Evaluation Of Tying Materials For Floating Tire Breakwaters

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**University of Rhode Island
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EVALUATION OF TYING MATERIALS FOR FLOATING TIRE BREAKWATERS

by

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INTRODUCTION

With the construction of floating tire breakwaters during the past several years, a serious problem of tying material failure has arisen. In an effort to find a tying material to eliminate these failures, in-situ testing was carried out in Narragansett Bay, Rhode Island. The tests, which ran from January 1976 to November 1976, were monitored at the University of Rhode Island's Bay Campus. Because of their location, the test breakwater modules rarely enjoyed the luxury of calm water. On several occasions, such as during Hurricane Belle on August 9, 1976, the modules were subjected to waves more than four feet high. In addition to wave action, the modules endured currents which averaged 0.7 knots and which, on many occasions, exceeded 1.3 knots. Water temperature ranged from 36°F in February to 66°F in August. No icing conditions were encountered during this period.

ENVIRONMENTAL CONSIDERATION

The demands upon a floating tire breakwater tying material are rigorous. The material must be capable of withstanding:

a. fatigue - brought about by continual flexing and twisting

b. abrasion - from chafe against marine growth, studded tires, steel bead, tire casings, ice, and other tying materials.

c. galvanic corrosion - when metallic components are employed. This corrosion is accelerated on most tying metals by:

    1. a highly oxygenated environment, a result of proximity to the surface and breaking waves. (Note: Stainless steels tend to stand up better in this type of oxygenated environment.)

    2. the fact that metallic tying systems usually employ more than one type of metal, thereby creating cathodic (protected) and anodic (destroyed) areas. Eventually, the anodic areas lose enough strength to cause a tying failure.

    3. a proliferation or marine growth which can cause severe corrosive damage to stainless steels and also produces substantial deposits that damage metallic components.

4. stress corrosion, in which areas under high stress (tight bends and areas under clamps and crimps) are more prone to corrosion than are areas under lower stress.

d. ultraviolet degradation - from sunlight which will affect most plastic tying materials if they are not screened.

e. attack - from marine organisms and fish bite.

TYING MATERIALS TESTED

The following materials were tested:

a. 3/16" 1x19 stainless steel wire with ball swedges

b. 5/32" 1x12 stainless steel wire with Kevlar core

c. 3/16" 1x7 galvanized steel wire with polypropylene coating

d. 3/16" 7x7 stainless steel wire impregnated with polypropylene

e. 1/2" polypropylene rope, regular lay

f. 1/2" nylon rope, regular lay

g. 1/2" Poly-D, regular lay

h. 1/2" Kevlar line

i. 3/8" nylon rope, braided

j. 3/16" regular welded, galvanized steel chain

k. 1/2" special chain, extended link, nonwelded, nongalvanized mild steel

l. 2" to 3" wide rubber conveyor belt edging, 0.420" thick

Other materials too numerous to list were considered but rejected as test specimens, because a variety of factors indicating poor reliability.

The tensile strengths of the above materials vary, but all were capable of supporting a minimum load of 2000 pounds at the beginning of the test. Working and breaking loads for most of the materials listed above can be obtained from most rigging handbooks. The average load required to spread a link of unused 1/2" special, nonwelded chain a half-inch was found to be 2,462 pounds. The rupture strength of the various rubber conveyer belt edgings with fabric plies (in unused condition with no stress risers, that is, areas of high stress such as punched holes) averaged 9,500 p.s.i.

Methodology

The modules were each constructed of 18 automobile tires, with an interlinking tire between modules, as described in Appendix I. The tying material being tested secured the tires in the same fashion as would be encountered in an actual breakwater, see Figures 1, 2, 3 and 4, Appendix I. No special tools were employed in tying the tires. Inexpensive tools obtainable from local supply houses were used in the tying of materials requiring nonstandard fastening. The modules were assembled on land and connected three to a group (total 56 tires), then tipped off the side of a pier. They were then secured to the other test sections, exposing the tying materials to actual breakwater conditions.

The properties of the tying materials were recorded at least three times: before exposure to the salt water environment, midway during the in-situ test, and at the end of the exposure period. In some cases visual observation was sufficient to determine a material's inability to serve as a tying material. In other cases, tensile strength tests were carried out to determine strength losses. Several samples of each test material were attached to the breakwater to permit quick removal for inspection and testing during the test period.

RESULTS and RECOMMENDATIONS (SUMMARY)

a. The 3/16" 1x19 stainless steel wire with ball swedges proved undesirable for the following reasons:

   1. The ball swedges showed severe preferential corrosion along its longitudinal axis (see Photographs 1, 2 and 3). This corrosion led to swedge failure on several specimens after only five months of immersion.

