National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Log H-542

Date: January 9, 1990

In reply refer to: H-89-56 through -64

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Administrator
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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]

About 11:00 a.m. on August 16, 1988, the day before the collapse, a motorist was traveling westbound across the bridge. He observed a "v" shaped depression about 10 to 12 inches deep and about 20 feet long, extending across the width of the bridge deck at the first west side span. After driving across the bridge, he observed a crack on the south side vertical face of the bridge that coincided with the depression in the deck. Following these observations, the motorist immediately drove to the Pocomoke City Police Department and reported the condition of the bridge to the police dispatcher. However, the dispatcher did not notify the officers on duty at the time, or record the complaint in the police log. Later that afternoon, at about 4:30 p.m., another motorist advised the Pocomoke City Police Chief of a low spot on the bridge. In response to the complaint, the Chief went to the bridge at about 5:00 p.m. and inspected the east side spans. The Chief stated that he observed a pothole at the east abutment, but he did not

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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).

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inspect the bridge's west side spans. He made no further observations of the bridge prior to the collapse.

Neither complaint received by the Pocomoke City Police Department was thoroughly explored, nor was the Maryland State Highway Administration (SHA) advised of the witness observations. One complaint was overlooked by the police dispatcher, and although the Police Chief inspected the east side spans of the bridge in response to the second complaint, he erroneously concluded that a pavement defect at the east abutment was the cause of the complaint, and he never inspected the west side bridge spans. Consequently, motorists were allowed uninterrupted use of the bridge as it was slowly collapsing. Even if police personnel had inspected the entire bridge, it is uncertain that they would have recognized the depression in the bridge deck as a potential hazard.

However, if the Police Department had notified the SHA District Office of the complaints, the SHA indicated they would have sent bridge inspectors to inspect the bridge. It is likely that they would have recognized the seriousness of the bridge deck depression, and they would have subsequently closed the bridge. Although this would not have prevented the collapse, it would have eliminated the potential hazard to motorists. Inherently, police personnel are not trained to identify or determine the seriousness of bridge defects, nor does the Safety Board believe that they should be. However, municipal governments should be encouraged to have their personnel notify State highway officials when any complaint is received concerning the condition of a bridge. In response, the State highway officials should have inspectors who are familiar with the bridge conduct an immediate review of the complaints. In this way an accurate assessment of the bridge condition can be made.

The main fixed span bridge girders and the 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.

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.

In cooperation with the Safety Board and the Maryland 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

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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.

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.

During the review of underwater inspection reports by the SHA Bureau of Bridge Inspection and Remedial Engineering (BI&R), engineers did not routinely refer to design plans or compare information from various bridge inspection reports. As a result, the remedial engineers that reviewed the data from the S.R. 675 bridge underwater inspection reports never identified the cross section loss of the submerged piles. Had the engineers reviewed the bridge design plans, they would have discovered that the pile diameters were not provided on the plans. Further, had they compared the three underwater inspection reports, the engineers could have discovered that some of the pile diameters measured during the inspections were well below diameters required by both the American Association of State Highway and Transportation Officials (AASHTO) specifications. Therefore, the Safety Board concludes that during the review of underwater inspection reports for the S.R. 675 bridge, SHA engineers did not make effective use of available data to properly evaluate the substructure of the bridge.

Further, the Safety Board believes 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.

Although the SHA provided most of its inspectors with a Federal Highway Administration (FHWA)-sponsored bridge inspection course, the engineers in the BI&R were not similarly trained. Since these engineers are responsible for bridge inspections in response to inspection crew requests, in addition to the review and interpretation of inspection reports, the Safety Board believes that they should also be trained in comprehensive bridge inspection methods.

The SHA has indicated that all timber pile bridges within the State are scheduled to receive a supplemental inspection that would include measurements of the pile diameters, batter and direction of piles, maximum ice pick penetration, and length of piles exposed to water. The Safety Board believes that the SHA should include the collection of these data in its regularly scheduled underwater inspections.

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. As illustrated by this collapse, the bridge substructure can become the weakest member of a 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.

Following the collapse of the S.R. 675 bridge, the SHA implemented a variety of policy and procedural changes to improve the inspection and evaluation of bridges within Maryland. Although the Safety Board recognizes the significance of these changes, it believes that additional changes would further improve the quality of the program.

The Chief of the BI&R not only supervises the inspection crews and remedial engineers, he is the person to be notified should inspection crews discover a defect within a bridge that requires immediate repair.

