FIU PEDESTRIAN BRIDGE COLLAPSE

AASHTO Committee on Construction VIRTUAL ANNUAL MEETING

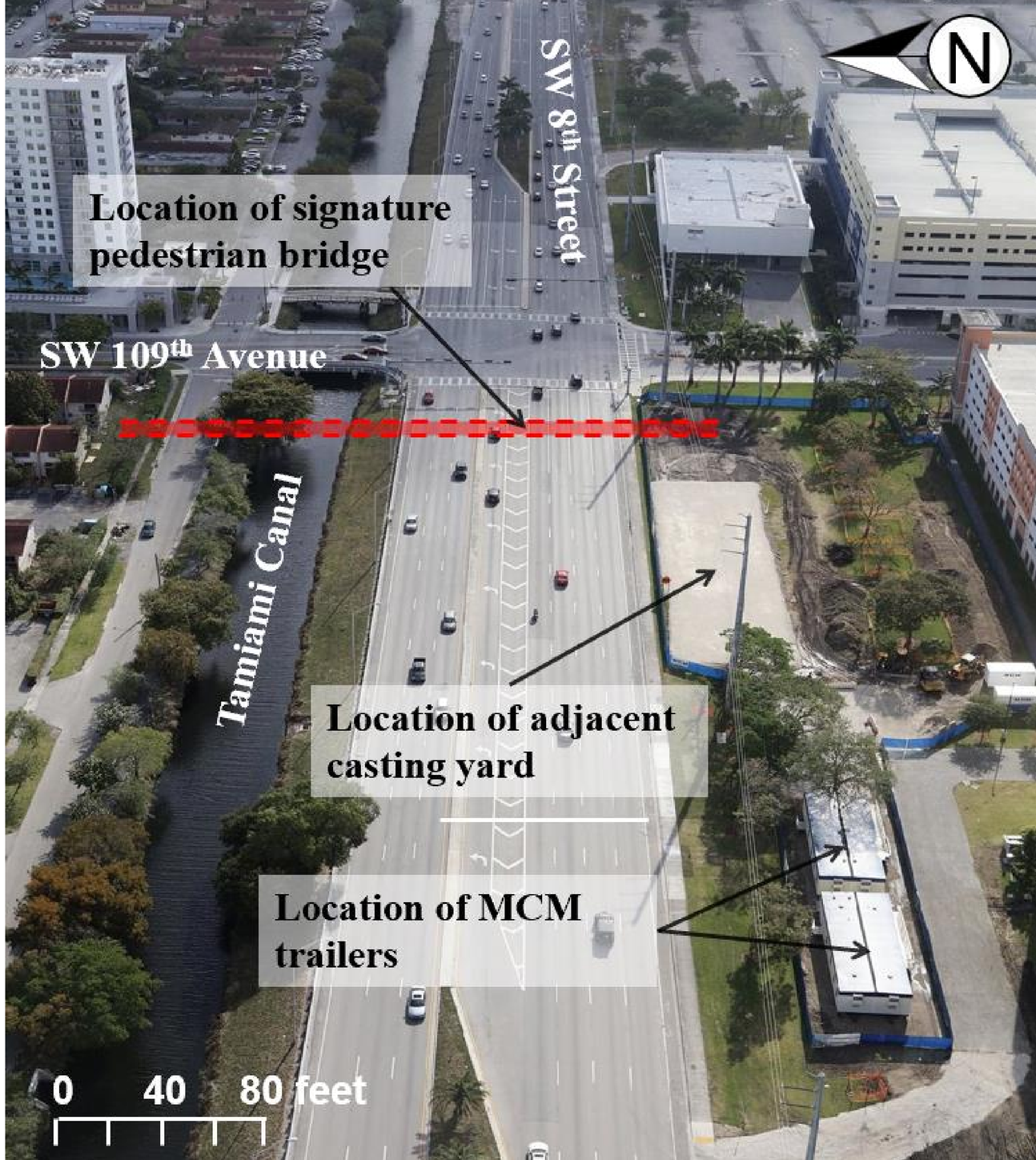
Gary J. Klein, P.E., S.E. – Wiss, Janney, Elstner Associates, Inc.

Alan R. Phipps, P.E., S.E. – FIGG Bridge Engineers, Inc.

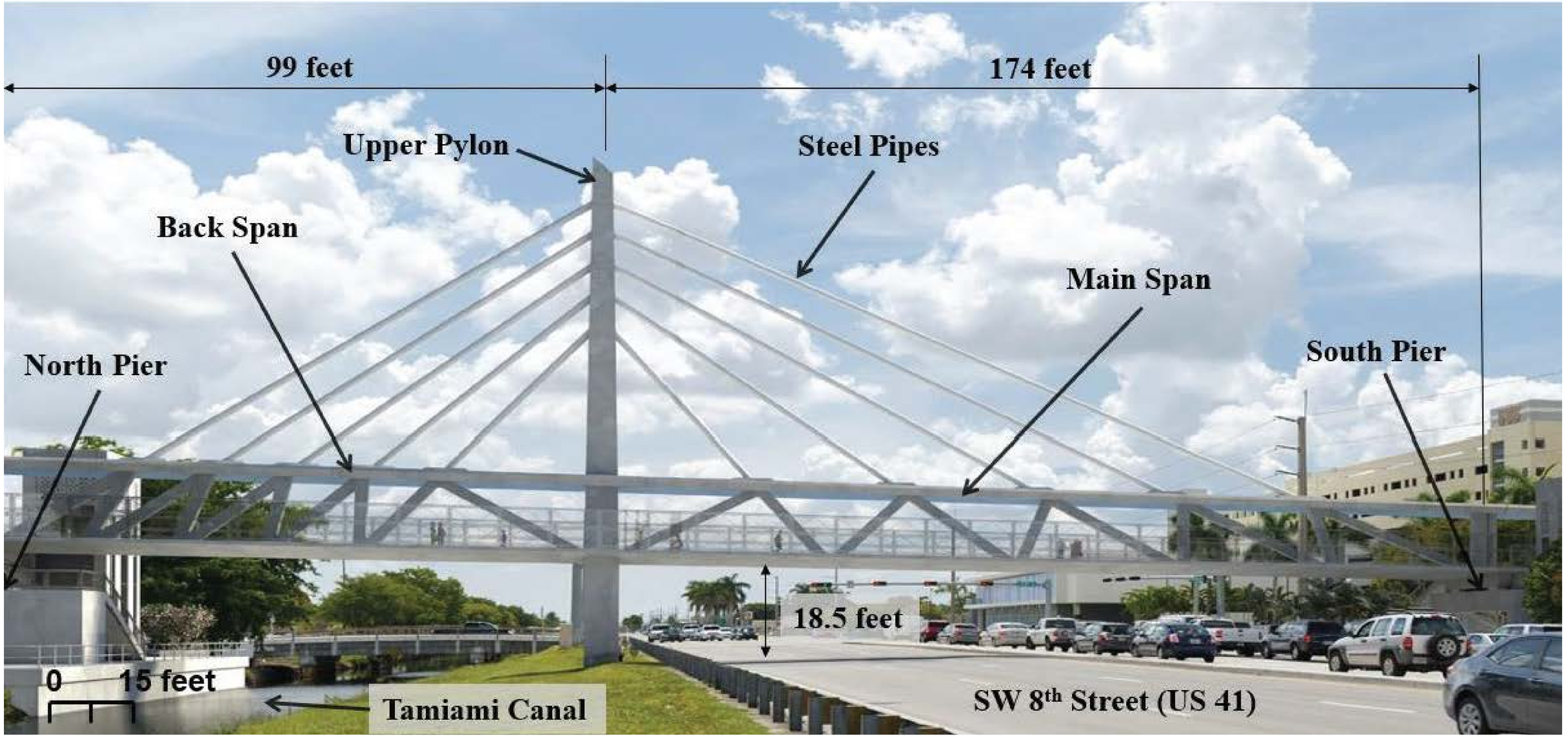
August 13, 2020

FIU UniversityCity Prosperity Pedestrian Bridge

Location of the signature bridge in red. Contractor’s adjacent casting yard and construction trailers on 3/26/2017.(Source: NTSB Factual Report)



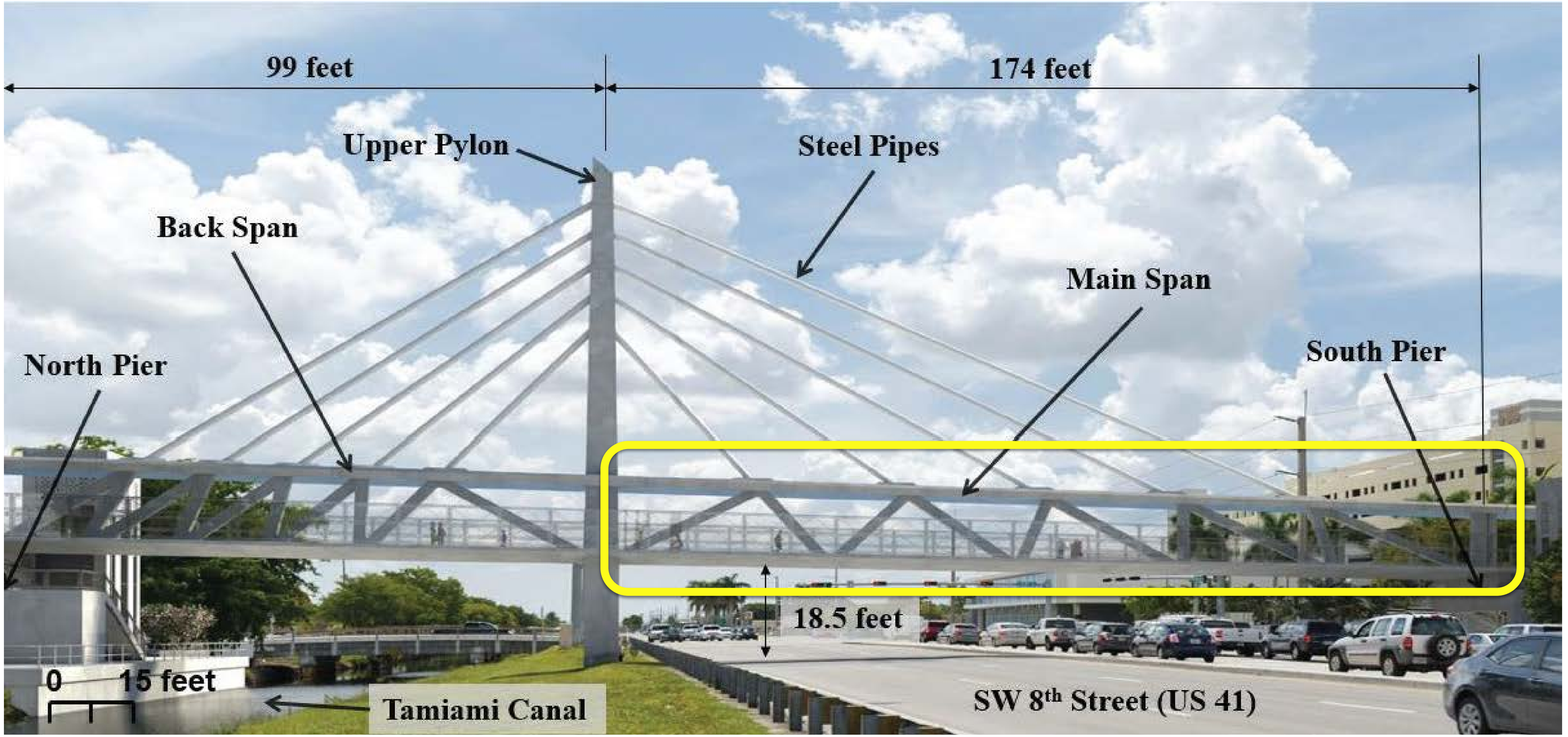
Rendering Of Proposed Signature Pedestrian Bridge



SOURCE: NTSB Factual Report

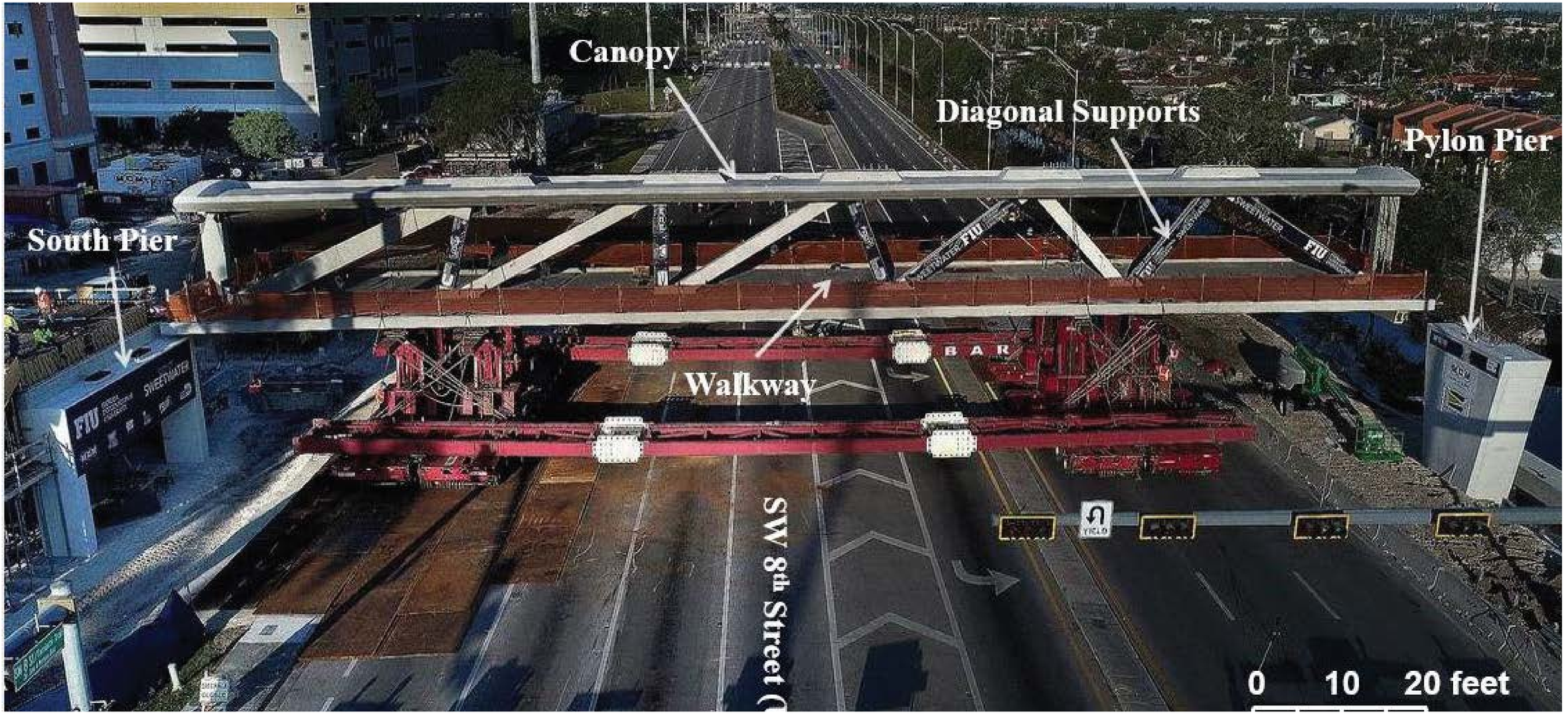
Location of Main Span

Main span was precast on land parallel to highway. Then, over part of weekend, it is moved into place as one piece and placed on piers



