Enhancing Wave Protection with Floating Tire Breakwaters

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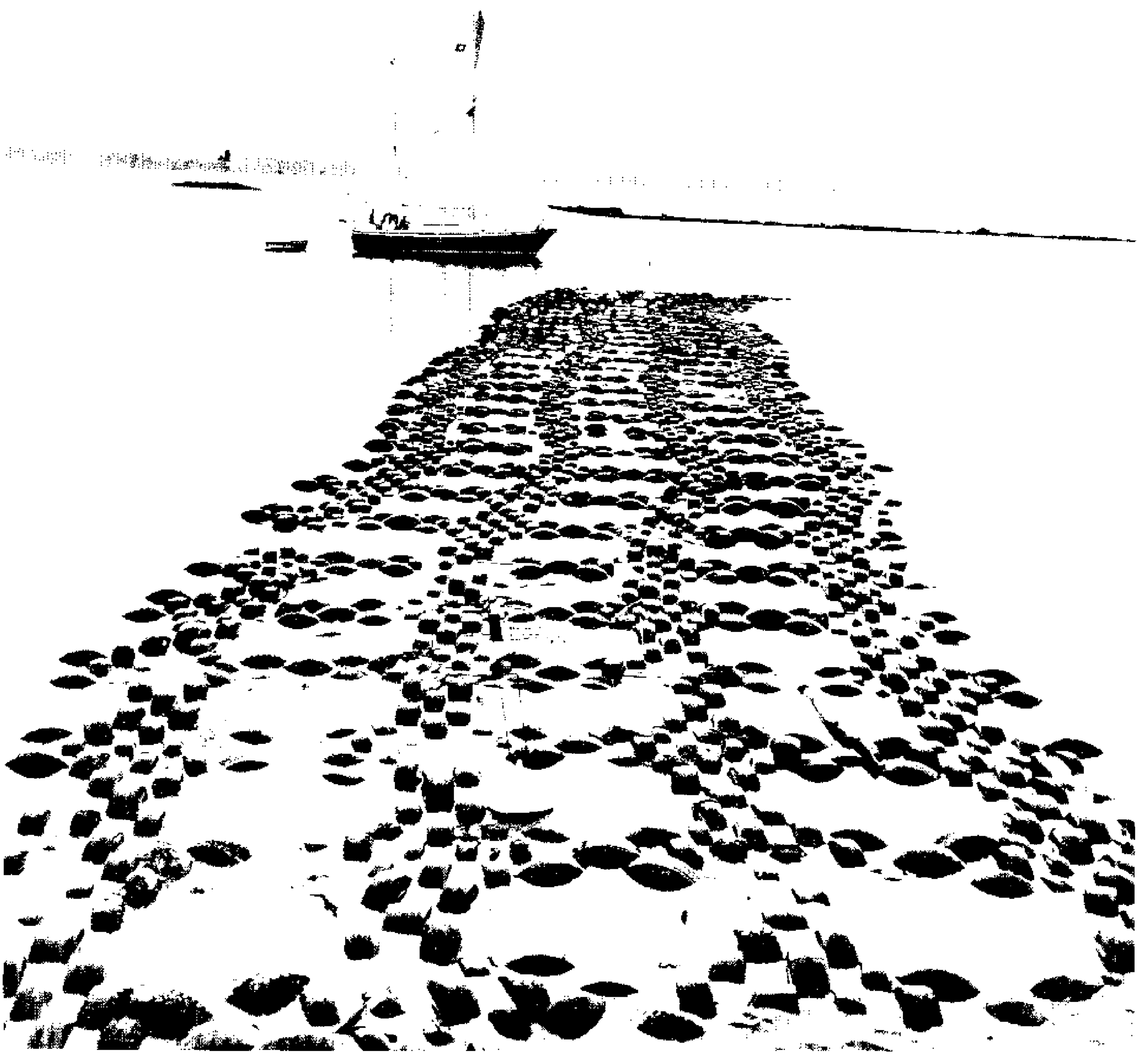

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***Cover photo.** Floating tire breakwater improving moorage wave protection at Dock and Coal Marina, Plattsburg, N. Y.*

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Introduction

Coastal harbors and marinas are under siege by nature's forces and people's desires. In those locations where steel and concrete have been combined successfully, the desires for calmer recreational and commercial moorage areas have been met. In areas that lack or have incomplete coastal protection, the loss has been substantial in terms of property damage and diminished commercial and recreational opportunity.

A recently designed device, termed *floating tire breakwater* (FTB), is an innovative approach for enhancing coastal protection and utilization. Built of lower cost materials, it has proved to be an affordable, yet effective, means for some areas to cope with wind-generated wave damages.

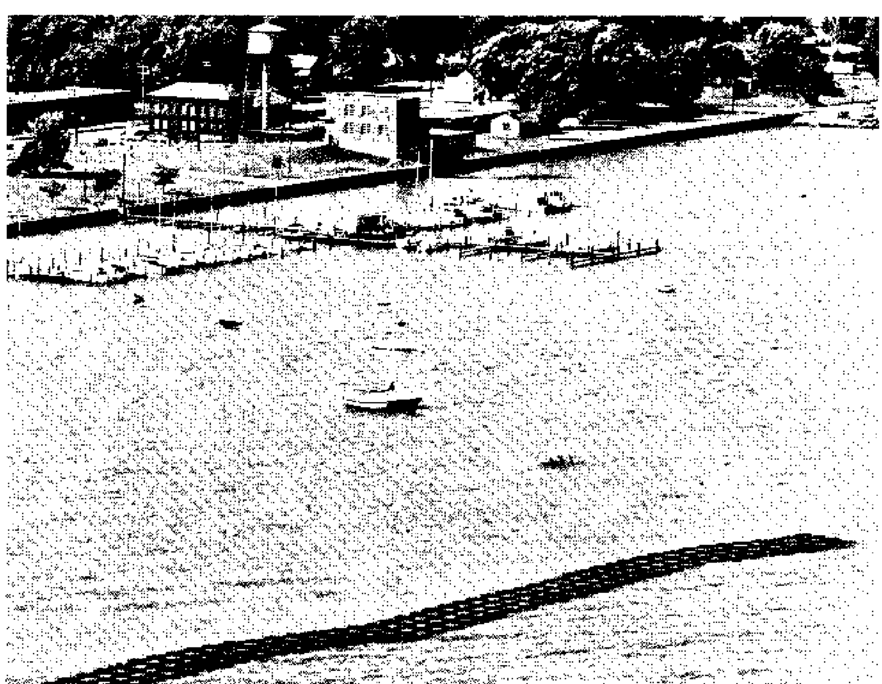
The purpose of this bulletin is to help you better understand how floating tire breakwater technology can relate to your business or community coastal protection needs. As such, it will assist you in evaluating whether a floating tire breakwater can be used effectively to improve facility wave protection in your location. It will also provide you with practical techniques and research information for planning and using this lower-cost coastal-protection device in applicable areas.

Because this device affords only partial protection under some conditions, this bulletin will help you to recognize the technological limitations of floating tire breakwaters and plan accordingly. For instance, in certain regions of the coast, winter icing conditions may preclude a single moorage location, and provision must be made for winter storage of the device. In other areas, floating tire breakwaters may not be used because of size constraints necessary for physical effectiveness or difficulties in obtaining installation permits from various governmental agencies.

Because each coastal site in which a floating tire breakwater might be used is different, this bulletin is written to help you plan for the conditions of your area. In this way, if you decide to build this device, it will be done in a cost-efficient and environmentally sound manner.

If and when a specific product or company is noted, this is not to be interpreted as the author's endorsement of that product or company. Rather, the author is citing the names of those companies that have supplied materials used in FTB installations to date.

Figure 1.



History of Floating Breakwaters

Although floating tire breakwaters are considered recent innovations in coastal protection technology, the concept of floating breakwaters is not. Dating back to 1842, the nomenclature and theory of floating breakwaters have reflected an idea in search of a need.

That need was manifested during World War II. In search of a transportable device to provide artificial harbor protection, Allied commanders had strong incentive for research and development of the "Bombardon," as it was called. During the invasion of Normandy, the Bombardon was utilized at the harbors of St. Laurent and Arromanches. More than 3 kilometers of breakwaters were installed in these locations to create the artificial harbors for supplying ground troops. Unfortunately, before their effectiveness could be fully utilized, a severe storm created wave conditions that exceeded those for which the breakwaters were designed, and they were destroyed.

The postwar years provided little incentive for the development of floating breakwater technology. The somewhat negative experience of the first attempt with the technology, coupled with sagging economic motivation, condemned the device to laboratory settings at best.

This situation would likely have continued had people not expressed their desire for increased coastal resource utilization. In the late 1960s that was demonstrated dramatically throughout coastal areas of our state (not unlike the country as a whole) as demand for safe recreational boating moorage outstripped supply. As harbor moorage areas expanded, so did the need for coastal protection. In an era of scarce funding resources for costly protective structures as well as increasing public concern for adverse environmental impact, incentive once again was provided for further research and development of floating breakwater technology.

The use of floating breakwaters in New York State has been made attractive by the desire of coastal facilities for improving wave protection. Because many of these are located in partially sheltered areas, the natural exposure limits the range of wave conditions. This had led to increased public interest in floating breakwater technology and has stimulated engineering innovations in material and design. One such innovation is a device commonly known as a floating tire breakwater (FTB).

Constructed of tires, an FTB appears as a matlike structure floating upon the water's surface. Its design refined by Goodyear Rubber and Tire Company in 1972, the FTB has been the subject of scientific examination and field use in recent years. Its increasingly widespread use in enhancing coastal protection for individuals and communities, coupled with cost effectiveness, has contributed to the notoriety that FTBs now enjoy. As research and development on this technology grows, undoubtedly the conventional FTB design (by Goodyear) will give way to alternate improved structural designs.

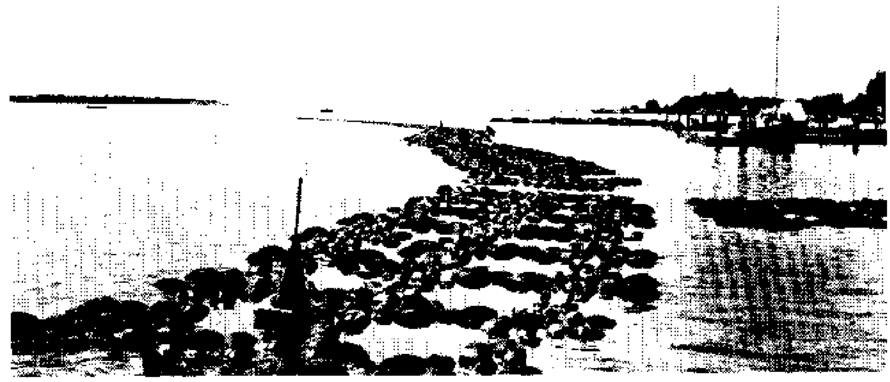


Figure 2. The FTB's low profile allows for increased wave protection without sacrifice of visual amenities.

Advantages and Disadvantages of Floating Tire Breakwaters

Some advantages are:

- Construction costs are lower than those of conventional breakwaters, and large quantities of materials are readily available. Can be built using semiskilled labor and light equipment.
- Effectively designed, an FTB can reduce wave height and facility damage in sheltered area behind the structure.
- Location and size can be modified to improve wave damping characteristics for a coastal region.
- Can be used in some regions where conventional bottom resting breakwaters are not feasible because of soft bottom, deep water, or sediment transport problems.
- Enhance biological resources in a localized area by providing artificial reef areas for organisms.
- Low profile in water does not inhibit scenic views of coastal water areas.
- Water currents are not impeded by a solid barrier; no stagnation problem as with conventional breakwaters.

• Compared with rock, wood, or metal breakwaters, FTBs are of less physical hazard to boaters.
• Will collect debris floating on the surface of the water and attract sea gulls away from recreational boats.

Some disadvantages are:

• Maintenance requires time and money not typically invested in conventional breakwaters.
• Cannot be moored year round in coastal areas experiencing severe icing conditions.
• Do not provide the degree of wave protection of conventional "bottom-resting" breakwaters.
• Can be a hazard to navigation and source of liability if not effectively marked.
• If longshore sand transport is significant in a predominant direction, an FTB could cause "downdrift" (sand transport parallel with shoreline) coastal erosion.
• There can be public opposition to perception of tires used in waterways.
• At this time (1978), used only to enhance wave protection of partially sheltered coastal areas; no "open-water" experiences to date.
• Do not effectively damp long-period waves or those having low steepness characteristics.
• Lower cost nature of the structure stimulates some builders to underdesign and cut corners when purchasing materials.

Floating Tire Breakwater Case Studies

One of the best ways to evaluate the effectiveness of any coastal protection method is to learn how well it works under physical conditions similar to your own. Then, if past experience and results dictate, use it on a trial basis for yourself.

This section considers how and where floating tire breakwaters are being used to improve wave protection. Insight into their use to improve harbor and marina protection in coastal New York State is given in two case studies. Other regions of the United States using this device are also cited to provide you with awareness of the diversity of FTB sites and uses. The listing is not meant to be comprehensive, but rather a representative sample.

Enhancing Great Lakes Harbor Protection: The Dunkirk Experience

Lake Erie's Dunkirk Harbor in New York is considered a semi-protected harbor (note harbor chart, (fig. 3). An outer permanent breakwater protects the harbor from waves coming from the north and northwest. But during northeast storms, waves enter the harbor unchallenged by any structure. Because of this lack of protection, marinas and yacht clubs in the harbor sustain yearly storm damage, as do boats moored at their slips (fig. 4). To help stop this destruction, the city of Dunkirk is working with the Corps of Engineers on a permanent structure for protecting the inner harbor. But because this project was not to begin for several years, the city needed a less expensive, yet effective, means of providing temporary harbor protection.

