

NATIONAL TRANSPORTATION SAFETY BOARD
Public Meeting of October 22, 2019
(Information subject to editing)

Pedestrian Bridge Collapse Over SW 8th Street
Miami, Florida
March 15, 2018
HWY18MH009

This is a synopsis from the NTSB's report and does not include the Board's rationale for the conclusions, probable cause, and safety recommendations. NTSB staff is currently making final revisions to the report from which the attached conclusions and safety recommendations have been extracted. The final report and pertinent safety recommendation letters will be distributed to recommendation recipients as soon as possible. The attached information is subject to further review and editing to reflect changes adopted during the Board meeting.

Executive Summary

On Thursday, March 15, 2018, about 1:46 p.m., a partially constructed pedestrian bridge crossing an eight-lane roadway in the city of Miami, in Miami-Dade County, Florida, experienced a catastrophic structural failure in the nodal connection between truss members 11 and 12 and the bridge deck. The 174-foot-long bridge span fell about 18.5 feet onto SW 8th Street, which consists of four through travel lanes and one left-turn lane in the eastbound direction, and three through travel lanes in the westbound direction. Two of the westbound lanes below the north end of the bridge were closed to traffic at the time of the collapse; however, one westbound lane and all five eastbound lanes were open.

The pedestrian bridge was under construction as part of the Florida International University (FIU) University City Prosperity Project. On the day of the collapse, a construction crew was working on retensioning the post-tensioning rods within member 11, connecting the bridge canopy and the deck at the north end. About 1:46 p.m., a video camera on a construction pickup truck traveling east, approaching the bridge, recorded the collapse sequence. The video showed the blowout of the concrete north of truss member 12, and the truss losing geometric stability. Eight vehicles that were located below the bridge were fully or partially crushed, seven of which were occupied. One bridge worker and five vehicle occupants died. Five bridge workers and five other people were injured.

The investigation of the collapse of the FIU pedestrian bridge focused on the performance of the northernmost nodal region (11/12 node) of the 174-foot-long main span. The failure of this nodal region was the triggering event for the bridge collapse. Factors in the collapse included bridge design errors, inadequate peer review of the bridge design, poor engineering judgment and response to the cracking that occurred in the region of eventual failure, and lack of redundancy in the bridge design. Specifically, the investigation focused on the following safety issue areas:

- **Bridge design and construction plan errors, and unique bridge characteristics and mechanisms of failure.** The uniqueness of designing a concrete truss bridge led to the

circumstances that accounted for the collapse of the pedestrian bridge. The bridge design team made two errors that resulted in the under-design of the nodal area (11/12) that failed, resulting in the collapse. First, the design team underestimated the demand (loads imposed on structural members) that would be acting on the nodal area. The investigation compared postcollapse calculations for the demands on the node with the design calculations. This comparison found that the demand for the node was nearly twice what the design team had calculated. The investigative report discusses how this error was made. Second, the design team also overestimated the capacity of the node to resist shear (horizontal force) where the nodal region (11/12) was connected to the bridge deck. This overestimation was the result of the designer using incorrect loads and load factors in its calculations. These two design errors resulted in a node that lacked the capacity to resist the shear force pushing the node to the end of the bridge. The NTSB recommends improving the discussion of calculating demand loads and capacity resistance in bridge design guides.

- **Independent peer review of complex bridge design.** Errors in design may occur, but systems should be in place to catch those errors when they do occur. In this case, a firm was hired to independently review the bridge design for errors. However, the review conducted by this firm did not evaluate the nodes of the bridge truss where they connected with the bridge deck and canopy nor did it consider the multiple stages the bridge construction involved. Although the design reviewer recognized that he should have examined the nodes and stages, he indicated that there was not enough budget or time to evaluate those factors. Contributing to this review failure was the reviewing firm's lack of qualification to do this work. Further, no specific guidelines call for nodes or construction stages to be included in independent bridge design reviews. The NTSB recommends changes to bridge design review procedures to ensure that bridge nodes and construction stages are included in independent design reviews.
- **Shortcomings in oversight of evaluation of and response to significant observed bridge structure distress prior to collapse.** As soon as the bridge had to support its own weight, cracks appeared at the under-designed nodes, particularly node 11/12. Over the next 19 days, the cracks grew until the bridge collapsed. The construction and inspection firms working on the bridge were aware of the cracks and reported the cracks to the design firm, asking for guidance. The engineer of record at the design firm repeatedly indicated that the cracks were of no safety concern. On the day of the collapse, the firms met to discuss a plan by the engineer of record to remediate the cracks. The bridge collapsed as the firms were implementing the remediation plan. In addition, the repair work was conducted without closing the road below the bridge to traffic. The NTSB recommends changes to Florida bridge construction oversight procedures to emphasize the need for bridge closure to protect public safety when structural cracking (beyond what sound engineering judgment considers acceptable) occurs and to increase state oversight of complex bridge construction.
- **Lack of redundancy guidelines in specifications for pedestrian and concrete truss bridges.** The design of the pedestrian bridge did not include redundancy in the bridge load path. As a result, when the 11/12 nodal region failed, the bridge collapsed. The design firm incorrectly believed that the bridge had a redundant design. For typical bridge designs, a bridge designer would use a safety factor greater than one to ensure

that the bridge was overdesigned to prevent a collapse. The NTSB, recognizing that no design guidance exists discussing redundancy in concrete truss bridges, recommends that bridge design guides include a discussion of redundancy in concrete bridge designs.

