Ltr 14-407

# NATIONAL TRANSPORTATION SAFETY BOARD
## WASHINGTON, D.C.

ISSUED: July 19, 1984

Forwarded to:

Honorable William A. O'Neill
Governor of Connecticut
State Capitol
Hartford, Connecticut 06106

SAFETY RECOMMENDATION(S)

H-84-31 through -39

At 1:30 a.m., e.d.t., on June 28, 1983, a 100-foot-long suspended span between piers 20 and 21 of the eastbound traffic lanes of the Interstate Route 95 highway bridge over the Mianus River in Greenwich, Connecticut, collapsed and fell 70 feet into the river below. Two tractor-semitrailers and two automobiles plunged into the void in the bridge and were destroyed by impact from the fall. Three vehicle occupants died, and the other three received serious injuries. 1/

The suspended span which collapsed was attached to the bridge structure at each of its four corners. To support the weight of the northeast and southeast corners of the suspended span, each corner was attached to the girders of the cantilever arm of an adjacent anchor span by a pin and hanger assembly. The pin and hanger assembly includes an upper pin attached through the 2 1/2-inch-thick web of the girder of the cantilever arm and a lower pin attached through the 2 1/2-inch-thick web of the girder of the suspended span. One and one half-inch-thick steel hangers connect the upper and lower pins—one on the inner side and one on the outer side of the web.

Sometime before the collapse of the suspended span, the inner hanger in the southeast corner of the span came off of the inner end of the lower pin. This action shifted the entire weight of the southeast corner of the span onto the outer hanger. Over a period of time, the added weight initiated a fatigue crack in the top outer end of the upper pin. The outer hanger gradually worked its way farther outward on the pin, and when it reached the fatigue crack, the shoulder of the pin fractured off and the assembly failed. The span briefly balanced on its connections at the other three corners and then collapsed, southeast corner first, into the river 70 feet below.

The National Transportation Safety Board determined that the probable cause of the collapse of the Mianus River Bridge span was the undetected lateral displacement of the hangers of the pin and hanger suspension assembly in the southeast corner of the span by corrosion-induced forces due to deficiencies in the State of Connecticut's bridge safety inspection and bridge maintenance program.

1/ For more detailed information read Highway Accident Report—"Collapse of a Section of Interstate Route 95 Highway Bridge Over the Mianus River, Greenwich, Connecticut, June 28, 1983" (NTSB/HAR-84/03).

Maintenance personnel testified that the drains on the bridge were difficult to keep open because the scuppers and downspouts were too small and because the hydraulic slopes of the piping were too shallow and the changes in direction were too abrupt. They said that because of the placement and routing of the drainage piping, much of the drainage system was inaccessible and difficult to repair or replace without the aid of scaffolding or mechanical equipment, which was not available. Therefore, maintenance personnel had cut holes in parts of the drainage system to increase drainage. Also, some parts of the drainage system which had fallen off had not been replaced. Some persons testified that at one time maintenance workers had power nozzles, vacuum equipment, and scaffolding to work on the drains and keep them open, but that this equipment had not been available for at least 10 years.

The roadway of the Mianus River Bridge was resurfaced in June 1973. One bridge maintenance worker testified that prior to the resurfacing, "we were ordered to go out there and cover up the drains with steel plates." He said that he did not recall who gave the order. He said that he cut the 12-inch by 12-inch by 1/4-inch steel plates and welded them over the grates. He said that it was his impression that the plates were installed just to protect the drains while the paving was being done. However, the asphalt and steel plates were never removed and were still in place after the bridge span collapsed. Therefore, for at least 10 years before the accident, the road surface between curbs on the suspended spans was being drained only through the expansion joints.

After the closure of the curb drains of the fallen span, the expansion joint trough and the smaller curb trough became the first collectors for water-borne sand, salt, dirt, and debris from the 240 feet of pavement above the expansion joint, a condition that was not predicted or predictable in the original design. Based on the amount of road surface originally drained by the expansion joint and the curb drains, it is estimated that the water and salt flow into the expansion joint increased by at least a factor of 10 after the curb drains were paved over. Approximately the same increase occurred at all four suspended spans which were affected by the overpaving in the same way. Those spans were found to have clogged expansion joints as well as severe pin and hanger corrosion.

