F 301 (1-68)

THE GOODYEAR TIRE & RUBBER COMPANY

AKRON, OHIO 44316

Enclosed for your information and reference are several reports on work The Goodyear Tire and Rubber Company has done in our scrap tire utilization program. The reports cover the new Goodyear modular constructed, sinking and floating type, scrap tire mat shore-protection structures. These reports will bring you up to date on the most recent developments in our efforts to find new uses for old tires. We are confident that you will find the innovative new approaches described herein informative and beneficial.

The use of the proposed scrap tire shore protection structures shall be at the sole risk and responsibility of the user with no liability of any nature whatsoever on the part of The Goodyear Tire and Rubber Company. In this regard your attention is directed to the following issued U S Patents of which we are aware that relate generally to tires for use other than on vehicles: 3,276,210, 3,728,749, and 3,848,853.

The University of Rhode Island is evaluating the floating type scrap tire breakwater structures in Narragansett Bay. Early prototypes were reported as 80 percent efficient in wave suppression. The new designs are expected to be even more efficient. The University will publish the results of the evaluation at the termination of the study.

The University of Michigan is exploring the use of scrap tires as a possible material for the construction of marine mats for coastal erosion control. The University's Department of Civil Engineering and Coastal Zone Laboratory are presently designing a scrap tire shore-protection structure utilizing the new Goodyear modular mat construction technique.

The results of this work will be published in an annual report titled "Shore Erosion Engineering Demonstration Projects", along with several other existing erosion control demonstration projects which are currently being sponsored by the State of Michigan Department of Natural Resources, Bureau of Water Management, Water Development Service Division, and NOAA Office of Sea Grant, Department of Commerce.

The effectiveness of this project will be evaluated and documented with respect to such factors as reduction of erosion rates, costs, construction difficulties and durability.

The scrap tire constructed erosion devices proposed for evaluation are innovative low cost structures and, if proven effective, will be a significant advance in the design of wave energy dissipating structures. Great sums are spent annually in the United States by federal, state, and municipal governments and private owners for structures designed to prevent erosion damage to sea-coasts and lake shores. Many of the existing structures have failed due to structural inadequacy, or they have deteriorated through lack of maintenance because they were functionally unsound or economically infeasible, all of which testifies to the need for the development of sound research programs in coastal engineering and the dissemination of the technical knowledge obtained.

We at Goodyear hope that our efforts are beneficial to people with your type of credentials, for success will only come by a united undertaking of this type of program.

It is not our intent to design shore protection structures. Our objective is to inform the designers of these structures that if they use scrap tires instead of the materials they are now using, they will produce a better product, at a reduced cost, and with an increased service life.

To this end, we are presently working with all benefits to be received being turned over to the public.

We would like to thank you in advance for your cooperation in this important project, and wish you every success in your endeavors.

Very truly yours,

R D Candle

Section Head, Engineering Research

R D Candle
ph

THE GOODYEAR TIRE & RUBBER COMPANY
AKRON, OHIO 44316

September 30, 1974

THE PROPOSED GOODYEAR MODULAR MAT TYPE

SCRAP TIRE FLOATING BREAKWATER

By R D Candle
D R Piper

This report is a continuation of and a supplement to the Goodyear report dated April 9, 1973, on the same subject, and by the same author.

The information reported herein is a description of design parameters (proposed by the Research Division of The Goodyear Tire and Rubber Company) of numerous scrap tire floating breakwater barrier concepts. The use of such scrap tire barrier design concepts shall be at the sole risk and responsibility of the user without liability of any nature whatsoever on the part of The Goodyear Tire and Rubber Company.

Introduction:

Scrap tires are proposed as a construction material for building large floating mat type breakwater devices. The Goodyear scrap tire floating breakwater assemblies are formed by securing together modular bundles of tightly interlocked scrap tires with high strength rope, cable, or special corrosion resistant steel rods. This construction procedure yields an easily installed, readily adaptable breakwater structure which has high energy absorbing capacity for normal loading conditions, but which deforms and yields when subjected to overloads.

The proposed designs rely on a modular bundle concept where a relatively few tires are secured together to form a small, easily assembled, portable building unit which serves as a basic building block from which giant breakwater devices can be constructed. Flotation is provided by placing a small amount of buoyant material in the crown of each tire, or by filling approximately 10% of the tires with buoyant foam.

The design possibilities using scrap tire building modules are virtually limitless. Tires may be laced together to form large flat single or multiple thickness shallow mats. They may be stacked vertically in single or multiple thickness bundles like bricks in a wall to form curtain type barriers. Variations in breakwater draft are made possible by adding modules above or below to vary the thickness and by combining constructions such as hanging a curtain on a mat structure. Also, mats with varying buoyancy may be moored on an incline for more efficient energy absorption.

The Goodyear Modular Mat Type Scrap Tire Floating Breakwater:

This report will cover only floating mat type breakwater concepts. Full scale testing results to date utilizing the mat type structures are available in Dr Kowalski's 1974 report on the University of Rhode Island's evaluation of the scrap tire breakwater.

All scrap tire breakwater constructions should be very effective as energy dissipators because of the pervious, and flexible nature of the modules. The scrap tires are ideal energy-absorbing components. They are inexpensive and nearly non-destructible.

The scrap tire is the basic construction component in the proposed breakwater designs. The objective is to use this basic component "as is" to obtain maximum economical gain. Tire alterations such as drilling or punching holes, chopping, grinding, or cutting the tires into pieces add unnecessary costs to the finished breakwater.

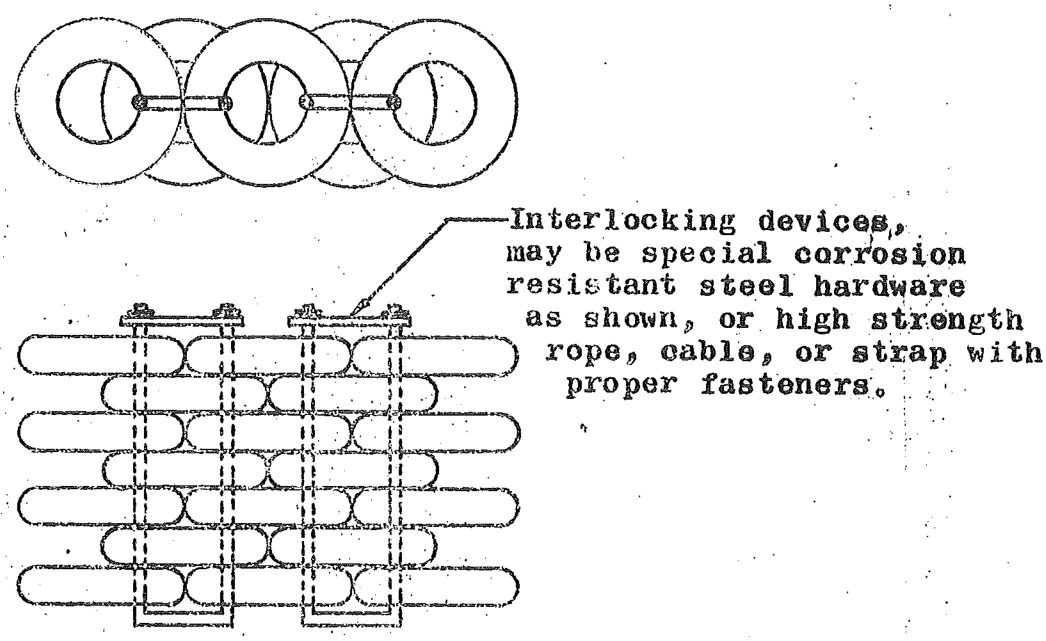
The floating scrap tire mat constructions proposed in this report are excellent examples of maximum optimization in utilizing the tires in their "as is" condition, and, therefore, result in very economical structures which are very rugged and long lasting. They are also capable of being constructed with simple hand tools, and require no special handling equipment.

The modular type construction technique is utilized in the proposed designs. First, simple floating modular construction blocks, consisting of 18 tires, are assembled into compact bundles. Next, the modular units are interconnected, usually in the water, to form the desired breakwater mat design. This requires two connecting tires, bringing the total tires used per each 7' x 6 1/2' module to 20. The modules can be interconnected to form mats with very porous open grid structures or can be interconnected very tightly compacted to yield a flexible closed grid blanket type structure.

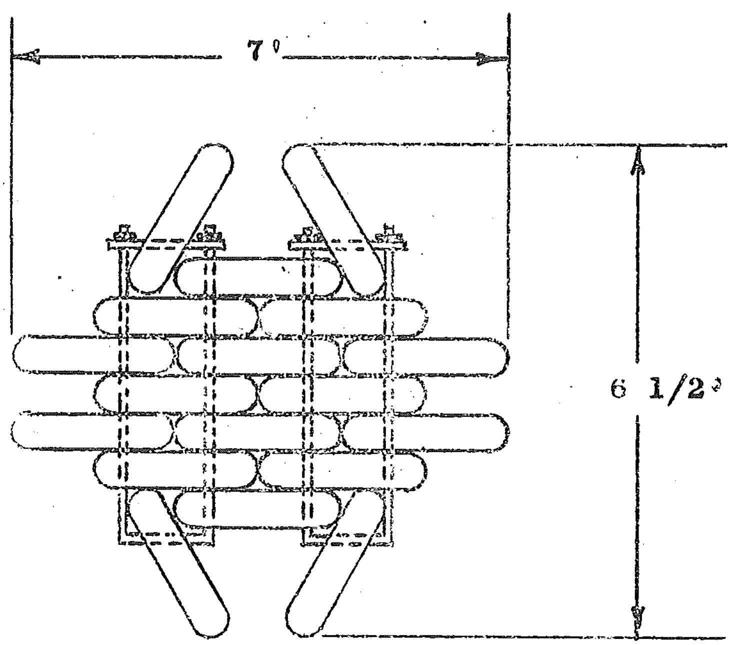
The major consideration on the length and the sea-to-shore dimensions of the proposed designs will be the physical limits of the actual area of the installation.

