National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation H-542A

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In reply refer to: H-89-65 through -68

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On August 17, 1988, at about 1:00 a.m. e.d.t., an 85-foot-section of the 275-foot-long S.R. 675 Bascule[1] Bridge over the Pocomoke River, near Pocomoke City, Maryland, fell about 30 feet into the river after two pile bents[2] supporting the bridge collapsed. Witness reports indicated that the bridge may have been sagging before the collapse and no vehicles were involved in the collapse sequence. The weather was clear and dry, and water conditions were reported to be calm.[3]

The main fixed span girders and the bridge deck were supported by four multiple pile bents. At each pile bent, the deck girders were supported by a reinforced concrete pile cap that extended 2 feet below the river mean low water level. Each pile cap was supported by 10 untreated timber piles that were generally embedded 2 feet into the concrete cap. Design plans indicated that the piles were to be about 1 foot in diameter, were to be embedded in the river bottom, and were designed to be exposed to water 12 to 20 feet between the bottom of the pile cap and the river bed. No as-built plans or calculations existed for this bridge, and the original design plans did not include the pile length, width, or wood type.

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[1] A bascule bridge consists of single or dual leaves which are mechanically rotated and lifted to provide an opening for marine navigation.

[2] A pile bent is a transverse structural framework composed of piles and a pile cap.

[3] For more detailed information, read Highway Accident Report--"Collapse of the S.R. 675 Bridge Spans Over the Pocomoke River Near Pocomoke City, Maryland, August 17, 1988" (NTSB/HAR-89/04).

After examining the piles from the collapsed section of the bridge (pile bents 1 and 2), it was obvious that there was a significant reduction in the cross sectional area of the piles along the entire length exposed to water. At pile bent 1, the piles showed an average reduction in cross sectional area of about 35 percent, and at pile bent 2 the reduction averaged about 18 percent. Pile bent 1 was the substructure element located underneath the area where witnesses saw a crack through the girder and a depression in the bridge deck prior to the collapse.

The Safety Board's investigation revealed that the reduction in pile cross section was the result of several related factors working together. The factors included: the deterioration of the timber piles by bacteria, decay, soft rot fungi, and aquatic insect larvae (caddisfly);[4] and the abrasive effects of the tidal water currents. These factors were interdependent, and in combination, amplified their individual degrading effects. The bacteria and fungi attacked several inches of the outer layer of the piles and weakened the wood in the area of attack making it attractive to the caddisfly larvae. The caddisfly larvae burrowed into the conditioned wood, creating new holes, which helped to further accelerate the attack of the bacteria and fungi into deeper portions of the timber piles. Flowing water carried the food supply needed by the caddisfly to support the growth of the larvae and the pupae. Also, the flowing water carried suspended sediment that abraded the degraded outer layers of the timber piles, causing the surface of the pile to wear. The Safety Board believes that the combined effects of bacteria, decay fungi, aquatic insect larvae, and tidal currents degraded and destroyed the exterior layers of the untreated timber piles, resulting in a reduction in the pile cross sections.

Discovery of caddisfly larvae during the examination of the treated fender and dolphin pile samples suggests that the larvae may be impervious to creosote treated wood. However, the U.S. Forest Products Laboratory (FPL) has indicated that creosote wood treatments will retard bacterial and fungal

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[4] Caddisflies are an order of insects closely related to the moths and butterflies that have a four stage life cycle. The first three stages (egg, larva, and pupa) live in an aquatic habitat. During the fourth stage (adult), the female places fertilized eggs on a suitable substrate by descending into the water, by dropping an egg mass into the water, or by laying the eggs near the edge of the water. When living in the water, the larvae and pupae either construct a portable case or dig a shelter into the substrate for protection.

Some species dig small holes into submerged timber for protection. The homes consist of a retreat which shelter the larva. This retreat is fixed to the substrate after the larva chews out a small depression to reduce its profile. In addition, an anterior net of some type which strains food from the flowing water is attached to the shelter. At the end of the larval stage, all species construct a shelter for the ensuing pupa. At this time the shelter is enlarged, deepened and strengthened. After completion of the pupal period, the pupa cuts its way out of the shelter, swims to the surface, and flies away, thus beginning the cycle again.

degradation. Therefore, if the piles that supported the S.R. 675 bridge had been chemically treated, it is unlikely that they would have experienced the same levels of bacterial and fungal degradation as observed on the untreated piles. Consequently, without the bacterial and fungal degradation of the timber, the level of caddisfly infestation and the abrasive effects of the tidal currents on the piles also would have been substantially reduced.

