PAVING BLOCK STUDY

Final Report

by

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FOREWORD

As a result of the research described in this project, the Louisiana Department of Highways has begun using cellular concrete block revetment. This type of revetment system is required on most projects having embankments subject to wave action and rapid draw-down of water surfaces. In addition, these revetment blocks are allowed as alternates to sacked concrete revetment and random riprap. This material has been specified for use on one important project for aesthetic reasons.

This is a relatively new concept in revetment. Some previous work has been done in this field by D. A. Parsons and R. P. Apmann, Hydraulic Engineers with the Agricultural Research Service of the U. S. Department of Agriculture. Their work was published in the Journal of the Waterways and Harbors Division, Proceedings of the American Society of Civil Engineers, May, 1965, as a paper entitled "Cellular Concrete Block Revetment." In spite of this favorable report, hydraulic engineers in the United States have not used this revetment concept to any extent.

Independent of the above mentioned research, Gobi, N.V. of Zutphen, The Netherlands, developed the same concept with the smaller concrete blocks described in this report. This system (trade-named Gobimat) is being used in The Netherlands for a variety of purposes such as stabilization of highway shoulders, parking areas, park roads, canal sections, bridge and overpass embankments and backslopes of dikes along the North Sea.

The author, being familar with the work of Parsons and Apmann, has used the general name "cellular concrete block revetment" to describe the system in this report and on all plans and specifications developed as a result of this study.

Since this report was completed and approved for publication, the Louisiana Department of Highways has constructed three miles of revetment along Highway 82 west of Holly Beach, Louisiana. This revetment, consisting of 800,000 blocks over plastic filter cloth, extends for $1\frac{1}{2}$ miles on each side of the test section installed in January of 1969.

Since the project was constructed (Fall of 1970), the area has been exposed to wave action, rapidly changing water levels and back-flow from storms which overtopped the road with wave wash and/or high tides in November 1970, February 1971, May 1971, July 1971, and three times within an 8-day period in September 1971, as a result of nearby Hurricanes Fern and Edith with no appreciable damage. This is in addition to wave action on the lower portion of the revetment several times each month as a result of normal high tides.

The wave action from Hurricane Edith was substantially greater than that associated with the storm of February 14, 1969 described in this report. The wave action from Hurricane Fern was equivalent to that of the storm of February 1, 1970.

The above information, which occurred after the completion of the research study, has been included in the foreword for the reader's information. The design, construction and performance of the cellular concrete block revetment at Holly Beach, Louisiana, will be presented in a forthcoming paper by the author.

Further research is being conducted at the Waterways Experiment Station under a Louisiana Department of Highways sponsored research project entitled "Lined Expansions at Culvert Outlets." Cellular concrete block revetment, sacked concrete revetment and riprap (all over plastic filter cloth) are being evaluated for their erosion prevention abilities as liners for channel expansions at culvert outlets. The Department is constructing prototype installations in the field and hopes to have some field data by the time the model tests have been completed. A final report on the above project is expected in 1973.

In June 1971, Erco Systems of New Orleans began operating a machine that fastens the blocks to plastic filter cloth to form a flexible mat 4 feet wide by lengths up to 35 feet. Present field handling systems limit the mat length to 20 feet or less.

The Louisiana Department of Highways has installed 20 of these mats partially under water along an eroding roadside canal in Terrebonne Parish. The canal is subject to tidal flow and boat waves. The performance has been satisfactory and future installations are planned.

The in-place cost with maintenance forces was $11 per square yard. This cost will probably range from $12 to $15 per square yard, for construction projects.

The reader is reminded that the conclusions and recommendations presented at the end were drawn from the author's observations of the limited field test installations discussed in the report and the letter report of December 5, 1968, from Mr. J. J. Vinje, Head of deVoorst Hydraulic Laboratory to Mr. J. C. Pillaar of Gobi, N.V. (See Appendix).

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ABSTRACT

The Louisiana Department of Highways has conducted field tests with an experimental revetment consisting of cellular concrete revetment blocks used in conjunction with plastic filter cloth and/or vegetation such as grass or vines. The precast blocks are of vibrated concrete, weigh 13 lbs. and are approximately 8" square by 4" deep. Each block has a $2\frac{1}{2}$" hole (cell) through the center with notches on four sides which match those of adjacent blocks to form additional cells. When they are laid side by side, a pervious, rough, flexible concrete revetment with approximately 30 per cent of the surface area consisting of 2 and $2\frac{1}{2}$ inch cells is formed.

This concept was developed in The Netherlands and has been used extensively in that country for a variety of purposes such as stabilization of highway shoulders, parking areas, park roads, canal sections, bridge and overpass embankments and backslopes of dikes along the North Sea.

Similar test areas selected for this study included shoulders subject to rutting from occasional traffic, ditch and culvert outlets, an overpass embankment subject to soil failure and erosion from embankment seepage and a highway embankment subject to rapidly changing water levels and wave action from the Gulf of Mexico.

These installations were observed for 12 to 18 months and judged to be equal or better than the revetment systems being used by the Department. The test installations and observations are described in the report with before and after pictures.

The cellular concrete blocks were recommended for the following uses:

1. Alternate revetment for sacked concrete or random riprap.
2. Required revetment for areas subject to wave action and rapidly changing water levels.
3. Required revetment for areas where other revetment systems are objectionable due to aesthetic reasons.
4. Linings for canals and drainage ditches.
5. Pavement for areas subject to occasional traffic.

Further studies were recommended in order to determine design criteria for protection at culvert outlets and drainage chutes subject to high velocity flows.

Material and construction specifications are presented in the report with typical plans. Plastic filter cloth is required for most installations.

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INTRODUCTION

Background

This study is the result of discussions and meetings between representatives of the Louisiana Department of Highways, Louisiana Concrete Products Company, Gobi, N.V.* and Erco Systems, Inc.** concerning the possible use of a specially designed cellular concrete paving block. The block system developed by Gobi, N.V. is being used in the Netherlands for a variety of purposes such as stabilization of shoulders, parking areas, park roads, canal sections, bridge and overpass embankments and backslopes of dikes along the North Sea.

Illustrations of field installations in the Netherlands and samples presented by the above firms indicated that the cellular block system did merit study by the Department for some of the above uses. The cellular block system is described below for the reader's convenience.

Description of Material

The cellular concrete blocks developed by Gobi, N.V. are of vibrated concrete, lightweight or standard aggregate. The blocks are approximately eight inches square by four inches deep. The

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* Gobi, N.V. of Zutphen, The Netherlands developed the Gobimat Design of Cellular Concrete Paving Blocks.

** Erco, Systems, Inc. of New Orleans, La., a Louisiana Corporation liscensed by Gobi, N.V. to produce and develop the Gobimat concept in the United States.

standard blocks weigh approximately 13 lbs. and the lightweight blocks weigh approximately 7.5 lbs. The blocks are installed by butting them against one another in a firm bed to form a rough paved area. Approximately 30 percent of the paved area consists of two inch and two and one-half inch holes, hence the general name cellular concrete paving blocks. These holes or cells are filled with soil, sand or gravel after the blocks are installed. These cellular openings allow relief of hydrostatic pressures under the paved area on slopes and in channel sections as well as infiltration. A plastic filter cloth is recommended for use under the blocks where erosive forces may lift the soil through the cells (See Figures 1 and 2).

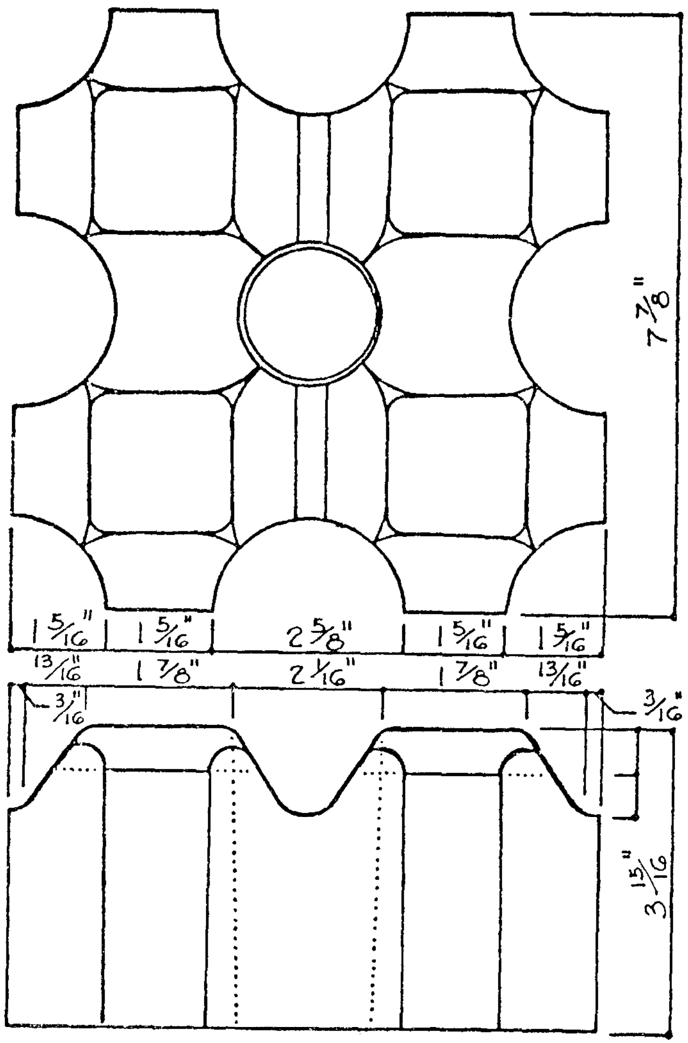
Grass, vines or small shrubs, can be planted in the holes for aesthetic purposes and to hold the soil when water flows over the blocks (See Figure 3). Anchor rods can be driven through the center hole to provide additional anchorage on steep slopes.

Conditions of Study

The study was conducted by the Drainage Research Unit* of the Department's Research and Development Section in co-operation with the Maintenance Section. The study was conducted with the following understanding

1. Louisiana Concrete Products Company would use Gobi's

* The author, formerly head of this unit, has been transferred to the Bridge Design Section as the head of the Hydraulics and Hydrology Unit.



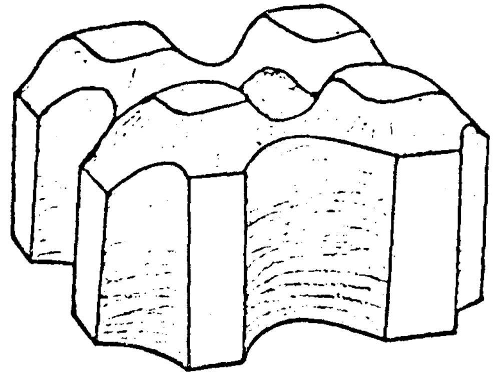


Figure 1.

Suggested Design for Cellular Concrete Blocks.

This Particular Design is Patented by N.V. Gobi of Zutphen, Holland.

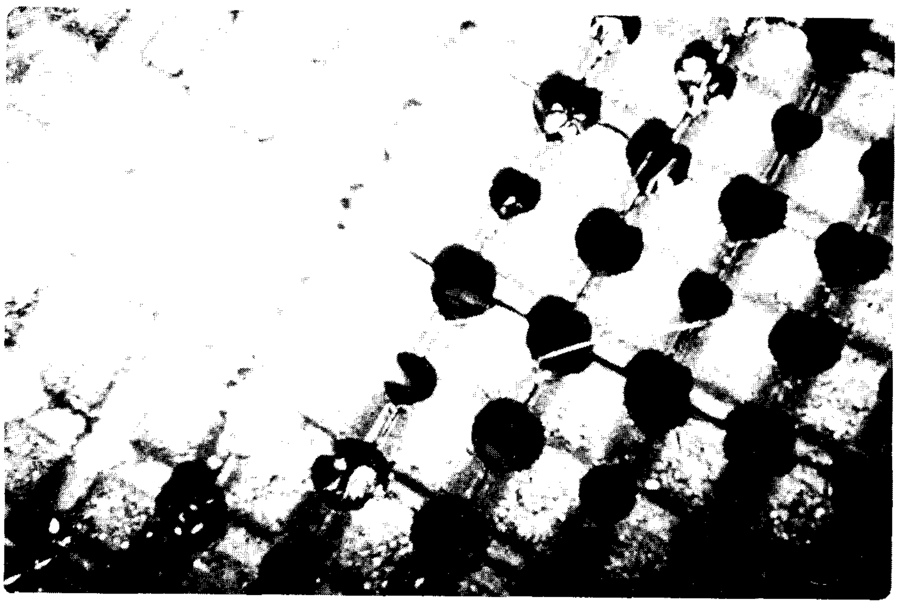


Figure 2. Cellular Concrete Blocks over Plastic Filter Cloth. This revetment was used for wave protection. The open cells had been filled with loose sand. The plastic filter cloth under the blocks prevented the wave action from undermining the block revetment.

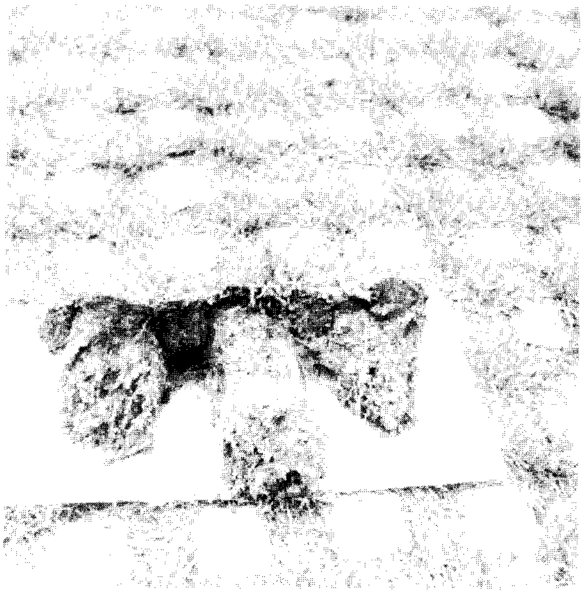


Figure 3. Cellular Concrete Blocks with Grass Established in the Cells. This combination of grass and concrete gives a flexible pervious paving suitable for protecting areas subject to occasional traffic and flowing water.

dies to manufacture the blocks for the test installations.

2. The blocks for the test installations would be furnished to the Department of Highways free of charge (not to exceed 25,000 blocks).

3. If the test results indicated that the cellular concrete paving blocks were acceptable for any of the proposed uses, the Gobimat Design, which is a proprietary product, would be intended to act as an accepted standard and that alternate designs could be submitted to establish compliance with the accepted design.

OBJECTIVE

The objective of this study was to evaluate specially designed cellular concrete paving blocks for the following possible uses by the Louisiana Department of Highways:

1. stabilization of shoulders and other areas subject to rutting damage from occasional traffic,
2. scour prevention at ditch and culvert outlets,
3. revetment at bridge and overpass abutments,
4. revetment along highway embankments subject to erosion from high water and wave action.

SCOPE

The research was to consist of installing several test sections at selected sites representative of the four problem areas listed below:

1. areas subject to rutting damage from occasional traffic,
2. ditch and culvert outlets subject to erosive forces,
3. bridge and overpass embankments subject to erosion damage from seepage, runoff from bridge and road surfaces and occasional highwater flows and
4. highway embankments subject to erosion damage from highwater and wave action.

The test installations, totalling 1,200 square yards of cellular concrete paving blocks, were to be observed for a one year period. During the observation period any special conditions which the test structures may have withstood or failed under were to be noted. In each case the success or failure was to be analyzed if possible. Accurate installation costs and any maintenance cost which might occur were to be recorded for an economic evaluation of the test installation for future use in larger test or prototype installations.

EXPERIMENTAL INSTALLATIONS

Stabilization of Areas Subject to Occasional Traffic

Rutting at pavement edges, access ramps to recreation areas, median crossings, service areas and other areas subject to occasional traffic is a continuous maintenance problem. Several field test installations of the cellular concrete blocks were installed at three areas where this problem was occurring.

The first test installation was installed by maintenance forces along U.S. 190 East in Baton Rouge. This installation consisted of single rows of blocks placed in the rutted area along the edge of the highly traveled four lane highway. The rutting was primarily the result of dual wheel traffic near the edge of the narrow outside lane. Three test sections totalling 600 feet were installed.

