Investigation of the November 2, 2013 collapse of concrete beams at Fort Lauderdale-Hollywood Airport runway project

U.S. Department of Labor
Occupational Safety and Health Administration
Directorate of Construction

April 2014

Investigation of the November 2, 2013 collapse of concrete beams at Fort Lauderdale-Hollywood Airport runway project

April 2014

Report Prepared by
Mohammad Ayub, P.E., S.E.
Office of Engineering Services
Directorate of Construction

Table of Contents | Page No.

LIST OF FIGURES

Introduction

On November 2, 2013, at approximately 1:30 p.m. an incident occurred at the construction site of the runway expansion project of Ft. Lauderdale-Hollywood International Airport when five precast concrete beams fell off their bearings, and an additional five beams slid off their bearings but remained over the concrete bents. The beams fell some 25 feet onto the railroad tracks owned by Florida East Coast Railways which operates trains multiple times a day hauling commodities across Florida. The beams were placed just a couple of days earlier and were to support the actual runway consisting of a post-tensioned concrete slab. One employee sustained minor injuries but the potential for multiple fatalities was very obvious.

The Regional Administrator of Region IV asked the Directorate of Construction (DOC), in OSHA's National Office to provide technical assistance to the Ft. Lauderdale Area Office in investigating this incident and in determining the cause of the collapse. A structural engineer from DOC visited the incident site on November 13 to examine the failed concrete beams and observe the failure. He took photographs, obtained necessary construction documents, and discussed the events leading to the incident with the construction personnel. He also closely examined the remnants of the beams stored at a location near the incident site.

Subsequently, additional documents were requested from the joint venture managing the design-build contract. Interviews were conducted with various eyewitnesses to determine the mode and sequence of the failure. The following is our report.

We thank Ft. Lauderdale OSHA Area Office for their cooperation in this investigation, in particular Mr. Anthony Campos, Compliance Officer, for his tireless efforts.

The Project

The design-build project was to expand runway 9R-27L of the Ft. Lauderdale-Hollywood International Airport under the jurisdiction of the Aviation Department of Broward County, Florida. The design-build contract was awarded to a joint venture of Tutor Perini Corporation and Baker Concrete Construction of Florida. The joint venture was called Tutor Perini Fort Lauderdale-Hollywood Venture. HNTB of Miami, FL provided the structural and civil design for the joint venture.

The actual runway was 150 ft. wide plus 175 ft. of safety width on either side, making a total width of 500 ft. of concrete construction, see Fig. 1.

