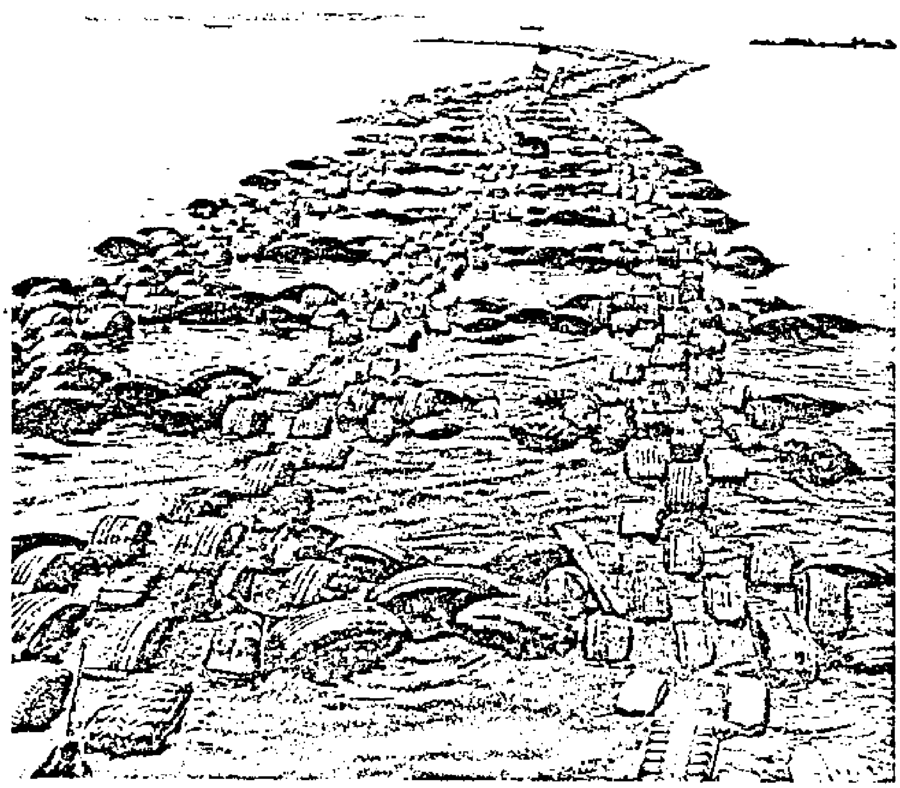
CONSTRUCTING FLOATING TIRE BREAKWATERS

Neil W. Ross
Marine Recreation Specialist
Marine Advisory Service
University of Rhode Island
Narragansett, RI

This paper updates the publication: How To Build a Floating Tire Breakwater, by Tadeusz Kowalski and Neil Ross, University of Rhode Island, Marine Bulletin No. 21, Narragansett, RI. 1975.

Paper presented at the American Chemical Society Symposium Conservation in the Rubber Industry, Chicago, ILL., May 5, 1977.

Breakwaters absorb the energy of incoming waves. Water on the "protected" side remains calm.



A 300' x 20' floating breakwater in Narragansett Bay.

LOW-COST SHORE PROTECTION

A marina cannot survive in an exposed location without protection against waves. Yet the cost per linear foot for conventional breakwaters ranges from $200 for wood bulkheads to more than $500 for rock groins. Thus, in 1972 several marina owners asked the Marine Advisory Service (MAS) at the University of Rhode Island to find out how to construct less costly breakwaters.

In the process of the MAS study, the Goodyear Tire and Rubber Company was contacted about their idea for using scrap tires for breakwaters. This report explains how the Goodyear modular design, for which a prototype was built, tested, and further developed at URI, can now be used by marinas to construct their own breakwaters at a cost per linear foot of less than $50.

The tests performed on the 100 x 25 x 2½-foot prototype showed it could reduce by 75 percent the wave heights of 3- to 4-foot waves, and up to 100 percent the height of ½-foot waves. This means that a typical 35-foot long, 3-foot-high wave, on the sea side of the breakwater is reduced to a wave 9 inches high on the lee side. Smaller waves are reduced by larger proportions, resulting in a much smoother sea behind the breakwater. This size of breakwater also suppresses almost entirely the wake from passing motor boats.

Besides low costs, these breakwaters present other advantages. They can be used where surface-to-bottom breakwaters are not feasible because of soft bottom, deep water, or problems of sand and silt transport, and they can be moved as needed. For example, they may be moved against the docks in the winter, then moved out to provide a sheltered anchorage area in the spring. With scrap tires accumulating in this country at a rate of about 200 million yearly, the breakwater utilizes a resource which is readily available at very low cost.

SOURCES OF TIRES

With an estimated existing stockpile of more than 2 billion scrap tires in the United States, marinas should not have much difficulty obtaining them. Large quantities are usually available from tire dealers, recapping centers, truck stops, highway departments, and town dumps. Most are eager to dispose of them and will even deliver them to the marina for a modest fee or free of charge.