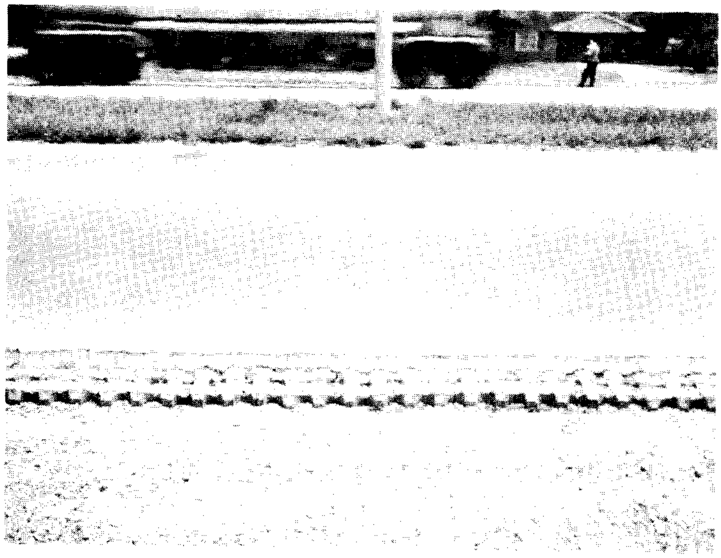
The developers of the paving block design expressed concern over the single row and indicated that the dual wheel vehicles would cause rutting at the outside edge of the blocks with subsequent overturning and displacement of the blocks. They indicated that at least three rows of blocks were used in the installations along highways in the Netherlands.

Rutting did occur at the outer edges of the single row of blocks causing some blocks to be displaced. The researcher drove an automobile and a dual wheel truck over the sections at various speeds. The rough surface served as a rumble strip creating enough noise and vibration to warn the driver that he was at the edge of the pavement. The effect was similar to that of raised pavement markers. This was not noticable when only the outside wheel of dual wheel vehicles was over the blocks, so apparently all rutting outside of the blocks could be attributed to dual wheel vehicles. Therefore, the additional rows recommended by the developers were necessary. See Figure 4 for views of test installation.

Additional tests with three rows of blocks covering 600 linear feet of shoulder were designed for installation along La. 426 near Baton Rouge. This is a highly traveled road with narrow lanes and narrow shoulders. Considerable rutting was evident and maintenance forces are continually patching these ruts with asphalt mix. This test installation has been delayed due to the District maintenance force's workload.

The District Maintenance force did install three short test sections of approximately 50 blocks each at the site. The excavations for the blocks were by pick and shovel and were not uniform due to the hard packed sand-clay-gravel in the shoulder. The uneven area was leveled with cold mix asphalt and then lined with two rows of blocks. See Figure 5.

The three sections were observed for a one year period. No blocks were dislodged even though subjected to continuous action by outside duals of heavy trucks. The surfaces of the sections were wavey due to the settling of the cold mix asphalt in the uneven



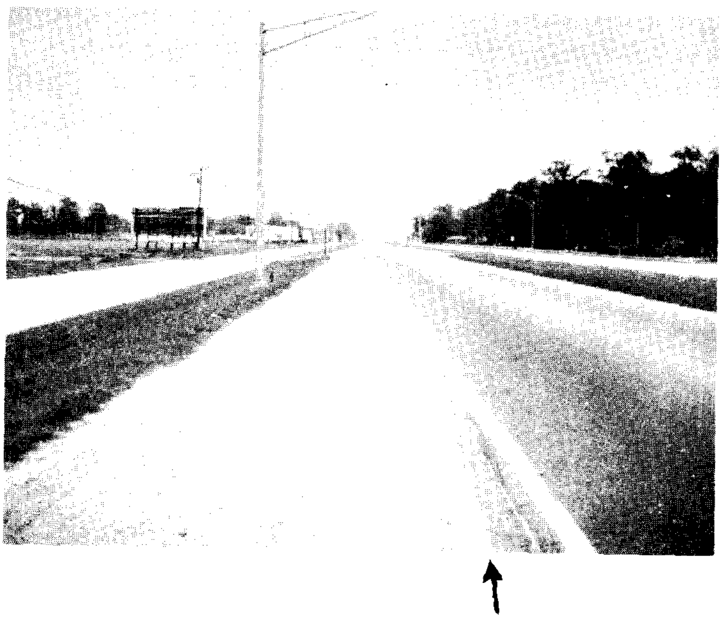


Figure 4. Cellular Concrete Blocks Used to Prevent Rutting of Pavement Edge Subjected to Continuous Dual Wheel Traffic. This installation is too narrow for the intended purpose, at least two additional rows are required. The rough surface serves as a rumble strip to warn the driver in time to recover. Additional testing is required for use such as this.

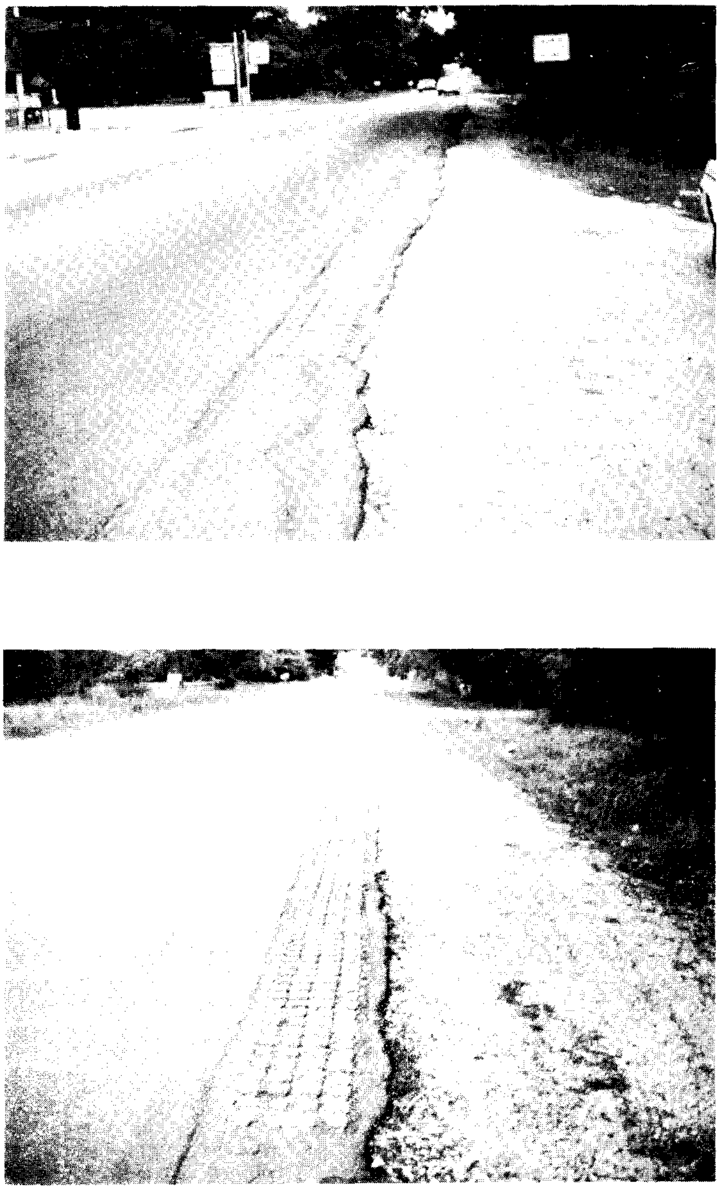


Figure 5. Two Rows of Cellular Concrete Blocks at the Edge of a Narrow Two Lane Highway. Some settling occurred as a result of the uneven excavation under the blocks.

excavation under the blocks. This indicates that the base below the blocks should be graded and compacted.

A combination test for shoulder paving, access ramp to beach area and revetment for wave action was installed along State Route 82 at Holly Beach, Louisiana. This test section was primarily for prevention of wave damage but was constructed so that the other two uses could be tested also. The revetment tests are described later in this report.

See Figure 16 , page 39, for a view of the site prior to construction of the test. The entire beach area along the road was inaccessible to vehicles prior to construction of the revetment test, therefore, the section shown in Figure 6, provided the only access for a two mile stretch of beach. An estimated 25 cars per day, during the summer of 1969, used the ramp without causing any damage. The section was also used as a service access for maintenance vehicles after two storms caused severe damage to the road along the beach.

The results of this test indicate that these cellular paving blocks can be effectively used to pave areas subject to light or occasional traffic such as shoulders, access ramps to recreational areas, and parking areas on median crossings. The only reservations made are for shoulder areas subject to heavy or high speed traffic. Additional testing is required in order to determine if these blocks can be used for stabilization of shoulders along heavily traveled roads.

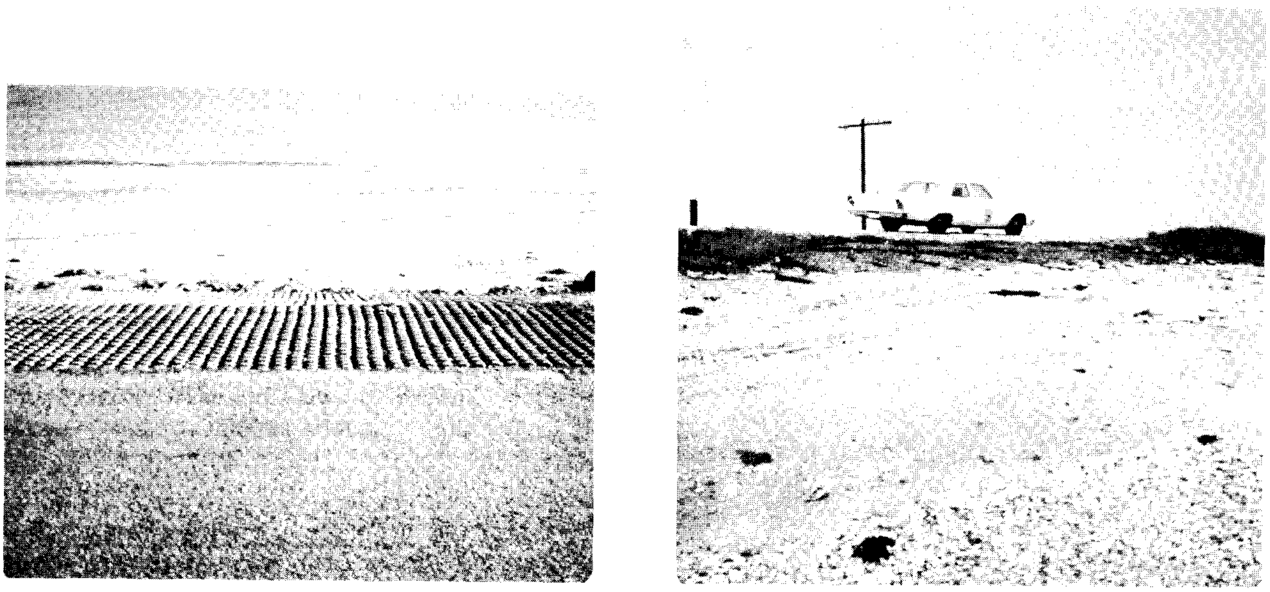


Figure 6. Cellular Concrete Paving Blocks Used for Combined Tests. This block structure serves as shoulder paving, beach access ramp and beach revetment. The structure is subjected to alternating high tides and traffic to the beach. Note the debris left on the structure by high tide.

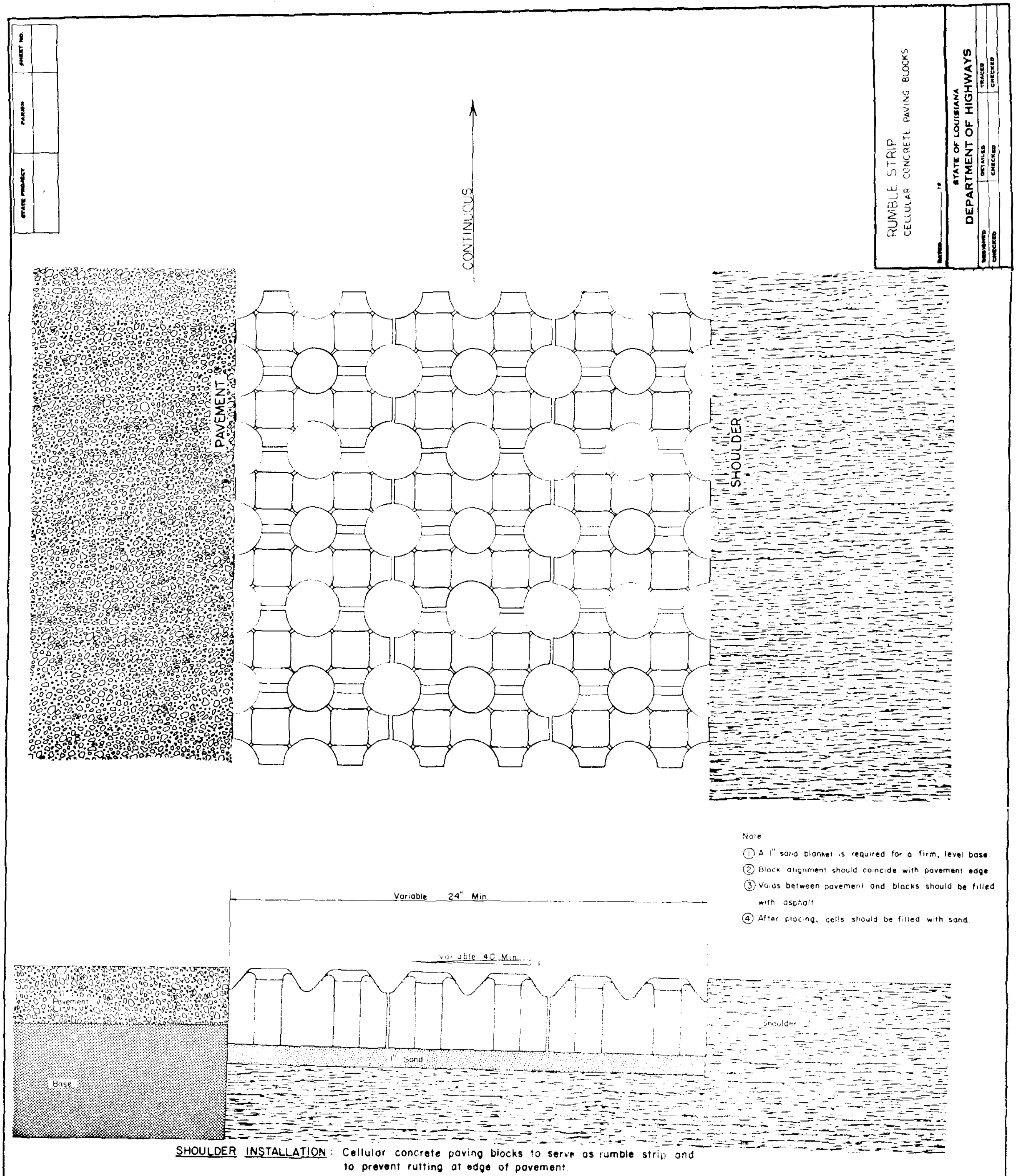


Figure 7. Proposed Design for Shoulder Stability Experiment

Ditch and Culvert Outlet Protection

Proper development of protective devices for ditch and culvert outlets should begin with model studies and an hydraulic analysis of the results. This was beyond the scope of this phase of the study. This phase of the study was conducted by installing two cellular concrete block structures at ditch outlets to convey runoff waters over drops of five to eight feet. A third test installation at a 5 ft. x 5 ft. culvert outlet was only partially completed when winter rains set in and prevented completion.

The first drop chute installation was at the point where a channel conveying several runoff flows of 30 c.f.s. spilled into a borrow pit. The drop at the site was nine feet of which three feet was a scour hole. A 5 x 5 R.C. Box 125 feet upstream of the fall was 2.2 feet higher than the crest of the fall. Gully erosion was advancing towards the R.C.Box. The existing ditch profile and the drop chute structure designed for the site are shown in Figure 8. Figure 9 shows the drainage chute in operation.

