Log# H-555 B/ SR-1

# National Transportation Safety Board

*Washington, D. C. 20594*

**Safety Recommendation**

**Date:** December 21, 1990

**In reply refer to:** H-90-103 through -106

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On May 26, 1989, about 5:25 p.m. eastern daylight time, a 140-foot section of the 556-foot Harrison Road temporary bridge over the Great Miami River fell about 40 feet into the rain-swollen river after a pile bent collapsed. Seven witnesses reported that a passenger car and a pickup truck fell into the river. However, only a passenger car and the bodies of the car's two occupants have been recovered from the river. No other vehicles were found in the river nor are any persons reported missing in the Miamitown area. Witnesses reported an unusual amount of debris floating down the river and striking the pile bents of the bridge prior to the collapse. Although the weather was clear and dry, flooding conditions existed at the time of the collapse and the river had overflowed its banks onto the flood plain.[1]

In May 1990, the Safety Board contracted with the University of Maryland (UMD) to conduct structural calculations to determine the lateral load capacity of the collapsed structure and the ability of the bridge to meet American Association of State Highway and Transportation Officials (AASHTO) lateral load specifications. Two types of computer analysis were carried out to determine the lateral load capacity and the sequence of failure from both elastic buckling[2] and an elasto-plastic[3] type failure.

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[1]For more detailed information, read Highway Accident Report--"Collapse of Harrison Road Bridge Spans, in Miamitown, Ohio, May 26, 1989" (NTSB/HAR-90/03).

[2]Elastic buckling analysis is a method used to determine the upper bound of the load-carrying capacity of a structure before buckling occurs.

[3]Elasto-plastic analysis is a method used to determine the upper bound of the load-carrying capacity of a structure before plastic deformation occurs.

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In performing its analysis, the UMD assumed that the pile bent failure resulted from some type of elasto-plastic yielding that led to the formation of plastic hinges. The UMD analysis indicated that at a combined impact and accumulated debris load of 7.5 tons, plastic hinges would begin to form. The UMD also concluded that collapse would occur when a critical number of plastic hinges[4] had developed throughout the substructure, at a combined impact and accumulated debris loading between 11 and 12.5 tons. Based on UMD's engineering analysis and the physical evidence, the Safety Board concludes that the collapse of pile bent 2 resulted from the formation of plastic hinges due to a combination of impact and accumulated debris loading on the upstream side of the pile bent.

The Safety Board's review of the National Engineering and Contracting Company (NECC) temporary bridge design indicates that the bridge was designed in accordance with AASHTO (HS20-44) vertical loading and with the Ohio Department of Transportation (ODOT) waterway opening specifications for temporary structures. At the Safety Board's request, the UMD reviewed the NECC temporary bridge to determine whether it would have met AASHTO specifications for group loading combinations and found that it did not. According to the UMD report, if the NECC temporary bridge had been designed to conform with AASHTO lateral load specifications, pile bent 2 would have had a safe load capacity of about 23 tons instead of its actual safe load capacity of about 3.5 tons. The designer of the NECC temporary bridge believed that the bridge's substantial vertical load design factor of safety (3.5 to 1) would also accommodate any lateral loads that the bridge would experience. As illustrated by this collapse, an increase in the vertical load capacity of a bridge may not result in a similar increase in its lateral load capacity. Therefore, the Safety Board concludes that it was inappropriate for NECC to assume lateral load capacity for the temporary bridge simply by providing a substantial vertical load factor of safety in its design calculations. Furthermore, the Safety Board concludes that had the NECC temporary bridge been designed for lateral loads such as those specified by AASHTO, the bridge would have withstood the combined debris loads that caused the collapse.

The Hamilton County Engineer's (HCE's) office uses consultants in the design, construction, and review of county projects because it does not have a sufficient engineering staff for these functions. Although the HCE reviewed NECC's temporary bridge design plans for construction purposes, Graham, Obermeyer & Partners, Ltd. (GOP) was retained to perform a design review of the proposed alternate bridge plans. During the review, GOP raised questions about NECC's design, noting that it included no calculations for lateral loading. The HCE did not require NECC to make lateral load calculations or design modifications to address GOP's concerns. As a result, the NECC temporary bridge was constructed with little consideration for lateral loads. Had the HCE's office required NECC to perform lateral load calculations, the office would have discovered that the NECC temporary bridge design had a low lateral load capacity. The Safety Board concludes that HCE's approval of the NECC design without requiring design calculations for lateral loads

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[4]When the number of plastic hinges formed exceeds those required for elastic stability, the overall collapse of the pile bent occurs.

resulted in the construction of a bridge that was inadequate for the lateral loading conditions imposed on it.

Although the construction crew was not at the site on the day of the accident, the Hamilton County assistant bridge engineer stopped by to check the work status. While he was at the site, the water level increased from 13 feet to 18 feet on the gauge. He stated that he was not alarmed by this because earlier in the week (3 days before the collapse) the river gauge had read 21 feet. He testified at the Safety Board's public hearing that there were no written procedures or policies for closing bridges.