WHAT THEY'RE LIKE AND WHAT THEY CAN DO

The present design calls for a vertical arrangement of tires, with supplemental buoyancy in the tire crowns. The construction is very simple and requires a minimum of tying material. These tires float approximately six inches out of the water and two feet submerged, providing about ten pounds of reserve buoyance per tire, or 200 pounds per unit of 20 standard (14-15 inch) tires. An effective unit must be of sufficient size to cope with local seas, and the design of a breakwater depends on the three principal dimensions of a unit.

Length: or the dimension parallel to the oncoming waves, is determined by the size of the area to be protected. The best arrangement in a cove is two overlapping breakwater sections that extend outward from the shore to form an "entrance" where the two sections cross. However, if the predominant direction of the waves is known, a shorter breakwater facing the waves may be sufficient; its length and its shape would then depend on the physical characteristics of the area to be protected as well as a consideration of wave diffraction around the ends of the unit. To control diffracted waves, a longer breakwater or an L-shaped one may be needed.

Beam: or width, is determined by the predominant wave length in the area to be protected. Increasing this dimension increases the suppression of wave height. The rule of thumb is that *the beam must be greater than half of the significant wavelength.*

To determine significant wave length, first determine the period (T) of the oncoming waves by measuring the average time in seconds between two successive wave crests passing a given point (such as piling or buoy) during an interval of about five minutes. Then calculate the significant wave length (L) using the formula: $L=5T^2$. This formula applies to deep-water waves or those where the depth of water is greater than half of the wavelength (L). In shallow water, the calculation is not as simple. For this design, however, the above formula is more than adequate.

Draft: or immersed depth, is determined by the height of significant waves occurring in the area. Again a rule of thumb: *draft should be greater than half of the height of the significant wave.* Breakwaters built of standard automobile tires are effective in seas of up to five feet high. Such breakwaters will suppress about 70 to 85 percent of the incoming wave height. Larger truck or tractor tires will increase the depth of the breakwater and control higher waves.

FIRST STEPS-SELECT A LOCATION AND GET THE PERMITS

Location: of the breakwater should be arranged with the leading edge parallel to the on-coming waves. The breakwater should be moored as close as possible to the protected area so that the wind will not have sufficient fetch to rebuild the waves behind the breakwaters.

Since the breakwater is very mobile, the best location can be found by trial. In fact, it can be shifted according to the seasonal variations in wave direction. To prevent the breakwater from sinking, it should be placed far enough offshore to avoid touching bottom at low tide or in low waters. The returning tide or rising mats may fill the tires with sand and sink them. For this reason, we do not recommend using these breakwaters without supplemental flotation in highly silted rivers. In high silt transport areas, the breakwater may continue to float if 2 x 3-inch holes are cut in the bottom of each tire to allow the sediment to wash through. This has not yet been tried.

Permits: In most places in or out of the water today, building permits, which sometimes require a statement on environmental impact, are required. Before beginning construction, contact local and state authorities and the U.S. Army Corps of Engineers to obtain the necessary permits. The process may delay the project simply because of the unfamiliarity of officials with these structures.

Additional delays can be avoided by filing for all permits at the same time. If any seasonal changes of the floating tire breakwater location is anticipated, the locations and approximate dates should be indicated on the permit site drawings.

HOW TO BUILD THEM

Tire floating breakwaters are formed by securing together bundles of 18 tightly interlocked scrap tires.

The result is an easily installed, readily adaptable structure with a high energy-absorbing capacity for normal loads. It deforms and yields when subjected to overloads.

Its design possibilities are virtually limitless. The bundles of tires can be constructed with simple hand tools and require no special equipment. It has been estimated that two unskilled laborers can build one bundle in 20 minutes. Moreover, the tires are used "as is."

Building Bundles and Mats: To make one bundle, secure 18 tires together as shown in Figures 1 and 2. This may be done on shore, but bundles are tied together in the water to form the breakwater mat. An easier method is to build each bundle on a dock or bulkhead. Stack the tires flat, but vertically, in a 3-2-3-2-3-2-3 combination (Figure 2), weaving the tying material through as you go. The increasing weight of the tire stack will compress the tires sufficiently to allow easy fastening of the tying material. By sitting on top of them you can compress them more, if needed. Next push the top of the bundle out toward the water, and the whole unit will tumble into the sea. It will float properly and will expand to pull the tying material sufficiently taut but without distorting the tires. If the bundle is fastened too tightly, some tires will stay crushed and will not hold enough air for floation.

Tow the unit over to the other bundles for securing. Be careful not to beach a tire bundle because it will rapidly fill with sand and will not float again. Swing the four outside tires about 130° as is shown in Figure 3. To attach one bundle to others requires two additional connecting tires, bringing the total number of tires per unit to 20.

