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SAFETY

Cracks Failed To Alarm Bridge Team

The morning of the collapse, the engineer of record assured the project team that the FIU pedestrian span was safe

On the morning of last year's Florida International University bridge collapse, when the engineer of record assured project team members that there were no safety risks related to cracks propagating across part of the unusual single-truss structure, other project team members voiced mild concern, but no alarm. In hindsight, considering that the bridge had no inherent structural redundancy as it sat, incomplete, straddling a busy highway—and would suffer a sudden, catastrophic and deadly collapse just hours later—the team's lack of urgency remains puzzling, say engineering experts who reviewed an account of what was said.

Minutes of the meeting in the contractor's field office recently released by the Florida Dept. of Transportation show that attendees offered modest suggestions and questions to FIGG Bridge Engineers.

Bolton Perez & Associates, the project's construction engineering and inspection contractor, asked, "Do we need temporary shoring?," for instance. FIGG officials responded that it was not necessary. Instead, the minutes show that FIGG staff suggested that steel channels and post-tension bars would "capture some of that force, which is better than vertical support. The diagonal member is what needs to be captured." To the suggestion that another

engineer should peer review the bridge's cracks, FIGG did concur.

An official with FIU also at the meeting asked representatives of Bolton Perez their opinion of FIGG's presentation analysis. Bolton Perez said they could not comment at the moment, but would "expedite" a response in two to three days, according to the notes.

Engineers asked by ENR to review the meeting presentation and minutes don't believe that it shows exactly what errors or mistakes precipitated the sudden collapse.

Unusual Design

Designed with a single central, open truss, the pedestrian bridge featured a narrower top chord that was to serve as a canopy over the wider bottom chord, which would be the walking surface. Cables from a 109-ft-high central pylon, not yet built at the time of the collapse, would add stability, according to the design-build proposal. The concrete deck was designed with two-way post-tensioning tendons.

At the time of the collapse, contractors were apparently adjusting a tension rod in one of the diagonal struts between the chords at one end of the bridge. It is possible that the project's prime contractor, MCM, and its post-tensioning subcontractor, in attempting to fix the problems,

made an error that caused the bridge's single truss to crack and give way. Lacking redundancy, the truss failed at that end and fell to the ground, claiming six lives.

Just days before the meeting, the truss structure cast alongside the road was loaded onto permanent supports and inspections showed no distressed members. But two days before the collapse, MCM emailed FIGG about cracks. FIGG responded by instructing MCM to install temporary shims in the base of a pylon near the cracked section, between the permanent support shims.

Then, on March 15, 2018, engineers, contractors, consultants, state DOT representatives and officials with FIU, the project owner, gathered to hear why the bridge designer thought cracks were occurring. The section in question was the

ONGOING INVESTIGATION The National Transportation Safety Board identifies on this photo key elements of the bridge.



bottom chord of the concrete truss comprising the bridge, at one of the diagonal web members at the structure's north end.

Meeting notes indicate that it was known that cracks were "growing daily."

Despite that, FIGG Bridge Engineers assured the team that it saw "no safety concern" due to the cracking. FIGG's lead technical designer, Denney Pate, led the presentation, according to FIU.

Team members in attendance probably held Pate's opinion in high regard. FIGG-MCM's design-build proposal lists numerous accolades for Pate in support of its description of him as "one of the leading bridge designers in the world." ENR honored Pate as a Newsmaker in 2007.

A slide from FIGG's presentation summarized the firm's conclusion: "After about an hour of review and evaluation, FIGG had conducted sufficient supplemental/independent computations to conclude that there is not any concern with safety of

the span suspended over the road."

Responding to ENR's request for comment, the Tallahassee, Fla.-based engineering firm stated: "The most important thing is to arrive at the truth. The complex investigative analysis of the construction accident is ongoing. It is inappropriate to speculate on potential outcomes with limited available information. The NTSB process precludes us from comment on investigative information."

In November, the NTSB issued an investigative update stating that "errors were made in the design of the 174-foot span and cracking observed prior to the collapse is consistent with those errors."

The update stated: "Errors made were in the design of the northernmost nodal region of the span where two truss members were connected to the bridge deck. The design errors resulted in an overestimation of the capacity (resistance) of a critical section through the node and an

apparent underestimation of the demand (load) on that section."

The NTSB's major investigations can take 18-24 months to complete, which would mean it would be later this year or early 2020 before its findings are made public.