The following sketches illustrate the modular units, assembly details, proposed hardware, and several of the more promising assembly configurations.

THE PROPOSED GOODYEAR BASIC SCRAP TIRE MODULAR CONSTRUCTION UNIT

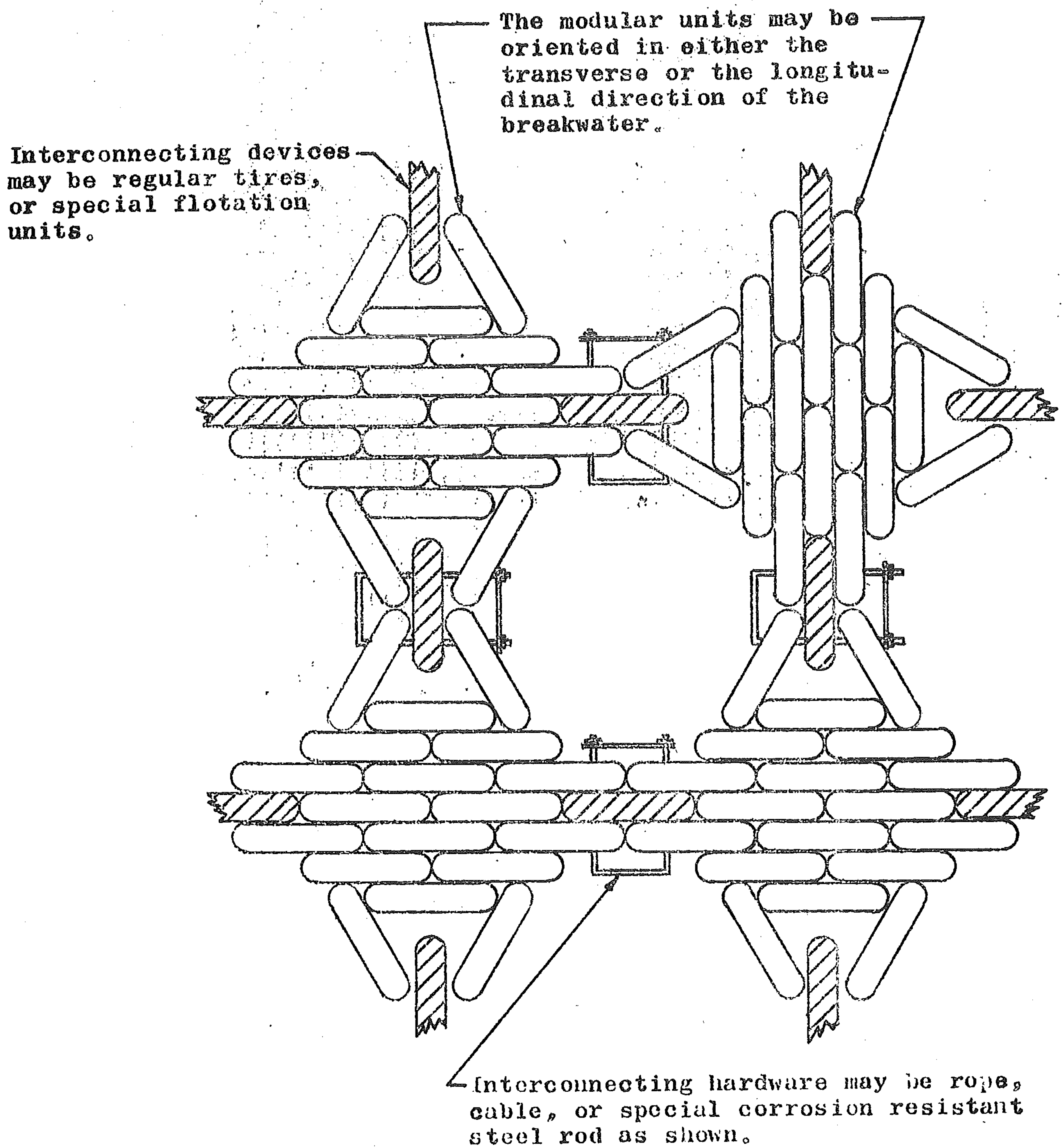


MODULAR UNIT SHOWN AS CONSTRUCTED

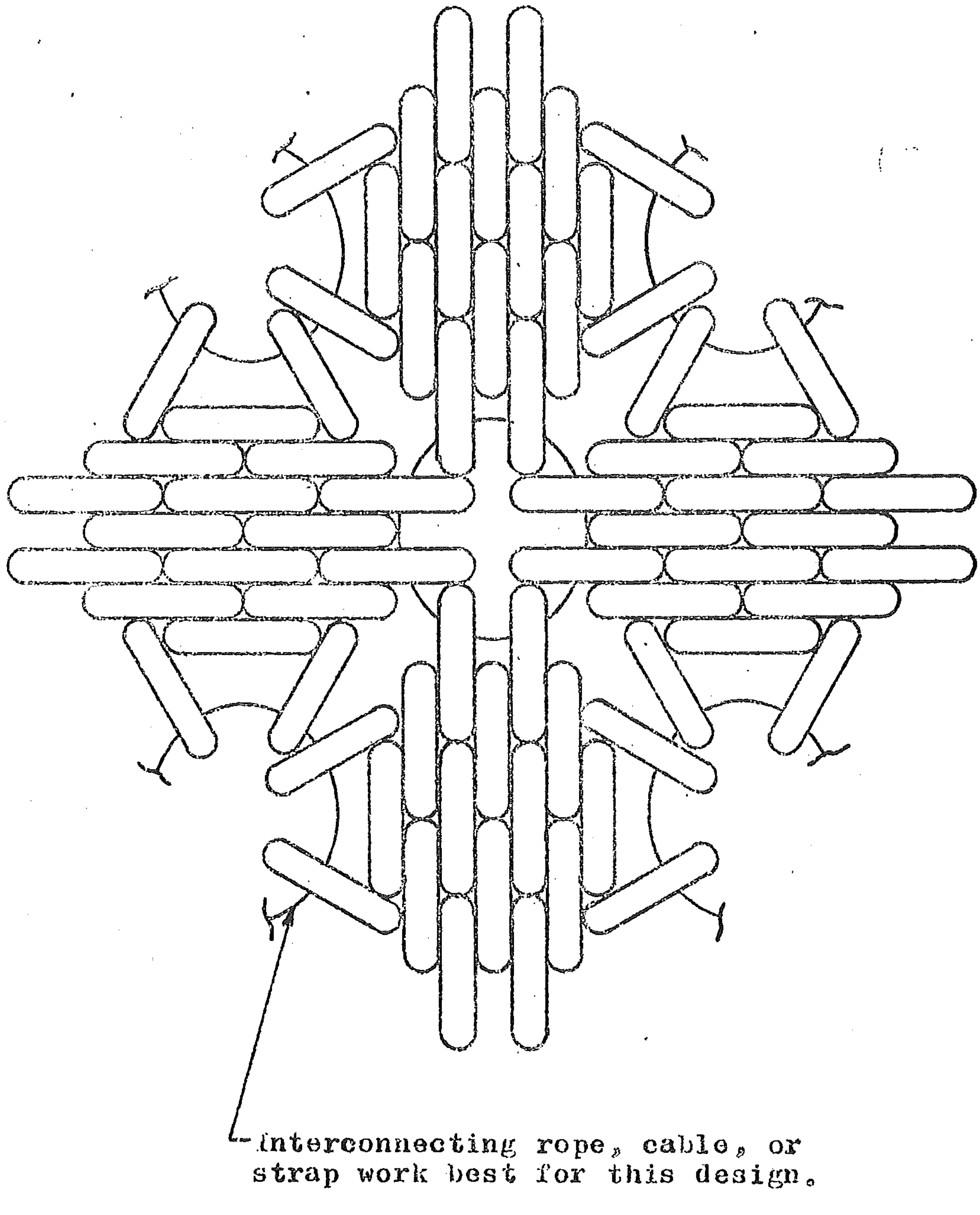


MODULAR UNIT SHOWN AS INSTALLED

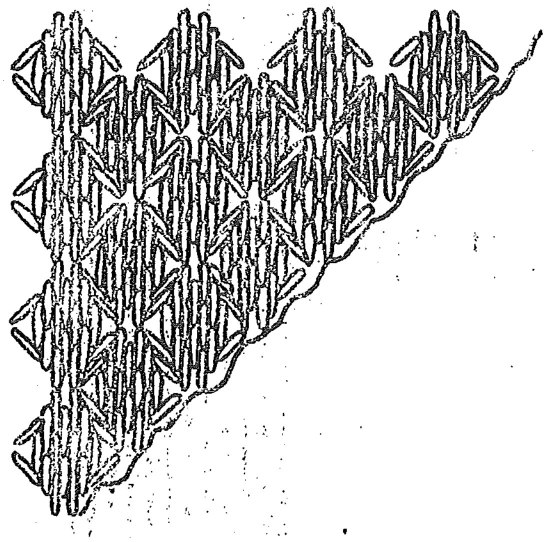
TYPICAL ASSEMBLY DETAILS OF THE GOODYEAR OPEN GRID MAT TYPE FLOATING BREAKWATER UTILIZING THE BASIC SCRAP TIRE CONSTRUCTED MODULAR UNITS



