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Forensic Structural Engineering and Structural Failure

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Restore | Repurpose | Renew

THE FIRST STEPS AFTER A STRUCTURAL FAILURE

- Safety and Structural Stability Assessment
- Preserve Destructible and Perishable Evidence
- Reserving Samples
- Documentation of Conditions
- Interviews
- Cooperation with Other Forensic Engineers
- Initial Document Gathering
- Preliminary Evaluation

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SAFETY AND STRUCTURAL STABILITY ASSESSMENT

- Identifying the safest routes through the debris
- Identifying the areas to be avoided until stabilized
- Identifying the components that potentially are in danger of further collapse
- Evaluate methods of stabilizing the structure
- Evaluate any required protection for public or restrict public access
- Evaluate alternative demolition or dismantling sequences

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PRESERVE DESTRUCTIBLE AND PERISHABLE EVIDENCE

After a collapse, any condition and circumstances of the site could be a potential evidence. There are durable evidences that may remain unchanged for a period of a time and there are perishable evidences that needs to be documented immediately after collapse. An example of a perishable evidence is the weight of the snow accumulation on the roof which is extremely important as it indicated whether the failure was due to the design or construction error or any unforeseen overload.

RESERVING SAMPLES

In large size structural failures, its not practical to reserve entire structure and therefore the forensic engineer needs to take sample of both failed and non-failed elements and components of the structure.

Documentation of Conditions

The documentation of the failure could be in form of field note, photographs, video, etc.

Interviews

- The interviews with witnesses and other persons on site could provide the valuable information for the forensic engineer. The interviews should be performed as soon as possible after collapse as they help to identify and locate the witnesses, receive fresh information and assist in formulating the scenarios for investigation.

COOPERATION WITH OTHER FORENSIC ENGINEERS

- There are common interests in initial stages of an investigation among all parties. Pooling resources could avoid duplication of efforts and establishing common knowledge base.
- Identifying certain components that multiple parties would like to perform destructive testing.
- Establishing a common identification system at early stage could avoid and minimize later debates and misidentification.

INITIAL DOCUMENT GATHERING

- Design Drawings
- Specifications
- Boring Logs
- Calculations of the engineers
- Erection and Shop Drawings
- Submittal Logs
- Inspection Reports
- Daily Reports
- Test Reports
- Correspondence

Preliminary Evaluation

- After initial information was collected during the above steps, the forensic engineers may be able to provide a preliminary evaluation and could develop the failure scenarios, testing program and perform the preliminary structural analysis. The engineers may identify the missing documents, additional required expertise and more persons for interview after the first steps.

Legal Process after a Failure

- Assembling the Investigative and Legal Response Team
- Developing an Action Plan
- Establishing a Plan to Protect Confidentiality
- Cooperating and Dealing with Public Agencies
- Dealing with the Media
- Special Considerations of Interested Parties
- Understanding the Legal Framework of the Failure
- Closure

Engineering Investigation of Structural Failures

a. Project Initiation
b. Assembling the investigation Team
c. Investigative Process
d. Document Review
e. Field Investigation
f. Laboratory Analysis
g. Structural Analysis
h. Determining the Cause of Failure and Preparing the reports

PROJECT INITIATION

a. Project Objective And Scope
b. Conflicts of Interest
c. Agreements
d. Establishing The Investigative Plan

ASSEMBLING THE INVESTIGATION TEAM

- Qualifications of the investigator
- Available Guides
- Team Organization
- Cooperative Efforts with Other Investigators

INVESTIGATIVE PROCESS

- Analysis Vs Synthesis
- Development and Analysis of Failure Hypotheses
- Team Organization
- Establishing the loads on the structure
- Establishing the capacity of the structure
- Advancement of Failure Hypotheses

Document Review

- Contract Drawings
- Contract Specifications
- Contracts
- Contract Revisions
- Shop Drawings and Other Submissions
- As-built Drawings
- Material Strength Reports or Certification
- Project Correspondence
- Consultant Reports
- Engineering Calculations
- Maintenance and Modification Records

Field Investigation

- Site Safety
- Samples
- Field Observations and Documentation
- Field Tests
- Eyewitness Accounts

