CHAPTER 62

USE OF PLASTIC FILTERS IN COASTAL STRUCTURES

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ABSTRACT

It has long been the opinion of many engineers that the primary cause of failure in certain coastal structures is due to an inadequate filter system. Normally, filters for granular soils are made up of layers of graded sand, gravel and stone materials in various combinations and thickness dimensions. Very often these materials are expensive and in some cases, due to geographic location, are unavailable. Even if the required materials are easily accessible, proper placement is tedious and demands strict supervision.

This paper discusses the use of "plastic filters" as a replacement for graded filter systems and filter blankets in coastal structures. While this discussion and illustrations are limited to coastal structures, plastic filters can and have been used in river, lake, canal, dam and other hydraulic structures.

INTRODUCTION

The term "plastic filters" in the title refers to cloths woven of modern synthetic fibers. While there are many synthetic fibers available, this paper deals exclusively with monofilament polyvinylidene chloride, and monofilament polypropylene yarns woven into cloths.

The field of soil mechanics has made great strides and there is no question that soils engineers can design graded filter systems that will function properly. However, in some cases the design of a proper filter has to be compromised due to the lack of readily available material. Unfortunately, in other instances, intricate and highly detailed, multi-phased, graded filter systems do not function properly due to installation difficulties and haphazard placement by labor during construction. Most of the difficulties previously experienced in design and placement of a competent filter system have been overcome by the development and use of plastic filters.

FUNCTIONS OF A FILTER

Due to the granular soils on which most coastal structures are constructed, filters are necessary for the stability of the structure.

A filter system must be permeable to water to prevent a buildup of hydrostatic pressure by allowing the water to pass thru without significant head loss. It must be impermeable to soil to prevent the soil from leaching thru the structure causing it to become unstable and/or to settle.

GENERAL ADVANTAGES OF PLASTIC FILTERS

There are several advantages to be realized by the use of plastic filters that are common to most types of structures 1) The filtering ability is factory controlled and cannot be altered due to careless placement by labor. 2) It is the only type of filter that has an independent tensile strength. This factor may prevent failure and the expense of reconstruction - i. e., if a portion of rubble is removed or rearranged in a revetment with a conventional filter system, the filter material is removed, then the soil, a cavity forms and a collapse follows. Due to the independent tensile strength of plastic filters they retain the soil and failure is eliminated, only minor maintenance is necessary to restore the structure to its previous condition. 3) Quick, visual inspection assures the engineer the filter is in place, as designed, when the structural materials are placed upon it. Screening and inspection of each truck of graded material, and inspection of placement to insure proper thicknesses and compaction are eliminated. 4) It permits greater opportunity for consistency in filter design. 5) Geographic location and availability of materials (sand & gravel) are eliminated as economic considerations in the design of the filter system.

EXAMPLES OF USES

REVETMENTS

Relief of water pressure and prevention of loss of soil is important in any coastal design, but it is especially critical in a revetment. A revetment depends upon the soil it lies upon for its stability, if the soil leaches thru, the revetment will fail.

Plastic filters have been successfully used to stabilize rubble (stone) and interlocking block revetments.

Rubble Revetments - Fig. 1 is a photograph showing plastic filter cloth being staked down, in the background draglines can be seen placing rock on previously installed plastic filters. This picture illustrates construction in Deerfield Beach, Florida, immediately following the March, 1962 storm which attacked the East Coast of the United States. The weights of the rocks used directly upon the cloth varied from 500 pounds to 2-1/2 tons. To this date there has been no settling of the revetment, nor has any maintenance been required. In addition to many northeast storms in the past four years, the structure has also been subjected to attack from three hurricanes without experiencing any damage.

Fig. 1.

There have been many other revetments constructed where rocks of similar weights have been placed directly on the plastic filter. However, it is the author's opinion that a layer of gravel or crushed stone be placed immediately on top of the filter cloth as shown in Fig. 2. Since this gravel layer would not be called upon to perform a filter function, whatever material is locally available and most economical may be specified. The purpose of this layer is to act as a pad to prevent rupture of the plastic filter by the heavier rocks when movement occurs during a storm or hurricane. The size of the structure, armor and intermediate stones will naturally dictate what size stone should be used in this protective pad. The stone in this pad should be large enough so that it cannot be sucked thru the rock layer above it. In various revetments the size of the material used in this protective layer has varied from 3/8" gravel to one-man stone (100-150 pounds).

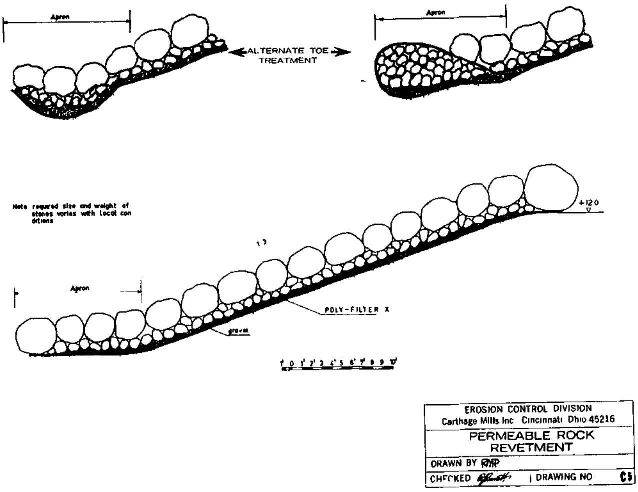

Fig. 2.

<u>Interlocking Block Revetments</u> - Fig. 3 illustrates the use of plastic filter beneath an interlocking concrete block revetment in Delray Beach, Florida. Plastic filters have been used beneath interlocking block revetments of basically similar design in Florida since 1958. The combined length of these individual segments of revetments is several miles long. To date there have been no failures even though some of the structures have been subjected to as many as three hurricane attacks. It will be noted that in addition to the plastic filter material, there is an 8" layer of crushed rock between the filter cloth and the blocks. This layer of crushed rock does not perform a filter function and it is unnecessary to specify gradations, as in filter use, provided the stone is open enough to allow for free flow of water. The primary function of this layer is to act as a reservoir so that water may be released from the soil over one hundred percent of the surface of the structure. The water thereafter relieves itself by seeping thru the cracks in the joints of the blocks.