It is well known that the use of salt to deice bridges in winter accelerates corrosion, especially where drainage conditions allow salty water to contact and remain on the steel structure. Salt not only accelerates corrosion, it increases the degree of corrosion. The Connecticut Department of Transportation (ConnDOT) had taken deck samples which indicated that there were excessive amounts of chloride in the bridge deck. Seventy-six percent of the 88 test core samples taken in 1978 contained more than the maximum acceptable chloride content. This knowledge should have raised questions about the reason for the excessive chloride, which should have revealed the plugged drains and disabled drainage system. It also should have resulted in a closer inspection of the steel superstructure. Use of salt is generally accepted because it is assumed that correct drainage and maintenance will prevent any kind of drainage water from contacting the critical parts of the structure. In this instance, the drainage system did not prevent water from flowing over the structure and pins and hangers; when that water contained salt, it accelerated corrosion. The use of deicing salt contributed to the corrosion and eventual bridge collapse only to the degree that the altered drainage system was unable to carry the salt away from the pin and hanger assembly.

At the southeast corner of the fallen span, the water marks clearly showed that water did flow over the hangers and pins and that parts of the troughs, which remained in place but which were filled with dirt and debris, prevented the normal direction of water away from the pin and hanger assembly. Water flow marks on the inner hanger indicate that the corroded area was subject to repeated wettings and a repeated water flow pattern. The heavily corroded lower end of the inner pin hanger showed water marks on both sides. The marks were above and below the areas of greatest corrosion.

Other than the drainage system, there were no other features to protect the pins and hangers from continual wetting or from corrosion. This was acceptable practice because it could be anticipated that failure of the drainage system would be detected by the bridge inspectors. In fact, the failures were seen and reported, but not corrected. It was stated that missing or damaged drainage troughs were not repaired because they were difficult to reach and because the concrete-mounted corroded bolts to which they were attached were very difficult to replace. However, this rationale was not applicable to other parts of the drainage system that also were not replaced. Moreover, no alternative remedy was taken. Holes were cut in the drainage systems, damaged or missing drainage system sections were not replaced, and drains were paved over by ConnDOT as a direct consequence of the need to minimize maintenance expenditures.

The paved-over curb drains were not addressed in the 10 years since the National Bridge Inspection Standards had come into effect. Although bridge safety inspectors knew that drains had been paved over on the Mianus River Bridge, the knowledge was not effectively reported to upper management. No direction was given to correct the paving for safety reasons because the chief of the Bridge Safety and Inspection Section was not aware of the need.

The reviewer of bridge safety inspectors' reports said that he believed that the drains reported as "plugged" were plugged with sand. It is understandable that a bridge inspector long familiar with the bridge and its drainage problems and the gradual reduction of maintenance workers might accept paving over as an officially condoned action. However, the next reviewer of reports, the Transportation Associate Engineer, had the duty to question each report that came before him. Even if he believed, as he said, that the drains were all plugged with sand, he still should have been concerned. There was no functional difference between drains paved over and drains plugged with something else, and the entry should have been cause for concern and inquiry. It is apparent that the report reviewer did not act on the warning regarding clogged drains given in the "Bridge Inspector's Training Manual" issued by the Federal Highway Administration (FHWA). The Board considers that because of the large number of plugged drains, an inquiry should have been made. The report reviewer, however, had little face-to-face contact with his inspectors and used the telephone to talk to them. The contacts were most often for the purpose of controlling movements and workload. ConnDOT should increase the attention given to reviewing bridge inspection reports and provide for face-to-face discussions of reports on selected bridges by reviewing and inspectors.

The steel superstructure on the Mianus River Bridge was not kept clean. Pigeon excrement was piled up 6 to 10 inches on the bottom flanges of some of the steel. Not only did this add to the corrosive process (pigeon excrement contains urea, an ammonia salt), but it also discouraged the inspectors from walking the steel for closeup examinations of the pins and hangers. The ConnDOT maintenance policy did not call for the flushing of bridge superstructures. Steel should be kept free not only of bird excrement (particularly urea) but also of dirt, which can accumulate and hold moisture, which along with oxygen will cause corrosion of unprotected structural steel.