Failure To Protect Public Safety

In retrospect, the reviewing engineers wonder why concerns raised by Bolton Perez didn't cause alarm, and why no one on the team insisted the busy road beneath the partly complete bridge be shut down.

Richard Rice, a certified forensic engineer and president with Mutual Engineering, Hampton, Ga., said that he's been in a similar meeting discussing mysterious cracking that led to the shutdown of a parking garage at Hartsfield-Jackson Atlanta International Airport in the late 1980s. The trouble turned out to be minor surface cracking in some precast double-tees. By comparison, the cracks occurring on the FIU bridge "were astonishing" in size, Rice says.

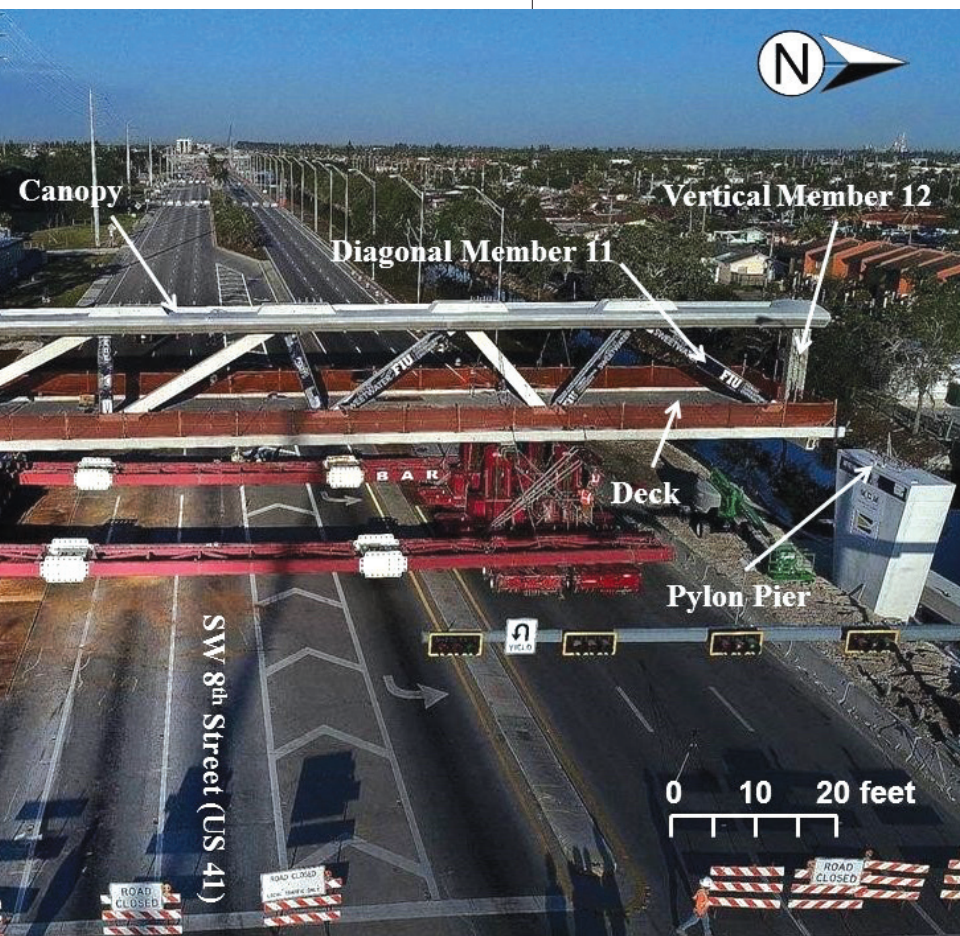
William L. Gamble, professor emeritus of civil and environmental engineering at the University of Illinois in Urbana, said that he was "dumbfounded, greatly surprised and appalled" at the documents detailing the meeting.

"I still find it hard to believe that anyone who had taken, and passed, a course on reinforced concrete design and behavior could not be greatly concerned," he added. "Cracks that one can stick the end of a tape measure into are a collapse waiting to happen."

Martin E. Gordon, a forensic engineer and professor at the Rochester Institute of Technology's College of Engineering Technology, says speculation about what happened can be misleading and any conclusions should await the publication of detailed analysis by forensic engineers.