The scour hole was filled with soil cut from the channel outlet to form the 2:1 slope. The fill material was supposed to be thoroughly compacted. When this was attempted, it was realized that the original scour hole was about six feet deep with three feet of soft muck sediment. The apron of the drop chute had to be constructed over soft fill material. The sheet aluminum weir

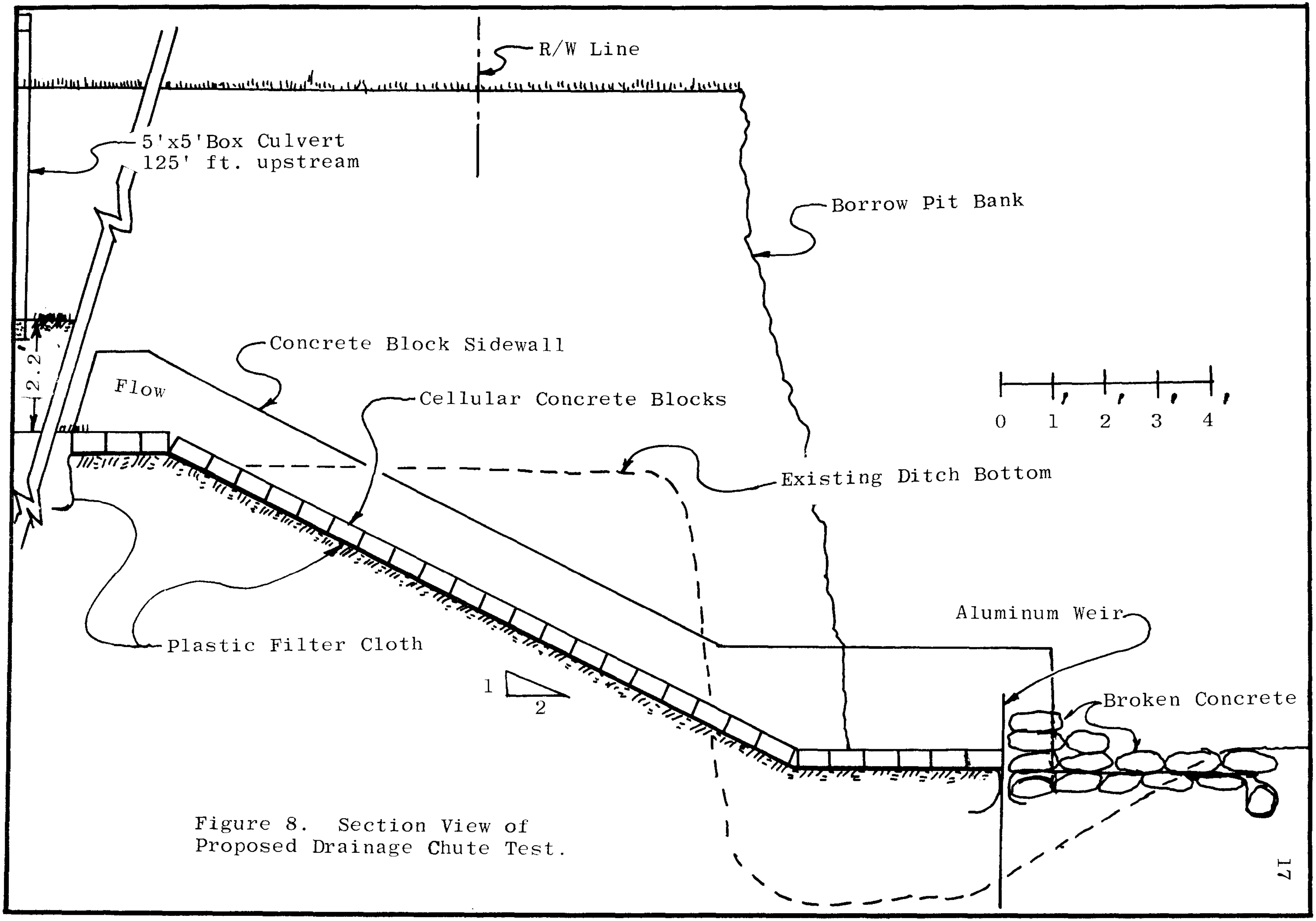


Figure 8. Section View of
Proposed Drainage Chute Test.

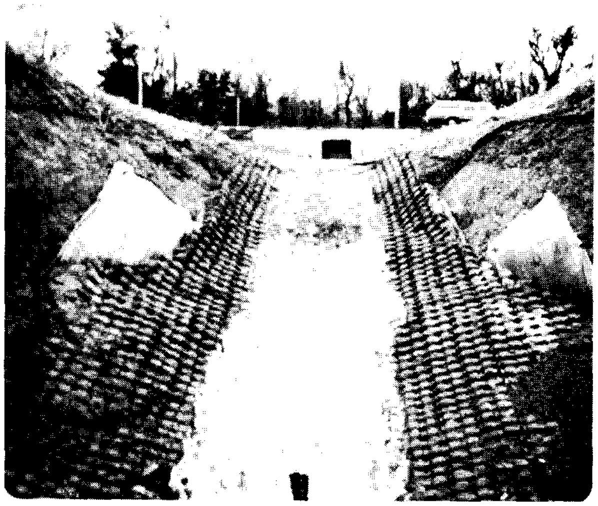


Figure 9. Drainage Chute Constructed with Cellular Concrete Paving Blocks. The blocks are over a non-woven plastic filter cloth. The chute drops the flow seven feet down a 2:1 slope.

was not long enough to penetrate firm soil. The 1968-69 winter rains set in before the longer sheet aluminum weir could be installed. Intermittent rains over the flat watershed above the structure resulted in continuous flow such as that shown in Figure 9. Then an intense rainstorm in February 1969, caused a peak discharge of approximately 50 c.f.s. scoured out the soft fill material beyond the apron of the structure. The resulting four foot deep scour hole undermined the apron and lower four feet of the chute. Approximately two-thirds of the chute portion of the structure was still in place at the end of the observation period.

The researcher is satisfied that the structure would not have failed if the sheet aluminum weir and riprap extension could have been installed before the 50 c.f.s. discharge occurred.

A second drop chute structure was installed at a site along U.S. 167 north of Lafayette, Louisiana. The site selected had been lined with cast-in-place concrete sections. The soil at the site was an expansive clay soil. Expansion and shrinkage of the soil under the rigid structure allowed runoff flows to undermine the structure. Approximately 30 square yards of concrete lining was undermined (See Figure 10).

The eroded area was backfilled with the same type of soil and shaped. The section was lined with plastic filter cloth and cellular concrete blocks. The resulting structure is shown in Figure 11. This structure has performed satisfactorily since it was installed in the Spring of 1969. Observations of the

Figure 10. Rigid Paved Drainage Chute Undermined by Surface Runoff. The intended use of this structure was to drop runoff flow from a roadside ditch into a canal eight feet deep. The expansion and contraction of the clay soils under the structure let runoff flow under the rigid structure resulting in the loss of approximately 30 square yards of four inch concrete.

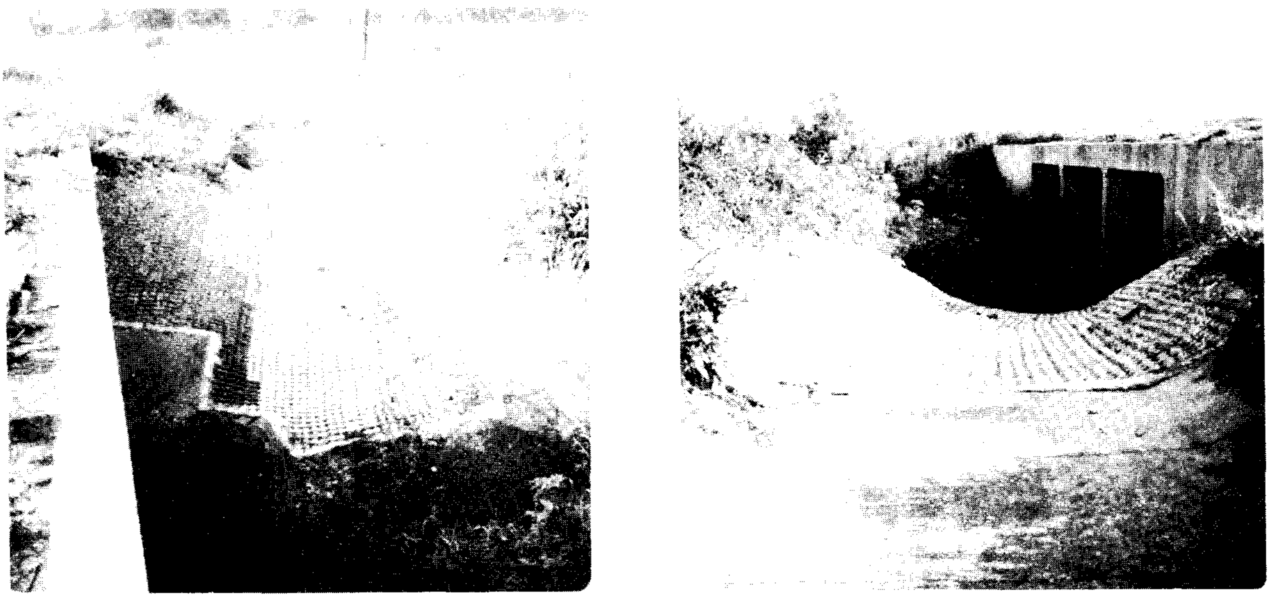


Figure 11. Two Views of a Drainage Chute Constructed with Cellular Concrete Paving Blocks. This is the same site shown in Figure 10. The chute drops the flow from a roadside ditch into a canal eight feet deep.

structure during different weather conditions indicate that the structure flexes with the soil expansions and contractions.

It can be concluded from these test installations that the cellular concrete revetment blocks can be used to convey runoff flows in steep highway drainage channels and drop chutes. The cellular block structures are flexible and can be tied in with sodded channels. In cases where the flows are intermittent, grass can be established over the structure to provide further protection from erosive flows. The plastic filter cloth is essential in structures where the grass cover cannot be established. Some provisions must be made to protect the downstream end of the structure such as a cutoff wall or burying the end of the apron.

Material and construction specifications for cellular concrete block lining for drainage chutes and channels are included in the Appendix. The inplace cost of these structures was approximately $7.50 per square yard. This included excavation, labor, transportation and material costs.

Revetment at Bridge and Overpasses

Introduction

Overpass and bridge ends are reveted to prevent damage from 1) surface runoff from the paved areas above the embankment, 2) seepage from the embankment and 3) in the case of bridges, occasional high water flows. Heavy revetment is also used to load the toe of the embankment to prevent slides usually as the result of saturated soils.

Overpass Revetment

Revetment for cases 1 and 2 need not be as heavy as that for flood flows and slide protection, however, the same revetment is usually specified for all cases. The developers of the block design believed that their lightweight blocks, 7.5 lbs. each, would be useful for revetment use in cases 1 and 2. Provisions were made for a test installation for this use.

The test site selected was a new embankment on U.S.90 North of New Iberia, Louisiana. The area to be revetted was a warped section between two skewed overpass bridges. The area had been lined with slab sod two times. Each time seepage from the steep embankment caused the slab sod to slide down the embankment (See Figure 12). The second installation had been staked to the slope. Evidently the slab sod was too impervious and the soil under the sod became fluid and slid down the slope with the stakes.

Figure 12. Test Site Selected for Lightweight Cellular Block Revetment. Continuous seepage from the embankment caused two successive installations of slab sod to slide from the steep warped slope. The second installation was staked to the slope.

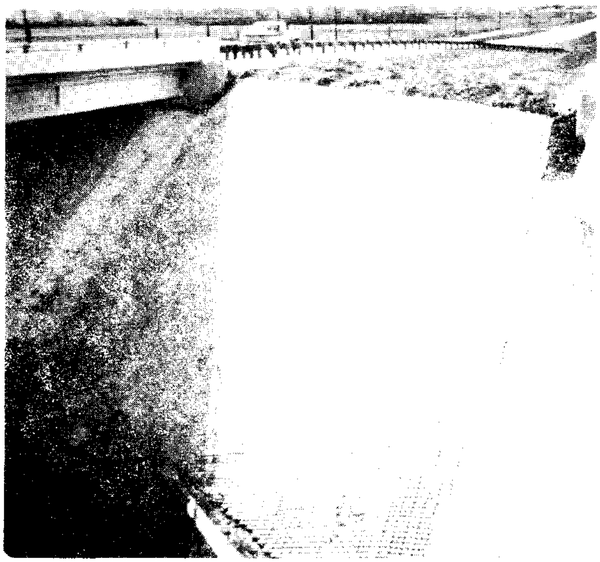
This area was lined with the lightweight blocks by maintenance forces at a total cost of $5.00 per square yard including hauling the blocks 80 miles and dressing the slope manually. The finished revetment conformed to the warped slope and presented a useful and aesthetically protective flexible cover for the critical area (See Figure 13).

This structure is over an expansive soil and has flexed as the soil expanded and contracted. Seepage water flows through the cellular openings in wet weather. Some runoff water flows over the revetment. No erosion damage or unusual settlement has occurred.

The results of this test indicate that these lightweight cellular concrete blocks can be used to protect areas around bridge and overpass ends from erosion from surface runoff from above and seepage from within the embankment. The cellular openings prevent hydrostatic pressures from lifting the structure and flowing along the soil surface

Bridge End Revetment

No test installations were made for bridge end embankments subject to high water flows. The researcher has concluded that the standard weight cellular concrete paving blocks can be used in conjunction with plastic filter cloth and seeding operations, to protect bridge ends and spur dikes set back on floodplains from occasional flood flows. This conclusion is based on the ease of installation for the overpass revetment test and the conditions encountered in the Holly Beach Revetment tests (See next section).



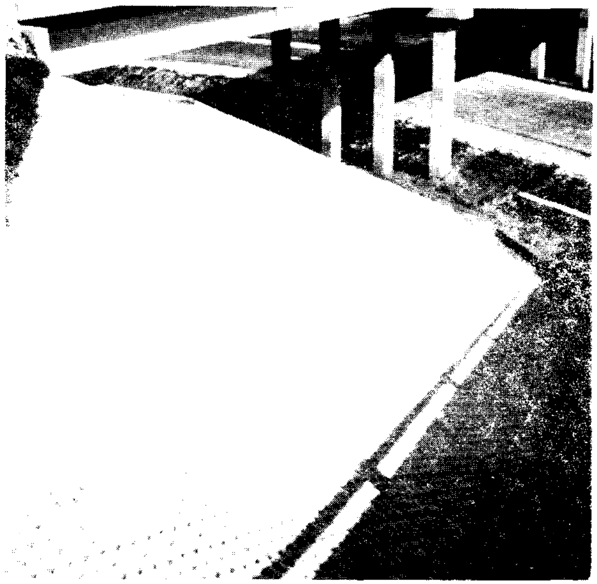


Figure 13. Two Views of the Lightweight Cellular Block Revetment on an Overpass Embankment. This is the same site shown in Figure **12**. The reveted area is a $1\frac{1}{2}$:1 warped slope between two skewed overpass bridges. Water continually seeps through the lower center portion of the revetment. Plastic Filter Cloth was not used in this installation.

As a result of this conclusion, this cellular block revetment is being allowed as an alternate for sacked concrete revetments at several bridges and spur dikes (See Appendix). It is estimated that the block and filter revetment will cost about $9.00 per square yard, in place, while the sacked concrete revetment costs about $12.00 per square yard, in place.

EXPERIMENTAL INSTALLATION

Stabilization of Highway Embankments Subject To Highwater Flows And Wave Action

General

Louisiana has considerable mileage of highway embankments subject to erosion from highwater flows and wave action. This includes those roads crossing wide flood plains and lakes as well as those running along streams and coastal area. In general, these areas are protected to some extent by vegetative growth. The more critical areas are protected by some form of revetment such as cast-in-place concrete slope paving, soil cement steps, sacked concrete revetment, rock or broken concrete riprap.

The Department has used soil cement steps to prevent wave damage at several lake crossings. This type of revetment is very effective where the water level does not fluctuate enough for embankment saturation to become a problem.

Some form of pervious flexible revetment is usually preferred in order to prevent damage from piping of surface and seepage water and swelling and shrinkage of expansive soils. Flexible revetments such as rock, broken concrete and sacked concrete are expensive in Louisiana. Therefore, there was a need for studies of other types of pervious flexible revetment.

The illustrations of the cellular concrete revetment blocks installations in The Netherlands indicated that the blocks could possibly be used for protecting highway embankments subject to highwater flows and wave action. Therefore, a test installation was proposed.

Selection of Holly Beach Test Site

Several months prior to the beginning of the research study with the cellular concrete blocks, representatives of the Corps of Engineers and the Department of Highways had met to discuss an erosion problem along State Highway 82 near Holly Beach, Louisiana.

The highway lies within an eroding area and is very susceptible to damage by storms that create an abnormal high tide. The Louisiana Department of Highways is constantly repairing this road and building up the fronting beach with miscellaneous fill material to reduce the damaging effect of high tides. As a result of Hurricane Carla in 1961, a three mile section of this road had to be completely rebuilt. Hurricane Cindy damaged 1-1/2 miles in 1963.