   2. Evidence of crevice corrosion was noticeable within the wire bundle.

   3. The method of holding cables securely in place was not positive enough; several "jumped" swedges.

   4. The wire severely chafes the tire casing (see Photograph 2).

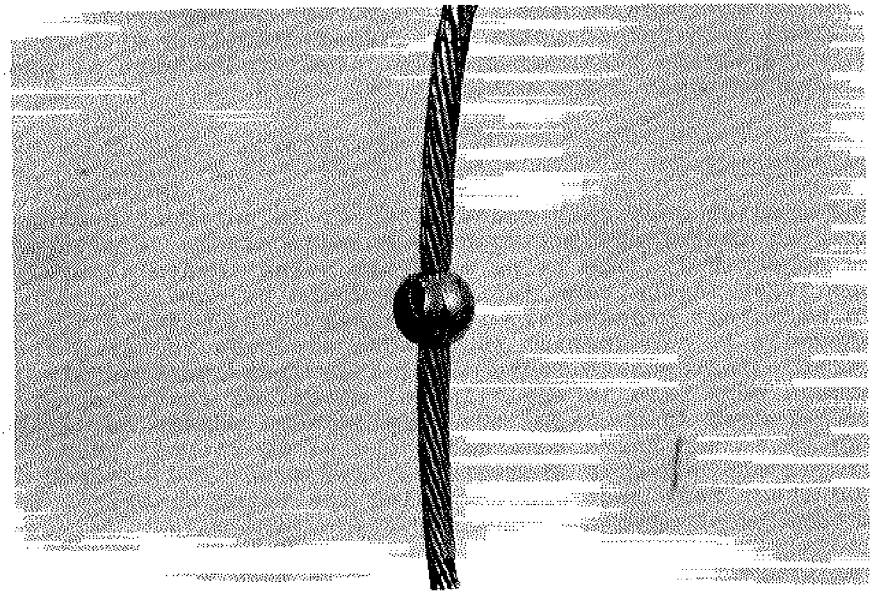


Photo #1 & #2. Severe corrosion on stainless steel ball swedged over stainless steel tying wire.

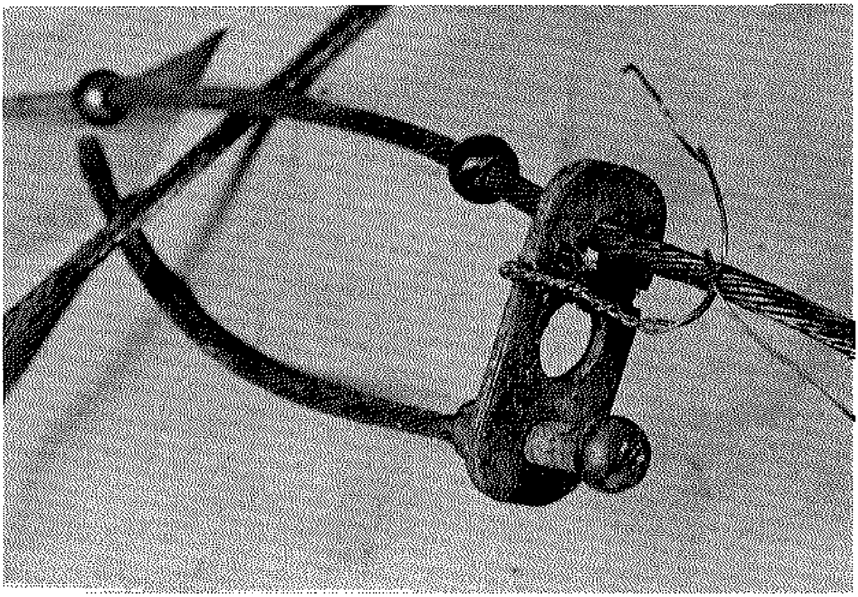


Photo #3. Positioning clamp showing function of stainless steel ball swedges on stainless steel tying wire.

   5. The life expectancy is poor because of corrosion accelerated fatigue.

b. The 5/32" 1x12 stainless steel wire with Kevlar core is undesirable:

   1. This material experienced multiple failures due to severe crevice corrosion and fatigue. Of all the wire ropes tested, this was the worst (see Photograph 4).

   2. The wire severely chafes the tire casing.

   3. The stainless clamps tend to induce crevice corrosion and stress rises in the cable.

c. The 3/16" 1x7 galvanized steel wire with polypropelyene coating is undesirable:

   1. The polypropylene wears off after only two or three months of service because of chafing between the tires (see Photograph 5).

   2. Wire chafes the tire casing (see Photograph 6).

   3. The method of fastening the wire causes damage to the protective coating and adds an additional metallic component to the system (see Photographs 7 and 8).

d. The 3/16" 1x7 galvanized steel wire with polypropelyene coating is undesirable because of problems similar to those stated for test material "c" above.

e. The 1/2" polypropylene rope withstood the rigors of the test better than any of the fiber ropes tested. It demonstrated superior chafe resistance and showed little evidence of fiber damage due to abrasion against the tire casings. However, it is not a recommended tying material because:

   1. It tends to lose strength and flexibility as a result of ultraviolet degradation caused by sunlight. However, it should be noted that polypropylene line can be purchased with coloring that screens it from ultraviolet radiation. Upon immersion in marine waters, the build-up of marine growths may actually create an effective screen.

   2. It is necessary to use 30 to 40 percent more regular lay line than the actual tie lengths to insure secure knots that will not loosen or fail under cyclic loading. This length can be reduced if seizing or splicing is carried out on all connec-