Gordon adds, however, that he wonders why the project team didn't shut the road beneath the bridge. "It would still be important to review the details of what caused them to make that decision, but on a personal basis I don't understand why they didn't isolate that bridge." ■

By Scott Judy and Richard Korman



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INSIDE:

**THE TOP 500
DESIGN FIRMS
SOURCEBOOK
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MAKING A SPLASH IN SINGAPORE

**DEVILISH DIFFICULTIES
CONQUERED AT FIVE-LEVEL
GARDEN UNDER GLASS,
WITH MIND-BOGGLING
WATERFALL (P. 30)**

BRIDGE FAILURES

FIGG Designer Takes Stand At Trial Hearing

OSHA report on fatal collapse notes engineer's alleged errors

One day after a new federal report sharply criticized the work of FIGG Bridge Engineers on the incomplete pedestrian bridge that collapsed at Florida International University last year, the lead technical designer of the structure—one of the country's most accomplished bridge engineers—found himself on the witness stand in Miami-Dade County court. He explained under oath, in a pretrial hearing of the many lawsuits targeting the project team, that his telephone and its messages had been damaged and become unusable as evidence.

Denney Pate, who stamped the plans for the bridge, told a judge June 12 that his wife accidentally put his pants with the phone in the pocket into a washing machine, inflicting damage that destroyed any call records or images.

The phone is sought along with other electronic devices and documents in a trial of claims that consolidates 19 lawsuits against Tallahassee-based FIGG and other project team members, including FIU. Among the plaintiffs are families of five motorists and a worker who were killed, plus others who suffered injuries.

Phones and electronic messages may play a significant trial role. Pate had left a voice message with a state official March 15, two days before the collapse occurred. The message assured the of-

ficial that the unfinished bridge was safe despite significant cracks. Released by the state last year, the recording has been cited in lawsuits.

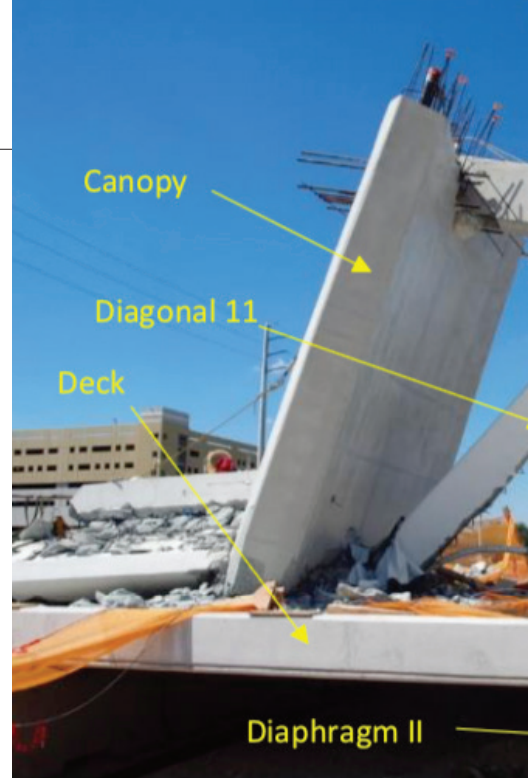
Pate has not commented since the tragedy and had not been seen in court prior to his recent testimony. After Pate was sworn in, a lawyer for another defendant asked him if he had taken photos of the cracks with his phone, since it was his first visit to assess them. "No, not to my knowledge," he replied.

Shortly after, according to a videotape of the court session, Judge Jennifer D. Bailey expressed frustration with what she had heard. "I can't tell whether any of this is remotely accurate and what may be out there that FIGG hasn't told us about," she said. Bailey had issued an order June 10

requiring witnesses to appear at a pretrial hearing. She wrote in the order that efforts to reach mediated settlements of the lawsuits must remain confidential but the lawsuits should move forward.

Bailey also wrote that she needed to know why FIGG had not yet provided phone and text messages requested for trial a year ago. She was unsatisfied with explanations FIGG had given so far about "what, if anything, may be lost or missing" from the document production phase that precedes civil lawsuit trials.