In cooperation with the Safety Board and the Maryland State Highway Administration (SHA), the University of Maryland (UMD) conducted computer modeling of the S.R. 675 bridge elements. The UMD modeled the substructure elements for pile bents 1 and 2, studied four scenarios with variable conditions, and utilized two different assumed pile lengths, 50 and 65 feet. The results of this computer modeling indicated that the deteriorated piles could not have supported the dead load of the bridge if they had been only 50 feet in length. The computer modeling further revealed that 65-foot piles, that were not deteriorated or reduced in diameter, could support the bridge dead load and a full dump truck weighing 65,000 pounds. This combined weight would have been only 49 percent of the load needed to buckle the piles in pile bent 1, and 40 percent of the load needed to buckle the piles in pile bent 2. However, when the same live and dead loads were applied to the bridge model that had 65-foot piles with reduced diameters, the combined weight was 94 percent of the load needed to buckle the piles in pile bent 1, and 58 percent of the load needed to buckle the piles at pile bent 2.

The S.R. 675 Bridge received three scheduled underwater inspections since 1977. During the three underwater bridge inspections, the inspection crews were not given any guidance from SHA concerning the measurement of piles. Additionally, the crews were not provided with the available bridge plans or copies of previous inspection reports. As a result, only a few random measurements were taken of the pile diameters. The locations and elevations of these measurements were not consistent from inspection to inspection; therefore, no comparison of the data was made by the inspectors to determine changes in individual piles. Also, the inspectors were unaware of the actual diameters of the piles as installed, and thus could not readily determine the extent of any reduction that may have taken place. Further, only one increment bore sample was extracted from a pile during the 1986 inspection. The single increment bore sample was placed in a plastic drinking straw for storage and was not given to SHA until the day after the bridge collapse. The contract engineer who retrieved the sample stated that his interpretation of timber core sample quality was based on whether the sample remained intact when extracted. If the core came out whole, it was of good quality, if it crumbled when extracted, it was considered to be decayed. The sample from the S.R. 675 bridge was intact, and therefore the engineer assumed that it was not decayed. Other than visual examination, no tests were performed on this sample, and no other core samples were ever taken from the bridge piles. At the time of the bridge collapse, the SHA had no established procedure for the examination of timber core samples. Further, none of the inspections had discovered the bacterial or fungal decay of the piles, or the presence of the aquatic insect larvae. Even though the information provided to and developed by the on-site inspectors was limited, two of the underwater inspection reports recommended repair of the untreated timber piles.

The Safety Board concludes that although several deficiencies in the methods and execution of the underwater inspections resulted in the production of limited data concerning the untreated piles, the information provided in the inspection reports and report recommendations was sufficient to alert SHA engineers of the diminished pile diameters.

As one measure of water quality, the Maryland Department of Environment (MDE) collects data on the insects that live in the water. Near the Pocomoke City Bridge site, caddisflies were collected and counted. The number of larvae per 1.5 square feet was provided from 1976 to 1986 and averaged 543.5, with a high in 1977 of 1,837 and a low in 1986 of 50. Further, the Safety Board calculated that in 1977, caddisflies may have occupied 30 to 100 percent of the bridge substructure pile surfaces. Prior to the accident, MDE did not share this information with the SHA. However, following the discovery of the caddisfly larvae infestation during the investigation, the Safety Board solicited data from the MDE that resulted in the identification of 10 other locations in Maryland where high levels of caddisfly larvae had been measured. Consequently, the SHA has initiated underwater inspections of bridges in those areas.

Prior to this accident, the MDE had not recognized the importance of the data it had collected concerning the caddisfly population in the Pocomoke River, and accordingly did not provide it to the SHA. The Safety Board believes that similar water quality data (concerning the presence of caddisfly larvae or other contaminants) collected by state environmental agencies throughout the country, can assist State highway engineers in identifying bridges that may be susceptible to underwater degradation.

A review of FHWA and the American Association of State Highway and Transportation Officials (AASHTO) publications dealing with bridge inspection and maintenance found no discussion of aquatic insect larvae (caddisfly) infestation. The "Bridge Inspectors Training Manual" and AASHTO's "Manual for Maintenance Inspection of Bridges" mentioned fungal and bacterial degradation of both treated and untreated timber piles. Both texts also contained information on gathering increment bore samples from timber piles, but did not discuss tests or examinations that could be conducted on the samples to determine the existence or level of bacterial and fungal infestation.

