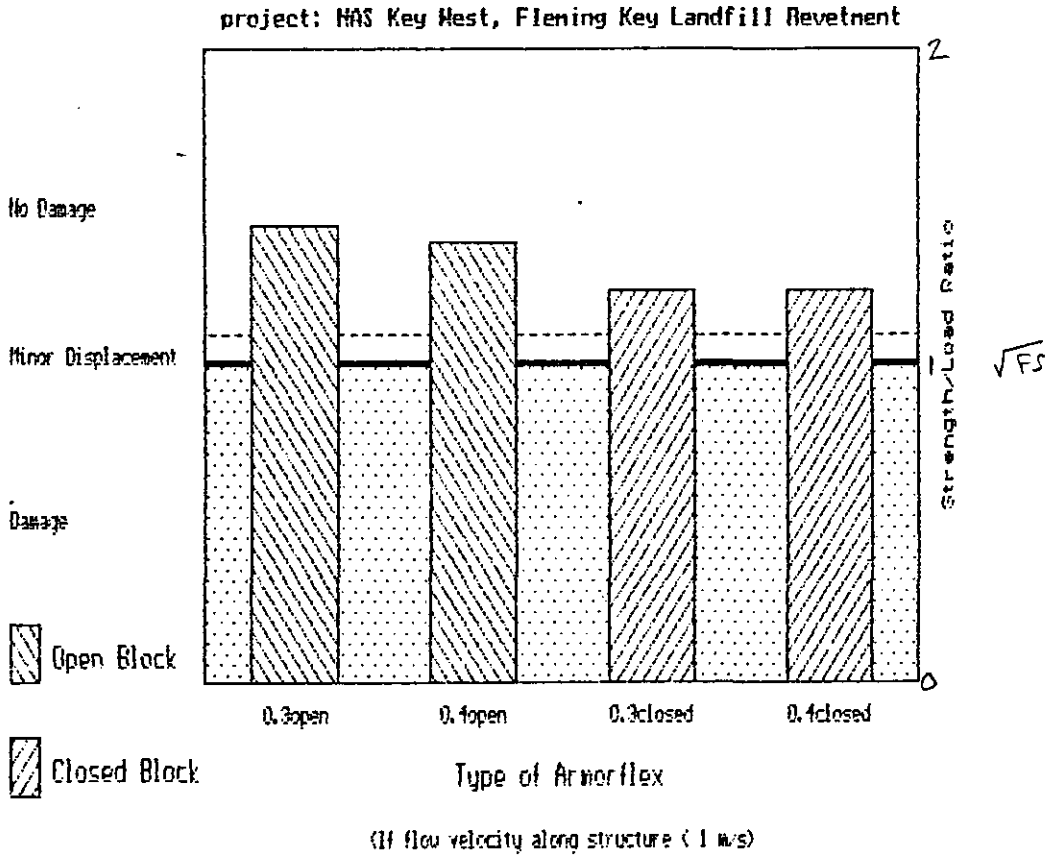
NICOLON bv DELFT HYDRAULICS

project: NAS Key West, Fleming Key Landfill Revetment

	EXPECTED PERFORMANCE OF ARMORFLEX			FILTER/BASE
type of ARMORFLEX	no damage	minor displacements	damage	use geotextile
0.3open	*			
0.4open	*			
0.3closed	*			
0.4closed	*			

E X P E C T E D P E R F O R M A N C E O F A R M O R F L E X

NICOLON bv DELFT HYDRAULICS



(If flow velocity along structure < 1 m/s)

CAUTION: these results are based on the positive interaction of interlocking ARMORFLEX blocks.
Results cannot be transfered to any other concrete block system

an interlocking system. This original design method, however, has been adapted to be applicable to Armorflex mattresses and can also be adapted to other block revetments that have been hydraulically testing under wave attack. The adapted model concerning the stability of the Armorflex mattress has been deduced from the results of large scale model tests in the Delta Flume of Delft Hydraulics and at the Oregon State University Wave Research Facility. The calculation of the performance of Armorflex under wave attack is based on the positive interaction of the individual blocks. It is the specially designed shape of the Armorflex block system that gives it its unique properties and stability. The cables, which join the blocks together are regarded as an extra factor of safety and do not influence the calculations.

CONSTRUCTION - PREPARATION AND INSTALLATION

Cabled preformed concrete block revetment systems have been proven technically and economically superior to traditional protective materials. When conditions such as poor soils, limited access, aesthetic and environmental considerations or a short construction season or schedule are primary factors, articulating revetment mats have proven to be the design solution.

Cabled block mats are delivered on trailers or barges as prefabricated mats, of up to 320 ft^2 per mat. Construction begins with site preparation of the area to be protected. Vegetation and obstructions, such as roots and projecting stones are removed. Holes, soft areas and large cavities are filled and compacted with suitable materials.

- Excavate toe, terminals and upper bank protection trenches as required.
- Filter fabric and/or graded filter material, is placed over the prepared subgrade.
- The first row of mats are placed side by side on the structure by attaching the cable loops at both ends of the mat to a spreader bar for placement by a crane or backhoe.
- Adjacent mats are connected by pouring side connecting keys and/or by fastening side connecting cables and end loops.
- Optional anchors are placed at the top of the slope.
- Backfill and compact the trenches as mat placement proceeds.
- Additional sections of mats are placed and connected until the desired limits of protection are reached.
- Backfill is spread over the mats and into the open cells, then sown or planted as desired.

Cabled block mats can be easily installed underwater. The spreader bar can be fitted with special, remote release clamps, which allow the mat to be released from the surface. There is no need to dewater the work area. The positioning of the mats can be done from the surface in shallow water or by divers in deep water. In addition, a structure can be easily built on an environmentally restricted site because there is no need for expensive cofferdams that disturb the natural environment surrounding the project site.

REFERENCES

Clopper, Paul E., "Protecting Embankment Dams with Concrete Block Systems," Hydro Review, Vol. X, No. 2, April 1991.

"Concrete Mats Help Make Flood Control Project ENVIRONMENTALLY 'FRIENDLY'," California Consulting Engineer, Vol. 4, No. 2, Summer 1991.

Simons, Li & Associates, Inc., Designing Stable Channels with Armorflex Articulated Concrete Block Revetment Systems, Copyright Nicolon Corporation, October 1990.

Delft Hydraulics Laboratory, Stability of Armorflex block slope protection mats under wave attack, Report on model investigation, May 1983.

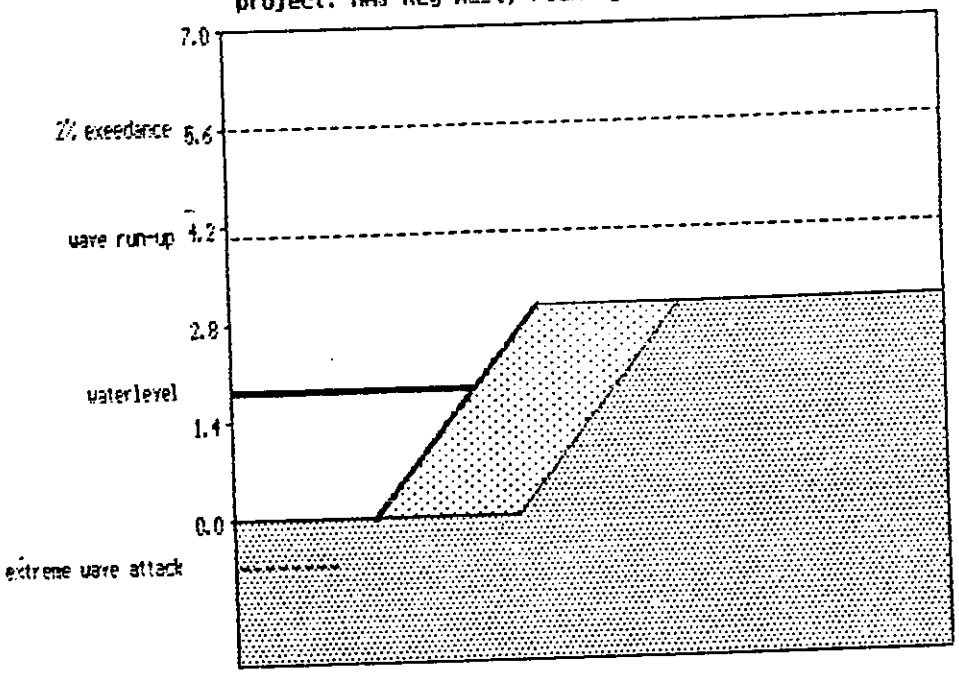
Weckmann, J. and Scales, John E., "Design Guidelines For Cabled-Block Mat Shore Protection Systems," Coastal Structures, pp. 295-306, 1983.

C R O S S S E C T I O N O F C O N S T R U C T I O N

NICOLON bv

DELFT HYDRAULICS

project: NAS Key West, Fleming Key Landfill Revetment



2% exeedance .....: 5.58m
wave runup .....: 4.02m
extreme wave attack:-0.66m
water depth .....: 1.80m
hight of structure : 3.00m

slope of structure 1:2.0
geotextile between ARMORFLEX and
thickness of filter: 0.20m
(vertically)

ATTACHMENT 12

Filterweave 40/10
Engineered Filtration Series Technical Data

Product Description

Filterweave 40/10 is a woven geotextile composed of polypropylene filaments which are formed into a stable network such that the filaments retain their relative position. The fabric is inert to biological degradation and naturally encountered chemicals, alkalies, and acids. Filterweave 40/10 conforms to the property values listed in the following table.

Property	Unit	Test Method	Minimum Average Roll Value	
			MD	CD
Grab Tensile Strength	ASTM D 4632	lbs	265	255
Grab Tensile Elongation	ASTM D 4632	%	16	15
Mullen Burst Strength	ASTM D 3786	psi	500	
Puncture Strength	ASTM D 4833	lbs	125	
Trapezoid Tear Strength	ASTM D 4533	lbs	80	70
Apparent Opening Size	ASTM D 4751	U.S. Std. Sieve	40 (0.420 mm)	
Percent Open Area	COE-02215-86	%	10	
Permittivity	ASTM D 4491	sec^{-1}	0.95	
Flow Rate	ASTM D 4491	gpm/ft^2	87	
UV Resistance after 500 hours	ASTM D 4355	% strength retained	90	

Filterweave 40/10 Packaging

STYLE NUMBER 64959	
ROLL DIMENSIONS	12′ x 300′
SQUARE YARDS PER ROLL	400
ESTIMATED ROLL WEIGHT	140 lbs

MD - Machine Direction
CD - Cross-machine Direction

APPENDIX

STORM SURGE

Using FEMA Flood Study, Monroe County, Florida, Table 2, Transect No. 1 in Man of War Harbor

50-yr stillwater elevation = +5.5 NGVD

DEPTH OF WATER AT STRUCTURE

Mean Low Water = 0.0'
50-yr Surge Elev. = 5.5'
10% Exceedence = 0.55'

Depth at Structure = +6.05'

Significant Wave Height

H_s = significant wave height = average of highest ⅓ of all waves

Assume the significant wave height = 60% water depth

$= (6.05 - 0.5)(.6) = 3.33'$

∴ Any waves greater than 3.33' in height will break prior to reaching the revetment system.

Runup Calculations

Using the USACE SPM, Section 7.2 –

Wave runup curves are for deepwater height, H_o'; the shallow water wave height of 3.33' must be converted to an equivalent deepwater value.