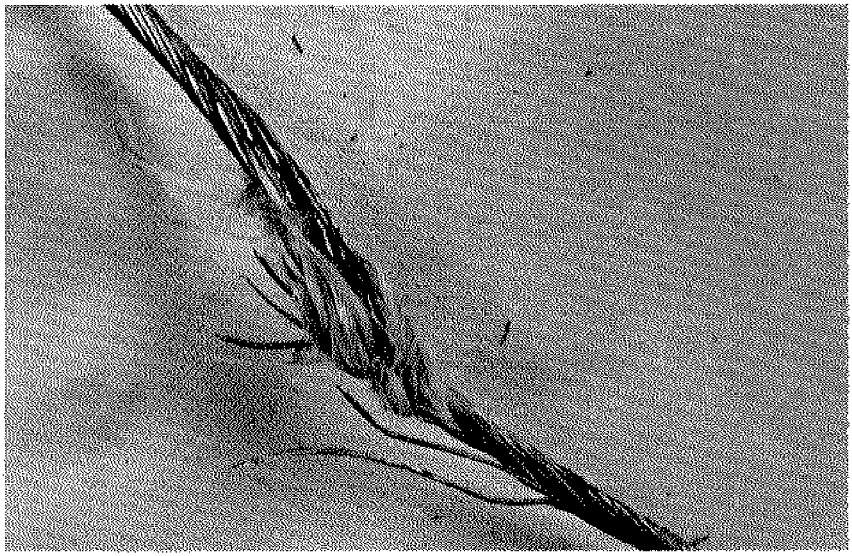


Photo #4. K-Core stainless steel wire showing typical failure. Wire has a central core of Kevlar fiber.

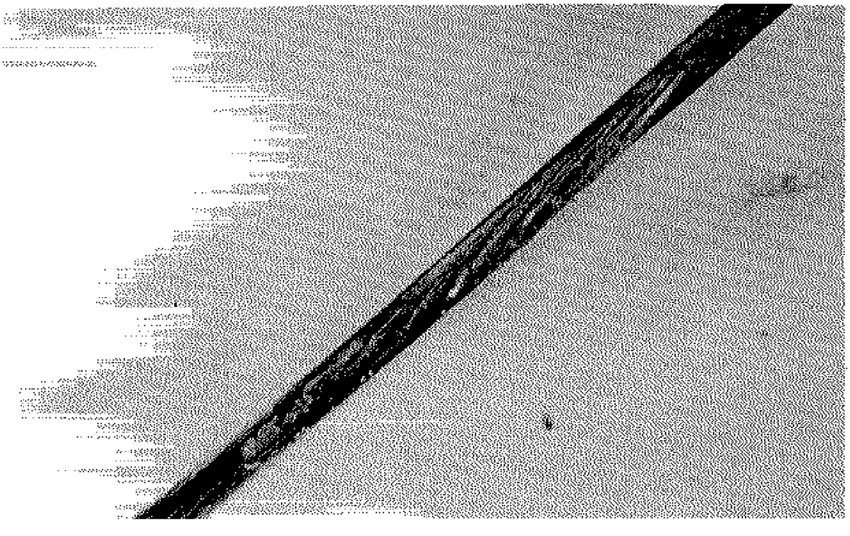


Photo #5. Polypropylene coated wire showing the exposed wire resulting from several months of abrasion against the tire casings.

Photo #6. Tire casing depicting a typical cut due to wire chafe.

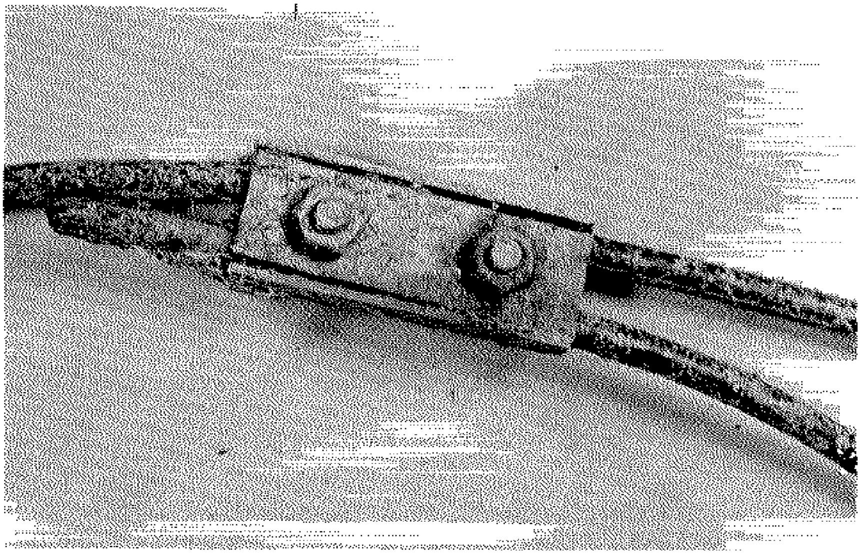


Photo #7. A stainless steel cable clamp holding polypropylene coated wire.

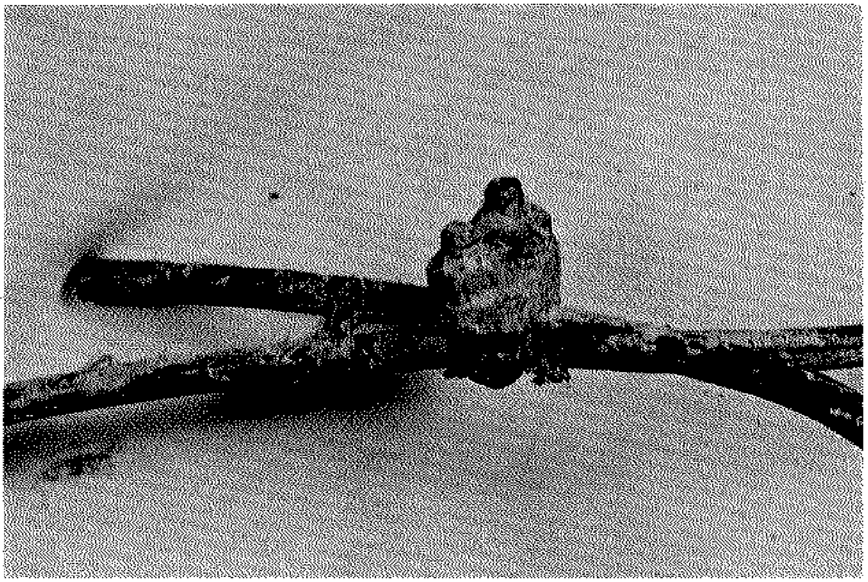


Photo #8. Steel cable clamp holding polypropylene coated wire.

tions. Also, the use of braided line will reduce the amount of line wasted and the time required for splicing.