Laboratory Analysis

- Material Testing
- Component Testing

Structural Analysis

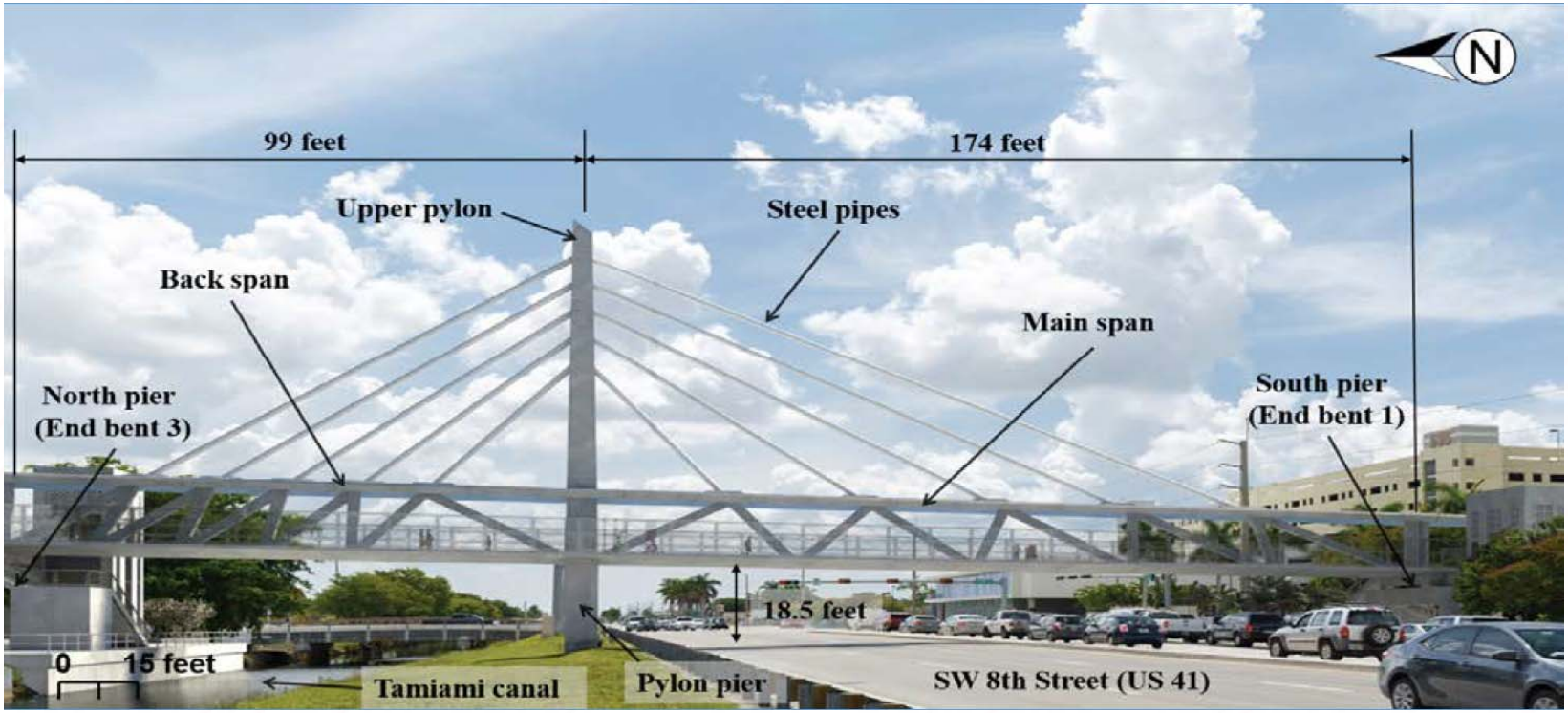
- Methods
- Precision and Sensitivity Analysis

