Newport bridge collision

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Newport Bridge Collision

Collision au pont de Newport

Newport Brückenzusammenstoß

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SUMMARY
In 1981 a main tower pier of the 488-m Newport suspension bridge in Rhode Island, USA, was struck head on by a fully laden 45,000-ton tanker. The ship was shortened 3.5 m through bow crushing, but the bridge pier suffered only superficial damage. Details of bridge design and accident are given, and forces developed during the collision are derived.

RÉSUMÉ
En 1981, un pétrolier de 45,000 tonnes en pleine charge, est entré en collision avec la partie inférieure d'une des tours principales du pont suspendu (488 m de longeur) de Newport, Rhode Island, USA. Cette collision, de plein fouet, a eu pour résultat de raccourcir de 3.5 m l'avant du navire. La pile cependant n'a subi que des dégâts superficiels. Les détails du projet du pont, et de l'accident sont présentés, de même que les forces développées pendant cette collision.

ZUSAMMENFASSUNG
Der Pfeiler der 488-Meter langen Hängebrücke in Newport, Rhode Island, USA, wurde 1981 von einem vollbeladenen, 45 000-Tonnen Tanker frontal gerammt. Durch das Eindrücken des Bugs wurde das Schiff zwar um 3,5 Meter verkürzt, dagegen erhielt jedoch der Brückenpfeiler nur Oberflächen-Schaden. Einzelheiten über den Brückenentwurf und über den Unfall sind dargestellt, und Berechnungen der Anprall-Kräfte sind angegeben.

1. THE BRIDGE

The Newport Bridge is approximately 3 km long, crossing the Eastern Passage of Narragansett Bay at Newport, Rhode Island (Fig. 1). The main shipping channel is bridged by a suspension span 488 m long, with a clear height of 66 m at the center of the channel. The water depth beneath the suspension spans ranges from 30 to 45 m. The tower piers are of "Potomac type" caisson construction, founded on steel H-piles driven into sands that fill the glacial gorge underlying the bay.

The bridge was completed in 1969. It was designed to provide clearance for aircraft carriers proceeding to U.S. Navy installations further up Narragansett Bay, as well as commercial shipping bound for Providence, at the head of the bay. Owing to the large expanse of very deep water, there is no defined shipping channel. Large vessels entering the bay from the ocean generally make a 45° port turn about 3 km below the bridge and a 15° starboard turn about 1 km below the bridge.

2. THE COLLISION

Shortly after noon on February 19, 1981, the bridge was struck by the tanker Gerd Maersk, which was proceeding up the bay toward Providence. The ship was fully laden with a cargo of fuel oil, and displaced 45,000 (metric) tons at the time of the accident. Navigating in a dense fog, the pilot had no warning

Fig. 1. Newport Bridge, Newport, Rhode Island, USA.

of the collision until the bow lookout cried out that the pier was dead ahead. The captain called for hard left rudder and full steam ahead (to increase steerageway), but there was insufficient room to affect the ship's course appreciably. The ship struck main tower pier 1E head on, nearly in its center and normal to the bridge axis. The estimated speed of the ship at impact was 6 knots.

2.1 Damage

The bow of the ship was crushed in to the extent that the ship was shortened 3.5 m (Fig. 2). The ship came to a complete stop and then drifted off. Although it took on some water through sprung plates, no oil was spilled, and the ship was never in danger of sinking.

Damage to the bridge was negligible. The pier suffered no displacement or rotation, and there was no misalignment of the roadway deck joints or any other superstructure elements. The side of the pier suffered extensive surface scrapes, gouges, and spalls of the concrete (Fig. 3) to a depth of 2 to 5 cm over an area roughly 7 m wide by 20 m high, approximately equally above and below the water line (Fig. 4).

There were a number of superficial tears in steel plating of the underwater caisson structure, but no damage to the concrete behind the plating. A spectacular blotch of gray paint decorated the side of the pier for several days before falling off.

Owing to the dense fog, the bridge operators, stationed at the administration building and toll booths about 2 km from the site of the collision, were unaware of the accident for some time. It is not known whether any motorists were on the suspension spans at the moment of impact. There were no eyewitness reports from the bridge.

Fig. 2. Collision damage to tanker.

3. STRUCTURAL DESIGN

Details and dimensions of the pier are shown in Figs. 5a and 5b. The dead weight of the pier (neglecting 12,000 tons buoyancy) is 32,000 tons, and the superstructure reaction to the piertop is an additional 11,000 tons.

The top of the pier pedestal is 8.5 m above sea level, and the bottom of footing is 37 m below sea level, or about 8 m below the natural bottom. This top layer of natural material was dredged out to permit placing the footing form on the excavated bottom. The overexcavated space around the footing was filled with dumped sand and covered with heavy stones for scour protection.