In a report on the disaster released in June, the Occupational Safety and Health Administration's Directorate of Construction spreads varying degrees of blame for the collapse on members of the project team. A Florida Dept. of Transportation engineer, although not a structural engi-



COMPONENTS OF DISASTER

How The FIU Bridge Team Came Up Short

SOURCE: OSHA REPORT ON THE PEDESTRIAN BRIDGE COLLAPSE OF MARCH 15, 2018

TEAM MEMBER	BREAKDOWN
FIGG Engineer of Record W. Denney Pate	Made design errors that opened door to collapse in construction phase 3 and failed to recognize collapse danger in wide, deep and growing cracks.
Bolton Perez and Associates Inc. Construction engineering inspector	Failed to exercise independent judgment in classifying cracks or recognizing danger of collapse
Munilla Construction Management (MCM) Design-Build Contractor	Failed to contradict FIGG's assessment that bridge was safe despite cracks
Louis Berger Group Peer review engineer	Contract with FIGG covered final structure but not temporary phases during construction



CRITICAL NODE Engineer Denney Pate stamped plans for pedestrian bridge where report claims key node at diagonal 11 was underdesigned.

neer, missed opportunities to take action when he learned of the developing crack problems after the structure was in place above traffic but not yet finished or in use.

The structure failed before an additional part of the bridge, called the back span, and another pylon would have reduced the load on a critical connection of the unusual, single concrete truss design.

Consistent with the company's branding of its "bridges as art," FIGG conceived of the design as an elegant link, a pleasant public space joining the campus and community. The truss was cast off-site, transported to its place at SW 8th Street, and swung into position and seated on its piers using the Accelerated Bridge Construction method. Some post-tensioning was required during the movement phase.

OSHA found key errors in the design that opened the door to failure prior to completion. The report alleges that FIGG underdesigned a key diagonal member of the truss's web, 11, and its connection to other structural components. OSHA criticized FIGG's use of a non-redundant design and claimed the company failed to assess the risk from widening cracks just prior to collapse.

FIGG "failed to recognize that the bridge was in danger of collapsing when it

inspected it hours before the collapse," wrote OSHA Office of Engineering Director Mohammad Ayub, the author of the report. On the morning of the collapse, the team convened a meeting to discuss the cracks. Despite knowledge that the cracks were growing in size, and were wide and deep, the [engineer of record] "stated more than once that the cracks did not present any safety concerns."

"The [engineer of record] should have immediately instructed that the bridge be shored at appropriate locations and SW 8th Street be closed," wrote Ayub.

Instead, two days before the collapse, FIGG recommended placement of a shim under the bridge diaphragm and retensioning of post-tensioning bars in diagonal 11. During the retensioning, the concrete blew out at the junction of diagonal 11 and 12, and the structure thereafter failed progressively. An employee of VSL, MCM's post-tensioning subcontractor, Navarro Brown, suffered fatal injuries as hundreds of tons of concrete and steel fell onto the road.

FIGG: Report Is Inaccurate

In a statement, FIGG disputed OSHA's findings, calling the report "factually inaccurate and incomplete" with "errors and flawed analyses."

FIGG hinted that construction-related activities, rather than design, could be chiefly to blame. According to the statement, FIGG claimed the report "does not include an evaluation of many important factors pertinent to the construction process leading up to the accident. Additionally, it has not been reviewed by any other entities involved in the accident investigation."

While a separate National Transportation Safety Board investigation continues, FIGG stated that "we are not able to elaborate further, but at the appropriate time the facts and the truth will be released to the public."

During the days leading up to the tragedy, different team members expressed different levels of concern, project records show. In its report, OSHA blamed Bolton Perez Associates, the

project's construction and engineering inspection contractor, for failing to exercise independent judgment in classifying cracks or recognizing danger of collapse. Munilla Construction Management (MCM), the design-build contractor that had teamed with FIGG and which earlier this year filed for bankruptcy protection, failed to contradict FIGG's assessment that the bridge was safe despite cracks. MCM "deferred to the decision of the [engineer of record] and failed to exercise its own independent professional judgment, as a constructor of the bridge, to close the traffic on SW 8th Street until the cause of the cracks were conclusively determined" and peer-reviewed, the report states. OSHA called the contractor's failure to take those steps "unreasonable." MCM did not respond to ENR's request for comment.

The report doesn't solve all mysteries about what occurred.

While OSHA investigators seemed most puzzled by what they saw as FIGG's inaction and complacency about the chance of collapse, OSHA was perplexed about the role played by Louis Berger Group, listed as the project's engineering peer review contractor. Berger did not analyze temporary conditions of the structure in the different phases of construction, OSHA wrote. "The forces in the truss members ... would be significantly different when the truss is continuous compared to the truss as simply supported on the south pier and north pylon."