The crushed rock layer is an absolute necessity as wave tank tests have shown that if the block is placed directly upon the filter cloth, seepage thru the joints will not be fast enough to prevent a buildup of hydrostatic pressure. Probes have shown a slight upward lifting of the blocks when they are placed directly on the plastic.

Plastic filters have also been used in conjunction with interlocking concrete blocks of other designs.

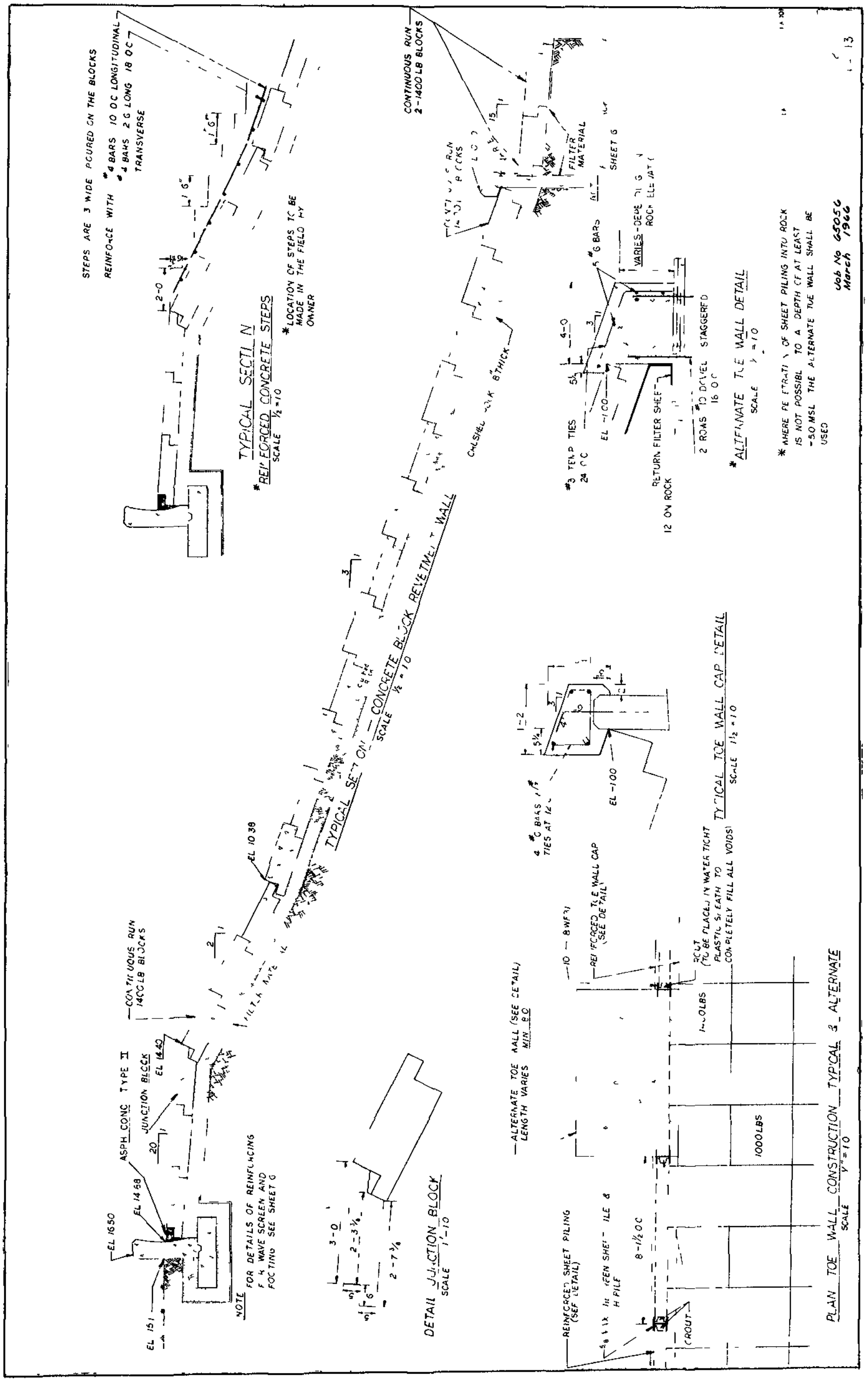
STEPS ARE 3 WIDE POURED ON THE BLOCKS
TRANSVERSE
CONTINUOUS RUN 2-1400LB BLOCKS
FILTER MATERIAL
CHUSHED ROCK 8" THICK
ASPH CONC TYPE II
JUNCTION BLOCK
DETAIL JUNCTION BLOCK
RETURN FILTER SHEET
12 ON ROCK
1000LBS
PLAN TOE WALL CONSTRUCTION TYPICAL 3 ALTERNATE

Fig. 3.

VERTICAL SEAWALLS

In vertical seawalls of concrete sheeting (tongue and groove, tee-pile and panel, king pile and panel) the normal procedure in the United States has been to grout the joints to prevent sand from leaching thru the structure and jeopardizing its stability. When this method is used, one of two things normally occurs - 1) if there is an excellent application of the grout, it not only prevents the sand from moving thru the structure, but also the water, and a hydrostatic head is built up. This either causes the bulkhead to topple forward or undermines the toe portion of the bulkhead, either case resulting in a failure. 2) More often the grout is blown (forced out of the joint) by the water pressure behind the structure and the soil leaches thru the joints, causing either a failure of the bulkhead or the expense of backfilling with additional soil. Many engineers have overcome this problem by lining the interior of the wall with plastic filter cloth. This allows the water to relieve itself through the joints while the filter retains the backfill.

Fig. 4 illustrates the lining of a tongue and groove concrete sheet pile wall. In this instance the engineer used vertical strips of lumber to secure the cloth to the rear of the wall. An advantage afforded by this method of securing the filter is that by tacking the cloth to the bottom of the wooden strips the engineer is certain that the filter is placed to his design depth. The filter cloth may also be tacked to the top of the piling and allowed to fall as a curtain, after backfilling takes place it will be held snugly against the wall by the fill material.