The pier is supported on 512 steel H-piles, driven an average of 28 m into the sand. The design capacity is 72 tons/pile. The footing and shaft are composed of reinforced structural tremie concrete, placed within steel shell forms that remain in place. The distribution slab and pedestal are composed of normal reinforced concrete placed in the dry in dewatered cofferdams.

It was considered impractical to provide free-standing fenders in 30-m water depth, and so the pier was designed for an arbitrary ship impact force of 1,650 tons, applied at Elev. +3 m. This was intended to represent the effect of a 20,000-ton ship traveling with a velocity component normal to the pier of 3 knots.

The (buoyant) dead load pile load is 60 tons/pile, and the design ship impact force applied normal to the bridge axis produced forces of $\pm$ 10 tons/pile in the outer rows. (The governing design case was dead load + quartering hurricane wind).

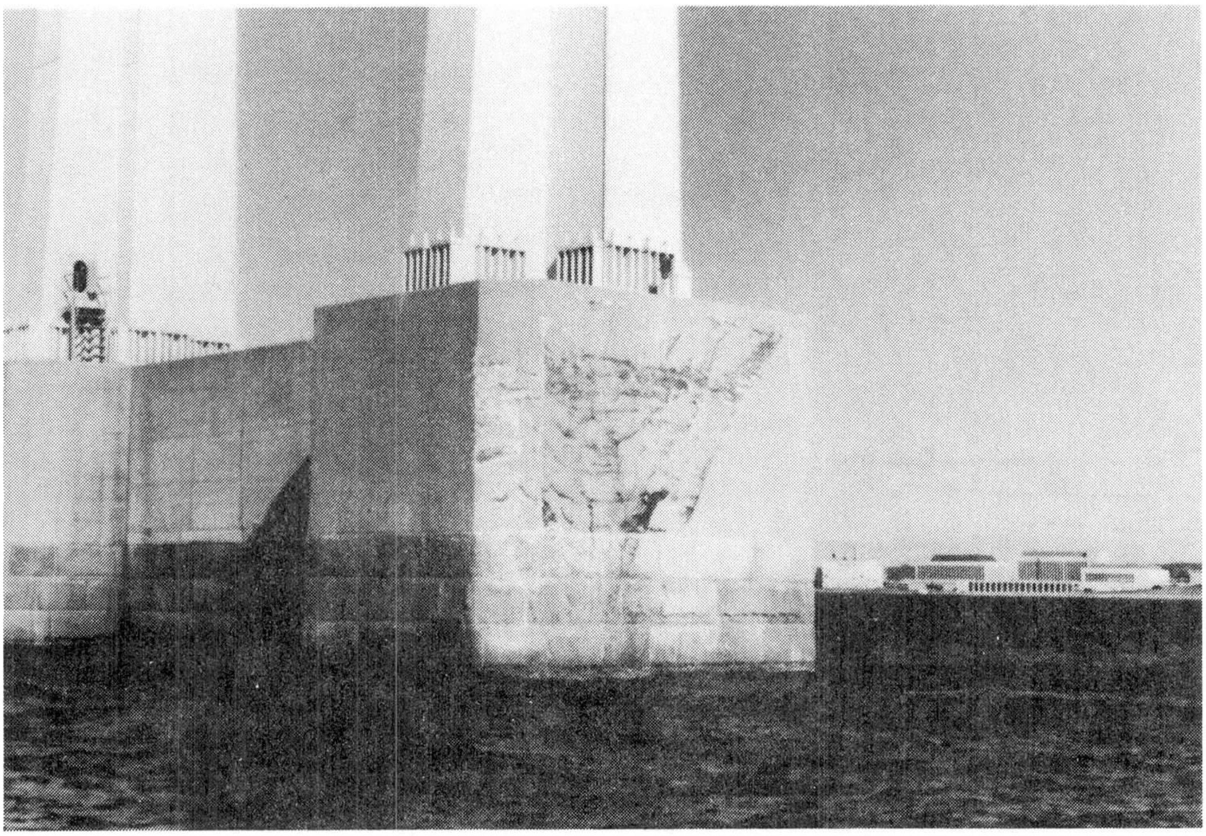

Fig. 3. Bridge pier damage.