Using $d = 5.55$
$T = 10$ sec (assumption)

$$\frac{d}{L_o} = \frac{d}{5.12\,T^2} = \frac{5.55}{5.12\,(10)^2} = .0108$$

From Table C-1, Appendix C

$$\frac{d}{L_o} = .0108$$

By visual interpolation,

$$\frac{H}{H_o'} = 1.41$$

$$\therefore H_o' = \frac{3.33}{1.41} = 2.36 \text{ (Deep water Wave height)}$$

To determine runup –

$$\frac{H_o'}{gT^2} = \frac{2.36}{32.2\,(10)^2} = 0.0007$$

Runup Calculation (Continued)

$$\frac{H_o'}{gT^2} = 0.0007$$

Depth at structure toe, $d_s = 5.55'$

$$\frac{d_s}{H_o'} = \frac{5.55}{2.36} = 2.35$$

Using Fig. 7-11, for a 1:2 slope -

$$\frac{R}{H_o'} = 3.9$$

Using Fig 7-12, for a 1:2 slope -

$$\frac{R}{H_o'} = 2.55$$

Interpolation between Fig 7-11 & 7-12 -

$$\frac{3.9 + 2.55}{2} = 3.22$$

∴ The runup, uncorrected for scale effects -

$$R = 3.22 H_o' = 3.22(2.36) = 7.6 \text{ ft.}$$

Runup Calculation (Continued)

The scale correction factor, K, is found from Fig 7-13 -

$$\text{Slope} = m = \tan\theta = \frac{1}{2} = 0.5$$

The corresponding correction factor for wave height, $H_o' = 2.36'$, is $K = 1.15$

$$\text{Corrected Runup} = R = 1.15(7.6) = 8.7 \text{ ft.}$$

From Table 7-2 -

$$\text{Roughness \& Porosity Correction Factor} = r = 0.80$$

$$R_{\text{rough slope}} = 8.7(0.80) = \underline{\underline{7.0 \text{ feet}}}$$

Sheet 3

Table C–1 – Continued

d/L_o	d/L	$2\pi d/L$	TANH $2\pi d/L$	SINH $2\pi d/L$	COSH $2\pi d/L$	H/H_o'	K	$4\pi d/L$	SINH $4\pi d/L$	COSH $4\pi d/L$	n	C_G/C_o	M
.006000	.03110	.1954	.1929	.1967	1.0192	1.620	.9812	.3908	.4008	1.077	.9875	.1905	133
.006100	.03136	.1970	.1945	.1983	1.0195	1.614	.9809	.3941	.4044	1.079	.9873	.1920	130
.006200	.03162	.1987	.1961	.2000	1.0198	1.607	.9806	.3973	.4079	1.080	.9871	.1935	128
.006300	.03188	.2003	.1976	.2016	1.0201	1.601	.9803	.4006	.4114	1.081	.9869	.1950	126
.006400	.03213	.2019	.1992	.2033	1.0205	1.595	.9799	.4038	.4148	1.083	.9867	.1965	124
.006500	.03238	.2035	.2007	.2049	1.0208	1.589	.9796	.4070	.4183	1.084	.9865	.1980	123
.006600	.03264	.2051	.2022	.2065	1.0211	1.583	.9793	.4101	.4217	1.085	.9863	.1994	121
.006700	.03289	.2066	.2037	.2081	1.0214	1.578	.9790	.4133	.4251	1.087	.9860	.2009	119
.006800	.03313	.2082	.2052	.2097	1.0217	1.572	.9787	.4164	.4285	1.088	.9858	.2023	117
.006900	.03338	.2097	.2067	.2113	1.0221	1.567	.9784	.4195	.4319	1.089	.9856	.2037	116
.007000	.03362	.2113	.2082	.2128	1.0224	1.561	.9781	.4225	.4352	1.091	.9854	.2051	114
.007100	.03387	.2128	.2096	.2144	1.0227	1.556	.9778	.4256	.4386	1.092	.9852	.2065	112
.007200	.03411	.2143	.2111	.2160	1.0231	1.551	.9774	.4286	.4419	1.093	.9850	.2079	111
.007300	.03435	.2158	.2125	.2175	1.0234	1.546	.9771	.4316	.4452	1.095	.9848	.2093	109
.007400	.03459	.2173	.2139	.2190	1.0237	1.541	.9768	.4346	.4484	1.096	.9846	.2106	108
.007500	.03482	.2188	.2154	.2205	1.0240	1.536	.9765	.4376	.4517	1.097	.9844	.2120	106
.007600	.03506	.2203	.2168	.2221	1.0244	1.531	.9762	.4406	.4549	1.099	.9842	.2134	105
.007700	.03529	.2218	.2182	.2236	1.0247	1.526	.9759	.4435	.4582	1.100	.9840	.2147	104
.007800	.03552	.2232	.2196	.2251	1.0250	1.521	.9756	.4464	.4614	1.101	.9838	.2160	102
.007900	.03576	.2247	.2209	.2265	1.0253	1.517	.9753	.4493	.4646	1.103	.9836	.2173	101
.008000	.03598	.2261	.2223	.2280	1.0257	1.512	.9750	.4522	.4678	1.104	.9834	.2186	100
.008100	.03621	.2275	.2237	.2295	1.0260	1.508	.9747	.4551	.4709	1.105	.9832	.2199	98.6
.008200	.03644	.2290	.2250	.2310	1.0263	1.503	.9744	.4579	.4741	1.107	.9830	.2212	97.5
.008300	.03666	.2304	.2264	.2324	1.0266	1.499	.9741	.4607	.4772	1.108	.9827	.2225	96.3
.008400	.03689	.2318	.2277	.2338	1.0270	1.495	.9737	.4636	.4803	1.109	.9825	.2237	95.2
.008500	.03711	.2332	.2290	.2353	1.0273	1.491	.9734	.4664	.4834	1.111	.9823	.2250	94.1
.008600	.03733	.2346	.2303	.2367	1.0276	1.487	.9731	.4691	.4865	1.112	.9821	.2262	93.0
.008700	.03755	.2360	.2317	.2381	1.0280	1.482	.9728	.4719	.4896	1.113	.9819	.2275	91.9
.008800	.03777	.2373	.2330	.2396	1.0283	1.478	.9725	.4747	.4927	1.115	.9817	.2287	90.9
.008900	.03799	.2387	.2343	.2410	1.0286	1.474	.9722	.4774	.4957	1.116	.9815	.2300	89.9
.009000	.03821	.2401	.2356	.2424	1.0290	1.471	.9718	.4801	.4988	1.118	.9813	.2312	88.9
.009100	.03842	.2414	.2368	.2438	1.0293	1.467	.9715	.4828	.5018	1.119	.9811	.2324	88.0
.009200	.03864	.2428	.2381	.2452	1.0296	1.463	.9712	.4855	.5049	1.120	.9809	.2336	87.1
.009300	.03885	.2441	.2394	.2465	1.0299	1.459	.9709	.4882	.5079	1.122	.9807	.2348	86.1
.009400	.03906	.2455	.2407	.2479	1.0303	1.456	.9706	.4909	.5109	1.123	.9805	.2360	85.2
.009500	.03928	.2468	.2419	.2493	1.0306	1.452	.9703	.4936	.5138	1.124	.9803	.2371	84.3
.009600	.03949	.2481	.2431	.2507	1.0309	1.448	.9700	.4962	.5168	1.126	.9801	.2383	83.5
.009700	.03970	.2494	.2443	.2520	1.0313	1.445	.9697	.4988	.5198	1.127	.9799	.2394	82.7
.009800	.03990	.2507	.2456	.2534	1.0316	1.442	.9694	.5014	.5227	1.128	.9797	.2406	81.8
.009900	.04011	.2520	.2468	.2547	1.0319	1.438	.9691	.5040	.5257	1.130	.9794	.2417	81.0
.01000	.04032	.2533	.2480	.2560	1.0322	1.435	.9688	.5066	.5286	1.131	.9792	.2429	80.2
.01100	.04233	.2660	.2598	.2691	1.0356	1.403	.9656	.5319	.5574	1.145	.9772	.2539	73.1
.01200	.04426	.2781	.2711	.2817	1.0389	1.375	.9625	.5562	.5853	1.159	.9751	.2643	67.1
.01300	.04612	.2898	.2820	.2938	1.0423	1.350	.9594	.5795	.6125	1.173	.9731	.2743	62.1
.01400	.04791	.3010	.2924	.3056	1.0456	1.327	.9564	.6020	.6391	1.187	.9710	.2838	57.8
.01500	.04964	.3119	.3022	.3170	1.0490	1.307	.9533	.6238	.6651	1.201	.9690	.2928	54.0
.01600	.05132	.3225	.3117	.3281	1.0524	1.288	.9502	.6450	.6906	1.215	.9670	.3014	50.8
.01700	.05296	.3328	.3209	.3389	1.0559	1.271	.9471	.6655	.7158	1.230	.9649	.3096	47.9
.01800	.05455	.3428	.3298	.3495	1.0593	1.255	.9440	.6856	.7405	1.244	.9629	.3176	45.3
.01900	.05611	.3525	.3386	.3599	1.0628	1.240	.9409	.7051	.7650	1.259	.9609	.3253	43.0
.02000	.05763	.3621	.3470	.3701	1.0663	1.226	.9378	.7242	.7891	1.274	.9588	.3327	41.0
.02100	.05912	.3714	.3552	.3800	1.0698	1.213	.9348	.7429	.8131	1.289	.9568	.3399	39.1
.02200	.06057	.3806	.3632	.3898	1.0733	1.201	.9317	.7612	.8368	1.304	.9548	.3468	37.4
.02300	.06200	.3896	.3710	.3995	1.0768	1.189	.9287	.7791	.8603	1.319	.9528	.3535	35.9
.02400	.06340	.3984	.3786	.4090	1.0804	1.178	.9256	.7967	.8837	1.335	.9508	.3600	34.4
.02500	.06478	.4070	.3860	.4184	1.0840	1.168	.9225	.8140	.9069	1.350	.9488	.3662	33.1
.02600	.06613	.4155	.3932	.4276	1.0876	1.159	.9195	.8310	.9310	1.366	.9468	.3722	31.9
.02700	.06747	.4239	.4002	.4367	1.0912	1.150	.9164	.8478	.9530	1.381	.9448	.3781	30.8
.02800	.06878	.4322	.4071	.4457	1.0949	1.141	.9133	.8643	.9760	1.397	.9428	.3838	29.8
.02900	.07007	.4403	.4138	.4546	1.0985	1.133	.9103	.8805	.9988	1.413	.9408	.3893	28.8

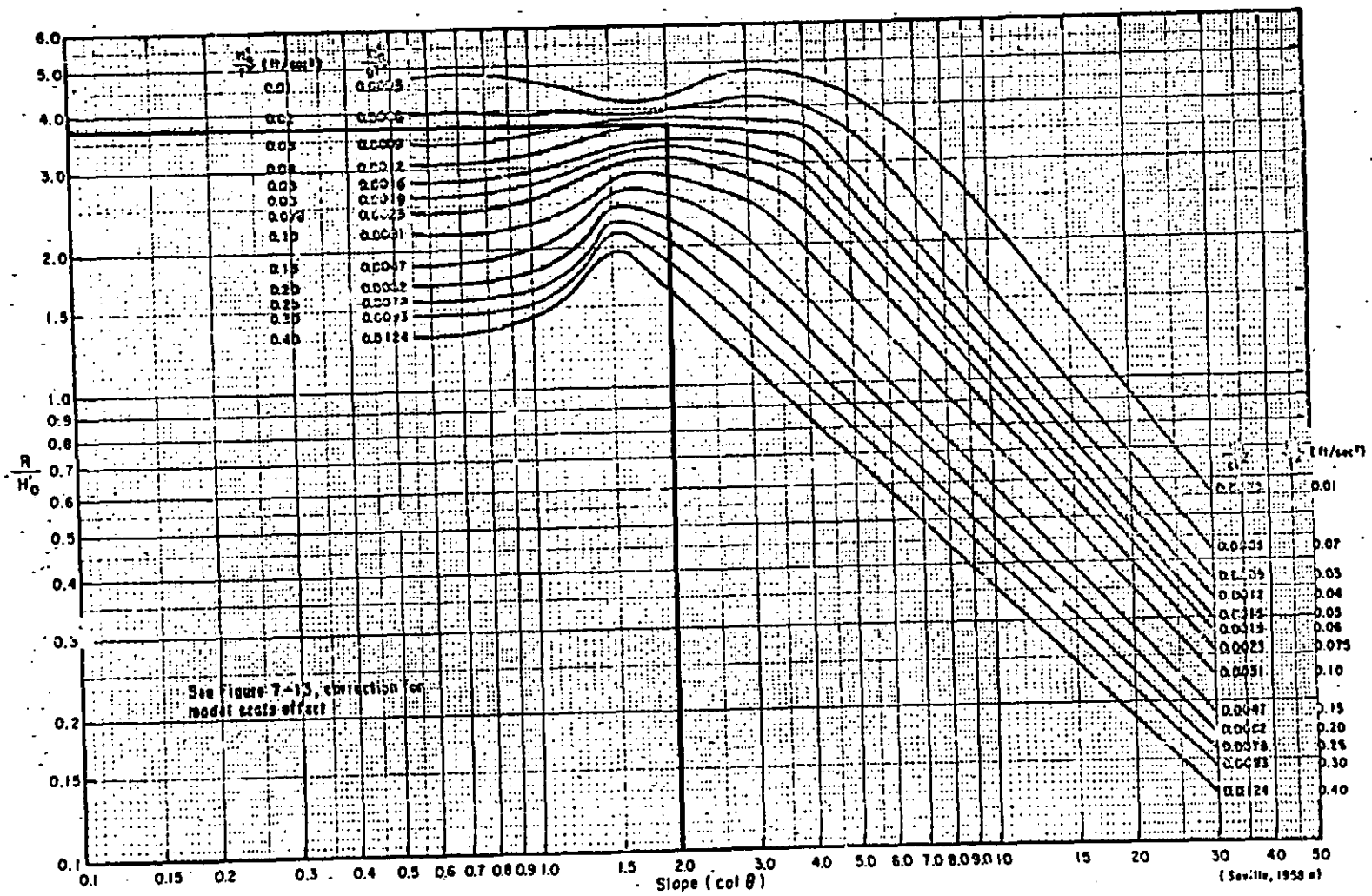


Figure 7-11. Wave Runup on Smooth, Impermeable Slopes, $d_s/H'_0 \approx 2.0$

Sheet 6

Sheet 1.