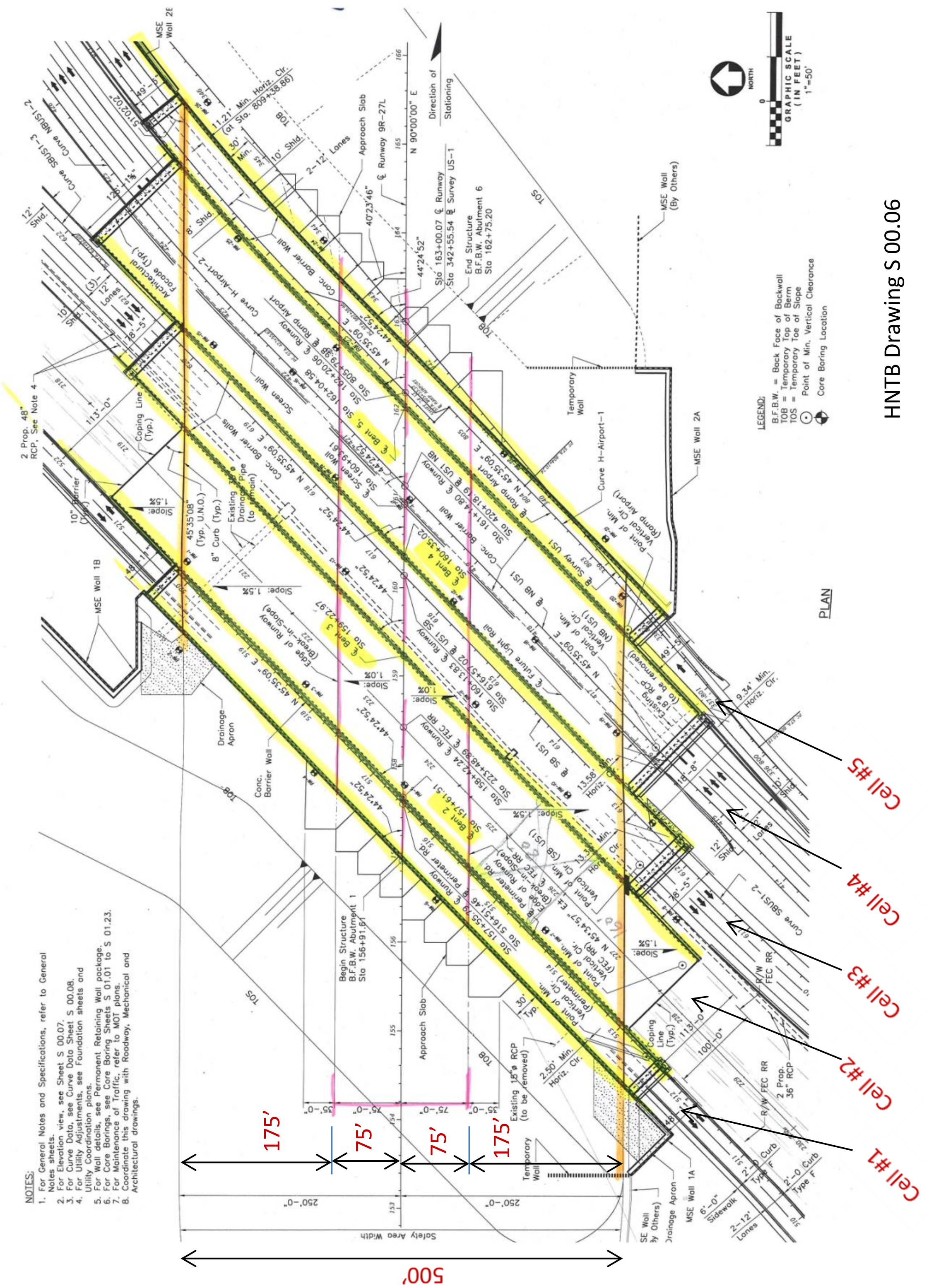
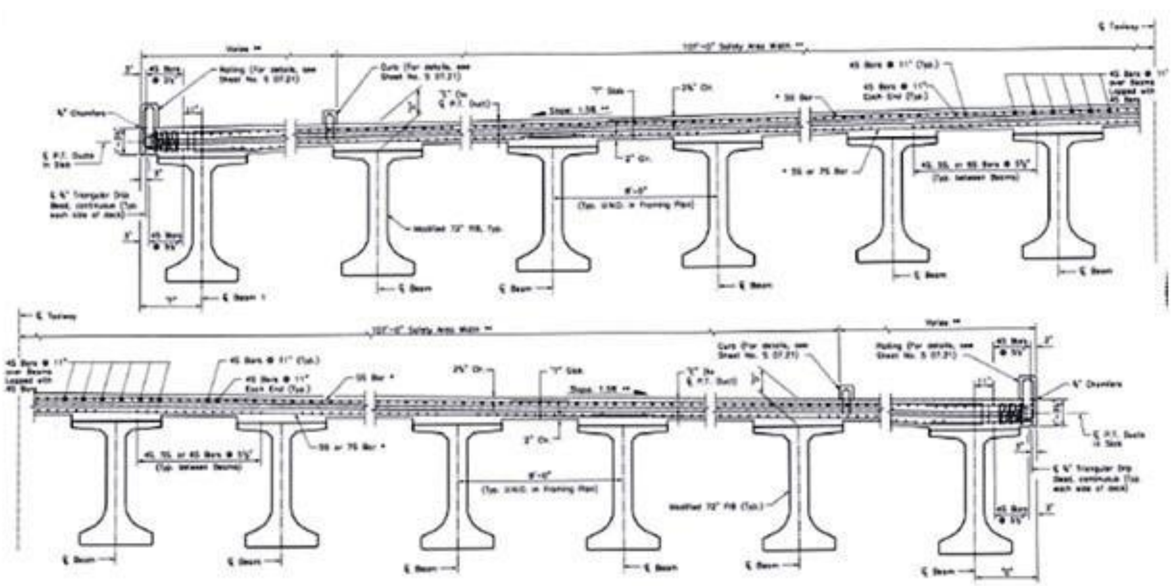