The bridge inspection process usually follows the outline of a two-page Bridge Inspection Report (BRI-18 Ed. 1-81) developed by ConnDOT. Inspections normally progress from west to east or from south to north, generally following the abutment and pier numbering system. The rating codes used by the inspectors are based on the "Recording and Coding Guide for the Structures Inventory and Appraisal of the Nation's Bridges," developed by the FHWA and published in January 1979. The Bridge Inspection Form developed by ConnDOT includes a section on "alignment of members" distinct from other forms of misalignment. However, it does not quantify the relationship between measurements of misalignment and alignment rating numbers. The Recording and Coding Guide does not include any mention of alignment of members.

Entries on the inspection report form are arranged by classes of structure and problems, rather than by a sequence of movement over the bridge. The report requires the inspector to consolidate statements on the condition of several bridge elements of the same class; it provides no specific space for recording the condition of the many individual elements which necessarily have to be inspected in order to arrive at overall ratings, nor is there an intermediate form for consolidating the observation of alignment at many locations into the overall rating which the form requires. There is a "Remarks" section which could be used for appropriate observations or comments pertinent to the inspection.

The bridge inspectors did not use a written checklist specific to this bridge on the job. They did not follow the details in the ConnDOT "Field Bridge Inspection Booklet" and the FHWA "Bridge Inspector's Training Manual" during their inspections. Both documents contained considerable detail not applicable to the Mianus River Bridge, and this may explain why they were not used. Moreover, the items to be inspected were not arranged in a sequence of movement over the bridge. The inspectors apparently had worked out their own sequence of inspection, but it was not in a written form. The bridge reports were filled out from notes and memory after the inspectors had left the bridge. This method did not ensure that all items were observed.

The bridge inspector's report of September 1982 rated "alignment of members" at "8," a rating that means the rated part is subjectively judged to be in as good condition as when built. There were no written, objective, dimensional standards for measuring "alignment of members," even though the FHWA "Bridge Inspector's Training Manual" makes it clear that misalignment raises questions regarding the condition of bearings. Misalignment found in other spans after the accident was due to corrosion, which does not develop in a short time. Therefore, the Safety Board believes that at least three of the four suspended spans had been misaligned vertically (sagged) for some time, that the spans may have been misaligned at the time of the September 1982 bridge inspection, and that the vertical alignment possibly had not been adequately inspected. The high rating assigned to "alignment of members" was misleading and may have prevented the engineers in the inspection program who reviewed the reports from being alerted to the serious problems which misalignment can indicate.

After the inside hanger had been displaced off the end of the lower pin at the southeast corner, the hanger would have moved along the upper pin so as to be at least 1/2 inch farther away from the girder than when it was installed. The spacer washers on the upper pin were observed to be dished outward by rust anywhere from 1/2 to 1 inch; they would have been occupying the additional space between the hanger and the girder. The junior inspector's finding of a "handful of flaked rust" in the joint did not cause him to record anything more than the general entry "laminated rust" in the "bearing" section of the inspection form, without any designation of which "bearing" (pin and hanger). Neither inspector noticed the change of dimensions that was observable, possibly because they did not get close enough, and an opportunity to detect the problem and prevent the collapse was missed.

Only the catwalk between the north girder of the eastbound lanes and the south girder of the westbound lanes provided arm's length access to the inside pin and hanger assemblies on those girders, and then only to the upper pin. To inspect the lower pins an inspector had to lie on his stomach and reach below the catwalk; even then it was difficult to view the lower pins adequately. A portion of the inside hanger assembly could be touched while standing on the superstructure and by reaching through the space between the webs of the cantilever arms and suspended spans. Measurements could have been made of the alignment of the webs relative to each other and the distance of the exterior hangers from the web. An inspector also could have placed a hand between the hanger and the web on the upper pins while standing on the median catwalk.

The junior inspector who examined the Mianus River Bridge testified that he had walked along the bottom flanges of the skewed end floor beams to "inspect" the northwest pin and hanger assembly connecting the north girder of the western suspended span to the adjacent cantilever arm of the anchor span of the westbound roadway. He gained access to these floorbeams from the north catwalk. He did not take any measurements and only observed the upper pin at close range. He reached over the top of the hanger into the space between the web and the hanger and on removing his hand found it covered with flaked rust. Such an observation should have suggested a critical fact—that severe corrosion was taking place. The inspection report should have reflected more than just a routine notation of "bearings--laminated rust," and the report should have been flagged for the immediate attention of a supervisor.