A meeting was held in Baton Rouge in the summer of 1968 at the Department of Highways in an effort to investigate solutions to the erosion problem. One alternative was to relocate the highway further into the marsh area north of the existing sand ridge. This is a distinctive possibility if one could be assured that the narrow sand ridge or cheniere would not be breached by a future storm, thus creating the identical erosion problem at the relocated site. This method would also be quite expensive, costing anywhere from $500,000 to $800,000 per mile.[1] The other alternative discussed was to protect the existing highway with a revetment system approximating closely the existing beach profile. Materials discussed for this use were riprap, soil-cement, asphalt, fabriform and concrete blocks. Designing a suitable revetment using conventional riprap and concrete blocks presents no great problem, and if cost is no objective, a system can be built to withstand practically any storm that might hit the area. The problem encountered at Holly Beach is that it lies within a relatively isolated area and most of the area behind the eroding portion of the highway is marshland. This being the case, it might be more economical to rebuild the highway than to go into an elaborate revetment design.

With cost being a major factor, a study was made of many methods being used to combat erosion. During this study it was suggested that the cellular revetment blocks might provide sufficient protection for a 10 to 25 year frequency storm. In this area major storms are capable of generating (at the coastline) significant wave heights of 3 to 4 feet and maximum wave heights up to 6.5 feet. Considering the waves that can strike the shoreline, the probable stability of this light block was discussed with the local sales representative.[2]

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[1] Preliminary estimates by the Louisiana Department of Highways. This highway is designated as a portion of the "Hug the Coast Highway." The cost would be less for a lower class highway.

[2] **Mr. J. A. W. Aalders, President of Erco Systems, Inc., New Orleans, Louisiana.**

In order to answer the question of stability, Gobi, N.V. decided to conduct a model test at the Voorst Laboratory, a part of the famous Delft Laboratory, in Holland. It was decided that the Louisiana Department of Highways would build a prototype test section at the site if the model test indicated sufficient stability. The Corps of Engineers furnished data concerning the geomorphology and wave conditions of the site.[3] A typical view of the beach and escarpment adjacent to the road is shown in Figure 16 on page 39.

Model Test for Gobimat Revetment

The model test was completed on December 5, 1968, and the following is a description of the test.[4]

1. General Information

In order to build the model, certain assumptions were made and a 1:3 profile was selected for the revetment. A sketch of the test situation is shown in Figure 14. A 1:5 scale model was used to determine the stability of the blocks under various water level and wave situations. Full scale tests were conducted with smaller waves to determine the structure's ability to contain the sand with a plastic filter cloth having a 300-micron mesh (See Figure 15).

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3 Letter from Col. Harr, District Engineer, U.S. Army Corps of Engineers, New Orleans District, to Mr. J. C. Pillaar, President of Gobi, N.W., Zutphen, The Netherlands, September 13, 1968.

4 The original test was described in Dutch and the above is a translated summary of the results. See Appendix for full report.

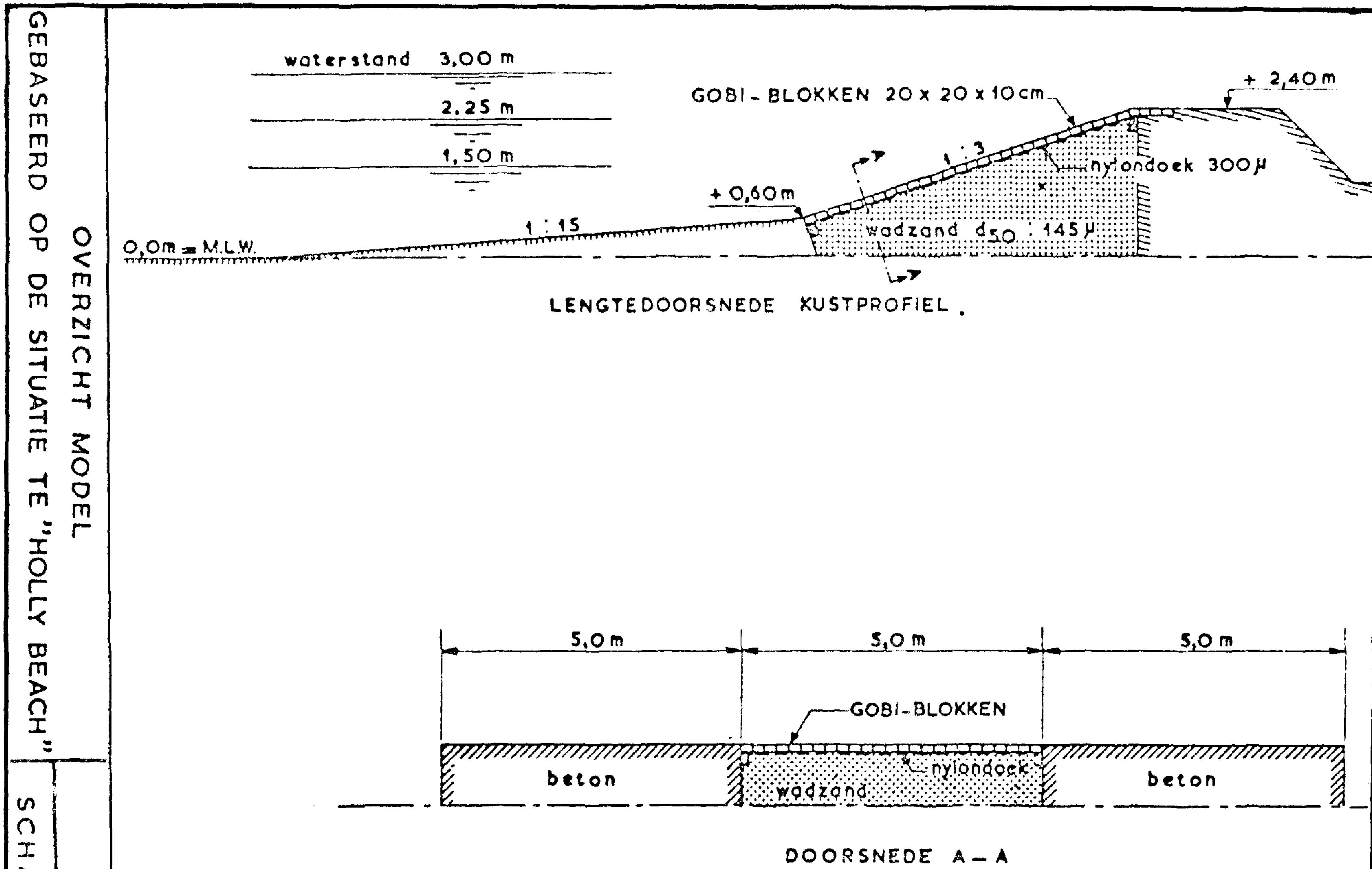

Figure 14. Sketch of the Model Based on the Situation at Holly Beach, Louisiana.
Source: Letter of 12/5/68 from J.J.Vinje, Head of deVoorst Hydraulics Laboratory to Mr. J.C. Pillaar, President of Gobi, N.V., Zutphen, The Netherlands.

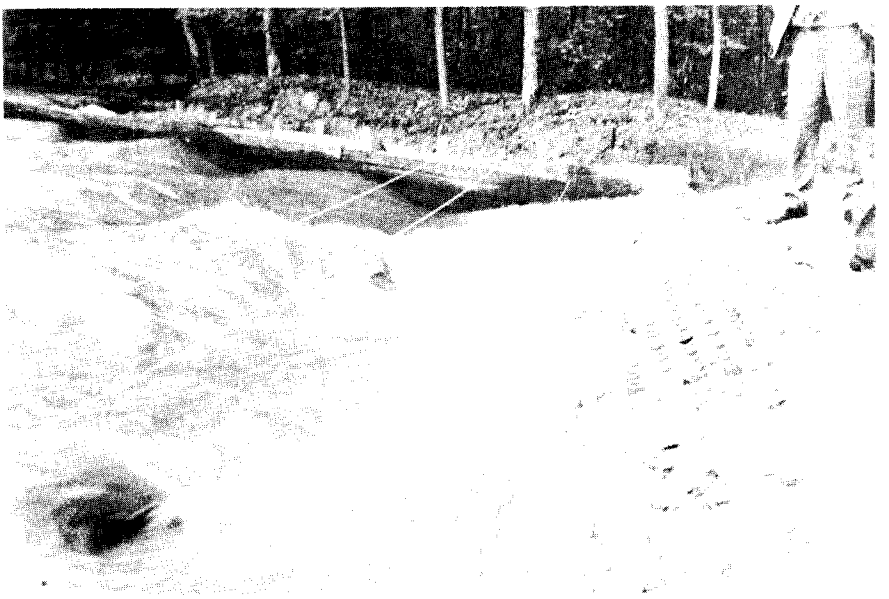

Figure 15. Views of Full Scale Model Tests of Cellular Concrete Block Revetment (Gobimat). Full-scale and 1:5 scale model test simulating the conditions at Holly Beach, Louisiana, were conducted by the Delft Hydraulics Institute for Gobi, N.V. of Zutphen, The Netherlands.

In an effort to test the model for different stillwater levels that would be created by reasonable storms, three water elevations were selected for the generation of waves. These levels were 1.5 meters (4.92 ft.), 2.25 meters (7.37 ft.), and 3.00 meters (9.84 ft.), all above the mean low water datum.[5] The direction of wave approach was assumed perpendicular to the coastline. An average wave period of 6.5 seconds was selected as representative of the Holly Beach location (wave period varies from 5 to 8 seconds).

At each of the three water levels, a regular wave pattern was generated and the wave heights were increased in steps until the foreshore slope of the revetment caused the waves to break.

The blocks can be adhered to a filter membrane to make an articulated mat, but the model blocks were not fastened in that manner since results based on the stability created by the shape and weight of the block, together with the friction between same, were desired. Wave runup was also measured to determine the percentage reduction created by the concrete blocks when compared to a smooth slope.

2. Model Test Results

In the first series of tests the blocks were placed so that there would be mutual contact or friction on all sides. At a water level of 1.50 meters (4.92 ft.), the revetment remained

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5 The Mean Low Water datum is approximately 0.78 ft. below Mean Sea Level datum and was the datum selected for the model test.

stable until the waves broke at wave heights of 0.85 meters (2.79 ft.). At the second water level of 2.25 meters (7.37 ft.), a few blocks were dislodged at a breakerheight of 1.05 meters (3.44 ft.). The blocks became dislodged at the transition of the revetment from the horizontal to the 1:3 slope since this point creates less friction due to orientation of the blocks (See Figure 14). At the third water level of 3.00 meters (9.84 ft.), the blocks were stable up to a wave height of 1.10 meters (3.61 ft.). The wave height was then increased to 1.30 meters (4.26 ft.) or the breakerheight. At this point the blocks were dislodged at the line where the waves broke on the revetment. The first blocks were dislodged where the trough of the waves struck the slope. Wave runup measurements were made at a water level of 1.50 meters (4.92 ft.) and the runup on the revetted slope was 65 to 70 percent of that for a smooth slope.

In the second series of tests the horizontal rows of blocks were separated from each other by a thin wire (2mm), which was placed immediately above the nylon filter sheet. The diameter of the wire was chosen so the blocks could overturn freely and thus determine the possibility of forming sides of the block with a beveled edge.[6] The above procedure reduced the available friction appreciably and was reflected in the results. At a water level of 1.50 meters the revetment was stable up to a wave height of 0.70 meters (2.3 ft.).

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[6] The beveled edge allows the block and filter mattress to sag when lifted by a crane with a stretcher bar. This system is used when the blocks are glued to the filter to form a mattress. The beveled edge blocks were not used at Holly Beach.

At this water level the breakerheight of 0.90 meters (2.96 ft.) dislodged some of the blocks slightly above the point where the wave trough struck the slope. At a water level of 3.00 meters in this second series of tests, the blocks were stable up to a wave height of 0.95 meters (3.12 ft.). After this they became unstable. Measurement of the wave runup was again made at a water level of 1.50 meters (4.92 ft.) and was 62 percent of the runup for a smooth slope.

Construction of Prototype Test Sections of Cellular Concrete Block Revetment

After receiving the results of the hydraulic model study, the Louisiana Department of Highways decided to construct a 200 ft. long test section at Holly Beach. The model test indicated that the revetment would remain stable for wave heights up to 1.10 meters (3.61 ft.). It was felt that the normal wave climate was less than this critical wave height. There was some doubt, however, that the Gobimat block would be able to withstand waves generated by severe storms, such as hurricanes with predicted significant wave heights of 3 to 4 ft. and possible wave heights up to 6.5 ft. The frequency of severe hurricanes as described is relatively rare and it was concluded that if the revetment withstood the lesser storms it would be very instrumental in reducing the high annual maintenance cost for this highway. In order to test the prototype under similar conditions as maintained for the model test, it was decided to hand place the individual Gobimat blocks directly on the filter screen without an adhesive. The Gobimat revetment was divided into two test sections, each being 100 ft. long. One section was placed on Poly-Filter X, with an interwoven mesh having a porosity of approximately 0.170 mm or 170 microns;[7] the second section of Gobimat blocks was placed on an imported filter from Holland, "Nicolon," which has a porosity of approximately 300 microns. The fine sand at Holly Beach has a median or D_{50} sieve size of approximately 150 microns. There was some concern that the Nicolon filter was too porous and that the sand foundation for the gobimat revetment would leach out when subjected to high tides and wave action. The engineers at Delft Laboratory advised us that the filter would be satisfactory and that a "secondary filter" of coarser sand and shell would quickly be built up directly underneath the Nicolon filter. They also expressed the opinion that a filter with a small percentage of void spaces would essentially act as an impervious membrane.

The representative from Carthage Mills, Mr. Robert J. Barrett also expressed concern that the Gobimat block was being placed directly above Poly-Filter X. Mr. Barrett indicated that it was customary to place a coarse aggregate layer between the concrete blocks and the filter screen. The engineers from Delft Laboratory felt that

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7 Poly Filter X is manufactured by Carthage Mills, Inc. in Cincinnati, Ohio. This filter cloth was donated to the Department for this test by the above firms representative, R. J. Barrett.

this coarse aggregate layer was not necessary for the Nicolon Filter; both 100 ft. test sections were built without this layer. Construction of the Gobimat test sections was largely completed by the middle of January. A slight trench (2 to 3 ft. deep) was dug on both ends of the test section and the filter was turned downwards to provide some flanking protection. This method was not considered adequate and it was proposed to build a better system for flank protection before the storm season arrived. (See Figures 16-19 for photographs of the construction of the Gobimat test section and condition of the Highway prior to construction of the test site.)

Storm of February 14, 1969

The revetment was put through a very severe test on February 14, 1969, much quicker than had been anticipated, when an unusual winter storm brought high tides to an elevation of approximately 6 ft. MSL, or about one foot below the crown of the road, with accompanying waves estimated at 3 to 4 ft. This was an estimate of the wave climate by Louisiana Department of Highways personnel located at the site. To verify these observations, tide records were taken at the Cameron Coast Guard Station located approximately 10 miles to the east. The highest stage recorded was approximately 5 ft. or one foot below observations at the site. The U.S. Weather Bureau located at Lake Charles, Louisiana, recorded winds from 40 to 50 mph, with occasional gusts up to 80 mph.

The Gobimat revetment that was placed on the Poly Filter-X was completely destroyed (See Figure 20). The revetment built with

Figure 16. Typical View of Beach and Escarpment Adjacent to State Route 82 near Holly Beach, Louisiana. Undermining of the shoulder and pavement by normal tides and wave action was a continual maintenance problem. This was the site selected for the cellular concrete block revetment test.

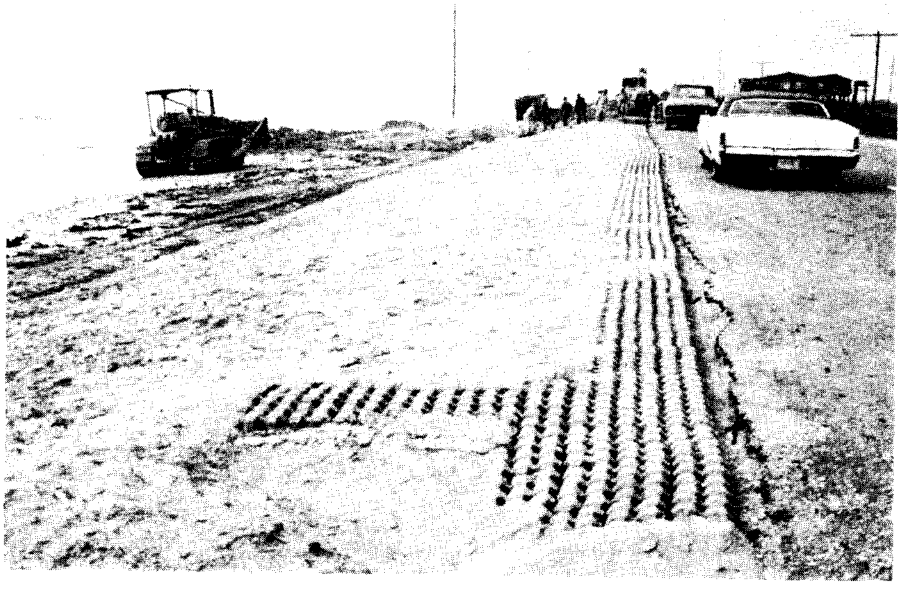

Figure 17. View of Same Site After Installation of Cellular Concrete Block Revetment Tests. The blocks were covered with beach sand to act as a dry mortar. The gap between the blocks and the pavement edge was filled with asphalt. The installation consisted of two test sections 100 feet long by 30 feet wide. One section (foreground) was over a 300-micron mesh plastic filter and the other (background) was over a 170-micron mesh plastic filter.