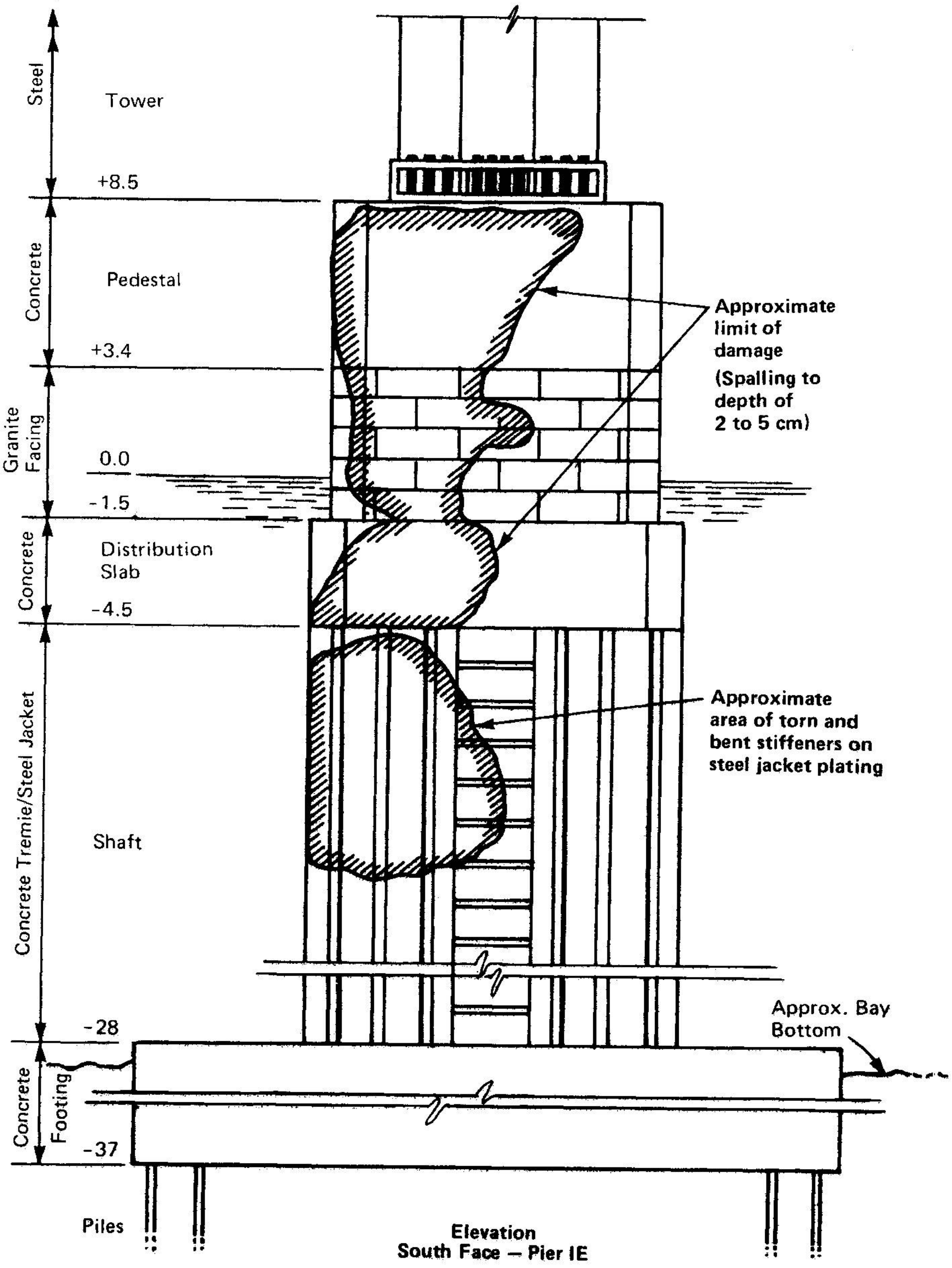

Fig. 4. Pier damage above and below waterline.