Fig. 1 Plan showing Cells #1 thru 5 and runway expansion

The runway expansion was not on grade but rather on a structural slab framed over concrete abutments and concrete bents similar to a bridge construction. For the purpose of this report, we will identify the structure as a runway bridge. The deck slab to be poured later was to consist of poured in place post-tensioned 15" thick slab over pre-stressed concrete girders generally spaced at 8 ft. on centers, see Fig. 2.



HNTB Drawing S 07.01

Fig. 2 Transverse cross section of the structure

The pre-stressed girders rested over abutments and bents. The abutments and bents were supported on 24" square pre-stressed concrete piles. The runway bridge had five spans of varying lengths ranging from 48 to 126 feet. The area below each span was identified as “cells” 1 thru 5. Except for cell 2, all the cells were designed to carry multiple lanes of vehicular traffic, see Fig. 3. Cell 2 had three railroad tracks for the South East Railroad, and no vehicular traffic lanes. The runway was oriented at an angle of approximately 44 degrees to the bents and abutments of the bridge, and was sloped 1.5% on either side of the center of the runway. The bents were also sloped from north to south.

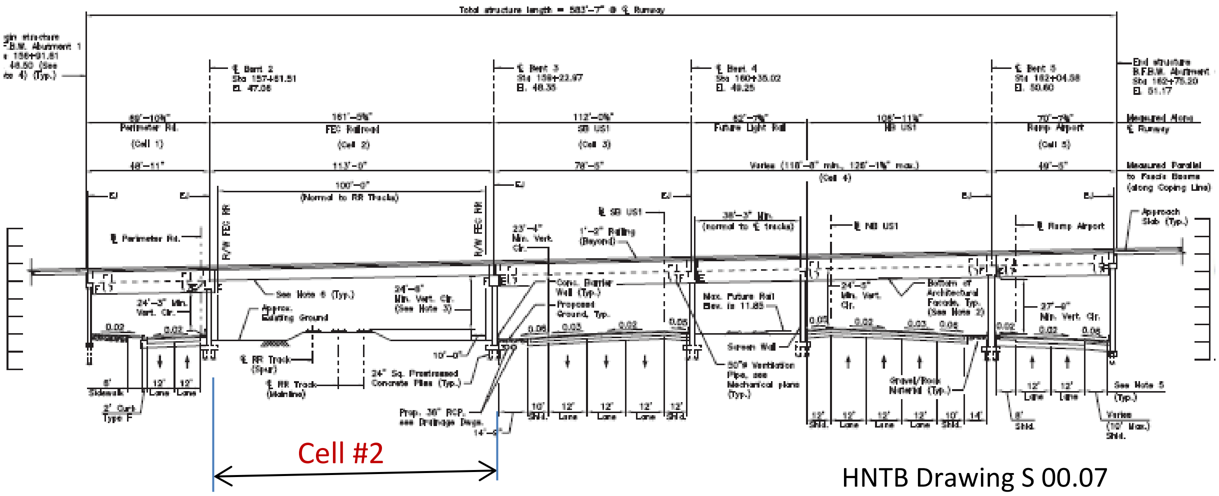


Fig. 3 Section showing cells

The following were the primary team members of the design-build project relevant to this investigation.