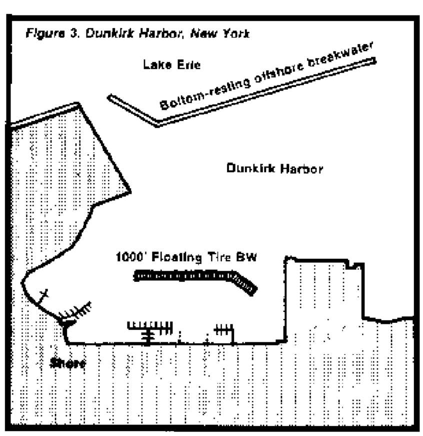


Figure 3. Dunkirk Harbor, New York

A solution to Dunkirk's dilemma came in the form of a floating tire breakwater. Meetings were held in the spring of 1975 with representatives of the Goodyear Tire and Rubber Company (initial developer of the device), Dunkirk city officials, and New York Sea Grant. The possibility of using a floating tire breakwater was discussed and accepted by the city officials. That summer, with the help of local interested citizens and donated money and materials, approximately 600 feet of floating tire breakwater were moored in Dunkirk Harbor. The breakwater worked effectively through the early winter, until storm waves began to break binding materials and move anchors out of position. It was then removed from its moorage in the harbor for the remainder of the winter.

In the spring of 1976, the city of Dunkirk evaluated the merits of the project and, after reviewing the initial results, not only decided to have the floating tire breakwater rebuilt with heavier materials, but also directed the city harbormaster to increase the size of the breakwater twofold! It was rebuilt with paid labor and actual cost materials (no donations) to its current length of 1,000 feet. Because Dunkirk Harbor re-

Figure 4. *For lack of effective wave protection, costly facilities and boat damages may occur each year.*

mains ice free, the FTB remained in its moorage location throughout the winter as well, enduring several severe storms.

The effects of this innovative breakwater have been graphic. From a physical standpoint, there has been little damage done to boats or docks in the harbor from northeast storms. Not surprisingly, the waterfront is now benefiting economically from the structure in several ways:

- A marina that has had empty mooring slips the last 3 years now has five rental customers because the breakwater was installed.
- A yacht club that perenially has had slips open has gained eight new permanent members because of a calmer mooring.
- Transient recreational boaters crusing along the coast now consider Dunkirk Harbor a refuge. This has been reflected in an increase in the fuel sold to boaters by harbor marinas and temporary mooring rentals by a local yacht club.
- The city of Dunkirk is considering building a new boat launch ramp, and the expected increase in "trailer-sailor" traffic to a calmer Dunkirk Harbor has motivated a prominent local restaurant to open a fast-food stand near the site.

Other special and economical spinoffs are likely to occur because of the floating tire breakwater. For instance, sport fishermen find that fish concentrate beneath the structure, and boaters benefit from the breakwater because the well-lit floating structure overlies a treacherous submerged navigational hazard.

These positive results would not have occurred had Dunkirk not used the floating tire breakwater, but, instead, had waited several years for a more-permanent high-cost structure. And who knows, after the structure is evaluated in terms of costs and benefits rendered to the community, it could remain moored in the harbor longer than the temporary period originally anticipated.

To date, this appears to be a success story and an answer to problems that other areas along our coasts are facing. But it is important to note difficulties experienced by this community:

- Stainless steel wire donated for module binding material proved ineffective for this coastal area.
- Cylindrical-shaped cement anchors rolled around the bottom. These were replaced with rectangular-shaped blocks which have proved more stable.
- Open-link chain in portions of the FTB has been spread apart by wave forces.
- Because of insufficient anchor weight (restraining force), the FTB has changed position on several occasions. Additional anchors have been added to counter this situation.
- Some air trapped in the crowns of tires for flotation escaped, and portions of the structure became submerged.

Table 1. Dunkirk Harbor floating tire breakwater – Dunkirk, N.Y. Assembly costs for 100' × 28' section – 1976

Item	*Quantity for 100' section FTB*	*Cost for 100' section of FTB*	*Remarks*
Auto tires	1,120	$ .00	Free from distributors.
Supplemental buoyancy flotation			City did not use because floating breakwater is a temporary measure.
Interconnecting bindings (3/8" welded-link chain)	1,624 ft	487.00	Includes materials for building individual modules and binding modules together.
Interlinking device (1/2" open-link chain)	224 links	35.84	Many types on market. City used 1/2" open-link chain for coupling chains together.
Anchors	4	80.00	City made its own 1,000-pound cement anchors (4' × 4' × 6').
Mooring chain (1/2" open-link chain)	320 ft	208.00	Amount needed is function of depth (Dunkirk Harbor – 8 ft); scope of chain 8:1.*
Labor time			
Construct 100' FTB section	50 hr	150.00	Can be done by nonswimmers on land; must have basic module construction training.
Placement into water	2.5 hr	65.00	Need hi-lifter tractor to place in water.
Onsite towage and anchor placement	2 hr	30.00	Need a captain and deckhand.
Onsite placement	2 hr	20.00	Need 2 people in water and support boat to carry tools.
Navigational lights and buoys	2	586.00	You must mark FTB after reaching agreement with Coast Guard.
Total cost per 100-foot section of FTB		$ 1,655.00	
Total cost of structure		$16,550.00 (59¢ per sq ft)	

Source: Data provided by harbormaster, city of Dunkirk. All costs were incurred at 1976 prices. Costs will vary with materials used and local conditions confronted.

*Amount of mooring line per 1 ft of water depth.

One Marina's Innovative Use of an FTB

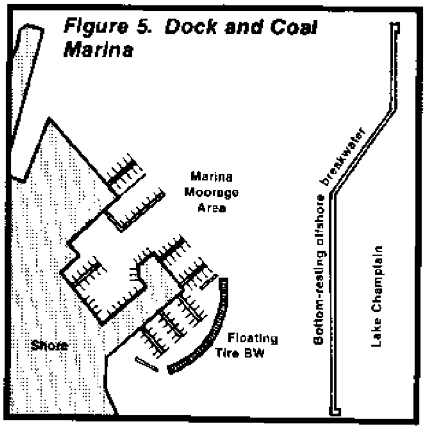


Figure 5. Dock and Coal Marina

The Dock and Coal Marina located along Lake Champlain near Plattsburg, New York, is now using a floating tire breakwater to enhance protection from choppy 2- to 3-foot-high lake waves. The marina is exposed (note fig. 5) to lake waves from the south; and with higher lake levels, waves from the east often breach the sheltering concrete breakwater. The exposure to lake waves resulted in damage to existing docks and inhibited future expansion of the marina's dock network. Since the marina serves a market like Montreal, such problems should be avoided.

To improve the marina's wave protection, the owner decided to use a floating tire breakwater on an experimental basis. After receiving necessary permits, the owner built it during the winter of 1976.

In constructing this FTB, the builders chose to "walk on water." They built the device on the frozen surface of Lake Champlain, using a lift truck and snowmobiles to haul construction materials to the future moorage site. The anchors were placed on the lake bottom by chopping holes through the lake's surface ice. These holes also allowed recreational ice fishing for workers during rest breaks (see fig. 6). The FTB was deployed into its seasonal moorage site by nature when warmer temperatures melted the lake's ice cover.

Although the FTB was built on ice, it has to be moved into a sheltered basin for protection from winter lake-ice damage. This is accomplished by unhooking the device from its summer moorings and towing it by boat into its winter anchorage area inside the nearby basin.

Has it proved worth the effort to this marina operator? The balance sheets say yes. Since the device was installed, not only have dock damages due to lake waves decreased, but also the marina has expanded. This year with the additional wave protection provided by the 400-foot FTB, two new dock systems were installed. According to Walter A. Cronin, president of Dock and Coal Marina, the floating tire breakwater makes possible the additional revenues from these new facilities.

A problem that this marina experienced in using an FTB was submersion of a portion of it by floating ice. For this reason, it is important to install and store FTBs in a manner appropriate to the season.

Some FTBs Being Used by Coastal Communities and Businesses

FTBs on the Great Lakes

Frank Napieralski, Harbormaster
Dunkirk City Hall
Dunkirk, New York 14048

The Dunkirk Harbor FTB is 1,000 feet by 28 feet and is used to enhance harbor protection for two marinas and a yacht club. Its moorage in an ice-free harbor along Lake Erie allows year-round protection.

Figure 6. *The benefits of constructing an FTB during the winter are numerous.*

Table 2. Dock and Coal Marina FTB – Lake Champlain, N.Y. Assembly materials and costs for 410′ × 28′ FTB — 1976

Item	*Type, size, number*	*Remarks*
Auto tires	4,480	
Buoyancy flotation	Every second tire	Styrofoam block jammed into crown of tire.
Interconnecting bindings	Campbell Chain Co. 1/2" open-link steel	Open-link chain easy to work with.
Anchors	300-lb concrete blocks	Positioned each 50′ on windward side; 100′ on leeward. Muddy bottom allowed them to sink in.
Mooring chain	Campbell Chain Co. 1/2" open-link steel	Used a scope of 5:1.*
Navigational lights and buoys	One at each end of FTB ($128 apiece)	Battery-powered photoelectric.
Total cost	$11,480 ($1 per sq ft)	

Source: Data provided by Walter A. Cronin, president, Dock and Coal Marina, Plattsburg, N.Y. All costs incurred at 1976 prices.
*Feet mooring line per 1 ft of water depth.

Walter Cronin, President
Dock and Coal Marina
1 Dock Street
Plattsburg, New York 12901

This Lake Champlain FTB is 400 feet by 28 feet and is used to protect a marina. The structure was built upon the frozen lake and was deployed when ice melted in the spring. This FTB has made possible the installation of two extra docks.

Donald Eno
Barcelona Harbor Commission
20 S. Gale
Westfield, New York 14787

Barcelona Harbor suffers from ineffective wave protection during storms. Permit applications have been filed by the Harbor Commission to install an FTB during the summer of 1978 to help remedy this situation.

Edward E. McCallum
Chicago Park District (Administration Bldg.)
425 East McFetridge Drive
Chicago, Illinois 60605

A 300-by-28-foot FTB is being used in Diversey Harbor channel mouth. It was built for $9.28 per square foot. Another is anticipated for use in Belmont Harbor by 1979 to improve moorage protection in this area of Lake Michigan.

William and Beatrice Schermerhorn
Schermerhorn Boat Sales, Inc.
Schermerhorn Landing, R.D. # 2
Hammond, New York 13676

A 300-by-40-foot FTB will be installed in the summer of 1978 to improve marina wave protection and afford some degree of erosion protection.

George Hayes, Commodore
Mentor Harbor Yacht Club
5330 Cornado Drive
Menton-on-the-Lake, Ohio 44060

An FTB is now being constructed. When completed, it will be 210 feet by 26 feet and will provide protection to sail boats entering and leaving the yacht club's facilities along Lake Erie.

FTBs in the East

Thomas W. Kingman
Cataumet Marina
Cataumet, Massachusetts 02534

This Cape Cod breakwater is 70 feet by 21 feet. It will soon be enlarged by an additional 500 feet. One-half-inch nylon line was used to bind the tires. This FTB is credited with minimizing damages to recreational craft moored at the marina during a hurricane.

U. S. Army Corps of Engineers
(Shoreline Erosion Control Demonstration Program)
Pickering Beach, Delaware

Floating tire breakwater sections, 1000 feet by 50 feet, will be anchored offshore to improve wave protection for a beach area. The FTB at this site is anticipated to be used for 5 years. Two types of FTB design will be tested and two types of anchors evaluated. Urethane foam will supplement tire buoyancy.

Paul Dodson, President
Newport Int. Sailboat Show
431 Thames Street
Newport, Rhode Island 02840

This 800-by-26-foot FTB was enlarged again in the fall of 1977 (fig. 7). This is the third year that a tire breakwater has protected the show boats at the International Sailboat Show, Fort Adams, Newport, R.I. The structure is located in Newport Harbor.

Bill Munger, Owner-Operator
Conanicut Marina
Conanicut Island
Jamestown, Rhode Island

The Conanicut Marina uses a 300-foot section of the Newport, R.I., tire breakwater during the off-season. It is towed 2½ miles across Narragansett Bay each year (takes approximately 3 hours).

Carl C. Crosen, General Manager
Great Bay Marina, Inc.
Fox Point Road
Newington, New Hampshire 03801

A 150-by-20-foot tire breakwater protects this marina. The area has a 6-knot current and 4-foot waves. Conveyor belt trimmings and nylon bolts bind the tires in this breakwater.

Richard Trexler, Manager
Moultonboro Marine, Inc.
Moultonboro Neck
Moultonboro, New Hampshire 03226

A FTB is proposed for underdock construction in Lake Winnipesaukee. This fresh-water structure should be installed in 1978.

Frank Balint, Manager
Wingfoot Lake Recreational Park
993 Goodyear Park Blvd.
Mogadore, Ohio 44260

This experimental breakwater is 550 feet by 26 feet and contains experimental flotation materials and interconnecting hardwares, which will be evaluated for per-

Figure 7. *Wave protection for craft displayed at the International Sailboat Show is improved by an FTB.*

formance and life. The breakwater protects the Wingfoot Lake Marina on an inland fresh-water lake located in a recreational park.

Karl L. Kohler, Past Commodore
Chrysler Yacht Club
P.O. Box 03651
Highland Park, Michigan 48203

A modified-design tire breakwater for under-dock installation is being used successfully at this fresh-water site for motorboat-wake suppression and wave control. The yacht club is located on Chrysler Island in the North Channel of Lake St. Clair. This FTB is constructed with truck tires chained together and tethered under the docks.

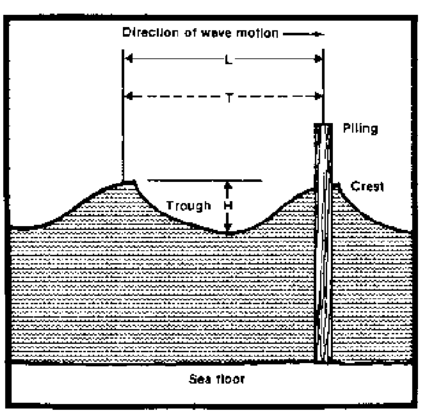
FTBs in the South

Dr. Charles A. Gifford
Baseline, Incorporated
Pensacola, Florida

A floating tire breakwater, 100 feet by 22 feet, was constructed in 1976 to control erosion of property along Santa Rose Sound, Florida. Since completion of the breakwater, significant sand accretion has been reported in the "wave shadow" of the structure.

Figure 8.