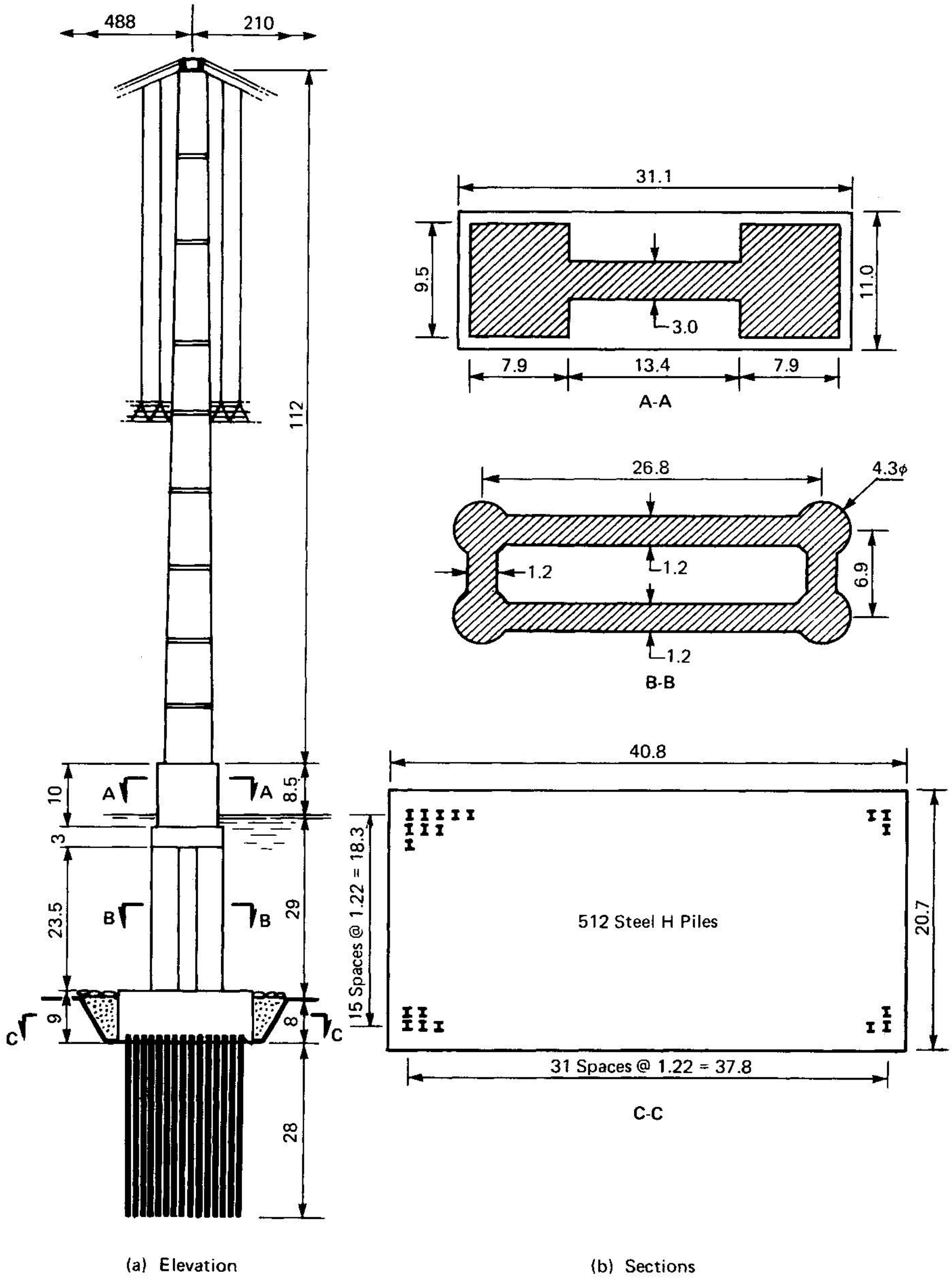

Fig. 5. Details and dimensions of pier.

4. COLLISION FORCES

For the actual collision, as a first approximation it may be assumed that the ship was decelerated from 6 knots (3 m/sec) to a dead stop in 3.5 m by a constant average force. For a 45,000-ton ship, this requires an average force of 6,000 tons applied for a duration of 2.3 seconds. The actual force-time-motion relation is of course more complex, and the instantaneous maximum force may have been 50% to 100% greater. Considering inertia and time effects, analysis of the stresses produced in the pier by a static horizontal force of 6,000 tons may give a feel for the expected performance of the pier.

Such an analysis yields maximum overturning forces of ± 70 tons/pile, compared to the dead load of 60 tons/pile. Since the piles were driven to resistance based on load tests to twice the 72-ton design load, and the uplift resistance of piles driven 28 m into sand is very large, it is reasonable to expect that the actual impact would not produce permanent tilting of the pier. Neglecting any passive pressure of the backfill around the footing, the average horizontal shear of 12 tons/pile would not be expected to produce translation of the pier.

Analysis of stresses at the bottom of the shaft (top of footing) indicates that under a 6,000-ton collision load the resultant force lies close to the edge of the kern of the section. The maximum compressive stress in the concrete is about 35 kg/cm^2, and a very slight tension exists on the impacted side. This is well within the capacity of the reinforcing steel, without counting on the steel shell form plate.

The analysis thus indicates that although the actual collision load substantially exceeded that assumed for design, the observed lack of damage to the pier is consistent with the results to be expected from an approximate rational analysis. It further indicates that it is possible to design and construct deep water bridge piers to absorb the effects of collision from substantial large ships.

The Newport Bridge is fortunate that it has good foundations, and that the requirement to design for hurricane winds gives it an extra margin of safety against ship collisions, beyond that assumed for design.

It is of course preferable, and for extremely large ships mandatory, to attempt to divert the ship and absorb some of the collision energy in a deformable fender system, where site conditions permit such construction.