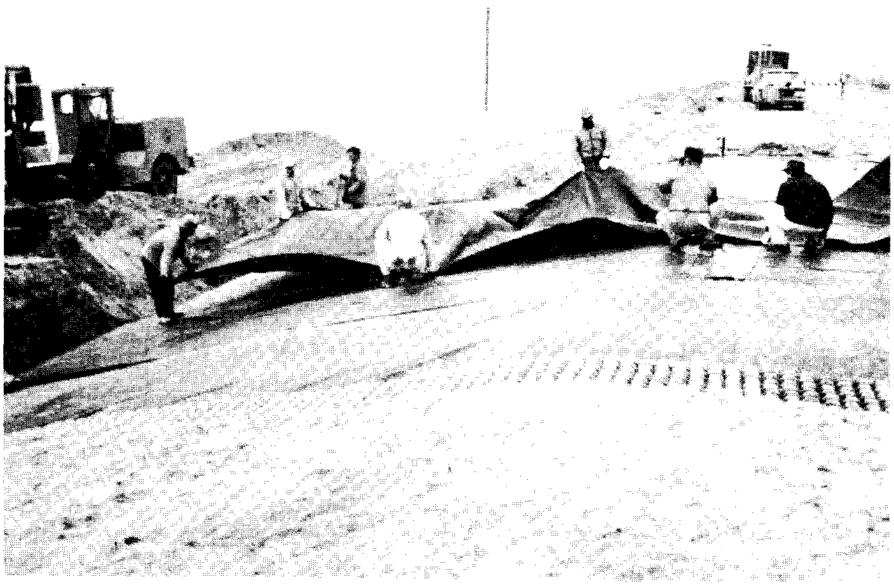

Figure 18. Installation of Plastic Filter Cloth. Two different filter cloths were used in the Test. One had a 300-micron mesh and the other had a 170 micron mesh. The Delft Model Tests specified a 300-micron mesh.

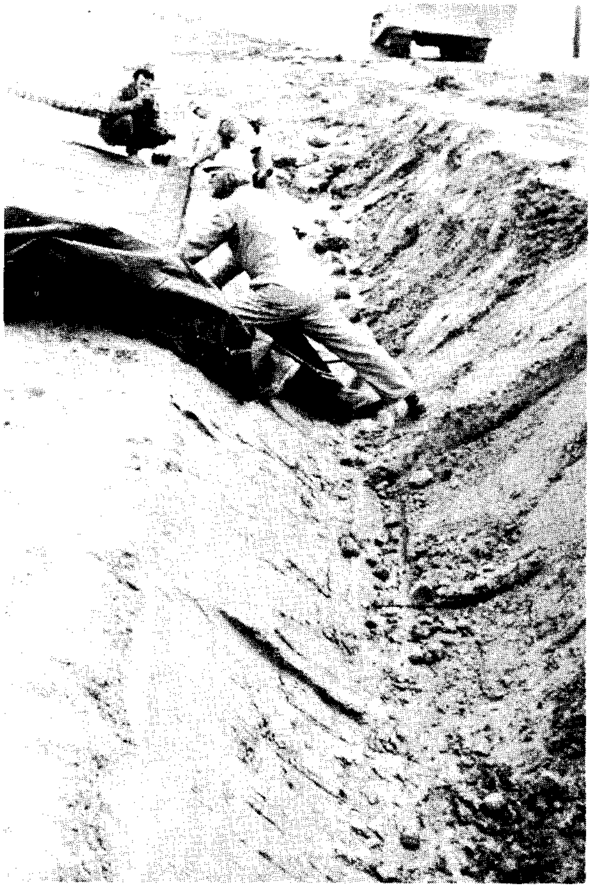

Figure 19. Toe Trench for Prevention of Undermining of Revetment by Wave Action. The end plastic filter cloth was burried in the trench with sand and riprap. The bottom of the trench is at -3.0 ft., M.S.L. The bottom of the revetment is at -1.0 ft. M.S.L.

Figure 20. General View of the Two 100-foot Test Sections Immediately After the Worst Part of the Storm of February 14, 1969. The average water level during the worst part of the storm was within one foot of the road surface with waves from 3 to 4 feet high running over the road. The entire 100-foot test section over the 170 micron plastic filter cloth (foreground) failed due to pumping action from the waves and surging hydrostatic pressures in the sand fill under the revetment.

Nicolon filter remained essentially intact with 65 ft. of the original 100 ft. construction withstanding the storm very satisfactorily as predicted by the model test. The 35 ft. that failed with the Nicolon filter was attributed mainly to flanking failure. Approximately 10 feet was lost on the east end of the structure when the inadequate flank protection failed. Approximately 25 feet was lost on the west end of the structure when the adjacent test section with Poly Filter-X failed (See Figure 21).

The cause of failure of the Poly Filter-X section was not exactly known due to the lack of proper flanking protection. Since the Nicolon section remained intact, however, the porosity of the Poly Filter-X was questioned. It was proposed that the Poly Filter-X was too impervious, thus causing a pumping action from the waves which dislodged the concrete blocks. It should be pointed out that the Poly Filter-X plastic filter is normally used in conjunction with revetment systems much heavier than the cellular block test system installed at Folly Beach.

The stability of the cellular block revetment over the Nicolon plastic filter cloth (300-micron mesh) is illustrated in the accompanying photographs. The photographs shown in Figures 20-24 were made by the author approximately four hours after the worst part of the storm of February 14, 1969. Occasional waves were still running across the road at the time these photographs were made. The photographs shown in Figures 25 and 26 were made the next morning after the storm.

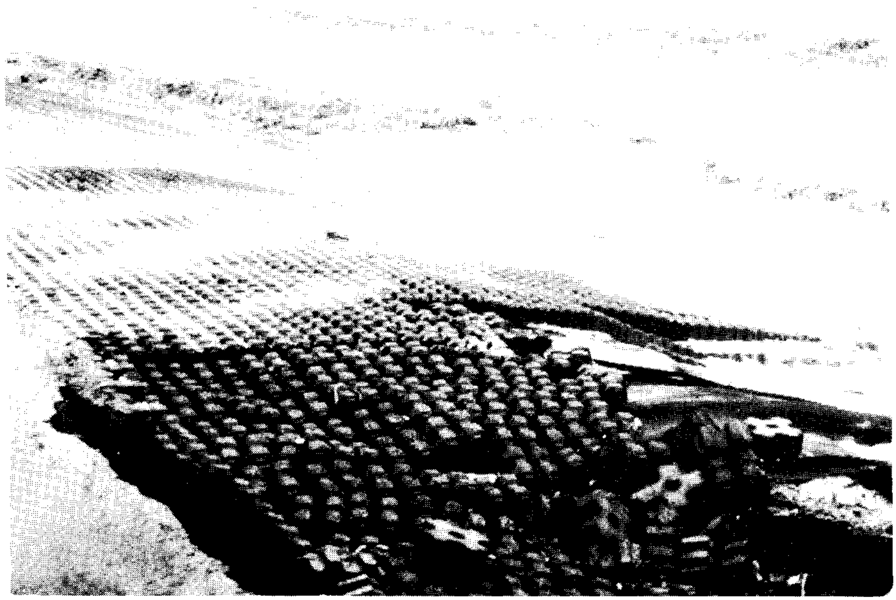

Figure 21. View of Cellular Block Revetment over 300-micron Plastic Filter. The damage in the immediate foreground occurred as a result of the failure at the adjacent test section.

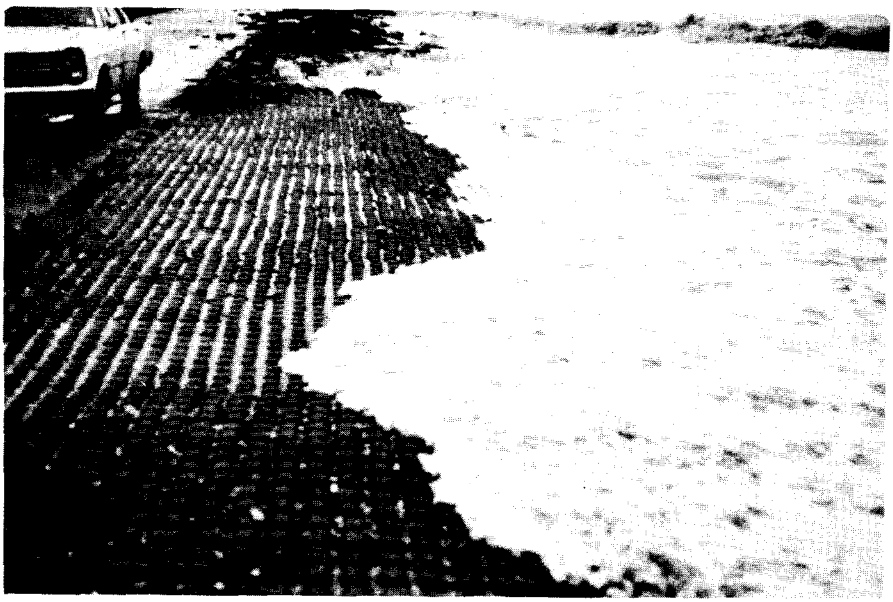

Figure 22. Illustration of Reduction of Wave Runup and Energy Dissapation of the Rough Pervious Surface of the Cellular Concrete Block Revetment.

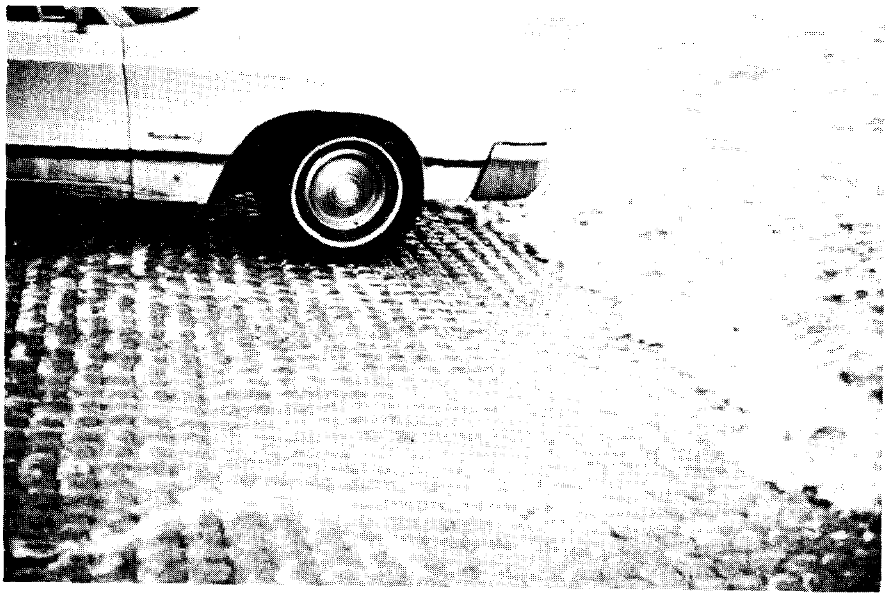

Figure 23. Illustration of Stability of the Cellular Concrete Block Revetment over Sand Fill and 300-micron Plastic Filter Cloth.

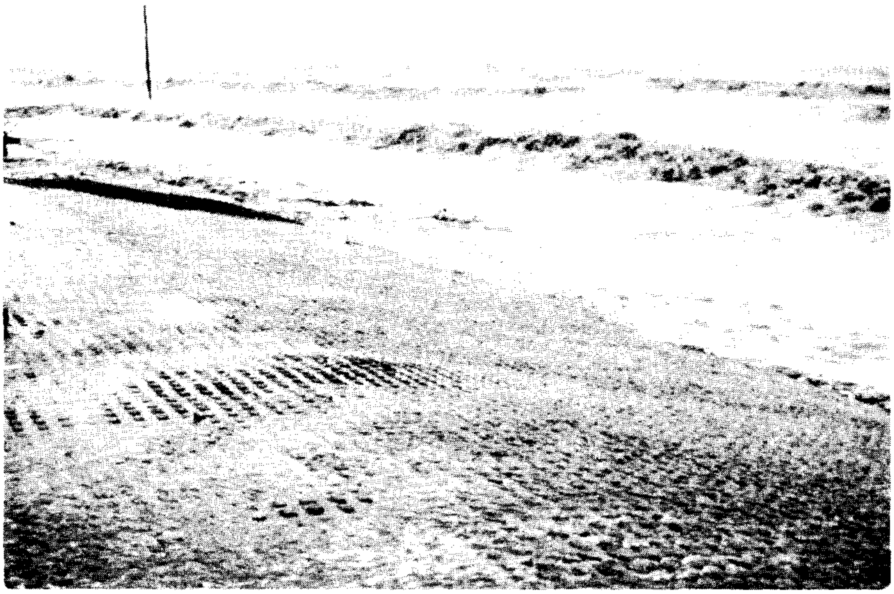

Figure 24. View of Cellular Concrete Block Revetment During Latter Part of Storm of February 14, 1969. The wave period at this time was approximately 7.5 seconds. It was estimated that the period was approximately 6.5 seconds during the worst part of the storm. The average water level was approximately 4.5 feet higher than shown here.

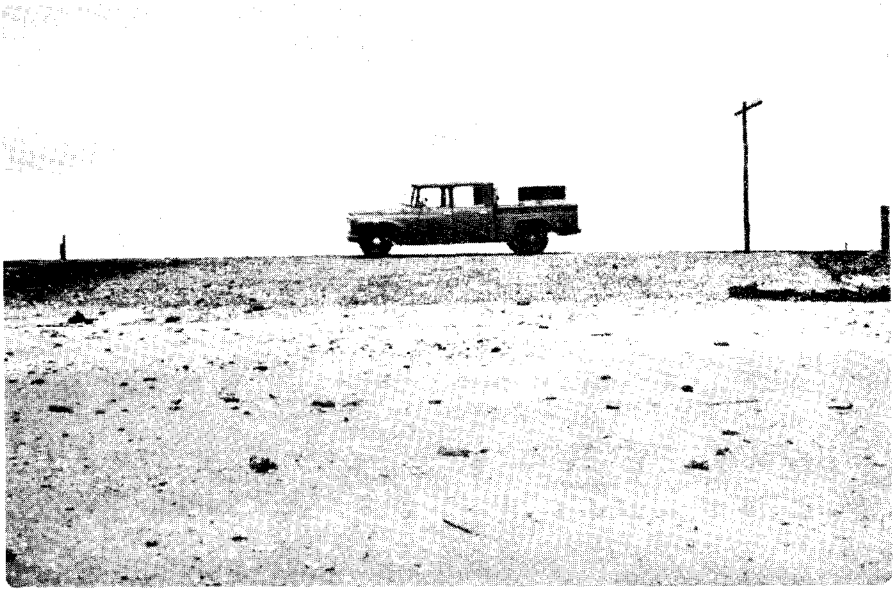

Figure 25. Test Section Viewed from the Beach, February 15, 1969. The test section over the 300-micron plastic filter cloth remained stable throughout the storm with some damage at the unprotected flanks. There was accretion of sand and shell beach material immediately in front of the structure. Apparently the combination of surface roughness, porosity and slope of the revetment dissipated sufficient energy to allow deposition in this area.

The photographs shown in Figure 26 illustrate the destructive energy of the storm. Severe damage to the road such as this occurred for a distance of approximately one mile on either side of the test section. Less severe damage occurred at points along the road for a distance of 10 miles eastward of the test site.

During the summer of 1969 there was considerable accretion of beach material at the test installation (See Figure 27). The test section provided the only vehicular access to the beach for a distance of two miles. The test section was continually subjected to tidal changes and minor wave action with no damage. There was continual flow of water through the lower portion of the structure from the marsh area northward of the road. This was observed several times during the interim period by excavating to the toe of the structure at low tide. The water coming through the structure was only slightly salty.