TYPICAL ASSEMBLY DETAILS OF THE GOODYEAR CLOSED GRID MAT TYPE FLOATING BREAKWATER UTILIZING THE BASIC SCRAP TIRE CONSTRUCTED MODULAR UNITS

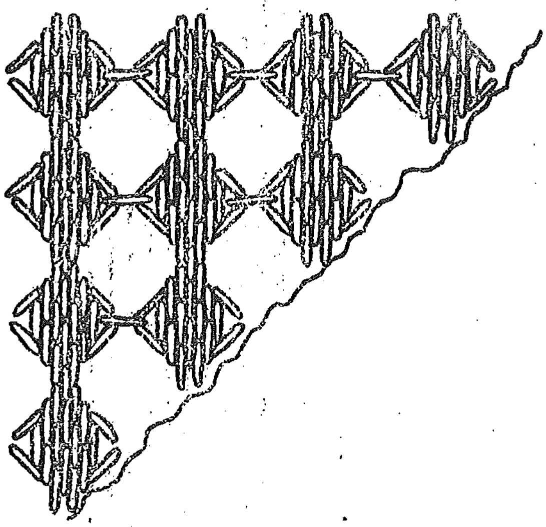


PROPOSED ASSEMBLY CONFIGURATIONS FOR THE GOODYEAR MAT TYPE FLOATING BREAKWATERS UTILIZING THE BASIC SCRAP TIRE CONSTRUCTED MODULAR UNITS



NOTE:
This breakwater may be tethered in either direction. The elasticity of this breakwater is different in each direction

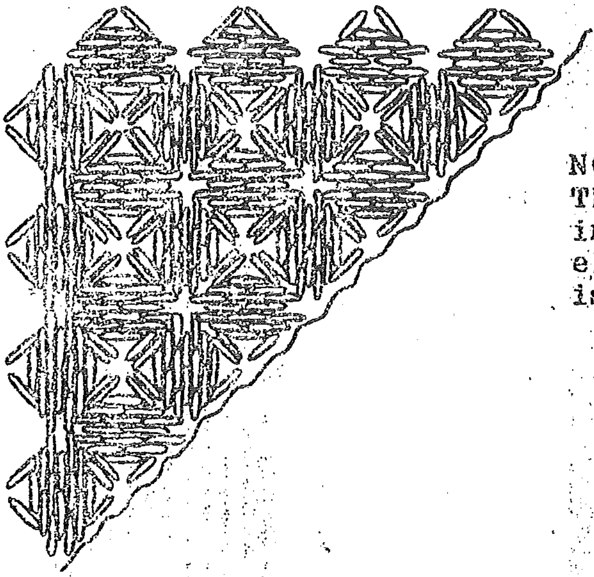
CLOSED GRID UNI-DIRECTIONAL MODULAR ASSEMBLY



NOTE:
(Same as above)

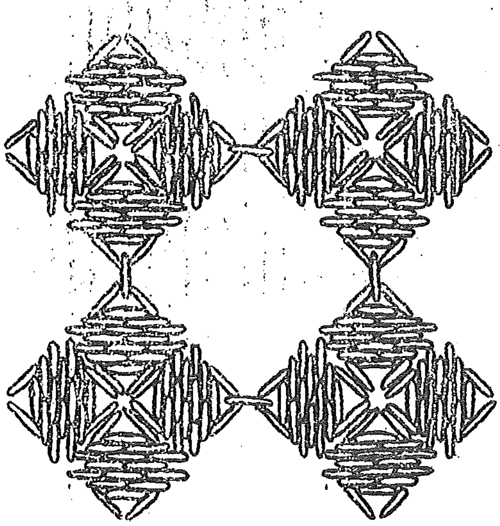
OPEN GRID UNI-DIRECTIONAL MODULAR ASSEMBLY

PROPOSED ASSEMBLY CONFIGURATIONS (CONTINUED)



NOTE:
This breakwater may be tethered in either direction. The elasticity of this breakwater is the same in each direction.

CLOSED GRID BI-DIRECTIONAL MODULAR ASSEMBLY

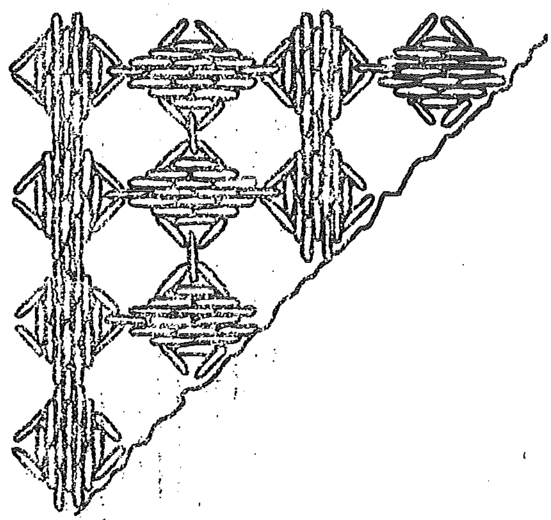


NOTE:
(Same as above)

Also, it is possible to construct a breakwater with different elasticity characteristics by reversing the modular bundle direction in each of the illustrated configurations.

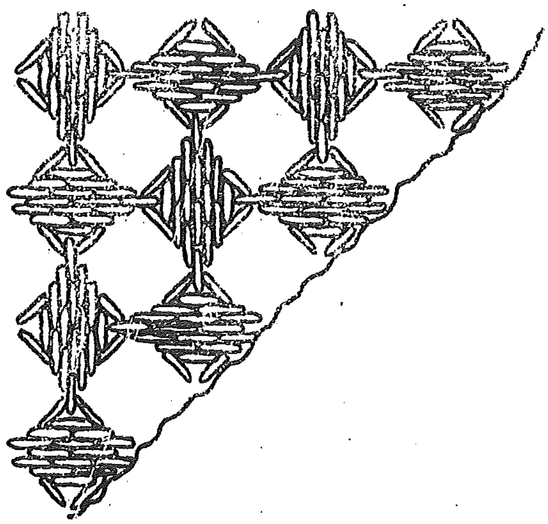
OPEN GRID BI-DIRECTIONAL MODULAR ASSEMBLY

PROPOSED ASSEMBLY CONFIGURATION (CONTINUED)



NOTE:
This breakwater may be tethered in either direction. The elasticity of this breakwater is different in each direction.

OPEN GRID ALTERNATING UNI-DIRECTIONAL MODULAR ASSEMBLY

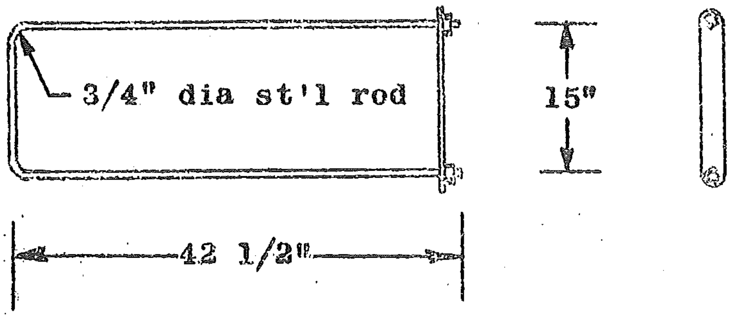


NOTE:
This breakwater may be tethered in either direction. The elasticity of this breakwater is the same in each direction.

OPEN GRID ALTERNATING BI-DIRECTIONAL MODULAR ASSEMBLY

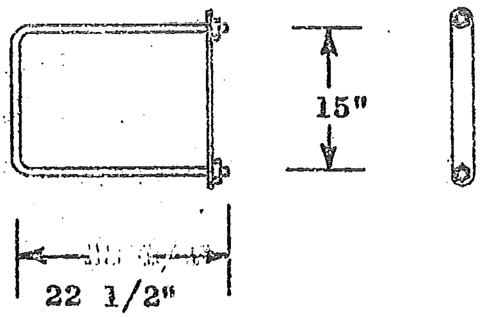
PROPOSED ASSEMBLY HARDWARE AND FLOTATION DEVICES

Interlocking Device - 2 required per module

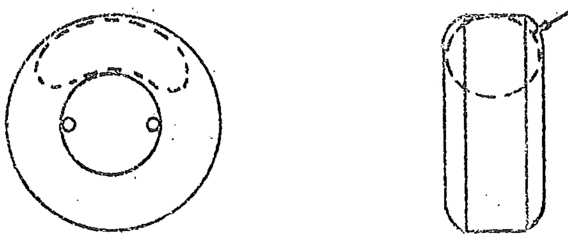


NOTE: All steel surfaces should be double hot dip coated with corrosion resistant zinc.