Determining the Cause of Failure and Preparing the Reports

- Analysis of Competing Failure Theories
- Closing The Loop
- Reports

Pedestrian Bridge Collapse

Miami, Florida
March 15, 2018



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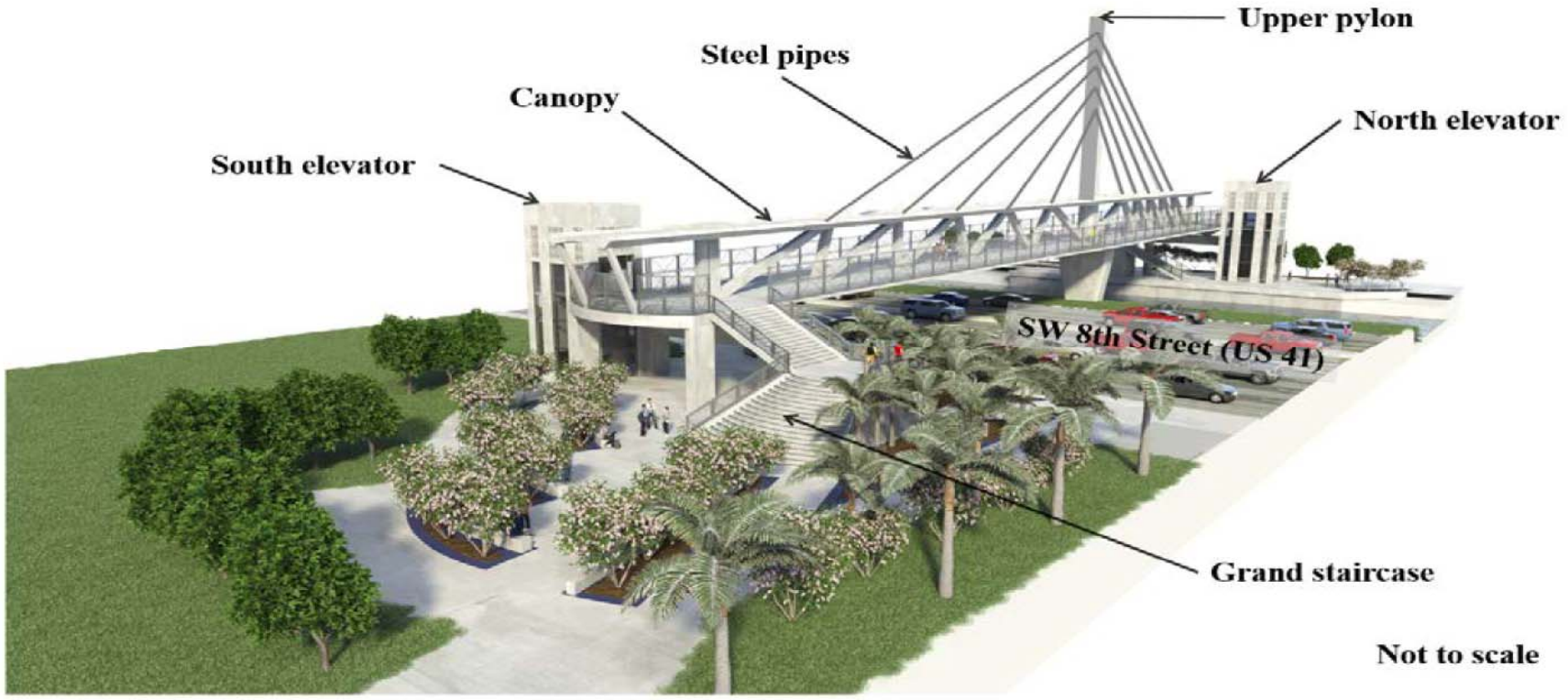
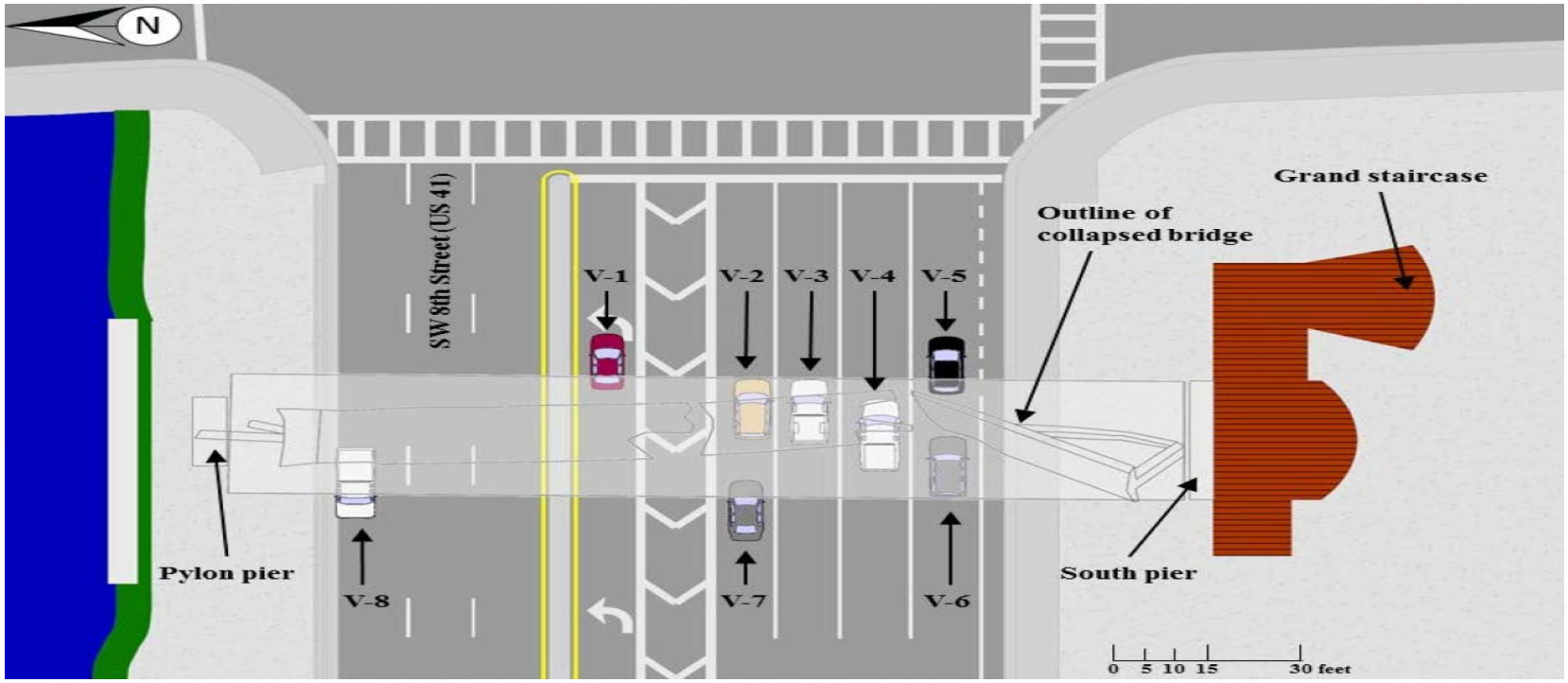
Design Rendering Of Completed Pedestrian Bridge



Pre collapse and Post collapse

Scene Diagram Of Vehicles Under Or Proximate To Bridge At Time Of Collapse



Injuries Among Bridge Construction Workers And Vehicle Occupants

Injury Severity[a]	Fatal	Serious	Minor	None	TOTAL
Bridge construction workers	1	4	1	0	6
Vehicle occupants	5	2	3	0	10
TOTAL	6	6	4	0	16

[a] Although 49 *Code of Federal Regulations* (CFR) Part 830 pertains only to the reporting of aircraft accidents and incidents to the NTSB, section 830.2 defines fatal injury as any injury that results in death within 30 days of the accident, and serious injury as any injury that: (1) requires hospitalization for more than 48 hours, commencing within 7 days from the date of injury; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, or tendon damage; (4) involves any internal organ; or (5) involves second- or third-degree burns, or any burn affecting more than 5 percent of the body surface.