3. The line tends to chafe grooves into the tire casings (see Photograph 9).

f. The 1/2" nylon rope is not recommended:

1. It demonstrated poor abrasion resistance. Several lengths had their breaking strength reduced by more than 75 percent as a result of abrasion during an eight-month period.

2. Ultraviolet degradation causes it to lose strength.

3. It is difficult to make reliable tie connections.

4. It cuts into tire casings (see Photograph 9).

g. The 1/2" Poly-D rope is not recommended for the same reasons as given for test material "f" above.

h. The 1/2" Kevlar line is definitely not recommended. It demonstrated the worst fatigue characteristics of all the fiber materials tested. Total failures were noted after only four months of testing (see Photograph 10).

i. The 3/8" nylon braided rope is not recommended. Although forming splices in this line is relatively easy, it possesses the poor characteristics listed for test material "f" above.

j. The 3/16" welded, galvanized steel chain withstood the test in excellent condition (see Photograph 11). The chain connections were made with 3/16" galvanized steel shackles. Although this chain remained in good condition, it is not recommended for long-term breakwater installations. Once the zinc coating has corroded away (it acts as a sacrificial anode) the attack on the underlying steel is relatively rapid, causing multiple failures after several years of immersion. Heavier galvanized chain would last longer but eventually undergo the same corrosion.

k. The 1/2" special chain developed by the Campbell Chain Company has the following characteristics:

1. It is formed from nonwelded links.

2. It is formed of a mild steel wire with a nominal diameter of 1/2 inch.

Photo #9. Tire casing chafe due to fiber rope abrasion.

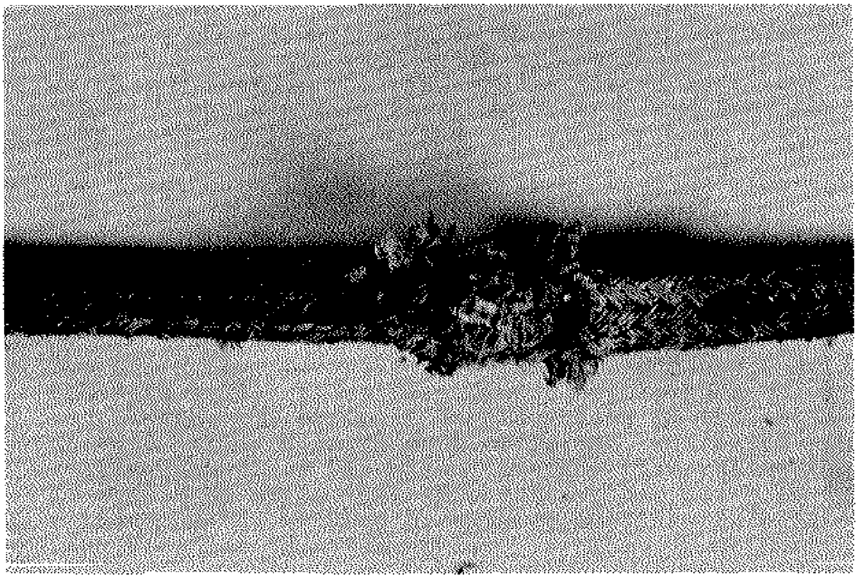


Photo #10. Kevlar rope showing beginning of fatigue-abrasion failure.

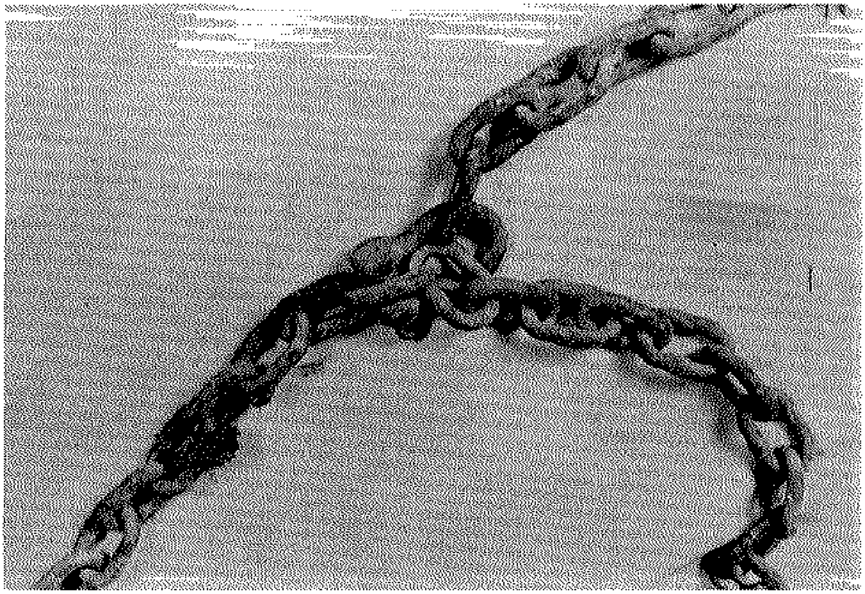


Photo #11. 3/16-inch galvanized chain and shackle.