There were no handgrips on the beams, so walking on them was treacherous. It was made even more difficult by the presence of large amounts of pigeon excrement. The beams could have been designed or fitted with handgrips or handrails, but apparently this was not considered in the design or as an addition that would help make inspections easier. There is no indication the inspectors ever asked for such additions, and they made inspections for more than 20 years without them.

One of the most important pieces of equipment to facilitate the effective inspection of large bridges is the snooper truck, yet it apparently had been used only once to inspect the Mianus River Bridge. There is no indication in any of the Mianus River Bridge inspection reports (which date back to January 23, 1962) that a snooper truck was ever used on this bridge in a safety inspection. There is no place on the bridge inspection report specifically for noting the use or non-use of a snooper truck. The junior inspector's efforts to gain access to the pin and hanger assembly, however, implies that if a snooper had been available at the southeast corner of the suspended span during the September 1982 inspection, he could have examined the pin and hanger assembly more closely.

Neither the FHWA nor the American Association of State Highway and Transportation Officials (AASHTO) have developed a written inspection technique to detect hanger displacement. Measurement of spaces between members was advocated in both the FHWA "Manual for Maintenance Inspections of Bridges" (1970) and the ConnDOT "Field Bridge Inspection Booklet." The FHWA was aware of the problem because the AASHTO "Manual For Bridge Maintenance" (1976) contained the hazard advisory about the difficulty of pin and hanger bearing inspection. However, the FHWA did not initiate a project to address the inspection problem, and no action was taken by either AASHTO or the FHWA to develop a workable inspection technique. Such action was within the FHWA's technical development responsibilities with respect to bridge inspection.

A ConnDOT engineer stated that dismantling of the pin and hanger assembly for inspection had not been considered before the collapse of the span. Had such consideration been given, and dismantling then been found too disruptive or costly, the need to address the uninspectable condition in some other way would have been obvious. It would have been logical, had the problem actually been studied, to direct closer attention to the presence of rust or to changes in span alignment, for example. Despite the hazard advisory in the AASHTO maintenance manual, ConnDOT did not realize, before this accident, that the safety of the bridge could not be ascertained with certainty without careful pin and hanger inspections.

The advisory statement on dismantling hangers in AASHTO's "Manual for Bridge Maintenance" was clear, but the fact that a bridge might collapse if bad bearings were not discovered was not explained. Further, the AASHTO statement did not actually

"recommend," much less assert, the critical need for a detailed inspection, much less one involving dismantling of bearings. Given the nature of the AASHTO advisory, failure to dismantle was most understandable. The advisory was based on the technical judgment of AASHTO that good practice calls for dismantling for inspection, but AASHTO did not word the statement in a way that clearly suggested an imperative need to follow this practice. AASHTO's failure to include the advisory in subsequent revisions of the "Manual for Maintenance Inspection of Bridges" left the problem unaddressed in any current AASHTO document. The original AASHTO document seems to have made little or no impression on ConnDOT employees. The purpose of the National Bridge Inspection Standards—to avoid a repetition of a previous catastrophic bridge collapse—was thereby defeated.

It appears that the AASHTO "maintenance" documents were not considered sources of safety knowledge by ConnDOT bridge safety inspectors. Although the documents were distributed at the working level, no direction mandating their use was given. Apparently, "maintenance" was considered to be a different function from safety inspection and was not directed primarily toward ensuring safety. AASHTO's "Manual for Bridge Maintenance" (1976) which contained the hazard advisory about dismantling pin and hanger assemblies had been only partially read by the immediate supervisor of bridge safety inspectors, who thought it was "for maintenance."