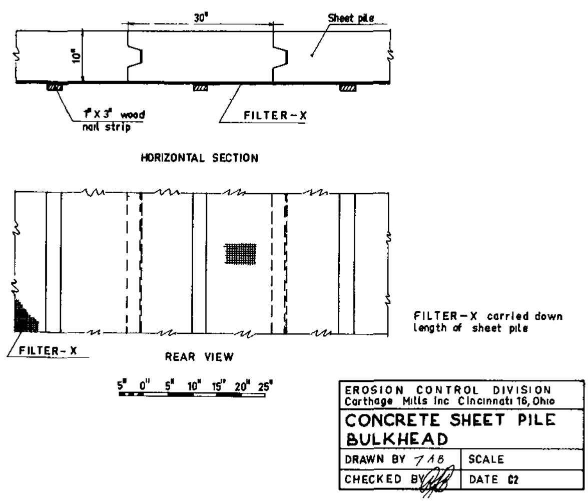

Fig. 4.

Fig. 5 shows a photograph taken in Nassau, British West Indies, of a harbor under construction using tee-pile and panel bulkheads. In this project plastic filter cloth was attached to narrow wooden strips and placed behind the joints where the concrete sheeting abutted the tee-pile. The wooden strips were jetted (where necessary) to design depth and then secured to the interior of the bulkhead with concrete nails. The plastic filter has retained the fill sand and no backfilling has been necessary since the installation five years ago. Personal observation shows excellent relief of water through the joints of this seawall.

Fig. 5.

There have been many similar applications using king pile and panels with a small hole being cut in the plastic filter cloth to allow the tie back rod to pass through the filter from the king pile. Plastic filters have also been successfully used to line the interior of timber bulkheads. To date the author knows of no installation of plastic filters in conjunction with vertical steel bulkheads but this would be an excellent safety factor to prevent the soil from leaching through the interlocks.

DRAINAGE SYSTEM

Where soil conditions require it, it has been necessary to install collector pipes (perforated pipe, tile pipe, etc.) behind vertical bulkheads. Engineers have found that they have been able to eliminate the cost of pipe entirely by using plastic filters. Fig. 6 illustrates the use of plastic filters by Parsons, Brinckerhoff, Quade & Douglas, Engineers, New York, at the Port of Toledo in the United States. In this instance the plastic filter cloth was laid in a trench immediately behind a steel bulkhead. The trench was then filled with gravel and covered by the plastic filter. Fill material was then placed on top of this new style "french drain". Weep holes were placed at given intervals to allow the water to drain through the structure.

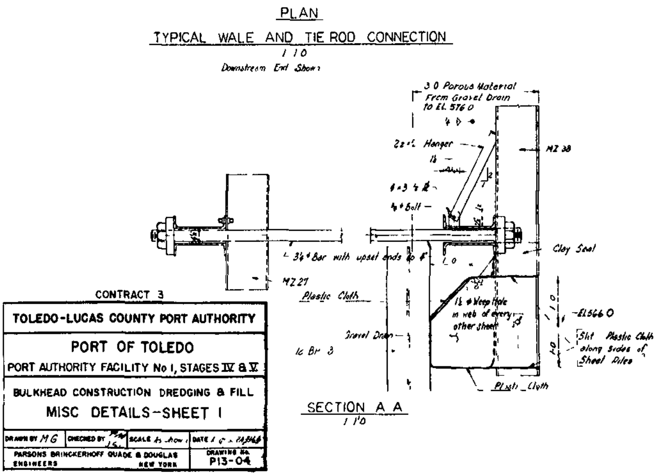

Fig. 6.

In other instances filter cloth has been used to wrap perforated pipe to prevent the intrusion of fines into the pipe and eventually clogging it. In some cases the filter cloth has been wrapped directly around the perforated pipe or the joints of tile drain pipe and the area then backfilled with permeable granular material to facilitate water flow into the drains. Another procedure has been to place the filter cloth against the soil, then place gravel between the plastic filter and the pipe and then the cloth wrapped over both the tile and the surrounding gravel. The latter method provides a greater area of draw and also stops the movement of fines before they get started.

SCOUR PROTECTION

Consistent with good engineering, when vertical bulkheads are called for it is necessary that scour protection be placed in front of the structure. In order to prevent the heavier rubble material from sinking into the sand, a filter media is required. Plastic filters have been used in many instances in this manner. One great advantage they offer over a conventional filter blanket or graded filter system is the fact that properly secured to the ocean floor, they remain in position until the heavier stones are placed upon them. This is not always true in the more conventional form of filter media as often wave and tidal action remove the lightweight filter gravels and sands, or reduce its thickness so that when the protective structure is completed, the filter does not function properly and sinking occurs. Fig. 7 shows the use made of plastic filters in this manner by the U. S. Department of the Navy at Rota, Spain.

JETTIES AND BREAKWATERS

Placement of filter systems under water as required beneath jetties and breakwaters has always been a difficult problem. Some engineers try to compensate for wave and tidal action by overdesign of the filter system. Even this offers no assurance that sufficient filter material is in place when the heavier structural members are put into position. Use of plastic filters in these structures has eliminated the "guesswork" as to the condition of the filter when the heavier stones are placed upon it.

Fig. 8 is a drawing of a jetty constructed at Fort Macon State Park in North Carolina. Plastic filter was used as the base filter beneath this jetty. The installation procedure used in this instance is illustrated in Fig. 9. In each end of individual sheets of the plastic filter, tubes were sewn by lapping the cloth back upon itself and then being seamed. Into these tubes were inserted pipes and then the filter sheet was rolled into a roll on the beach. The first roll was then secured to the beach at the shoreward terminus of the jetty. The pipe attached to a yoke on a barge. The cloth was unrolled by pulling the yoke seaward to the barge. When the end of one sheet was reached, the second roll was lowered into position from the barge with a minimum of 2' overlap. The operation was then repeated, unrolling the second section of plastic filter. Small stones (100-200 pounds in weight) were randomly dropped onto the filter cloth to hold it in position until ensuing steps of construction were undertaken. Care was taken to make sure that the overlap was especially well covered with stone so that no peeling of the cloth could occur due to wave and tidal action.