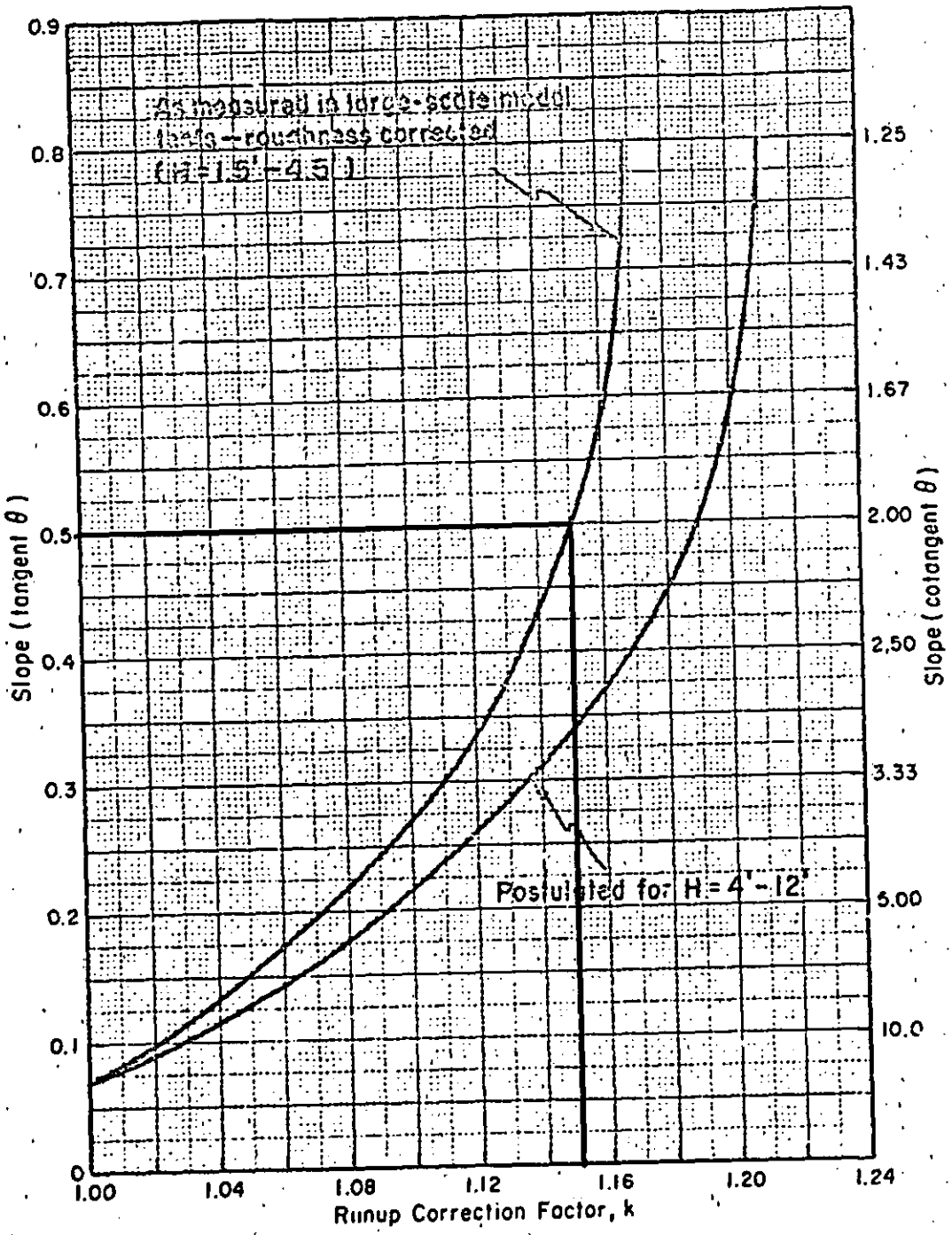


Figure 7-13. Runup Correction for Scale Effects

$$r = \frac{R\ (\text{rough slope})}{R\ (\text{smooth slope})} = \frac{R\ /H_o'\ (\text{rough slope})}{R/H_o'\ (\text{smooth slope})} \qquad (7\text{-}7)$$

Table 7-2 indicated the range of values of r for various slope characteristics.

This roughness and porosity correction factor is also considered applicable, as a first approximation, in the analysis of wave runup on slopes having surface materials with two or more different roughness values, r. Until more detailed guidance is available, it is suggested that the percentage of the total slope length, ℓ, subjected to wave runup of each roughness value be used to develop an adjusted roughness correction value. This is expressed by the equation

$$r\ (\text{adjusted}) = \frac{\ell_1}{\ell} r_1 + \frac{\ell_2}{\ell} r_2 + \frac{\ell_3}{\ell} r_3 + \ldots \qquad (7\text{-}8)$$

where ℓ is the total slope length, ℓ_1 is the length of slope where the roughness value r_2 applies, ℓ_2 is the length of slope where the roughness value r_2 applies, and so on. This procedure has obvious deficiencies as it does not account for location of the roughness on the structure and the varying interaction of slope roughness characteristics to the depth of water jet running up the structure slope.

Table 7-2. Value of r for various slope characteristics (after Battjes, 1974).

Slope Surface Characteristics	Placement	r
Smooth, impermeable	------	1.00
Concrete blocks	Fitted	0.90
Basalt blocks	Fitted	0.85 to 0.90
Gobi blocks ☆	Fitted	0.85 to 0.90
Grass	------	0.85 to 0.90
One layer of quarrystone (impermeable foundation)	Random	0.80
Quarrystone	Fitted	0.75 to 0.80
Rounded quarrystone	Random	0.60 to 0.65
Three layers of quarrystone (impermeable foundation)	Random	0.60 to 0.65
Quarrystone	Random	0.50 to 0.55
Concrete armor units (~ 50 percent void ratio)	Random	0.45 to 0.50

The use of the figures to estimate wave runup is illustrated by the following example.

☆ - ARMORFLEX is Rougher and more permeable than the old Gobi Block.

Overtopping Rate Calculation

- Runup for the design significant wave & structure = 7.0 ft
- Slope = 1:2
- H_o' = deepwater wave height = 2.36 ft
- T = 10 sec (assumed)
- d_s = depth of water at structure = 5.55 ft
- Crest Elevation = 10.0 ft = h

Obtain coefficients α and Q_o^* from Fig 7-24 & 7-25

Fig. 7-24

$$\left.\begin{aligned} \frac{d_s}{H_o'} &= 2.35 \\ \frac{H_o'}{gT^2} &= 0.0007 \end{aligned}\right\} \quad \begin{aligned} \alpha &= 0.08 \\ Q_o^* &= 0.065 \end{aligned}$$

Fig 7-25

$$\left.\begin{aligned} \frac{d_s}{H_o'} &= 2.35 \\ \frac{H_o'}{gT^2} &= 0.0007 \end{aligned}\right\} \quad \begin{aligned} \alpha &= 0.063 \\ Q_o^* &= 0.04 \end{aligned}$$

Visual interpolation gives, $\alpha = 0.07$

$Q_o^* = 0.05$

Overtopping Rate Calculation (Continued)

Using Eqn 7-6 –

$$Q = (g\, Q_o^* H_o'^3)^{1/2}\, e^{-\left[\frac{0.217}{\alpha} \tanh^{-1}\left(\frac{h-d_s}{R}\right)\right]}$$

$$Q = \left[(32.2)(0.05)(2.36)^3\right]^{1/2} e^{-\left[\frac{0.217}{0.07} \tanh^{-1}\left(\frac{10-5.55}{7.0}\right)\right]}$$

$$Q = 4.60\, e^{-\left[\frac{0.217}{0.07} \tanh^{-1}(0.64)\right]}$$

To evaluate $\tanh^{-1}(0.64)$, find 0.64 in Column 4 of Table C-1, Appendix C, and read the value of $\tanh^{-1}(0.64)$ from Column 3 –

$$\tanh^{-1}(0.64) \approx 0.76$$

Calculating the exponent –

$$\frac{0.217}{0.07}(0.76) = 2.4$$

$$Q = 4.60\, e^{-2.4} = 0.42\ ft^3/sec\ ft = 39\ \ell/sec\text{-}m$$

In order to add the effects of winds on the overtopping rate, we will use the following equation from the "ACES Technical Reference" provided by Jianlu Xu of Bechtel:

$$C_W = 1 + W_f \left(\frac{F}{R} + 0.1\right) \sin\theta$$

where C_W = wind correction factor
R = runup = 7.0 ft
F = $h_s - d_s$ = freeboard
h_s = height of structure = 10.0 ft
d_s = water depth at structure = 6.05 ft
θ = 90° (assume perpindicular to shore)

Based on conversations with Jianlu Xu of Bechtel, the wind speed used to calculate the wind correction factor should be the normal wind speed for the area.

For the calculations, assume wind speed, U, is 50 mph

$$W_f = \frac{U^2}{1800} = \frac{50^2}{1800} = 1.39$$

$$C_W = 1 + 1.39\left(\frac{10-6.05}{7.0} + 0.1\right) \sin(90°)$$

$$C_W = 1.92$$

$\therefore$ Overtopping rate = Q = 1.92 (39) = <u>75 ℓ/sec-m</u>

Monochromatic Wave Overtopping

The method implemented within this ACES application was developed by Weggel (1976) using data reported by Saville (1955) and by Saville and Caldwell (1953). It consists of an empirical expression for the monochromatic-wave overtopping rate:

$$Q = C_w \sqrt{g Q_0^* H_0^3} \left(\frac{R+F}{R-F} \right)^{\frac{-0.1085}{\alpha}} \tag{9}$$

where

Q = overtopping rate/unit length of structure

C_w = wind correction factor

g = gravitational acceleration

Q_0^*, α = empirical coefficients (see SPM (1984) figures)

Note: An average value for $\bar{\alpha}$ as a function of structure slope may be approximated by:

$$\bar{\alpha} = 0.06 - 0.0143 \ln(\sin\theta)$$

This option is available in the application.