3. It has an overall link length of 3-5/8".
4. It has an approximate weight of 1.9 pounds per foot.
5. It has no protective coating.
6. The average load required to spread a new link to a 1/2" gap was determined to be 2,462 pounds.

The results of the in-situ test for this chain in the marine environment of Narragansett Bay are as follows:

1. Approximately 30 percent of the test chain links showed 13 to 16 percent reduction in cross sectional area as a result of only 9.5 months immersion (see Photographs 12 and 13). The remaining 70% of test chain showed varying degrees of corrosive decay ranging from 3 to 10 percent reduction. This corrosion was primarily concentrated on the "solid" length of the chain link, i.e., the portion which bears the bending and tensile loads. The preferential corrosion in this area is probably due to the method of forming the chain links. In any case, the reduction of area because of corrosion results in an average decrease in chain strength of 14 percent.

   There is some question as to whether the corroded chain was from the same batch as the unused chain, which was tested. It can only be stated that both 100-foot batches were received at the same time during 1975.

2. The continual flexing of the chain, coupled with abrasion against the tire casings, tends to keep any corrosion deposits from building up on the chain. These deposits, if allowed to remain intact, would retard further corrosion and thereby slow down the process of corrosion.

3. The chain cuts severely into the tire casings (see Photograph 14), reducing buoyancy by creating holes and letting air escape. The roughness of the chain's surface, which results from corrosion, increases the cutting action of the chain into the tire casings. It should be noted that this cutting has not been noticed on the chained breakwater sections in place on Lake Wingfoot in Akron, Ohio.

4. The buoyancy of the overall tire module is reduced by the weight of the tying chain more so than in other systems. This means that additional reserve buoyancy should be added to each tire to prevent sinking resulting from marine growth and loss of entrapped air.

Photo #12 & #13. Half-inch special chain, non-galvanized, showing the results of corrosion.

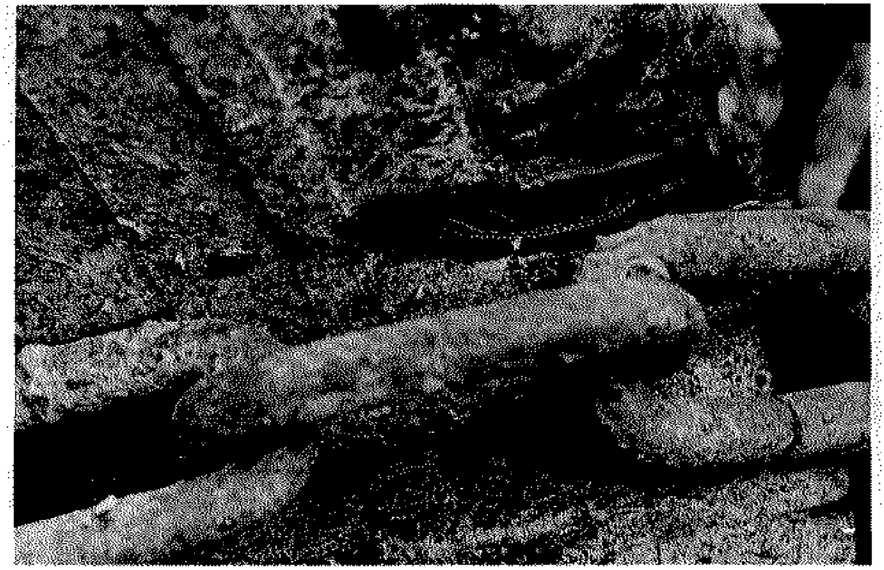


Photo #14. Cut into tire casing as a result of half-inch special chain abrasion.

When these factors are taken into consideration, the 1/2" special chain appears to be undesirable for use in a marine breakwater. However, there are several "special chain" breakwaters in existence on freshwater lakes that have performed satisfactorily for more than 18 months. This fact indicates that the use of "special chain" may be acceptable for freshwater use, due to its much lower corrosive rate as compared to that of salt water.

1. The 2 to 3 inch wide rubber conveyer belt edging had the following characteristics:

    1. It is a scrap product resulting from the "sizing" of rubber conveyer belts used in industry.

    2. It is available from several different rubber companies and comes in a wide (sometimes unpredictable) range of widths and thicknesses. For breakwater application, belting with a width of less than 2.0" or a thickness of less than 0.375" is generally undesirable. By making arrangements with a rubber company, the shipping of unusable belting can be avoided.

    3. It is constructed of tough, flexible rubber with varying numbers of fabric plies.

    4. The fabric generally used is a polyester (low stretch) fiber running in the longtudinal direction, with a nylon fiber running in the transverse direction.

    5. The belting displays an ultimate tensile strength on the order of 9500 p.s.i. when no stress risers, such as bolt holes or cuts, are present.

    6. It can be easily cut on a band saw or with a hand saw or axe. Holes for bolts can be punched individually or with a multiple gang punch.

    7. The material is virtually inert in the marine environment.

    8. It is pliable enough to be handled easily by one man during its assembly into tire modules.

Nylon bolts, nuts, and washers were used to fasten the belts. This makes a tying system that is totally organic in nature and inert in the marine environment. The nylon fasteners should be dyed black before they are used to screen them from the ultraviolet rays of the sun, thus preventing the sunlight from degrading the nylon. Dyeing the fasteners with simple dye in boiling water for several minutes is sufficient for this purpose.

