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A PROPOSAL FOR GUARDING MARINE INFRASTRUCTURE AGAINST COLLISIONS BY LARGE VESSELS

Executive Summary

A system is proposed for improving protection of bridge supports and other endangered marine infrastructure from large ships. The system would employ large "forests" of reinforced plastic pilings armored with old tires to reduce the number of pilings and increase energy absorption. These pilings are existing technology and are made from recycled plastic.

Background

The destruction of the Francis Scott Key Bridge near Baltimore by the container ship MV Dali highlights the problem of very large ships colliding with critical infrastructure. While the investigation is ongoing, and the exact cause of the collision will be investigated in depth, we may nevertheless immediately conclude that this type of collision has devastating consequences, potentially killing hundreds of people and producing billions of dollars of damage plus other economic impact.

The diagram below was taken from a Wikipedia article on the Key Bridge.
https://en.wikipedia.org/wiki/Francis_Scott_Key_Bridge_(Baltimore)

Figure 1. The impacted pillar of the Key Bridge.

The collapse was caused when the left (west) main span support pillar shown above was struck by the Dali, a 300-meter container ship. The exact tonnage and speed will be determined by the NTSB investigation, but preliminary data suggests the ship was traveling 8.7 knots and may have slowed to about 6.8 knots just before collision. The ship was loaded with around 4700 shipping containers. Even at this low speed, the ship was a battering ram that overwhelmed the minimal collision barriers around the support pillar.

https://en.wikipedia.org/wiki/Francis_Scott_Key_Bridge_collapse

The support pillar was demolished, causing the end of the truss it supported to fall. The bridge is a “cantilever” design, which means that it is built with two truss zones, each essentially a balanced see-saw, with the strongest point just above the support pillar. The two balanced truss sections join in the center of the arched span, so that normally the stresses in the center of the arch are relatively low. However, no design of long span bridge is expected to stand with a main support pillar failure. The side above the failed pillar (left side in the diagram above) dropped, which ripped the center span from the right side truss, leaving the right side unbalanced. The right side toppled toward the eastern (right) shore, and in seconds the entire truss structure was down.

Had this been a suspension bridge, the outcome would have been similar. The same could be said for a compression-loaded high span arch. It is critical that any bridge that relies on a limited number of key pillars be protected against impact of those pillars by large ships.

The Proposal

I spent years working for a small testing company, which included extensive destructive testing of marine materials. I also did various tests for a Virginia company that branched out from making marine “fenders” (large floating bumpers that prevent docked ships from rubbing directly against a pier) to making marine pilings from recycled plastic.

Traditionally, marine pilings had been essentially tree trunks milled to a consistent diameter and treated with preservatives. The wood typically has a service life of around 20 years, after which the pilings must be extracted, disposed of as hazardous waste due to the preservatives, and replaced.

The product I had the opportunity to test was pilings made from recycled plastic. At the time, only milk jugs and similar undyed polyethylene containers were being recycled, while colored laundry product jugs and similar containers were rejected. However, for the pilings, color did not matter. The process added black coloring, which improves resistance to UV light, so this opened up an application for huge amounts of recycled plastic jugs. These pilings were reinforced with longitudinal fiberglass/resin rods around the circumference. I include below a link to an NYU article on this type of piling, from which I have borrowed two photos. The pilings I worked with had a diameter of 16 inches and a length of about 60 ft (18 meters). Plastic is one of the most durable materials we make, and these pilings will certainly have a much longer service life than wood. When their useful life is over they may be recycled again.

https://wp.nyu.edu/plasticpiles/


Figure 2 Plastic marine pilings.


Figure 3 Plastic marine piling reinforcement.

For the protection of the Key Bridge or other infrastructure on commercial shipping channels, a longer piling may be needed in order to assure they are sufficiently anchored. These channels typically have a depth on the order of 45 ft (14 meters) or more. The main reason the standard pilings were 60 ft was to allow convenient shipping by truck, and there is no reason they could not be made longer, or to any diameter desired.

Plastic pilings are relatively flexible and are intended more for absorbing impact than for making a rigid structural barrier. Notice the curvature in the Figure 2 above. If needed, they can be made more rigid by the use of the fiber reinforced rods or larger diameter, but for the intended purpose of absorbing impact, flexibility is a good property.