H_0 = unrefracted deepwater wave height

R = runup

$F = h_s - d_s$ = freeboard

h_s = height of structure

d_s = water depth at structure

Wind Effects

Onshore winds can increase the overtopping rate at a barrier. The effect is dependent upon wind velocity, direction with respect to the axis of the structure, and structure characteristics. This increased overtopping rate is approximated by adjusting the above value for Q with a wind correction factor C_w (SPM, 1984):

$$C_w = 1 + W_f \left(\frac{F}{R} + 0.1 \right) \sin\theta \tag{10}$$

where

$$W_f = \frac{U^2}{1800} \tag{11}$$

U = onshore wind speed (mph)

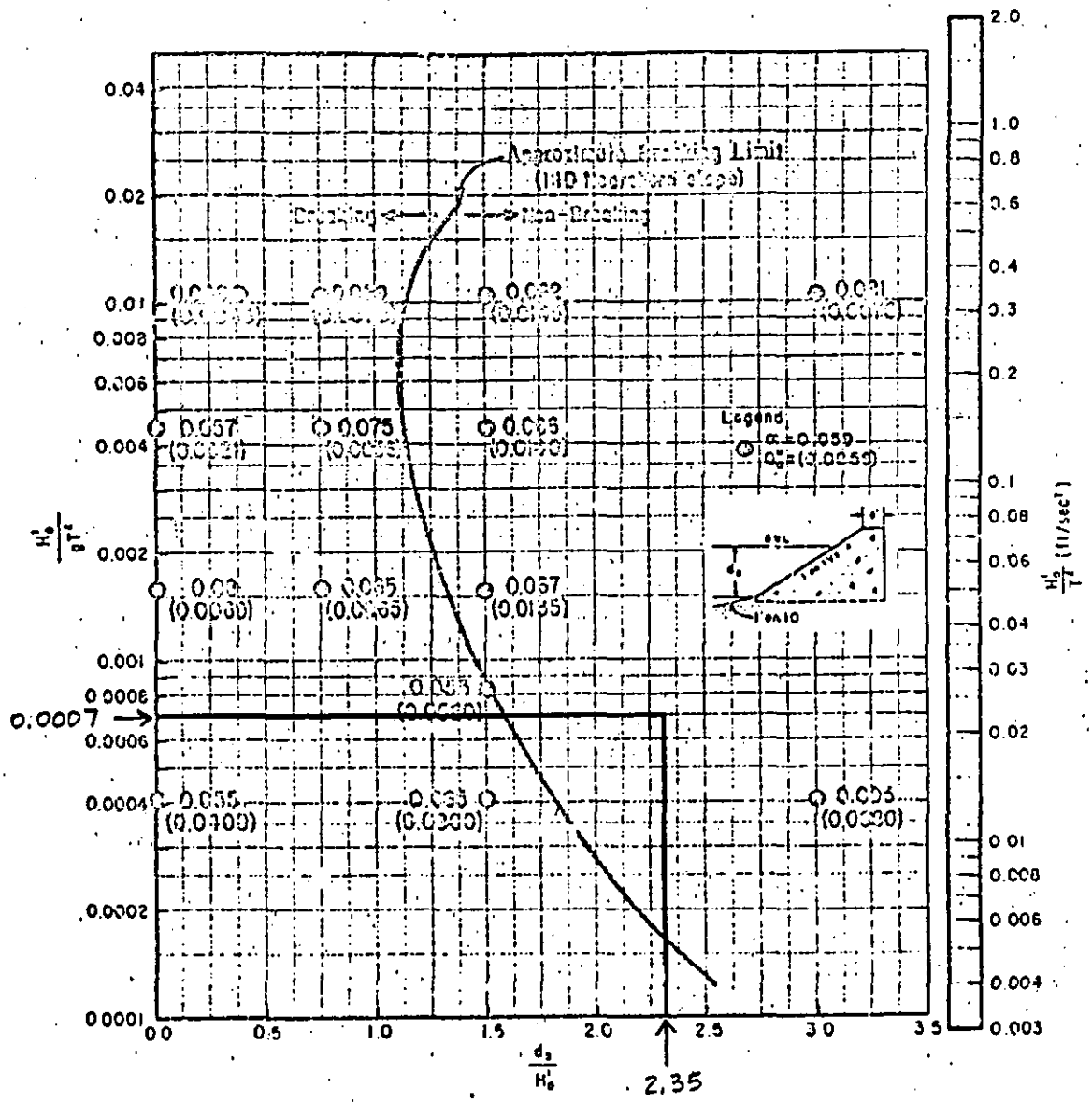


Figure 7-24. Overtopping Parameters, σ and Q_0^* (Smooth 1:1-1/2 Structure Slope on a 1:10 Nearshore Slope)

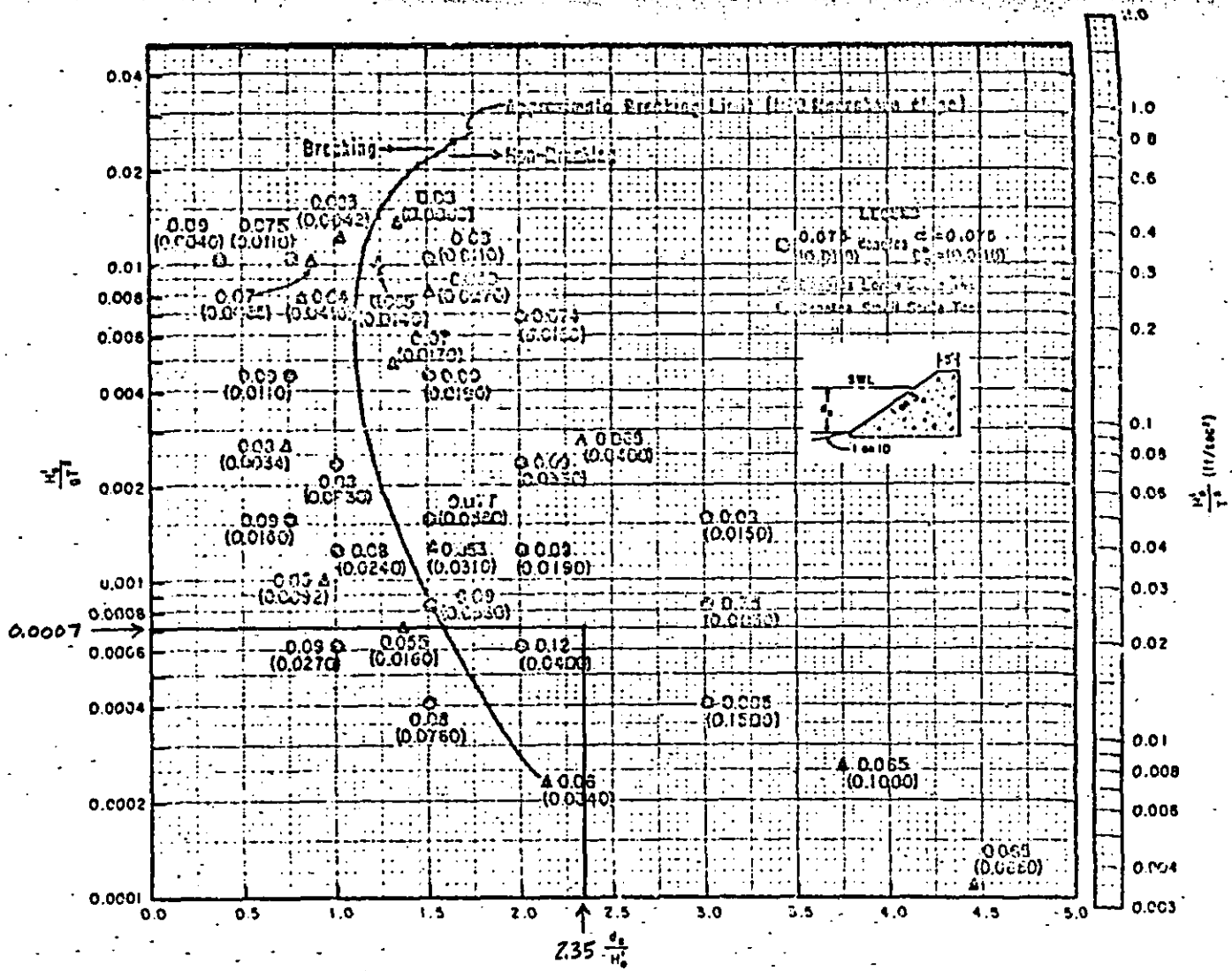


Figure 7-25. Overtopping Parameters, a and Q_0^* (Smooth 1:3 Structure Slope on a 1:10 Nearshore Slope)