Another method of placing and securing plastic filters beneath sea level is illustrated in Fig. 10. In this instance the cloth is sewn to a frame of reinforcing rod or other weighty material, making sure that the cloth is in a loose condition and not stretched so that it can more easily conform to the bottom contours. The frames are picked up by a dragline working from the beach seaward and placed into position beneath water level. After several frames are in position, the dragline places the required base course of rubble and uses this as a roadway to walk upon as the construction continues seaward. The process is

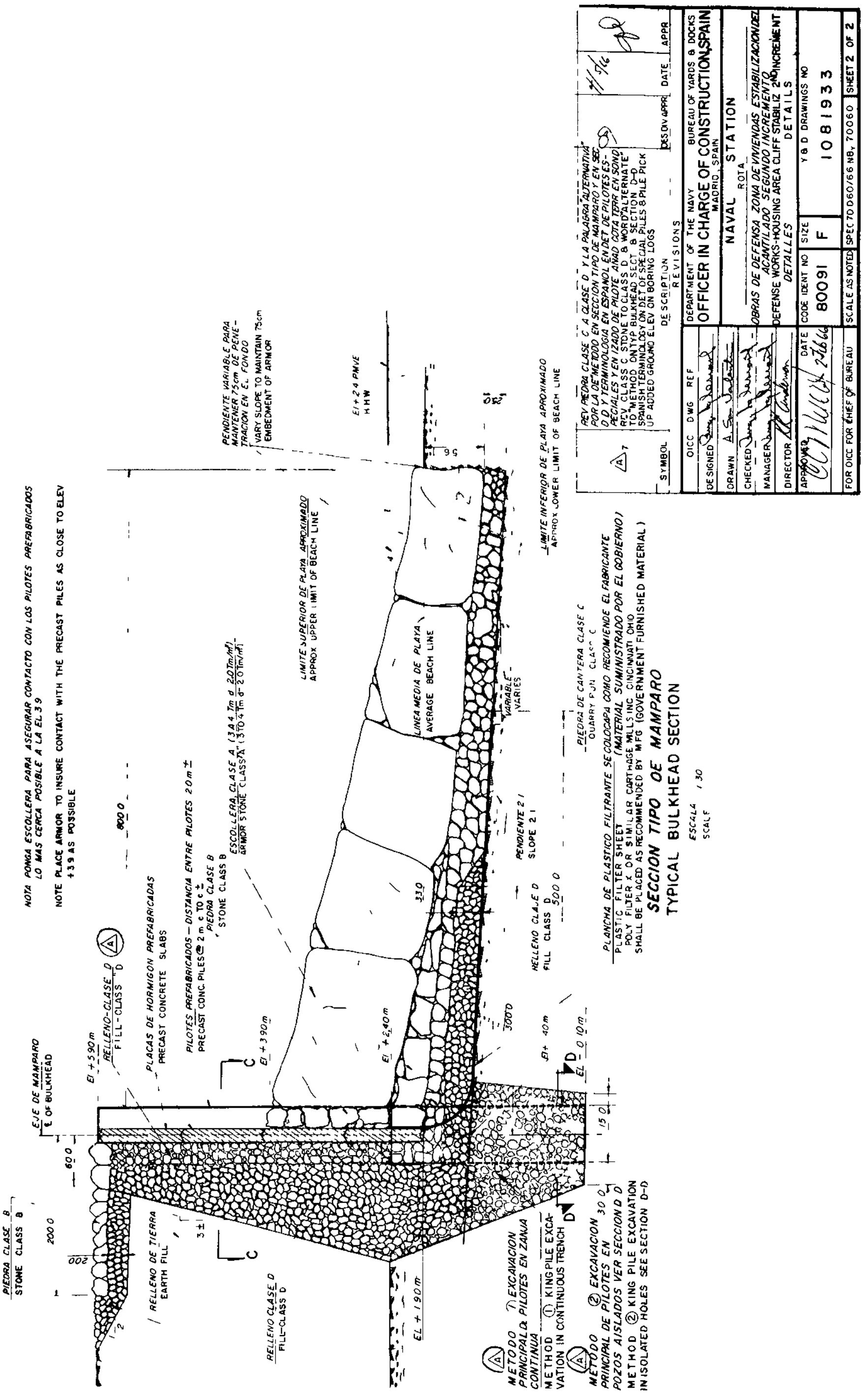
SECCION TIPO DE MAMPARO
TYPICAL BULKHEAD SECTION
ESCALA 1:30
SCALE
NOTA PONGA ESCOLLERA PARA ASEGURAR CONTACTO CON LOS PILOTES PREFABRICADOS LO MAS CERCA POSIBLE A LA EL 39
NOTE PLACE ARMOR TO INSURE CONTACT WITH THE PRECAST PILES AS CLOSE TO ELEV +39 AS POSSIBLE
EJE DE MAMPARO
℄ OF BULKHEAD
PIEDRA CLASE B
STONE CLASS B
RELLENO DE TIERRA
EARTH FILL
RELLENO CLASE D
FILL-CLASS D
PLACAS DE HORMIGON PREFABRICADAS
PRECAST CONCRETE SLABS
PILOTES PREFABRICADOS — DISTANCIA ENTRE PILOTES 2.0 m ±
PRECAST CONC. PILES @ 2 m c TO c ±
PIEDRA CLASE B
STONE CLASS B
ESCOLLERA CLASE A
ARMOR STONE CLASS A
LIMITE SUPERIOR DE PLAYA APROXIMADO
APPROX UPPER LIMIT OF BEACH LINE
LINEA MEDIA DE PLAYA
AVERAGE BEACH LINE
LIMITE INFERIOR DE PLAYA APROXIMADO
APPROX LOWER LIMIT OF BEACH LINE
PENDIENTE VARIABLE PARA MANTENER 75cm DE PENETRACION EN EL FONDO
VARY SLOPE TO MAINTAIN 75cm EMBEDMENT OF ARMOR
PENDIENTE 2:1
SLOPE 2:1
RELLENO CLASE D
FILL CLASS D
PIEDRA DE CANTERA CLASE C
QUARRY RUN CLASS C
PLANCHA DE PLASTICO FILTRANTE SE COLOCAPA COMO RECOMIENDE EL FABRICANTE
PLASTIC FILTER SHEET
POLY FILTER X OR SIMILAR CARTHAGE MILLS INC CINCINNATI OHIO
SHALL BE PLACED AS RECOMMENDED BY MFG (GOVERNMENT FURNISHED MATERIAL)
METHOD ① KINGPILE EXCAVATION IN CONTINUOUS TRENCH
METHOD ② KING PILE EXCAVATION IN ISOLATED HOLES SEE SECTION D-D
DEPARTMENT OF THE NAVY
BUREAU OF YARDS & DOCKS
OFFICER IN CHARGE OF CONSTRUCTION, SPAIN
MADRID, SPAIN
NAVAL STATION
ROTA
DEFENSE WORKS-HOUSING AREA CLIFF STABILIZ 2ND INCREMENT
DETAILS
80091
F
1081933
SHEET 2 OF 2

Fig. 7.