The size and number of fasteners that are employed is important. Two basic systems that have been employed are these:

System 1. The use of three 3/8-16 bolts per tie, as shown in Photograph 15. The belt width used with this pattern should be no less than 2.00" 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. Note that washers must be employed under the bolt head and nut to prevent them from pulling through the rubber. Voids in the center of these 3/8-16 injection-molded bolts cause the strength of these bolts to vary by several hundred pounds. For this reason, system number two is recommended over use of the 3/8-16 bolts. This is not meant to indicate that 3/8-16 bolts cannot hold a breakwater together; there are several such breakwaters in use at present that have been in the water for over nine months. One of these at Great Bay Marina, N.H., is 100 feet in length and positioned perpendicular to a daily tidal flow in excess of three knots.

System 2. The use of two 1/2-13 bolts per tie as indicated in Diagram 1. The belt width used should be no less than 2.00 inches, and preferably 3.00 inches, to prevent belt tearing. The average strength of this pattern is 2,150 pounds. In this system the bolts do not fail: They pull through the rubber belting, or the belting tears. 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 the 3/8-16 bolts. The strength of this system tends to be more predictable. From a design point of view, it is the better system.

There are several points to mention in regard to the nylon fasteners:

(a) When 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 (only flat washers are recommended, i.e., no lock washers). A slight cupping indicates that the nut is tight enough.

(b) Bolts should be purchased long enough to permit at least 1/4" of thread to protrude through the nut. Allowance for varying belt thicknesses and the two flat washers should be made accordingly.

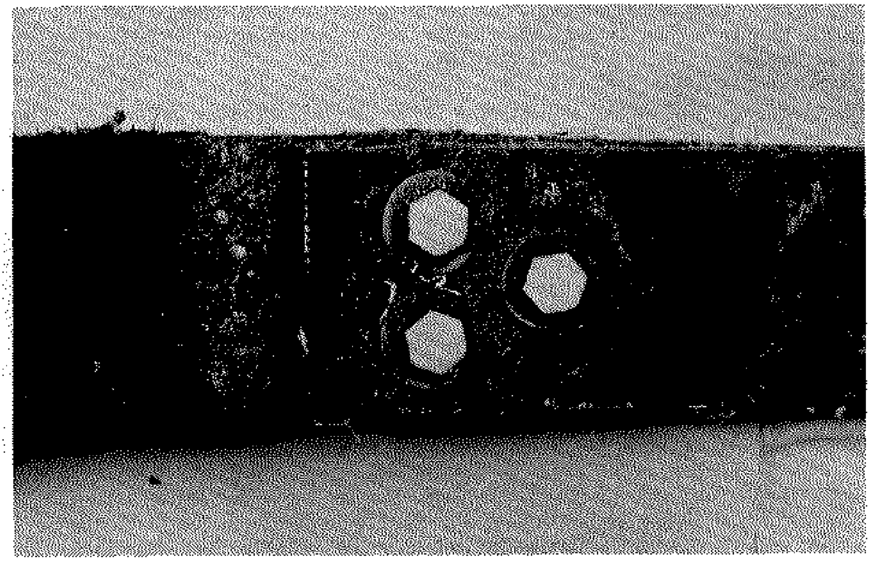
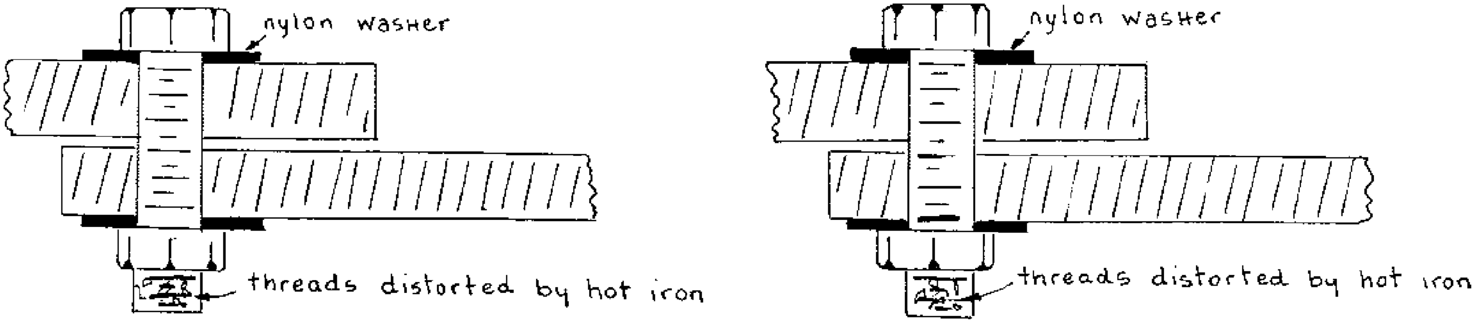