Column 3 Column 4

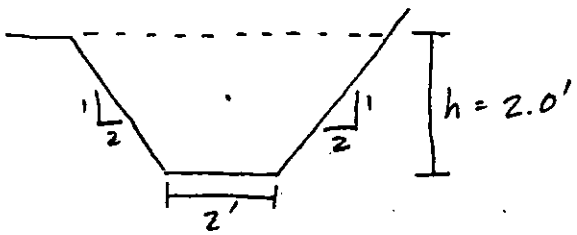
Table C–1 – Continued

d/L_o	d/L	$2\pi d/L$	TANH $2\pi d/L$	SINH $2\pi d/L$	COSH $2\pi d/L$	H/H'_o	K	$4\pi d/L$	SINH $4\pi d/L$	COSH $4\pi d/L$	n	C_g/C_o	M
.03000	.07135	.4483	.4205	.4634	1.1021	1.125	.9073	.8966	1.022	1.430	.9388	.3947	27.9
.03100	.07260	.4562	.4269	.4721	1.1059	1.118	.9042	.9124	1.044	1.446	.9369	.4000	27.1
.03200	.07385	.4640	.4333	.4808	1.1096	1.111	.9012	.9280	1.067	1.462	.9349	.4051	26.3
.03300	.07507	.4717	.4395	.4894	1.1133	1.104	.8982	.9434	1.090	1.479	.9329	.4100	25.6
.03400	.07630	.4794	.4457	.4980	1.1171	1.098	.8952	.9588	1.113	1.496	.9309	.4149	24.8
.03500	.07748	.4868	.4517	.5064	1.1209	1.092	.8921	.9737	1.135	1.513	.9289	.4196	24.19
.03600	.07867	.4943	.4577	.5147	1.1247	1.086	.8891	.9886	1.158	1.530	.9270	.4242	23.56
.03700	.07984	.5017	.4635	.5230	1.1285	1.080	.8861	1.0033	1.180	1.547	.9250	.4287	22.97
.03800	.08100	.5090	.4691	.5312	1.1324	1.075	.8831	1.018	1.203	1.564	.9230	.4330	22.42
.03900	.08215	.5162	.4747	.5394	1.1362	1.069	.8801	1.032	1.226	1.582	.9211	.4372	21.90
.04000	.08329	.5233	.4802	.5475	1.1401	1.064	.8771	1.047	1.248	1.600	.9192	.4414	21.40
.04100	.08442	.5304	.4857	.5556	1.1440	1.059	.8741	1.061	1.271	1.617	.9172	.4455	20.92
.04200	.08553	.5374	.4911	.5637	1.1479	1.055	.8711	1.075	1.294	1.636	.9153	.4495	20.46
.04300	.08664	.5444	.4964	.5717	1.1518	1.050	.8688	1.089	1.317	1.654	.9133	.4534	20.03
.04400	.08774	.5513	.5015	.5796	1.1558	1.046	.8652	1.103	1.340	1.672	.9114	.4571	19.62
.04500	.08883	.5581	.5066	.5876	1.1599	1.042	.8621	1.116	1.363	1.691	.9095	.4607	19.23
.04600	.08991	.5649	.5116	.5954	1.1639	1.038	.8592	1.130	1.386	1.709	.9076	.4643	18.85
.04700	.09098	.5717	.5166	.6033	1.1679	1.034	.8562	1.143	1.409	1.728	.9057	.4679	18.49
.04800	.09205	.5784	.5215	.6111	1.1720	1.030	.8532	1.157	1.433	1.747	.9037	.4713	18.15
.04900	.09311	.5850	.5263	.6189	1.1760	1.026	.8503	1.170	1.456	1.766	.9018	.4746	17.82
.05000	.09416	.5916	.5310	.6267	1.1802	1.023	.8473	1.183	1.479	1.786	.8999	.4779	17.50
.05100	.09520	.5981	.5357	.6344	1.1843	1.019	.8444	1.196	1.503	1.805	.8980	.4811	17.19
.05200	.09623	.6046	.5403	.6421	1.1884	1.016	.8415	1.209	1.526	1.825	.8961	.4842	16.90
.05300	.09726	.6111	.5449	.6499	1.1926	1.013	.8385	1.222	1.550	1.845	.8943	.4873	16.62
.05400	.09829	.6176	.5494	.6575	1.1968	1.010	.8356	1.235	1.574	1.865	.8924	.4903	16.35
.05500	.09930	.6239	.5538	.6652	1.2011	1.007	.8326	1.248	1.598	1.885	.8905	.4932	16.09
.05600	.1003	.6303	.5582	.6729	1.2053	1.004	.8297	1.261	1.622	1.906	.8886	.4960	15.84
.05700	.1013	.6366	.5626	.6805	1.2096	1.001	.8267	1.273	1.646	1.926	.8867	.4988	15.60
.05800	.1023	.6428	.5668	.6880	1.2138	.9985	.8239	1.286	1.670	1.947	.8849	.5015	15.36
.05900	.1033	.6491	.5711	.6956	1.2181	.9958	.8209	1.298	1.695	1.968	.8830	.5042	15.13
.06000	.1043	.6553	.5753	.7033	1.2225	.9932	.8180	1.311	1.719	1.989	.8811	.5068	14.91
.06100	.1053	.6616	.5794	.7110	1.2270	.9907	.8150	1.3231	1.744	2.011	.8792	.5094	14.70
.06200	.1063	.6678	.5834	.7187	1.2315	.9883	.8121	1.336	1.770	2.033	.8773	.5119	14.50
.06300	.1073	.6739	.5874	.7256	1.2355	.9860	.8093	1.348	1.795	2.055	.8755	.5143	14.30
.06400	.1082	.6799	.5914	.7335	1.2402	.9837	.8063	1.360	1.819	2.076	.8737	.5167	14.11
.06500	.1092	.6860	.5954	.7411	1.2447	.9815	.8035	1.372	1.845	2.098	.8719	.5191	13.92
.06600	.1101	.6920	.5993	.7486	1.2492	.9793	.8005	1.384	1.870	2.121	.8700	.5214	13.74
.06700	.1111	.6981	.6031	.7561	1.2537	.9772	.7977	1.396	1.896	2.144	.8682	.5236	13.57
.06800	.1120	.7037	.6069	.7633	1.2580	.9752	.7948	1.408	1.921	2.166	.8664	.5258	13.40
.06900	.1130	.7099	.6106	.7711	1.2628	.9732	.7919	1.420	1.948	2.189	.8646	.5279	13.24
.07000	.1139	.7157	.6144	.7783	1.2672	.9713	.7890	1.432	1.974	2.213	.8627	.5300	13.08
.07100	.1149	.7219	.6181	.7863	1.2721	.9694	.7861	1.444	2.000	2.236	.8609	.5321	12.92
.07200	.1158	.7277	.6217	.7937	1.2767	.9676	.7833	1.455	2.026	2.260	.8591	.5341	12.77
.07300	.1168	.7336	.6252	.8011	1.2813	.9658	.7804	1.467	2.053	2.284	.8572	.5360	12.62
.07400	.1177	.7395	.6289	.8088	1.2861	.9641	.7775	1.479	2.080	2.308	.8554	.5380	12.48
.07500	.1186	.7453	.6324	.8162	1.2908	.9624	.7747	1.490	2.107	2.332	.8537	.5399	12.34
.07600	.1195	.7511	.6359	.8237	1.2956	.9607	.7719	1.502	2.135	2.357	.8519	.5417	12.21
.07700	.1205	.7569	.6392	.8312	1.3004	.9591	.7690	1.514	2.162	2.382	.8501	.5435	12.08
.07800	.1214	.7625	.6427	.8386	1.3051	.9576	.7662	1.525	2.189	2.407	.8483	.5452	11.95
.07900	.1223	.7683	.6460	.8462	1.3100	.9562	.7634	1.537	2.217	2.432	.8465	.5469	11.83
.08000	.1232	.7741	.6493	.8538	1.3149	.9548	.7605	1.548	2.245	2.458	.8448	.5485	11.71
.08100	.1241	.7799	.6526	.8614	1.3198	.9534	.7577	1.560	2.274	2.484	.8430	.5501	11.59
.08200	.1251	.7854	.6558	.8687	1.3246	.9520	.7549	1.571	2.303	2.511	.8413	.5517	11.47
.08300	.1259	.7911	.6590	.8762	1.3295	.9506	.7522	1.583	2.331	2.537	.8395	.5533	11.36
.08400	.1268	.7967	.6622	.8837	1.3345	.9493	.7494	1.594	2.360	2.563	.8378	.5548	11.25
.08500	.1277	.8026	.6655	.8915	1.3397	.9481	.7464	1.605	2.389	2.590	.8360	.5563	11.14
.08600	.1286	.8080	.6685	.8989	1.3446	.9469	.7437	1.616	2.418	2.617	.8342	.5577	11.04
.08700	.1295	.8137	.6716	.9064	1.3497	.9457	.7409	1.628	2.448	2.644	.8325	.5591	10.94
.08800	.1304	.8193	.6747	.9141	1.3548	.9445	.7381	1.639	2.478	2.672	.8308	.5605	10.84
.08900	.1313	.8250	.6778	.9218	1.3600	.9433	.7353	1.650	2.508	2.700	.8290	.5619	10.74

END OF SWALE EROSION PROTECTION

Based on the worst case scenario of the swale full of water as a result of wave overtopping,

Calculate flowrate in swale –



Manning's Eqn => $Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$

$S = 0.005$

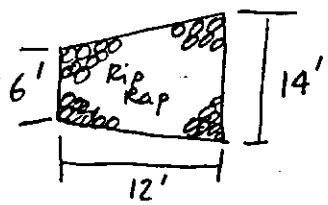
$A = \frac{1}{2}(2)(2+10) = 12$

$R = \frac{A}{WP} = \frac{12}{10.94} = 1.1$

$n = 0.06$ (Class D vegetation)

$\therefore Q = \frac{1.49}{.06}(12)(1.1)^{2/3}(.005)^{1/2} = 22.4$ cfs

$\therefore$ Rip Rap for swale protection dimensions = 6' x 12' x 14' x 18" thick



Source: USDA-SCS

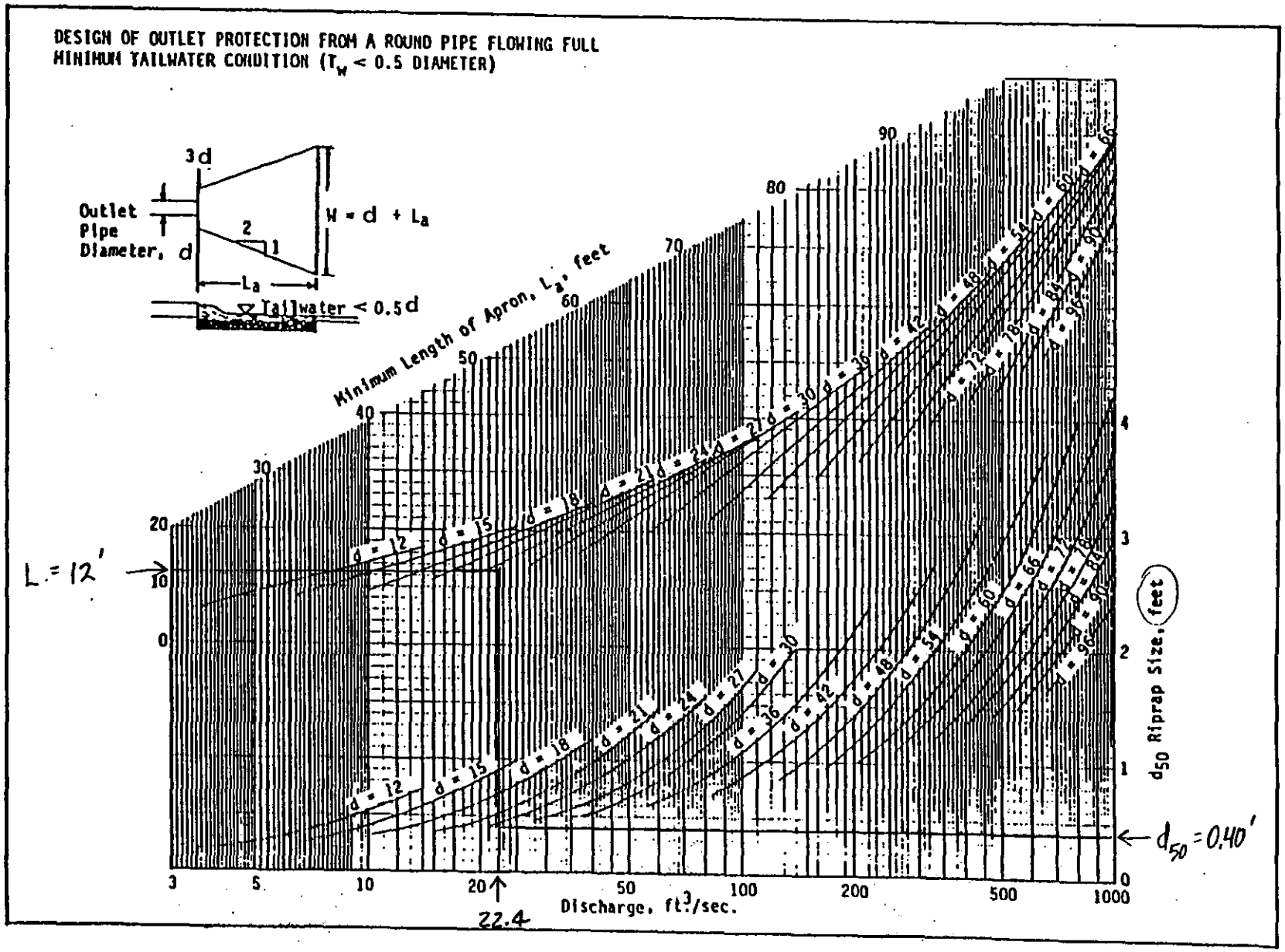


Figure 6-17.3

Sheet 15

Table 4-3 Classification of Vegetal Covers as to Degree of Retardance. (4)

Retardance Class	Cover	Condition
A	Weeping lovegrass	Excellent stand, tall (average 30") (76 cm)
	Yellow bluestem Ischaemum	Excellent stand, tall (average 36") (91 cm)
B	Kudzu	Very dense growth, uncut
	Bermuda grass	Good stand, tall (average 12") (30 cm)
	Native grass mixture (little bluestem, bluestem, blue gamma, and other long and short midwest grasses).....	Good stand, unmowed
	Weeping lovegrass	Good stand, tall (average 24") (61 cm)
	Lespedeza sericea	Good stand, not woody, tall (average 19") (48 cm)
	Alfalfa	Good stand, uncut (average 11") (28 cm)
	Weeping lovegrass	Good stand, unmowed (average 13") (33 cm)
	Kudzu	Dense growth, uncut
	Blue gamma	Good stand, uncut (average 13") (28 cm)
C	Crabgrass	Fair stand, uncut (10 to 48") (25 to 120 cm)
	Bermuda grass	Good stand, mowed (average 6") (15 cm)
	Common lespedeza	Good stand, uncut (average 11") (28 cm)
	Grass-legume mixture-- summer (orchard grass, redtop, Italian ryegrass, and common lespedeza)....	Good stand, uncut (6 to 8 inches) (15 to 20 cm)
	Centipedegrass.....	Very dense cover (average 6 inches) (15 cm)
	Kentucky bluegrass.....	Good stand, headed (6 to 12 inches (15 to 30 cm)
D	Bermuda grass.....	Good stand, cut to 2.5-inch height (6 cm)
	Common lespedeza	Excellent stand, uncut (average 4.5") (11 cm)
	Buffalo grass	Good stand, uncut (3 to 6 inches (8 to 15 cm)
	Grass-legume mixture-- fall, spring (orchard grass, redtop, Italian ryegrass, and common lespedeza).....	Good stand, uncut (4 to 5 inches) (10 to 13 cm)
	Lespedeza sericea	After cutting to 2-inch height (5 cm) Very good stand before cutting
E	Bermuda grass	Good stand, cut to 1.5 inch height (4 cm)
	Bermuda grass	Burned stubble

NOTE: Covers classified have been tested in experimental channels. Covers were green and generally uniform.