Crest - high point of a wave
Trough - low point of a wave
H, wave height - vertical distance from trough to crest (in feet)
L, wave length - horizontal distance between successive crests (in feet)
T, wave period - amount of time between successive wave crests passing by a fixed object in the water, such as a pile



City of New Orleans
Orleans Levee Board

The city of New Orleans is facing increasing demand for recreational-boat-mooring facilities. To cope with this, a private consultant has designed a 2130- × 62-foot FTB, to form and protect a harbor area on Lake Pontchartrain. If adopted for use, this will be the largest FTB constructed in a hurricane-prone area.

Identifying Waves Damaging Your Facilities

Of the many types of waves present in bodies of water, the most important type for you to consider in designing a floating breakwater are the waves raised by the wind. This section discusses wind wave formation and the characteristics of the waves damaging your coastal facilities. A wave information work-sheet is included to help you to gather necessary information for designing an effective floating tire breakwater.

Wind waves are born as wind moves across water, creating ripples. Once a ripple has formed, there is a steep side against which the wind can press directly, and energy is transferred from air to water more effectively. As the sea surface takes energy from the wind, the small waves give way to larger ones.

The size of wind waves is related to the wind's velocity, the length of time the wind blows, and the size of open water across which it blows. Additionally, when waves generated by wind offshore progress into coastal waters, the changing water depth alters the wave's appearance and chacter-

Wave Information Worksheet

Season waves damage coastal facilities: ______________________

Predominant direction of wave causing damage: ______________________

Wave height (H) in feet: ______________________

Wave period (T) in seconds: ______________________

Water depth (d) in area to be protected: ______________________

istics. These are the principal factors determining the differing directions of movement, heights, wavelengths, and periods of waves (see fig. 8). You will want to determine these characteristics for waves typically causing damage to your facilities. Then, you will be able to plan for the most effective size of your floating tire breakwater and the most appropriate moorage location. To ensure that your floating tire breakwater is designed effectively, use the work-sheet (fig. 8) provided here several times while making firsthand observations. Do this when your typical wave problem is occurring.

Once worksheet data has been collected, you will have information relating to typical damaging waves. If you want to design your FTB for maximum effectiveness under worst possible wave conditions, expect to do some searching for wave condition information and to have additional construction costs. To learn about "worst possible conditions," you might ask residents of your region about past storms. Although some people may recall the ferocity of past storms, most have not made the measurements necessary for completing your worksheet.

A more effective means to acquire this information is through recent public and private agency studies of your coastal harbor or area. Often these studies are made for the design and construction of major coastal facilities and include the worksheet information you will need. To discover whether this type of information is available for your use, contact the appropriate Sea Grant office for your region (note page 13) and explain your needs. Or inquire at your township library, harbormaster's or municipal engineer's offices. Be aware, however, that these studies and reports may contain dated information if physical changes have occurred since their publication, for example, water depth changes, varying coastal configurations, and new harbor protective structures.

Reduction of Wave Energy by Floating Breakwaters

The amount of wave energy striking coastal facilities can be decreased by several methods. Fixed bottom-resting structures such as caissons and riprap reflect most wave energy and, thereby, provide protection to those facilities located behind them. Typically, such structures cost more than $200 per foot with relatively low maintenance costs and greater longevity than floating structures.

Research and experience have shown that floating breakwaters are effective for improving coastal protection during specific wave conditions. Typically, these structures cost less to construct than conventional fixed structures, but have a shorter lifetime and ongoing maintenance costs. In this section, we will consider how floating breakwaters may act to reduce wave energy, their effectiveness during various wave conditions, and research related to this technology.

To date, floating breakwaters have been moored predominantly in lakes, embayments, or within natural harbor areas. In each successful case, the structural design and moorage position of the device have been carefully planned. Performance field observations of floating breakwaters and controlled laboratory investigations provide increasing knowledge about the technology. To design an effective floating tire breakwater, you need to know how the device works and wave conditions under which it does not work effectively.

Most types of breakwaters (floating or bottom-resting) function primarily as wave reflectors: the wave energy is intercepted; some is dissipated upon the structure, but the largest portion is generally redirected seaward again, a sheltered region of lesser wave energy being produced in the lee of the structure. The converse is true for the typical FTB. This breakwater is principally an energy dissipator: Most of the wave energy is transformed into turbulence within and around the many small components of this structure (eventually being converted to thermal energy), whereas only a small portion of the wave energy is reflected seaward again. This fundamental difference is not only conceptually helpful, but also of importance in the analysis and design of such structures.

Depending on the characteristics (such as height, wavelength, and period) of waves striking a floating tire breakwater, the structure will provide *varying degrees of wave protection* for your facilities. Why is this? What is the significance of this for facilities you wish to protect with an FTB? To answer these questions, we

Figure 9. *Investigators explore the effectiveness of floating breakwaters in research laboratory wave tanks by reproducing natural wave conditions.*

must consider research done on this device.

Research on the effectiveness of floating breakwaters has been conducted by public and private universities and governmental agencies. These investigations have sought to document the effectiveness of floating breakwater devices (including FTBs) through several methods. These include using computers to simulate environmental conditions, placing scale model floating breakwaters into tanks filled with water and artificially reproducing natural wave conditions (fig. 9), and measuring full-scale floating breakwaters subject to natural coastal wave conditions. It is difficult for computers and wave tanks to accurately mimic all of nature's complexities, and measuring the effectiveness of floating tire breakwaters in coastal waters limits results to environmental conditions at that site. By evaluating the results of each type of research project, scientists can now indicate when floating breakwaters operate effectively.

One of the inherent problems of floating breakwaters is their ability to reduce surface wave motion, but not all subsurface motion. This means that water currents are not affected (which is a good attribute), but also that some wave energy may pass into the area you seek to protect. Thus, floating breakwaters do not usually provide as effective wave protection as bottom-resting, conventional breakwaters.

Research has also shown that the amount of protection that a floating breakwater may provide for your facilities is related to the characteristics of the striking wave. Floating breakwaters are most effective in reducing the energy of a wave having the characteristics for which the structure was designed. Waves that have other characteristics than these will be damped to differing degrees. For instance, FTBs provide decreasing protection against waves having a longer wavelength than that for which the FTB was designed. As the size of wavelength gets longer than that for which your FTB was designed, less protection is provided by the FTB. On the other hand, as the size of wavelength decreases relative to the design wave size for your FTB, greater wave protection is provided by the device.

Some might wonder what the wave limitations are for an FTB to be effective. Long-period waves such as Great Lakes seiches will not be effectively diminished by an FTB. The limitations for using FTBs to protect against oceanic wave conditions would be the size of structure needed and high mooring and binding forces encountered in holding it stationary.

How Much Will My FTB Cost?

Environmental considerations such as water depth and wave conditions at the moorage location will influence the size (cost) of your FTB. The price of construction materials, labor, service rental (e.g. tow boat), and ongoing maintenance also enter into the overall cost.

What is the appropriate amount of money to spend for an FTB? As discussed in the design section of this bulletin, you must identify the degree of wave protection desired for your facilities. Research indicates that the amount of wave protection provided by an FTB is related to its size and the wave conditons being experienced.

If you want to improve wave protection during the summer for boat moorage, design your FTB's size for waves encountered only during this season. Likewise, if you are interested in enhancing protection from storm waves experienced during the fall, design your structure's size for those conditions rather than for atypical storm waves. Because wave conditions at your coastal FTB site will vary throughout a given year (see table 3), careful planning is needed to determine the appropriate level of capital investment.

Some builders have been tempted to build the structure from the cheapest materials available. In the case of one harbor community, the gift of free wire for use in binding their FTB spelled its failure. The entire structure had to be rebuilt when

Table 3. Wave characteristics for Barcelona Harbor, New York

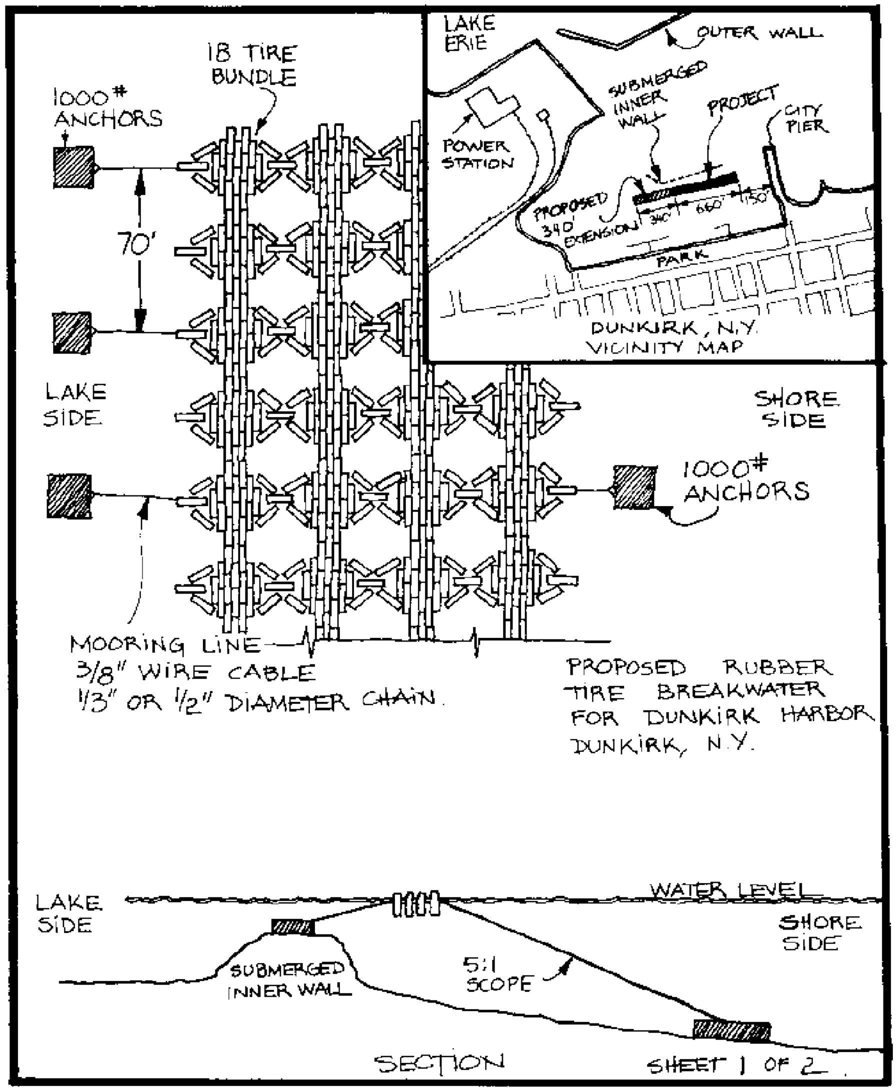
Wave amplitude (ft)	*Duration (hr/yr)*
0.25 - 0.5	208
0.5 - 1.0	1310
1.0 - 1.5	868
1.5 - 2.0	514
2.0 - 2.5	248
2.5 - 3.0	98
3.0 - 3.5	34
3.5 - 4.0	16
4.0 - 4.5	18
4.5 - 5.0	2
5.0 - 5.5	6

Source: Design memorandum on Barcelona Harbor, N.Y., U.S. Army Corp of Engineers, March 1958.

Figure 10. *Transporting tires on land is cumbersome and can be minimized with careful planning.*

the wire began to break, its overall cost being significantly increased because of duplicated labor. The objective in building an FTB is to improve wave protection at an affordable price, not to gain additional problems at a cheaper price!

Many people interested in building an FTB ask others how much the structure has cost per linear foot. If you are interested in cost comparisons, inquire about *cost per square foot;* that cost will allow standardization of costs for a structure having variable width (or beam) components. Floating tire breakwaters built to date have cost between $0.60 and $9.28 per square foot (at 1977 prices).



Figures 11 and 12. Above and *opposite, plan drawings submitted for Dunkirk Harbor FTB.*

Planning a Floating Tire Breakwater

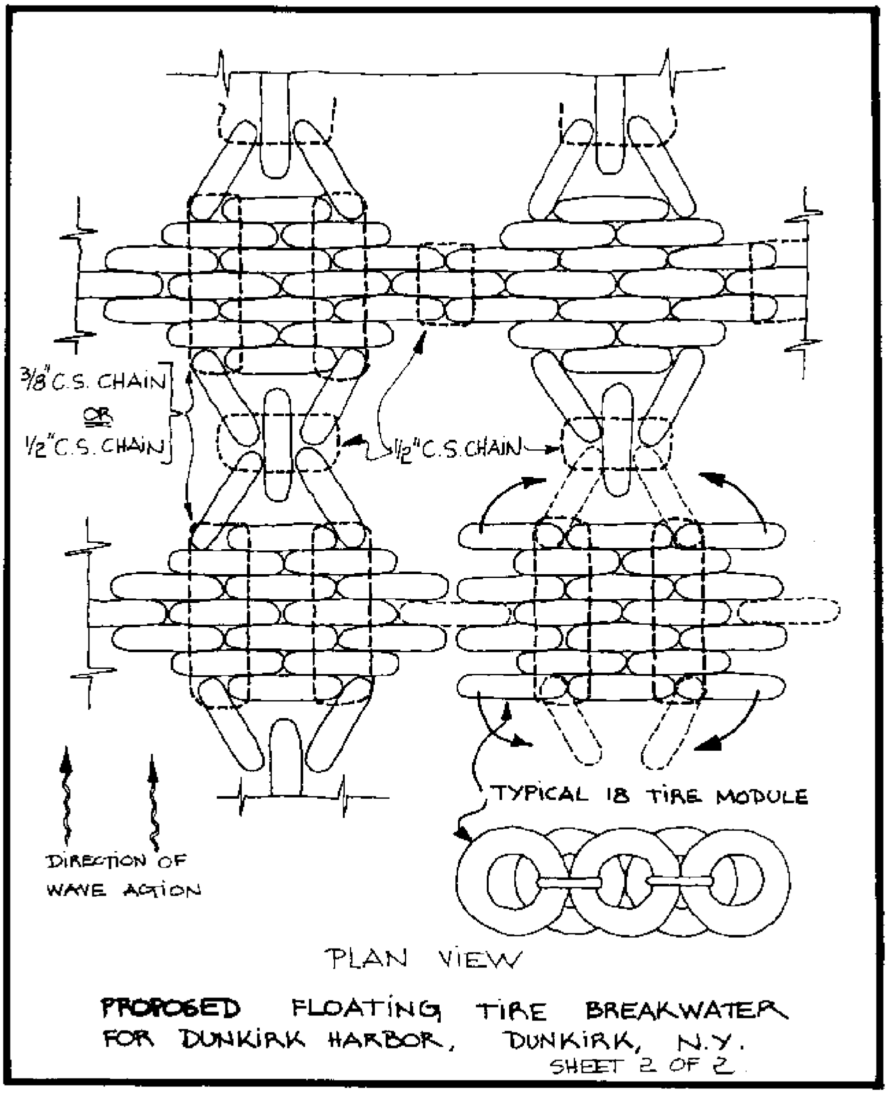
As the structure's name implies, the basic construction material is tires. Whether the tires are new or used, the physical performance of the structure is the same, and the acquisition of tires has been of little challenge for past builders.