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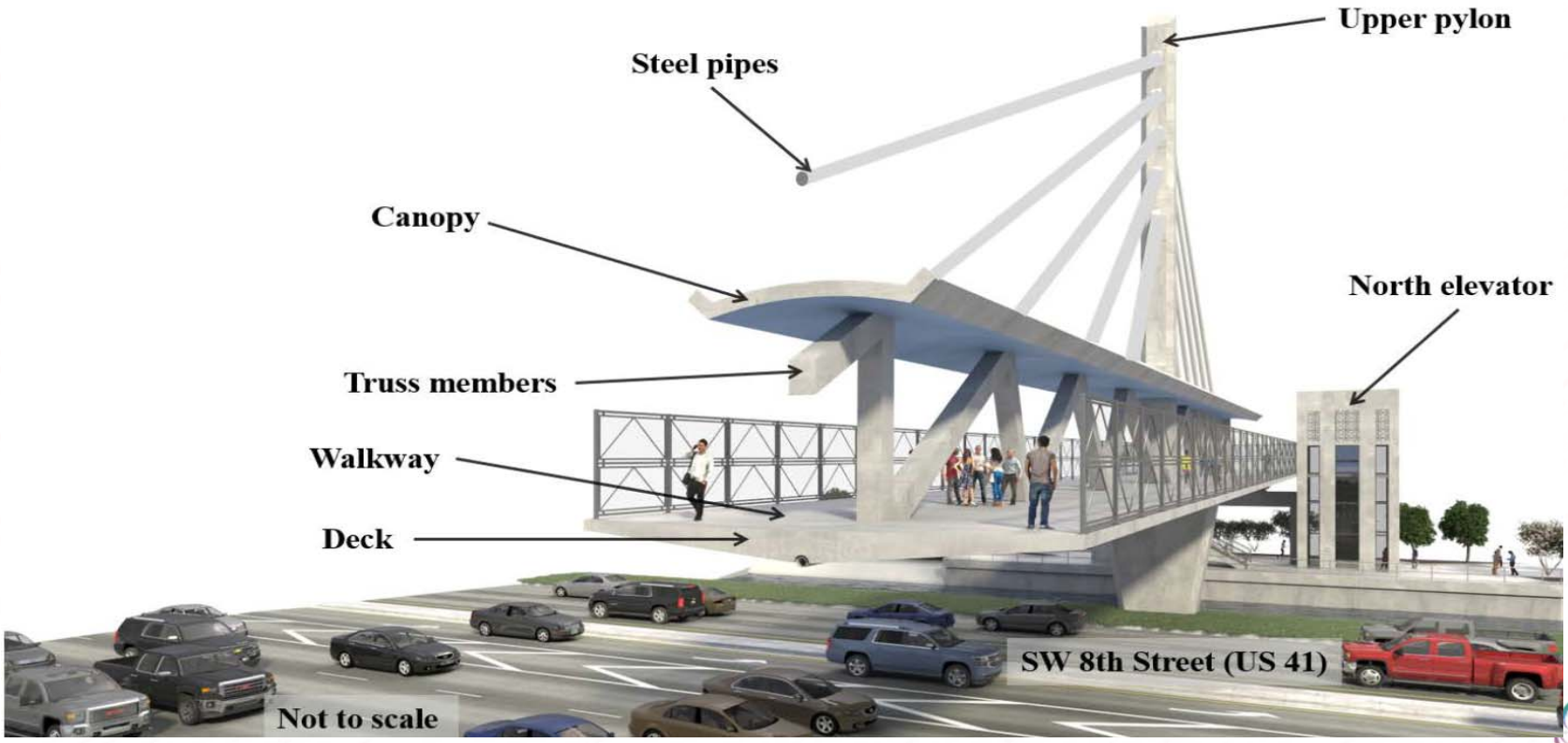
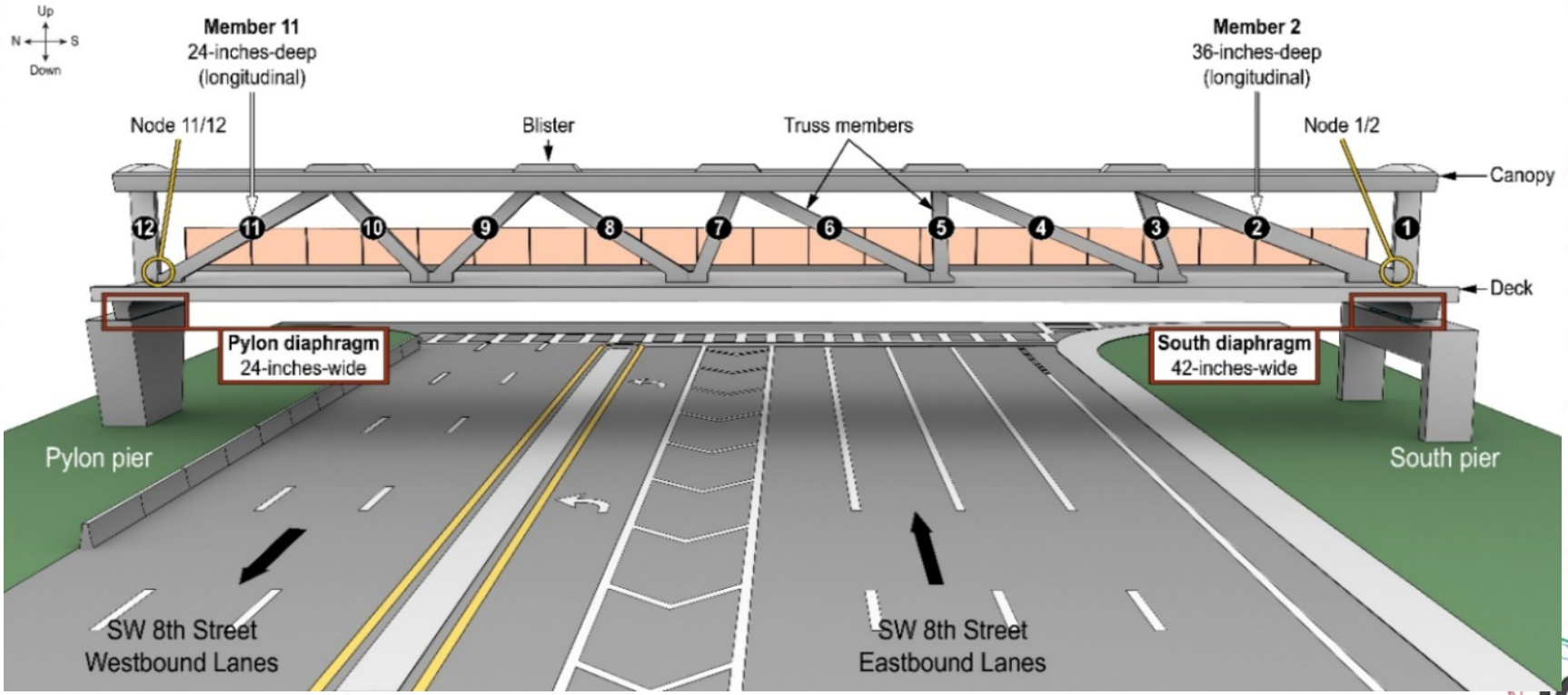
Cross-section Rendering Of Pedestrian Bridge