SOURCE: NTSB Factual Report, with added outline

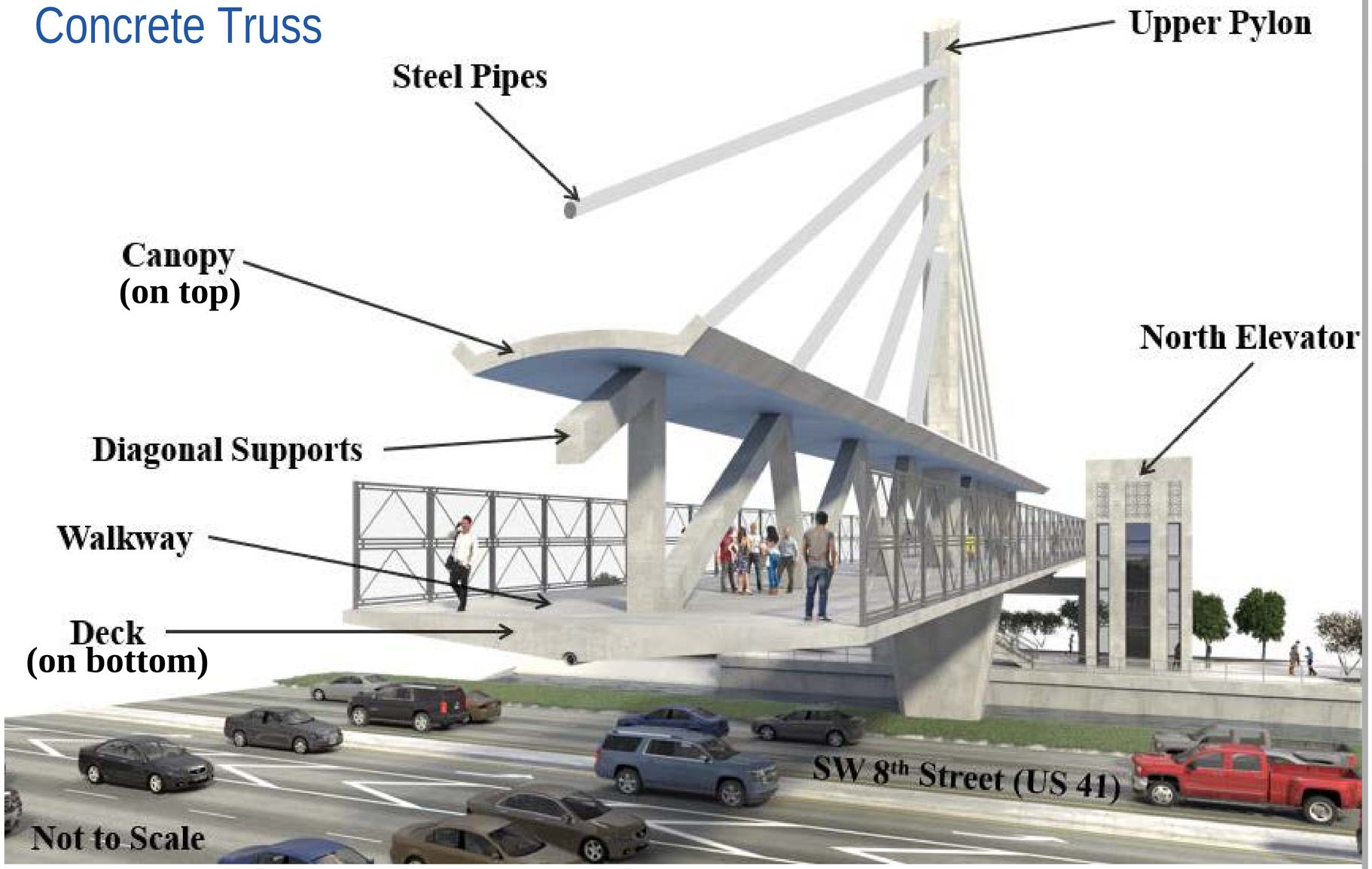
Moving Main Span Into Place On March 10, 2018



SOURCE: NTSB Factual Report

Rendering Of Bridge Cross Section

Concrete Truss

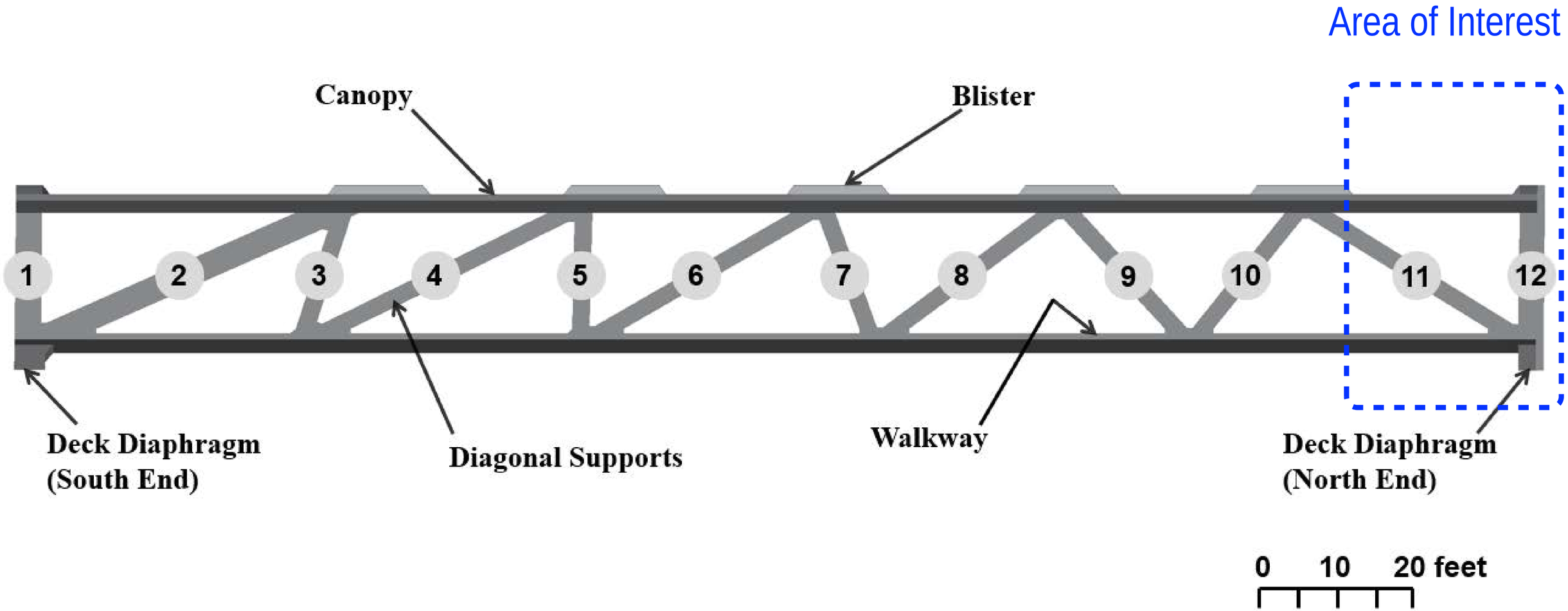


SOURCE: NTSB Factual Report

Analogous to large concrete beam with struts running along centerline

Typical Precast Concrete I-Beam

Map Illustrating Nomenclature Of The Diagonal And Vertical Members Of The Bridge Main Span



Project Participants

OWNER

Florida International University (FIU)

STATE AGENCY SUPPORT

Florida Department of Transportation (FDOT)

OVERSIGHT OF LOCAL PROJECT

ON-SITE

CONSTRUCTION

OWNER'S CONSTRUCTION ENGINEERING & INSPECTION

Network Engineering Services, Inc. d/b/a Bolton-Perez and Associates (BPA)

CONTRACTOR FOR PROJECT DESIGN-BUILD

Munilla Construction Management, LLC (MCM)

CONSTRUCTION

MCM

CONCRETE SUBCONTRACTOR

The Structural Group of South Florida, Inc (TSG)

POST-TENSIONING SUBCONTRACTOR

Structural Technologies, LLC (Structural or VSL)

FORMWORK SHORING SUBCONTRACTOR

RC Group, LLC (RCGROUP)

BRIDGE MOVE SUBCONTRACTOR

Barnhart Crane and Rigging, Co. (Barnhart)
with Subcontractors
Bridge Diagnostics, Inc. (BDI)
RLT Engineering Solutions, LLC (RLT)

CRANE SUBCONTRACTOR

George's Crane Service (George's Crane)

OTHER SUBCONTRACTORS

OFF-SITE

DESIGN

DESIGN CONSULTANT / ENGINEER OF RECORD (EOR)

FIGG Bridge Engineers, Inc. (FIGG)

Design Management
Bridge Design
Submittal reviews at design office and occasional site visits during construction as requested by MCM

INDEPENDENT PEER REVIEW

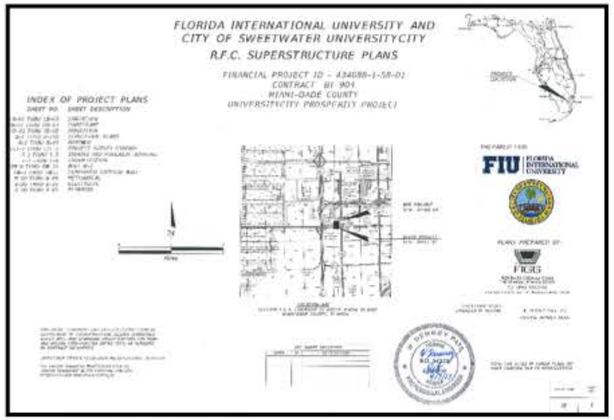
The Louis Berger Group, Inc. (Louis Berger)

Independent Engineering Analysis and review of bridge design

Roles and Responsibilities - OFF-SITE

To Design Project following National & State Codes and Florida Standard Construction Specifications

FDOT rules: Engineer of Record (EOR) is not permitted to have an inspection role during construction with full time oversight (Safety Recommendation is to change this)



FLORIDA
DEPARTMENT
OF
TRANSPORTATION

Centennial FDOT 1915 ★ 2015

STANDARD SPECIFICATIONS
FOR
ROAD AND BRIDGE
CONSTRUCTION

JULY 2015

Design Consultant/Engineer of Record (EOR)

FIGG Bridge Engineers Inc.

Design Manager
Bridge Design
Submittal Reviews at design office
Occasional site visits during construction as requested by MCM

Independent Peer Review

The Louis Berger Group

Letters stated all design requirements were met
Review Plans & Specifications

Elements Considered

Design

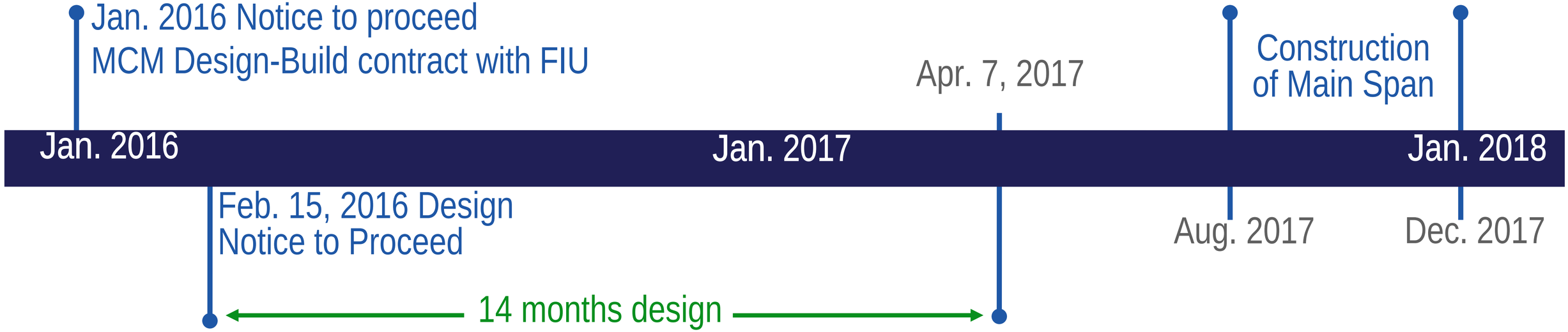
- Calculations (WJE)
- Redundancy

Construction

- Construction of Member 11/12 deck connection (WJE)
- Bridge move
- Communication between construction site and design engineer
- Crack monitoring
- Street closure

Design

All Aspects of the design by FIGG were the subject of numerous Governmental, Contractor, and Peer Reviews over a 14 month period.
All accepted before construction started

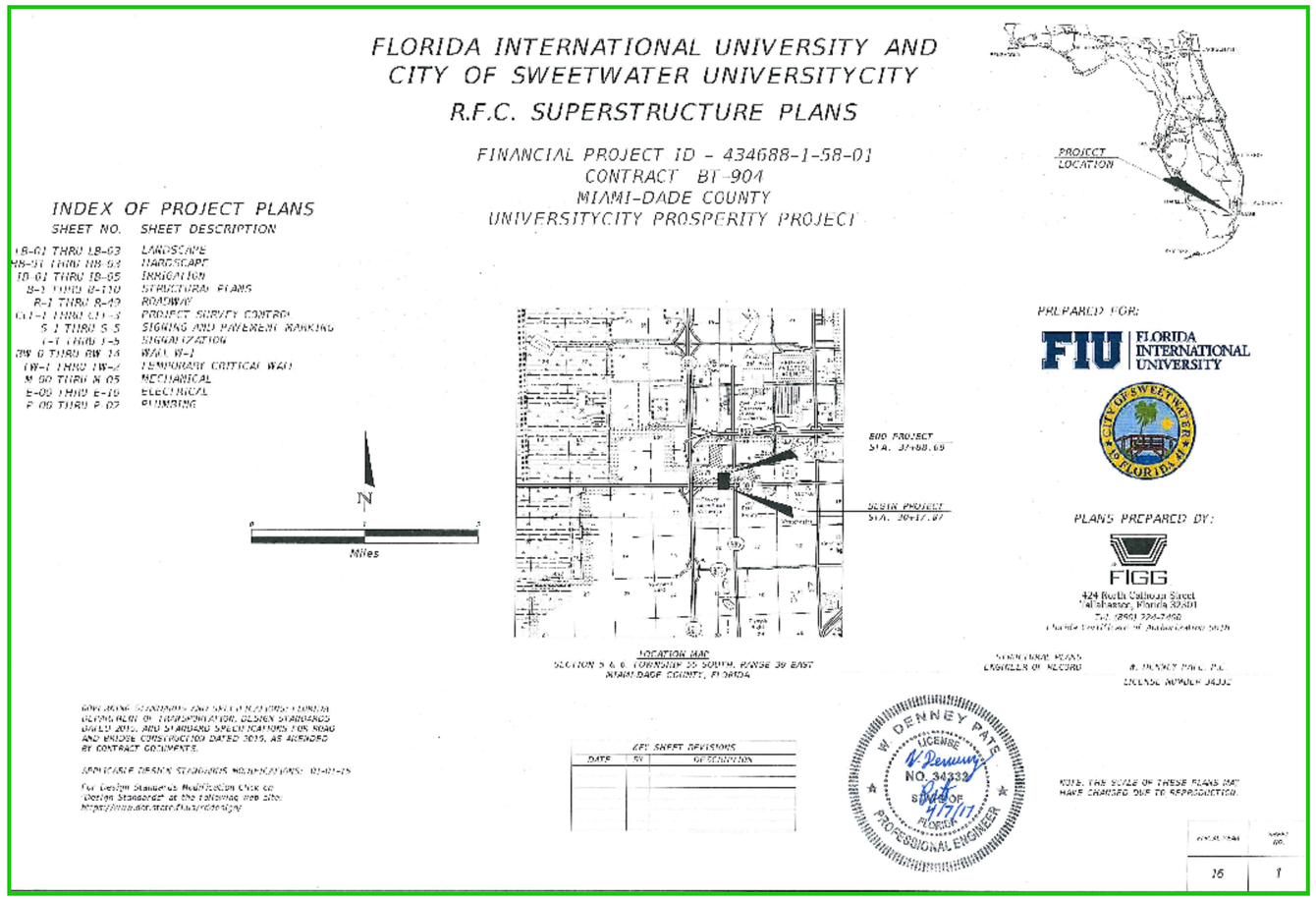


9 Submittals to FDOT for review at 30%, 90%, 100% design plans
32 reviewers - FDOT with 3 outside consultants
Over 340 written comments (electronic review system) resolved to acceptance before release for construction plans issue
37 Reviewers - FIU, FDOT, FHWA, Miami-Dade County