To tighten the bundles together in the water, thread a piece of rope with eyes at each end through the connecting tires. With a 2 x 3 inch board placed through the two eyes, twist the rope enough to pull bundles tightly together. Next weave the permanent tying material through the 5 connecting tires and secure, before releasing the twisted rope.

The resulting mat, shown in Figure 4, has great strength-as much as 55,000 pounds' breaking strength on a seven-foot spaced longitudinal and transverse-grid with the ability to absorb great amounts of energy by yielding and deforming. This provides safety not available in protection structures of conventional materials. A breakwater of approximately 500 x 21 feet will contain 213 bundles, or 4260 automobile tires.

Flotation: Assembled, the basic 20-tire units weigh approximately 500 pounds, but when placed in water they weigh only about 100 pounds. Since the tires are placed vertically in the water, the *air trapped in their crowns provides sufficient buoyance* to keep approximately 6 inches of each tire above the water. The pumping action of the waves replenishes the air in the crowns. A unit of 18 tires plus two connecting tires provides approximately 200 pounds of buoyancy. Care must be taken not to use tires with holes through which the air can escape.

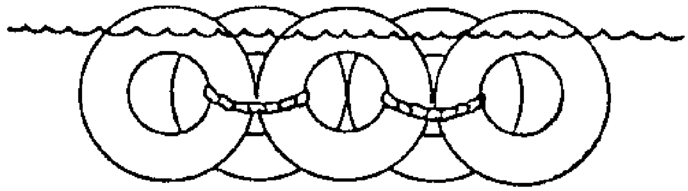


Figure 1: Side view of bundle of 18 tires in the water.

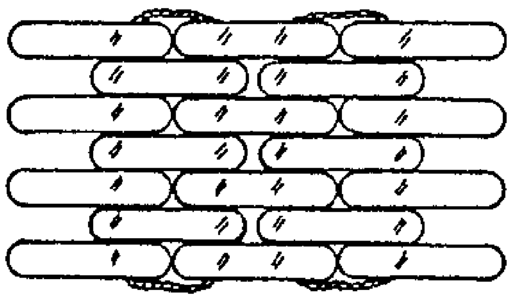


Figure 2: Top view of the same bundle as it is constructed on land.

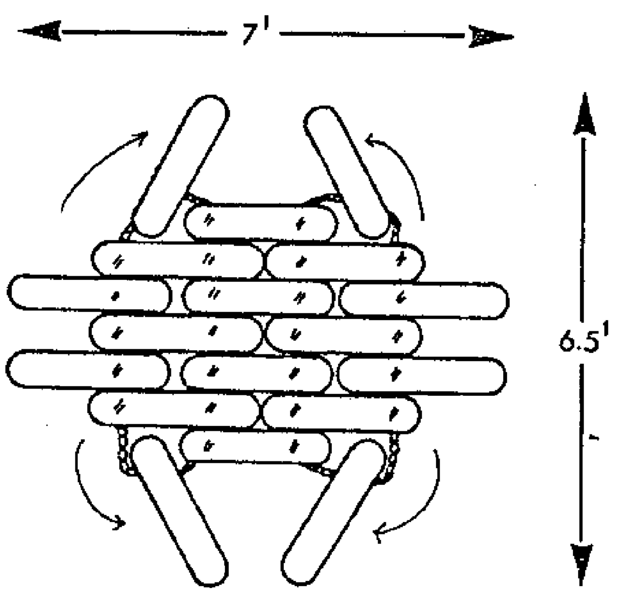


Figure 3: Top view of the same bundle preparatory to attachment to other bundles.