Nomenclature Of Bridge Components And Numbering Of Diagonal And Vertical Truss Members

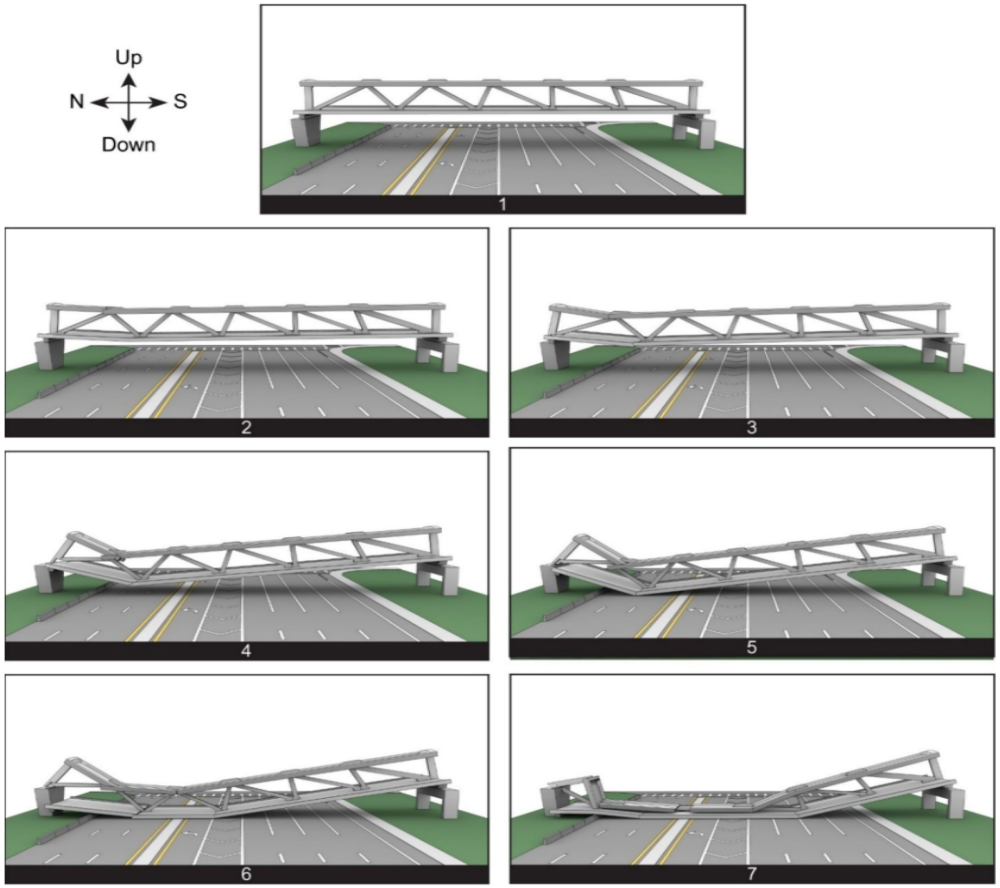


Still image (time stamp 13:46:43:881) from in-vehicle mounted video camera on pickup truck traveling east on SW 8th Street, showing concrete dust and debris blowout at north end (pylon pier), March 15, about 1:46 p.m.