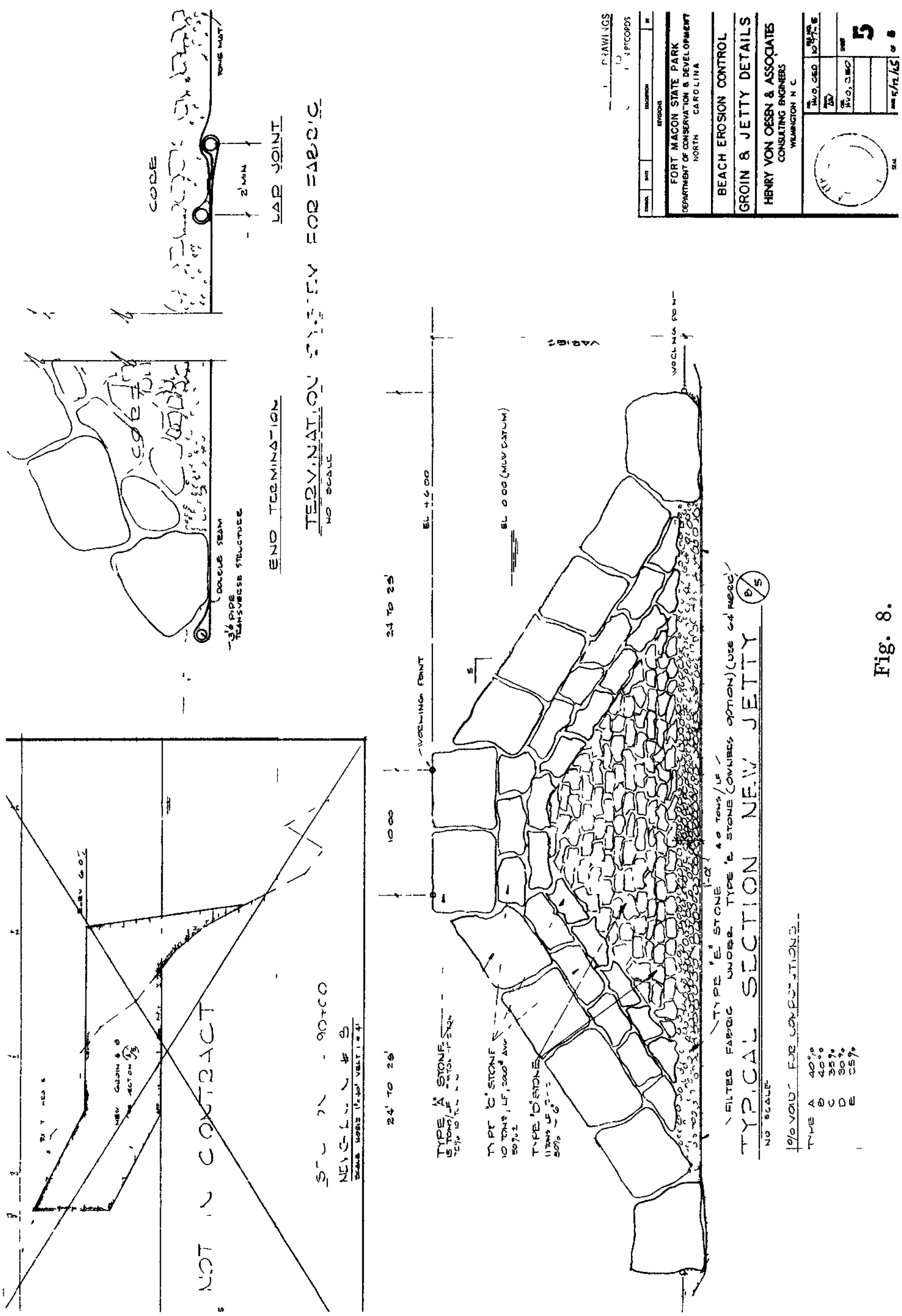
FORT MACON STATE PARK
DEPARTMENT OF CONSERVATION & DEVELOPMENT
NORTH CAROLINA
BEACH EROSION CONTROL
GROIN & JETTY DETAILS
HENRY VON OESEN & ASSOCIATES
CONSULTING ENGINEERS
WILMINGTON N C
LAP JOINT
END TERMINATION
TYPICAL SECTION NEW JETTY
NO SCALE
EL 0.00 (MLW DATUM)
24' TO 26'
10.00
NOT IN CONTRACT
% VOIDS FOR COMPUTATIONS
TYPE A 40%
B 40%
C 35%
D 30%
E 25%

Fig. 8.

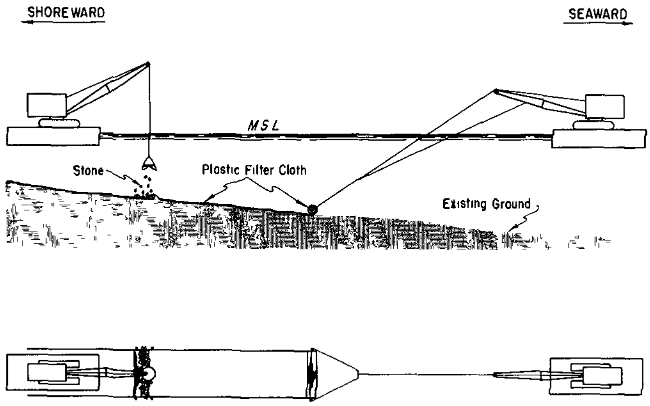

Fig. 9.