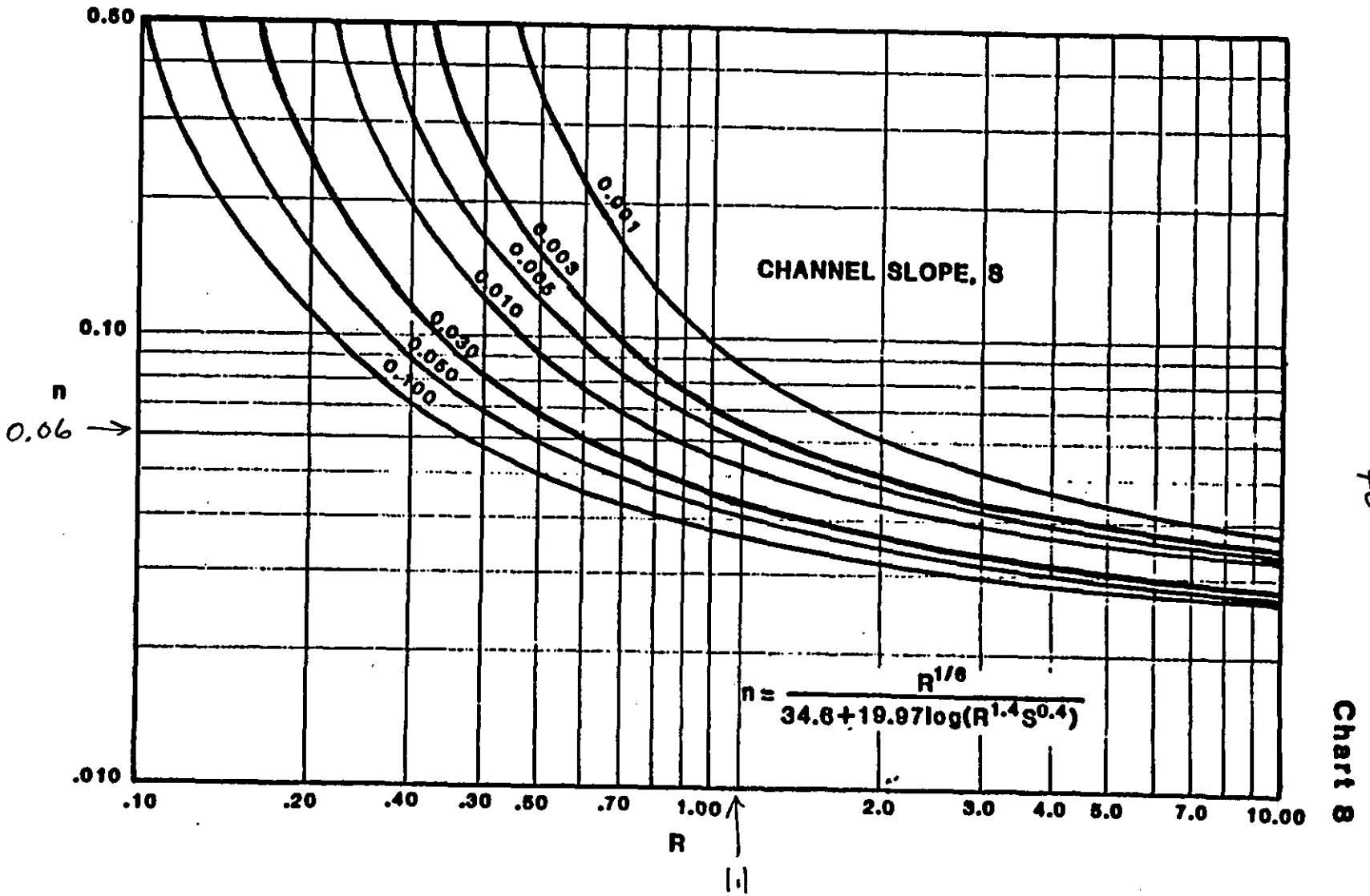


Chart 8

Fig. 4-12d

Chart 8. Manning's n versus hydraulic radius, R, for class D vegetation. (after 5)

Sheet 17

Scour Protection Calculation

Using Eqn 7-105 –

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

where W = weight in pounds of individual stone. The stones range from 0.75W to 1.25W with 75% weighing more than W.

w_r = unit weight of stone

H = design wave height

S_r = specific gravity of stone to water = w_r / w_w

w_w = 64 lb/ft^3

θ = angle of structure = 1:6

K_D = stability coefficient

$$W = \frac{(145)(3.33)^3}{3.5\left(\frac{145}{64} - 1\right)^3 6}$$

$$\underline{\underline{W = 125 \text{ lbs}}}$$

Flank Protection Calculation

Using Equation 7-105 -

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

where W = weight in pounds of individual stone
w_r = unit weight of stone
H = design wave height
S_r = specific gravity of stone in water $= w_r / w_w$
$w_w = 64\ lb/ft^3$
θ = angle of structure = 1:2
K_D = stability coefficient

$$W = \frac{(145)(3.33)^3}{3.5\left(\frac{145}{64} - 1\right)^3 2}$$

$$W = 377\ lbs$$

Sheet 20

Table 7-6. Suggested K_D Values for Use in Determining Armor Unit Weight

No-Damage Criteria and Minor Overtopping							
Armor Units	n *	Placement	Structure Trunk		Structure Head		
			K_D §		K_D		Slope
			Breaking wave	Nonbreaking wave	Breaking wave	Nonbreaking wave	cot θ
Quarrystone							
Smooth rounded	2	random	2.1	2.4	1.7	1.9	1.5 to 3.0
Smooth rounded	>3	random	2.8	3.2	2.1	2.3	‖
Rough angular	1	random †	†	2.9	†	2.3	‖
Rough angular	2	random	3.5	4.0	2.9 2.5 2.0	3.2 2.8 2.3	1.5 2.0 3.0
Rough angular	>3	random	3.9	4.5	3.7	4.2	‖
Rough angular	2	special ‡	4.8	5.5	3.5	4.5	‖
Tetrapod and Quadripod	2	random	7.2	8.3	5.9 5.5 4.0	6.6 6.1 4.4	1.5 2.0 3.0
Tribar	2	random	9.0	10.4	8.1 7.8 7.0	9.0 8.5 7.7	1.5 2.0 3.0
Dolos	2	random	22.0 ¶	25.0 ¶	15.0 13.5	16.5 15.0	2.0 £ 3.0
Modified Cube	2	random	5.8	7.8	—	5.0	‖
Hexapod	2	random	8.2	9.5	5.0	7.0	‖
Tribar	1	uniform	12.0	15.0	7.5	9.5	‖
Quarrystone (K_{RR}) Graded angular	–	random	2.2	2.5			

* n is the number of units comprising the thickness of the armor layer.

† The use of single layer of quarrystone armor units subject to breaking waves is not recommended, and only under special conditions for nonbreaking waves. When it is used, the stone should be carefully placed.

‡ Special placement with long axis of stone placed perpendicular to structure face.

§ Applicable to slopes ranging from: 1 on 1.5 to 1 on 5.

‖ Until more information is available on the variation of K_D value with slope, the use of K_D should be limited to slopes ranging from 1 on 1.5 to 1 on 3. Some armor units tested on a structure head indicate a K_D-slope dependence.

¶ Data only available for 1 on 2 slope.

£ Slopes steeper than 1 on 2 not recommended at the present time.

Wave Reflection Calculation

- Wave Height $= H_o = 3.33'$
- Slope $= 1:2$
- Wave Period $= T = 10$ sec

Deepwater wave length $= L_o = \frac{gT^2}{2\pi} = \frac{32.2(100)}{2\pi} = 512$ feet

$$\frac{H_o}{L_o} = \frac{3.33}{512} = 0.0065$$

The steepest incident wave which can be nearly perfectly reflected, from Fig 2-62 –

$$\left(\frac{H_o}{L_o}\right)_{max} = 0.037$$

Wave reflection coefficient $= \chi = \chi_1 \chi_2$,
where χ_1 depends on roughness and permeability $= 0.6$ (for ACB)
χ_2 depends on slope and wave steepness

From Eqn 2-86b, – $\chi_2 = 1$ when $\left(\frac{H_o}{L_o}\right) \leq \left(\frac{H_o}{L_o}\right)_{max}$

∴ Wave reflection coefficient, $\underline{\underline{\chi = (1)(0.6) = 0.6}}$

Wave Reflection Calculation (Continued)

To obtain the wave reflection coefficient specified, $x = 0.25$, the ACB revetment slope will be as follows -

$x = x_1 x_2$ where $x_1 = 0.6$ (ACB)

$x_2 = \frac{x}{x_1} = \frac{0.25}{0.60} = 0.42$

Using Fig 2-63, $x_2 = 0.42$, $\frac{H_o}{L_o} = 0.0065$

$\cot \beta = 6$ $\therefore$ Slope = 1:6

To obtain the wave reflection coefficient specified, $x = 0.25$, a rip rap protected slope will be as follows -

$x = x_1 x_2$ where $x_1 = 0.3$ (rip rap)

$x_2 = \frac{x}{x_1} = \frac{0.25}{0.30} = 0.83$

Using Fig 2-63, $x_2 = 0.83$, $\frac{H_o}{L_o} = 0.0065$

$\cot \beta = 4.7$ $\therefore$ Slope = 1:5

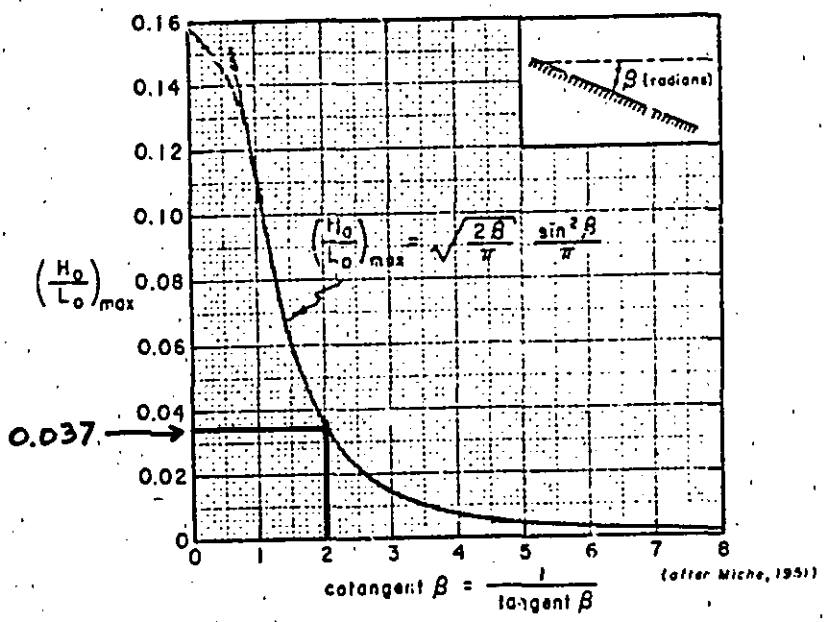


Figure 2-62. $(H_o/L_o)_{max}$ Versus Beach Slope

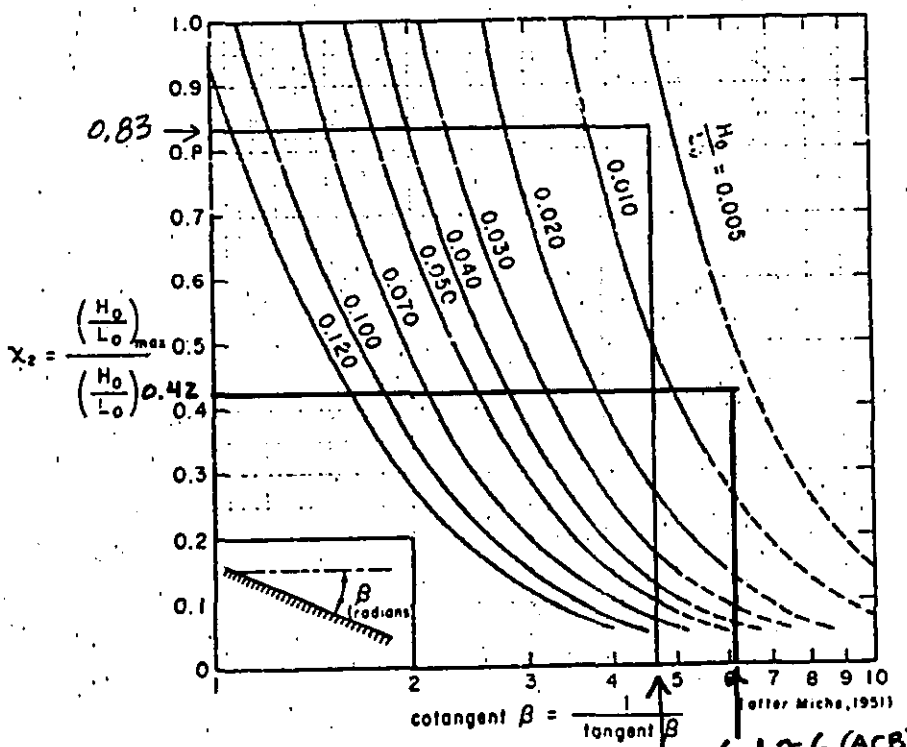


Figure 2-63. X_2 Versus Beach Slope for Various Values of H_o/L_o

SLIDING ANALYSIS

Analysis of potential sliding of drainage layer across geotextile filter.