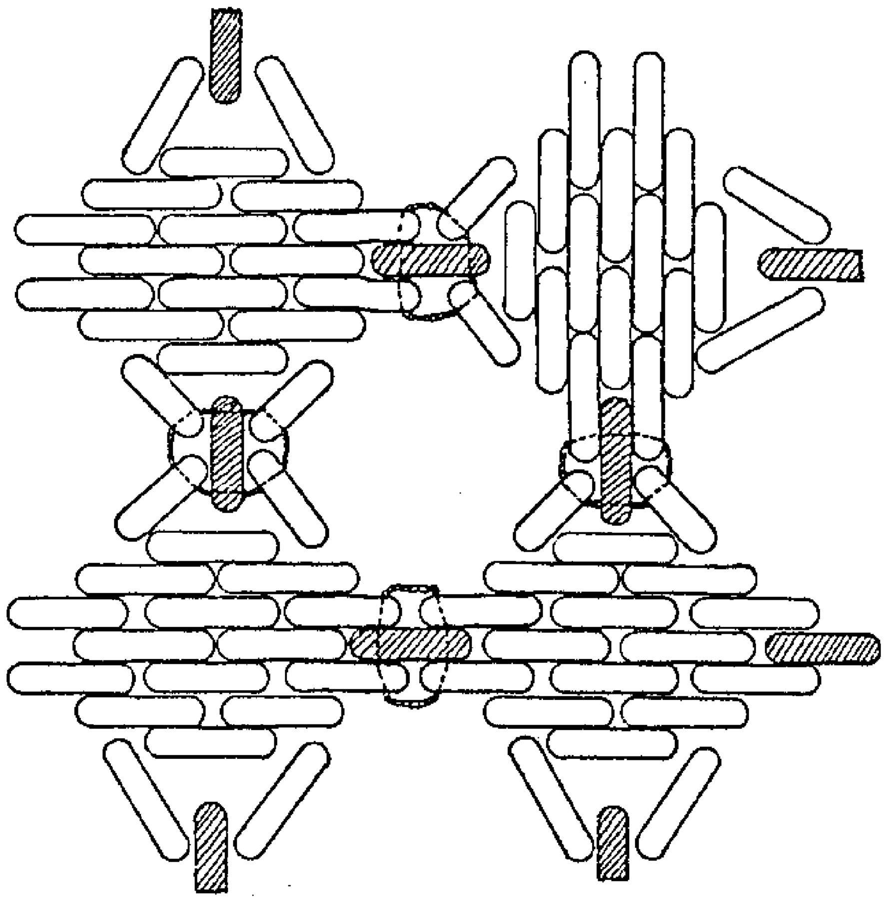


Figure 4: Top view of four bundles attached. Cross-hatched tire connects bundles. Bundles may be oriented parallel or alternate bundles may be turned at right angles.

Breakwaters in salt water have proven to be excellent artificial reefs, but this success has caused problems. In southern New England, floating tire breakwaters without supplemental flotation began to sink from the weight of extension fouling during their second year of use. When this heavy fouling condition exists, it is very important to clean or scrape off the growth annually, or more often if the structure shows signs of sinking.

Should a tire breakwater sink, it can be easily raised by first giving it a cleaning and then blowing compressed air into the tires. In colder climates hauling the breakwater ashore for several days of sub-freezing weather will kill the growth, which will fall off when the system is returned to the water. Anti-fouling paint is not recommended for use on the tires, for both ecological and economic reasons.

In waters where marine fouling is a problem, it is recommended that supplemental foam flotation fill one-third of each tire crown. The easiest way to install foam is to pour liquid urethane foam into the tires prior to assembling the bundles. The foam can be mixed and poured in by hand, or injected with a spray nozzle. While floating tire breakwaters are inexpensive when compared to fixed breakwater systems, it is false economy to neglect the use of foam flotation when fouling or extended periods of calm water may be a problem.

TYING MATERIALS

The ideal tying material should be able to hold together for ten years in an aerated-seawater condition subject to corrosion, fatiguing, and abrasion-and at a reasonable cost. In fresh water, corrosion and abrasion will be less of a problem.

The tying material is the weak link in the floating tire breakwater system. After four years of research and field observations, the following materials can be recommended for use:

1) Conveyor belt edgings: This scrap product, resulting from the trimming of conveyor belts, appears to be the best material for use in breakwaters and has an estimated life of 5 to 10 years in salt water. Three-ply belting, 3" x 3/8" thick, when fastened together with 2½" nylon bolts, nuts, and washers, has minimum tensile strength of 2,100 lbs. The nylon fasteners should be dyed black to make them resistant to ultraviolet light. While belting is not an "off-the-shelf" item, it is available from a few scrap belt distributors and may be split from either new or used conveyor belts, such as those used in sand and gravel operations. The combination of conveyor belt edging and nylon bolts comes closest to the ideal tying material for use in salt water.

2) <u>Galvanized steel chain</u>: Five-sixteenths-inch galvanized steel chain secured with galvanized steel shackles should work well for 2-3 years as a tying material in salt water. The cost and weight of the chain are its major disadvantages.

3) <u>Polypropylene line</u>: Half-inch diameter braded polypropylene line is also recommended as a tying material and should last for 2-4 years. Since knots tend to loosen easily with polypropylene line, splicing the ends together is recommended. Ultraviolet resistant polypropylene is available and might be considered for use in clear, fresh water where light damage could occur.

4) <u>Half-inch special nonwelded chain</u>: The 1/2" floating breakwater chain is made by the Campbell Chain Co. It is formed from nonwelded links of mild steel with links averaging 3-5/8" and with no protective coating. It weighs 1.9 lbs./ft. This chain has been used successfully on several large breakwaters in fresh water and can be recommended for such sites. Salt water testing, however, has shown fairly rapid corrosion and loss of strength. It is therefore not recommended for marine locations. Price and weight are additional disadvantages to the use of this chain. It is, however, easy to install.