Interconnecting Device - 2 required per module

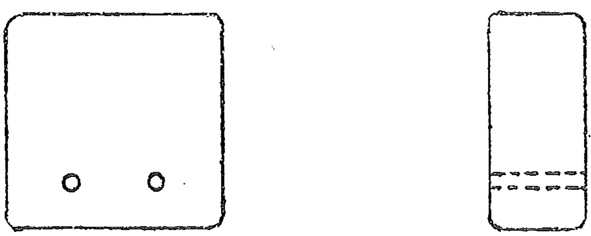


TYPICAL FLOTATION PROVISIONS



Flotation material placed in the crown of each scrap tire as shown. Material may be rigid or flexible foams, or air tight plastic or rubber enclosures.

SPECIAL FLOTATION PROVISIONS



The colorful outer shell may be molded fiberglass, plastic, etc. The inner core may be buoyant foam, balso wood, air, etc.

Flotation:

The basic 20 tire units as assembled weigh approximately 500 lbs; when placed in the water they weigh only about 20% of 500 lbs or 100 pounds.

An old auto tire when placed in the water vertically traps air in the crown portion of the torous shaped carcass. This trapped air provides a buoyant force sufficient to support the weight of the immersed tire, plus 10 additional pounds. Therefore, a bundle of 20 tires provides a buoyant force sufficient to support the immersed weight of the tires plus 200 pounds additional mass.

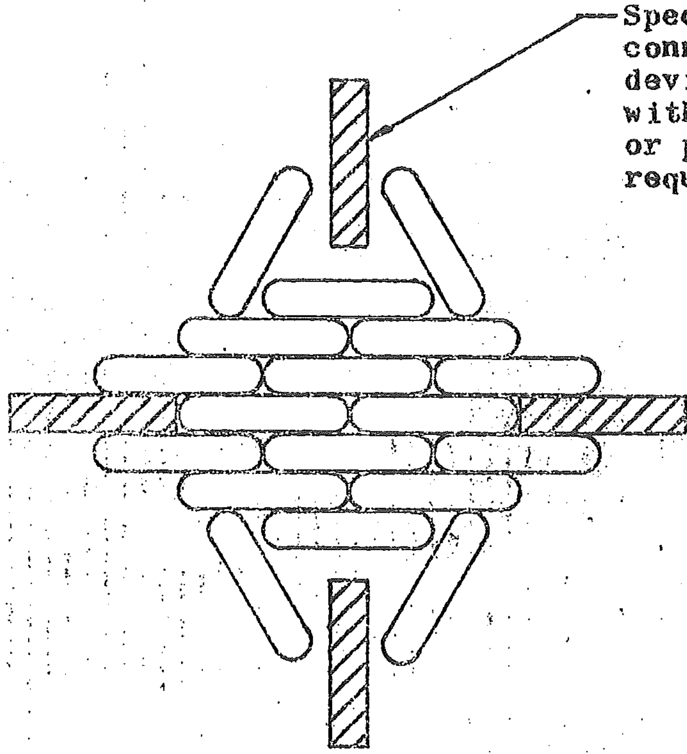
Our full scale testing program has demonstrated that this trapped air does provide more than adequate uniform buoyance for the basic modular construction units. But it is only a matter of time before the trapped air will be dissolved into the water, and then the units will sink. Therefore, to provide lasting uniform flotation it is necessary that permanent flotation material be placed in each tire. Typical flotation materials are rigid urethane or polystyrene foams, closed cell flexible foams, or air tight enclosures such as plastic bags of air, blow molded polyethylene floats, etc. Materials with a buoyancy equivalent to the trapped air volume and positioned in the same crown position will do the job nicely.

The completely uniform flotation provided by this technique is aesthetically pleasing, and will facilitate interconnecting the units in the water. The independent flotation of each unit provides a very stable installation, and the interconnecting hardware is utilized with maximum efficiency.

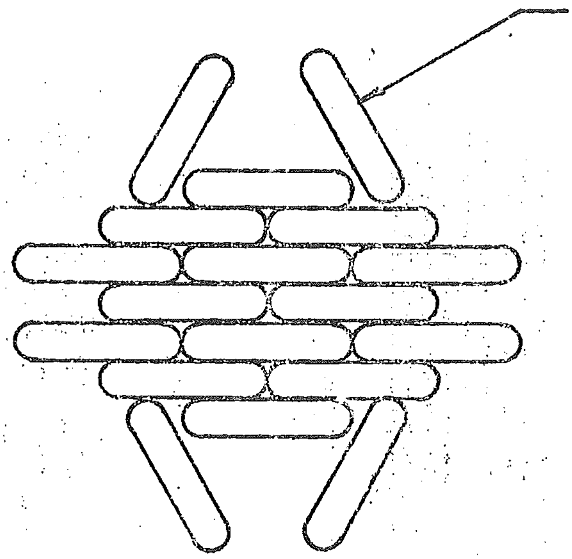
If desired, the buoyancy of the units may be varied by selective placement of the buoyant materials. For installation where aesthetics are not an important factor, it may be more economical to place all of the buoyant material in only 2 of the 20 tires in the basic modular construction units. A scrap tire completely filled with foam has a lift of 100 lbs, using two foamed tires per module, yields a minimum buoyancy force that is at least twice as large as is necessary for floatation of the module. An ordinary tire tube may be substituted for the foam to simplify installation.

For installations where aesthetics are most important, buoyancy may be provided at the interconnecting modular points by use of aesthetically pleasing special designed floats, (not foam filled tires). This will position the bulk of the tire units slightly below the water surface, out of sight, but in an ideal position to attenuate wave energy. The tires may also be painted with a latex or urethane based paint for improved aesthetic appearance. The following sketches illustrate a few of the many variations in buoyancy placements possible.

TYPICAL PROPOSED PLACEMENTS OF FLOTATION DEVICES



Special buoyant inter-connecting devices. The devices may be constructed with reinforced fiberglass or plastic to provide the required 10 year life.



Placing a small amount of buoyant material in the crown of each tire provides completely uni-form ideal buoyancy. Also, any two symetrically located tires completely filled with foam will provide adequate buoy-ancy for the entire bundle.

Draft Variation Consideration:

The length and width of the proposed assembled floating modular mat breakwaters may be varied as desired. The proposed modular units may also be interconnected in the thickness dimension (draft) of the breakwater. Therefore, utilizing the proposed basic modular construction components, one can assemble the floating breakwaters with any variation in draft desired.

The proposed 20 tire basic modular units float with 6" exposed above the water and a 24" draft with uniform buoyant material in the crown of each tire.

Design Consideration:

The basic modular construction components as proposed have equal load carrying capacities in both directions. But the elongations differ in each direction. They have a maximum elongation of 45% in the longitudinal direction, and 30% in the transverse direction. It should be noted that these maximum elongations only occur under extremely high loading conditions, and that the modules do return to their normal shape under no load conditions with no permanent deformation resulting.

The modules may be interconnected in all directions. This allows one to orient each module in any direction desired when assembling the breakwater. Therefore, it is possible to assemble the modules in such a manner as to take advantage of their difference in elongation characteristic. By alternating the direction of adjacent modules one can average the elongations and, therefore, design a mat with equal elongations in each direction, or if desired one can uniformily orient all the modules and produce a mat with 45% elongation in one direction and 30% in the other. This load vs elongation characteristic of the basic module unit adds further to the versatility in designing the scrap tire mat type floating breakwaters.

Utilizing the modular construction concept, one can design breakwaters in nearly any shape and size desired. The shapes illustrated in this report are only representative of the many possible designs. The breakwater designer is urged to use this report as a guide only, and to freely combine any of the shapes and configurations shown to construct a breakwater with the shape requirements to satisfy each individual installation.

Cost Estimate for the Modular Mat Type Scrap Tire Floating Breakwater

Bundle Size = 7' wide x 6 1/2' long x 2 1/2' thick.
Bundle Weight = 500 pounds

Bill of Materials to Furnish and Install this Sub-Assembly:

Material Description	Quantity	Cost Each	Cost
Scrap Tires	18	.15	$ 2.70
Foam Filled Scrap Tires	2	4.00	8.00
Interlocking Hardware	2	18.50	37.00
Assembly Labor	2/3 hr	12.00	8.00
Cost to provide modular bundle sub-assembly			$55.70
Interconnecting Hardware	2	14.00	28.00
Installation Labor	2/3 hr	12.00	8.00
Cost to Assemble and Install Modular Unit			$91.70

Calculations:

Area coverage cost = 91.70 ÷ 7.0 x 6.5 = $2.00 per sq ft.

Cost Summary:

a) Estimated cost to install a closed grid modular mat type scrap tire floating breakwater which has a 30 feet shore-to-sea dimension is 30 x 2.00 = $60.00 per linear foot.

b) Estimated cost to install an open grid modular mat type scrap tire floating breakwater which has a 30 feet shore-to-sea dimension and a 7 by 6 1/2 feet open grid structure is 30 x 2.00 ÷ 2 = $30.00 per linear foot.

NOTE: Estimated costs do not include mooring lines and anchoring costs.