Clearly a single such piling is not going to stop a runaway container ship. However, a sufficiently numerous forest of them should do the job if arrayed intelligently. Furthermore, my idea is to use them in conjunction with a really cheap and available material in shipping channels: dredge spoils. And I believe another recycled item can reduce the number of pilings needed: old tires.

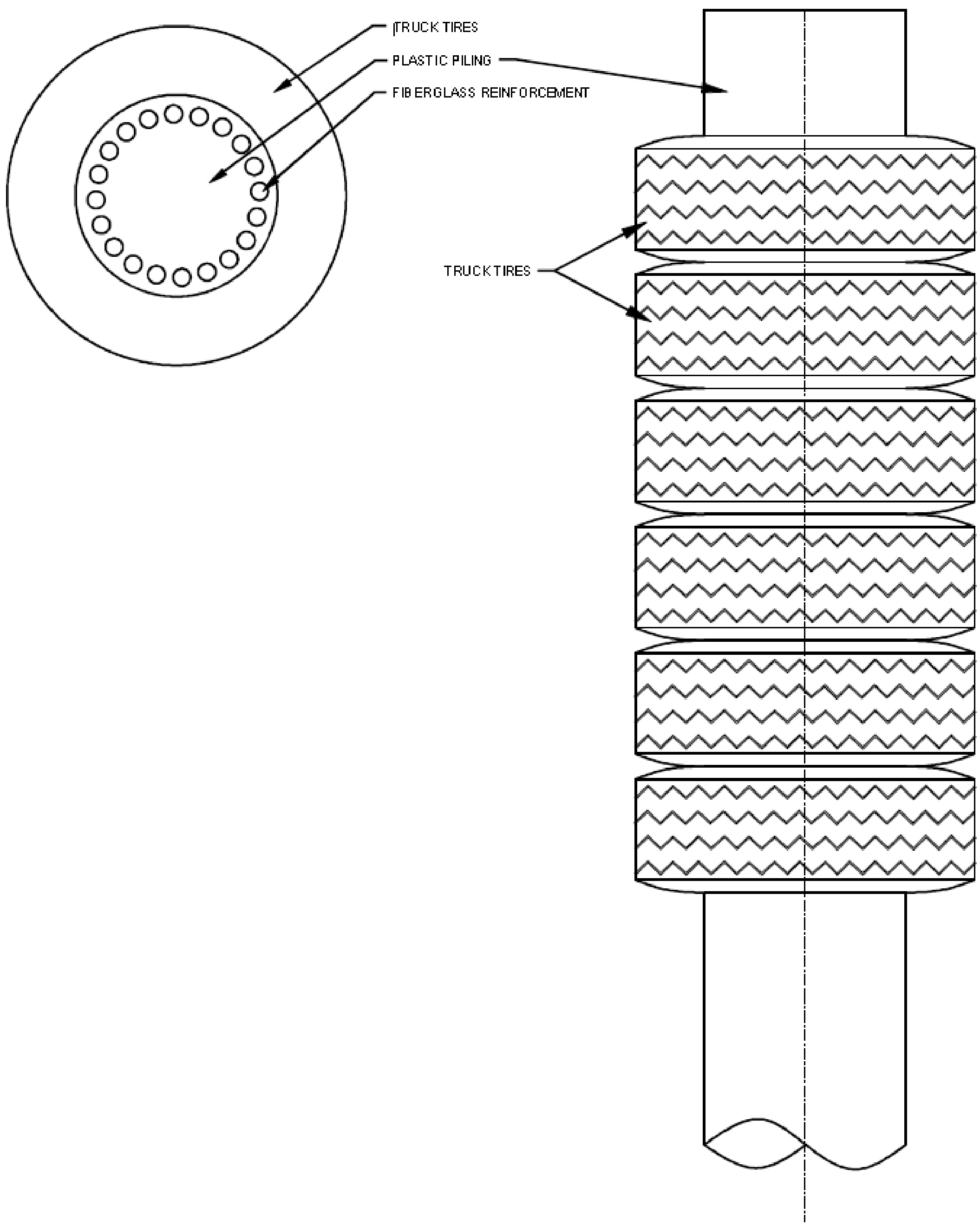

Figure 4 Tire cushions around plastic marine pilings.