Rather, the problem is receiving too many tires after publicly announcing the need for them. Because many landfill sites are now charging user fees for tire disposal, most people, as well as retail tire businesses, are searching for less costly disposal methods. You can profit from this by knowing how many tires you will need and underselling the landfill disposal cost. In this way, you gain the needed tires and additional funds to help defray construction costs!

Before announcing your need for tires, take time to plan for the area in which you will store construction material (tires and binding), construct tire modules, assemble the FTB from modules, and launch the FTB. The closer the site is to the water, the less time and effort you will spend in transporting the FTB on land (fig. 10). Because bundles of tires are cumbersome to move, a few minutes of thoughtful preplanning are better than hours of unnecessary labor later.

What Permits Are Needed?

Utilizing a floating tire breakwater in most waterways of the United States can be undertaken legally only after obtaining a permit from federal, state, and sometimes local governmental agencies. This section will help you identify appropriate agencies and obtain necessary permit application forms. It will also provide insights into the effective completion and filing of the required permit forms to ensure timely response to your request.



Federal Agency Permit

If your proposed floating tire breakwater will be located in or will affect navigable waters of the United States, you must submit a permit application to the Army Corps of Engineers. The Department of the Army permit application ENG Form 4345 must be completed and submitted to the District Engineer. You can obtain this form and a pamphlet *Applications for Department of the Army Permits for Activities in Waterways,* which describes the permit in detail, from the following district offices in New York State:

District Engineer
U.S. Army Engineer, Buffalo District
1776 Niagara Street
Buffalo, NY 14207
(716) 876-5454

District Engineer
U.S. Army Engineer, New York District
26 Federal Plaza
New York, NY 10017
(212) 264-0184

For locations outside New York State, consult your telephone book under Government - United States Army, Department of the Corp of Engineers

This permit form consists of a two-page questionnaire and a detailed plan (drawing) form. To complete the form, follow the directions given in the Corp of Engineers' permit pamphlet. If you have difficulty in drawing a detailed plan of a floating tire breakwater, the Dunkirk Harbor plan (see figs. 11 and 12) will aid in envisioning your own. To ensure an effective drawing on the permit form, use the handy checklist given in the Corp of Engineers' permit pamphlet in Appendix C.

How applications are processed

Public notice. After the District Engineer determines that the application is in proper order, a public notice (usually 30 days) is issued to all known interested individuals, groups, and governmental agencies. Substantive comments received in response to the public notice are furnished the applicant to afford opportunity to resolve or rebut the comments or objections.

Public meetings and hearings. The District Engineer may hold a public meeting to give interested parties full opportunity to express their views and to develop pertinent data to evaluate the permit application. In addition, the District Engineer must hold a public hearing when requested by any party who may be affected by issuance of a permit. In such cases, arrangements will be coordinated with the applicant, and a 30-day advance notice will be issued to the public.

Evaluation factors. The decision whether to issue a permit will be based on an evaluation of the probable impact of the proposed activity on the public interest. That decision will reflect the national concern for both protection and utilization of important resources. The benefit that may reasonably be expected to accrue from the proposal must be balanced against its reasonably foreseeable detriments. All factors relevant to the proposal will be considered. Among those are conservation, economics, aesthetics, general environmental concerns, historic values, fish and wildlife values, flood damage prevention, land use classification, navigation, recreation, water supply, and water quality — in general, the needs and welfare of the people.

Timing. If there are no substantive objections to the proposed activity and the necessary state and local approvals are obtained, a permit can usually be issued within 90 to 120 days after receipt of a completed application. However, if the application becomes controversial and a public hearing or public meeting is necessary, or an environmental impact statement must be prepared, the processing of the application could take up to 1 year or more. Therefore, your permit applications must be submitted well in advance of the date that work is proposed.

Permit fee. The permit processing fee is $10 for individuals and $100 for commercial enterprises. Federal, state, and local governmental entities are exempt. The fee is not assessed until after the permit application has been subjected to public interest review.

State Approvals

The Department of Environmental Conservation (DEC) is the New York State permitting agency. As such, it is responsible for evaluating environmental activities taking place in navigable waters of the state.

Depending on where your proposed floating tire breakwater is to be located, you may or may not be required to complete a state permit. For instance, if you want to locate your FTB in or near a freshwater or tidal wetland, a state permit is typically required. This is also true if an excavation, fill, or dock installation is associated with the building of your floating tire breakwater.

If none of the given conditions relate to your proposed use of an FTB, then you may not be required to complete a formal permit for DEC. Instead, the Regional Permit Administrator may ask for enough plan information to grant a Water Quality Certification, (also known as a 401 Certification) sometimes required by involved federal agencies (the Corps of Engineers or Coast Guard). This certificate ensures that your FTB will not degrade the quality of the water body in which it is to be moored.

For specific guidance on information that must be filed for state approval of your FTB, contact the appropriate Regional Permit Administrator for the DEC.

Regional DEC Offices

Region	*Counties*	*Address*
1	Nassau and Suffolk	N.Y.S. Dept. of Environ. Conservation Building 40 - SUNY at Stony Brook Stony Brook, NY 11794 (516) 751-7901
2	New York City (5 counties)	N.Y.S. Dept. of Environ. Conservation 2 World Trade Center - 61st Floor New York, NY 10047 (212) 488-2758
3	Dutchess, Orange, Putnam, Rockland, Sullivan, Ulster, and Westchester	N.Y.S. Dept. of Environ. Conservation 21 South Putt Corners Road New Paltz, NY 12561 (914) 255-5453
4	Albany, Columbia, Delaware, Greene, Montgomery, Otsego, Rensselaer, Schenectady, and Schoharie	N.Y.S. Dept. of Environ. Conservation Region 4 Office Rt. #10 Stamford, NY 12167 (607) 652-7364
5	Clinton, Essex, and Franklin	N.Y.S. Dept. of Environ. Conservation Rt. #86 Raybrook, NY 12977 (518) 891-1270
	Hamilton, Saratoga, Warren, Washington, and Fulton	N.Y.S. Dept. of Environ. Conservation Hudson Street Warrensburg, NY 12885 (518) 623-3671
6	Herkimer, Jefferson, Lewis, Oneida, and St. Lawrence	N.Y.S. Dept. of Environ. Conservation State Office Building 317 Washington Street Watertown, NY 13601 (315) 782-0100 - Ext. 314
7	Broome, Cayuga, Chenango, Cortland, Onondaga, Oswego, Madison, Tioga, and Tompkins	N.Y.S. Dept. of Environ. Conservation P.O. Box 1169, Fisher Avenue Cortland, NY 13046 (607) 753-3095
8	Chemung, Genesee, Seneca, Livingston, Monroe, Wayne, Ontario, Orleans, Schuyler, Steuben, and Yates	N.Y.S. Dept. of Environ. Conservation P.O. Box 57 Avon, NY 14414 (716) 226-2466
9	Allegany, Cattaraugus, Chautauqua, Erie, Niagara, and Wyoming	N.Y.S. Dept. of Environ. Conservation 584 Delaware Avenue Buffalo, NY 14202 (716) 842-5828

If a state permit is required for your FTB, the maps and drawings submitted to the Corps of Engineers will also be accepted by the Department of Environmental Conservation. The processing period for this permit ranges from 30 to 60 days. DEC charges a permit application processing fee related to the scope of your project.

N.Y. State Underwater Land Easements

If you own shorefront property, most likely the people of N.Y. State are one of your adjoining owners. The State of New York holds title to a variety of lands for which it has no particular use. The Commissioner of N.Y. Office of General Services has jurisdiction over land under the waters of tidal or navigable streams, lakes, or other bodies of water. The state typically owns the land under tidal water to the mean high water line. In most cases, for inland lakes and rivers, the state owns land under water to the mean low water line.

Commercial enterprises contemplating use of an FTB should decide if acquisition of a N.Y. State Underwater Land Easement is appropriate. Public bodies (municipalities, etc.) need not pursue this, for it applies only to private entities.

What is an easement? The conveyance of an easement is a legal transaction that gives documented interest in certain described real property. Although the interest is less than complete ownership, easements carry the right of limited use of another's land. An easement is typically appropriate for personal use of land under water in a temporary way. The charge for an easement is based on the number of square feet of underwater land occupied and value of the upland property. Easements are usually issued for 25-year periods.

Why apply for an easement? As a shorefront owner, you have a unique collection of rights called *riparian rights*. Among these is the right to gain access to navigable water by building out into the water. The Office of General Services suggests that a grant of easement be obtained from the state because:

- It gives you real property interest in the area on which your improvement will be located.
- It typically gives you, in effect, the exclusive right to use the area for the term of the easement.
- It will legalize what may be a trespass on state lands exceeding the owner's riparian rights.

If you wish to apply or gain further information on this *option*, contact:

Office of General Services
Division of Land Utilization
Tower Building
Empire State Plaza
Albany, NY 12242
(518) 474-2195

Local Approvals

To gain insight into local approvals required for your proposed FTB, contact your county planner or the appropriate Sea Grant Extension Specialist for your area:

New York Sea Grant Institute
State University of New York
99 Washington Avenue
Albany, NY 12246
(518) 474-5787

Sea Grant Extension Program
Morgan III
SUNY/Brockport
Brockport, NY 14420
(716) 395-2638

Sea Grant Extension Program
Cooperative Extension Regional Office
412 E. Main Street
Fredonia, NY 14046
(716) 672-2191

Sea Grant Extension Program
Youth Development Program
381 Park Avenue South
Room 621
New York, NY 10016
(212) 685-5081

Sea Grant Extension Program
246 Griffing Avenue
Riverhead, NY 11901
(516) 727-7850

Sea Grant Extension Program
Office of the Program Leader
Fernow Hall
Cornell University
Ithaca, NY 14853
(607) 256-2162

Sea Grant Extension Program
Rich Hall
SUNY/Oswego
Oswego, NY 13126
(315) 341-3042

Sea Grant Extension Program
129 Merritt Hall
SUNY/Potsdam
Potsdam, NY 13676
(315) 268-3303

Sea Grant Extension Program
South Campus, Building H
SUNY/Stony Brook
Stony Brook, NY 11794
(516) 246-7777

Sea Grant Extension Program
Farm and Home Center
21 S. Grove Street
East Aurora, NY 14052
(716) 652-3370

Permit Application Hints

Although the Corps of Engineers prefers that you obtain state and local approvals before submitting the federal permit application, these applications can be accepted and processed simultaneously. However, the Corps will not issue its permit until you obtain the required state and local approvals. By submitting all applications at the same time, you can minimize the time spent in acquiring the necessary approvals.

When preparing a permit application, specify all areas you are considering for FTB moorage sites. Because floating tire breakwaters are mobile, you may plan to use your FTB on a trial basis in several locations before choosing the most effective site. If you do this, clearly indicate the initial site and others under consideration. Then notify the permit agencies before each site change to allow time for them to contact those who would be affected by the change.

Floating tire breakwaters are not yet included within the General Permit Program of the Corps of Engineers. For this reason, each FTB permit application is reviewed on its own merit. In some cases, the Corps may require an engineering assessment to be performed. This request has not been made frequently, but presumably would include an engineer's certification of the integrity of your structure's design and materials. If this request is made by the Corps of Engineers, it would take place after your permit application is submitted.

Because of the relatively recent design and use of floating tire breakwaters, some agency personnel are not familiar with FTB technology. You can increase their awareness and understanding of FTBs by submitting a copy of this information bulletin with your permit applications. In this way, communications regarding your proposed FTB will take place with a common understanding of terminology.

Floating Tire Breakwater Navigational Aids

If your FTB is to be placed into navigable waters of the United States, you must meet the navigational marking requirements of the Coast Guard. Typically, the Coast Guard will contact you when the public notice for the proposed structure is placed into newspapers by the Corps of Engineers.

Representatives from the Coast Guard District serving your region will reach an agreement with you on the appropriate aids to navigation for your FTB's size and location. These private aids to navigation then must be purchased, installed, and maintained by you during the period your FTB is in the water (fig. 13). The aids to navigation designated for your use must be noted on the Private Aids to Navigation Application - CG 2554, which you must obtain from, and file with, the Coast Guard. The Coast Guard will inspect your FTB's navigational markings annually and review the marking information noted on your application.

The appropriate individual within the Coast Guard who can give you assistance in planning your FTB navigational markings may be contacted at:

N. Y. Great Lakes Region
COMMANDER, Office of Aids to Navigation (o.a.n.)
9th Coast Guard District
1240 East Ninth Street
Cleveland, OH 44199
(216) 522-3990

N. Y. Marine Region
COMMANDER, Office of Aids to Navigation (o.a.n.)
3rd Coast Guard District
Governor's Island, NY 10004
(212) 264-8650

When contacting the Coast Guard, explain your proposed FTB and inquire about the private aids to navigation that will be required for the structure. In some cases, Coast Guard representatives will meet with you onsite to gain a better understanding of your local coastal conditions.

If your proposed FTB is to be moored in a nonnavigable waterway, the Coast Guard does not have jurisdictional responsibility for ensuring that the structure is marked. From the standpoint of limiting legal liabilities should an accident occur, you may wish to invest in day markers (e.g., cones) and night beacons (e.g., buoys with battery-powered strobe lights). It is desirable for you to place a notice in local newspapers each year, noting the FTB's location, size, period of use, and owner.