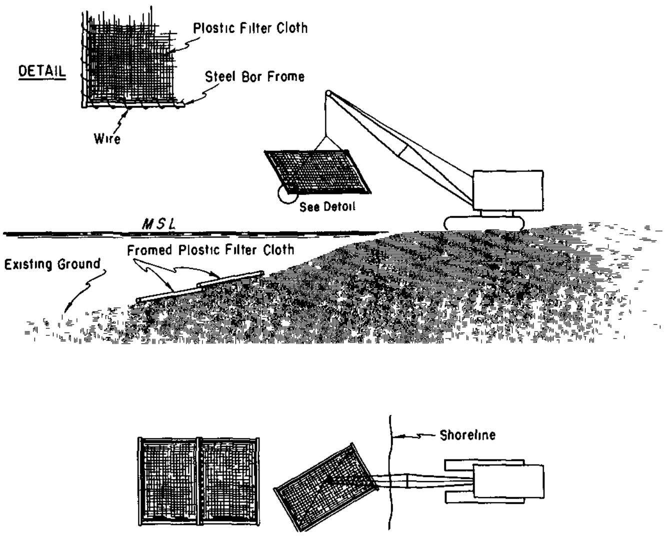

Fig. 10.

repeated with additional frames being lowered to the bottom, a base course placed upon it, and the dragline moving out on top of the base course. When the seaward end of the jetty has been reached, the dragline places the upper portion of the structure as it "walks" back to shore. It is supplied with the necessary stones to "top off" by trucks using the base course as their roadway. This method of placement was used in a cooperative groin repair project by the State of Pennsylvania and the Buffalo District of the U. S. Army Corps of Engineers, as shown in Fig. 11.

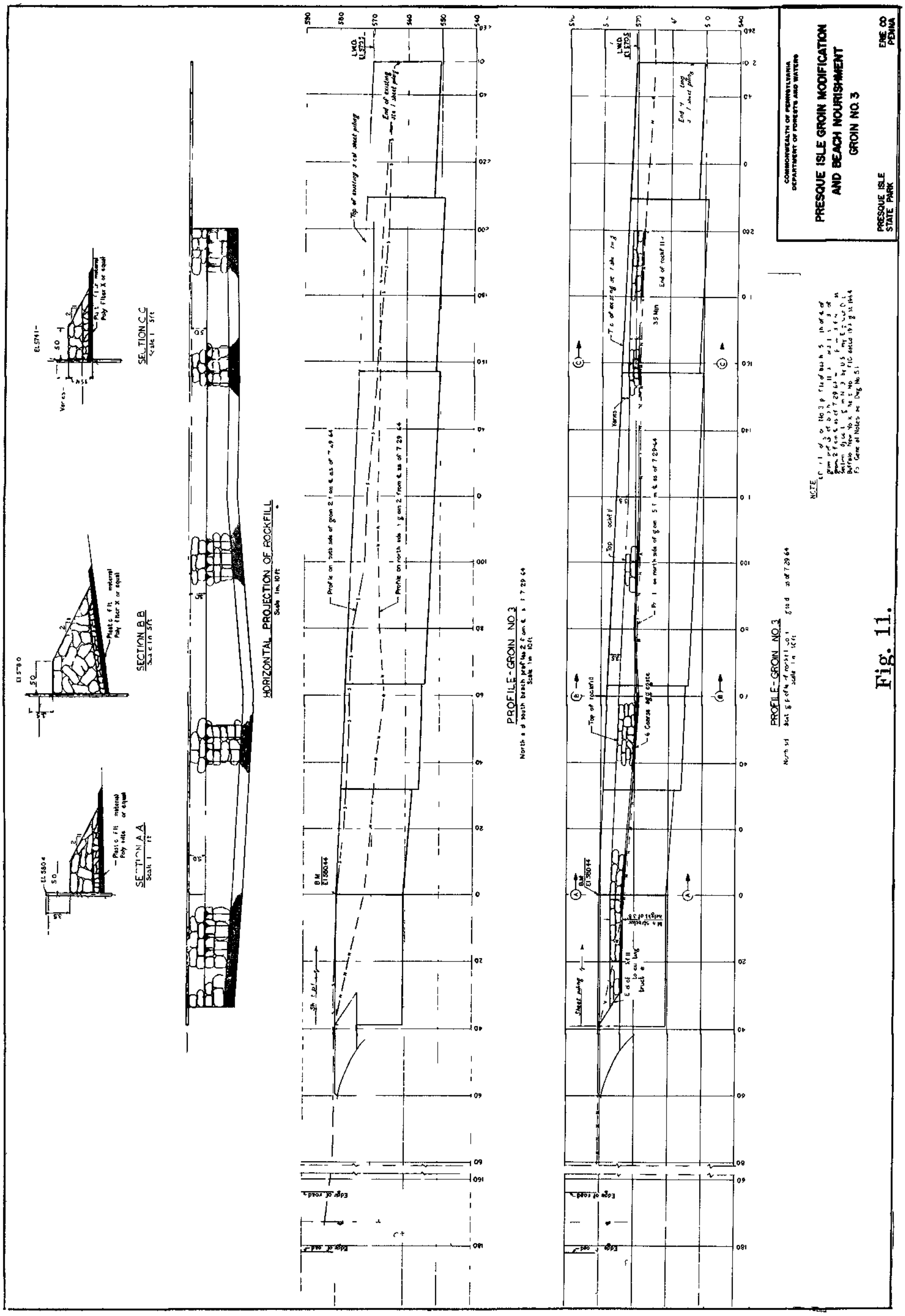
COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF FORESTS AND WATERS
PRESQUE ISLE GROIN MODIFICATION
AND BEACH NOURISHMENT
GROIN NO. 3
PRESQUE ISLE STATE PARK
ERIE CO PENNA
HORIZONTAL PROJECTION OF ROCKFILL
PROFILE-GROIN NO. 3
PROFILE-GROIN NO. 3
SECTION A-A
SECTION B-B
SECTION C-C
NOTE
Edge of road
Top of existing steel sheet piling
End of existing steel sheet piling
Profile on south side of groin
Profile on north side of groin
Top of rockfill
End of rockfill
6" Coarse aggregate
Varies
Sheet piling

Fig. 11.

Plastic filters have been placed to a depth of 30' in the Pacific Ocean and in a project just begun will be used at -150' in the North Sea.

When rock and other natural materials are not locally available, great savings can be made in the cost of jetties, etc., by pumping a sand core, covering this with a plastic filter, then a reduced amount of stone and finally the required armored layer. In this design the slope would have to be flatter than in a pure rubble jetty, but this permits a reduction in the weight requirement of each individual armor unit. The reduced amount of stone in the overall structure results in a substantial financial saving. The impermeable core also prohibits transmittal of energy thru the structure to the protected area. (See Fig. 12).