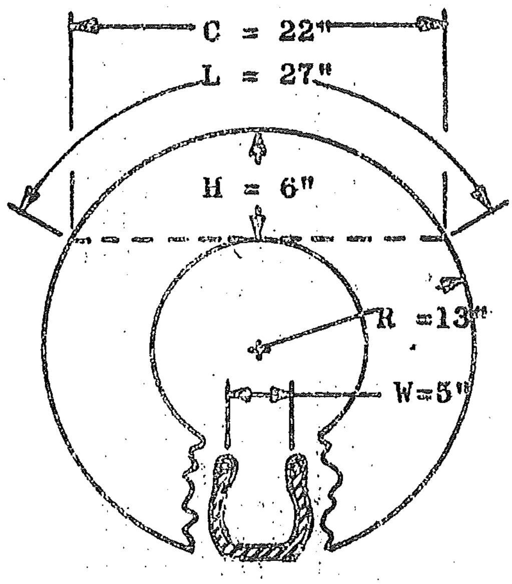
Also, estimated costs do include costly corrosion resistant steel interlocking hardware. If rope or cable are used, the hardware costs can be reduced by one half or more.

September 30, 1974

TECHNIQUE FOR PROVIDING FLOTATION TO THE VERTICAL IMMERSED SCRAP TIRES

The vertical immersed tires used in the floating mats trap a volume of air in the crown area. This trapped air provides approximately 14 lbs buoyancy per tire, but will probably diminish with time due to the air dissolving into the water or from possible physical rejection by wave action. To provide permanent flotation, rigid urethane foam may be used to fill this crown volume. A two component liquid foam mixture of 20:1 expansion ratio may be poured into the tire supported in a vertical position. The expanded foam should fill the crown volume and provide about 13 pounds of total buoyancy.

TYPICAL CALCULATIONS



14" SCRAP TIRE

$$\text{Approx Vol} = \frac{RL - C(R-H)}{2} \times W$$

$$\text{Vol} \approx \frac{13 \times 27 - 22\ (13-6)}{2} \times 5$$

$$\text{Vol} \approx 500\ \text{in}^3$$

Using urethane foam mixture, 20:1 expansion:

$$\frac{500\ \text{in}^3}{20} = 25\ \text{in}^3 \text{ liquid foam mixture}$$

$\approx$ 400 cc $\approx$ .1 gal $\approx$ 1 lb

Cost $\approx$ \$.60/lb

Other possible candidates which might be considered for insertion in a tire to provide flotation, but which have not been tested, include the following:

Item	Cost Estimate
1. Rigid urethane foam (as above)-30:1 expansion ratio	$ .40/tire
2. Ethafoam Rod - 6" dia	$1.61/foot
3. Ethafoam Rod - 5" dia	$1.11/foot
4 1/2 or 1 gal plastic bottles (milk, Clorox, etc)	scrap
5. Special blow molded polyethylene containers	$.50-.60/tire
6. Styrofoam premolded shape	$.50/tire
7. Blown film air container bags, heat sealed ends	$.20/tire
8. Trapped air - for prototype testing	free

ESTIMATING THE NUMBER OF TIRES REQUIRED

The number of tires required for construction of the Goodyear scrap tire mat may easily be calculated if the final mat size is known. Each of the scrap tire building block modules requires eighteen passenger car tires with two connecting tires which gives a total of twenty tires required per unit. Each bundle module will measure approximately 6 1/2 feet wide by 7 feet long when standard 14" and 15" tires are used. The resulting area covered per tire module is about 45 1/2 square feet, as shown in the closed grid mat constructions. For an open grid mat construction, the number of tires would be one half or ten tires for every 45 1/2 square feet of coverage.

F 301 (1-68)

THE GOODYEAR TIRE & RUBBER COMPANY

AKRON, OHIO 44316

Design concepts set forth herein are theoretical, intended only for academic purposes and not recommended or proposed as engineering specifications for practical application.

SUBJECT: Cost Estimate to Furnish and Install the Proposed Goodyear Modular Mat Tire Scrap Tire Floating Breakwater.

Introduction:

There is a need for effective, low cost, mobile floating breakwater devices for lakes, rivers and oceans. Possible locations for such devices include harbors, marinas, swimming areas and shore erosion areas.

Our preliminary research has indicated that simple modular bundles of scrap tires, properly secured together will form easily installed, readily adaptable floating breakwater barriers.

The scrap tires are ideal energy absorbing components. They are inexpensive and nearly non-destructive. The most efficient method of packaging these components is utilized by simply lashing them together with bands in tension.

Summary:

Table of costs to furnish and install a single tire depth, open grid, mat type scrap tire floating breakwater approximately 26' wide.

Length (Feet)	F & I (Man-Hours)	Material Costs for Alternative Constructions: 5 Yr Life	10 Yr Life	20 Yr Life
600	600	$12,000	$18,000	$30,000
500	500	10,000	15,000	25,000
400	400	8,000	12,000	20,000
300	300	6,000	9,000	15,000

Example: A breakwater 600 feet long, and with a life expectancy of 20 years will require 600 man-hours labor and material costs of $30,000.

Alternatively, the same 600 feet long breakwater constructed with materials having a life expectancy of only five years, will require 600 man-hours labor and material costs of $12,000.

Construction:

The breakwater would be constructed from scrap tires, partially foam-filled and fastened together to form modules of 18 tires each, similar to those described in the accompanying reports. A total of 344 modules would be fastened together with appropriate hardware in a configuration four units wide and 86 units long. The breakwater would be moored to the lake bottom by using 28 dead weight concrete anchors with cables attached on the seaward side and 28 cables and smaller anchors on the shoreward side of the breakwater. See Figure 1.

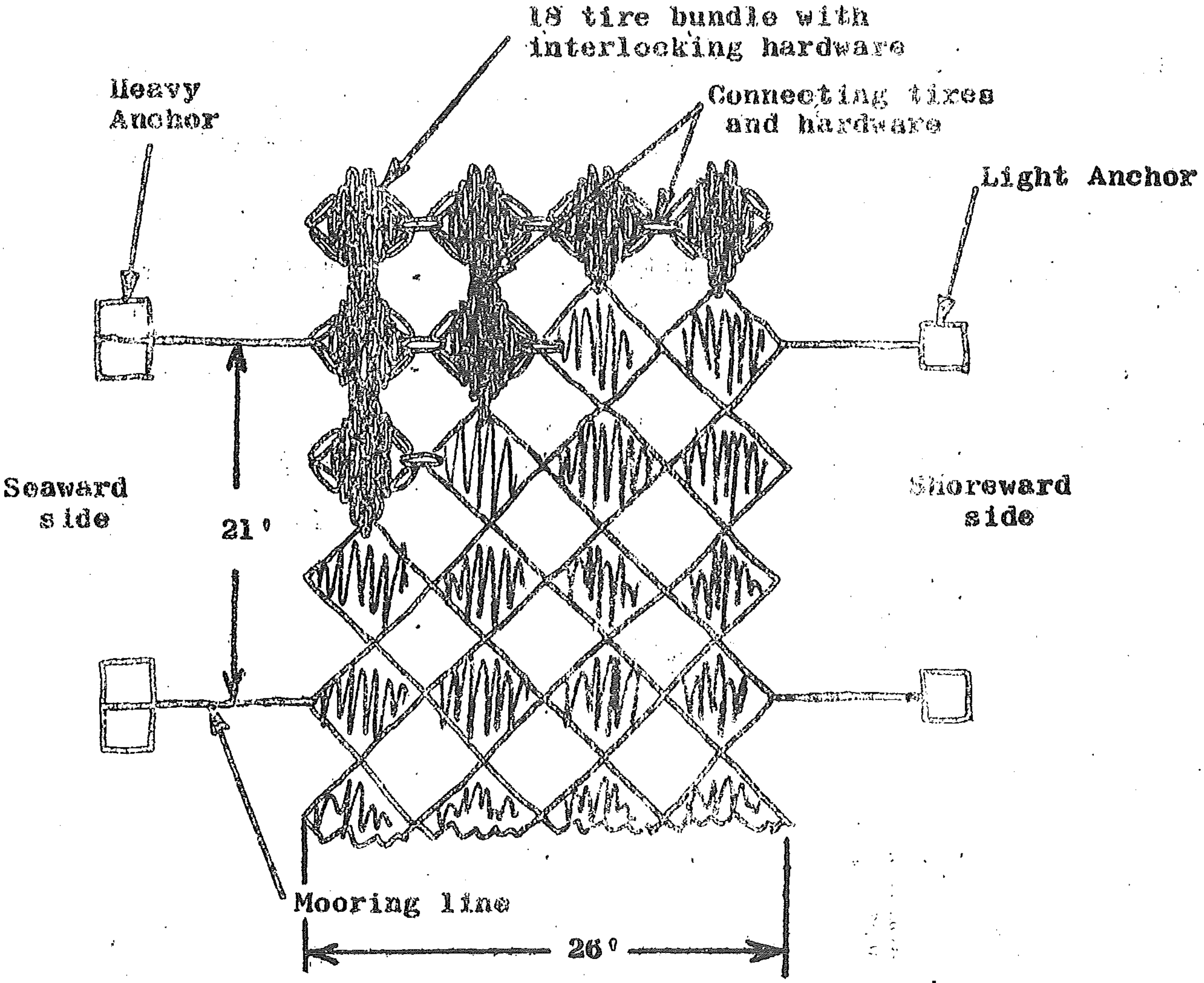


FIGURE 1

OPEN GRID MAT TYPE BREAKWATER

The proposed construction materials and techniques are as follows:

1. Partially foam fill 6790 scrap tires using 400 cc (about 1 lb) of two-component liquid rigid urethane foam mixture poured into the bottom of each tire, with the tire supported in an upright position. A 20:1 expansion ratio foam will provide about 13 lbs of buoyancy in each tire.