By marking your structure effectively, regardless of regulation requirements, and informing the general public of its presence, you benefit twofold. Not only is your coastal protection increased, but those using the waterway will more likely be appreciative rather than angry about your efforts.

Designing an Effective FTB

Your FTB's size can be planned by guessing at possible dimensions or by calculating appropriate design factors. Clearly the latter method is more apt to provide for optimal wave protection. This section will review those fac-

Figure 13. *Private aids to navigation such as day markers and night beacons are typically required for FTBs moored in navigable waters.*

tors that will determine the effectiveness of your planned FTB. It will also assist you in designing an appropriately sized FTB for your conditions.

What Are Your Conditions?

Research has identified two factors that are important in determining appropriate FTB size. The first relates to the type and size of the typical wave from which you are seeking increased protection. As shown in the Wave Information Worksheet ("Identifying Waves Damaging Your Facilities"), these wave characteristics are unique to your coastal area.

The second factor is the amount of wave protection you desire. Clearly the size of the area you wish to protect will influence this, as will the degree of protection for that area.

When designing your FTB's size, these factors must be considered. Design calculations for a particular FTB are given as an example.

FTB Example

Wave conditions at a coastal marina were causing damage to facilities and recreational boats. The owner decided to increase wave protection by installing an FTB (see fig. 14). The area to be protected is about 200 feet long. Using the Wave Information Worksheet, the owner noted that waves typically causing difficulties are 3 feet in height (*H*), come from the northwest, and have a wave period of 4 seconds. The depth of the water was generally 8 feet. The owner wants the FTB to provide a sheltered area with waves 1½ feet in height.

Step 1: Using the graph in figure 15 and information from the Wave Information Worksheet, determine the wave length (*L*) for the problem-causing waves. Do this by marking the appropriate wave period on the lower horizontal scale. For the example given, a wave period of 4 seconds is marked.

Step 2: Draw a vertical line perpendicular to that point. Where that line intersects the appropriate water depth curve for your coastal area (8 feet in the ex-

Figure 14.

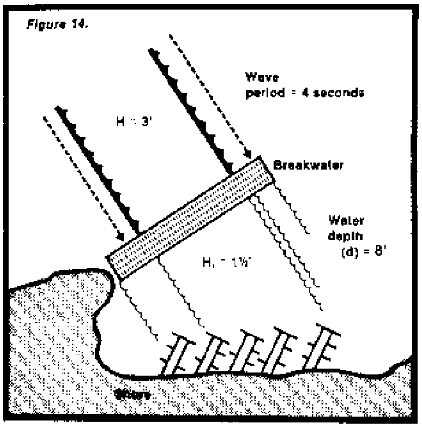
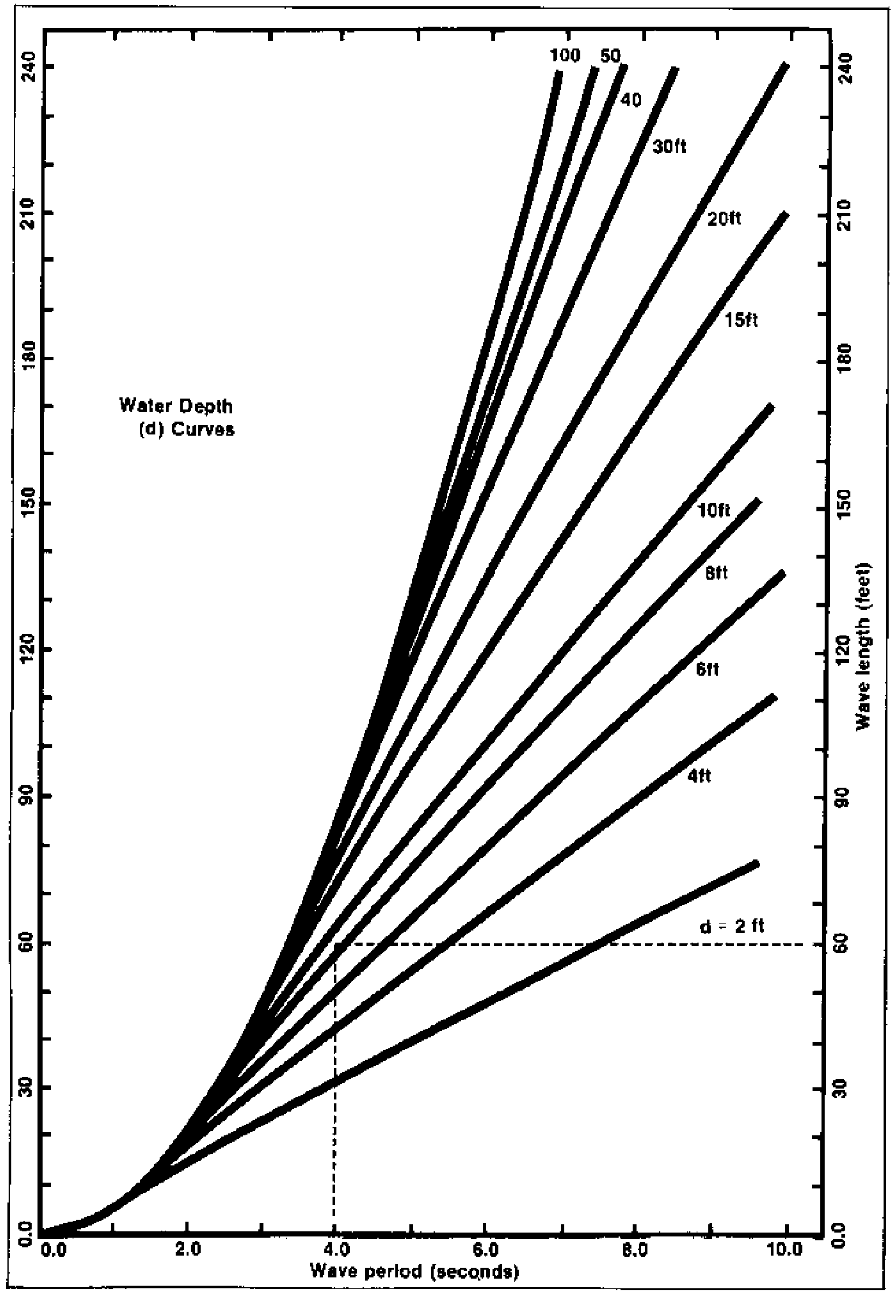


***Figure 15.** Relationship between wavelength, wave period, and water depth (linear theory).*



ample), draw a horizontal line to the graph margin. This value represents the size of wave length (L) for the damaging waves. Note for the marina example, wavelength (L) = 60 feet.

Step 3: Determine the wave-height transmission ratio (C_t) for your conditions. This is calculated by the formula: $C_t = \frac{H_t}{H}$

where

H_t = the wave height desired, and

H = the existing wave height.

For the example, this would be: Transmission ratio $C_t = \frac{1.5 \text{ feet}}{3 \text{ feet}}$ = 0.50.

Step 4: Determine the steepness of waves for your coastal area. Use the formula:

Wave steepness = $\frac{\text{Wave height } (H)}{\text{Wavelength } (L)}$

For the example, this would be:

Wave steepness = $\frac{3 \text{ feet}}{60 \text{ feet}}$ = 0.05 or 5%.

Step 5A: Research has shown that FTB effectiveness is related to the size of its beam (width) and the wavelength (L) of the problem wave. This L/B relationship for a site can be found by using the graph in figure 16.

Step 5B: To use this graph, mark the appropriate transmission ratio C_t determined in Step 3 on the vertical graph scale. Draw a horizontal line across the graph. (In the example, C_t = 0.5).

Step 5C: Where the horizontal line intersects the curve within the graph, draw a vertical line. Read the L/B value at the bottom of the graph.

In the marina example (dotted lines on graph), the relationship L/B = 0.9.

Step 6: Determine appropriate width of FTB beam for your conditions by using the formula:

FTB Beam (B) = $\frac{\text{Wavelength } (L)}{L/B}$

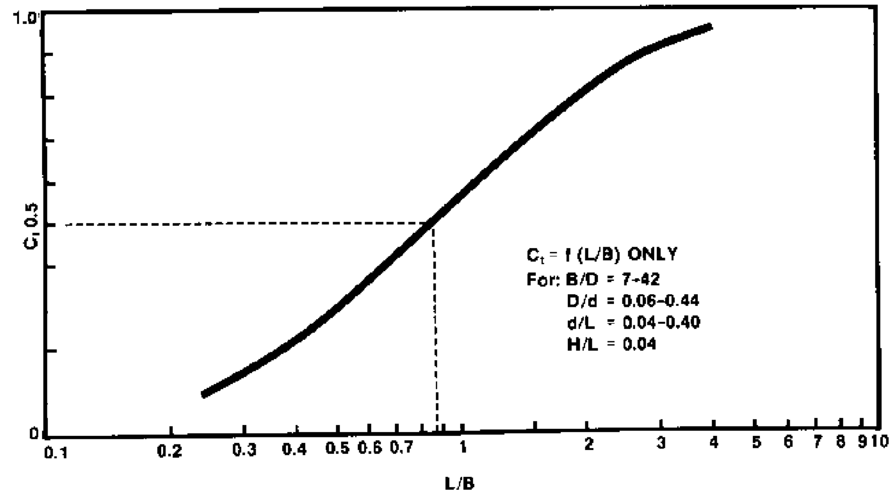


Figure 16. *Design wave transmission curve for Goodyear FTB. (Harms and Bender 1978)*

In the marina example, this would be:

Beam (B) = $\frac{60 \text{ (from Step 2)}}{0.90 \text{ (from Step 5)}}$ = 54 feet.

Because each conventional FTB module is 7 feet × 7 feet, in this example, the appropriate beam is 8 modules in width.

Other FTB Size Considerations

Questions concerning FTB-size considerations other than appropriate width of beam are important. A question that many ask is, "If I increase the draft of my FTB by using larger tires, will my wave protection increase?" Research done on this aspect reveals that wave protection does not increase if the draft of the structure is between 6% to 50% of the mooring site's water depth (termed relative draft). The importance of this information is manifest in increased costs of FTB binding material, flotation, and moorings for no significant gain in wave protection.

To determine the relative draft of your structure, use the formula:

Relative draft (D/d) = $\frac{\text{Draft of tire}}{\text{Water depth}}$

For the marina example,

Relative draft (D/d) = $\frac{2 \text{ feet}}{8 \text{ feet}}$ = 0.25 or 25%.

Another design aspect of FTBs is their appropriate length and positioning. Clearly the length of FTBs is related to the area to be protected. Some wave energy contacting FTBs will "bend" around the ends of the structure. For this reason you may design it to be slightly longer than the area to be protected. Experience in using the structure will guide appropriate future lengthening for increased effectiveness.

The structure is typically positioned within 4 wavelengths (L) of the area to be protected. Its mobility allows for adjustments to be made in moorage position. The structure is placed parallel to the approaching wave fronts causing damage.

Designing an Effective Mooring System

Moorage systems for FTBs can be designed by guessing at appropriate sizes or calculating forces exerted by anticipated waves. Clearly the latter method is more apt to result in an effective system. This section will review the components of an FTB moorage system. It will help you design effective moorings and choose appropriate anchors for your coastal area.

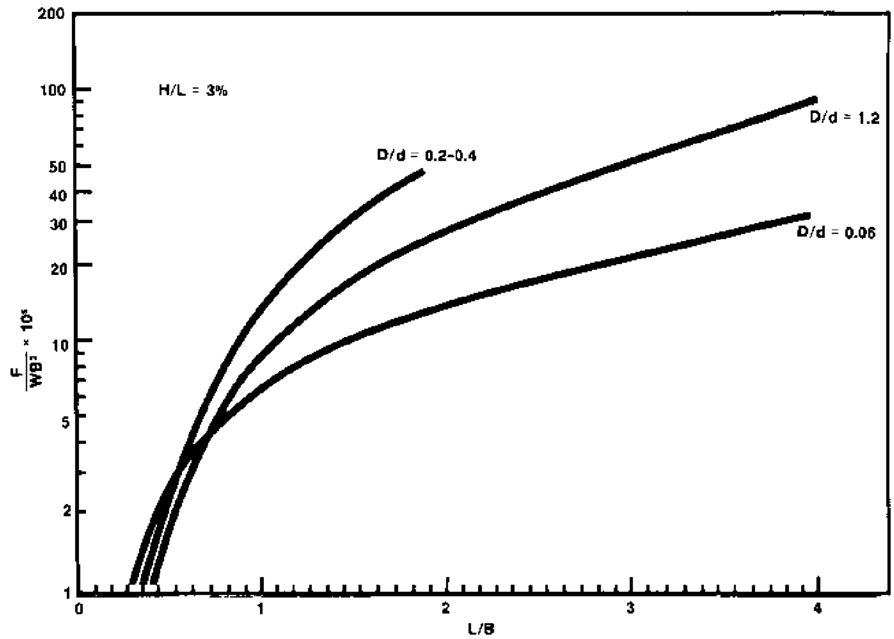


Figure 17. *Force design curves for Goodyear FTB,* H/L = *3%. (Harms and Bender 1978)*

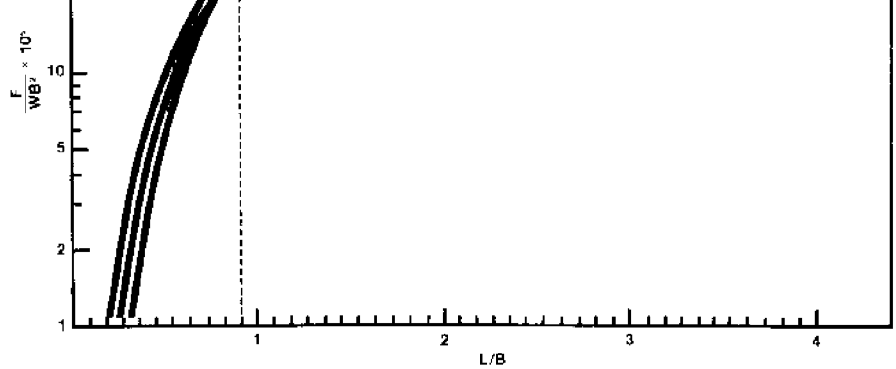


Figure 18. *Force design curves for Goodyear FTB,* H/L = *6%. (Harms and Bender 1978)*

Calculating Mooring Forces

Research show that FTB mooring forces vary with the type of waves encountered and the width (beam) of the FTB. As wave height increases for a given wave length (called wave steepness) or the width (beam) of the structure is enlarged, FTB mooring forces increase dramatically. Hence, these forces must be accounted for in the design of an FTB moorage system. An example of mooring force calculations for an FTB is given.