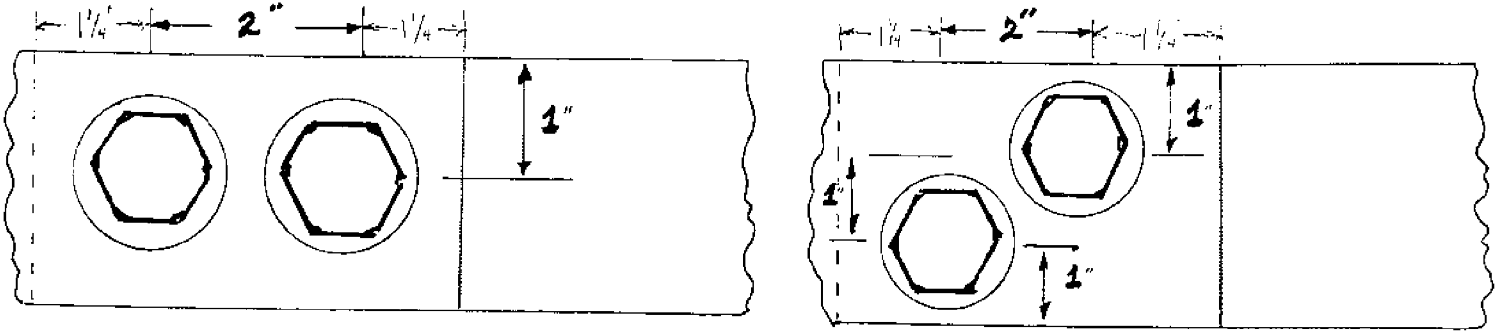
Photo #15. Rubber conveyor belt edging showing 3/8-16 nylon bolt pattern with washers.

Diagram #1 Bolt pattern for 2 bolt system employing ½-13 nylon bolts for belt fastening.



Second Bolt omitted in this view

Second Bolt omitted in this view



minimum distance for this configuration

minimum distance for this configuration

> One-quarter inch of protruding thread allows a propane soldering tip to melt and distort a sufficient number of threads to prevent the nut from "backing off." Also, the growth of marine plants in the exposed threads greatly hampers the nut's working loose (see Photograph 16).

The following information is a result of the <u>in-situ</u> test employing rubber conveyer belting and nylon fasteners as a tying system for floating breakwaters:

1. The belting and nylon fasteners are inert in the sea water environment.
2. The belting is resistant to abrasion against the tire casings, other tying materials, and marine growth such as barnicles and mussels.
3. The belts show no signs of delamination (separation along fabric plies) after nine months of immersion.
4. A slight increase in tensile strength (approximately two to three percent) was noticed after six months of immersion. This could be due to a better dissipation of the heat generated by internal tensile straining through the wet fiber plies.
5. The material is easily handled by one or two workers during assembly.
6. The system allows localized loads to be readily distributed throughout the breakwater.
7. The system can withstand low water temperatures and ice, high-load conditions due to currents, towing, or wave action, and cyclic fatigue loading.
8. It does not pollute the environment.
9. The system has a negligible negative-buoyancy effect upon the breakwater modules.
10. It can be readily unfastened for the addition of tires or repairs.

Summary

To summarize, of all the tying materials tested or evaluated, rubber conveyer belt edging with nylon fasteners is recommended above all others. Second to this system is chain with a minimum wire diameter of 1/2" preferably galvanized. Third best is polypropylene, either braided (for use in splicing) or regular lay. If polypropylene is employed in this capacity it should have an ultraviolet screen to retard degradation. All other materials are not recommended as tying materials on marine floating breakwaters.

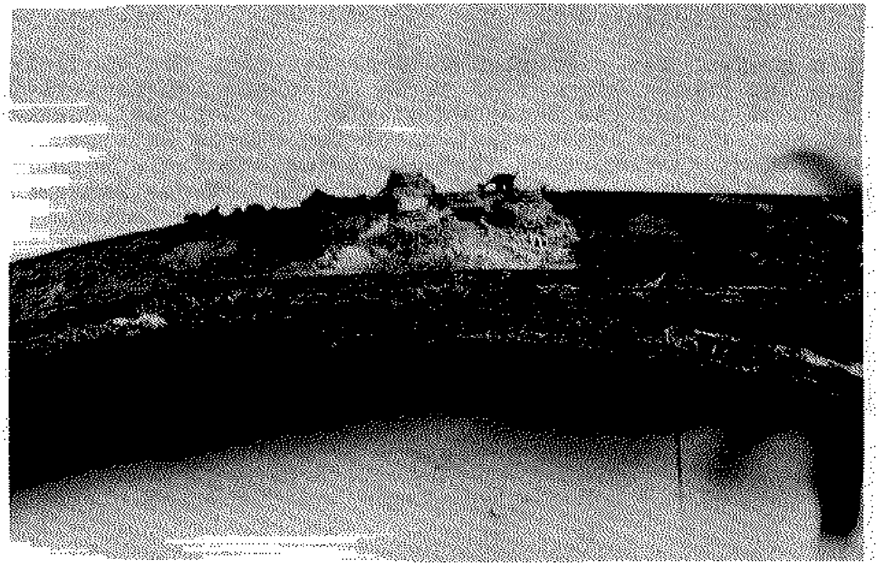


Photo #16. Edge view of rubber conveyor belt joint fastened with 3/8-16 nylon bolts.

ACKNOWLEDGMENTS

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References

Candle, Richard D., and William J. Fischer. "Scrap Tire Shore Protection Structures." 1976. Engineering Research Department, Research Division, The Goodyear Tire and Rubber Company, Akron, Ohio.

Kowalski, Tadeusz and Neil Ross. "How to Build a Floating Tire Breakwater." 1975. University of Rhode Island, Marine Bulletin No. 21. Narragansett, R.I.