Calculations

Final design is shown in the approved release for construction (RFC) plans

RFC PLANS ARE BUILT



FLORIDA INTERNATIONAL UNIVERSITY AND
CITY OF SWEETWATER UNIVERSITYCITY
R.F.C. SUPERSTRUCTURE PLANS

FINANCIAL PROJECT ID - 434688-1-58-01
CONTRACT BT-904
MIAMI-DADE COUNTY
UNIVERSITYCITY PROSPERITY PROJECT

INDEX OF PROJECT PLANS

SHEET NO.	SHEET DESCRIPTION
LB-01 THRU LB-03	LANDSCAPE
HB-01 THRU HB-03	HARDSCAPE
IR-01 THRU IR-05	IRRIGATION
S-2 THRU S-10	STRUCTURAL PLANS
R-1 THRU R-12	ROADWAY
CL1-1 THRU CL1-3	PROJECT SURVEY CONTROL
S-1 THRU S-5	SIGNING AND PAVEMENT MARKING
T-1 THRU T-5	SIGNALIZATION
RW-0 THRU RW-14	WALL W-1
TW-1 THRU TW-4	TEMPORARY CRITICAL WALL
M-00 THRU M-05	MECHANICAL
E-00 THRU E-16	ELECTRICAL
P-00 THRU P-07	PLUMBING

PROJECT LOCATION

PREPARED FOR:
FIU FLORIDA INTERNATIONAL UNIVERSITY
CITY OF SWEETWATER FLORIDA

PLANS PREPARED BY:
FIGG
424 North Calhoun Street
Tallahassee, Florida 32301
Tel: (850) 224-2468

STRUCTURAL ENGINEER OF RECORD: W. DENNEY PATE, P.E.
LICENSE NUMBER 34332

LOCATION MAP
SECTION 5 & 6, TOWNSHIP 53 SOUTH, RANGE 39 EAST
MIAMI-DADE COUNTY, FLORIDA

800 PROJECT STA. 37+68.69
DESTIN PROJECT STA. 30+17.97

N
0 1 2 Miles

APPLICABLE DESIGN STANDARDS AND SPECIFICATIONS: FLORIDA DEPARTMENT OF TRANSPORTATION, DESIGN STANDARDS DATED 2015, AND STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION DATED 2015, AS AMENDED BY CONTRACT DOCUMENTS.

APPLICABLE DESIGN STANDARDS MODIFICATIONS: 01-01-15

For Design Standards Modification Click on "Design Standards" at the following web site: http://www.dot.state.fl.us/rddesign/

RFC SHEET REVISIONS

DATE	BY	DESCRIPTION

W. DENNEY PATE LICENSE NO. 34332 STATE OF FLORIDA PROFESSIONAL ENGINEER
4/7/17

NOTE: THE SCALE OF THESE PLANS MAY HAVE CHANGED DUE TO REPRODUCTION.

TOTAL SHEETS	SHEET NO.
16	1

FIGG

Sum-It: AASHTO LRFD Load Combination Generator
Figg Bridge Engineers, Inc.
User's Load Input
File Name: Diagonal Loads_Back Span_South End Pinned.sum

Page 53 of 59
9/19/2016
9:30:27 PM

Limit State: STRENGTH III

TU Uniform Temperature
LF: 0.5
TU1: TU-
TU2: TU+
TU3: TU+Temp. Diff.

DC DL Structural Components & Attachments
LF1: 1.25
LF2: 0.9
DC1: DC

FR Friction
LF: 1
FR1: CR+SH+PT_EOC
FR2: CR+SH+PT_D10K

WS Wind Load on Structure
LF: 1.4
WS1: WS_0 DEG
WS2: WS_15 DEG
WS3: WS_30 DEG
WS4: WS_45 DEG
WS5: WS_60 DEG
WS6: WS_-15 DEG
WS7: WS_-30 DEG
WS8: WS_-45 DEG
WS9: WS_-60 DEG
WS10: WS+RUP

DW DL Wearing Surfaces & Utilities
LF1: 1.5
LF2: 0.65
DW1: DW

Load (Row) Number	User's Load ID	Member ID	Joint ID	Fx (kips)	Fy (kips)	Fz (kips)	Mx (ft*kip)	My (ft*kip)	Mz (ft*kip)
1	CR+SH+PT_D10K	741	727	134.9	0	-1.8	0	27.1	0
2	CR+SH+PT_D10K	741	728	-134.9	0	1.8	0	14.2	0
3	CR+SH+PT_D10K	744	729	-207.1	0	1.5	0	-11.8	0
4	CR+SH+PT_D10K	744	730	207.1	0	-1.5	0	-9.9	0
5	CR+SH+PT_D10K	747	731	139.6	0	13.9	0	-55.7	0
6	CR+SH+PT_D10K	747	732	-139.6	0	-13.9	0	-63.2	0
7	CR+SH+PT_D10K	750	733	-300.6	0	4.3	0	-29.1	0
8	CR+SH+PT_D10K	750	734	300.6	0	-4.3	0	-31.8	0
9	CR+SH+PT_D10K	753	735	208.6	0	19.6	0	-75.9	0
10	CR+SH+PT_D10K	753	736	-208.6	0	-19.6	0	-73.5	0
11	CR+SH+PT_D10K	756	737	-316.8	0	4.9	0	-30.7	0
12	CR+SH+PT_D10K	756	738	316.8	0	-4.9	0	-39.6	0
13	CR+SH+PT_D10K	759	739	208.2	0	19.7	0	-72.5	0
14	CR+SH+PT_D10K	759	740	-208.2	0	-19.7	0	-65.7	0
15	CR+SH+PT_D10K	762	741	-197.9	0	3.5	0	-14.1	0
16	CR+SH+PT_D10K	762	742	197.9	0	-3.5	0	-36.7	0
17	CR+SH+PT_D10K	765	743	168.3	0	13.1	0	-41.7	0
18	CR+SH+PT_D10K	765	744	-168.3	0	-13.1	0	-43.8	0
19	CR+SH+PT_D10K	768	745	49.6	0	2.1	0	-2.5	0
20	CR+SH+PT_D10K	768	746	-49.6	0	-2.1	0	-32.5	0
21	CR+SH+PT_D10K	771	747	4.1	0	28.7	0	-8.9	0
22	CR+SH+PT_D10K	771	748	-4.1	0	-28.7	0	-363.2	-0.1

1056

Calculations are not built

Release for Construction (RFC) Plans incorporate calculations, comments, constructibility comments, final decisions, etc.

1st Page of Approved RFC Plans is General Notes that apply to Entire Set of construction drawings (Standard Industry Practice)

CONSTRUCTION SPECIFICATIONS:

1. FLORIDA DEPARTMENT OF TRANSPORTATION STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION 2015.
2. AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO) LRFD BRIDGE CONSTRUCTION SPECIFICATIONS, SECOND EDITION, 2004 WITH INTERIMS THROUGH 2006.

DESIGN SPECIFICATIONS:

1. AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO) LRFD BRIDGE DESIGN SPECIFICATIONS SEVENTH EDITION WITH 2015 INTERIMS.
2. FDOT STRUCTURES DESIGN MANUAL, JANUARY 2015.
3. AASHTO LRFD GUIDE SPECIFICATIONS FOR DESIGN OF PEDESTRIAN BRIDGES, SECOND EDITION (2009).
4. CEB-FIP MODEL CODE, FIRST EDITION, 1990, TIME DEPENDENT BEHAVIOR OF CONCRETE, CREEP AND SHRINKAGE.
5. AASHTO/AMERICAN WELDING SOCIETY (AWS) D1.5 BRIDGE WELDING CODE (2005).
6. 28 CODE OF FEDERAL REGULATIONS PART 36, 2010 AMERICANS WITH DISABILITIES ACT (ADA) STANDARDS FOR ACCESSIBLE DESIGN.
7. AASHTO GUIDE FOR THE DEVELOPMENT OF BICYCLE FACILITIES, 1999.
8. BUILDING CODE REQUIREMENTS FOR STRUCTURAL CONCRETE, ACI 318-14.
9. BUILDING CODE REQUIREMENTS FOR MASONRY STRUCTURES, TMS 402-13 CODE.

FLORIDA
DEPARTMENT
OF
TRANSPORTATION

Centennial FDOT 1915★2015

STANDARD SPECIFICATIONS
FOR
ROAD AND BRIDGE
CONSTRUCTION

JULY 2015

Redundancy

Redundancy: “…the capability of a bridge structural system to carry loads after damage to or failure of one or more of its members.” (AASHTO)

Types of redundancy (FHWA)

- Internal (member with multiple parallel elements)
- Structural (continuous members, fixed connections)
- Load path (more than two primary load carrying members)

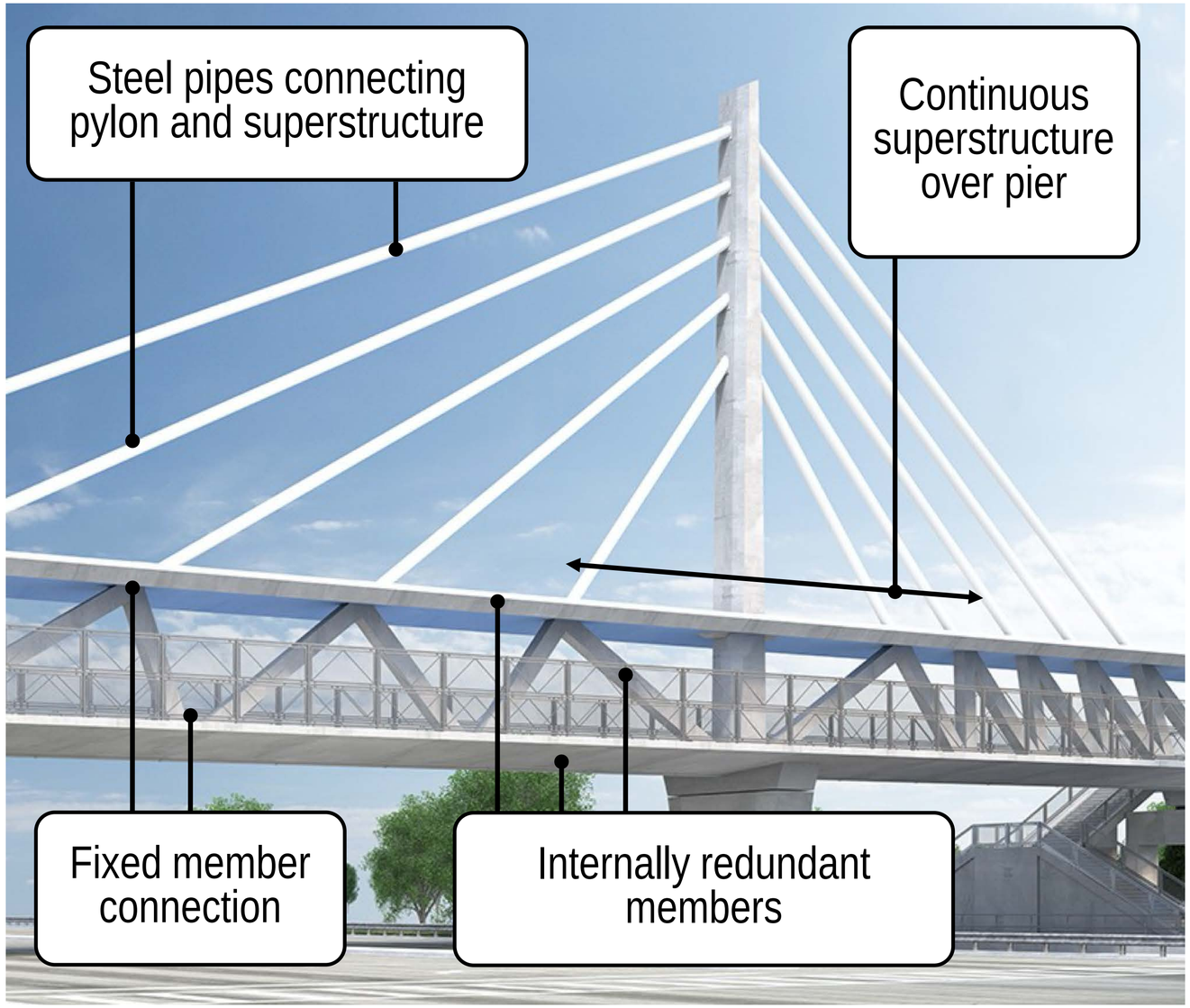
Redundancy considerations not applicable for temporary construction phases

AASHTO Design Code general provision for less redundant bridges is to increase design loads by 5%

Redundancy

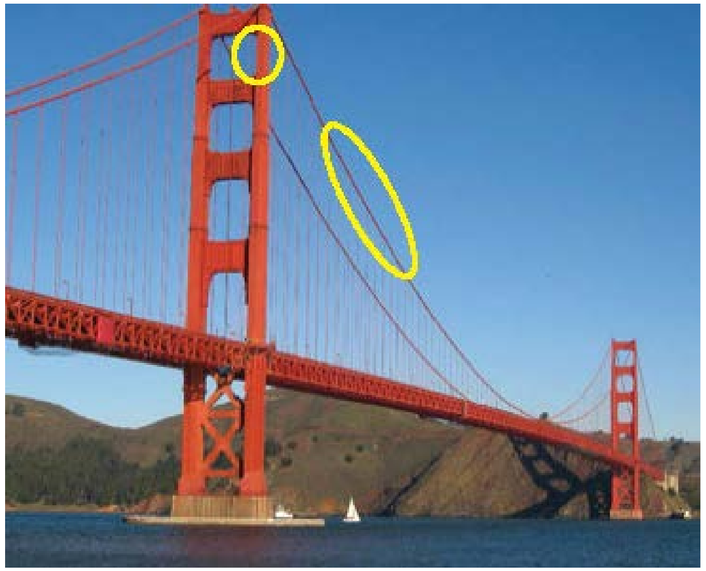
Redundant features of FIU Pedestrian Bridge