Using NAVFAC DM 7.1, Soil Mechanics and DM 7.2, Foundations and Earth Structures –

Soil classification of drainage layer = GW

↑ #4 GP

Using Table 3, DM 7.2 –

γ = 130 pcf = maximum dry unit

Using Figure 7, DM 7.1 –

ϕ' = internal friction angle of drainage layer = –

Assume interface friction angle, ϕ_i, between drainage layer and geotextile fabric is 85% of ϕ'.

$$\tan \phi_i = 0.85 \tan \phi' = 0.85 \tan 36° = 0.618$$

β = slope angle = 26.6° = 2:1 slope

$$\therefore \text{Factor of Safety}_{sliding} = \frac{\tan \phi_i}{\tan \beta} = \frac{0.618}{\tan 26.6} = 1.23$$

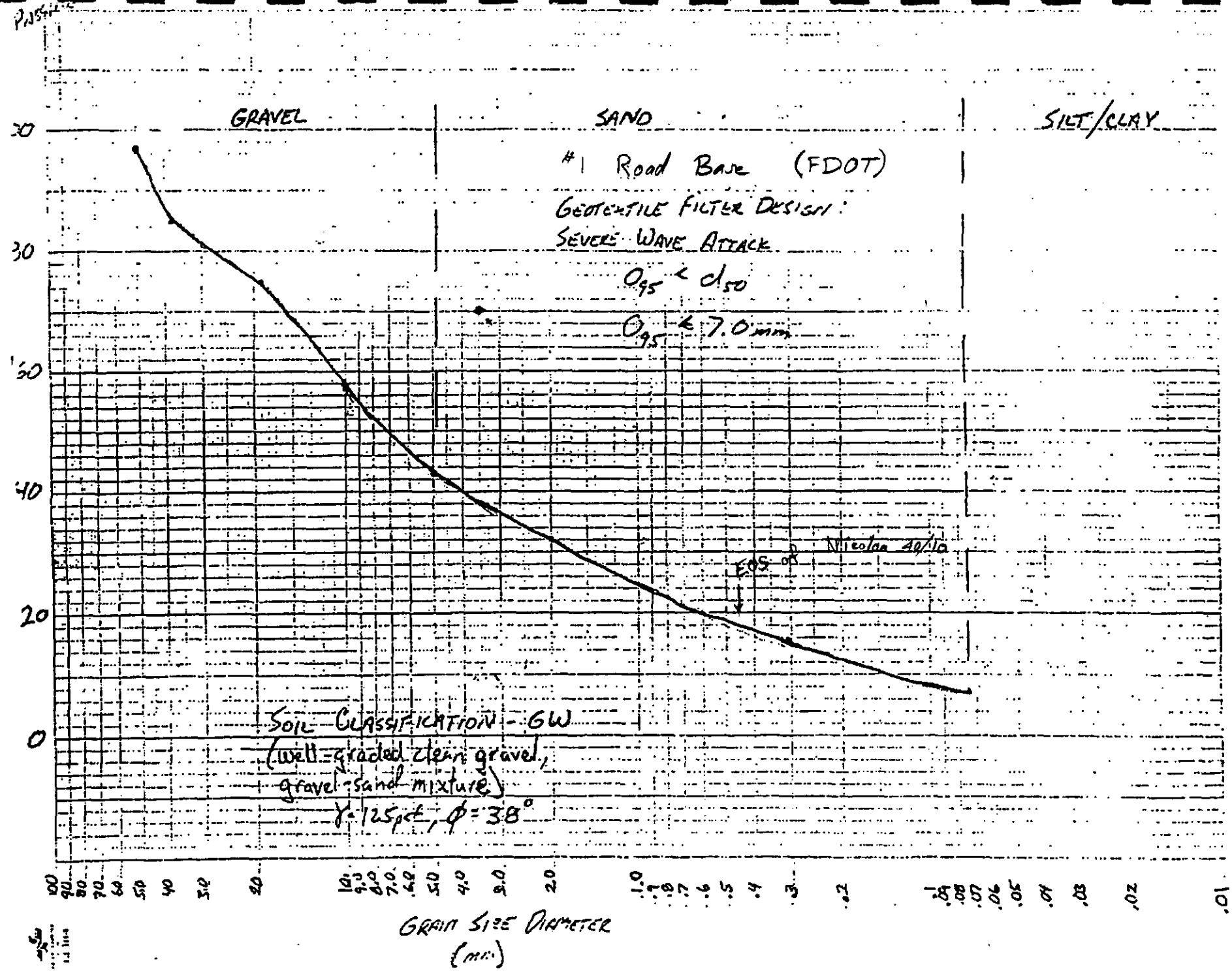

GRAVEL
SAND
SILT/CLAY
#1 Road Base (FDOT)
GEOTEXTILE FILTER DESIGN:
SEVERE WAVE ATTACK
$O_{95} < d_{50}$
$O_{95} < 7.0$ mm
Nicolon 40/10
EOS of
SOIL CLASSIFICATION - GW
(well-graded clean gravel, gravel-sand mixture)
$\gamma = 125$ pcf, $\phi = 38°$
GRAIN SIZE DIAMETER (mm)

TABLE 3-3

TYPICAL PROPERTIES OF COMPACTED MATERIALS [Ref. 12]

Group Symbols	Soil Groups	Range of Maximum Dry Unit Weight, pcf	Range of Optimum Moisture %	Typical Strength Characteristics: Cohesion (as compacted) psf	Cohesion (saturated) psf	ϕ (Effective Stress Envelope) deg
GW	Well graded clean gravels, gravel-sand mixtures.	125-135	11-8	0	0	>38
GP	Poorly graded clean gravels, gravel-sand mix.	115-125	14-11	0	0	>37
GM	Silty gravels, poorly graded gravel-sand-silt.	120-135	12-8	.....	.....	>34
GC	Clayey gravels, poorly graded gravel-sand-clay.	115-130	14-9	.....	.....	>31
SW	Well graded clean sands, gravelly sands.	110-130	16-9	0	0	38
SP	Poorly graded clean sands, sand-gravel mix.	100-120	21-12	0	0	37
SM	Silty sands, poorly graded sand-silt mix.	110-125	16-11	1050	420	34
SM-SC	Sand-silt clay mix wit slightly plastic fines.	110-130	15-11	1050	300	33
SC	Clayey sands, poorly graded sand-clay mix.	105-125	19-11	1550	230	31
ML	Inorganic silts and clayey silts.	95-120	24-12	1440	190	32
ML-CL	Mixture of Inorganic silt and clay.	100-120	24-12	1350	460	32
CL	Inorganic clays of low to med plasticity.	95-120	24-12	1800	270	28
OL	Organic silts and silt-clays, low plasticity.	80-100	33-12	.....	.....	.....
MH	Inorganic clayey silts, elastic silts.	70-95	40-24	1500	420	25
CH	Inorganic clays of high plasticity.	75-105	36-19	2150	230	19
OH	Organic clays and silty clays...	65-100	45-21	.....	.....	.....

NOTES:

1. All properties are for condition of "standard Proctor" maximum density.
2. Typical strength characteristics are for effective strength envelopes and are obtained from USBR data.
3. (>) indicates that typical property is greater than the value shown. (.....) indicates insufficient data available for an estimate.

Ref: Soil Mechanics and Foundations and Earth Structures, NAVFAC DM-7.1 & 7.2, Dept. of the Navy (May 1982)

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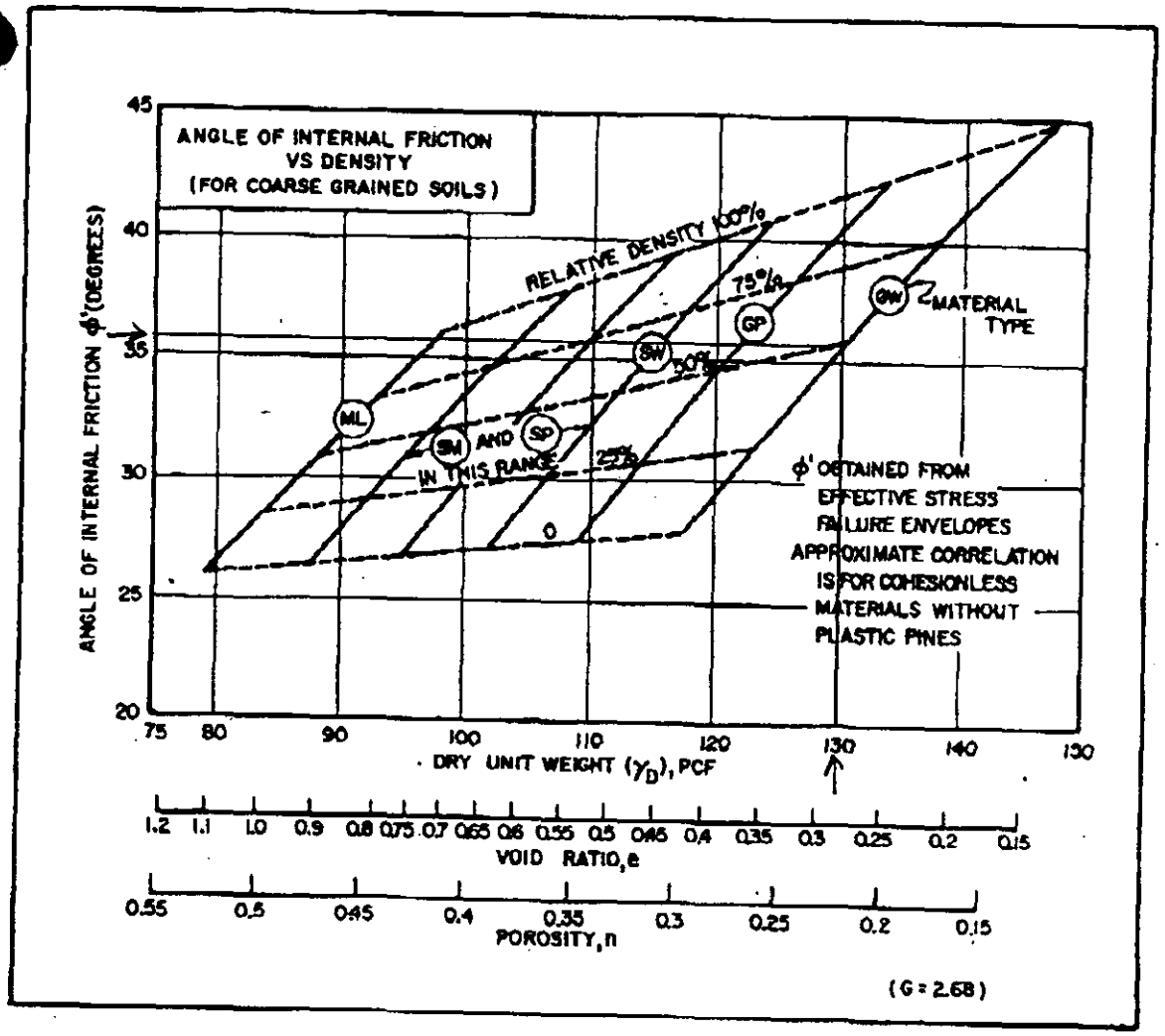