An NECC superintendent stopped by to check the construction site about 4:20 p.m. He did not notice anything unusual about the bridge but was alarmed by a telephone pole leaning precariously toward it. According to testimony at the Safety Board's public hearing, the superintendent apparently believed that he needed to get permission from the HCE's office before taking action to close the bridge. In addition, HCE employees testified that they expected to be contacted regarding a decision to close the bridge. Even though the superintendent's actions were not in response to a potential collapse of the bridge, had a procedure been in place that provided the superintendent with the authority to close the bridge, he could have closed it before the collapse.

At the time of the collapse, the HCE knew that lateral loads had not been calculated in the design of the temporary bridge and was aware of the flood conditions during the week preceding the collapse. Because the lateral design capacity of the bridge was not known, the HCE should have initiated procedures for monitoring the bridge during the flood conditions. During the initial contractual arrangements, the HCE's office and NECC should have agreed on procedures for monitoring and closing the temporary bridge structure. The Safety Board concludes that the HCE's failure to establish a policy and to develop procedures for monitoring and closing the temporary bridge during flooding conditions contributed to the severity of this accident. The Safety Board believes that the HCE should establish policies and develop procedures for bridge closure. Furthermore, the Safety Board believes that all States should require that any bridges susceptible to hydraulic and debris loading be monitored during flood events to ensure that they are closed when lateral loads exceed the design loads.

According to the testimony from the chairman of the AASHTO Subcommittee on Bridges and Structures, AASHTO specifications for bridge design address all the forces a bridge is expected to safely withstand during the life of the structure. AASHTO does not differentiate between permanent and temporary bridges and thus, according to AASHTO, all temporary bridges should be designed in accordance with the same AASHTO loading specifications that are applicable to permanent structures. Based on the UMD analysis, the Safety Board concludes that had NECC considered AASHTO lateral loads in the design of its temporary bridge, the bridge would have withstood the debris loading that caused the collapse. Moreover, the UMD noted that the GOP temporary bridge design met AASHTO lateral group loading specifications, indicating that it is reasonable to design temporary bridges in accordance with these specifications. Therefore, the Safety Board believes that all public bridges should be designed and built in accordance with AASHTO vertical and lateral loading specifications.

Section 3.18 of AASHTO standard specifications for highway bridges states that all piers and portions of structures that are subjected to flowing water are to be designed to resist the maximum stresses induced by stream flow, floating ice, wind, and debris. The specifications provide detailed criteria for calculating the maximum expected loads and stresses for each of these conditions except debris. The specifications do not provide any guidance for calculating impact and accumulated debris loads.

According to testimony provided by the chairman of the Subcommittee on Bridges and Structures, debris loading is partly accounted for by the safety factor incorporated into the design and may also be estimated based on bridge site visits or historical data on river debris. Most structures that are built in accordance with AASHTO loading specifications for allowable working stress have a factor of safety of about 2 to compensate for unanticipated loads. However, this factor of safety is based on the assumption that the designer has tried to consider all known forces (vertical, lateral, and so forth) that may be imposed on the bridge during its service life. The factor of safety is intended to provide for variations in the different types of loads that are specifically considered.

Many permanent bridges are built with massive substructures to support the weight of the superstructure and, as a result, far exceed AASHTO criteria for lateral loads. These bridges are protected from debris loading by the inherent nature of the massive substructures. However, those bridges that do not have massive piers in the water, such as this bridge, are susceptible to being overstressed from loads caused by debris impact and accumulation. Therefore, it is imperative that all significant lateral forces, including debris loading, be considered in the design process. Because no specific guidance is provided by AASHTO for calculating debris loads, the Safety Board believes that AASHTO, in cooperation with the Federal Highway Administration and the U. S. Geological Survey, should conduct research to develop methods for estimating maximum debris loads, that is, frequency, size, and magnitude, for design purposes. The Safety Board believes that once these methods are developed, AASHTO should include in the "Standard Specifications for Highway Bridges" detailed criteria for calculating the maximum expected debris loads and should specify analytical methods for determining the stresses imposed by impact and accumulated debris loads on highway bridges.

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

> Undertake a research program in cooperation with the American Association of State Highway and Transportation Officials and the U.S. Geological Survey to develop methods for estimating maximum debris loads for bridge design purposes. (Class II, Priority Action) (H-90-103)
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> Establish, in cooperation with the American Association of State Highway and Transportation Officials, standard analytical methods to determine loads imposed by debris impact and by debris accumulation on bridge substructures. (Class II, Priority Action) (H-90-104)

Encourage the States to determine bridge design capacities and to establish policies and procedures to close bridges when conditions exceed the design capacity. (Class II, Priority Action) (H-90-105)

Encourage all States to require the American Association of State Highway and Transportation Officials loading specifications as minimum design criteria for all bridges open to the public. (Class II, Priority Action) (H-90-106)

Also, as a result of its investigation, the Safety Board issued Safety Recommendation H-90-98 to the Hamilton County Engineer's Office; H-90-99 through -102 to the Ohio Department of Transportation; H-107 through -109 to the American Association of State Highway and Transportation Officials; and H-90-110 to the U. S. Geological Survey.

KOLSTAD, Chairman, COUGHLIN, Vice Chairman, and LAUBER, BURNETT, and HART, Members, concurred in these recommendations.

By: James L. Kolstad
Chairman