<u>These tying materials are not recommended for use in salt water</u>: a) Nylon lines. This rope demonstrates poor abrasion resistance, knot loosening, and ultraviolet degradation; b) Kevlar line. The internal fiber friction during flexing of the rope severely reduces its strength; c) Any metallic wire rope, such as plain steel, galvanized steel, or stainless steel, is not recommended because of corrosion problems particularly around the clamped or swedged ends, metal fatigue due to constant flexing, and cutting into the tire body.

<u>The Bridle</u>: To prevent any individual bundles from separating and drifting away in the event of a break in the tying material, a bridle line should be threaded through the outside tires around the perimeter of the breakwater (Figure 5). Secure the line to the two outside tires in each bundle to prevent chafing. The material could be one of the recommended tying materials.

<u>Moorings</u>: The tension in the mooring lines is remarkably low. The 100 x 21 x 2½-foot prototype breakwater was temporarily moored using two 3/4-inch nylon lines attached to 100-pound Danforth anchors at each corner. In three-foot waves with 15- to 20-knot winds, the tension in each of the two forward lines was about 30 pounds.

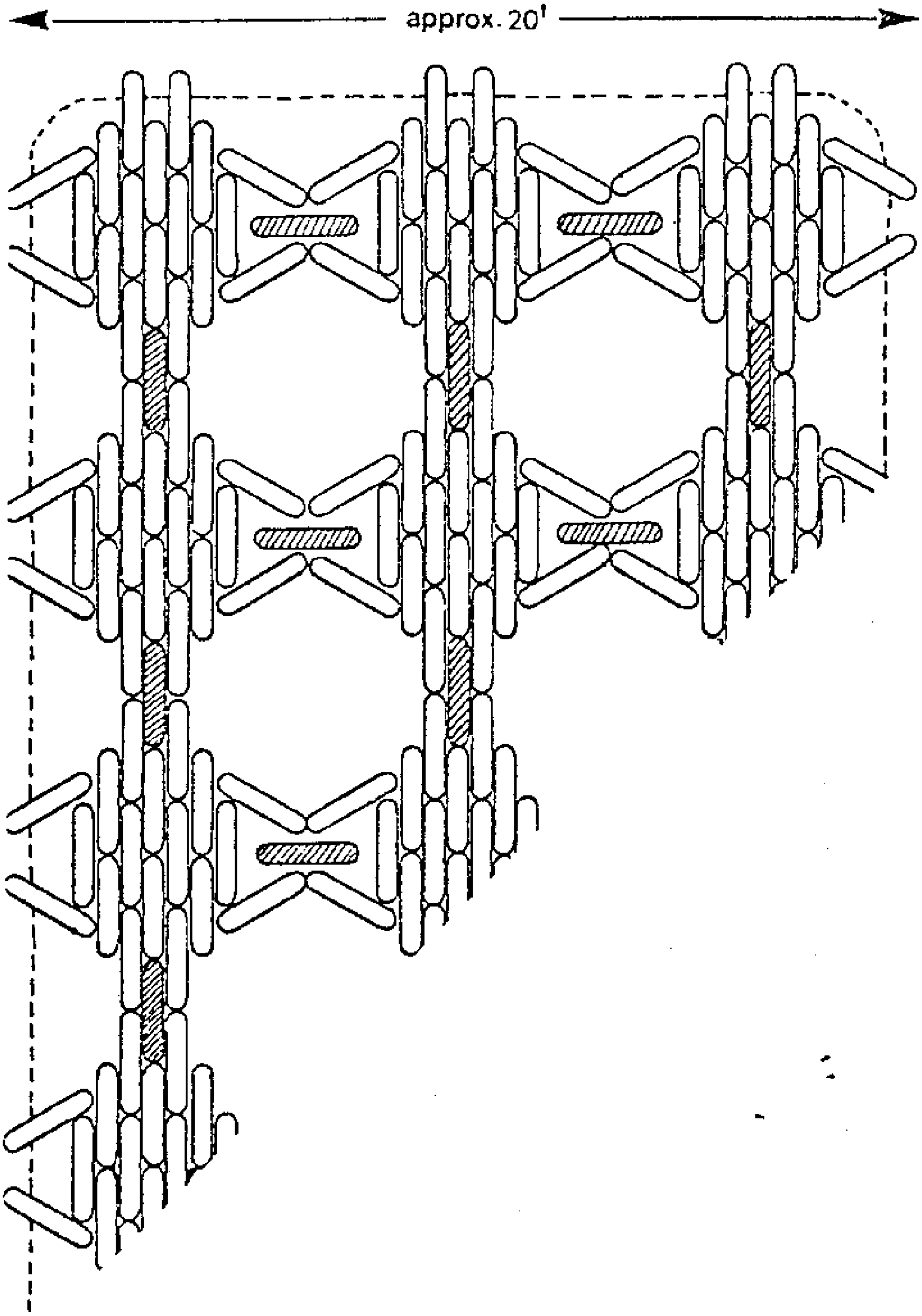


Figure 5: Top view of scrap tire mat. Dotted line indicates bridle. May be tethered with either side facing the waves.