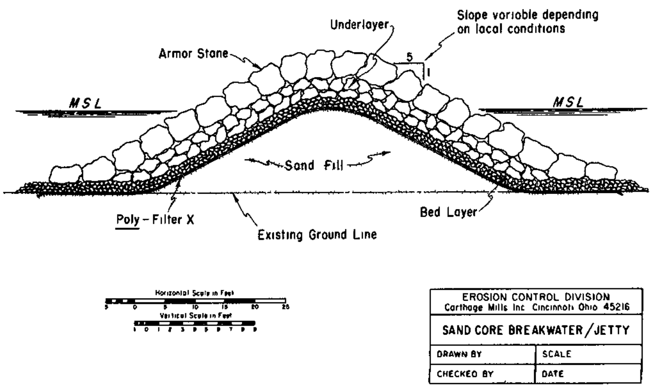

Fig. 12.

STEEL CELLS

Some engineers will not use sand to fill steel cells because they fear sand will leach thru the interlocks. Once again, plastic filters have solved the problem. The interior walls of the cells are lined with filter cloth to prevent the sand from leaching out. In 1965, Commonwealth Associates, Inc., Engineers, Jackson, Michigan, specified cells to be lined with plastic filter cloth and then sand filled. They report that in this particular project a saving of $ 5,000.00 per cell was realized over the more conventional method of using rock as the fill material. Naturally, the geographic location and availability of rock is a variable factor in determining the savings that can be made by using this method in each individual project.

MATTRESSES

The Rijkswaterstaat in the Netherlands has used woven cloths seamed together at given intervals so that sand or other weighty substances could be pumped in to line canal bottoms as scour protection. Experiments are being conducted on the Atlantic Coast of the United States with plastic filter cloths which have a 1' tube running the length of the cloth, at 4' intervals. This "mattress" was placed on the beach, at the beach's natural slope (approximately 1 on 10) and then covered with sand. It is felt that a "mattress" of this type will reduce the amount of sand lost during a storm and therefore make it more economical to nourish the beach to its previous profile. The performance of this "mattress" in a fairly well protected area has been satisfactory over a two year period.

Another application of a "mattress" of this type would be as temporary protection after a storm until a more permanent protective measure could be undertaken. An advantage of this type of temporary protection is the fact that it would provide the filter system for the permanent structure when constructed at a later date.

PHYSICAL CHARACTERISTICS OF PLASTIC FILTERS

As mentioned before, the plastic filters discussed in this paper are two woven cloths; one of polyvinylidene chloride yarns and the other of polypropylene. There are many other plastic yarns available, but in the author's opinion, these two synthetics offer the most advantages consistent with sound economics and performance requirements.

Regardless of the plastic selected, it is absolutely necessary that monofilament yarns be used so that the filter cloth maintains a consistent particle retention and permeability. If multifilament yarns are used, the filtering ability of the cloth would vary greatly after being exposed to water. The reason for this is that multifilament yarns absorb water, causing the individual yarns to swell, therefore the size of the openings is reduced and the permeability of the filter decreased.

Listed below are some of the physical properties of the two types of filters referred to above. Where applicable, ASTM Test Nos. are shown in parentheses as different types of tests would yield conflicting values. These plastic filters have been used in the United States for the past eight years.

While these physical characteristics do not relate to the "filter function", they are important in establishing a plastic filter criteria and are responsible for many of the advantages that are realized when plastic filters are used.

		Polyvinylidene Chloride	Polypropylene
Thickness (ASTM D-19100		15 Mils	16.8 Mils
Weight (Oz. / sq. ft.) (ASTM D-1910)		1.29	.80
Specific Gravity		1.7	.95
Tensile Strength (lbs. /inch)	Warp	230	380
(ASTM D-1682)	Fill	103	200
Abrasion Resistance (Taber: CS-17/1000 gram) (ASTM D-1175-D)		800 cycles	3,700 cycles
(Stoll: 2# head, 3# air, "0" grit) (ASTM D-1175-A)		10,000 cycles	25,000 cycles
% Stretch Before Breaking		33%	33%
Loss of Strength When Wet		Nil	Nil
Moisture Regain (ASTM D-629)		None	None
Effect of Salt Water		Nil	Nil

Thickness - This figure is given so that those engineers who are unfamiliar with woven filter cloth can visualize this unusual slender dimension.

Weight - Weight is a consideration in two respects, due to the lightness of the material the filter cannot be considered a contributing factor to the weight of the overall structure. Also, the light weight of the cloth makes it easier to install sheets of larger dimensions reducing the number of overlaps required.

Tensile Strength - This is important since rocks of varying sizes will be dropped or placed upon the filter during construction procedures. The cloth will also be subjected to pressures from wave action and in some structures, rapid draw down. As stated before, the fact that plastic filter cloths have an independent tensile strength contributes to their superior performance over the more conventional filter media.

Abrasion Resistance - During storm conditions rocks and/or blocks may be subject to movement while under attack and the cloth must be able to withstand this abrasion.

% of Stretch - If the filter is unable to stretch when structural members are placed upon it, it could not conform to the contours of the earth and would rupture and could no longer perform its function of soil retention.

Loss of Strength When Wet - Effect of Salt Water - If the filter would lose strength when wet or salt water had a deteriorating effect upon the cloth, its original characteristics would be altered and therefore could not be depended upon to perform consistently.

Moisture Regain - As mentioned above, if water were absorbed, the yarns would swell causing the openings to close and the permeability to be decreased.

FILTER FUNCTIONS

It has been previously stated that a filter must be permeable to water and impermeable to soil to properly serve its purpose in a given structure. Since soils vary greatly in both size and shapes, the only reliable method of determining these capabilities are thru soils tests.

Soils tests conducted by Soils Testing Services, Inc., Northbrook, Illinois, U.S.A., indicate these filters have an effective particle retention of .078 millimeter grain size. These tests also indicate the average permeability of one filter is 4.8×10^{-2} CM/SEC[1] and between 3.3 & 3.8×10^{-2} CM/SEC[2] for the other. In most cases the permeabilities of the filters were greater than the permeabilities of the material they were protecting. However, their protective use does not have to be restricted to these fine soils since they can also be employed to retain soils of greater permeability.