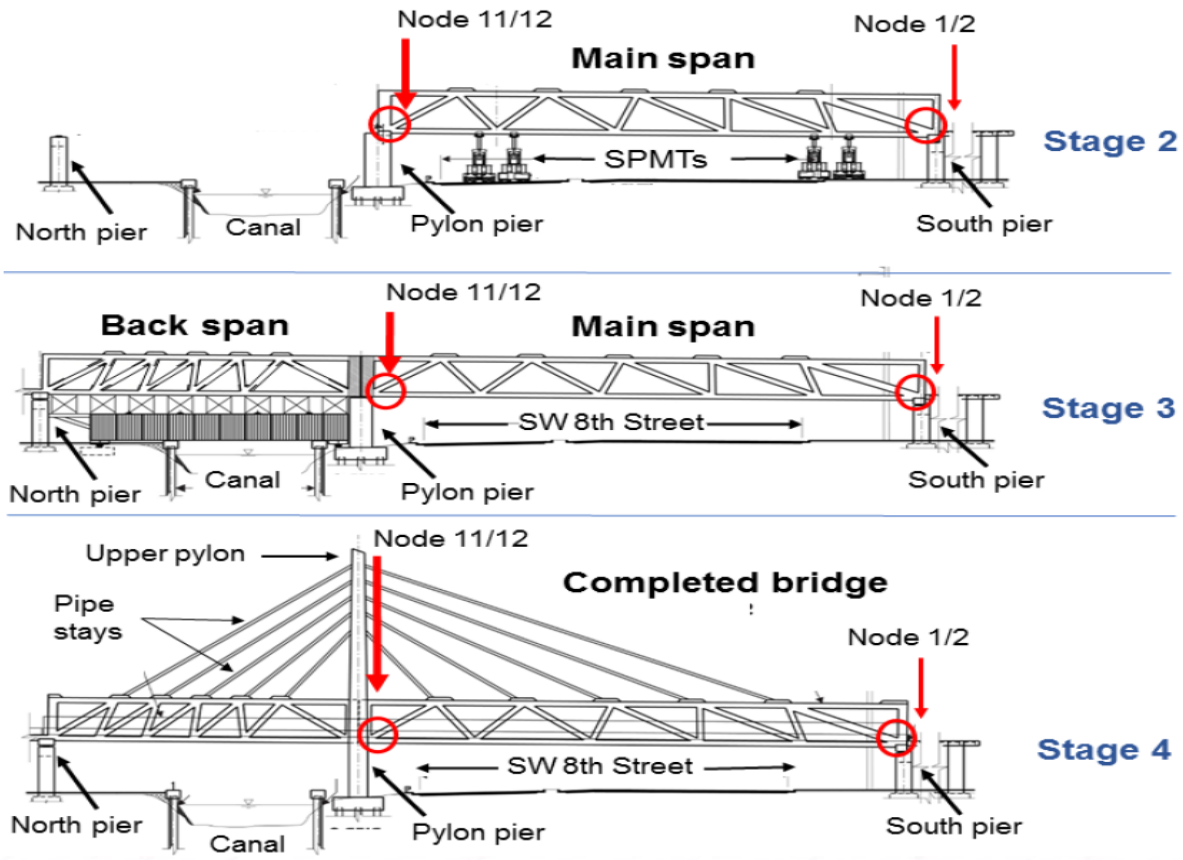
Still image (time stamp 13:46:44:046) from in-vehicle mounted video camera on pickup truck traveling east on SW 8th Street, showing full-width canopy fracture and deck fracture areas at north end (pylon pier), March 15, about 1:46 p.m.

Still image (time stamp 13:46:44:310) from in-vehicle mounted video camera on pickup truck traveling east on SW 8th Street, showing main span completely collapsed, March 15, about 1:46 p.m.