2. Construct 344-18 tire modules (6 1/2' x 7') using two interlocking galvanized steel "U" bolt assemblies with plates and nuts to fasten the tires together. Align the tires so all foam is oriented on top side of the modules.

3. If it is desired to paint the top section (foamed area) of the breakwater, it should be done before installing the modules in the water. One method involves dipping the tire into a pan of paint before assembling in the modules. The other technique is to spray or brush paint the top of the modules after assembly. If a urethane paint is used, the tires must be prepared first. Latex, aluminum or urethane paints are possible candidates for marine applications, but life and durability in the water has not been tested.

4. Assemble the four modules wide by 86 modules long breakwater by interconnecting the modules using single tires and the "U" bolt hardware. If possible, sets of two or four modules which form the width dimension might be preassembled on dry land and then rolled into the water to connect with other sets. An alternative to this assembly technique is to connect all the single modules together in the water.

5. Position the assembled breakwater and tether in position, using dead weight concrete anchors attached to the breakwater with galvanized steel mooring lines. Proposed mooring positions would be located on the seaward and shoreward sides, starting at the second bundle from the end and every third bundle thereafter.

It is felt that a minimum of 28 heavy anchors on the seaward edge and 28 lighter anchors on the shoreward side should prove adequate. However, we have little experience in anchoring this particular breakwater design, and it may be necessary to install additional anchors if the breakwater is found to move from its original position.

Calculations:

Cost Estimate for 26' x 600' Breakwater with
a 20 Year Life Expectancy

Item		Quantity	Unit Cost	Cost
1)	Scrap Tires	6790	$ .15	$ 1,019
2)	Urethane Foam	6790 lb	.60/lb	4,074
3)	Interlocking Hardware	688 units	18.50 ea	12,728
4)	Connecting Hardware	598 units	14.00 ea	8,372
5)	Mooring Cable - 1/2" Galv Strand, 1 x 7	1400 ft	.35/ft	490
6)	Mooring Clips (1/2" Crosby)	336	.90 ea	303
7)	Mooring Thimbles (Heavy Galv)	56	.70 ea	40
8)	Handmade 500# Concrete Anchors	28	15.00 ea	420
9)	Handmade 250# Concrete Anchors	28	10.00 ea	280
10)	Labor Estimate - 1 1/3 hr per Bundle-Build & Install = 460 hrs			

Notes:

The major costs are in the hardware and foam components. The costs can be reduced if shorter life expectancy materials are selected.

A. If 3/8" 6 x 19 galv steel cable and cable clips are substituted for 3/4" rod assemblies quoted in items 3) and 4):

3) Total cost of interlocking hardware =

Cable = 6192 ft x $.30/ft = $1858
Clips = 2752 clips x $.60 ea = 1652

Cost = $3510

4) Total cost of connecting hardware =

Cable = 5382 ft x $.30/ft = $1615
Clips = 2392 clips x $.60 ea = 1436

Cost = $3051

Or total cost items 3) & 4) = $6561

B. If 265 lb concrete parking bumpers with eye bolts and nuts are substituted for items 8) and 9):

8) Total cost = 2 bumpers x 28 x $10 ea = $560

9) Total cost = 1 bumper x 28 x $10 ea = $280

C. If 40 lb concrete blocks with 1/2" galvanized strand cables are substituted for items 8) and 9):

8) Total cost =	13 blocks x $.42 ea x 28 =	$153
	14' cable x $.35/ft x 28 =	137
	3 clips x $.90 ea x 28 =	76
	Total cost =	$366
9) Total cost =	7 blocks x $.42 ea x 28 =	$ 83
	10' cable x $.35/ft x 28 =	98
	3 clips x $.90 ea x 28 =	76
	Total cost =	$257

R D Candle

R E Payne

Engineering Research
RESEARCH DIVISION

R D Candle, Section Head
R E Payne
ph

Typed: 10/1/74

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September 30, 1974

THE PROPOSED GOODYEAR SINKING SCRAP TIRE MARINE MAT

by R D Candle
W J Fischer

The following is a procedure for the fabrication of a general purpose sinking marine scrap tire mat for use as an erosion control device. Scrap tires are the main construction material for building these large marine mat type structures.

Modular Bundle Construction:

The basic designs rely on a modular bundle concept where a relatively few tires are secured together to form a small, easily assembled, portable building unit. The Goodyear Scrap Tire Marine Mats are formed by securing together the modular units as shown in Figures 1 and 2. This construction procedure yields an easily installed, readily adaptable structure which has high energy absorbing capacity for normal loading conditions, but which deforms and yields when subjected to overloads.

Interlocking and Interconnecting Hardware:

a) Galvanized Rod Type:

The scrap tire modules are fabricated by interlocking the worn-out tires to form a compact bundle. "U" bolt type devices as shown in Figure 3 may be used to interlock the tires. A 3/4" diameter steel rod is bent into a 42 1/2" long by 15" wide "U" bolt configuration with 6" long threaded ends to form the interlocking hardware. All steel components are double galvanized to provide maximum corrosion resistance. The interconnecting hardware is identical to the interlocking "U" bolts except that they are only 22 1/2" long. Two interconnecting and two interlocking "U" bolts are required for each bundle assembly.

b) Non-Corroding Wire Rope Type:

The "U" bolt type interlocking devices used in the bundle modules may be replaced with high strength stainless or galvanized wire rope in some applications which do not require the added strength and long life of the 3/4 diameter steel rods. Two nine foot lengths of cable are required to interlock the tires into the modular bundle, and two six foot lengths are required to interconnect the bundles to form the mat assemblies. Each cable requires two cable clips. These scrap tire modules are capable of being constructed with simple hand tools, and require no special handling equipment. Cable sizes up to 3/8" diameter may be used.

c) Synthetic Rope Type:

Synthetic rope may be used for light duty and short life expectancy installations. Many types of synthetic rope such as nylon, Dacron, polypropylene, and polyethylene are suitable for marine applications. But, due to the abrasive nature of the scrap tire mats, the service life of this type of assembly may be short.

d) Plastic Strap Type:

Another possibility is to band the tire bundles with high strength reinforced plastic or metal straps. This method would only be recommended for light duty, or prototype assemblies due to the low strength and the short service life of the bands and the fasteners that hold them.

Selecting the Interlocking Hardware:

The type of interlocking hardware which is used in the construction of the Goodyear Scrap Tire Marine Mat will be dependent upon the desired strength and expected service life of the installation. The estimated breaking strength of each interlocked tire module is about 24,000 pounds in both the longitudinal and transverse directions. This figure is calculated by using the tire bead breaking strength. An equivalent strength in the interlocking hardware would provide an optimum performance, but may not be necessary for all applications.

Factors which should be taken into consideration when selecting hardware are service life, maintenance requirements, installation, location and overall mat size. The design engineer on each project must select the most economical combination of construction components to best suit the particular requirements of the site.

Estimating the Number of Tires Required:

The number of tires required for construction of the Goodyear Scrap Tire Mat may easily be calculated if the final mat size is known. Each of the scrap tire building block modules requires eighteen scrap tires with two connecting tires which gives a total of twenty tires per unit. Each bundle module will measure approximately 6 1/2 feet wide by 7 feet long when standard 14 and 15 inch tires are used. The resulting area coverage for the closed grid mat construction as shown in Figure 5 is about 45 1/2 square feet per bundle. For an open grid mat design such as shown in Figure 6, the number of tires would be reduced by one half or ten tires for every 45 1/2 square feet of coverage.

Venting the Tires for Erosion Mat Applications:

It will be necessary to provide ventilation holes in the tires for applications where the mats are installed on the lake or ocean floor. A single 2" diameter or larger hole in the tread of each tire is recommended to allow trapped air to escape.

The tires must be oriented at assembly such that the vent holes are located at the top of the mats to allow trapped air to escape.

A simple hand punch and mallet may be used to punch the required vent holes. The punch can be mounted on a frame, as is shown in Figure 4, to simplify the operation.

Another simple method of venting the tires is to use an electric drill motor and a circle cutter or hole saw.

For applications which require a large number of vented tires, it may be more economical to use an automatic punching device. An air operated power punch was designed by The Goodyear Tire and Rubber Company for punching vent holes in tires for use in our artificial reef projects. Detailed drawings of the power punch may be obtained by writing to: Community Relations Manager, Department 798, The Goodyear Tire and Rubber Company, Akron, Ohio, 44316. The power punch can be built by most commercial machine shops, or the punch may be ordered from the Reliable Manufacturing Company, 2689 Wingate, Akron, Ohio, which produced the prototypes for Goodyear. The purchase price for the power punch in June 1974 was $2200. The punch requires 100 psi air pressure for operation. If this is not available, a gas driven compressor of sufficient size may be purchased for approximately $800, or an air compressor may be rented.