The size of the moorings and anchoring system will vary, depending on the type of bottom (sand, rock or mud) and local tides and currents, as well as the amount of exposure to wind and waves. Anchors, mushroom moorings, or concrete blocks heavy enough to resist drag are satisfactory. Design the mooring system as you would for boats over 30 feet. Local experience with moorings will be the best guide. Wood pilings may be used in place of moorings, with the breakwater built around them. It is recommended that moorings be placed a maximum of 50 feet apart on the wave side and every 100 feet on the lee side. Mooring lines should be attached to the breakwater in such a way that the load is distributed between two or more bundles.

MAINTENANCE

Being a dynamic structure, the breakwater system will be subject to wear and deterioration. Therefore, it should be inspected regularly and after each storm, especially during the first few months after installation. When the breaks in the tying material occur, they should be repaired promptly. Moorings should be checked annually. Repairs and clean-up can be easily made in the water, and most inspections can be done without moving the breakwater.

The tire mat is a very efficient collector of floating bottles, bags, boards, and other debris. While an environmental plus, it will require frequent "harvesting," or the breakwater will indeed become an eyesore.

In areas of winter ice formation, consideration should be given to protecting the breakwater from moving ice floes. In such situations, the breakwater should be moved into protected areas prior to ice formation or hauled out of the water.

LEGAL LIABILITY

Clearly, the person or firm installing a floating tire breakwater is legally responsible for the structure. For example, should the breakwater come loose and float off, doing damage to fixed fishing gear downstream, the owner would be held liable. In cases of breakup, the owner is responsible for retrieving each tire section. Many breakwaters are being constructed of tires branded with a distinctive mark before launching. It commonly happens that, as soon as a permit is granted for the construction of a tire breakwater, someone tries to make the owner liable for every derilict tire for miles around. Tire branding clearly defines the limits of liability. If, however, the structure does break up, the owner should know about it and assume the responsiblity.

While, to date, no boating accidents have involved tire structures, in some areas it would seem prudent to construct some type of simple navigational markings on the structure.

AN ECOLOGICAL PLUS

Floating breakwaters become floating fishing reefs, too. Tires provide an excellent substratum for marine growth, which in turn provides both food and habitat for game fish. It is thought that, as an artifical reef, this floating structure will be more effective than a structure placed on the bottom because it is located in the upper three feet of the water, where there are higher light intensities, warmer temperatures, and higher oxygen levels.

Biologicial studies in southern New England have identified the following species, typical of intertidal fouling growth, on and in the tires: red and green algae, deckers, barnacles, soft and hard shelled clams, tunicates, mud crabs, starfish, amphipods, grass shrimp, mussels, oysters, jingle shells, and calcium tube worms. These breakwaters seem to have potential for aquacultural production of shellfish. Similar floating tire systems have been used in fresh water both as fishing reefs and to protect the spawning grounds of largemouth bass.

Tires have been used successfully for over 15 years for the construction of artificial fishing reefs, and they are considered by the Environmental Protection Agency to be one of the best substrates for such uses. Tires (including white walls) appear to be nontoxic and are quite stable in marine environments.

ULTIMATE DISPOSAL OF THE SYSTEM

Until many years have passed, no one will be able to determine what the life expectancy of a floating tire breakwater will be: 10, 20, 50, or even 100 years with proper maintenance. Ultimately, the system will no longer be needed or will be replaced, and at such time the removal and disposal of the tires will become necessary. Before constructing any floating tire breakwater, thought should be given to the ending of the system. There are several options available for the disposal of the breakwater:

1. Dissembly, removing the tires to land fills or to rubber reclamation centers.

2. The tire mat could be buryied behind bulkheads.

3. The breakwater could be moved onto the shore, forming a protective tire mat to control erosion.

4. The breakwater could be towed to and then sunk at an approval artificial reef site.

ROOM FOR IMPROVEMENT

More research is needed and is being done in several areas. Because the first floating breakwater was placed in the water in September 1974, long-range data on its performance do not exist.

The present breakwater design is limited to abating relatively small waves with short periods. Long-period ground swells roll through the system with little wave energy reduction. But, unlike others, if the system fails and protection is lost, the breakwaters may not suffer significant damage.

Numberous other uses for the tire mats can be envisioned. These include shore erosion control, aid in building sand dunes, dredge material containment, a mat to hold artificial marsh plantings, bulkheads, a fender to protect boats from colliding with submerged hazards or rock jetties with high accident records, protection for guest mooring basins at island parks, floating fish reefs, protection for oil spill clean-up operations, offshore protection for construction sites, drill rigs, and harbors of refuge, and for aquaculture.