Collapse Sequence Diagram

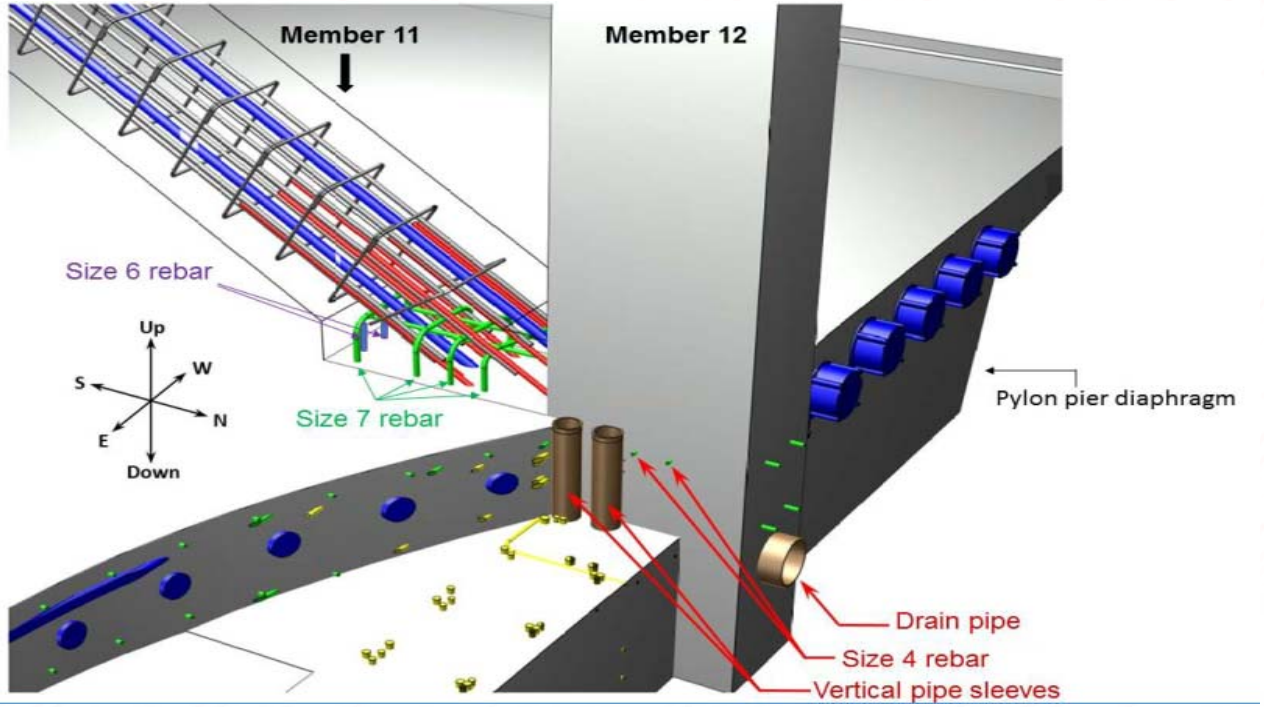


Construction Stages

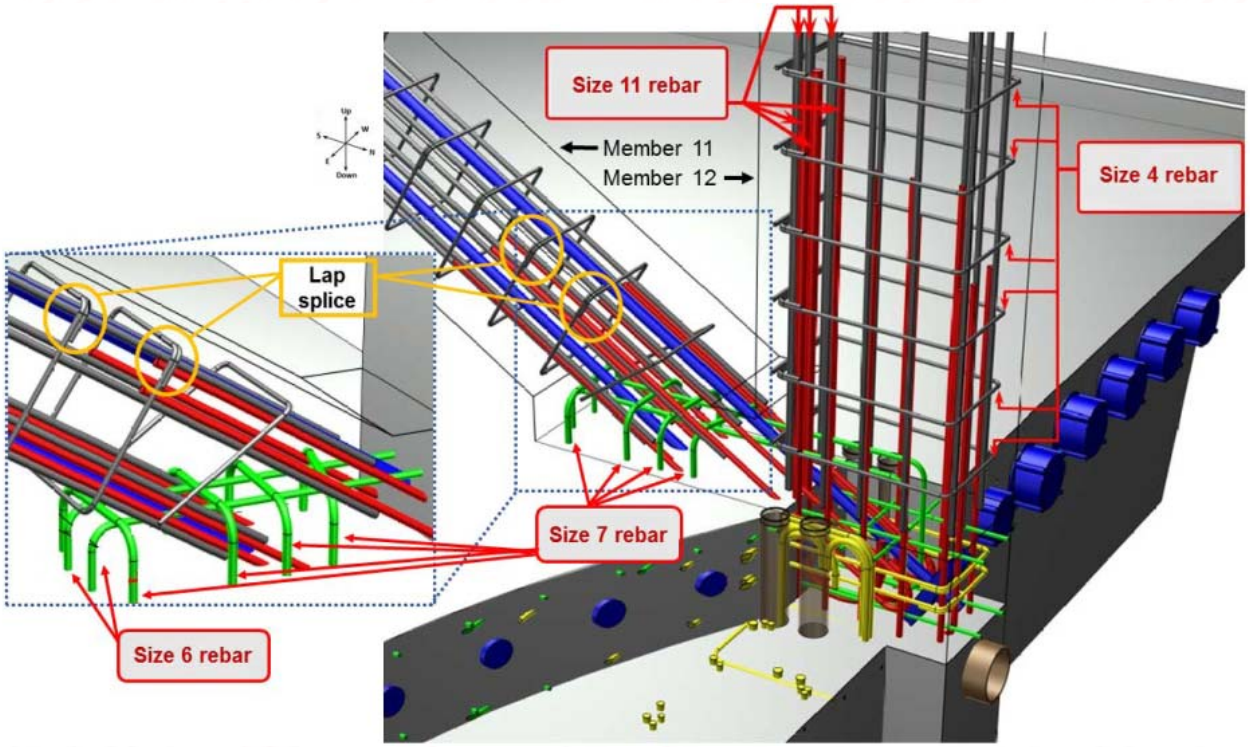


Temporary falsework supporting the bridge span in the casting yard on February 24, 2018, being sequentially removed from the middle of the span toward the ends of the span

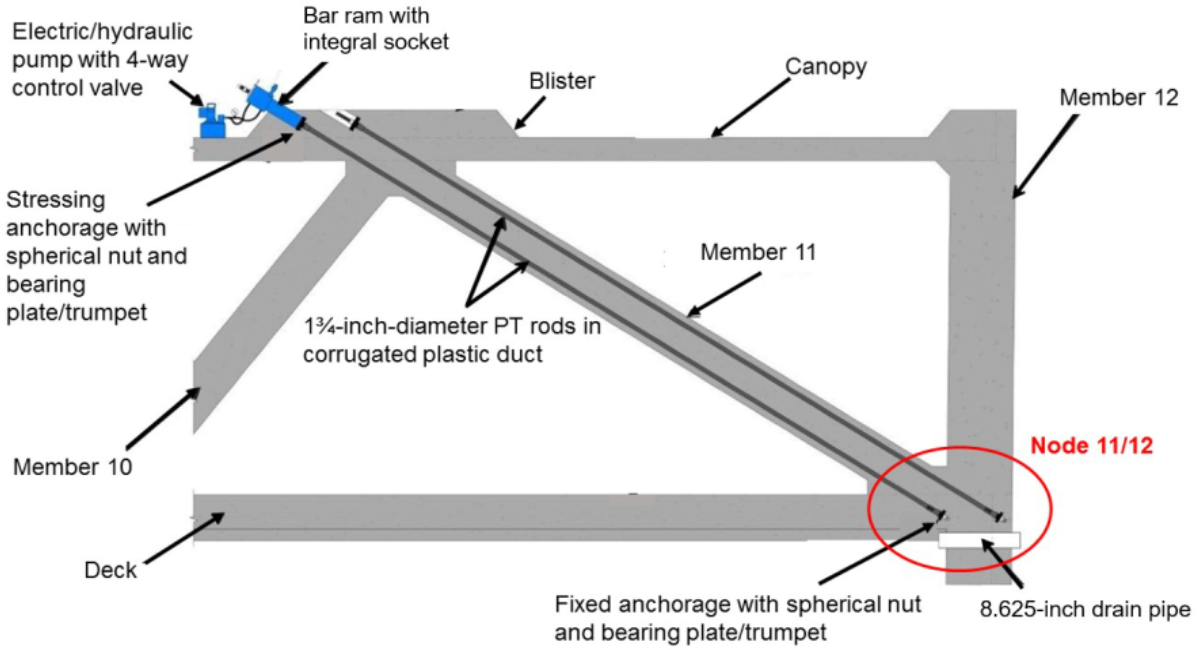
Main span, north end, showing steel rebars in member 11, vertical pipe sleeves, end of drain pipe location, and size 4 rebar at member 12