According to the report, Berger explained to OSHA investigators that FIGG contracted the firm only to do the final check and not the design check at intermediate stages. "If Louis Berger had checked the design at Stage 3, it could have discovered structural deficiencies in the design, and this incident could have been prevented," the OSHA report speculated. OSHA investigators claimed that the company did not respond to repeated requests to provide Berger's peer review computations and emails with FIGG for OSHA investigators to examine. ■

By Richard Korman and Scott Judy

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RISK REPORT

THE HOTTER ZONE

**DO TESTS FOR
COMBUSTIBLE
EXTERIOR WALLS
MATCH REAL-LIFE
FIRE INTENSITY?
(P.22)**

INVESTIGATIONS

NTSB: Errors By FIGG Led To Collapse

An inadequate peer review and the project team's failure to protect public safety also contributed to the tragedy

Multiple design errors by FIGG Bridge Engineers and its engineer-of-record were the primary probable cause of last year's Florida International University pedestrian bridge collapse, the National Transportation Safety Board announced Oct. 22.

In a more than three-hour presentation of its findings, the three-member board pointed to FIGG's "load and capacity calculation errors" and its "design of the main span truss Member 11-12 nodal region and connection to the bridge deck" as key explanations of the collapse.

Several other factors contributed to the March 15, 2018, tragedy at FIU, which killed one worker and five motorists when the under-construction structure suffered a catastrophic collapse. Here, too, the safety board singled out the bridge designer, stating that "the failure of FIGG's 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" contributed to the tragedy.

But numerous other project team members were responsible for contributing to the collapse, the NTSB found.

Among those was Louis Berger

Group, which NTSB cited for the contributing factor of an "inadequate peer review" that "failed to detect the calculation errors in the bridge design."

FIGG hired Berger, now a division of WSP, to perform the project's peer review. However, Berger did not perform a comprehensive peer review that should have been required. NTSB investigators expressed the opinion that it was "incumbent" upon Berger to have performed a full and complete review of FIGG's design.

NTSB CHAIRMAN SUMWALT SAID "OVERSIGHT OF THE PROJECT, LIKE THE BRIDGE ITSELF, COLLAPSED."

Still, despite the incomplete review of a flawed design, the tragedy could have been avoided had any of numerous members of the project team with implied authority to shut down the project taken action to do so, the NTSB found.

"Contributing to the severity of the



collapse outcome was the failure of MCM, FIGG, Bolton, Perez & Associates Consulting Engineers, FIU and the Florida Dept. of Transportation to cease bridge work when the structure cracking reached unacceptable levels and to take appropriate action to close Southwest 8th Street as necessary to protect public safety," the NTSB stated in its findings of probable cause.

In his concluding remarks, NTSB Chairman Robert Sumwalt offered a harsh assessment of FIGG and the entire project team.

"FIGG Bridge Engineers severely underestimated the demand on the bridge and significantly overestimated the bridge's capacity," Sumwalt said. "And they incorrectly determined the bridge to be ... a redundant structure among other calculations.

"But another structure failed in this accident—the structure of the public safety oversight," he continued. "This structure should have ensured that a qualified, independent firm provide effective peer review of the bridge plans as required. Louis Berger was not qualified and produced an incomplete report."

Additionally, Sumwalt concluded: "When cracks in the bridge reached unacceptable levels, the oversight structure



TRAGIC RESULT The March 15, 2018, collapse killed six people, including one project worker and five motorists.

should have resulted in suspension of work and in road closures. And it did not.”

As a result, he added, “Oversight of the project, like the bridge itself, collapsed.”

Speaking to reporters after the NTSB’s presentation of findings, FIU President Mark Rosenberg offered condolences to those who lost family members or were injured.

Asked why FIU didn’t act on the warning signs, Rosenberg said, “FIU was continually and repeatedly told that cracks were not ... serious.” He added, “What

you heard today was that they indeed were very serious.” Asked whether FIU neglected its responsibility, Rosenberg said, “Not at all. We followed state of Florida regulations all the way.”

FDOT was criticized for multiple shortcomings by the NTSB report. FDOT Secretary Kevin Thibault said in a statement: “The department has and will continue to cooperate fully with the NTSB as part of this process and has already implemented many of the improvements discussed today. I remain committed to ensuring that all NTSB recommendations are followed so a tragedy like this never happens again in Florida.”