FIGURE 7
Correlations of Strength Characteristics for Granular Soils

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Leaching Stone/Geotextile Sliding

Case I - Infinite Slope Analysis modelling "during construction"

$$FS = \tan\delta / \tan\beta = \tan 32^\circ / \tan 26.6^\circ = 1.25$$

Case II - Finite Slope Analysis modelling "after construction"

Cover Soil Thickness, T_c = 12 inches

Slope Height, H = 16 feet

Slope Angle, β = 26.6°

Internal Friction Angle of Soil Cover, ϕ_c = 38°

Unit Weight of Cover Soil, γ_c = 130 pcf

Interface Friction Angle, δ = 32°

Analysis based on the following:

McKelvey, J.A. and Deutsch, W.L., "The Effect of Equipment Loading and Tapered-Cover Soil Layers on Geosynthetic Lined Landfill Slopes", Fourteenth Annual Madison Waste Conference, Sept. 25-26, 1991, Dept. of Engineering Professional Development, Univ. of Wisconsin - Madison

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Calculate Weight of Buttressing Wedge, W_1

$$W_1 = \frac{\gamma_c T_c^2}{\sin 2\beta} = \frac{(130\,pcf)(1)^2}{\sin 2(26.6)} = 162.4\ lb/ft$$

Calculate Equipment Loading, W_2

Equipment will not be riding on the slope. Therefore, $W_2 = 0$

Calculate the Weight of the Driving Wedge, W_2

$$W_2 = \frac{\gamma_w T_c^2}{\sin 2\beta}\left[\frac{2H\cos\beta}{T_c} - 1\right] + W_2$$

$$W_2 = \frac{(130)(1)^2}{\sin 2(26.6)}\left[\frac{2(16)\cos 26.6^\circ}{1} - 1\right] + 0$$

$$W_2 = 162.4(27.6)$$

$$W_2 = 4482.2\ lb/ft$$

Calculate the Factor of Safety, FS

$$FS = \text{Resisting Forces} / \text{Driving Forces}$$

$$FS = (W_2\cos\beta\tan\delta + W_1\sin\phi_c/\cos(\beta+\phi_c)) / W_2\sin\beta$$

$$FS = (4482.2(\cos 26.6)\tan 32^\circ + 162.4\sin 38^\circ/\cos(26.6+38^\circ)) / 4482.2\sin 26.6$$

$$FS = (2504.3 + 233.11) / (2006.9) = 1.36$$

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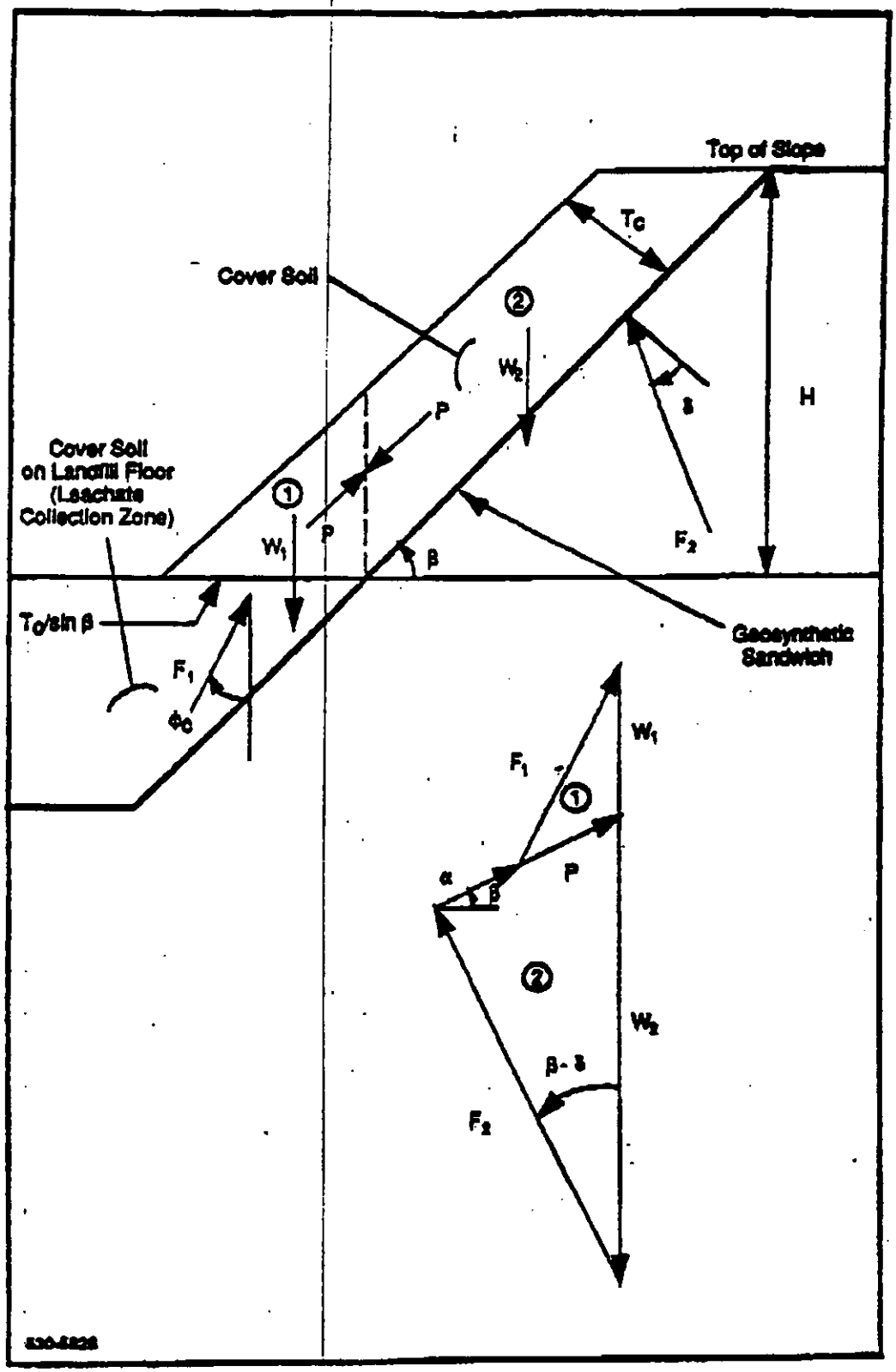

FIGURE 1 GEOMETRY OF BUTTRESSING WEDGE W_1 AND DRIVING WEDGE W_2 IN GIROUD AND BEECH MODEL

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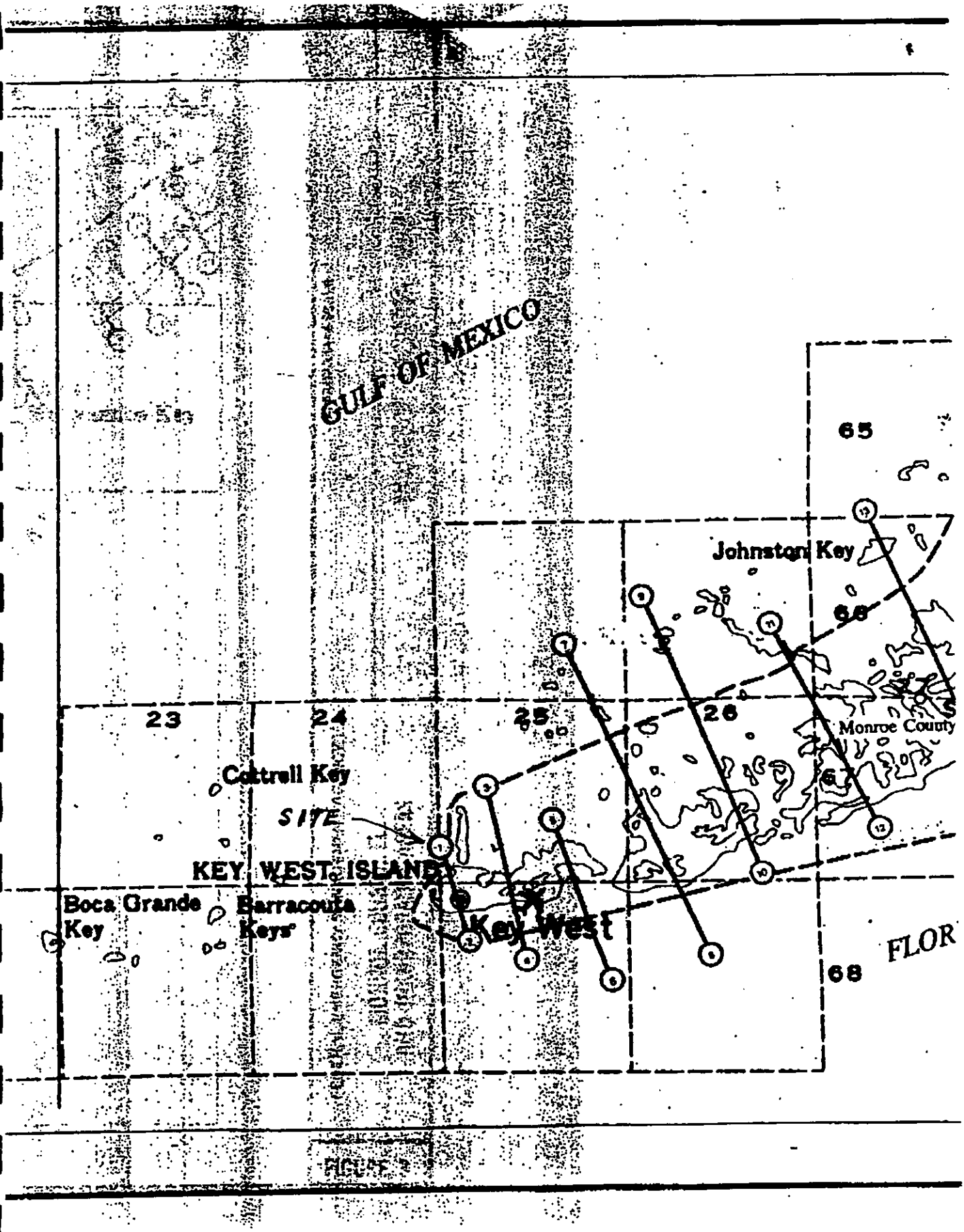

FIGURE 2

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EXISTING

FLOODING SOURCE AND TRANSECT	FLOOD INSURANCE RATE MAP PANEL	STILLWATER ELEVATIONS (NGVD) 10-YEAR	50-YEAR	100-YEAR	500-YEAR	ZONE	BASE FLOOD ELEVATIONS (FEET NGVD)
GULF OF MEXICO	1708/1718	3.2	5.5	6.4		VE AE	11–13 8–10
		3.2	5.5	6.8	7.3		9–11 7–8
ATLANTIC OCEAN 2	1718	2.7	4.8	7.6	8.4	VE AE	10–12 8–10
		2.7	4.8	6.0	8.4	AE	8–8
GULF OF MEXICO 3	1709	5.1	6.6	7.4	9.2	VE AE	9–11 7–8
ATLANTIC OCEAN 4	1709/1917	3.0	5.5	6.6	7.4	VE AE	11–13 9–11
		3.0	5.5	7.2	7.4	VE AE	9–11 7–8
GULF OF MEXICO 5	1728	4.7	7.6	8.4	10.4	VE AE	11–13 9–11

[1]ROUNDED TO THE NEAREST FOOT AND MAY INCLUDE EFFECTS OF WAVE ACTION
[2]DUE TO MAP SCALE LIMITATIONS, BASE FLOOD ELEVATIONS SHOWN ON MAP MAY REPRESENT AVERAGE ELEVATIONS FOR THE ZONES DEPICTED
[3]INCLUDE EFFECTS OF WAVE SETUP

TABLE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

MONROE COUNTY, FL
AND INCORPORATED AREAS

SUMMARY OF STILLWATER ELEVATIONS

GULF OF MEXICO—ATLANTIC OCEAN