Main span, north end, showing rebar detailing in member 11, member 12, and node 11/12. Inset shows another view of rebar in node 11/12 and detail of lap splice from member 11



Main span, north end, showing post-tensioning specialized equipment in relation to location of PT rods in member 11

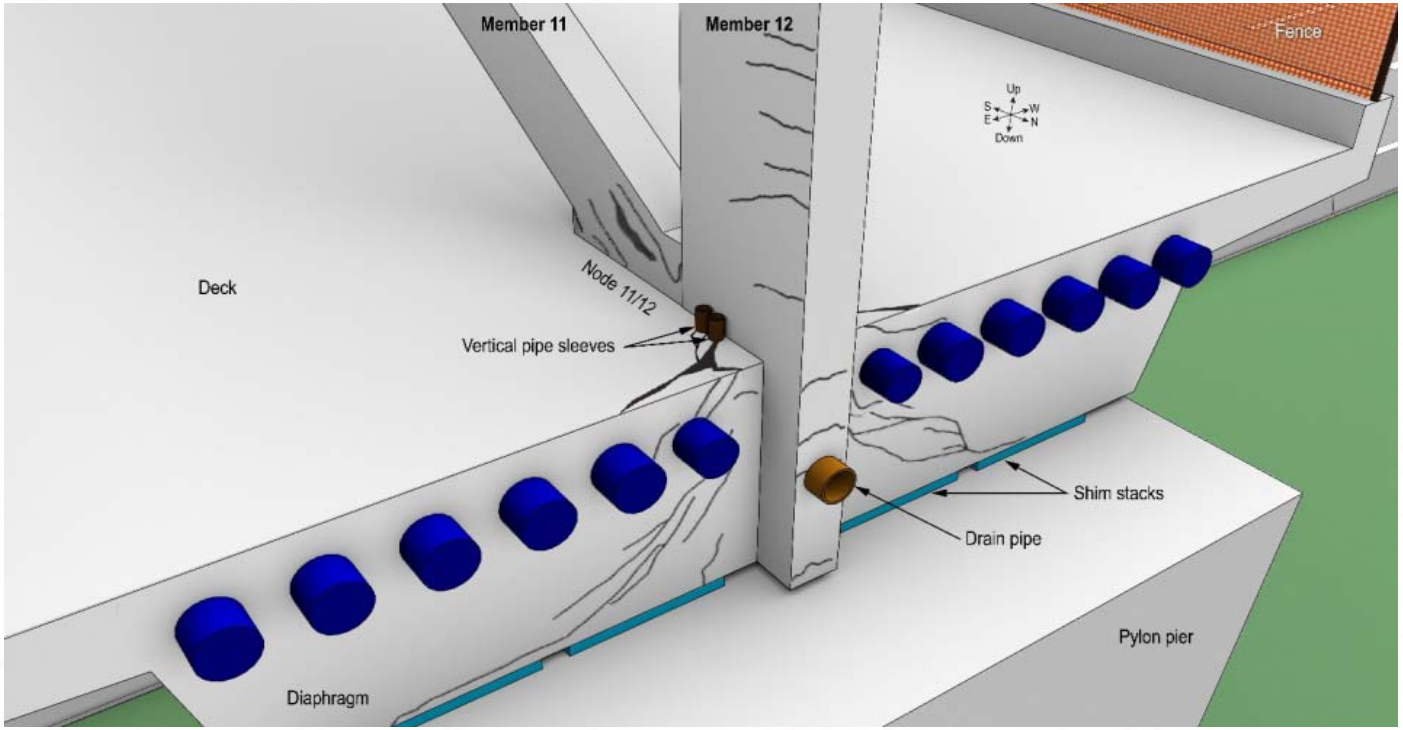


Cracks of 3–4 inch depth at northern end of precast main span, along west side of diaphragm 2 (north view), March 13, 11:17 am

Cracks at bottom of diagonal member 11 (west view), March 15

Cracks at bottom of diagonal member 11 (east view), March 15

South and east view of extent of cracking at member 11/12 nodal region, deck, and diaphragm, indicating structural distress.



Probable Causes

- Load and capacity calculation errors in design of the main span truss member 11/12 nodal region and connection to the bridge deck
- Inadequate peer review
- Failure 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
- Fail 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

References:

1. Robert T. Ratay, “Forensic Structural Engineering Handbook”, January 2000.
2. National Transportation Safety Board, Highway Accident Report, NTSB/HAR-19/02, PB2019-101363 “Pedestrian Bridge Collapse Over SW 8th Street, Miami, Florida- March 15, 2018”.

Questions?

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