Contractor MCM issued a statement that read, “The MCM family is heartbroken for those who were affected by the failure of the FIU pedestrian bridge. We will continue to work closely with all parties to resolve ongoing legal and financial issues in an expeditious manner.”

Louis Berger Group responded, in part, by stating that its role “was limited by contract to a peer review specified by the designer of the project, FIGG Bridge Engineers,” adding that its review was led by a “highly-qualified engineer.”

Refuting the Findings

Hit with the NTSB’s harshest criticism, FIGG Bridge Engineers responded by disputing the findings of the Federal Highway Administration (FHWA), which provided the NTSB with re-

search and technical analyses.

“At the NTSB meeting today, it was evident that the investigation into the FIU pedestrian bridge construction accident presented challenges for the agency to accurately understand all of the technical and factual components,” FIGG stated. “The accident was the result of a complex series of events and failings by parties at multiple stages of the project.”

The Tallahassee-based bridge designer instead argued that the analysis conducted by Wiss, Janney, Elstner Associates, on behalf of FIGG, “proved that if the construction joint at Member 11 had been built as required by Florida Dept. of Transportation Standard Construction Specifications, the construction accident would not have occurred.”

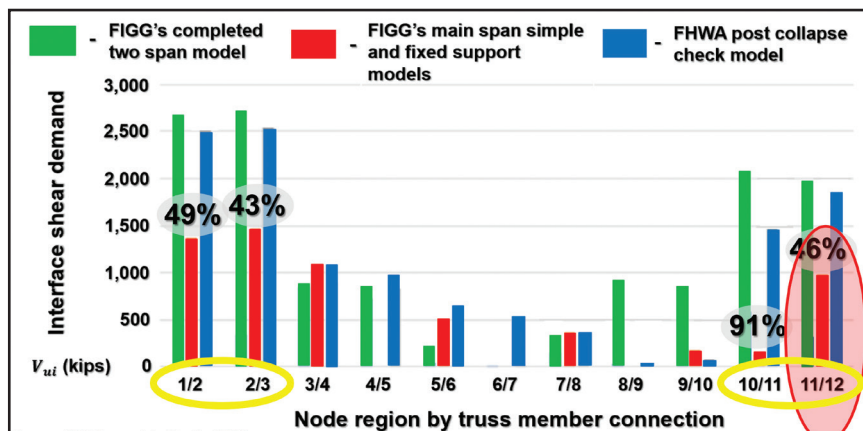
However, a “Bridge Design Errors” report presented at the NTSB meeting by investigator Dan Walsh, a certified engineer, stated that a “severe underestimation of demand and significant overestimation of capacity” in the bridge’s 11-12 nodal region led to the collapse.

In estimating the structure’s capacity, for instance, NTSB reported that FIGG’s use of a “non-conservative” load factor of 1.25, instead of a conservative factor of 0.90, resulted in “significant overestimation of capacity at the 11-12 nodal region with insufficient reinforcing across the interface shear surface.”

That report further summarized that FIGG “made significant errors in determination of loads; chose the wrong interface shear demand value, [which] led to a severe underestimation of demand; [and] chose the wrong load factor in calculating the permanent compression loading, [which] led to a significant overestimation of capacity.”

Walsh noted in the report that FIGG performed four demand models. Just one of those models estimated demand consistent with FHWA’s findings, however. Critically, FIGG used the other models, which estimated demand to be between 43% and 91% lower than FHWA’s estimates had calculated. ■

By Scott Judy, with Tom Ichniowski in Washington, D.C.



FAULTY DEMAND ESTIMATES? An NTSB report on bridge design errors noted that the demand model FIGG used underestimated the demand that the structure would experience.