Another polypropylene filter tested by the above firm, but not yet in actual use, has a particle retention of .044 millimeter grain size.[3]

When plastic filters are specified in structures in which a small initial loss of soil is not critical (revetments, scour protection, etc.), they may be used to retain soil with a grain size content of 50% below their rated particle retention. It has been observed, (in the Soils Tests mentioned above and actual prototype use) that, because of the tensile strength of the cloth, "progressive stabilization" occurs with these filters; and after a small initial loss of fines, the remaining sand and silt particles interfere with one another to the extent that they form a filter medium to the remaining fines. It is doubted that this phenomena could occur if the cloth did not have an independent tensile strength.

OTHER TYPES OF PLASTIC FILTERS

Other types of plastic filters have been investigated by the author but have not proven satisfactory.

Perforated Plastic Film (Foil) - Due to the flexibility of plastic films, the perforations were distorted to such an extent and with an overwhelming irregularity so that no consistency of function could be maintained. After initial testing further investigation was considered unrealistic and therefore discontinued.

Glass Fiber Mat - A glass fiber mat of porous layers of glass fibers bonded together with resins and coated with neoprene (to give tensile strength to the mat) was tested both in laboratory and prototype. The thickness of the mat was approximately two inches. This type of filter was found unsatisfactory for the following reasons· when loading the mat (placing stone, rock, or other weighty material upon it) an irregular particle retention and permeability resulted. This is due to the fact that the porous layer of glass fibers are compressed in an uncontrolled manner accounting for complete impermeability in one area while another area may have a high permeability and low particle retention property. As the loading varies (a heavier weight in one square foot and a lesser weight in the adjacent square foot), these variables of performance are even more apparent. The tensile strength is insufficient- drop tests proved the mat more easily ruptured than either plastic filter previously referred to. In prototype when heavier structural members were lifted by wave action from the mat, the individual fibers separated and were no longer effective.

Glass Fiber Cloth - Initial investigation showed this type of filter to be brittle and also abrasive unto itself. The individual fibers had an abrasive action on each fiber it crossed with the result that after sufficient time it would cut the fiber therefore allowing larger holes to appear in the cloth eliminating its effectiveness as a filter.

SOME CONSIDERATIONS REGARDING PLASTIC FILTERS

Since plastic filters are relatively new to many engineers, care must be taken in the selection and specification of a filter cloth. The author has already given his opinion as to what he considers currently to be the best plastics for this purpose.

Since soil is the material to be protected, a soils test should be required by the engineer of the supplier of the filter.

The cloth should have flexibility so it can adjust to irregularities in the slope if being used in a revetment or in bottom protection, yet have enough firmness so there is a minimum amount of slippage of the yarns so that a consistent filtering ability is maintained.

Specifications should state that the filter is loosely laid and not placed in a stretched condition. This is necessary so that it can conform to the irregularities in the soil when heavier members are placed upon it.

Where two sheets join together, they should be overlapped a minimum of 8" if the work is in the dry, and a minimum of 2' if being placed under water.

It is advisable as a safety factor to state a drop limitation in the specifications. Drop tests show that a rupture is effected at 10' with a 500 pound stone. The most common drop limitation has been 3'.

Just as no one filter design is an "answer-all" to every soil condition, neither are plastic filters an "answer-all" to every filter problem. Depending upon local soil conditions and the type of structures under consideration, in some instances the plastic cloth should be used in conjunction with another filter medium. In cases where thickness is required, this element would have to be realized by the addition of a layer of gravel or crushed stone. If the soil to be protected has an excessively high silt content, it would be advisable to place a sand pad beneath the plastic filter. The engineer will have to keep these considerations in mind for each project and vary his design for that individual requirement.

CONCLUSION

Plastic filters have been successfully used in rubble & interlocking block revetments, rubble breakwaters & jetties, cribs, cells, sand cement bridge abutments, channel linings, drop structures, rock sills, locks and dams, vertical walls, "french drains" and to wrap collector pipe. Investigation has shown that the engineers responsible for these projects consider the filter performance superior as of this time. In some instances it was stated that maintenance has been eliminated.

Plastic filters do not eliminate the soils engineer. They can simplify his work by assuring him of consistency of particle retention and permeability. They have greatly eliminated the possibility of human error in placement of the filter system during construction, therefore assuring the engineer of the performance he requires. They make possible a greater consistency in filter systems (regardless of geographic location) and reduce the time required to be devoted to this portion of the overall design. They have eliminated the great variation in filter costs from one location to another and the time consuming effort of computing these cost estimates.

In view of the outstanding performance record of plastic filters, it is the author's sincere opinion, that they should be given thorough consideration in every structure in which filters would normally be required. The engineering profession does, and should always, have as its goal - a superior structure - brought about by a better design - through the use of modern materials and methods!

ACKNOWLEDGMENTS

The author wishes to express his thanks to the U. S. Army, Coastal Engineering Research Center, Washington, D. C., and the Coastal Engineering Laboratory of the University of Florida for the opportunity and privilege of observing all their wave tank tests which included plastic filters. To Carthage Mills Incorporated, Cincinnati, Ohio, for product data, Soils Test Reports and the use of Figs. 2, 4 & 12. To Norman Scott of Commonwealth Associates, Inc., Jackson, Michigan, for financial information regarding steel cells. To Clyde N. Baker, Jr. and Sylvio J. Pollici of Soils Testing Services, Inc., Northbrook, Illinois, for their many consultations. To Dr. Per Bruun, National Engineering Science Company, McLean, Virginia, for information regarding the mattress test and his sincere interest and assistance over the past eight years. And to the following organizations for permitting me to use their photos and/or drawings to illustrate this paper Engineering Department, City of Deerfield Beach, Deerfield Beach, Florida- Fig. 1, Glace Engineering Corporation, St. Petersburg, Florida- Fig. 3; Parsons, Brinckerhoff, Quade & Douglas, New York, New York- Fig. 6; Department of the Navy, Bureau of Yards & Docks, O. I. C. C., Madrid, Spain- Fig. 7; Henry Von Oesen & Associates, Wilmington, North Carolina- Fig. 8; Department of Forests & Waters, Commonwealth of Pennsylvania, Fig. 11.

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