Internal Redundancy

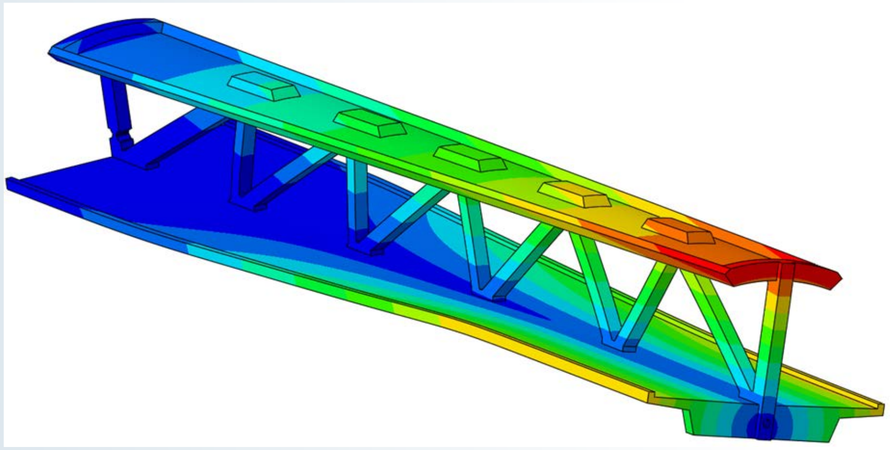


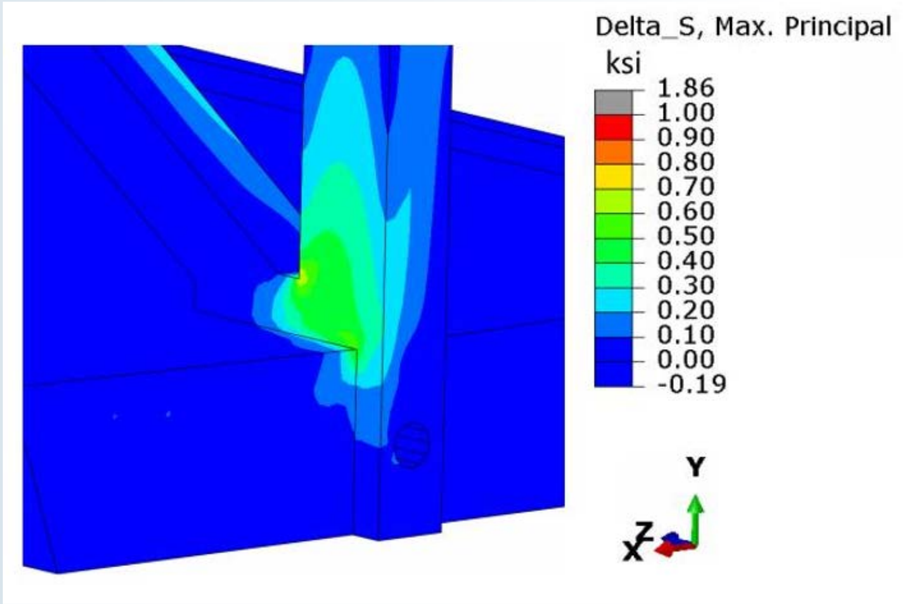
Redundancy

Common examples of less redundant bridges



Bridge Move – Twist Exceedances during Main Span Transport





- *FIGG established a 0.5-degree twist limit to control cracking.*
- *However, after the accident it was learned that this limit was exceeded. The full degree of the exceedance is somewhat uncertain due to "spikes" in the rotation and twist readings.*
- *The tilt associated with exceeding the established twist limits caused high stresses in the region. Along with other factors, this stress may have contributed to damage in the region and ultimately to the collapse.*

Communications – Inaccurate, Misleading and Untimely Information from Construction and Inspection Team On-Site to Designer Off-Site

By contract, FIGG did not have a person on-site except for occasional visits – relied on Contractor for information

No information on cracking after bridge move on March 10 provided to FIGG until late on March 12 – pertained almost exclusively to the north diaphragm

FIGG was unaware that the construction joint had not been roughened or that the twist limit had been exceeded

FIGG (Designer)

On-Site Construction/Inspection

SAT 3/10

SUN 3/11

MON 3/12

FIGG staff at site observe no change from pre-move. Leave site at 12:40pm

Bridge move complete 12:30 pm

BPA finds significant change in cracking 3:00pm

Member #11 PT bar destressed 4:30pm

SW 8TH Street opened to traffic 6:00pm

Subcontractor text to coworker:
"It cracked like hell" 7:08 pm

MCM e-mail to FIGG with 16 photos 4:51pm
mostly of north diaphragm

MON 3/12

MCM e-mail to FIGG with 16 photos 4:51pm
mostly of north diaphragm

TUES 3/13

MCM call with FIGG 9:30am
> Cracks observed Saturday before destressing
> Increased some with destressing and have not increased since

FIGG opens e-mail
Call with MCM
E-mails to place shims under diaphram and restress #11 to return to prior stage

Analysis and Presentation
focused on diaphragm

WED 3/14

MCM sends FIGG additional photos without commentary 1:38pm

FIGG staff leave to travel to Miami for meeting

THURS 3/15

Site tour with FIGG 7:45am

Meeting with FIU, FDOT, FIGG, and BPA 9:00am

Meeting ends approx. 10:30am

Restressing PT in member #11 - Starts Approx. Noon

Accident occurs at 1:47pm

FIGG staff at site

Attended Meeting

Leave for Tallahassee for further analysis approx. 10:30am

Lack of Crack Monitoring during Re-Stressing

- *Contrary to FIGG instructions and Structural/VSL Safety Guidelines, no one closely monitored cracks in the north-end diaphragm during re-stressing of Member 11*
- *If closely monitored by MCM, Structural/VSL, BPA or Corradino, increases in crack width could have been readily detected by several means, including use of wood block crack gauges, which were already used at the site.*

Street Closure – Failure to Close SW 8th Street While Investigating

FDOT, FIU, MCM and BPA had the authority (alone or collectively) to close traffic.

MCM opened traffic at 6:00 pm on March 10 despite observed worsening cracking.
Text at 7:08 pm: “It cracked like hell”.

From March 12 through March 14, MCM and BPA had full-time site presence and were monitoring cracking. No actions to close traffic.

Street Closure – Failure to Close SW 8th Street While Investigating

No one at the March 15 meeting the morning of the accident suggested closing SW 8th Street.

Subcontractor restressing PT bars in Member #11 only defined the work zone as the north two lanes.

Preeminent Forensic Structural Engineering Experts

Wiss, Janney, Elstner Associates, Inc. (WJE)

Gary J. Klein, P.E., S.E.
Executive Vice President and Senior Principal

Bachelors and Master in Civil Engineering
Professional Engineer in Florida

Since 1979 Gary has investigated hundreds of structures

I-35W Bridge collapse in Minnesota
State investigation coordinating with NTSB on Final Results

Serves on 6 Technical Committees for American Concrete Institute

Named to prestigious National Academy of Engineering in Washington, D.C.
"for investigations of National and International infrastructure and conveying knowledge from these investigations to the profession."

NTSB investigation of I-35W, Minnesota

FIU UNIVERSITYCITY PROSPERITY PEDESTRIAN BRIDGE PROJECT

WJE

Testing of Full-Size Replicas of Failed Connection

Introduction

Bridge Description

- Two-span truss; 175 foot main span
- Pylon and stay cables (actually pipes) are architectural features
- Canopy and 32-foot wide deck are post-tensioned
- Most diagonals are posttensioned

Introduction

Move of Main Span into Position: March 10, 2018

Introduction

Collapse: March 15, 2018

Introduction

Scope of WJE Investigation

- Evaluation of Failure Pattern
- Structural Analyses
  - Finite Element Analyses
  - Code Evaluation of Failed Deck Connection
- Construction Joint Conditions
- Interface Shear Transfer Testing
- Test-based Evaluation of Deck Connection Failure
- Other Factors

Introduction

NTSB Probable Cause

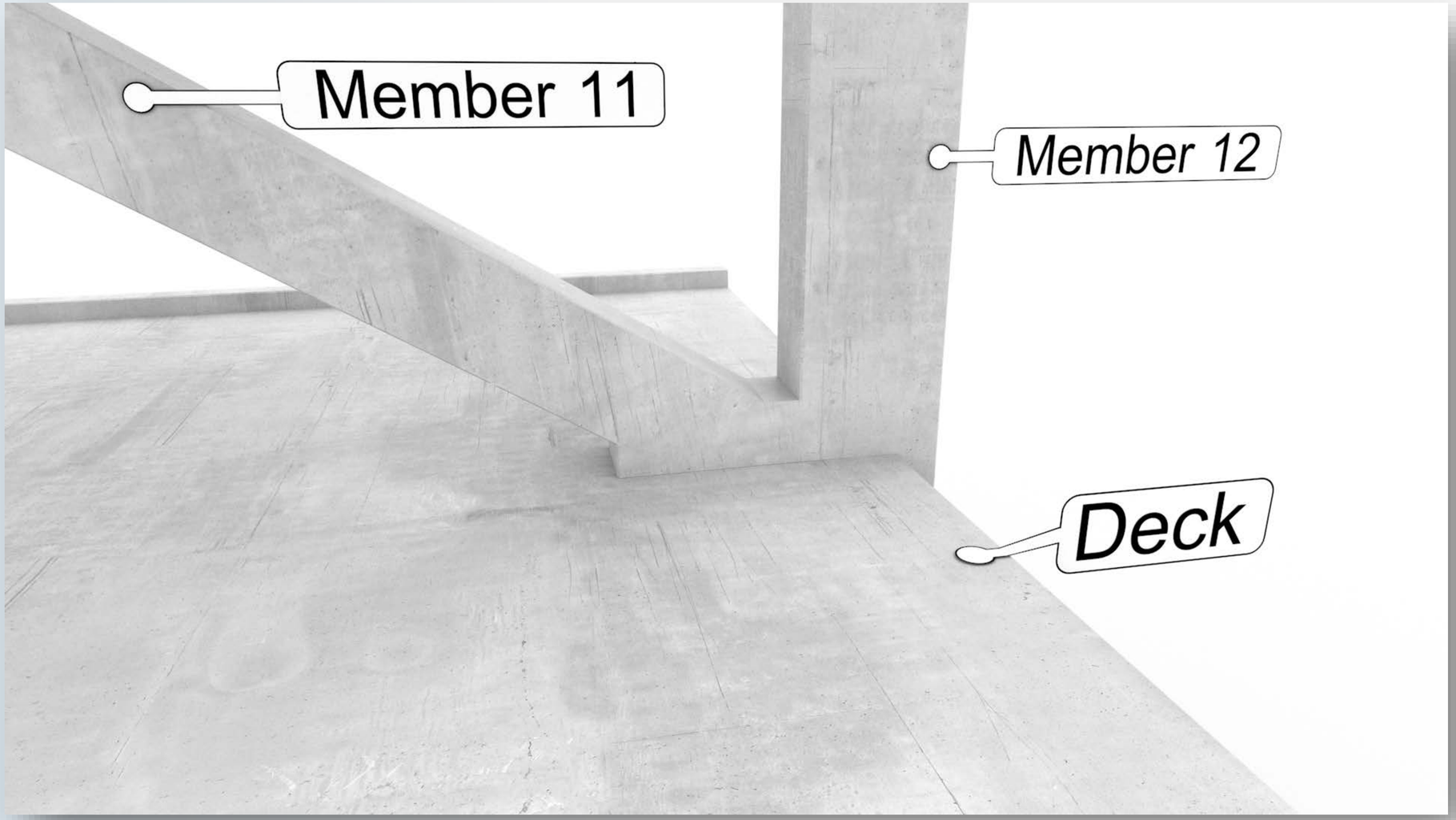
Design mistakes by FIGG as to the load and capacity of the Member 11/12 deck connection

Introduction

WJE Exceptions to NTSB/FHWA Probable Cause

1. Considering the entire construction joint between member 11/12 and the deck, the design as shown on the contract documents meets the AASHTO Code.
2. If the construction joint were roughened as required by the project specifications, which were reconfirmed by email, the collapse would not have occurred.

Background

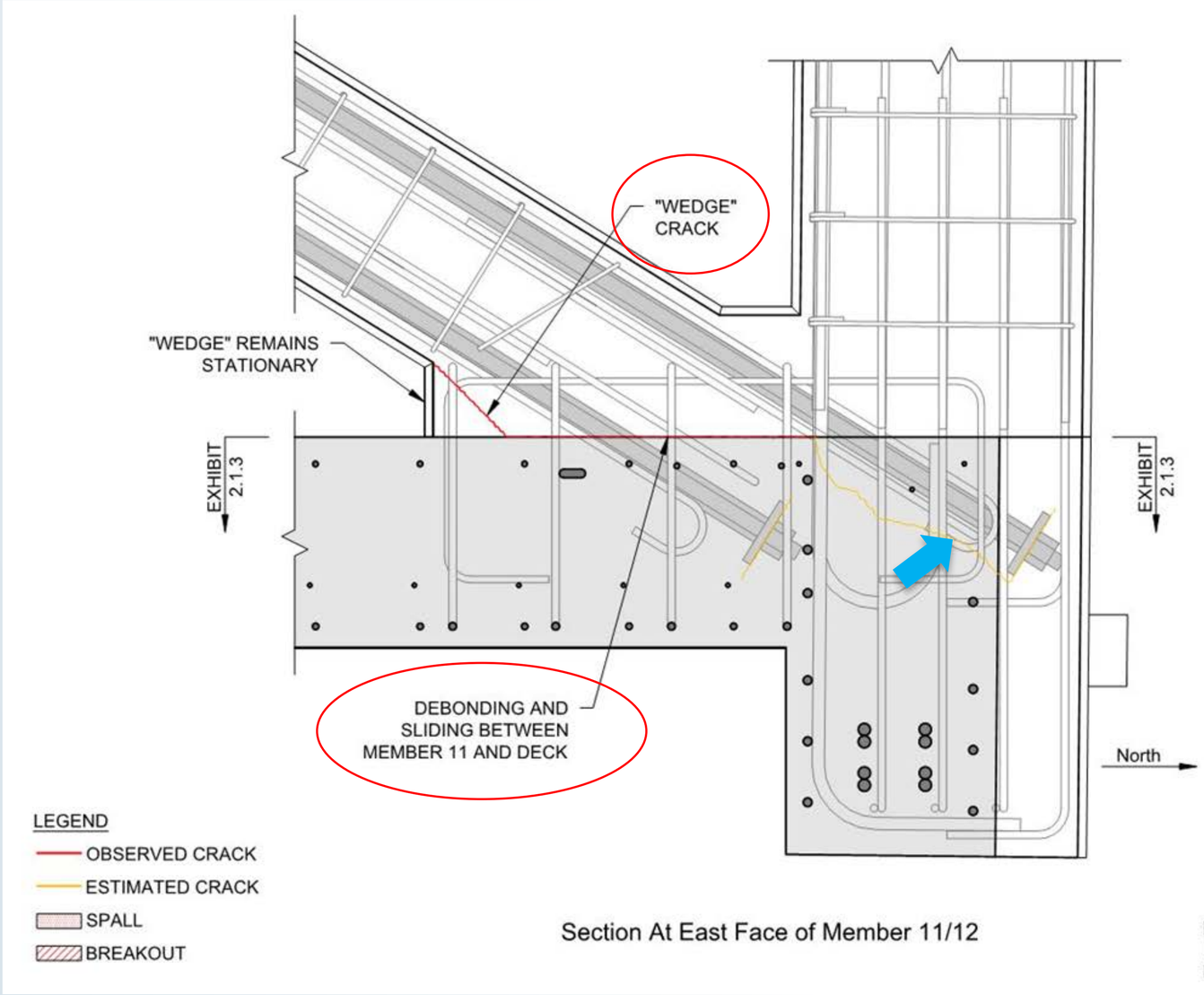


Background

Timeline

October 19, 2017	Deck concrete casting
February 24, 2018	Shoring removal (cracking observed)
March 10, 2018, 12:30 PM	Main span moved into final position
March 10, 2018, 3:07 PM	Very significant widening of cracks observed
March 15, 2018, 11:49 AM	Re-tensioning of member 11
March 15, 2018, 1:45 PM	Main span collapses