Hurricane Camille did not affect this area of the Gulf Coast.

Storm of February 1, 1970

Another unusual winter storm occurred at the test site on February 1, 1970 less than one year after the first storm. The storm tide associated with this storm was within two foot of the surface of the road. The wind generated waves were 2.5 to 3.5 feet high over the road.

The cellular block revetment test section survived this storm with only minor damage at the flanks (See Figure 28). Even though

Figure 26. General Views of Damage to State Route 82 at Holly Beach, La. Caused by Storm of February 14, 1969. Damage such as this occurred for a distance of one mile on either side of the revetment tests.

Figure 27. Accretion of Sand and Shell Beach Material over the Cellular Block Revetment. This photograph was made in August, 1969, seven months after the storm damage occurred. The long gentle waves during the late spring and early summer generally cause accretion of beach material.

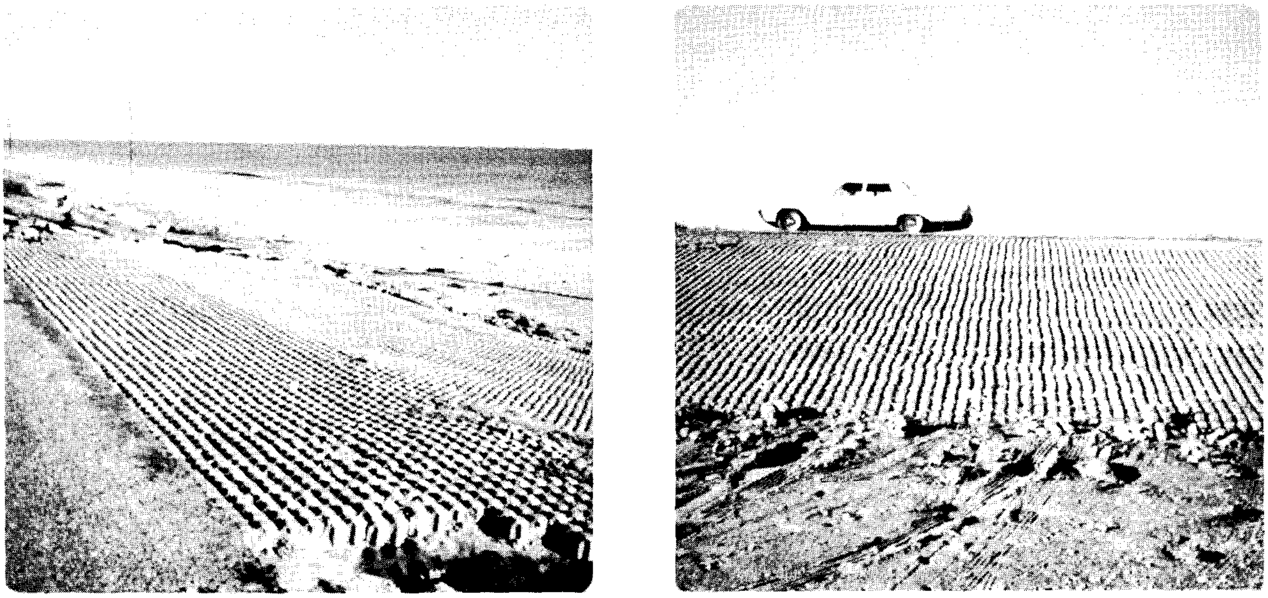

Figure 28. Views of the Cellular Concrete Block Revetment after the Storm of February 1, 1970. There was no damage to the structure as a result of this storm. The average water level for this storm was within 1.5 feet of the road surface with waves three to four foot high running across the road. More beach material was lost in this storm than in the prior storm.

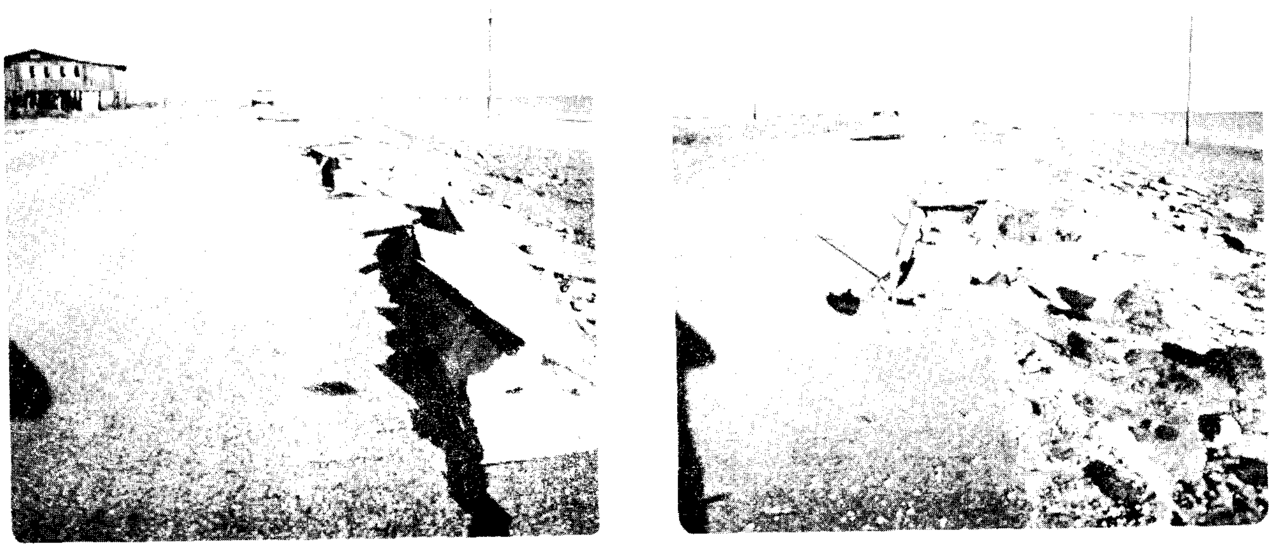

Figure 29. General Views of Damage to State Route 82 Caused by Storm of February 1, 1970. Damage such as this occurred for a distance of approximately one mile on either side of the test section.

there had been considerable accretion of beach material at the site, this storm caused more erosion at the site than the first storm. Approximately three miles of the newly repaired road suffered damage such as that shown in Figure 29. The lifting action of the waves running over the road did not appear to cause as much severe damage to the road surface as the first storm.

Conclusions from Holly Beach Tests

The cellular concrete block revetment test installation at Holly Beach performed as predicted by the model tests conducted at the Delft Hydraulics Laboratory. The storm of February 14, 1969, duplicated the model test condition 2. The storm of February 1, 1970 was only slightly less than condition 2 of the model test.

The cellular concrete block revetment used in conjunction with 300-micron mesh plastic filter and adequate toe and flank protection will prevent the extensive damage associated with the storms similar to those of February 14, 1969 and February 1, 1970. These storms were estimated to be 15-year frequency and 12-year frequency events. The revetment system will prevent major damage to the road for the 25 year event, but may suffer damage in the process.

The most critical condition will occur as high storm tides rapidly recede and cause the sea water that has flowed into the marsh to flow back across the road and revetment section at high velocities. The sea water returning from the marsh as the storm tide receded caused a large amount of the damage during these two storms. Most of this return flow was the result of waves running into the marsh.

Since this return flow did not damage the structure, the researcher has concluded that this type of revetment is suitable for other areas subject to high velocity flows such as spur dikes, bridge ends and embankments on flood plains and next to streams.

The researcher is of the opinion that Poly Filter-X will perform satisfactorily when used in conjunction with heavy revetment and has written specifications for use of the material at other sites since these tests. The material is not satisfactory for use with relatively light revetment systems under conditions similar to Holly Beach. Since these tests, Carthage Mills has woven a new filter similar to the Nicolon for experimental purposes. The Corps of Engineers is conducting additional research with plastic filters.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions:

The following conclusions are based on the author's observations discussed in this report, discussions with several revetment engineers and the model study report presented in the Appendix.

The cellular concrete paving blocks discussed in this study can be used to stabilize areas subject to light traffic such as park roads, service ramps, some shoulder areas, and median cross-overs. Additional studies need to be conducted to determine the stability of the blocks when used for prevention of shoulder rutting at the edge of pavements subject to high speed traffic. The test installations in Baton Rouge indicated that this use is feasible.

The cellular concrete blocks can be used to line drainage chutes and roadside channels. Additional hydraulic tests need to be conducted in order to determine the limiting capacity of such structures. A plastic filter cloth is essential for areas where grass cannot be readily established in the cells.

The lightweight cellular block revetment can be used to provide an aesthetic protective cover for overpass embankments. This system is especially recommended for use with those embankments subject to damage from shrinking and swelling soils as well as seepage.

The heavyweight blocks can be used with plastic filter cloth to revet spur dikes, bridge ends and embankments subject to highwater flow and wave action. Adequate flank and toe protection are necessary in all installations.

The inplace cost of cellular concrete block revetment should be between $8.00 and $10.00 per square yard depending on quantity and construction procedures.

Plastic filter cloth such as that described in the specifications in the Appendix, should be considered for use under all light revetment systems such as cellular concrete blocks, sacked concrete, random riprap less than one foot thick, and broken concrete. The tighter weave plastic filter cloths such as Poly Filter-X are recommended for heavier revetment systems.

<u>Recommendations:</u>

The 13 pound cellular concrete revetment blocks evaluated in this study or equivalent blocks meeting the specifications presented in the Appendix, are recommended for the following areas:

1. Alternate revetment for sacked concrete, random riprap and cast-in-place concrete revetment.
2. Required revetment for areas subject to wave action and rapidly changing water levels.
3. Required revetment for areas where other revetment systems are objectionable due to aesthetic reasons.
4. Lining for canals and drainage ditches subject to erosive flows.

5. Aesthetic flexible pavement with grass cover for areas subject to occasional traffic such as parking areas, park roads and access ramps.

Further research is recommended in order to determine design limits and criteria for use of this revetment to line channel expansions at culvert outlets and drainage channels subject to high velocity flow.

Cellular concrete revetment installed for the above recommended uses should be observed during any extreme events in order to determine design limitations.

The Appendix includes plans showing the cellular concrete blocks used in conjunction with plastic filter cloth for revetment at Holly Beach, Louisiana. This project which includes 42,000 square yards of cellular concrete block revetment was under construction at the time this study was completed. The unit cost of the revetment over plastic filter cloth was $7.50 per square yard in place.

Also included in the Appendix is a standard plan showing the cellular concrete blocks and plastic filter cloth as an alternate to a single layer of sacked concrete revetment.

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APPENDIX A

Results of Model Test of Gobi Block Revetment for a Situation Such As that of Holly Beach

The following is a copy of a letter report from Mr. J. J. Vinje, Head of deVoorst Hydraulics Laboratory to Mr. J. C. Pillaar of Gobi N. V. (Translated copy attached.)

WATERLOOPKUNDIG LABORATORIUM
LABORATORIUM DE VOORST

N.V. Gobi,
Industrieweg 104,
Zutphen.
(t.a.v. de heer J.C. Pilaar).

afdeling: Maritieme constructies.
onderwerp: Voorlopig verslag modelresultaten.
in behandeling bij: ir. A. Wevers.
uw brief: –

ons kenmerk: V5587/M1018/We/R.

datum: 5 december 1968.

In aansluiting op het gesprek d.d. 1 november 1968 tussen de heer Taat van Gobi N.V. en de heren v.d. Weide en Wevers van het Waterloopkundig Laboratorium, delen wij U, vooruitlopend op het definitieve modelverslag, het volgende mede:

1. Teneinde gegevens te verkrijgen betreffende de stabiliteit van de huidige Gobi-blokken in golven, zijn in het Laboratorium de Voorst enige modelproeven uitgevoerd. Voor het onderzoek is een concrete situatie, namelijk die te "Holly Beach", als uitgangspunt gekozen, vanwege de mogelijke toepassing van een Gobi-taludbekleding aldaar. Een overzicht van de situatie, in de modelopstelling, wordt gegeven op bijlage 1. De hierop vermelde maten en afmetingen zijn, evenals de verder in deze brief genoemde maten, alle prototype waarden. Voor het onderzoek naar de stabiliteit van de blokken in golven is een modelschaal (n_L) 5 aangehouden. Dit wil zeggen dat de verhouding prototype afmeting gedeeld door modelafmeting gelijk is aan 5. De proeven zijn verricht bij drie verschillende waterstanden, te weten M.L.W. + 1,50 m, M.L.W. + 2,25 m en M.L.W. + 3,00 m. Bij deze waterstanden werd een regelmatig golfpatroon opgewekt, waarvan de golfhoogte in stappen werd opgevoerd tot die hoogte, waarbij de golf reeds op de vooroever ging breken. De golfrichting was loodrecht op het talud, terwijl de golfperiode steeds ca. 6,5 sec. bedroeg.

bijlagen: 1.

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Om de invloed van de duurzaamheid en de sterkte van de verlijming van de Gobi-blokken aan het onderliggende nylondoek te elimineren, is de stabiliteit van de blokken in het model bepaald, zonder rekening te houden met de aanhechting van de blokken aan het onderliggende doek. Daarnaast was het mogelijk visueel de reductie van de golfoploop bij de Gobi-blokken ten opzichte van een glad betonoppervlak te bepalen (zie bijlage 1).

2. Resultaten van de modelproeven.

a. In de eerste serie proeven is de stabiliteit van de Gobi-blokken bekeken, wanneer deze direct naast en tegen elkaar zijn geplaatst. Bij een waterstand van M.L.W. + 1,50 m bleek de taludbekleding tot de brekerhoogte (H = 0,85 m) stabiel te zijn. Bij een waterstand van M.L.W. + 2,25 m werden bij een golfhoogte gelijk aan de brekerhoogte (H = 1,05 m), enkele blokken weggeslagen. Het punt waar het talud bezweek was gelegen op de overgang van de helling 1 : 3 naar het horizontale gedeelte.
Bij een waterstand van M.L.W. + 3.00 m bleek de taludbekleding stabiel tot een golfhoogte van 1,10 m. Bij een golfhoogte gelijk aan de brekerhoogte (H = 1,30 m) werden de blokken, gelegen in het gedeelte van het talud dat aan golfaanval blootstond, weggeslagen. De blokken, gelegen op een hoogte juist boven het golfdal van een aankomende golf, werden hierbij als eersten uit het talud getild. Bij een waterstand van M.L.W. + 1,50 m is bovendien de golfoploop bij een talud met Gobi-blokken bepaald. Deze golfoploop bedroeg 65 - 70 % van de golfoploop bij een volkomen gladde taludbekleding.

b. In de tweede serie proeven waren de horizontale rijen Gobi-blokken van elkaar gescheiden door een draad (diameter in model 2 mm), welke direct boven het nylondoek was gespannen. Op deze manier werd de wrijving van een blok met het boven- en ondergelegen blok aanzienlijk verminderd. Bovendien was de diameter van de nylondraad zodanig gekozen dat het blok vrijuit kon kantelen. Met deze proef werd beoogd in het model de invloed van een eventuele tweezijdige afschuining van de Gobi-blokken op de stabiliteit van de blokken te bepalen. Bij een waterstand van M.L.W. + 1,50 m bleek de taludbekleding nu stabiel tot een golfhoogte van 0,70 m.

Bij een golfhoogte gelijk aan de brekerhoogte H = 0,90 m bleken enkele blokken, gelegen juist boven het golfdal, uit het talud te worden gelicht. Bij een waterstand van M.L.W. + 3,00 m bleek de taludbekleding stabiel tot een golfhoogte van 0,95 m. Bij een golfhoogte hoger dan 0,95 m werden de blokken gelegen in het gebied van de golfaanval weggeslagen.
De golfoploop in deze situatie, gemeten bij een waterstand van M.L.W. + 1,50 m en een golfhoogte van 0,45 m, bedroeg 62 % van de golfoploop bij een gladde constructie.

c. In de laatste serie proeven werden de Gobi-blokken omgekeerd en, evenals in serie a, direct naast elkaar geplaatst. De stabiliteit van de taludbekleding was in deze serie vrijwel gelijk aan die in serie a. De reductie van de golfoploop was bij een dergelijke plaatsing echter geringer. Nu bedroeg de golfoploop 75 % van de golfoploop bij een gladde taludbekleding.