Additionally, the Chief is required to review each defect sheet, review and supervise bridge rehabilitation designs, and monitor municipal government compliance with the National Bridge Inspection Standards. Further, SHA has indicated that the Bureau Chief will now have control of the scope and schedule of maintenance and repair work performed on State bridges. In the 1988 review of the SHA bridge inspection program, FHWA indicated a need for an increase in staff to monitor bridge repairs. Also, the FHWA recommended that a new position be created within the SHA to monitor bridge inspection of county and city bridges. The Safety Board concurs with the FHWA recommendations and believes that the SHA should go further in implementing staff improvements. Now that the SHA is placing emphasis on underwater inspections, and the responsibility for maintenance and repair of State bridges has shifted to the BI&R, the increased work associated with the inspections and maintenance could overwhelm the existing staff. Due to the complex nature of the underwater inspections, and the demonstrated weakness of the SHA inspection report review process, the Safety Board believes that the SHA should provide the engineering staff of the BI&R with sufficient capability to monitor underwater inspections and to perform more in-depth reviews of underwater inspection data.

During the investigation of this accident, the SHA extracted 4-inch concrete core samples from the bridge wreckage. These samples were subsequently tested and revealed a low modulus of elasticity for the concrete. The Safety Board conducted a review of the test data and determined that the size of the concrete aggregate, as much as 2.2 inches in diameter, influenced the test results. To clarify this condition, Safety Board investigators asked the SHA to extract larger core samples, but the SHA did not have the equipment to take 6-inch or 8-inch concrete cores. Through an independent contractor, the Safety Board later extracted 6-inch concrete core samples from the bridge wreckage and had them tested in accordance with the American Society for Testing and Materials (ASTM) standards for modulus of elasticity. The resulting moduli of elasticity were much higher than the results of the original tests performed by SHA, and they revealed that the concrete did in fact have an adequate modulus of elasticity, and it was not fatigued. In examining concrete from bridges, the modulus of elasticity tests are essential to determine load distributions and fatigue conditions of the concrete. The Safety Board believes that the SHA should obtain equipment capable of extracting larger concrete core samples for testing in accordance with ASTM standards.

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

> Modify bridge inspection procedures to provide inspectors with "as built" plans if available, during on-site inspections. (Class II, Priority Action)(H-89-56)
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> Modify bridge inspection report review procedures to require reviewers to compare all inspection reports, design plans, and "as built" plans, if available. (Class II, Priority Action)(H-89-57)

Review the load rating calculations for all bridges within the State and consider the load carrying capacities of substructure members during the calculation process. (Class II, Priority Action)(H-89-58)

Reevaluate the load rating for bridges for which the substructure was not considered in load rating calculations. (Class II, Priority Action)(H-89-59)

During regularly scheduled underwater bridge inspections, require bridge inspectors to record at a minimum: incremental measurements of pile diameter, pile batter and direction, maximum ice pick penetration, and length of exposed piles. (Class II, Priority Action)(H-89-60)

Train, on comprehensive bridge inspection methods, State Highway Administration engineers who review bridge inspection reports and rate the bridges within Maryland. (Class II, Priority Action) (H-89-61)

Provide the engineering staff in the SHA Bureau of Bridge Inspection and Remedial Engineering with sufficient capability to monitor the State underwater inspection program, the quality of reports and report reviews, the underwater inspection program for county and city bridges, and bridge maintenance, rehabilitation, and repairs. (Class II, Priority Action)(H-89-62)

Require when evaluating concrete bridges, that concrete core samples be 6-inches or larger in diameter to improve the analysis of these structures. (Class II, Priority Action)(H-89-63)

Establish procedures for municipal governments to notify the State Highway Administration District Maintenance Office of any reported complaint concerning the condition of a bridge structure, and develop procedures to investigate all notifications thoroughly. (Class II, Priority Action)(H-89-64)

The National Transportation Safety Board is an independent Federal agency with the statutory responsibility "... to promote transportation safety by conducting independent accident investigations and by formulating safety improvement recommendations" (Public Law 93-633). The Safety Board is vitally interested in any action taken as a result of its safety recommendations. Therefore, it would appreciate a response from you regarding action taken or contemplated with respect to the recommendations in this letter. Please refer to Safety Recommendations H-89-56 through -64 in your reply.

Also, as a result of its investigation, the Safety Board issued Safety Recommendations H-89-65 through -68 to the Federal 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.

James L. Kolstad

By: James L. Kolstad
Acting Chairman