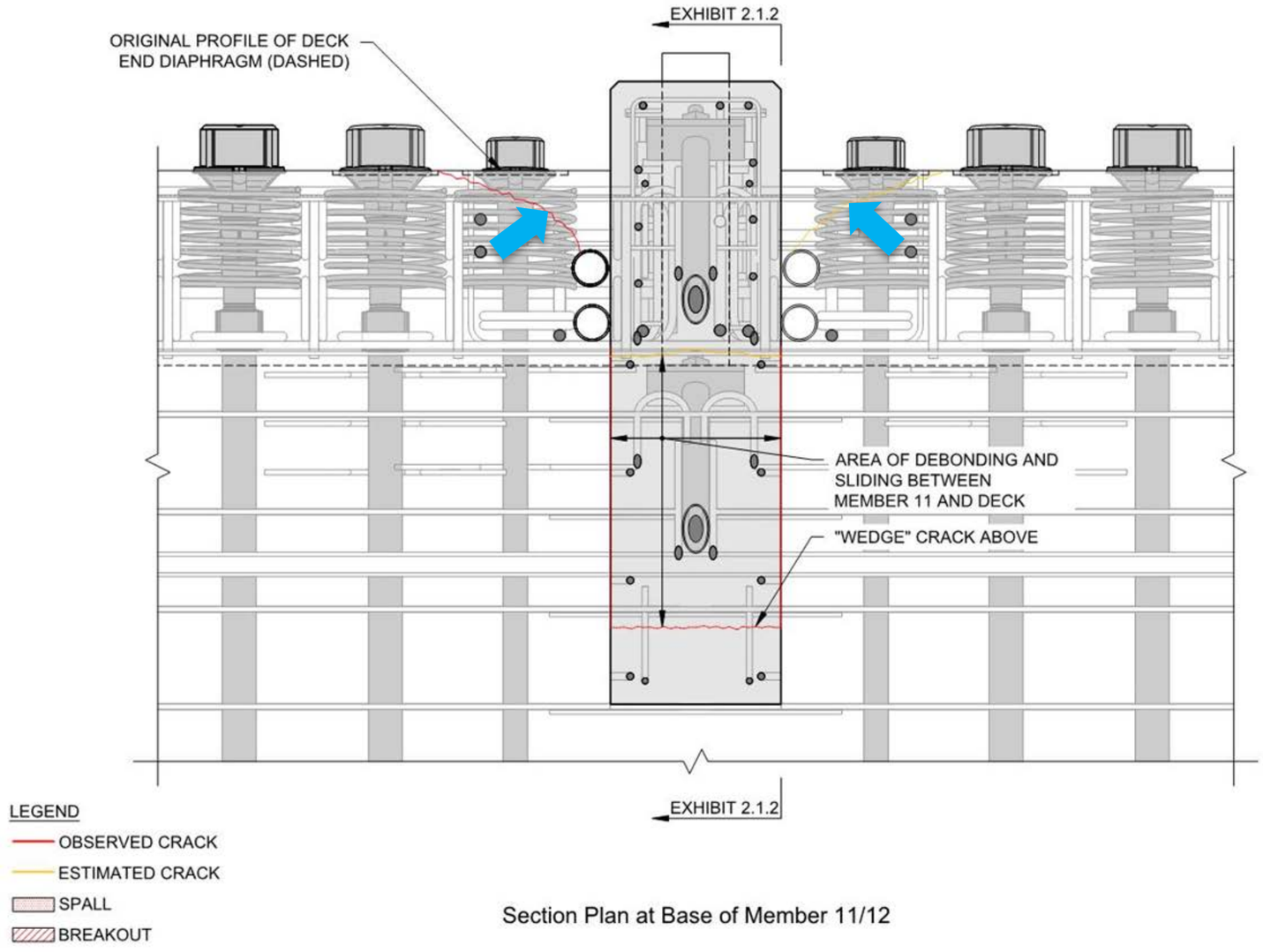
After Shoring Removal and Before Move (February 12-March 9, 2018)



Section At East Face of Member 11/12

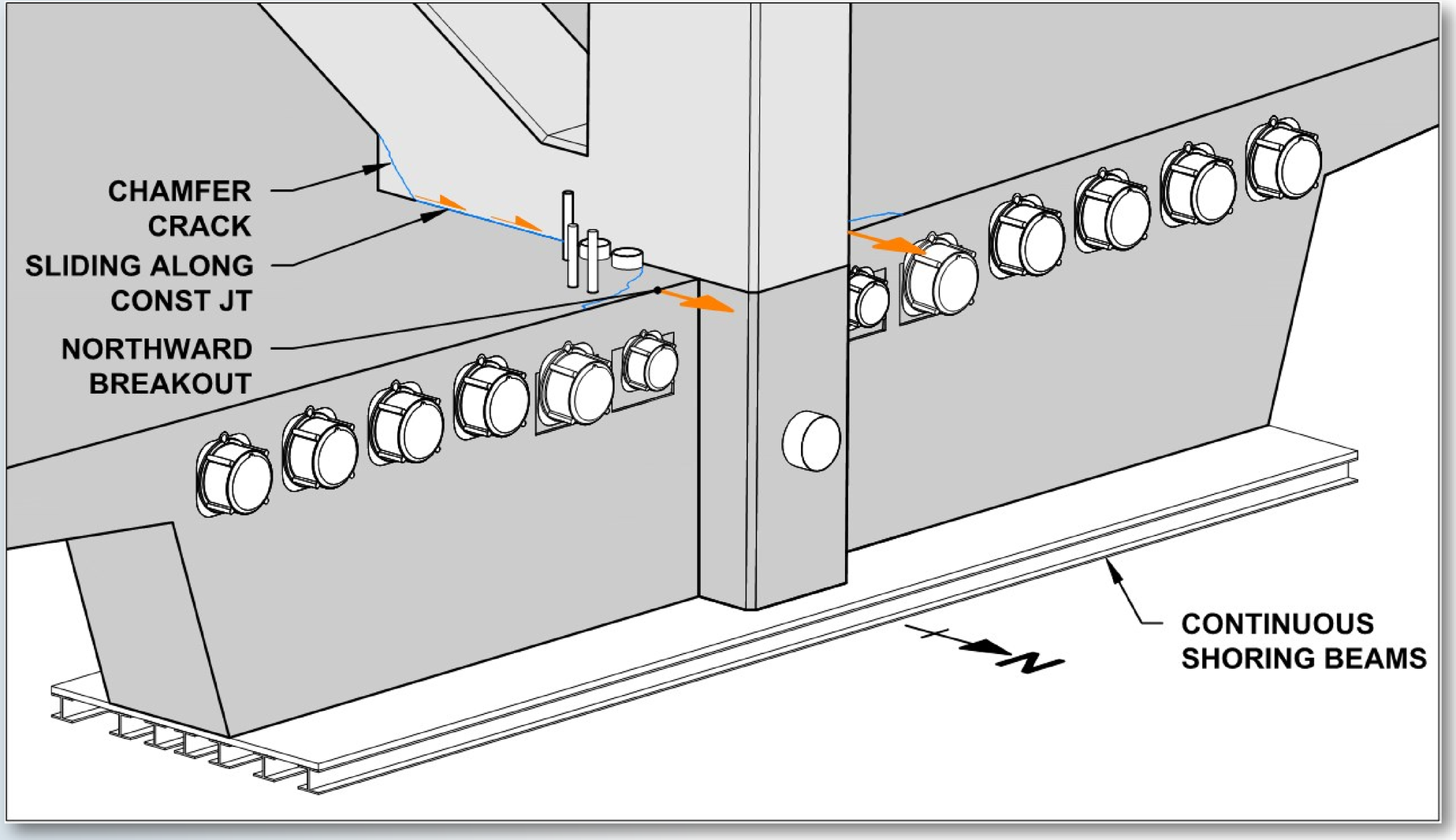
NOTE: RE
IN PLAN L
LOCATIO

After Shoring Removal and Before Move (February 12-March 9, 2018)

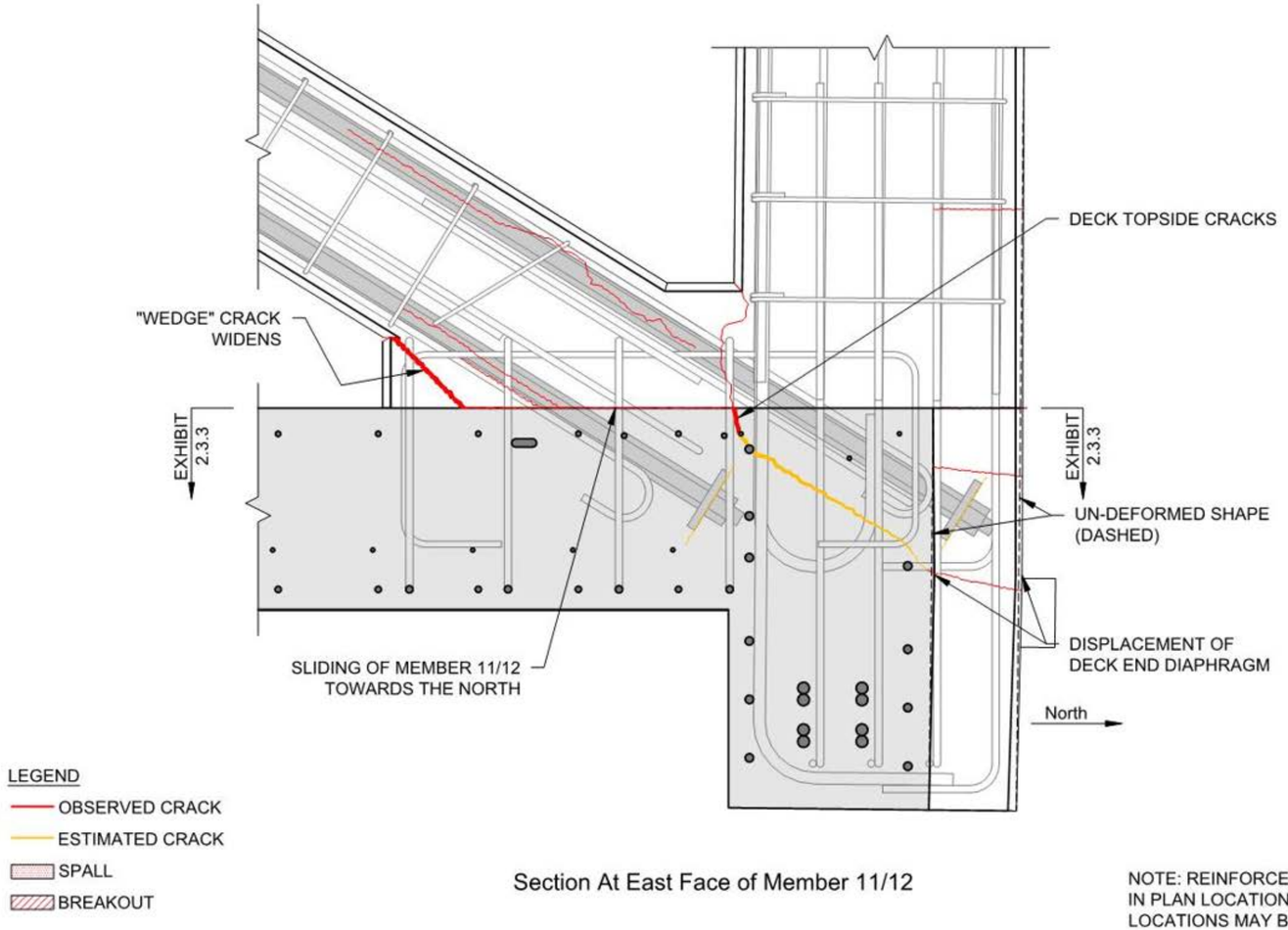


Section Plan at Base of Member 11/12

After Shoring Removal and Before Move (February 12-March 9, 2018)