Old tires in this environment would fill with water and/or sediment. Either would enhance energy absorption on impact. The tires would allow the more expensive pilings to be spaced further apart. Multiple rows of pilings would be used, with a fabric or polymer membrane between the innermost row and any dredge spoil retained behind the pilings for additional protection. The outer row of pilings could also be bound by tensioned cables to prevent these fairly flexible pilings from leaning outward into the channel. The channel depth would likely be 15 meters or more, and the pilings, membrane, and cables would provide a barrier to keep dredge spoil from slumping into the channel.

The installation might look something like the drawing below, scaled to absorb the required energy and to prevent hull contact with the protected objects. An actual installation might use a thousand or more pilings and a hundred thousand tires.

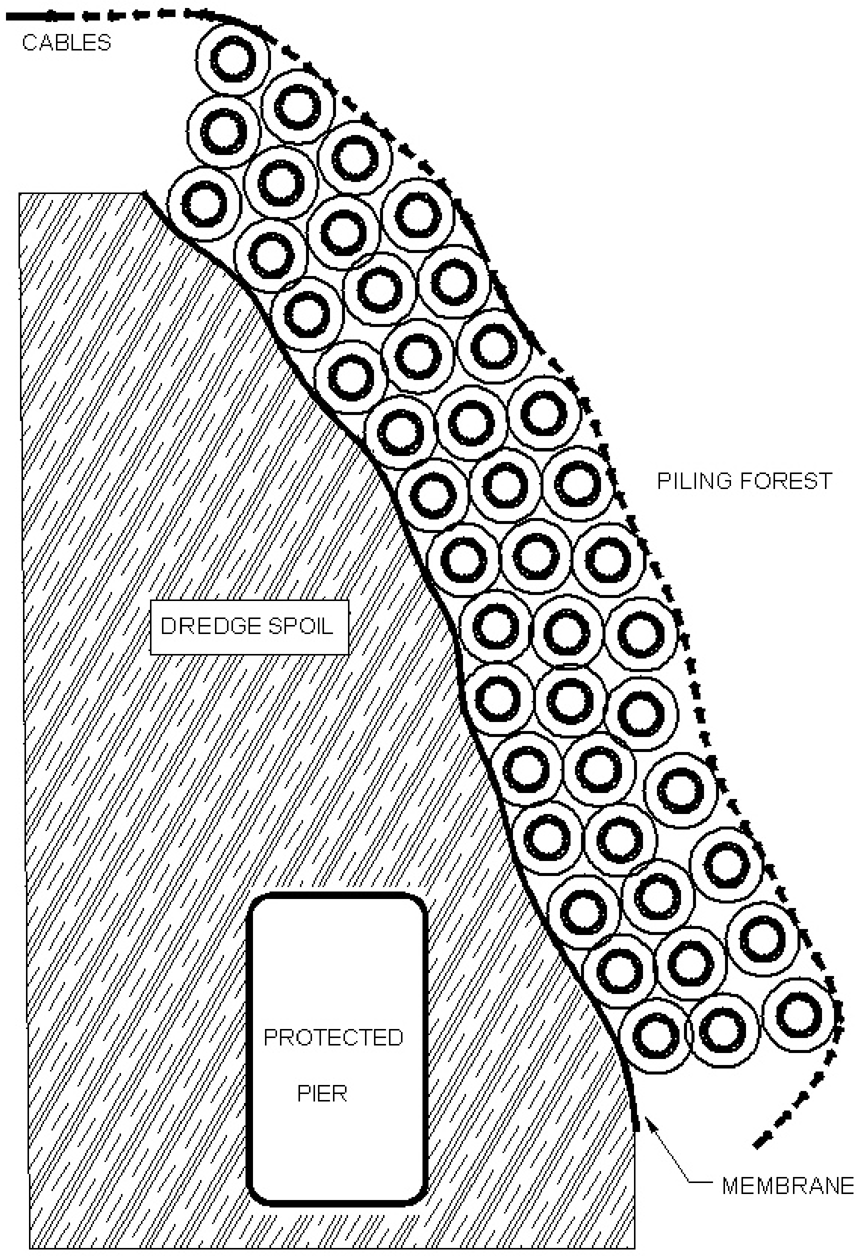

Figure 5 Example of a "forest" of pilings retaining dredge spoil.

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