Findings

1. The emergency response by local fire departments and law enforcement personnel was timely and adequate.
2. The concrete and steel materials used during construction of the pedestrian bridge were not a factor in its collapse.
3. The hydraulic jack used to post-tension the steel rods in member 11 was operating as expected at the time of the bridge collapse.
4. (1) The FIGG Bridge Engineers (FIGG) bridge design was nonredundant because it provided only a singular load path, (2) FIGG used poor judgment when it determined the bridge was a redundant structure, and then, (3) FIGG erroneously used a redundancy factor of 1.0, which is commonly used for structures with redundant load paths.
5. Even if the cold joint surface of nodal region 11/12 had been roughened to a 0.25-inch amplitude, node 11/12 would not have had sufficient capacity to counteract the demand load for interface shear—and the bridge would still have been under-designed and could have failed.
6. The FIGG Bridge Engineers construction plans inconsistently identified when intentionally roughened surfaces were needed to fulfill the assumptions of the bridge design.
7. Because FIGG Bridge Engineers (1) did not use the lower bound load factor for determining the governing net compression, P_c , in the interface shear; and (2) incorrectly increased and amplified the effects of the clamping force across the interface shear surface, its bridge design calculations resulted in a significant overestimation of capacity.
8. FIGG Bridge Engineers (1) made significant design errors in the determination of loads, leading to a severe underestimation of the demands placed on critical portions of the pedestrian bridge; and (2) significantly overestimated the capacity of the member 1/2 and 11/12 nodal regions.
9. Based on analytical modeling results, FIGG Bridge Engineers should have considered the loadings from all critical construction stages when designing the pedestrian bridge and determining the governing interface shear demands.
10. In several instances throughout the bridge design process, the FIGG Bridge Engineers models produced reasonable estimations for interface shear demand, but these values were not always used in the design of truss members to resist force demands.
11. FIGG Bridge Engineers' analytical modeling for the bridge design resulted in a significant underestimation of demand at critical and highly loaded nodal regions.

12. The concrete distress initially observed in nodal region 11/12 is consistent with the underestimation of interface shear demand and the overestimation of identified capacity in the bridge design.
13. The FIGG Bridge Engineers design of the rebar placement in node 11/12 resulted in less reinforcing steel being available and diminished resistance to the critical interface shear demand, which contributed to the collapse of the bridge.
14. The member 11/12 nodal region contained nonstructural voids (four hollow vertical pipe sleeves and the horizontal drain pipe) within the concrete that made it less able to resist applied loads, which contributed to the destabilization of this node through overstress and the subsequent collapse of the main span.
15. Although it may be generally accepted that concrete itself is susceptible to cracking, the rate of premature concrete distress was clear evidence that the structure was progressing toward failure and should have alerted FIGG Bridge Engineers and MCM to the origin of the distress mechanism that was causing the cracking and the rapidity of cracking progression.
16. Louis Berger was not qualified by the Florida Department of Transportation to conduct an independent peer review and failed to perform an adequate review of the FIGG Bridge Engineers design plans and to recognize the significant under-design of the steel reinforcement within the 11/12 node, which was unable to resist the horizontal shear between diagonal 11 and the bridge deck.
17. FIGG Bridge Engineers' failure to adhere to the Florida Department of Transportation *Plans Preparation Manual* requirements for a complex category 2 bridge structure within its work proposal to MCM, calling for an independent firm to conduct a comprehensive peer review, led to the inadequate peer review performed by Louis Berger, which failed to detect the under-design of the bridge.
18. Had the Florida Department of Transportation *Plans Preparation Manual* called for all nodal forces of category 2 bridge structures to be checked and verified by a qualified independent peer review, this collapse might have been prevented.
19. As part of its oversight of local agency program projects and new construction, the Florida Department of Transportation should have verified Louis Berger's qualifications as an independent peer review firm for complex bridge design—concrete upon receiving the 100 percent certification letters for the bridge foundation, substructure, and superstructure plans.
20. FIGG Bridge Engineers did not perform its due diligence when it contracted with Louis Berger for the independent peer review of the highly complex and uncommon concrete bridge design.
21. The restressing of member 11 was a manipulation of loads that constituted a change to the FIGG Bridge Engineers design, and, before being implemented, should have been independently peer reviewed and signed and sealed by a professional engineer.
22. The structural cracking and northward dislocation of the upper part of the member 11/12 nodal region, as documented in the days leading up to the collapse, was strong evidence that the structure was progressing toward failure; and the detensioning of the

post-tensioning rods located in member 11 significantly increased the damage to the member 11/12 nodal region.