Oviatt, Dr. Candace, et al. "Development of Fouling Communities on Floating Tire Breakwaters in Narragansett Bay." 1976. University of Rhode Island, Marine Advisory Service Misc. Paper. 2 pages. Narragansett, R.I.

Ross, Neil. 1975. "Floating Tire Breakwaters: Who Can Use Them and Why?" Paper presented to the 1975 ANERAC Conference, University of Rhode Island, Kingston.

Leach, Robert. 1965. "Riggers Bible", Handbook of Heavy Rigging. Published by Robert P. Leach, 16th Printing, P.O. Box 3302, Glenstone Station, Spring Missouri.

APPENDIX I

BASIC TIRE BREAKWATER CONSTRUCTION

Scrap tire floating breakwaters are formed by securing bundles of tightly interlocked scrap tires with a reliable tying material. The result is an easily installed, readily adaptable structure with a high energy absorbing capacity for normal loads, which deforms and yields when subjected to overloads.

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

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

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

To tighten the bundles together in the water, thread a piece of rope with eyes at each end through the connecting tires. With a 2"x3" board placed through the two eyes, twist the rope enough to pull the bundles tightly together. Weave the permanent tying material through the five connecting tires and secure before releasing the twisted rope.

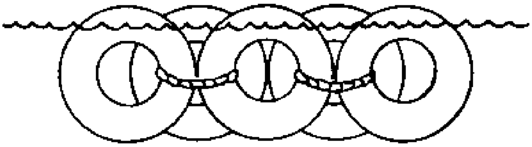

Figure 1: Side view of bundle of 18 tires in the water.

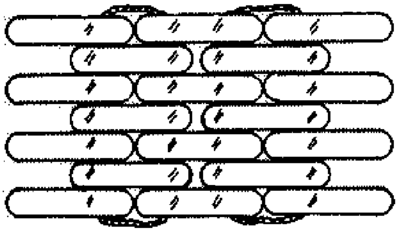

Figure 2: Top view of the same bundle as it is constructed on land.

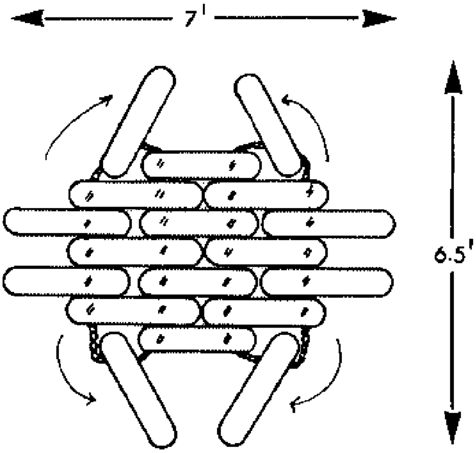

Figure 3: Top view of the same bundle preparatory to attachment to other bundles.

The resulting mat, shown in Figure 4, has great strength - as much as 55,000 pounds' breaking strength on a seven foot spaced longitudinal and transverse grid - with the ability to absorb great amounts of energy by yielding and deforming. This provides safety not available in protection structures of conventional materials. A breakwater of approximately 500x21 feet will contain 213 bundles, or 4260 tires.

Flotation. Assembled, the basic 20-tire units weigh approximately 500 pounds, but when placed in water they weigh only about 100 pounds. Since the tires are placed vertically in the water, the air trapped in their crowns provides sufficient buoyancy to keep approximately six inches of each tire above the water. The pumping action of the waves replenishes the air in the crowns. A unit of 18 tires plus two connecting tires provides approximately 200 pounds of buoyancy. Care must be taken not to use tires with holes through which the air can escape. In time, marine growth or siltation will weigh down the breakwater, and so additional buoyancy is recommended for all marine applications. This can be supplied by pouring a small amount (approximately 1/2 pound) of liquid styrofoam inside the tires in each bundle.

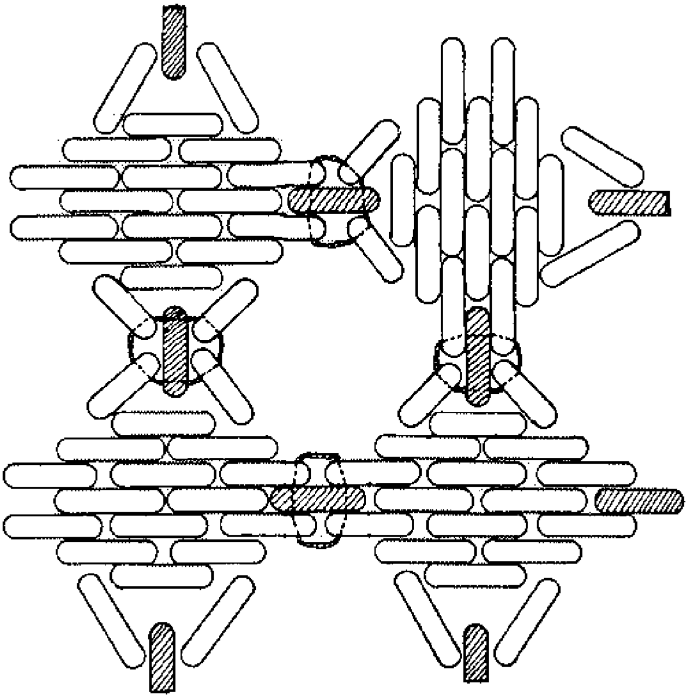

Figure 4: Top view of four bundles attached. Cross-hatched tire connects bundles. Bundles may be oriented parallel or alternate bundles may be turned at right angles.