A SUMMARY OF ADVANTAGES

1. Construction cost is low, under $50 per linear foot.

2. Floating tire breakwaters may be used where surface-to-bottom breakwaters are not feasible because of soft bottom, deep water, or sand and silt transport problems.

3. The system is easy to build and requires no heavy equipment.

4. The tire breakwaters are easy to repair in the water.

5. They require a simple mooring arrangement. Low tension in the mooring lines should allow the breakwater to ride out even major storms with minimal damage to the system.

6. They can be moved from one site to another as needed.

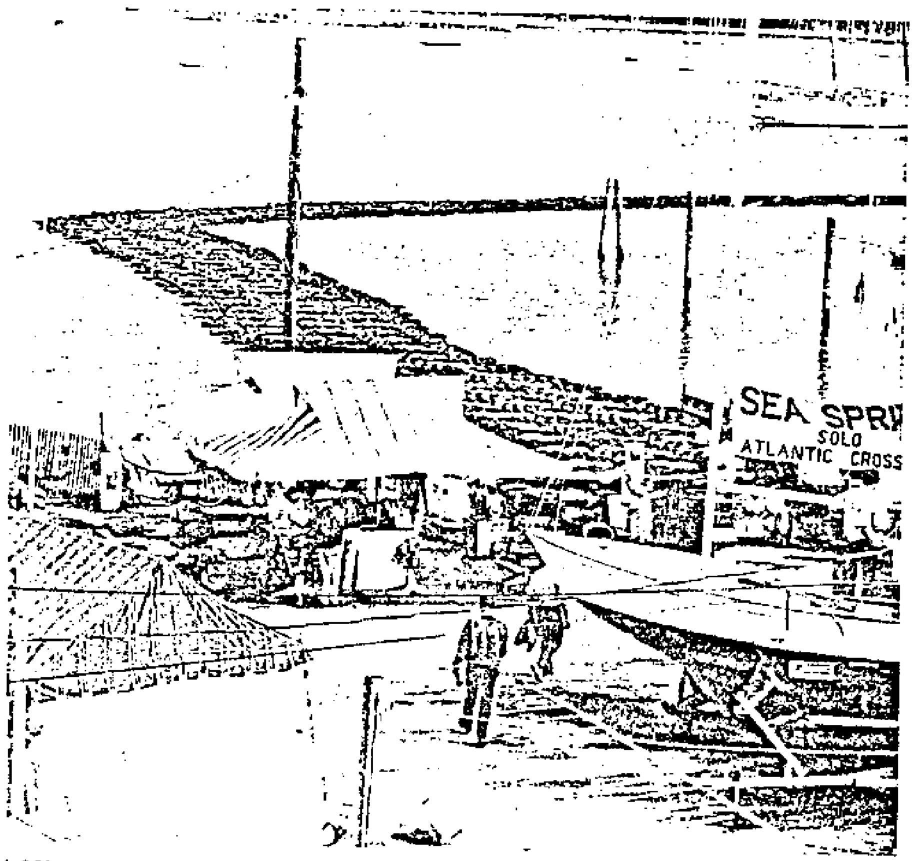
7. Their low profile above the water assures that the breakwater will respond to water conditions, not wind direction.

8. They provide wave supression without impeding tidal and current flow, a definite environmental plus.

9. They are a minimal safety hazard to boats, especially when compared to rock, wood, or metal breakwaters.

10. They will become a floating fishing reef.

11. They make use of a nontoxic waste material, which is easily handled and available in large quantities near recreational marinas at almost no cost.



A 28' x 500' floating scrap-tire breakwater of 5,680 tires effectively protected the 1975 Newport, Rhode Island, International Sailboat Show.

A Disclaimer

The use of any of the scrap tire structures described in this paper, or in any of our published reports, *shall be at the sole risk and responsibility of the user* with no liability of any nature whatsoever on the part of the University of Rhode Island. *Kingston, 1975.*

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APPENDIX A

CHECKLIST FOR PLANNING FLOATING TIRE BREAKWATERS (FTB)

Neil Ross and Albert Davis
University of Rhode Island Sea Grant Program
1976

I. <u>FTB Installation</u>

A. Waves - typical and storm

1. height and length
2. direction
3. fetch
4. shore configuration (as it affects wave reflection)
5. bottom configuration (wave refraction)

B. FTB location

1. area and object to be protected
2. water circulation (tide and current)
3. effect on navigation (inside and outside), navigational workings (only if needed)
4. seasonal variation

C. FTB system

1. design
    a. length
    b. width
    c. tire orientation
    d. pattern of matrix
2. source and average size of tire
3. flotation
    a. air, foam, other
    b. percentage reserve buoyance necessary for possible sediment accumulation and/or marine growth
4. tying material
    a. type (chain, rope, belt)
    b. strength
    c. method of fastening (clamp, bolt, splice, other)
    d. expected life of material under conditions of abrasion, corrosion, fatigue, ultraviolet exposure, biological attack
    e. bridle around system