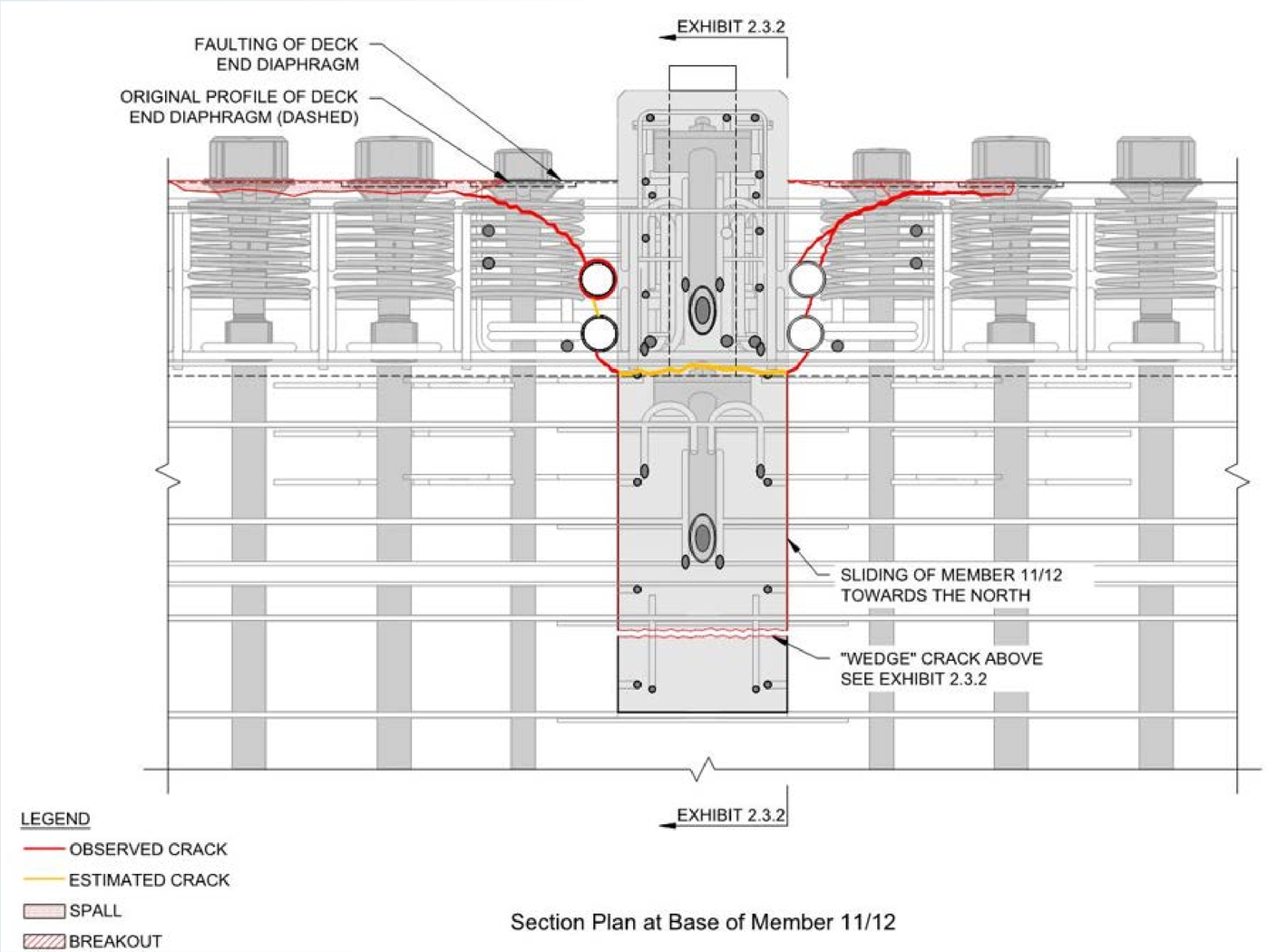
March 12, 2018 at 3 PM



Section At East Face of Member 11/12

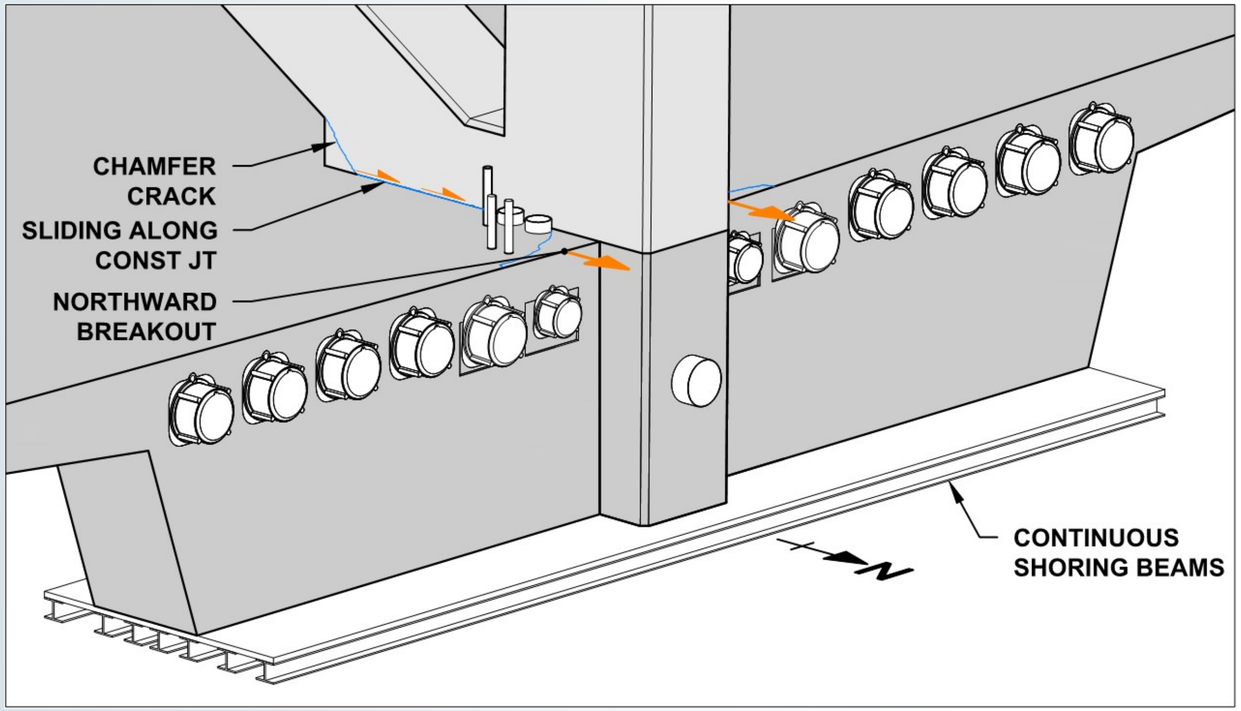
NOTE: REINFORCEMENT IS SHOWN IN PLAN LOCATIONS. AS-BUILT LOCATIONS MAY BE DIFFERENT.

March 12, 2018 at 3 PM

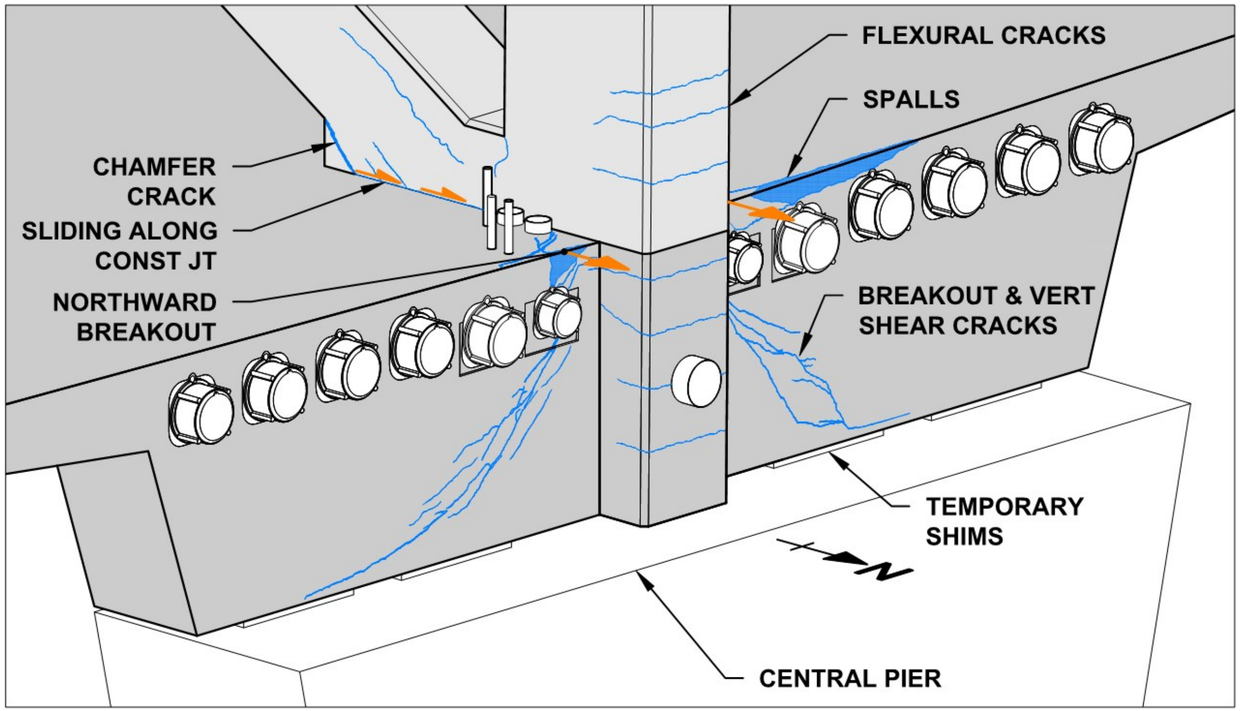


Section Plan at Base of Member 11/12

After Shoring Removal: Feb. 24

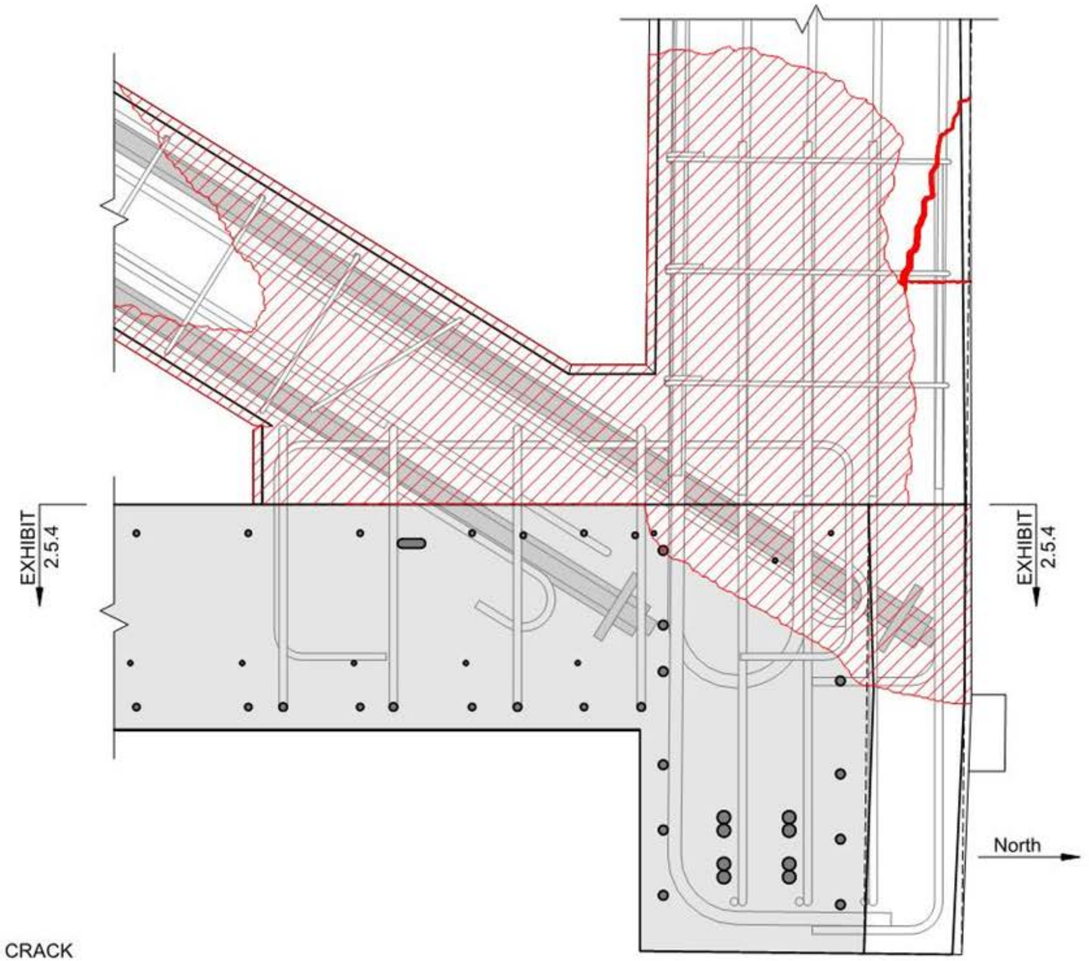


On Final Supports: March 12



After Collapse (March 15, 2018)

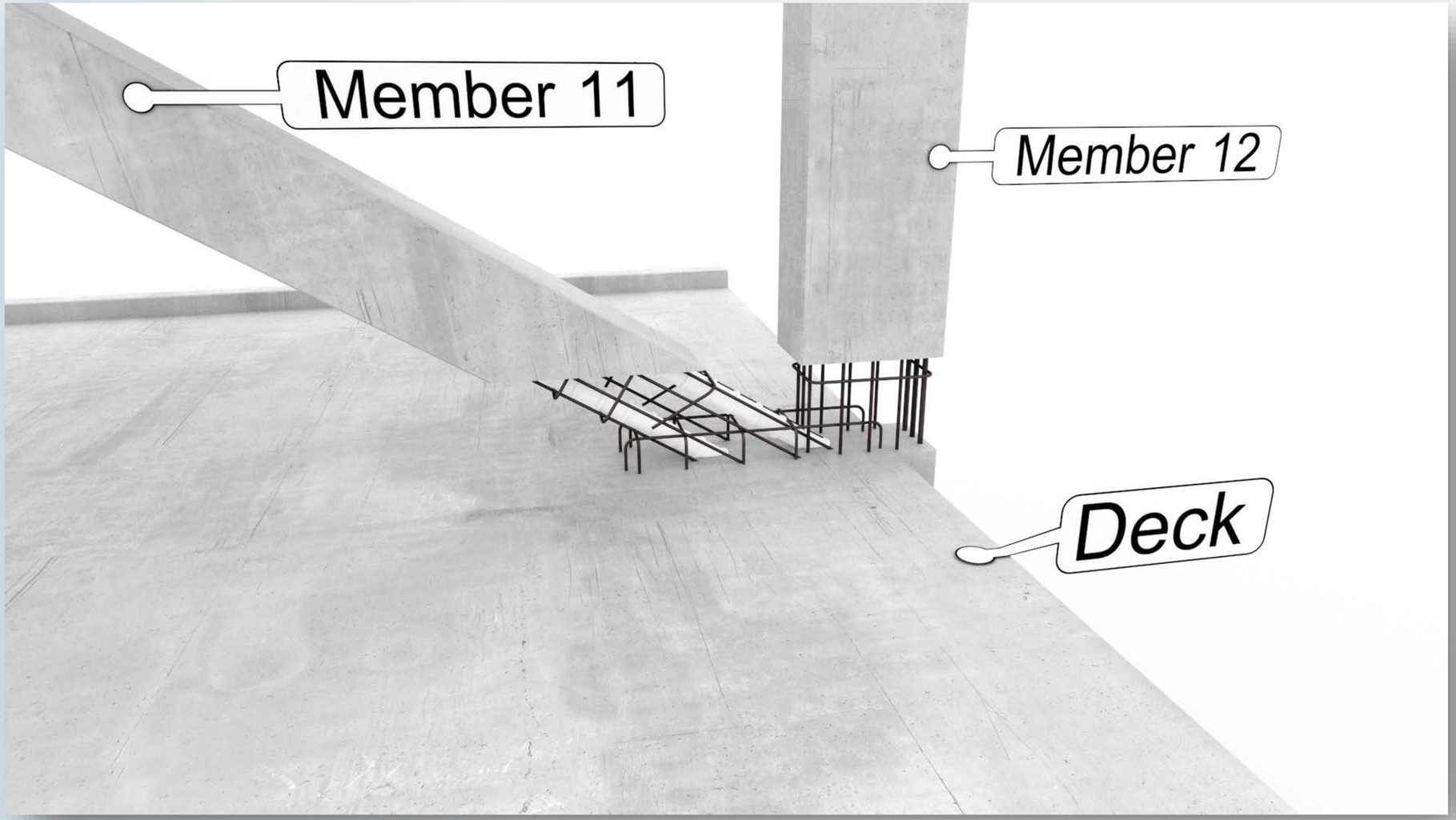
After Collapse (March 15, 2018)