3. Aannemend dat voor dit geval de formule van Hudson mag worden toegepast, kunnen, aan de hand van bovengenoemde resultaten, de benodigde blokgewichten en/of -afmetingen van de Gobi-blokken voor golfomstandigheden waarin de huidige Gobi-blokken worden weggeslagen, worden bepaald. Deze formule, oorspronkelijk afgeleid ter bepaling van de benodigde steengewichten voor golfbrekers, luidt:

$$W = \frac{\varrho_{bl} \, H^3}{K_d \left(\frac{\varrho_{bl} - \varrho_w}{\varrho_w}\right) \cot \alpha}$$

waarin:

W = benodigd steengewicht in kg.

ϱ_{bl} = dichtheid Gobi-blok in kg/m^3.

H = significante golfhoogte in m.

$\frac{\varrho_{bl} - \varrho_w}{\varrho_w}$ = relatieve dichtheid.

α = taludhelling.

K_d = dimensieloze coëfficient.

Bij een waterstand van M.L.W. + 3,00 m was de taludbekleding in serie a stabiel tot een golfhoogte van 1,10 m.

Met behulp van de formule van Hudson kan nu het benodigde steengewicht voor een significante golfhoogte van 1,50 m worden berekend. Er dient te worden opgemerkt dat deze berekening slechts opgaat voor dezelfde situatie als waarvoor de modelproeven zijn uitgevoerd i.c. de situatie te "Holly Beach". Het benodigde steengewicht voor een significante golfhoogte van 1,50 m is dan:

$$\frac{W_2}{W_1} = \frac{\dfrac{\varrho_{2bl}\, H_2^{\,3}}{K_{2d}\left(\dfrac{\varrho_{2bl} - \varrho_w}{\varrho w}\right)^3 \cot \alpha}}{\dfrac{\varrho_{1bl}\, H_1^{\,3}}{K_{1d}\left(\dfrac{\varrho_{1bl} - \sigma_w}{\varrho w}\right)^3 \cot \alpha}}$$

Stelt men nu $K_{2d} = K_{1d}$: hetgeen zeer aannemelijk is omdat de omstandigheden verder niet veranderen,

en $\varrho_{2bl} = \varrho_{1bl}$: zwaarder blok dezelfde dichtheid als het huidige blok,

dan is $W_2 = W_1 \cdot \dfrac{H_2^{\,3}}{H_1^{\,3}} = 2{,}54\ W_1$

Een andere mogelijkheid is het steengewicht gelijk te laten, maar de dichtheid van de blokken te vergroten. Analoog aan het bovenstaande volgt hieruit:

$$\frac{\varrho_{2bl}}{\left(\dfrac{\varrho_{2bl} - \varrho_w}{\varrho_w}\right)^3} = \frac{H_1^{\,3}}{H_2^{\,3}} \quad \frac{\varrho_{1bl}}{\left(\dfrac{\varrho_{1bl} - \varrho_w}{\varrho_w}\right)^3}$$

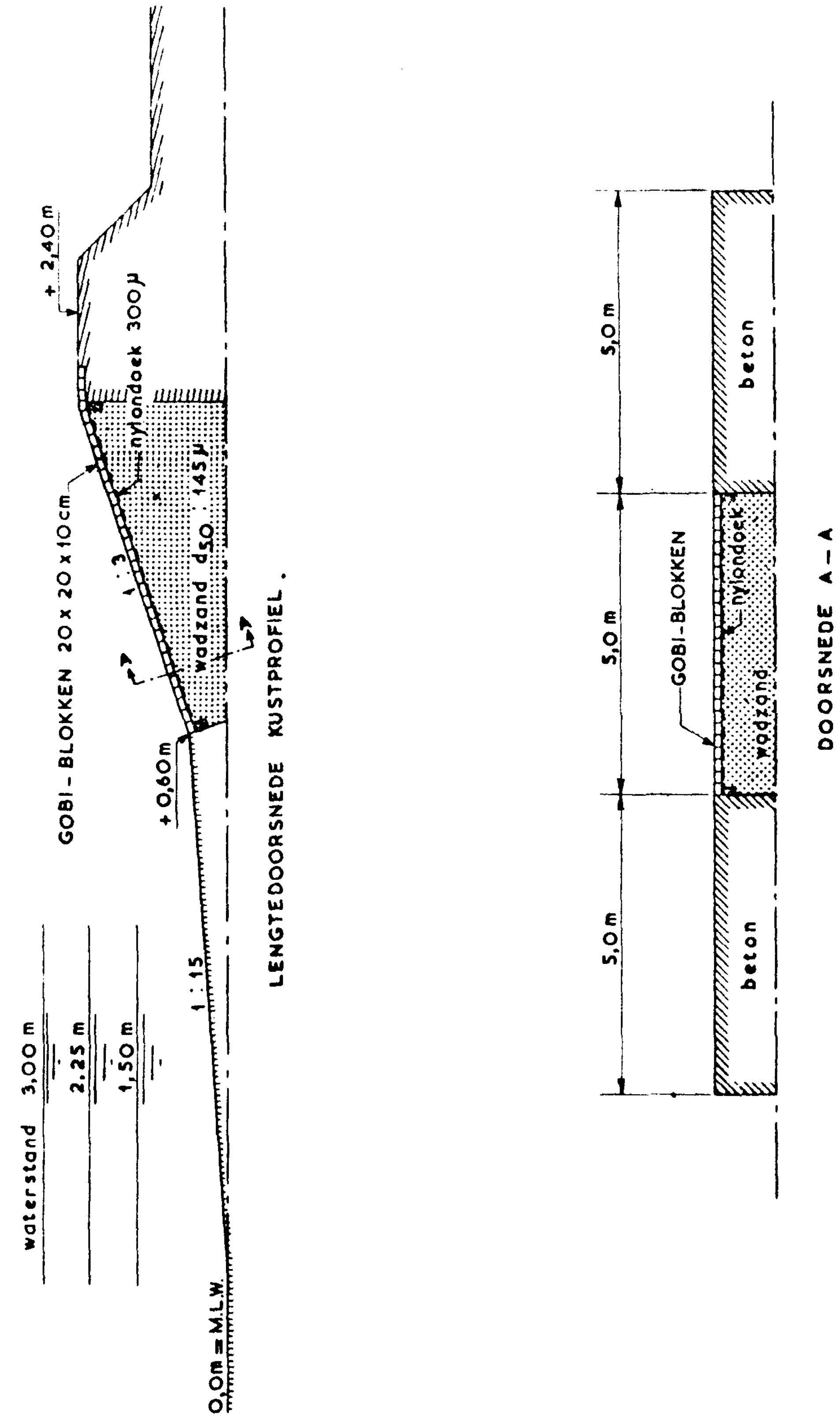
zodat $\varrho_{2bl} = 1{,}3\ \varrho_{1bl}$

4. De resultaten, zoals hierboven vermeld, zijn gevonden uit proeven met regelmatige golven. Uit proeven, verricht door het Waterloopkundig Laboratorium, is gebleken dat de resultaten van proeven in onregel-

matige golven kunnen afwijken van die in regelmatige golven. De gevonden waarden dienen derhalve slechts als indicatie. Voor een juiste dimensionering van de taludbescherming zijn derhalve proeven in onregelmatige golven noodzakelijk.

Waterloopkundig Laboratorium,

(ir. J.J. Vinjé)
Hoofd Laboratorium de Voorst.



OVERZICHT MODEL GEBASEERD OP DE SITUATIE TE "HOLLY BEACH"	SCHAAL 1 : 100	
WATERLOOPKUNDIG LABORATORIUM	M. 1018	BIJL. 1

Translation of letter of December 5, 1968, from Mr. Vinje, head of Devoorst Hydraulic Laboratory to Mr. J. C. Pillaar of N. V. Gobi. Copies of original attached.

In reference to our conversation of November 1, 1968 between Mr. Taat of Gobi N. V. and Mr. V. D. Weide and Mr. Wevers of the Waterloopkundig Laboratorium, we inform you, in anticipation of the final model report, the following:

(1) In order to obtain data concerning the stability of the present Gobi blocks in waves, some model test have been carried out in the laboratory at the Voorst. For the investigation an existing situation, that of Holly Beach, was taken as a guide, in connection with a possible application of a Gobi cover there. A review of the situation in the model has been given in Appendix 1. The measurements on this sketch, as are those mentioned further in this letter, all are prototype values. To investigate the stability of the blocks in waves, a model scale of (N_L) 5 has been used. This means that the ratio of the prototype measurements over the model measurements equals 5. The test have been carried out for three different water levels, M. L. W. + 1. 50m, M. L. W. + 2. 25m and M. L. W. + 3. 00m. With these waterlevels a regular wave pattern was generated, of which waves to break on the foreshore. The direction of wave incidence was perpendicular to the shore, whereas the wave period was always on the order of 6. 5 seconds. To eliminate the influence of the durability and the strength of the glue-fastening of the Gobi blocks to the underlying nylon material, the stability of the blocks in the model has been determined without consideration of

this fastening of the blocks to the underlying material. Besides this it was possible to determine visually the reduction of the wave run-up on Gobi blocks in comparison to a smooth concrete surface (see Appendix 1).

(2) Results of the model test.

a. In the first series of test the stability of the Gobi block has been viewed, the blocks being placed in mutual contact in both directions. For a waterlevel of M. L. W. + 1. 50m the slope cover appeared stable up to a breaker height of (H = 0. 85m) for a water level of M. L. W. + 2. 25m a few blocks were dislodged when wave height was equal to the breaker height (H = 1. 05m). The point where the slope gave way was located at the transition of the slope 1:3 to the horizontal part. For a waterlevel of M. L. W. + 3. 00m the slope was appeared stable up to a wave height of 1. 10m. At a wave height equal to the breaker height (H = 1. 30m) the blocks were dislodged in that part of the slope that was attacked by the waves.

The blocks being dislodged first were those located at an elevation just above the trough of an approaching wave. For a waterlevel of M. L. W. + 1.50m the wave run-up has been determined for a slope with Gobi blocks. This wave run-up amounted to 65-70% of the run-up for a completely smooth slope cover.

b. In the second series of test the horizontal rows of Gobi had been separated from each other by a wire (diameter in model = 2mm) which was placed immediately above the nylon sheet. In this way the friction of a block with the upper and lower bounding blocks was decreased considerably. Besides, the diameter of the nylon wire had been chosen such that the block could overturn freely. With this test it was meant to determine in the model the influence on the stability of the blocks for possible slanting of two sides of the Gobi blocks. At a waterlevel of M. L. W. + 1.50m the slope cover now was stable to a waveheight of 0.70m. For a waveheight equal to the breaker height (H = 0.9m) some blocks located just above the wave trough were dislodged at a waterlevel of M. L. W. + 3.00m the slope cover was stable to a wave height of 0.95m. For a wave height more than 0.95m the blocks located in the zone of wave attack were dislodged. The run-up in this situation as measured at a water-level of M. L. W. + 1.50m and for a waveheight of 0.45m was 62% of the run-up for smooth construction.

c. In the last series of test, the Gobi blocks were turned and as in series "a", placed immediately next to each other. The stability of the slope cover was in this series practically equal to that in series "a". The reduction of the wave run-up was for such a construction less, being 75% of the wave run-up for a smooth slope cover.

(3) Using the above result and assuming that for this case Hudson's formula can be used, the necessary block weight and/or size of the Gobi blocks can be determined for known wave conditions under which the present Gobi blocks were discharged. This formula, initially used for determination of the needed amount of rock-weight for grams equal:

The results, as given above, have been determined from test with regular waves. From test, carried out by theHydraulics Laboratory, it appeared that the results of the test for irregular waves may differ from those for regular waves. The resulting values therefore serve only as an indication. In order to find the correct dimensions for the slope cover, test with irregular waves are necessary.

Waterloopkundig Laboratorium

Signed/J. J. Vinje
Head Laboratorium de Voorst

APPENDIX B

Specifications and Typical Installations of Cellular Concrete Block Revetment

Rev. 7/71
Orig. 9/70
Page 1 of 2 pages

SPECIAL PROVISIONS
STATE PROJECT NO.

ITEM S- , CELLULAR CONCRETE BLOCK REVETMENT: This item consists of furnishing and constructing cellular concrete block revetment on plastic filter cloth at locations shown on the plans, in accordance with plan details and the following requirements.

Samples of approved filter cloths and cellular blocks, and photographs and motion pictures of this type revetment can be seen in the offices of the Bridge Design Engineer.

Materials:

(a) Plastic Filter Cloth: Plastic filter cloth shall consist of linear polypropylene or polyethylene monofilimant yarn woven into sheets of 20 to 30 mils thickness. The lengths and width of sheets may be varied to suit the manufacturer's standards. Seams meeting strength requirements of the plastic filter cloth will be permitted. Additional yarn of other material or steel wire may be woven into the cloth to increase overall strength. The following plastic filter cloths are qualified products:

1. Poly-Filter-GB - Carthage Mills Inc., 124 W 66th St., Cincinnati, Ohio 45216
2. Nicolon 66301 - A Dutch Product - U. S. Agent, Erco Systems, Inc., P. O. Box 4133, New Orleans, La. 70118
3. Plastic Filter Cloth with Flexile Filter Erosion Control Mattress - Erco Systems, Inc., New Orleans, La.

If plastic filter cloth other than one of the above is proposed for use, the contractor shall submit complete information for approval, including textile tests indicating:

Property	Requirements
Thickness (ASTM: D 1910)	20 to 30 mils
Weight (ASTM: D 1910)	5 to 10 oz./sq. yd.
Open Area	24 to 30 %
Equivalent Opening Size (U.S. Standard Sieve Size)	45 to 35
Tensile Strength	
ASTM: D 1682 Warp	200 lbs./in.
Fill	200 lbs./in.
Burst Strength	500 psi
Abrasion Resistance (ASTM: D 1175)	
Stoll (2# head, 3 psi air, 0 grit)	20,000 cycles to failure
Taber (C5-17/1000 grams)	10,000 cycles to failure

Fibers of other composition or steel wire may be woven into the cloth for reinforcing purposes. The durability of these fibers must be equivalent to that of the plastic filter cloth.

A certified copy of permeability and filtration tests from a qualified laboratory showing the performance of this filter with fine sands and water stating both particle retention and permeability shall be included with a sample of the material. Sampling of the product shall be as follows:

(1) Qualification test sample shall consist of 2 square yards of material.

SPECIAL PROVISIONS
STATE PROJECT NO.

(2) Acceptance Sampling: The material shall be subject at all times to inspection at the places of manufacture, and every facility shall be afforded the Department personnel in the prosecution of their work. Individual samples shall not be mixed. Samples shall be labeled with lot and batch number, date of sampling, contract number, and specifications.

(b) Cellular Concrete Blocks: Cellular concrete block design shall be in accordance with plan details or approved equal design. Blocks shall be manufactured by machines employing high vibratory compaction.

Concrete blocks shall conform to ASTM Designation: C 145, as amended by the following requirements. Oven-dry weight of concrete shall be at least 135 pounds per cubic foot. Aggregate gradation and variation in block dimensions shall be as directed.

Construction Requirements:

(a) Site Preparation: All logs, stumps and other undesirable material shall be removed from the limits of construction to the satisfaction of the engineer. The entire area for the revetment system shall be filled and graded to obtain reasonable conformity with the grades and cross sections shown on the plans. Sandy soil shall be used to bring the area to grade and compacted to the engineer's satisfaction before final grading.

(b) Plastic Filter Cloth: Ends of the filter shall be buried for anchorage as shown on the plans. A minimum overlap of 10" is required for adjacent strips. Pins are required at 5-foot intervals to hold the filter overlap in place until blocks are placed. Care shall be taken to prevent damage to the filter cloth.

(c) Cellular Concrete Blocks: Placing of blocks shall commence in a trench or against a suitable anchorage at the downslope end of the area to be reveted and shall progress upslope. Each block shall be laid perpendicular to the slope and shall be bedded firmly against adjoining blocks. Cement grout may be required to fill unaligned joints or breaks at slope changes if directed by the engineer. Individual blocks shall not be grouted to each other.

(d) If a combination block and cloth mattress revetment is used, the foregoing requirements shall be modified as required to permit placement of the revetment in panels; however, the 10" overlap between adjacent panels shall apply.

(e) After completion of the revetment, topsoil shall be loosely spread over the revetment to partially fill the cell openings. The topsoil shall be seeded and fertilized in accordance with Sections 717 and 718 of the Standard Specifications at the time of other seeding operations. All costs for furnishing and placing topsoil, seeding and fertilizer shall be included in the bid price for the revetment.

Measurement and Payment: Cellular concrete block revetment will be measured by the square yard of completed and accepted revetment.