D. FTB mooring system

1. depth of water - normal and storm range
2. type of bottom (sand, rock, silt, ledge)
3. anchoring system
   a. type of anchor
   b. mooring material (line, chain, belt)
   c. spacing (outside and inside) and scope
   d. method of attachment to breakwater

E. FTB environmental impact

1. wave suppression
2. water flow constriction and effect on sediment movement
3. biological habitat (artificial reef)
4. appearance

F. Legal liability

1. name, address and telephone of responsible person or firm
2. branding tires for identification
3. bonding requirements

G. Installation

1. dates
2. possible expansion plans

H. Estimated cost of FTB

II. <u>FTB Maintenance</u>

A. Name, address and telephone of person or firm responsible

B. Anticipated maintenance under normal and critical storm conditions

1. mooring system failure
2. flotation loss
3. tying material and bridle breakup
4. drifting loose tires
5. clean up of trapped debris and flotsam
6. being rammed by floating objects (boats, barges, trees)
7. ice movement

c. Estimated annual costs

III. FTB Removal and Ultimate Disposal

A. Expected life or use of FTB system at site

B. Disposal plans

1. disassemble, remove, and dispose on land
2. bury the system
3. protective tire mats (PTM) for shore erosion control
4. sink FTB in approved artificial reef site
5. transfer ownership and move to another site

C. Anticipated disposal cost

APPENDIX B

TO: Permit Agencies DATE: 1977

FROM: Neil Ross and Albert Davis, Jr
University of Rhode Island
Narragansett, RI 02882

SUBJECT: Suggested Floating Tire Breakwater (FTB) Permit Considerations

In addition to normal requirements and conditions for permits, consider the following special conditions for FTB permit applications for sheltered marine waters.

1. Flotation - If the FTB is to remain in the water more than six consecutive months, then enough supplemental flotation will be introduced into all the tires in each module to insure continued flotation.

2. Tying material - Only tying materials selected from the approved list will be permited.

3. Mooring system - The FTB will be secured to a mooring or piling spaced a maximum of 50 feet on the outside, exposed edge, and a maximum of 100 feet on the inside, lee edge. The type of mooring, anchor, or piling shall be compatible with the site's bottom conditions. To distribute the load, each mooring line must be attached to two or more tire modules.

4. Seasonal location - If any seasonal variance of the FTB location is anticipated, the locations and dates of relocation shall be indicated on the site drawing.

5. Navigational markings - The FTB shall be adequately marked at all times so as to not become a hazard to navigation.

6. Identification - To insure proper identification of the FTB or portion thereof, each tire will be branded with a distinct mark before being placed into the water. The Permittee will submit to this agency a description of the mark and its approximate location on each tire.

7. Maintenance - The FTB shall be built and maintained in such a manner to insure high conditions of water quality, biological habitat, and aesthetics. Should the FTB or any portion thereof fall into disrepair, break loose, or sink, that portion shall be immediately repaired or removed from the water.

8. Modifications - If design modifications are required after issuance of this permit, the permittee shall furnish this agency with revised plans detailing the modification and obtaining approval in the form of an amended permit prior to making the changes.

9. Disposal - In the event that the FTB is no longer needed, or that the permittee ceases or suspends the operation requiring FTB protection, then it is to be removed from the water and properly disposed of. If the operation should be sold or the FTB transferred to a new owner elsewhere, then the new owner(s) shall assume all responsibilities for permits, maintenance and eventual disposal of the FTB. In all such cases, this agency will be notified in writing of the disposal plans.

10. Assent will be issued for a period of three (3) years with renewal subject to the satisfactory condition of the FTB at that time.

APPENDIX C

SOURCES OF BELT TYING MATERIALS*

While conveyor belting seems to be the best material for tying material for tire breakwaters, it is not an "off the shelf" item as are chain and rope. Belt edge trimmings are not uniform but are a scrap of varying widths in each production run. When ordering, give the supplier the minimum dimensions required and at least three months lead time. Usually the cost for edge trimmings is by the pound plus shipping.

Martin Due, Sales Manager
Cincinnati Rubber Manufacturing Co.
4900 Franklin Ave.
Cincinnati, Ohio 45212 tel. 513-631-0691

Glenn Campbell, Manager
C.F. M. Inc.
404 Oak St.
Marysville, Ohio 43040 tel. 513-644-0404

Other sources may be found in your local areas. Mining operations and sand/gravel suppliers may be sources of used conveyer belts which might be cut (stripped) to desired sizes.

Nylon bolts are made in several areas. Check your Yellow Pages. One source is:

Non-Metallics Co.
58 Felton St.
Waltham, Massachusetts 02154 tel. 617-899-2530

Caution, do not buy your bolts before receiving your belting since it may be thicker than ordered.

* Sources listed are not endorsed by URI, but have supplied materials for FTB construction in the past.