Recall from a preceding section that a marina owner wanted to increase wave protection with an FTB. The typical problem waves for that coastal area had a steepness (*H/L*) of 5%. The area's wave conditions and degree of protection desired were used in calculating an FTB beam (width) size of 54 feet. The ratio of wave length to FTB beam size (*L/B*) was 0.90, and the relative draft (*D/d*) was calculated to be 0.25 for the given conditions.

To calculate the mooring forces on the planned structure, use the following method:

Research has shown wave steepness to be an important design consideration. Depending upon the calculated wave steepness (*H/L*), use either graph in figures 17 and 18. Find the calculated value (*L/B*) on the horizontal scale and mark it (0.9 for the example). Draw a perpendicular line from this point vertically through the graph (note example dotted line). Where this dotted line intersects the appropriate relative draft *D/d* curve, draw a horizontal line to the graph margin. For the example, the value $A = (F/WB^2 \times 10^5) = 28$.

To find the mooring force, use the equation:

$$\text{Mooring force } (F) = \frac{A \times W \times B \times B}{100{,}000}$$

where

$A = F/WB^2 \times 10^5 = 28$,

W = density of freshwater, = 62 pounds per foot[3],

OR

= density of saltwater, = 64 pounds per foot,[3]

B = calculated FTB beam size = 54 feet.

For the example, this would be:

$$F = \frac{28 \times 62 \times 54 \times 54}{100{,}000},$$

= 51 pounds per foot of FTB.

If the marina owner in the example wants to place an anchor every 50 feet on the front (windward) FTB side, the restraining force for each would be 2,550 pounds (50 feet × 50 pounds per foot). This value is based upon the peak moorage load that could be expected.

Only limited research has been done on the shoreward side FTB mooring forces. Experience would indicate that the rear anchor system should be designed for the force of waves approaching from the shore. At a small distance from shore, it should be designed for about 20% of the restraining force on the windward site.

Planning for Appropriate Moorage Materials

As with all FTB components, the planning and design of your mooring and anchoring systems warrant careful attention. The size of the mooring and anchor systems will vary with the type of bottom (sand, mud, or bedrock) present, local currents and tides, as well as the amount of wind and wave exposure.

The type of line or chain used to moor your FTB is as important as the anchors you ultimately choose. Local experience in mooring larger craft (say over 30 feet in length) is a good guide to follow. The length and weight of your mooring line are vital to its effectiveness. Past experience has shown a mooring line length of 6 feet for each 1 foot of water depth (this ratio typically referred to as a 6:1 scope) to be effective. The type of mooring line utilized is also crucial to the success of the system because its weight acts as an anchor. During storm periods, local seas will have to lift the mooring line off the bottom before forces are applied directly to drag the anchor.

For this reason some builders of FTBs have utilized chain rather than other materials in their moorage system. If you should decide to use chain, attach it to the FTB in a manner that distributes the load between two or more modules. This can be done by attaching a short bridle to the outer tires of the modules and then binding the mooring chain to the bridle.

When choosing an anchor, you must evaluate not only the aforementioned physical factors, but also the number of seasons of projected use. For instance, wood pilings could be used in place of other anchors in some areas, but are typically more expensive and subject to ice damage. Anchors such as concrete blocks and mushroom, stockless, and Danforth anchors, heavy enough to resist drag, have also proved to be effective. These anchors placed 50 feet apart on the windward (front) side and 100 feet apart on the leeward side have been utilized in a number of FTBs.

If you intend to build concrete block anchors, be sure to use a rectangular mold rather than cylindrical to decrease the likelihood of your anchors rolling around the bottom. Pad eyes for mooring line attachment can be formed from reinforcing rod, but their base must be implanted several inches into freshly poured concrete. Do not overlook the buoying force of water reducing the gross weight of your anchors by 62 pounds/foot[3] in freshwater and 64 pounds/foot[3] in saltwater.

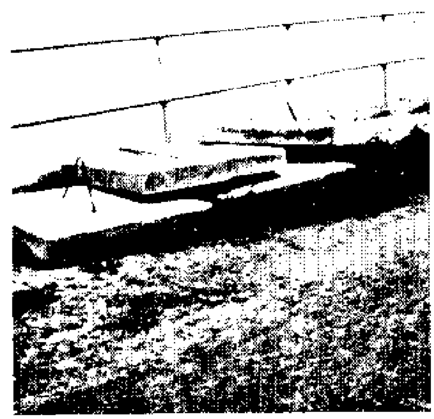


Figure 19. *Reinforcing rod forms pad eyes for mooring line attachment in concrete anchors.*

Binding Your FTB

The most appropriate binding material for your floating tire breakwater is related to the physical parameters of the FTB moorage site, the projected number of years of service, economic considerations, the weight and strength factors of the binding materials, and the availability of various binding materials.

This section will help you to evaluate these factors when choosing a binding material appropriate for your coastal setting.

Environmental Demands on FTB Binding Materials

As the utilization of floating tire breakwaters has increased, the varieties of materials used for binding the tires together has proliferated, some being satisfactory in performance, others disastrous.

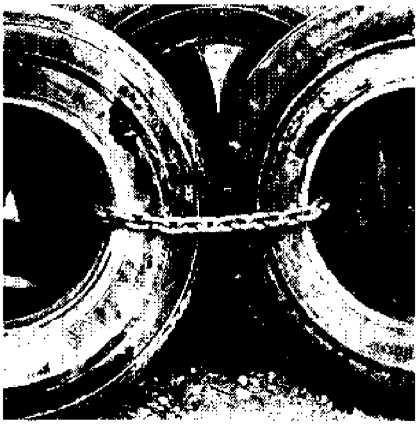


Figure 20. Welded-link chain has been effectively used in freshwater FTB sites.

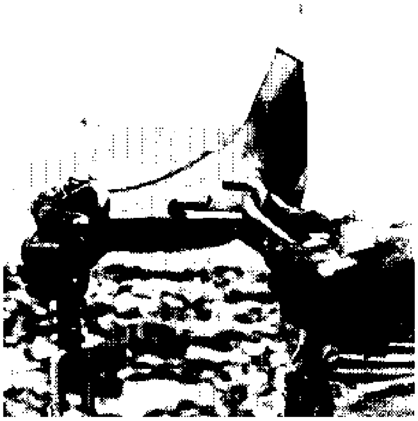


Figure 21. Open-link chain can be effectively used in some coastal areas.

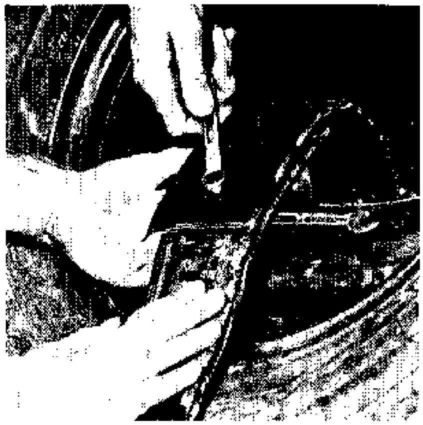


Figure 22. Conveyor belt edging is a relatively strong, durable binding material.

Research engineers at the University of Rhode Island recently tested strength and performance characteristics of materials typically used to bind FTBs. Their research findings indicate that environmental demands on FTB binding material are significant. Experiments conducted in the laboratory and on FTBs placed in Narragansett Bay revealed that binding materials are subjected to strength fatigue by continual wave flexing, abrasion from chafing against other materials, and galvanic corrosion of metal components. The binding materials tested were additionally subject to stress corrosion, biological attack from marine organisms, and ultraviolet degradation of plastic materials not dyed for protection. These findings help to clarify why some binding materials have performed poorly in the past.

FTB Binding Material Performance

Because binding materials being used in floating tire breakwaters have different compositions, their response to environmental stress varies considerably. Engineers from the University of Rhode Island documented these performance variations by placing modules into Narragansett Bay for 10 months. During this period the binding materials being tested were subjected to stresses typical of this marine environment. Information on binding material performance characteristics was recorded before, during, and after the test period. Tensile strength tests were carried out where visual observations were insufficient indexes of performance.

The following is a list of materials that you might consider to bind FTB tires together. To assist in your evaluation of these materials, the performance characteristics are noted below. When two or more materials share common characteristics, these materials are grouped together.

STAINLESS STEEL WIRE (3/16", 1 × 19) WITH BALL SWEDGES

- This wire chafed tire casing during the testing period.
- The cables were not held securely; several "jumped" swedges during on-site experiments.
- Severe corrosion of swedges took place after 5 months of immersion in salt water.
- Crevice corrosion was noticeable within wire bundle.

STAINLESS STEEL WIRE (5/32", 1 × 12) WITH KELVAR CORE

- This wire chafed tire casing during the testing period.
- Multiple failures (breaks) took place with this wire because of severe corrosion and fatigue.
- Stainless clamps induced crevice corrosion.

GALVANIZED STEEL WIRE (3/13", 1 × 7) WITH POLYPROPYLENE COATING, STAINLESS STEEL WIRE (7 × 7) IMPREGNATED WITH POLYPROPYLENE

- The protecting coating wore off within 3 months' service because of tire chafing.
- The wire chafed the tire casing.
- The method of fastening the wire caused damage to protective coating.

POLYPROPYLENE LINE (1/2"), KEVAL LINE (1/2"), NYLON LINE (1/2"), POLY-D LINE (1/2")

- Displayed little evidence of fiber damage from abrasion against tire casings (line is chafe resistant).
- If the line is not purchased with ultraviolet (sunlight) radiation screen, it tends to lose strength and flexibility.

- On 30% to 40% of actual line, length was necessary to ensure secure knots. Splicing or sizing the line at all connections reduced this problem.

NYLON BRAIDED LINE (3/8")

- Exhibited poor abrasion resistance; breaking strength was reduced by more than 75% during 8-month test period.
- It was difficult to make reliable tie connections.
- Ultraviolet sunlight degradation caused loss of the line's strength.
- The line cut into tire casings.

WELDED GALVANIZED STEEL CHAIN (3/16") (fig. 20)

- The chain performed well during tests. The zinc coating acted as a sacrificial anode against corrosion.
- This chain is more useful in freshwater than saltwater since corrosion eventually deteriorates sacrificial anode in salt-water.
- The chain connections were effectively made using 3/16" galvanized steel shackles.

OPEN-LINK NONGALVANIZED STEEL (1/2") (fig. 21)

- The links of this chain, developed by Campbell Chain Company, can be spread open/closed with special hand tools (no cutting torch necessary). This chain costs approximately 78 cents per foot.
- The link length is 3-5/8", with an approximate weight of 2 pounds per foot. The average load required to spread a new link to 1/2" gap was 2,462 pounds.
- After 10 months of immersion in saltwater, there was a 3% to 16% reduction in cross-sectional link area due to corrosion. Experience has shown this rate is lower in freshwater, where corrosion rates are slower.
- Several open-link chain FTBs are located in freshwater lakes. These are working effectively after 24 months of service.
- This chain is available from:
  Campbell Chain Company
  2990 East Market Street
  York, PA 17402
  (717) 755-2921

RUBBER CONVEYOR BELT EDGING (2" to 3")

- This material is composed of flexible rubber with nylon and polyester fabric plies. It is a scrap material derived during the manufacture of conveyor belts.
- The belting is noncorrosive and had an ultimate tensile strength of 9,500 pounds per square inch.
- The material had only a slight negative bouyancy. It resisted abrasion and showed no sign of ply separation after 9 months' field use.
- The conveyor belt edgings are typically 2" to 4" wide, 3/8" to 3/4" thick, coiled and banded for shipping at a price of 6 cents per foot and greater, depending upon specifications.
- Research indicates that the conveyor edging should be at least 2" wide and 3/8" thick for effective performance as FTB binding material.

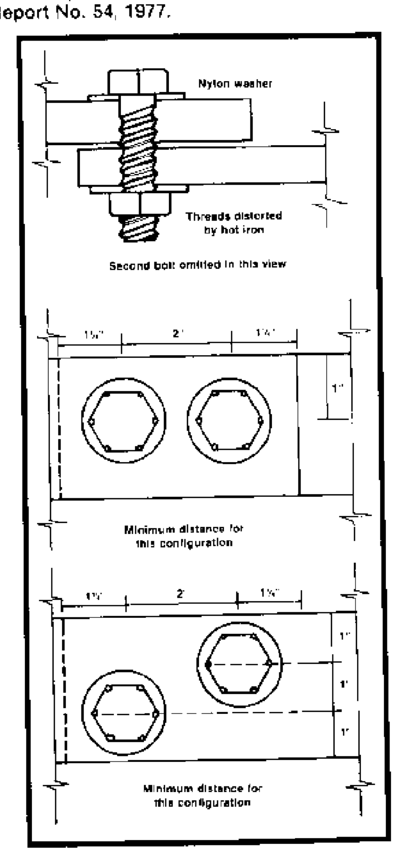
Binding Your FTB with Conveyor Belt Edging

Conveyor belt edging holds promise as a strong, less expensive and relatively lightweight binding material. It can be cut with readily available tools, such as an ax, hand saw, or band saw. Likewise, holes for the bolt fasteners can be punched individually with a hammer and metal punch or with a multiple gang punch.

If your FTB is to be moored in freshwater, metal bolts, nuts, and washers can be used. In saltwater, however, the corrosion rates are considerably higher. To mitigate this problem, nylon fastening components can be used. The nylon fasteners should be dyed black before use to prevent ultraviolet sunlight degradation of the material. Boil the nylon fasteners for several minutes in water with household dye.