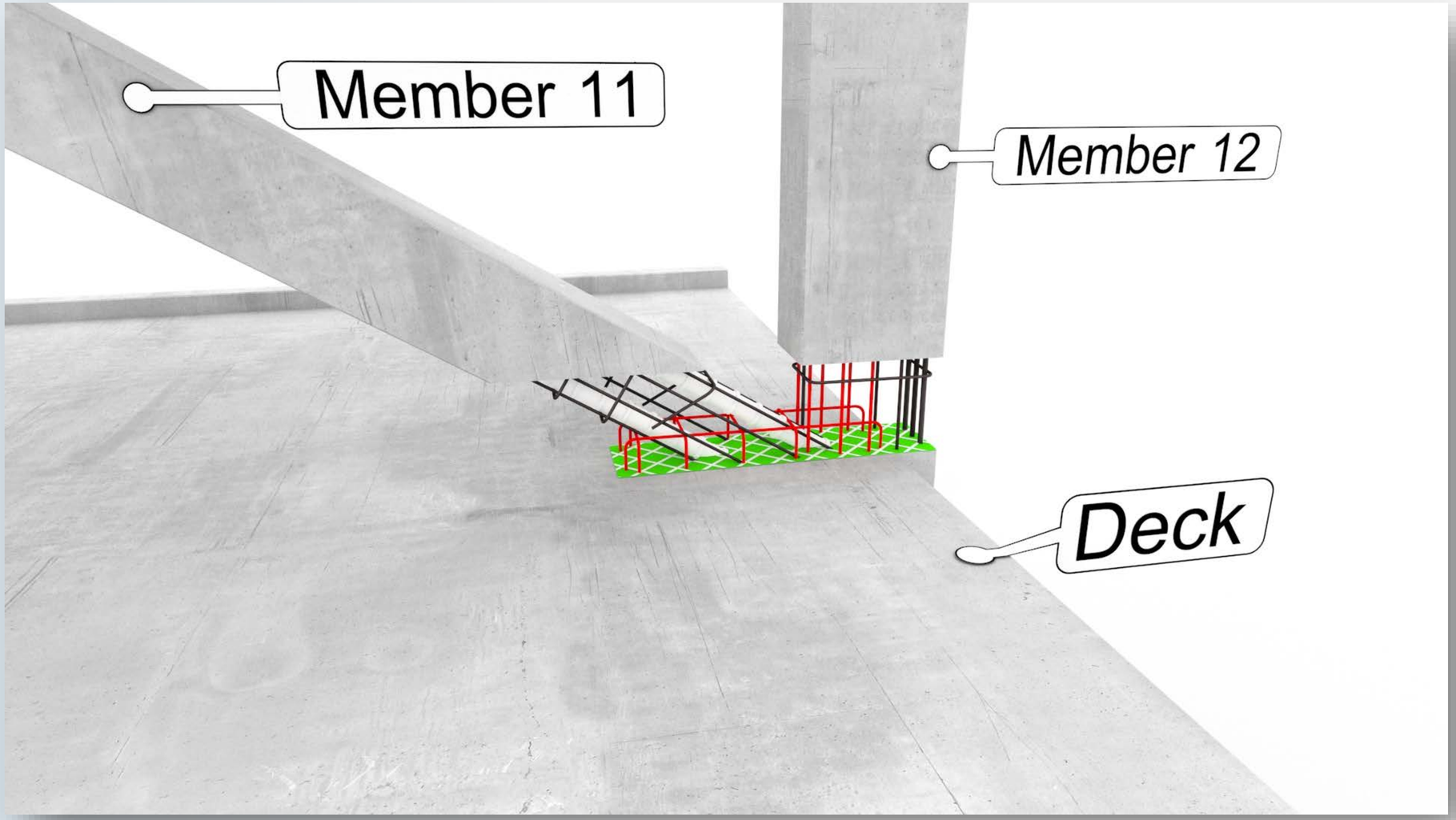
Section At East Face of Member 11/12

NOTE: REINFORCEM
IN PLAN LOCATIONS.
LOCATIONS MAY BE

Code Evaluation of Member 11/12 Deck Connection

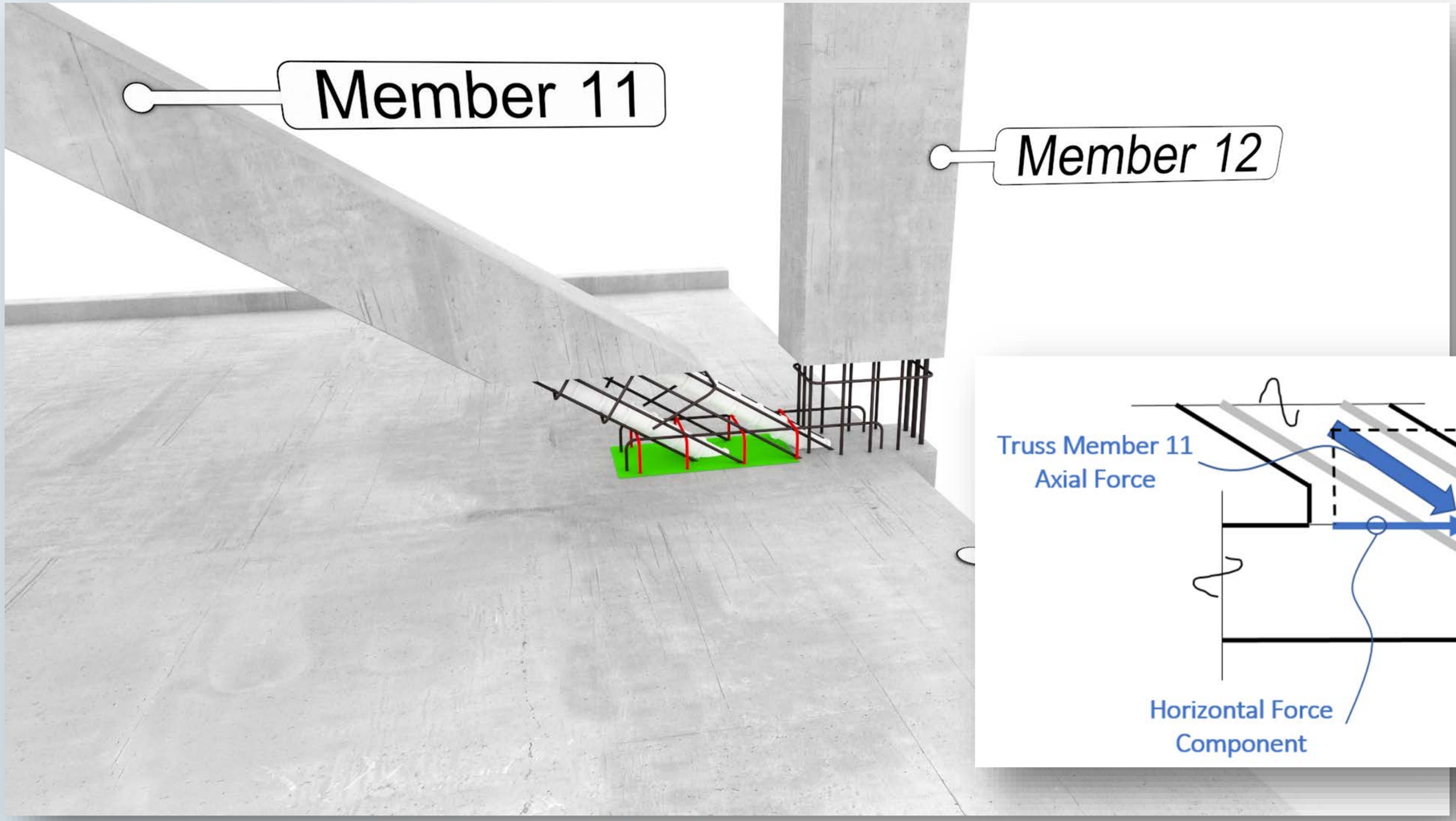


Code Evaluation of Member 11/12 Deck Connection



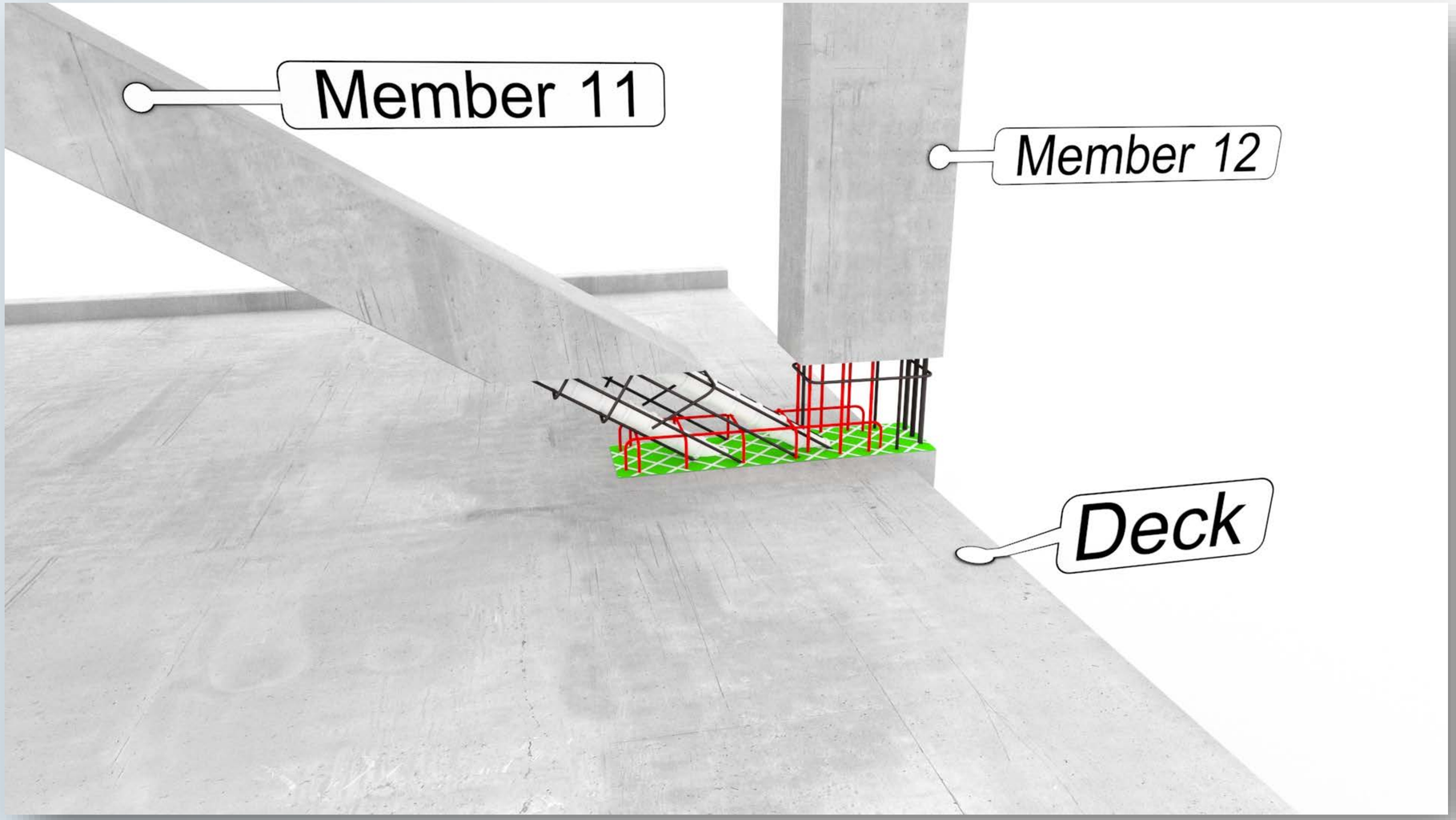
WJE Evaluation

Code Evaluation of Member 11/12 Deck Connection



FHWA Evaluation

Code Evaluation of Member 11/12 Deck Connection



WJE Evaluation

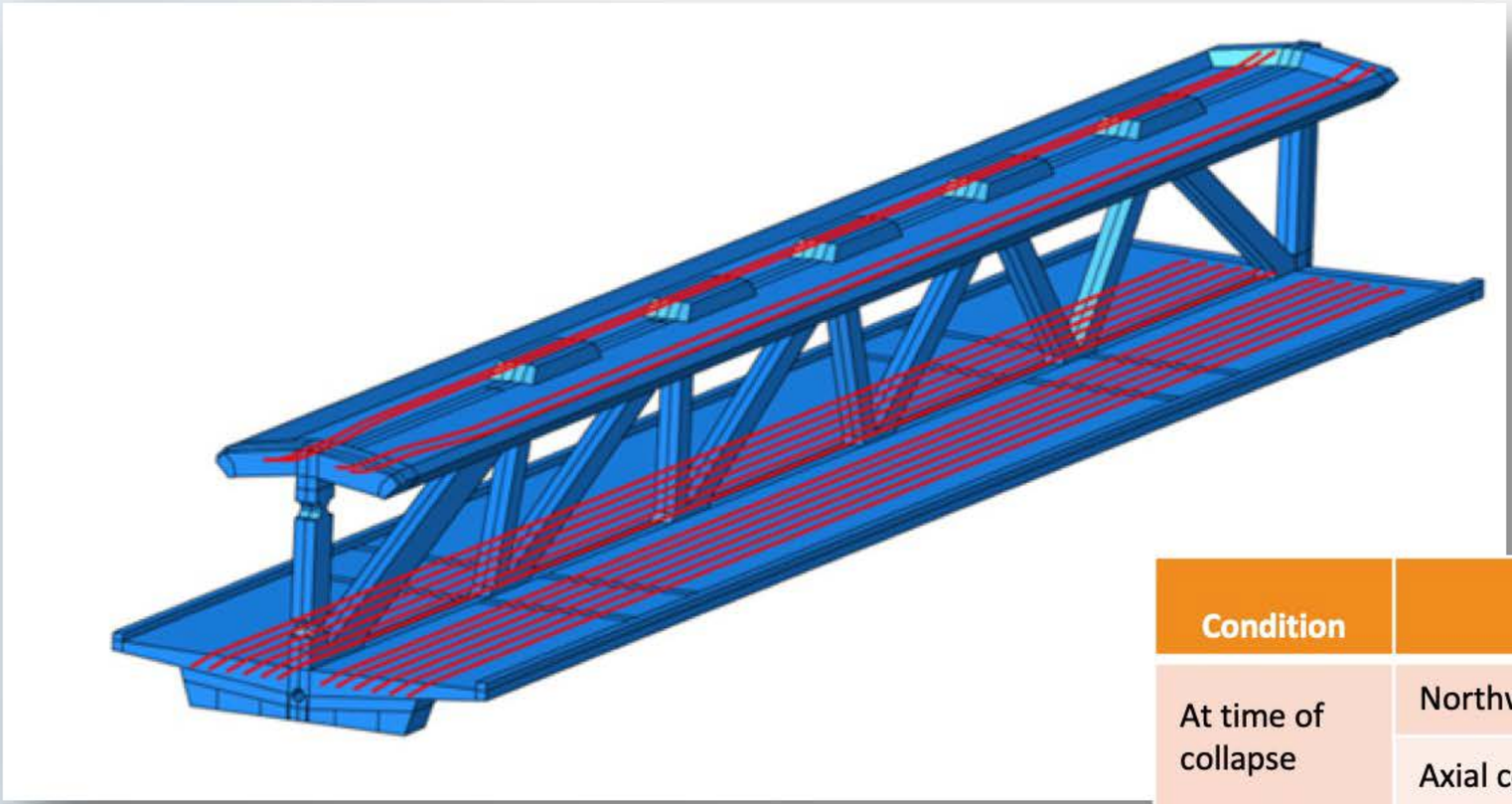
Code Evaluation of Member 11/12 Deck Connection

AASHTO Code:

$$V_{ni} = cA_{cv} + \mu\left(A_{vf} f_y + P_c\right)$$

- *c is the cohesion factor*
- *P_c is defined as the permanent compressive force*
- *For concrete that is roughened to amplitude of 0.25 inches:*
  - *c = 0.24 ksi; μ = 1.0*
  - $v \leq 0.25 f_c' \leq 1.5 ksi$
- *For concrete that is not intentionally roughened (but laitance is removed):*
  - *c = 0.075 ksi; μ = 0.6*
  - $v \leq 0.20 f_c' \leq 0.8 ksi$