Scrap Tire Sources:

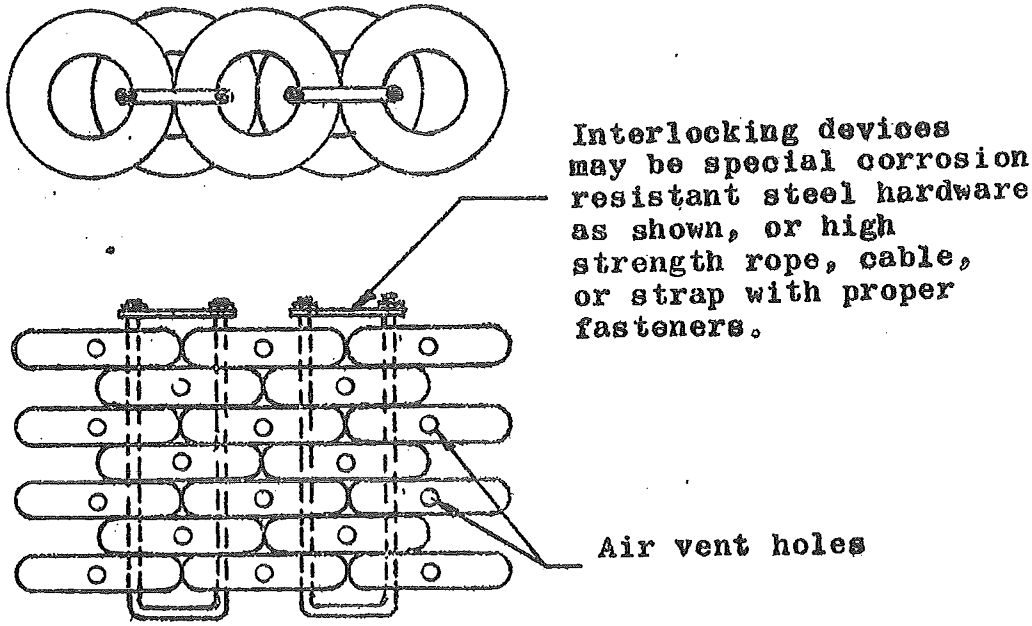
Obtaining the worn-out tires to build a scrap tire marine mat should be no problem in any area of reasonable population density. Recapping shops, service stations, and tire dealers are always looking for ways to dispose of scrap tires. Also, municipal and private waste haulers must find ways to dispose of tires which they collect.

Used tires may also be purchased. Normal charges range from $10 to $20 per ton (approximately 100 tires) delivered to your construction site. Often publicizing your need for scrap tires and providing a convenient drop-off or collecting station will produce an over abundance of tires. Standard 14" and 15" passenger tires work best for marine mat applications.

THE PROPOSED GOODYEAR SCRAP TIRE MODULAR CONSTRUCTION UNIT

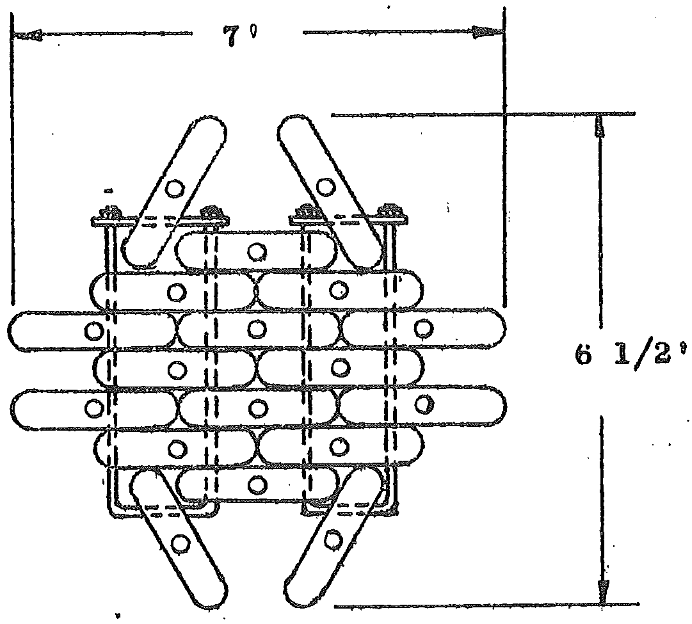
(Side View)

(Top View)



Modular Unit Shown as Constructed

Figure 1

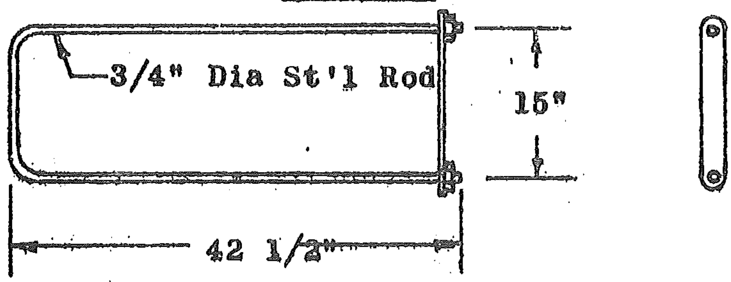


Modular Unit Shown as Installed

Figure 2

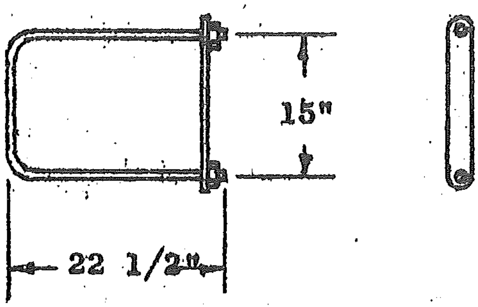
PROPOSED ASSEMBLY HARDWARE

FIGURE 3



Note: All steel surfaces should be double hot dip coated with corrosion resistant zinc.

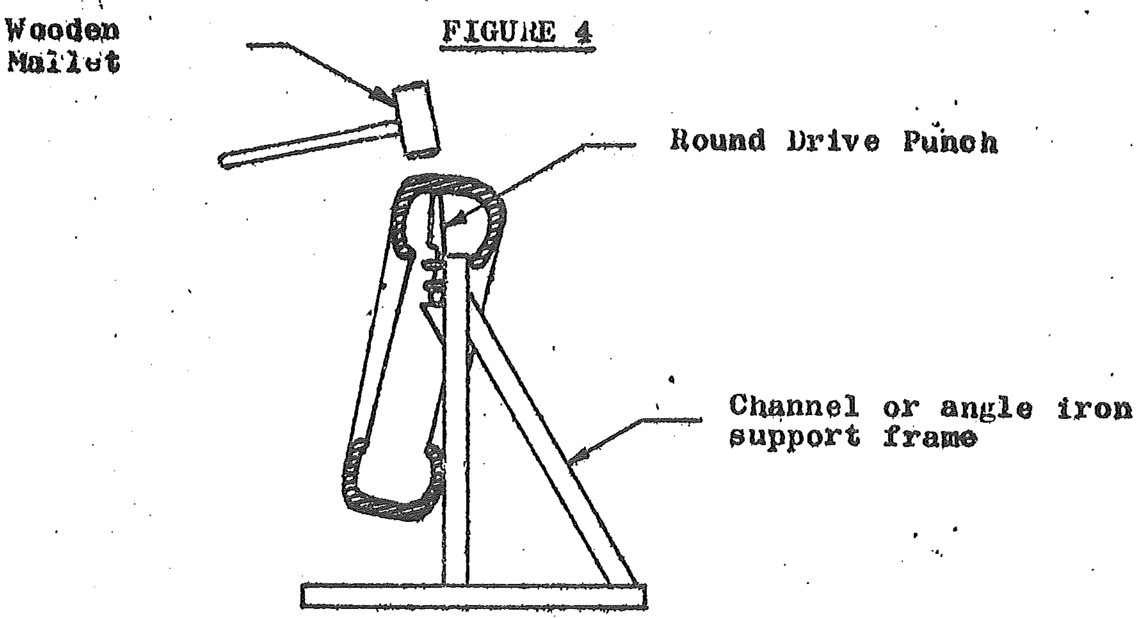
Interlocking Device - 2 required per module