The concept of AASHTO publications, that they serve only to help States exchange technical knowledge and they are purely advisory, was well illustrated in this instance. For example, two pieces of advice in AASHTO manuals--that hangers should be dismantled for inspection and that designed drainage should be preserved by cleaning--were worded so as not to suggest they were mandatory and were placed in publications that were not enforceable. States may be unable to follow all of the technical advice in AASHTO documents for such reasons as lack of funds. However, the failure to follow AASHTO advice in this case involved other questions than money. ConnDOT supervisors had the documents, but did not even bother to read them in many cases. The bridge inspectors most in need of the advice never received the manuals. The advice in the AASHTO publications was not considered and then rejected for any studied reason; it was simply unassimilated. The reviewer of bridge inspection reports did not believe the AASHTO maintenance publications had any bearing on "safety," and the Director of Maintenance had given no instructions to use the manuals, even though he had personally participated in developing some of them. For these reasons, the guidance in AASHTO manuals, which carried potentially life-saving information, was ineffective in triggering action by ConnDOT that probably would have prevented the collapse of the Mianus River Bridge span. Their content did not command the same response as the National Bridge Inspection Standards, which carried no advisory about the need to dismantle hangers.

The Safety Board has concluded that at the time the Mianus River Bridge was designed, standards for designing stuctures did not give sufficient attention to ensuring inspectability and maintainability. Inspectability and maintainability are not prominent goals in the state-of-the-art of bridge design even now. These considerations, which are elements of "reliability and maintainability," essentially require that a structure be designed so that it can be inspected and maintained as a reliable system. Inspection manuals and maintenance manuals, when based on a specific bridge and its environment, are of more value to workers than general instruction books such as the "Bridge Inspector's Training Manual." This manual was not used by inspectors because it was not targeted toward specific bridges and because it contained much material that had no application. The Safety Board believes that the bridge safety inspection unit should review the plans for a new bridge to determine if the structure can be safely and

adequately inspected and maintained. Inspectors also should conduct a postconstruction survey of a new bridge to ensure that specifications for inspection and maintenance have been met by the builder.

Therefore, the National Transportation Safety Board recommends that the Connecticut Department of Transportation:

Reopen the paved-over drains on the Mianus River Bridge and any other bridge in Connecticut which may have paved-over drains, institute a program to modify the bridge drainage systems so that they provide for proper runoff of surface water and to require regular cleaning and maintenance of drainage systems. (Class II, Longer Term Action) (H-84-31)

Establish and enforce a policy of reviewing and evaluating proposed modifications of bridge drainage systems to preclude reducing the effectiveness of the systems. (Class II, Priority Action) (H-84-32)

Require the cleaning of critical elements of bridges and access routes thereto immediately before or in the course of major bridge safety inspections. (Class II, Priority Action) (H-84-33)

Improve the quality of review of bridge inspection reports, and provide for face-to-face reviews of reports on a selected sample of bridges by reviewers and inspectors. (Class II, Priority Action) (H-84-34)

Revise Bridge Inspection Form BRI 18 (Ed.1-81) to provide for the recording of information regarding:

(1) specified critical elements with individual ratings supported by a narrative explanation;
(2) observations and measurements of alignment of members; and
(3) use of specialized equipment to gain access to the bridge area being inspected or the reasons why specialized equipment was not used. (Class II, Priority Action) (H-84-35)

Prepare individual inspection and maintenance manuals for large or complex bridges within Connecticut. (Class III, Longer Term Action) (H-84-36)

After consultation with the Bridge Safety and Inspection Section, install as necessary, handholds, safety belt connections, handrails, catwalks, and safety wires on existing bridges to assist inspectors in safely moving through the superstructures and gaining access to critical elements of the bridge. (Class III, Longer Term Action) (H-84-37)

Review the bridge safety inspection manuals and bridge maintenance manuals and voluntary standards of the American Association of State Highway and Transportation Officials and incorporate those which affect bridge safety into the Connecticut Department of Transportation bridge safety inspection procedures and bridge maintenance practices. (Class II, Priority Action) (H-84-38)

Require that a representative of the Bridge Safety and Inspection Section review the plans for new bridges for safe and effective inspectability and maintainability before acceptance of the design. (Class II, Priority Action) (H-84-39)

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 actions taken as a result of its safety recommendations and would appreciate a response from you regarding action taken or contemplated with respect to the recommendations in this letter.

BURNETT, Chairman, GOLDMAN, Vice Chairman, and BURSLEY and GROSE, Members, concurred in these recommendations.

By: Jim Burnett
Chairman