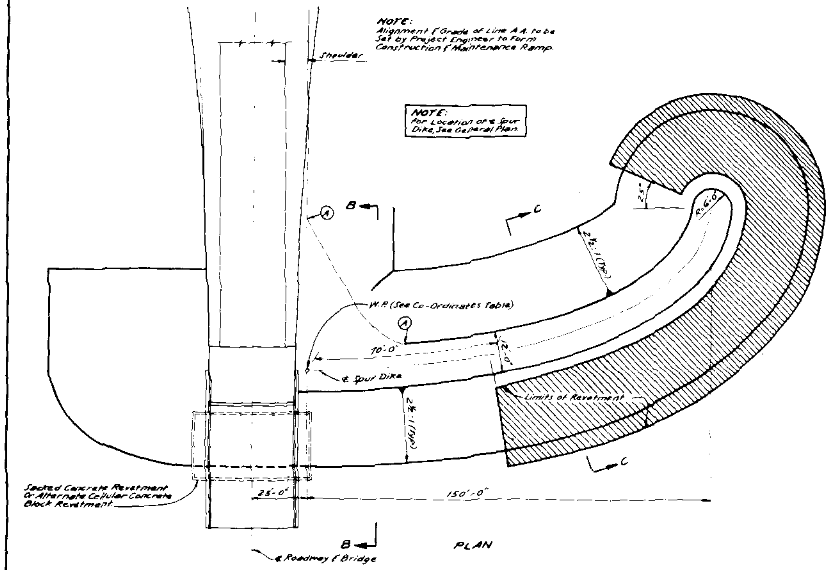
The accepted quantity of cellular concrete block revetment will be paid for at the contract unit price per square yard, which includes site preparation, furnishing and placing plastic filter cloth, cellular concrete blocks, topsoil, seeding and fertilizer. Payment will be made under:

Item S- , Cellular Concrete Block Revetment, per square yard.

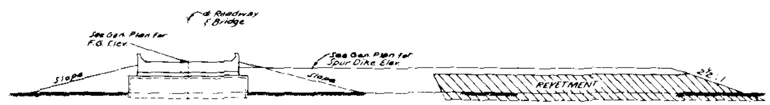
STATE PROJECT	PARISH	SHEET NO.

NOTE:
Alignment & Grade of Line A A. to be Set by Project Engineer to Form Construction & Maintenance Ramp.

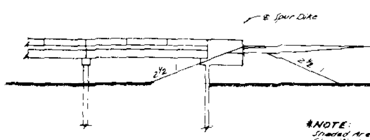
NOTE:
For Location of ℄ Spur Dike, See General Plan.



PLAN

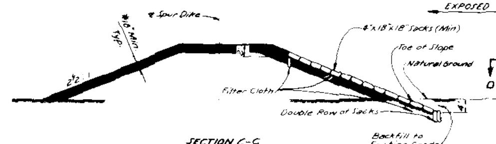


ELEVATION

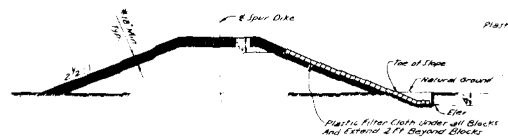


SECTION B-B

***NOTE:**
Shaded Area to be Material Classified as A-4, A-6, A-7-5, And/or A-7-6 Payment to be Under Item 203(5) Special Borrow Excavation, or as Otherwise Noted on this Sheet.

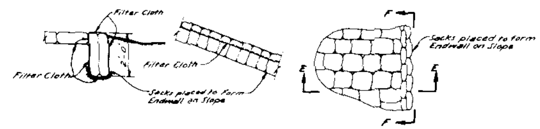


SECTION C-C
SACKED CONCRETE REVETMENT



SECTION C-C
ALTERNATE
CELLULAR CONCRETE BLOCK REVETMENT

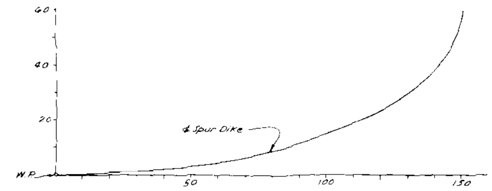
NOTE TO CONTRACTOR:
All Areas of Berm Slope, Side Slopes & Spur Dikes not Revetted to be Mulch Sodded & Treated with Fiber Glass Roving & Asphalt Material, Unless Otherwise Noted On Plans.



SECTION E-E SECTION F-F TYPICAL PART PLAN

DETAILS FOR SACKED REVETMENT

NOTE:
NO END REQ'D. BELOW TOE OF SLOPE.
All Excavation, Backfill, and work Necessary to Complete Placement of Sacked Concrete Revetments to be Included in Price Bid for Sacked Concrete Revetments, S-Item, per Cu. Yd.



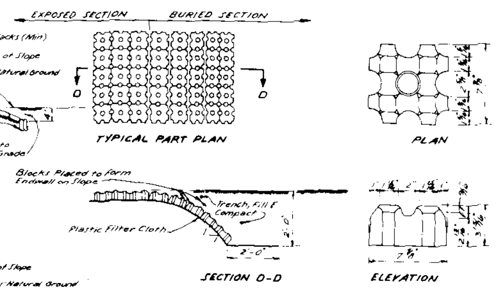
SPUR DIKE CO-ORDINATES TABLE							
X (FEET)	Y (FEET)	X (FEET)	Y (FEET)	X (FEET)	Y (FEET)	X (FEET)	Y (FEET)
0.00	0.00	80.00	9.25	134.00	33.04	145.00	44.64
10.00	0.13	90.00	12.00	136.00	34.69	146.00	46.24
20.00	0.54	100.00	15.28	138.00	36.48	147.00	48.06
30.00	1.21	110.00	19.21	140.00	38.46	148.00	50.23
40.00	2.17	120.00	24.00	141.00	39.53	149.00	53.08
50.00	3.43	125.00	26.83	142.00	40.67	149.50	55.11
60.00	5.01	130.00	30.07	143.00	41.88	150.00	60.00
70.00	6.93	132.00	31.50	144.00	43.20		

CELLULAR CONCRETE BLOCK REVETMENT:
The Contractor will be Permitted to use CELLULAR CONCRETE BLOCK REVETMENT over Plastic Filter Cloth in Accordance with Details shown On this Sheet and as Described in the Special Provisions in Lieu of "SACKED CONCRETE REVETMENT," S-Item.

Concrete Blocks, as Detailed on this Sheet, were Developed by Gabimat Erco System, Inc., of New Orleans, La. However, the Contractor will be Permitted to Submit Alternate Designs for the Cellular Concrete Blocks, Meeting all the Requirements of the Special Provisions, to the Bridge Design Engineer for Approval.

All Excavation, Backfilling, Slope Dressing, Plastic Filter Cloth and Cellular Concrete Blocks are to be Included in the Price Bid on S-Item, Cellular Concrete Block Revetment (Alternate), per Sq. Yd.

NOTE:
Fill for Spur Dike to be Obtained From Drainage Excavation as Directed By the Project Engineer and La. Dept. of Hwys. Standard Specifications, if Suitable Material is Available on the Project.
If Suitable Material is not Available, Fill for Spur Dike is to be Paid for under Item 203(5) "SPECIAL BORROW EXCAVATION" per Cu. Yd.



TYPICAL PART PLAN PLAN
SECTION D-D ELEVATION

DETAILS FOR CELLULAR CONCRETE BLOCKS

SPUR DIKE

**SPUR DIKE
AT BRIDGE ENDS**

DATED AUG. 26, 1971

STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS

DATE	DESCRIPTION	BY
5-25-71	Width of top of Dike	O.S.H.

REVISIONS

DESIGNED [illegible] DETAILED [illegible] TRACED [illegible]
CHECKED [illegible] CHECKED [illegible] CHECKED [illegible]

BRIDGE DESIGN SECTION

S.D.150

STATE PROJECT	PARISH	SHEET NO.
384-02-11	Cameron	1

STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS

PLANS OF PROPOSED
STATE HIGHWAY

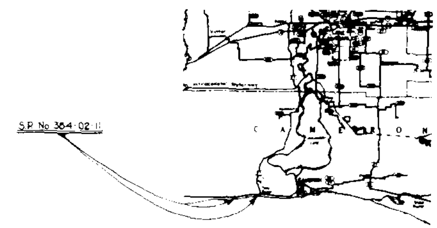
STATE PROJECT NO. 384-02-11
JOHNSON BAYOU SCHOOL-HOLLY BEACH HWY.
(BANK PROTECTION)
CAMERON PARISH
La 82

INDEX TO SHEETS

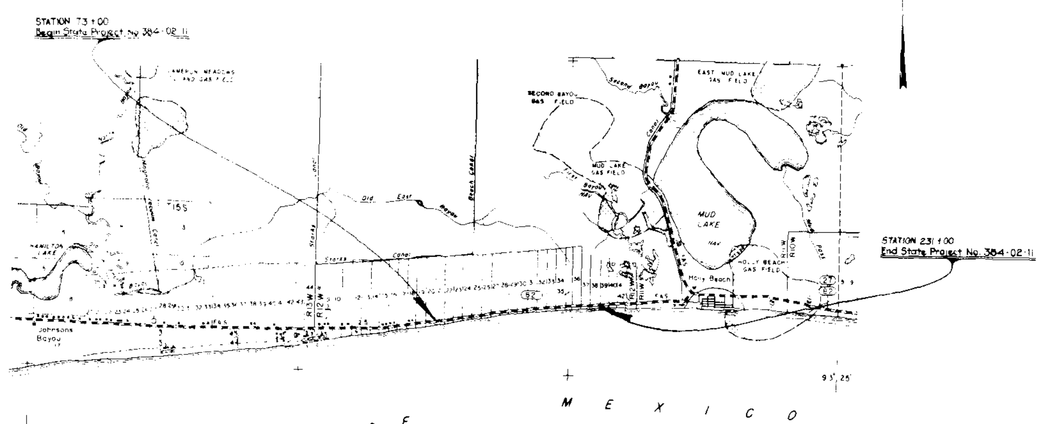
SHEET No.	DESCRIPTION
1	Title Page & Layout Map
2	Typical Sections & Details & Summary of Estimated Quantities

	STANDARD PLANS	REVISION DATE
201-204	RS-24 Rev	-69

Total Number of Sheets 2



VICINITY MAP



LAYOUT MAP ONLY

80

SCHEDULE OF REVISIONS

DATE	REVISION	DATE	RECOMMENDED	DATE	APPROVED
6-8-70	Sheets 1 & 2	6-8-70	Hal Colvin		

TYPE OF CONSTRUCTION: Bank Protection

DATUM USED:
MAG. VAR.:
BEARINGS ARE
TRANSIT BOOKS: 82-681
LEVEL BOOKS: 79-536
SCALES PLAN:
PROFILE: HOR.
VERT.

LAYOUT MAP
SCALE: 1 INCH 5280 FEET

LENGTH OF PROJECT

DESCRIPTION	ALGEBRAIC SUM OF ALL EQUATIONS	GROSS LENGTH	EXCEPTION	BRIDGE LENGTH		ROADWAY LENGTH	
STA. TO STA.	FEET	FEET	FEET	FEET	MILES	FEET	MILES
73+00-231+00		15800.00				15800.00	2.992
TOTAL LENGTH OF BRIDGES							
TOTAL LENGTH OF ROADWAY						15800.00	2.992
TOTAL MILES				2.992			

RECOMMENDED FOR APPROVAL
TRAFFIC & PLANNING ENGINEER
DATE 6-8-70

RECOMMENDED FOR APPROVAL
BRIDGE DESIGN ENGINEER
DATE 6-8-70

RECOMMENDED FOR APPROVAL
Acting ROAD DESIGN ENGINEER
DATE 6-8-70

RECOMMENDED FOR APPROVAL
CHIEF LOCATION & DESIGN ENGINEER
DATE 6-8-70

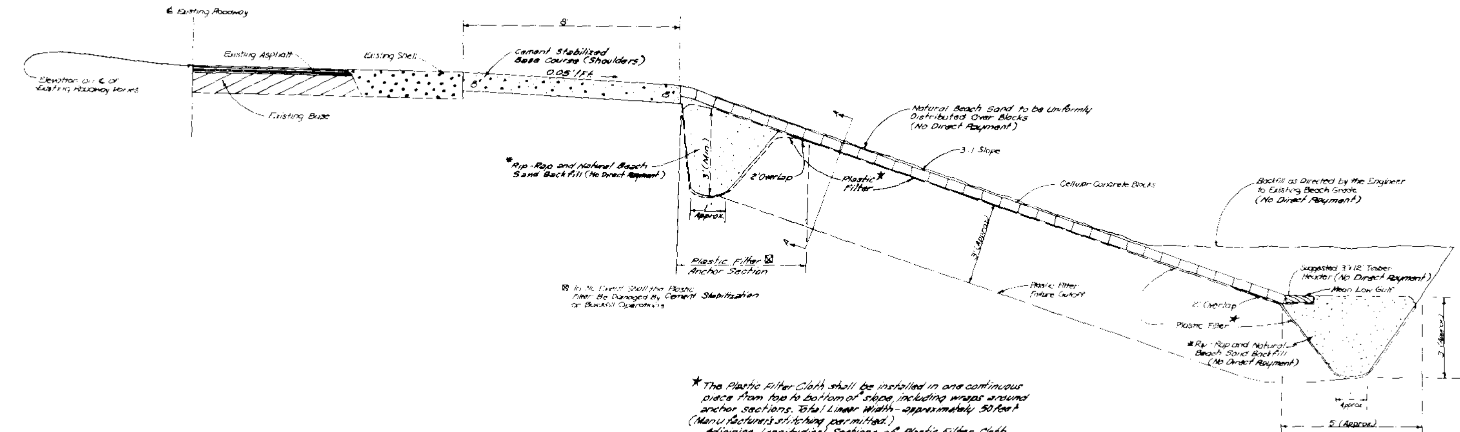
APPROVED
CHIEF ENGINEER
DATE 6-8-70

RECOMMENDED FOR APPROVAL DATE ______
[redacted]
DISTRICT ENGINEER
DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
BUREAU OF PUBLIC ROADS

APPROVED DATE ______
[redacted]
DIVISION ENGINEER
DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
BUREAU OF PUBLIC ROADS

STATE PROJECT	PARISH	SHEET NO.
384-02-11	Cameron	2

Note: Existing Pipe to be Covered or Removed as Directed by the Engineer (No Direct Payment)



Note: Suggested Timber Header May Be Removed After Backfill Operations.

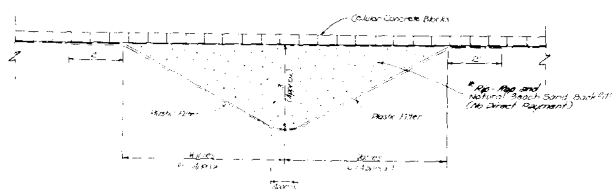
*The Plastic Filter Cloth shall be installed in one continuous piece from top to bottom of slope, including wraps around anchor sections. Total Linear Width - approximately 50 feet (Manufacturer's stitching permitted.)
Adjoining Longitudinal Sections of Plastic Filter Cloth (Suggested Length - 100 feet) shall be overlapped a minimum of 2 feet.

* Existing Rip-Rap Along Beach to be Placed in Trench as Directed by the Engineer (No Direct Payment)

SUMMARY OF ESTIMATED QUANTITIES

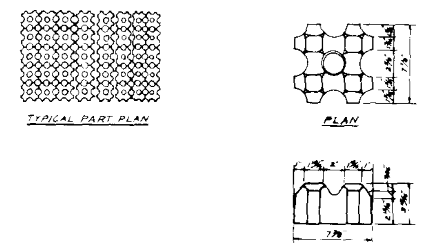
ITEM NO.	ITEM	UNIT	QUANTITY
303(1)	Cement Stabilized Base Course (Shoulders) (12 % by Volume)	Sq. Yd.	14044
713(1)	Signs and Barricades	Lump	Lump
S-1	Cellular Concrete Block Revetment	Sq. Yd.	42133*

* Approximately 89000 Sq. Yds. Plastic Filter Required To Be Included in Price Bid for Item S-1, Cellular Concrete Block Revetment.



SECTION A-A

DETAIL OF PLASTIC FILTER FAILURE CUTOFF



DETAILS FOR CELLULAR CONCRETE BLOCKS

TYPICAL SECTIONS & DETAILS AND SUMMARY OF ESTIMATED QUANTITIES

DATED MAY 1970

STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS

DESIGNED | DETAILED | TRACED C.T. Dominick
CHECKED | CHECKED | CHECKED

REVISIONS: II 6-23-70 General Revisions H.J.C.