A Physics Lesson Learned the Hard Way

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A moored fuel barge needed to be moved about 60 feet down a pier so other operations could occur. Personnel lifted the pier-side eyes of the mooring lines and used a workboat to give the barge a shove to get it moving in the desired direction. When the barge reached the desired position, the workers placed the eyes of the lines over pier cleats to stop and hold the craft in place.

Unfortunately, two of the lines failed, hitting and injuring a person on the pier. The victim spent five days in a hospital but is expected to make a full recovery.

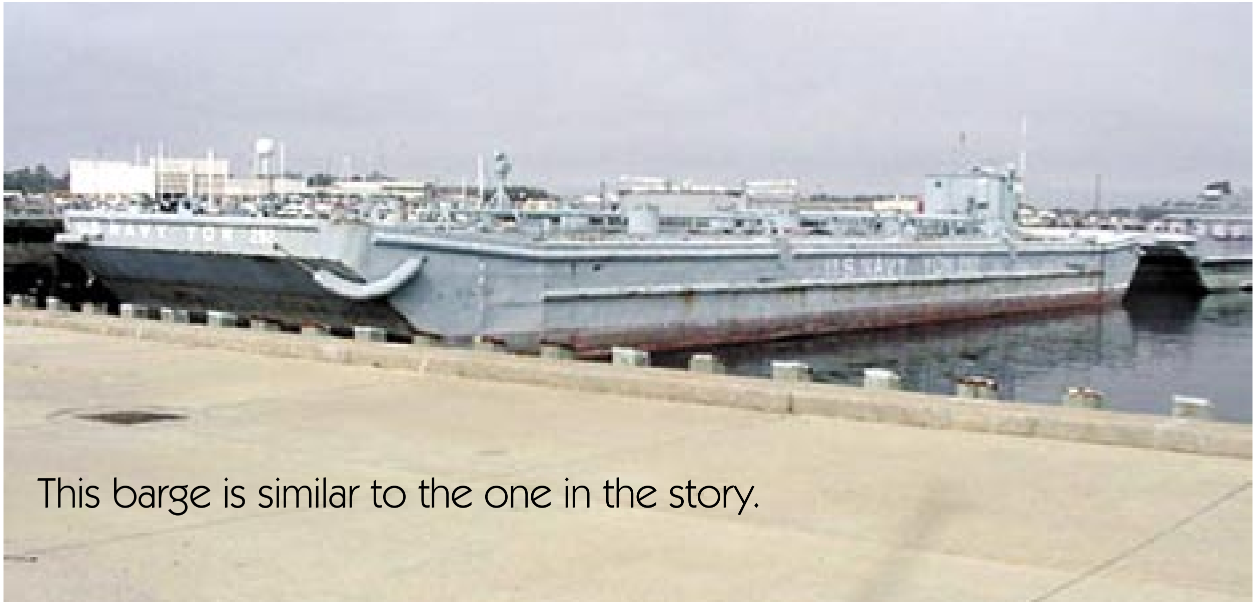
Everyone should remember these basic principles of physics from high school:

- Energy neither can be created nor destroyed—just converted in form (the first law of thermodynamics).
- An object in motion tends to remain in motion until acted upon by an external force (Newton's first law of motion).
- Force is equal to the product of an object's mass and the acceleration imposed on that object (F = MA).

When traveling in your car, stopping usually involves a conversion of the vehicle's kinetic energy into heat energy from the friction of the brakes and tires. The higher the speed, the greater energy conversion is required, and stopping will result in corresponding higher temperatures in the brake components. This fact is demonstrated in a dramatic way during nighttime auto racing, where a red glow often can be seen around the hubs and brake disks of racecars entering a turn. Most of us can relate to the great energy associated with a fast-moving object, such as a speeding bullet.

Another way an object can have a tremendous amount of kinetic energy is if it's relatively massive. A large object moving at a comparatively slow rate can possess huge amounts of kinetic energy that may not be apparent to observers. To stop such an object, its kinetic energy has to be converted to another form. Otherwise, a tragedy can occur. The key to success is recognizing that a large amount of kinetic energy exists and that it must be dissipated safely, which didn't happen in this case.

Here are some assumptions and calculations



This barge is similar to the one in the story.

Here's what one of the mooring lines looked like after it snapped.

that should give you an idea of the immense forces that likely were generated in this near-tragedy:

Assumptions

Barge weight (mass) was approximately 1,300 tons (2,600,000 pounds). Speed of barge (velocity) was about 2 mph (approximately three feet per second). The workers intended to stop the barge in about one second. Acceleration (deceleration) of the barge is given by dividing the desired change in speed (three feet per second to zero feet per second) by the desired time interval (one second).

Calculation

Using the relationship F = MA, where the generated force is equal to the product of the mass of the object and its acceleration, the generated force is a whopping 7.8 million pounds.

The rated working load of the three mooring lines used on this barge was 26,000 pounds each, for a combined rating of only 78,000 pounds of force. No one made any effort to tend or "surge" the mooring lines to absorb the energy of slowing the barge. Instead, the force generated by the kinetic energy of the barge was directly and rapidly applied to the lines. The energy conversions that took place included heating and stretching of the line, permanent deformation, and failure of the line, increasing the kinetic energy of the line (snapback). Loud pops filled the air as the lines parted, and the mishap victim absorbed some of their kinetic energy.

How could this mishap have been prevented? Moving the barge at a slower speed greatly would have reduced the potential energy. A speed of .5 mph (0.73 feet per second) would have taken only one minute longer. Hand-tending the lines would have allowed more time for the barge to dissipate energy and to stop; it also would have reduced the possible generation of force. If the lines had been surged and tended for 60 seconds, the deceleration would have become much smaller.

By slowing down the operation by a mere two minutes (one minute for the reduced speed, and one minute for tending the lines), the force would have dropped from 7.8 million pounds to a manageable 31,633 pounds—well within the combined rated load of the mooring lines.

Supervisors can't be expected to calculate and analyze every barge movement to this extent, but they do have a responsibility to use ORM and to understand the energies and forces involved in routine tasks. Take a few minutes for safety! S