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INSIDE:
2020
FORECAST
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UNDER PRESSURE

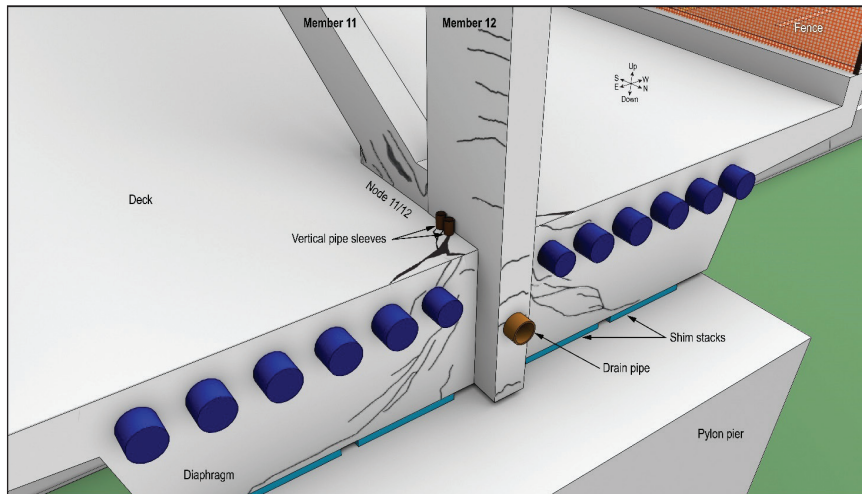
**FIXED-PRICE RISKS
WEIGH ON JOB
COMPLETIONS AND
BOTTOM LINES
(P. 28)**



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CONSTRUCTION ACCIDENTS

Final NTSB Collapse Report Details Bridge Team Failures



CRACKS BEFORE COLLAPSE This image from the NTSB's final report shows a south and east view of the extent of cracking at member 11/12 nodal region, deck and diaphragm, indicating structural distress.

The final report on the Miami bridge collapse, released Nov. 12, adds new details on the project team's numerous failures leading up to the tragedy, especially those committed by FIGG Bridge Engineers and Louis Berger Group. Both FIGG and Berger, now part of WSP, declined further comment.

The National Transportation Safety Board's probable cause statement remains unchanged from the agency's Oct. 22 announcement. The board cited "load and capacity calculation errors" by FIGG in its design of the unusual concrete truss structure's main span member 11/12 nodal region and connection to the bridge deck. The board also cited an "inadequate peer review performed by Louis Berger" and "the failure of the FIGG engineer of record to identify the significance of the structural cracking observed in this node before the collapse."

Without naming him, the agency details the actions of engineer-of-record Denney Pate—who is frequently referred to as "the FIGG EOR"—and others with FIGG who repeatedly emphasized to contractor MCM and other project team

members that the cracking occurring across the unfinished structure posed no safety hazard.

On March 13, 2018, for instance, just two days before the March 15 collapse, a FIGG design manager twice told MCM that the cracking did not constitute a hazard. On the morning of the collapse, Pate led a presentation to project team members in which he noted that "there is no safety concern relative to the observed cracks and minor spalls."

The partial peer review performed by Louis Berger Group failed to catch the alleged design errors.

The NTSB found that though Berger performed a limited peer review of the bridge's design, FIGG never authorized anything less than a full review.

Instead, "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," the report states.

In a post-collapse interview, Berger's peer-review engineer told NTSB: "In the beginning, I suggested to do this kind of

analysis, to analyze the connections. I'm talking about the nodes, or the joints to analyze the connections. However, the budget and time to do this actually was not agreed upon with the designer."

In a statement, Bruce Landsberg, an NTSB vice chairman, criticized Berger for the limited review, stating: "It was in violation of FDOT's requirement that there be an independent second set of eyes to review everything—not just what was economically convenient."

On March 13, the NTSB reports that FIGG officials recommended a plan to MCM for "restressing the temporary PT rods in member 11 to return it to its previous state when the cracks were known by MCM to have been smaller."

FIGG's plan to fix the cracking was never subjected to independent peer review, as it should have been, the NTSB found. The fix was not originally included as part of the engineer's plans.

According to NTSB: "Post-collapse, the FIGG EOR stated that the retensioning of this truss member would bring the main span back to its 'pre-existing condition'—of a previous stage. According to FIGG, this decision was based on judgment that returning the main span to its preexisting condition was not a change to the FIGG design and was the right thing to do."

To this, the NTSB report replies: "The retensioning of member 11 on March 15 was the final stressing force that resulted in the failure of the member 11/12 nodal region."

The structure's sudden collapse on March 15 killed six people.

In his statement, vice chairman Landsberg criticized all members of the project team, commenting: "Every organization absolved themselves of responsibility by rationalizing that if the EOR says it's OK, it must be OK, and if anything bad happens—it's on him."

"That is not the intent of peer review or safety oversight, and certainly fails the system of checks and balances in place to prevent catastrophes like these." ■

By Scott Judy