Two techniques have been used to date in the fastening of conveyor belt FTB bindings. One of these uses three 3/8-16 bolts per tie, as shown in figure 23. The belt width used with this pattern should be no less than 2 inches in the bolt zone to prevent the belting from tearing through to the edges. This pattern can support an average load of 2,100 pounds before the bolts fail. Washers must be used under the bolt head and nut to prevent them from

Figure 23. From A. P. Davis, Jr., *Evaluation of Tying Materials for Floating Tire Breakwaters*, University of Rhode Island, Marine Technical Report No. 54, 1977.



pulling through the rubber. Voids in the center of these 3/8-16 injection-molded bolts cause their strength to vary by several hundred pounds. Several floating tire breakwaters are using this fastening technique successfully in the Northeast (note FTB site listing).

The second technique for fastening the conveyor edging uses two 1/2-13 bolts per tie as indicated in figure 23. The belt width used should be no less than 2 inches in the bolt zone to prevent belt tearing. The average strength of this pattern is 2,150 pounds. These bolts differ from the 3/8-16 in that they are manufactured from cast nylon bar stock on a screw machine and do not have the voids that are present in other bolts. For this reason, engineering tests have shown their strength to have less variation.

Acquiring Conveyor Belt Binding Materials

Conveyor belt edging is not a readily available manufactured product. Rather, it must be acquired from companies that discard used conveyor belts or purchased from the following:

W. Y. Boyle Company
812 Bloomfield Avenue
Windsor, CT 06095
(513) 644-0404

C.M.F., Inc.
404 Oak Street
Marysville, OH 48040
(203) 688-8305

Cincinnati Rubber Mfg. Company
4900 Franklin Avenue
Cincinnati, OH 45212
(513) 631-0691

J. A. Webb, Inc.
92 Pearl Street
Buffalo, NY 14202
(716) 852-6062

Because of the periodic availability of this binding material, you must make arrangements to get it well in advance of FTB construction.

Floating Your FTB

When assembled, the 20-tire units weigh approximately 500 pounds on land or 100 pounds in water. Since the tires are oriented vertically in the water, the air trapped in their crowns provides 10 pounds of reserve buoyancy per tire. A unit of 18 tires plus the 2 connecting tires, therefore, provides approximately 200 pounds of buoyancy. This means that when an FTB is placed in the water, 6 inches of each tire is typically visable above the water. The air trapped in the crowns is replenished when waves interact with the floating tire breakwater. Do not use tires with holes, because air can escape through them (fig. 24).

Other causes for the sinking of tires within a structure include lack of wave action to recharge air lost from tire crowns by absorption into water or leakage, deposits of sand and silt in bottoms of tires, snow or ice accumulation, and marine-fouling organisms in salt water environments. In those areas where wave action is not recharging the trapped air effectively, some tires must be lifted out of the water by hand to replenish trapped air.

When heavy fouling conditions exist, one must scrape off the

Figure 24. *Supplemental buoyancy is highly desirable in areas having heavy winter snowfall or marine fouling organisms. Note submerged tires in this FTB section.*

marine growth on a regular basis. In colder climates, the breakwater can be hauled ashore during subfreezing weather to kill the growth, which will fall off when the FTB is placed back into the water.

If you are planning to use your FTB for several years, supplemental flotation is highly desirable, especially in salt water environments where fouling by marine organisms is a problem or in areas of possibly heavy snowfall.

Though many flotation materials will improve the buoyancy of your FTB, some have drawbacks which need to be recognized at the outset. For instance, empty plastic containers (such as bleach bottles) are difficult to

Nylon Bolt Fastening Hints

In tightening the nuts, torque limits should be maintained. These will vary with the size of the bolt being used. A good method is to watch the nylon washer for cupping as the nut is tightened (use flat washers rather than lock washers). A slight cupping indicates that the nut is tight enough.

Bolts should be long enough to permit at least 1/4 inch of thread to protrude through the nut. Make allowances for varying belt thicknesses and the two flat washers; and distort the ends of the thread to prevent the bolt from backing off.

secure effectively inside a tire. Another material, styrofoam, is susceptible to physical and chemical degradation.

A buoyant material used effectively in several FTBs to date is urethane foam. The easiest way to install it is to pour about ½ pound of liquid urethane foam into tires prior to constructing modules. Builders who have filled one-third of every other tire have had satisfactory results. When you construct the modules, make sure the foamed tire crowns will be at the water's surface when the FTB is launched.

Although floating tire breakwaters are relatively inexpensive to build when compared with fixed breakwater systems, do not be misled into building them as cheaply as possible. It is false economy to neglect the use of supplemental flotation when fouling or extended periods of calm water may be a problem. The objective in building an FTB is to enhance coastal protection at a reasonable price, not to gain an additional problem at a cheaper price.

Manufacturers of urethane foams for marine uses include:

General Latex Corp
66 Main Street
Cambridge, MA 02142
(617) 864-7750
Vultafoam — Catalog 16F-2702

PPG Industries, Inc.
151 Colfax Street
P.O. Box 127
Springdale, PA 15144
Selectrofoam — Catalog 67040

Insta-Foam Products, Inc.
2050 N. Broadway
Joliet, IL 60435

Constructing and Launching Your FTB

Floating tire breakwaters are built of tires bound together to form modules. These modules are attached to other modules to construct the floating tire breakwater. Because the physical integrity of the device is dependent upon its components, each should be constructed with care.

All workers building your FTB should be made aware of effective construction of the most basic component, the module.

Each module is constructed from 18 tires bound together as shown in figures 25 and 26. The module can be constructed with hand tools by two laborers in 5 to 10 minutes. Although the tires can be stacked free standing in a 3-2-3-2-3-2-3 vertical combination, you may wish to construct a tire rack (see fig. 25). Either way, the binding material must be woven through the module as shown in figure 26. The fastening of bindings can be made easier by sitting or standing atop the 18-tire module. But remember that crushed tires will not contain enough air to float; so secure the bindings taut enough to keep the module rigid but not distorted. (fig. 27). Once bound, tip the module over, remove the tire-stacking rack, and haul the 18-tire unit to the FTB assembly area.

The assembly of a section of FTB requires bound modules as well as unbound tires. The assembly begins by swinging the 4 outside tires out as shown in figure 28. Attaching one module to another requires 2 additional connecting tires for each linkage. Orient the module tires parallel

Figures 25 and 26. *A rack can be made to aid in the construction of FTB modules. Binding material is woven through tires stacked in a 3-2-3-2-3-2-3 combination to form the FTB module.*

to each other to expose maximum tire surface area to oncoming waves (see fig. 29).

Experience has shown that some components should be assembled on land, others in the water. Previous builders have constructed a section of FTB on land. Then, while that section was being launched and moored, another section was being constructed (fig. 30).

The size of a section usually depends on *how* it is launched. In the case of Dunkirk Harbor, New York, builders assembled FTB sections, 13 modules by 2 modules (100' by 14'), along the edge of a pier. After they completed two of these sections, a tractor with a high lift launched each (fig. 31). Shallow water depths along the pier allowed workers to bind these sections in the water to form a 100-by-28-foot FTB segment. Then, this segment was towed to the harbor moorage location where it was anchored into place to await additional segments.

A floating tire breakwater constructed by Great Bay Marina, Newington, New Hampshire, was launched off a beach. In this case, workers constructed segments with the exact FTB beam size and towed each 100-foot-long segment off the beach for moorage.

Building FTB segments on a beach requires a towboat with thrusting power proportionate to the size of FTB segments. The larger the segment built on land, the more force required to drag it off a beach.

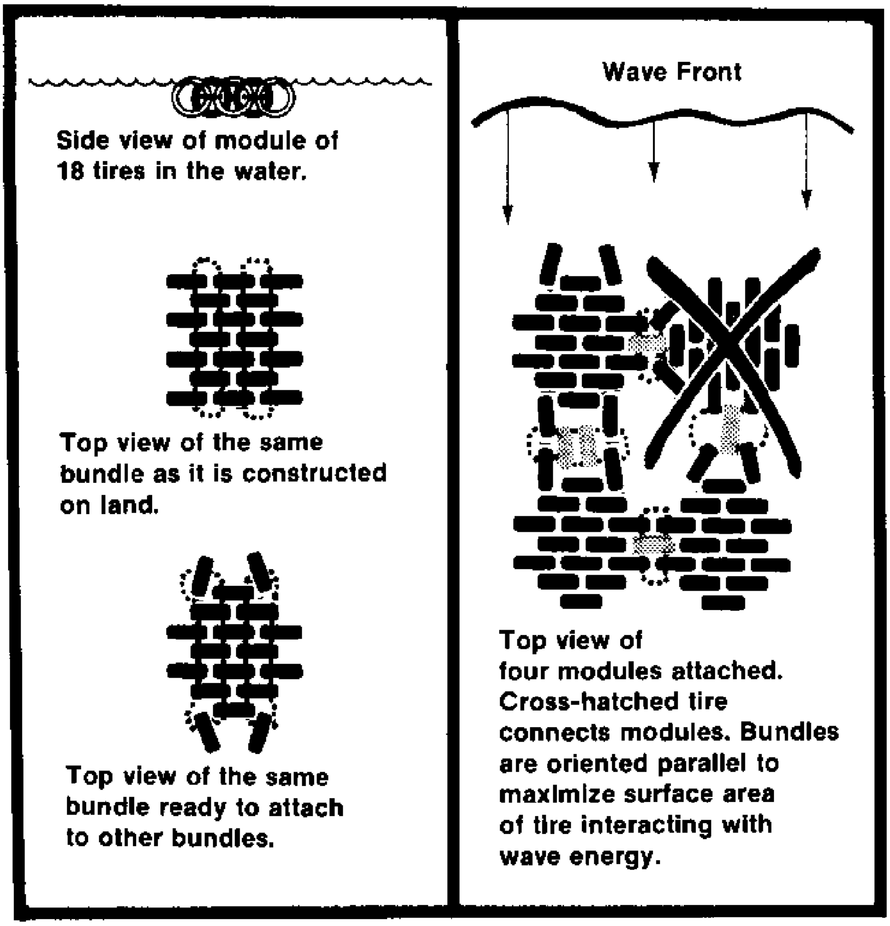
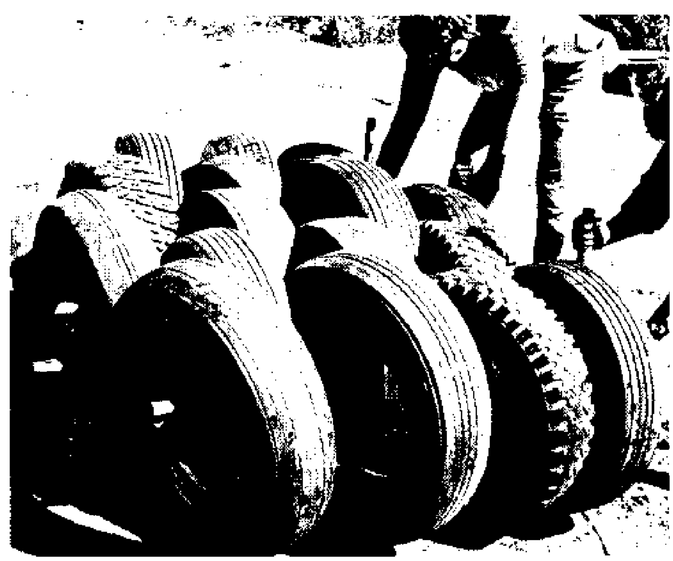


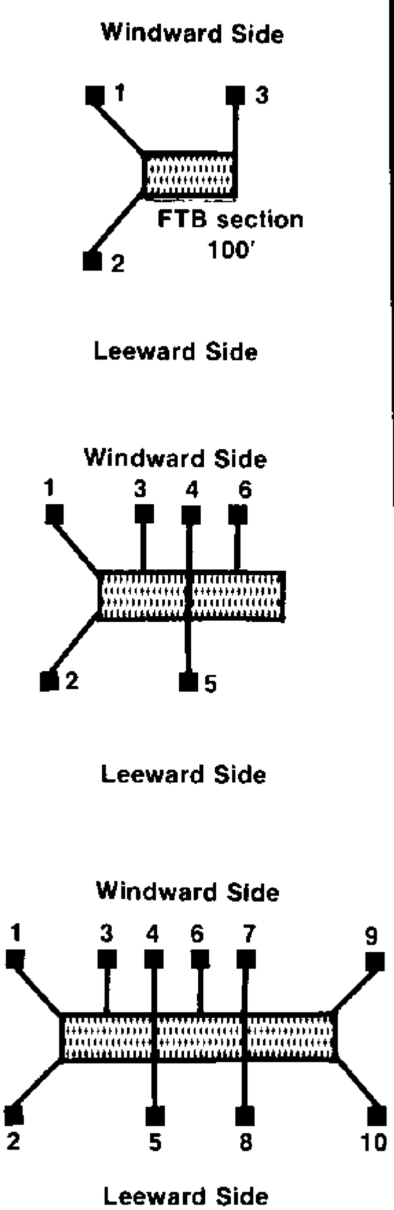
Figure 29.



Figures 27 and 28. *After the 18-tire module is formed, the binding material is fastened, and the module tipped on its side as it will be oriented in the water.*

Figures 30 and 31. *FTB sections are typically constructed on land and can be launched from piers by using a tractor with a high lift.*

Figure 32.



Constructing an FTB on winter ice cover was another launching technique effectively used on an inland lake. The launch occurred when the spring thaw melted the ice cover, and the FTB dropped into its lake moorage location. This technique may not have application for areas experiencing thick ice cover, because of ice pack movements over the structure before melting.

Getting Your FTB Onsite and Moored

Towing an FTB to its moorage area can usually be accomplished with one towboat. The size or power of towboat necessary depends on the size of the section of FTB to be towed (see fig. 33) and the method of FTB launching used. In addition to the towboat, a small boat is useful for carrying tools, moorage supplies, or divers. Often this boat is stationed close to work areas where sections of FTB are being joined to form a single structure.

To begin the process of getting an FTB onsite and moored, a procedure used is to connect one end of the moorage chain to a windward anchor and the other to the windward corner of the FTB. By doing so, the first sections can be towed onsite using the chain as a tow line. When the FTB section floats into its moorage position, its anchor is dropped (see fig. 32A). While this anchor holds the section in position (pick a calm day), moorage chain is attached to a leeward anchor and the leeward corner of the FTB. The towboat then transports this anchor to its anchorage location and drops it into position (anchor #2 on fig. 32A) along with anchor #3. In positioning anchors, the mooring chain should not be stretched taut or in a pile directly below the FTB. Rather, a midpoint position is desirable.