In response to FHWA reviews encouraging the SHA to check its bridges to determine the safe load, the inventory and operating rating for the S.R. 675 bridge was calculated in March 1987 by SHA consultants, and again in May 1987 by SHA engineers. As a result, the SHA concluded that the bascule span was the weakest member of the bridge, and it subsequently recommended that the bridge be posted with a 25-ton weight restriction and a 25-mph-speed limit.

In both sets of calculations, the bridge substructure elements were not considered, even though recommendations had been made to the SHA during a 1981 underwater inspection to determine the load capacity of the pile bents. The operating rating of the bridge was determined assuming that only one maximum-legal-load truck was on the structure at a given time. Thus, no calculations were made to determine the bridge operating capacity based on the substructure elements, to account for two fully loaded trucks on the superstructure, or to account for the actual physical condition of the substructure, nor were they required.

The Safety Board believes that because SHA did not account for these conditions in its load rating calculations, the bridge was posted with an unrealistically high weight restriction. The posted load limits would have allowed two 50,000-pound vehicles to pass each other on the bridge at the same time, thus exceeding the buckling capacity of pile bent 1.

The Safety Board previously addressed the issues of load rating and underwater bridge inspection in its 1986 final report on the Collapse of the U.S. 43 Chickasawbogue bridge spans.[5] As a result of that investigation, the Safety Board issued the following recommendation H-86-5 to the FHWA:

> Require State highway officials to determine the safe load capacity for all bridges. Ensure that the underwater elements of all bridges over water have been recently examined before the safe load capacity is determined.

The recommendation is currently classified as open-acceptable action. It calls for the inspection of underwater bridge elements prior to load rating calculations; however, it does not require that information developed during these inspections be used in the calculations. The SHA had determined the load capacity for the S.R. 675 bridge and had performed an underwater inspection of the structure about two years prior to the collapse. However, the SHA did not use the information collected during this inspection to determine the safe load rating for this bridge.

The AASHTO Manual for Maintenance Inspection of Bridges does recommend that the deteriorated conditions of bridge members be considered during load rating calculations. The AASHTO Manual also recommends that computations for stresses and allowable loads consider only one maximum loaded vehicle on the bridge, and in some conditions two maximum loaded vehicles on the bridge, but in the same lane. As a bridge experiences a live load, the load is transferred to the bridge substructure through the superstructure. Therefore, when two adjacent lanes experience live loads simultaneously, those loads are transferred to the substructure, and the superstructure elements surrounding each load are not significantly affected by the load in the adjacent lane. However, the substructure supporting the bridge at that location is subjected to the combined weight of both loads. As illustrated by this collapse, the bridge substructure can become the weakest member of the bridge. Therefore, the Safety Board believes that substructure elements should be evaluated during load rating calculations. Consequently, these calculations should consider two maximum loaded vehicles in adjacent lanes to accurately represent loading conditions of the bridge substructure.

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[5] For more information, see Highway Accident Report--"Collapse of the U.S. 43 Chickasawbogue Bridge Spans Near Mobile, Alabama, April 24, 1985" (NTSB/HAR-86/01).

Therefore, the National Transportation Safety Board recommends that the Federal Highway Administration:

> Modify the Bridge Inspectors Training Manual to include information on the identification and detection of aquatic insect larvae infestation in submerged timber piles, the techniques for analyzing increment bore samples for bacteria, fungi, or other contaminants, and the need for sufficient measurements to enable complete assessment of the condition of timber piles. (Class II, Priority Action)(H-89-65)
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> Issue, as an interim measure, a technical advisory that discusses bacteria, fungi, and aquatic larvae infestation of submerged timber piles and the potential for cross sectional area loss of submerged timber piles as a result of these infestations. (Class II, Priority Action)(H-89-66)
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> Require State highway officials to include the condition of underwater bridge elements in load capacity calculations. (Class II, Priority Action)(H-89-67)
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> Develop guidelines and establish criteria, in cooperation with the American Association of State Highway and Transportation Officials, for testing timber increment bore samples to determine the presence of bacteria and decay fungi, and require that increment bore samples are retrieved during underwater inspections of bridges with submerged timber piles. (Class II, Priority Action)(H-89-68)

Also, as a result of its investigation, the Safety Board issued Safety Recommendations H-89-56 through -64 to the Maryland State Highway Administration, H-89-69 through -74 to the American Association of State Highway and Transportation Officials, and H-89-75 to the International Association of Chiefs of Police, Inc.

KOLSTAD, Acting Chairman, and BURNETT, LAUBER, NALL, and DICKINSON, Members, concurred in these recommendations.

By: James L. Kolstad
Acting Chairman