- Owner: Broward County, FL.
- Owner's representative: Broward County Aviation Department.
- Tutor Perini Fort Lauderdale-Hollywood Venture: The joint venture (JV) company of New Rochelle, NY is under direct contract with Broward County which is responsible for the entire construction. JV was also responsible for fabricating all precast concrete beams, all cast-in-place concrete, the placement of all bearings, etc.
- Baker Concrete Construction: This company of Ft. Lauderdale, FL was part of the joint venture as a junior partner.
- HNTB: The principal structural and civil consultant to design the expansion for the joint venture.
- Parsons Transportation Group: Construction Manager under direct contract with the Owner.
- Contex Construction Company, Inc., of Miami, FL: Responsible for erection of all the precast concrete beams.
- Cemex of Miami, FL: Supplied concrete for the project.
- D S Brown Company of North Baltimore, OH: Furnished all bearings for the precast concrete beams.

- Southern Florida Paving Group: This company from Davie, FL, was responsible for the site work, underground pipes, sanitary pipes and fire hydrant pipes, etc. They installed the fire hydrant lines.
- Construction Engineering Consultants, Corp. This consultant of Hollywood, FL, was retained by Contex to design the temporary bracings for the concrete beams.
- Gator Engineering Associates Inc.: The engineering company located in Cooper City, FL, was retained by Southern Florida Paving to design the framing to suspend the water main line between the two concrete beams.

Events Leading to the Incident

The discussion here will essentially be limited to Cell #2. Contex Construction Company Co. began placing precast concrete beams in Cell # 2 sometime in October 2013, spanning bent 2 and bent 3. The bents consisted of concrete walls supported over pile caps. There were four fabricating plants to manufacture pre-stressed precast beams for the project. The beams for Cell #2 came from two plants; one in Medley, Florida and the other from the plant established at the site by the joint venture. The beams were 6 ft. deep with top and bottom flanges 4′-4" wide and 3′-6" wide, respectively, and were approximately 112 ft. long, see Fig. 4.

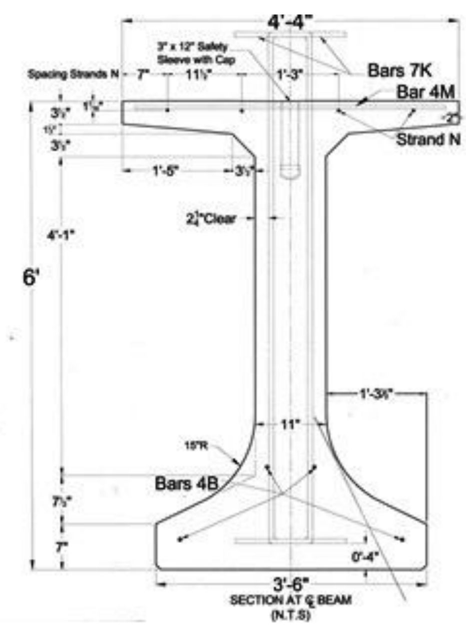


Fig. 4 Typical concrete beam

The erection began from the north end, also known as taxi way end, progressing towards the south end, also known as the runway end. Before the placement of the beams began, the joint venture had placed the bearing pads on the pedestals on bent 2 and bent 3. There were 115 beams to be placed in cell #2 spaced at 8 ft. on centers, see Fig. 5. Each beam had a mark and a unique identification for correct placement. Up to the time of the incident, 93 beams had been placed, see Fig. 6. After all the precast beams were placed, a concrete deck was to have been cast over them to provide the surface for the runway.