Having secured the first section of FTB in its moorage position as shown in figure 32A, you can tow another section on-site in the same manner; but do not drop an anchor until the two sections are bound together with connecting tires (fig. 34). When this has been accomplished, the anchors shown in figure 32B can be positioned effectively. This procedure can be followed until the last section is positioned (fig. 32C), and the final corner anchors are dropped into their anchorage locations.

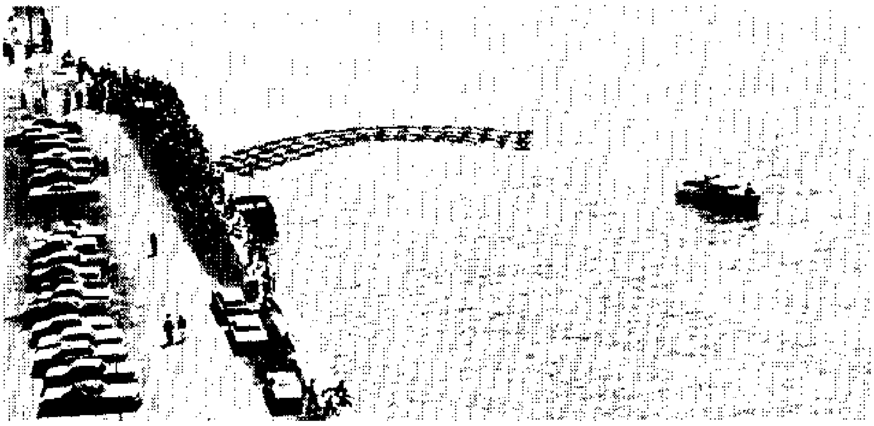


Figure 33. The size and power needed by the towboat depend upon the size of FTB sections to be transported on site.

Maintaining Your FTB

Since floating tire breakwaters are built of lower-cost materials, they are subject to more rapid wear and deterioration than conventional breakwaters. Although tires used in the structure can absorb large amounts of energy by yielding and deforming, binding materials and moorage system components are not typically so resilient. To ensure the integrity of your FTB, these components should be inspected on a regular basis. Although they can be visually inspected from a boat, experience has shown that periodic underwater inspections are also desirable.

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

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

Figure 34. Divers bind adjacent sections together to construct the FTB.

Limiting Your FTB Legal Liabilities

When you place an FTB into a waterway, be aware that you assume legal responsibilities. This section has been written with the aid of a coastal resources legal specialist. It provides information for you on how to cope with these responsibilities and limit the liabilities assumed when construction begins on your FTB. Before building an FTB, you might want to check with your own lawyer for further understanding of your responsibilities.

The following questions are often asked by those building FTBs. The responses reflect legal probabilities, rather than absolute answers.

Q: Is an FTB an attractive nuisance if moored alongside a dock or in the middle of a harbor? If so, how can legal liabilities be minimized?

R: Any structure that is unusual for an area or captures the imagination of people is potentially an attractive nuisance. To limit your liabilities, post a conspicuous sign that states the danger (e.g.,

DANGER — SWIMMERS MAY BECOME ENTANGLED IN BREAKWATER). Because some children cannot read and adults may have impaired vision, you should also try to control access to the structure. This can be done by placing a barrier or fence between the structure and others.

Q: Who is liable if a boat or water skier collides with the structure and injury occurs?

R: If the FTB is well marked and visable, negligence for the accident may be that of an inattentive boater. Remember, also, that the low profile of your FTB and its flexibility helps to reduce the probability that significant structural damage will be done to a boat if it should run "aground." It would be a good idea to place a notice in local newspapers each season telling where the FTB is located, and giving its size and owner's name.

It would be prudent for FTB owners to have insurance covering these types of occurrences. Municipalities can choose to have the structure covered by the general liability insurance policy which they most possess. Private owners may wish to contact their insurance broker and arrange for a rider for the FTB to be placed on an existing insurance policy.

Q: If the tires used in my FTB are "branded" (spray paint initials, etc.), will this limit my liability for tires washed up on other private property?

R: Yes, it will, if all tires are branded with a mark not made known to the general public. This method of branding would also help you to retain property rights should someone try to tow your structure from its moorage site. After all, you have invested money in your FTB.

Q: If under severe storm conditions (an act of God) the FTB is deposited upon someone's property, how quickly must it be removed? Can it be left until after the storm has subsided?

R: Yes, you will have a reasonable amount of time to remove the FTB (say 1 to 2 weeks) from the standpoint of legal responsibilities. If the structure should break loose under severe storm conditions, recovering it would generally not be considered a trespass of private property rights. You would be given access rights to reclaim the structure. Barring real property damage, you would typically not be liable for the presence of the FTB on someone's coastal property.

Q: What if adjacent property owners perceive the FTB as causing increased coastal erosion; might I be liable for damages?

R: *If property owners can prove* that the FTB is the proximate cause of increased coastal erosion, they may retain a lawyer and seek to obtain an injunction to stop its use. Be aware that the physical attributes of nature are quite complex, thereby, making it difficult for someone to obtain the burden of proof necessary for such action.

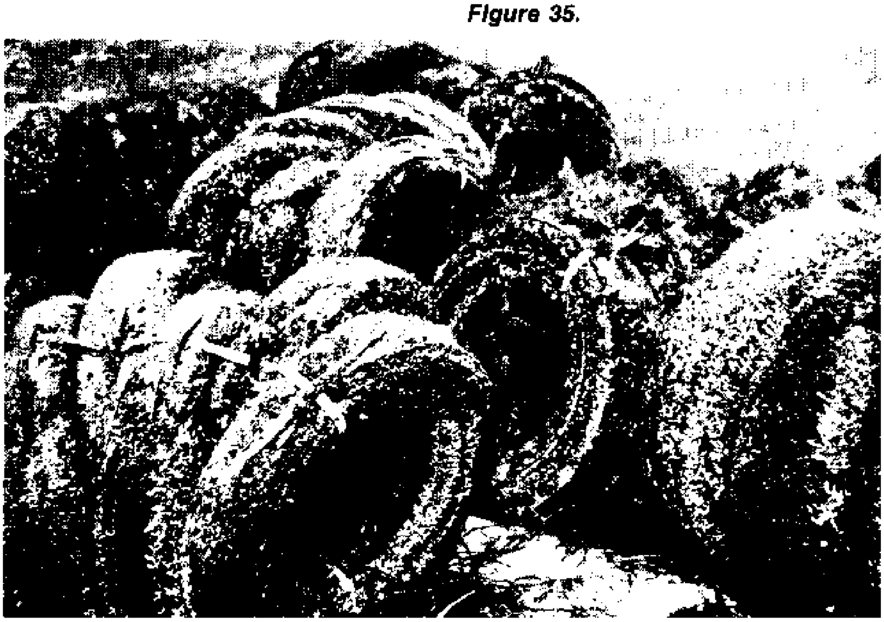
An Ecological Plus

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. As an artificial reef, this floating structure is felt to be more effective than a structure placed on the bottom because in the upper 3 feet of the water, light intensities are higher, temperatures warmer, and oxygen levels higher.

Biological studies in southern New England have identified the following species as 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 as fishing reefs and as protection for the spawning grounds of largemouth bass.

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

Figure 35.



FTBs Protecting Eroding Coastlines — Fact or Fiction

The problem of protecting coastal properties from erosion has puzzled and plagued many coastal people. Many conventional protective structures such as seawalls, bulkheads, and groins are expensive. In addition, because of the complexities of coastal processes and the prohibitive price of correcting mistakes, state and federal agencies have been increasingly reluctant to permit widespread use of these structures.

Several erosion protection projects using tires have been implemented. This section reviews two of these efforts.

Offshore Erosion Protection

Recently, the Florida Sea Grant Program published a case study of an offshore FTB used to control shoreline erosion. In the pamphlet, "FTBs — A Case Study of a Potential Low Cost Structure . . .", marine engineering specialists describe preliminary results of a demonstration site located on the south shore of Santa Rosa Sound (located near Pensacola Beach, Florida). The site exhibited traits common to many eroding shorelines in Florida's coastal bays, with about 30 feet of erosion in 5 years. Apparently, the beach was eroding because sand was sloughing off an inner shelf area into deeper water where it could not migrate back.

A floating tire breakwater was placed shoreward of this steep slope, and sand accumulated in the wave shadow cast by the breakwater. The accretion does not resemble a migrating transverse bar, but rather a "tombolo" sand accumulation, which typically occurs when longshore currents enter sheltered coastal areas. No adjacent coastal property erosion has occured to date, perhaps because sand transport is predominantly in an onshore-offshore direction. In those areas having strong long-shore parallel to shore) sand transport, an FTB placed offshore could cause "downdrift" erosion if not removed for part of the year.

Tire Mats Used for Onshore Erosion Protection

Rogers City, Michigan, is not unlike many coastal cities of New York. Located along Lake Huron, Rogers City experienced rapid erosion between 1970 and 1974 near its sewage plant. To cope with the problem, state funds were appropriated to build a tire mat to protect the area. In 1976, a tire mat, 56 feet wide and 210 feet long, was placed partially onshore and offshore, so that the offshore portion of the mat was submerged on the lake bottom.

The structure was built using offshore anchors, onshore pilings, filter cloth, and tires punched to inhibit flotation (fig. 36). Although this protection effort was the first of its type, monitoring at the site during construction and during the following year showed that the beach increased in size. The tires evidently trapped and effectively held sand from the littoral drift, though part of the structure was removed to make way for a rock gabion subsequently installed by the Corps of Engineers. A detailed report of this effort is given in the paper *Utilizing Tires as Onshore Protective Structures*, which is listed in the reference section on page 29.

When Its Days Are Done as an FTB

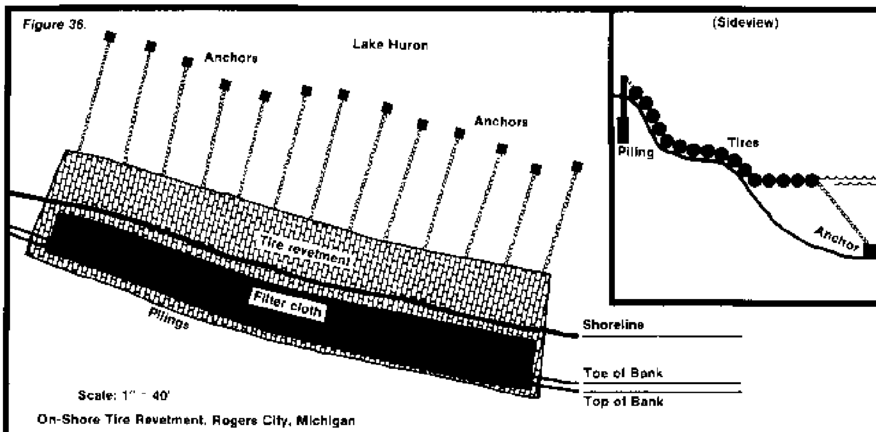
To predict the life expectancy of a floating tire breakwater is difficult. Rubber itself is an inert material which is chemically stable in water. Recently, a piece of natural rubber found in one of England's harbors was dated to the 18th century.

Other materials used in FTB construction could experience less longevity depending on environmental conditions and degree of maintenance. If your FTB is performing satisfactorily, you might want to replace these materials.

Before constructing your floating tire breakwater, consider where it will be disposed of or next used when its FTB days are done. Several options for evaluation follow.

- The breakwater could be moved onshore for coastal erosion protection.
- If maintained, it could be sold to another coastal business or community for enhancing wave protection. (It can be towed.)
- The breakwater could be used as a floating or submerged artificial reef.
- After disassembling it, the tires could be transported to land fills or rubber reclamation centers.

Figure 36.



On-Shore Tire Revetment, Rogers City, Michigan

Checklist for Building Your FTB

FTB Installation

- ☐ 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)
- ☐ 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
- ☐ FTB system
  1. Design
     a) Length
     b) Width
     c) Tire orientation
     d) Pattern of mat
  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 abrasions, corrosion, fatigue, ultraviolet exposure, biological attack
- ☐ FTB mooring system
  1. Depth of water - normal and storm range
  2. Type of bottom (sand, rock, silt, mud)
  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
- ☐ FTB environmental impact
  1. Wave suppression
  2. Water flow constriction and effect on sediment movement
  3. Biological habitat (artificial reef)
  4. Appearance
- ☐ Legal liability
  1. Name, address, and telephone number of responsible person or firm
  2. Branding tires for identification
  3. Bonding requirements
- ☐ Installation
  1. Dates
  2. Possible expansion plans
- ☐ Estimated cost of FTB

FTB Maintenance

- ☐ Name, address, and telephone number of person or firm responsible
- ☐ Anticipated maintenance under normal and critical storm conditions
  1. Mooring system failure
  2. Flotation loss
  3. Tying material
  4. Drifting loose tires
  5. Clean up of trapped debris and flotsam
  6. Being rammed by floating objects (boats, barges, trees)
  7. Ice movement, seasonal storage
- ☐ Estimated annual costs

FTB Removal and Ultimate Disposal

- ☐ Expected life or use of FTB system at site
- ☐ 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
- ☐ Anticipated disposal cost

For Further Reading

Armstrong, J.M. 1976. *Utilizing tires as onshore protective structures.* Copies available at cost from Ithaca Sea Grant Extension Program Office.

Candle, Richard D., and Fischer, William J. 1976. *Scrap tire shore protection structures.* Engineering Research Department, Research Division, The Goodyear Tire and Rubber Company, Akron, Ohio.

Davis, Albert P., Jr. 1977. *Evaluation of tying materials for floating tire breakwaters.* University of Rhode Island, Marine Technical Report No. 54. Narragansett, R.I.

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Editor's Note: This Information Bulletin represents a compilation of data in an attempt to provide detailed information on many aspects of floating tire breakwaters. Some of this manuscript has been reprinted or adapted from publications already in print. For a complete list of works cited, refer to the reference listing "For Further Reading" above.

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