Interconnecting Device - 2 required per module

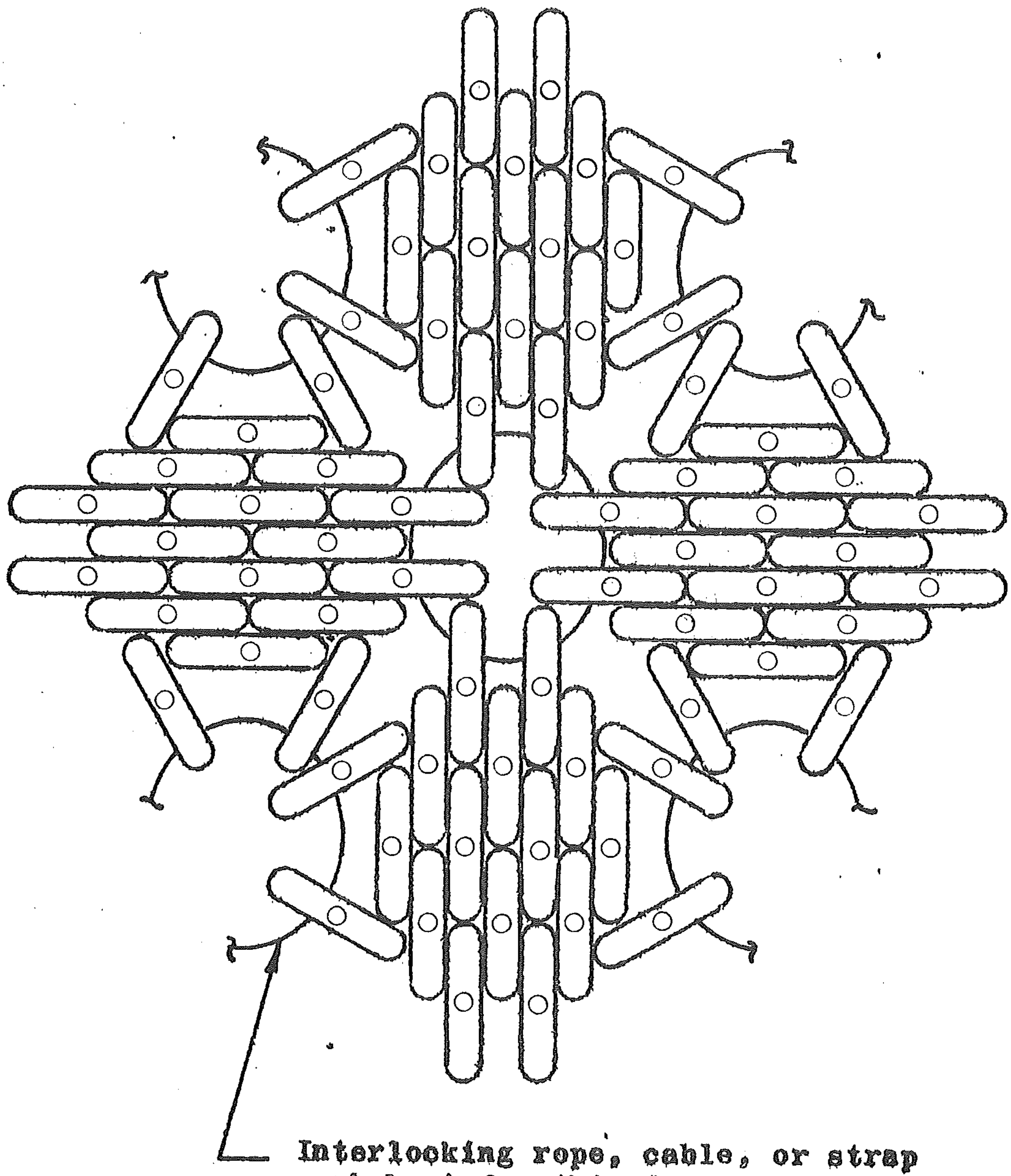
HAND PUNCH AND FRAME

FIGURE 4



TYPICAL ASSEMBLY DETAILS OF THE GOODYEAR CLOSED GRID MAT UTILIZING THE BASIC SCRAP TIRE CONSTRUCTED MODULAR UNITS

FIGURE 5



Interlocking rope, cable, or strap work best for this design.

TYPICAL ASSEMBLY DETAILS OF THE GOODYEAR

OPEN GRID EROSION MAT UTILIZING THE BASIC SCRAP TIRE

CONSTRUCTED MODULAR UNIT

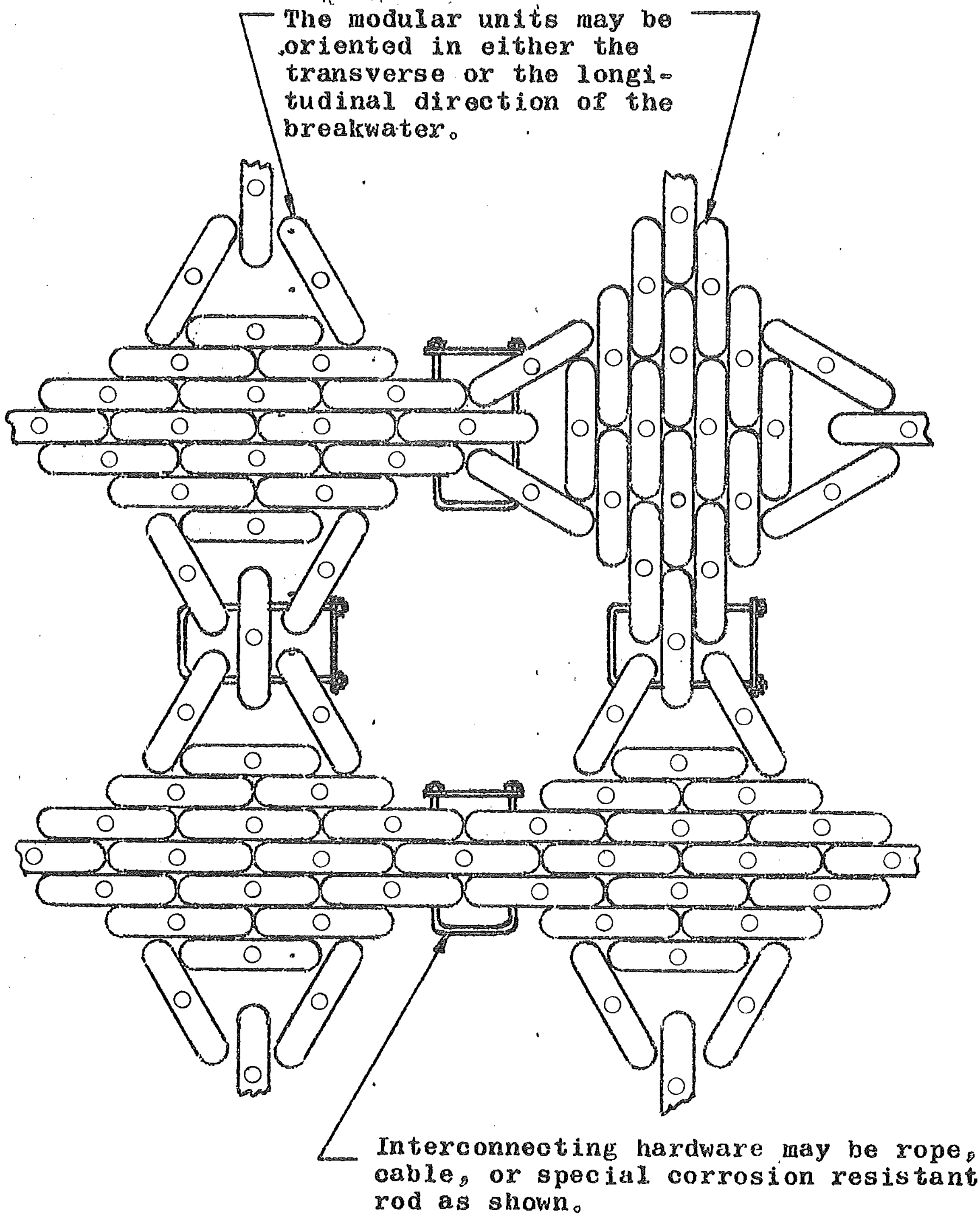


FIGURE 6

Cost Estimate for the Goodyear Scrap Tire Marine Mat:

Bundle Size: 7 ft long x 6 1/2 ft wide x 2 1/2 ft thick.
Bundle Weight: Approximately 400 pounds.

Bill of Materials to Furnish and Install Sub-Assemblies Using Hand Punching Technique and Steel Rod Connectors:

Material Description	Quantity	Cost Each	Cost
Scrap Tires	20	$ .15	$ 3.00
Tire Venting Labor *	1/2 hr	12.00	6.00
3/4" Steel Interlocking Rods **	2	18.50	37.00
Assembly labor	1/2 hr	12.00	6.00

Cost to provide modular bundle sub-assembly - $52.00

3/4" Steel Interconnecting Rods **	2	$14.00	$28.00
Installation Labor	1/2 hr	12.00	6.00

Cost to assemble and install unit - $86.00.

Calculations:

Area Coverage cost = $86.00 ÷ 6.5' x 7' = $1.89 per sq ft.

Bill of Materials to Furnish and Install Sub-Assembly Using Automatic Punch and Steel Cable Connectors:

Material Description	Quantity	Cost Each	Cost
Scrap Tires	20	$ .15	$ 3.00
Tire Venting Labor *	1/4 hr	12.00	3.00
3/8" Galvanized 6 x 19 wire rope	18 ft	.30	5.40
3/8" Grosby-Laughlin Cable Clips	4	.92	3.68
Assembly Labor	1/2 hr	12.00	6.00

Cost to provide modular bundle sub-assembly - $21.08

3/8" Galvanized 6 x 19 wire rope	12 ft	$ .30	$ 3.60
3/8" Crosby-Laughlin cable clips	4	.92	3.68
Installation labor	1/2 hr	12.00	6.00

Cost to assemble and install modular unit - $34.36

Calculations:

Area coverage cost = $34.36 ÷ 7.0 x 6.5 = $ .75 per sq ft.

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* Estimated costs do not include initial cost of mechanical tire punch.

** Estimated costs do not include costly corrosion resistant steel interlocking hardware or mooring lines.

Cost Summary:

a) Estimated cost to install a closed grid modular scrap tire mat which has a 30 feet shore-to-sea dimension is:

For Hand Punching and Galvanized Steel Rod Connectors

30 x $1.89 = $56.70 per linear foot.

For Automatic Punching and Galvanized Steel Cable

30 x $ .75 = $22.50 per linear foot.

b) Estimated cost to install an open grid modular scrap tire mat which has a 30 feet shore-to-sea dimension and a 7 ft x 6 1/2 ft open grid structure is:

For Hand Punching and Galvanized Steel Rod Connectors

30 x $1.89 ÷ 2 = $28.35 per linear foot.

For Automatic Punching and Galvanized Steel Cable Connectors

30 x $ .75 ÷ 2 = $11.25 per linear foot.