23. Although the FIGG Bridge Engineers engineer of record and design manager were engaged by MCM to assess the increased cracking of the structure, they neither recognized that the singular load path in this nonredundant bridge had been compromised nor took appropriate action to mitigate the risk of failure.
24. Beginning with the cracking identified on February 24, 2018, the distress in the main span structure was active, continued to grow, and was well documented by all parties involved in the design, construction, and oversight of the bridge.
25. Neither Florida International University, MCM, FIGG Bridge Engineers, nor Bolton, Perez and Associates Consulting Engineers took the responsibility for declaring that the cracks were beyond any level of acceptability and did not meet Florida Department of Transportation standards.
26. Under the terms and conditions of the contract, Bolton, Perez and Associates Consulting Engineers had the authority to direct or authorize partial or complete road closures as necessary, acting in concert with the Florida Department of Transportation and Florida International University; however, none acted to close the road under the bridge, contributing to the severity of the impact of the bridge collapse.
27. Local agency program agreements require stronger language to clarify that the certified local agency has the authority to immediately close a bridge when structural cracks are first detected or in situations that require further investigation to protect the health, safety, and welfare of the public.
28. Given the pedestrian bridge's unique, nonredundant design, the Florida Department of Transportation should have ensured that the local agencies involved in the project had adequate staff who were trained and experienced in administering these types of uncommon bridge designs.
29. The Florida Department of Transportation should have provided greater oversight of this complex local agency program project to ensure that all safety issues were identified and addressed.
30. Given the serious consequences of the error made by FIGG Bridge Engineers in assuming that the bridge had a redundant design, when it did not, and the current lack of guidance concerning redundancy design in concrete and pedestrian bridges, design specification publications for concrete and pedestrian bridges should be revised to include redundancy guidance.

Probable Cause

The National Transportation Safety Board (NTSB) determines that the probable cause of the Florida International University (FIU) pedestrian bridge collapse was the load and capacity calculation errors made by FIGG Bridge Engineers, Inc., (FIGG) in its design of the main span truss member 11/12 nodal region and connection to the bridge deck. Contributing to the collapse was the inadequate peer review performed by Louis Berger, which failed to detect the calculation errors in the bridge design. Further contributing to the collapse was the failure of the FIGG engineer of record to identify the significance of the structural cracking observed in this node

before the collapse and to obtain an independent peer review of the remedial plan to address the cracking. Contributing to the severity of the collapse outcome was the failure of MCM; FIGG; Bolton, Perez and Associates Consulting Engineers; FIU; and the Florida Department of Transportation to cease bridge work when the structure cracking reached unacceptable levels and to take appropriate action to close SW 8th Street as necessary to protect public safety.

Recommendations

New Recommendations

As a result of its investigation, the National Transportation Safety Board makes the following new safety recommendations.

To the Federal Highway Administration:

1. Assist the American Association of State Highway and Transportation Officials with developing a requirement that concrete bridge structures be designed with reasonable estimates for interface shear demand, the cohesion and friction contributions to interface shear capacity, and the clamping force across the interface shear surface.

To the Florida Department of Transportation:

2. Revise your *Plans Preparation Manual* to require that the qualified independent peer review for category 2 bridge structures include checking and verifying the design calculations used for all nodal forces.
3. Revise your *Plans Preparation Manual* to require the engineering firm or company independently peer reviewing bridge design plans to submit a prequalification letter showing that it is qualified in accordance with *Florida Administrative Code* Rule 14-75 before permitting the firm to sign and seal the 100 percent certification letters indicating that the bridge designs have been peer reviewed.
4. Revise local agency program agreements to specify that when structural cracks are initially detected during bridge construction, the engineer of record, construction engineering inspector, design-build firm, or local agency that owns or is responsible for the bridge construction must immediately close the bridge to construction personnel and close the road underneath; fully support the entire bridge weight using construction techniques that do not require placing workers on or directly under the bridge during installation; and restrict all pedestrian, vehicular, and construction traffic on the bridge until the complete support is in place and inspected.
5. To help facilitate compliance with Florida Department of Transportation standards, require your personnel to monitor and inspect all local agency

program bridge projects determined by the department to have uncommon designs.

6. Add a discussion about redundancy to the *Structures Manual, Structures Design Guidelines*, emphasizing uncommon bridge designs, as determined by the Florida Department of Transportation.

To the American Association of State Highway and Transportation Officials:

7. Work with the Federal Highway Administration to develop a requirement that concrete bridge structures be designed with reasonable estimates for interface shear demand, the cohesion and friction contributions to interface shear capacity, and the clamping force across the interface shear surface.
8. Add a discussion about redundancy in the design of concrete structures to section 5 of the *LRFD [Load and Resistance Factor Design] Bridge Design Specifications*.
9. Add a discussion about redundancy to the *LRFD [Load and Resistance Factor Design] Guide Specifications for the Design of Pedestrian Bridges*, emphasizing uncommon bridge structures.

To FIGG Bridge Engineers, Inc.:

10. Train your staff on the proper use of P_c (the permanent net compressive force normal to the shear plane) when calculating nominal interface shear resistance.
11. Institute a company policy to obtain a prequalification letter before finalizing any peer review contract with any engineering firm or company being considered to conduct peer review services.