Code Evaluation of Member 11/12 Deck Connection



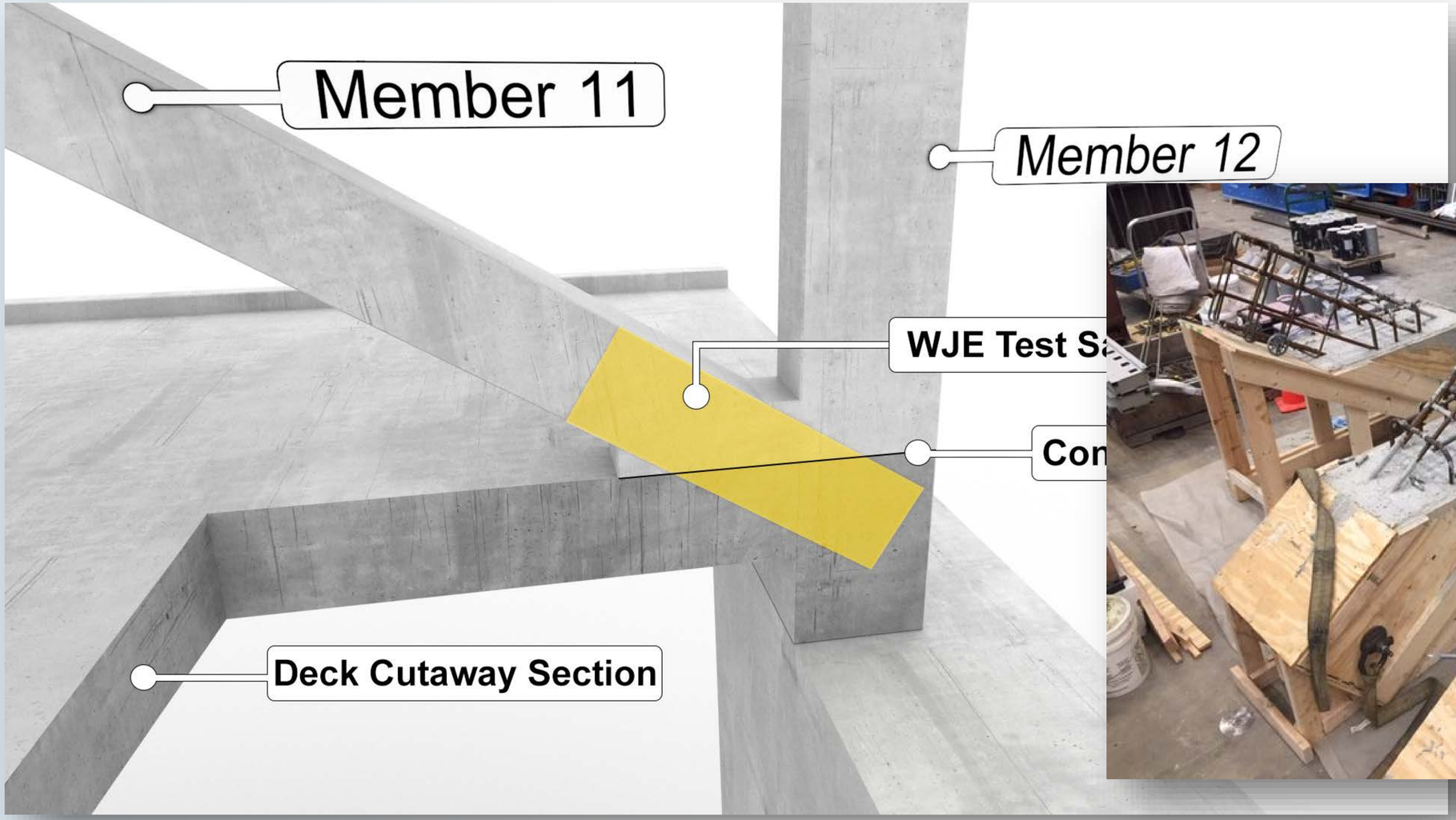
Abaqus Finite Element Model

Condition	Calculated Demand (kips)	WJE	FHWA
At time of collapse	Northward force at M11/12 connection	1677	
	Axial compression in member 11	**1743**	
Factored per AASHTO	Northward force at M11/12 connection	**1979**	1835*
	Axial compression in member 11	2236	
*Does not include construction live load			

Code Evaluation of Member 11/12 Deck Connection

Summary of Shear-Friction Resistance			
Factored Northward Force (kips)	**Surface Condition**	**Factored Resistance**	**Capacity/Demand Ratio (CDR)**
1979	Roughened	2150	1.09
	Not Roughened	1157	0.58

Interface Shear Transfer Testing: Specimens



Interface Shear Transfer Testing: Construction Joint Condition

400-9.3 Preparations of Surfaces: *Before depositing new concrete on or against concrete which has hardened, re-tighten the forms. Roughen the surface of the* ***hardened*** *concrete in a manner that will not leave loosened particles, aggregate, or damaged concrete at the surface. Thoroughly clean the surface of foreign matter and laitance, and saturate it with water.*

Interface Shear Transfer Testing: Construction Joint Condition

June 13, 2017, 7:48 a.m.– BPA to FIGG and MCM

"Please make sure we have FIGG blessing for the construction cold joints treatment…"

June 13, 2017, 7:56 a.m.– FIGG to BPA and MCM

"We have had previous communications with MCM regarding this topic and the FDOT specifications referenced below was to be followed. Let us know if you have any further questions."

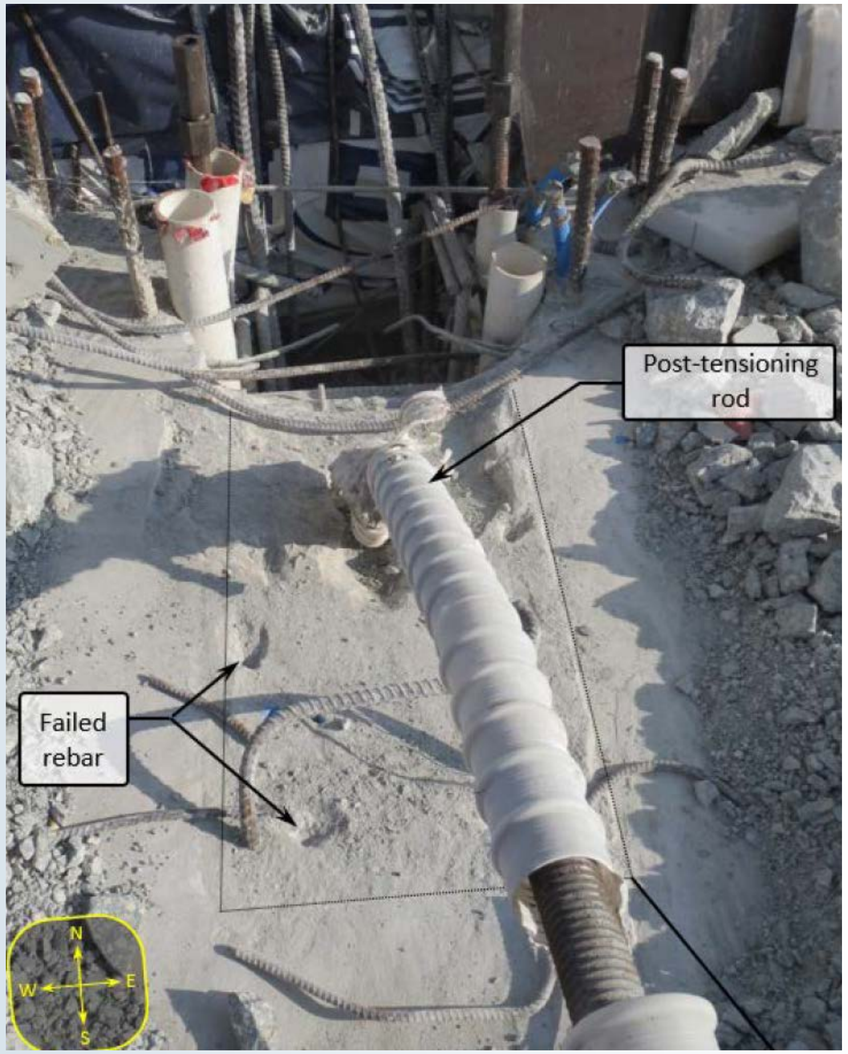
June 13, 2017, 8:04 a.m.– BPA to FIGG

"Thank you."

Interface Shear Transfer Testing: Construction Joint Condition

400-9.3 Preparations of Surfaces: *Before depositing new concrete on or against concrete which has hardened, re-tighten the forms. Roughen the surface of the* ***hardened*** *concrete in a manner that will not leave loosened particles, aggregate, or damaged concrete at the surface. Thoroughly clean the surface of foreign matter and laitance, and saturate it with water.*

Interface Shear Transfer Testing: Construction Joint Condition



FHWA Report on Member 11/12 Joint

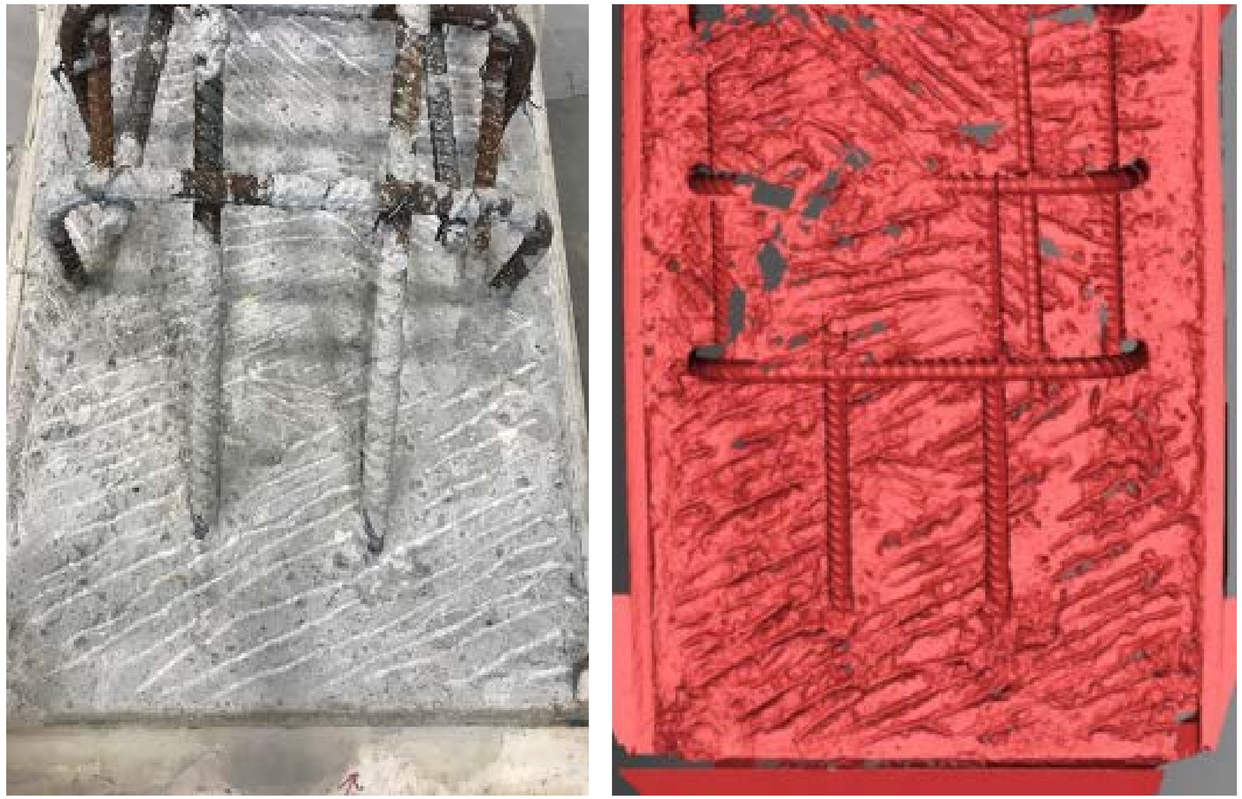
FHWA Conclusion: "The evidence indicates that the failure interface coincides with the original cold joint and that the cold joint was not intentionally roughened."

Interface Shear Transfer Testing: Construction Joint Condition

Photograph and laser scan of WJE Specimen 3 (As-placed)

Interface Shear Transfer Testing: Construction Joint Condition

Surface roughening trials



Photograph and laser scan of WJE Specimen 4 (Roughened)

Interface Shear Transfer Testing: Construction Joint Condition

Laser Scan Data: Standard Deviation (mm)	
Deck Specimen 1 (recovered by NTSB from site)	0.76
WJE Specimen 3 (as-placed)	0.94
WJE Specimen 4 (intentionally roughened)	2.16

Interface Shear Transfer Testing: Pre-Cracking

Stone-splitting wedge sets being used to create a crack across the construction joint of Specimen 6. Most specimens were pre-cracked.

Interface Shear Transfer Testing: Loading and Instrumentation

Linear displacement transducers across interface

University of Illinois Southward-Emery test machine (3 million pounds capacity)

Interface Shear Transfer Testing: Results (pre-cracked specimens)

Specimen	Peak Load (Average)	Member 11 Load at Failure	%
Roughened	2,594 kips	1,743 kips	149%
Non-roughened	1,455 kips	1,743 kips	83%

Interface Shear Transfer Testing: Results

Findings:

- ***Intentional roughening improved the shear capacity of the cracked interface by a factor of 1.78 compared to the as-placed specimens with a cracked interface.***

- ***If the construction joint were roughened as required by the project specifications, which were reconfirmed by email, the collapse would not have occurred.***

Conclusions

WJE Exceptions to NTSB/FHWA Findings

1. Considering the entire construction joint between member 11/12 and the deck, the design as shown on the contract documents meets the AASHTO Code.
2. If the construction joint were roughened as required by the project specifications, which were reconfirmed by email, the collapse would not have occurred.

Lessons Learned

AASHTO LRFD Bridge Construction Specifications: Article 8.8.2— Bonding

Unless otherwise specified in the contract documents, horizontal joints may be made without keys, and vertical joints shall be constructed with shear keys. Surfaces of fresh concrete at horizontal construction joints shall be rough floated sufficiently to thoroughly consolidate the surface and intentionally left in a roughened condition….

All construction joints shall be cleaned of surface laitance, curing compound, and other foreign materials before fresh concrete is placed against the surface of the joint. Abrasive blast or other approved methods shall be used to clean horizontal construction joints to the extent that clean aggregate is exposed. All construction joints shall be flushed with water and allowed to dry to a surface dry condition immediately prior to placing concrete.

Consider:

- *Specifying method for measuring surface roughness where ¼ inch amplitude is specified.*
- *Allowing 1) roughening of plastic concrete (followed by abrasive blast cleaning) or 2) roughening of the hardened concrete in a manner that does not damage surface.*

Lessons Learned

For Consideration by the AASHTO Committee on Construction…

1. Ensure that the Engineer of Record is on-site during construction.
2. Ensure careful inspection of construction joints, including joints between precast beams and cast-in-place decks.
3. Emphasize importance of closing traffic if there is any doubt about safety.

QUESTIONS?

FIU PEDESTRIAN BRIDGE COLLAPSE

AASHTO Committee on Construction VIRTUAL ANNUAL MEETING

Gary J. Klein, P.E., S.E. – Wiss, Janney, Elstner Associates, Inc.

Alan R. Phipps, P.E., S.E. – FIGG Bridge Engineers, Inc.

August 13, 2020