Ft. Lauderdale International Airport
Expansion of Runway 9R-27L

Photo from Consultant

Fig. 5 Aerial view on Oct. 25, 2013

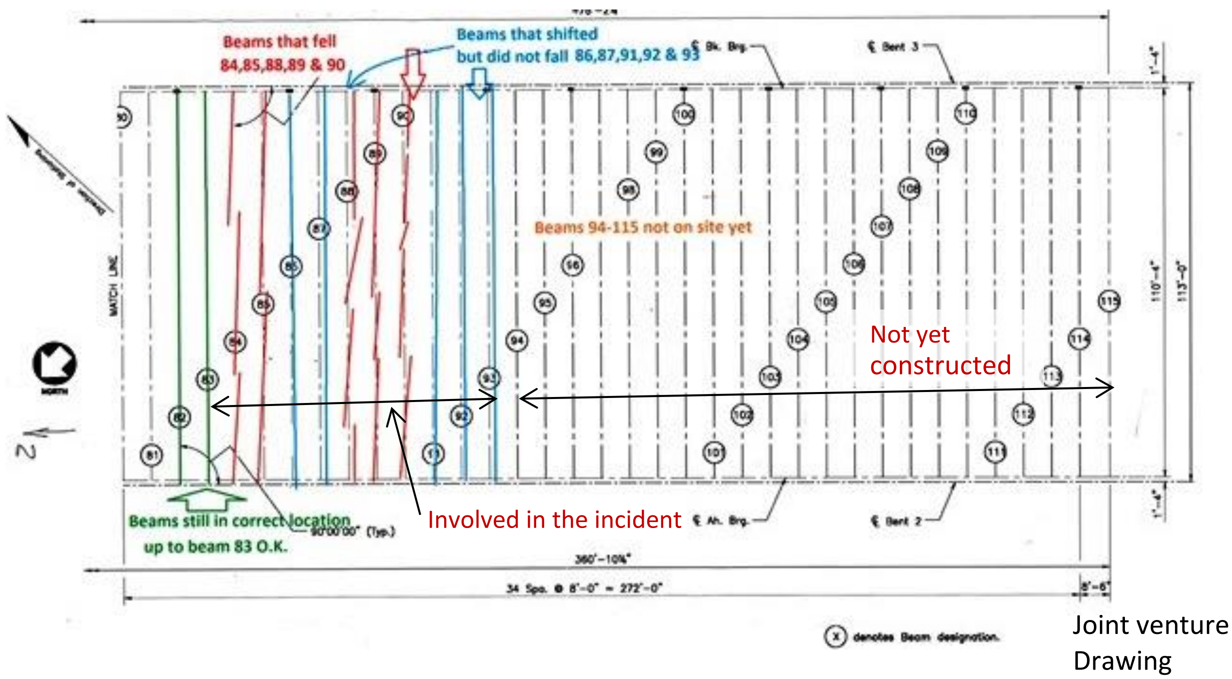


Fig. 6 Cell #2 Plan showing concrete beams involved in the incident

The first beam on the north end was marked as 1 and the last was marked as 93. Twenty-two (22) additional beams remained to be placed. It takes approximately 20 to 30 minutes to hoist a beam and place it at its final location, but due to railroad traffic in Cell # 2, it took longer due to the need to suspend work during train passage.

Up to the time of the incident, beams 1 thru 93 in Cell #2 had been installed. But the diaphragms between the beams 1 thru 93 were not yet installed, although forming for the diaphragm and placement of rebars had begun. Beams 82 thru 93 were involved in the incident that occurred on November 2, 2013. The last batch of beams (86 thru 93) was erected approximately on October 29-30, 2013. Beams 82 thru 85 were erected much earlier. As part of the temporary fire suppression system, a 12" diameter water main ductile iron pipe was to be placed over bent 2 and bent 3, located between the bottom flanges of beams 83 and 84. The overhead pipes were then connected to the riser pipes on the east and west sides. The riser pipes were then connected to the horizontal pipes running towards the south at the foot of the bents 2 and 3 supported over grade. It is understood that the grade was not compacted.

Southern Florida Paving Group was responsible for erecting the pipe. The pipe was supported between the two beams (83 and 84) over steel channels spaced at approximately 8 ft. on centers with all-thread bolts.

The installation of the pipe began on October 31, and by November 1, the pipe was completely installed. The next day, November 2, 2013, there were no activities in Cell #2, but in Cell #1, concrete beams were being installed approximately 300 feet north to the last southern beams of Cell #2. The crane hoisting those beams was approximately 30-40 ft. to the west of abutment 1.

The Incident

At approximately 1:30 p.m. on November 2, 2013, five concrete beams (84, 85 and 88 thru 90) suddenly fell to the ground over the railroad tracks. Another set of five beams (86, 87, and 91 thru 93) shifted and overturned but remained on the bents. The fall of the concrete beams created havoc, but due to lack of activity in cell # 2, there were no injuries, see Fig.s 7 thru 12.

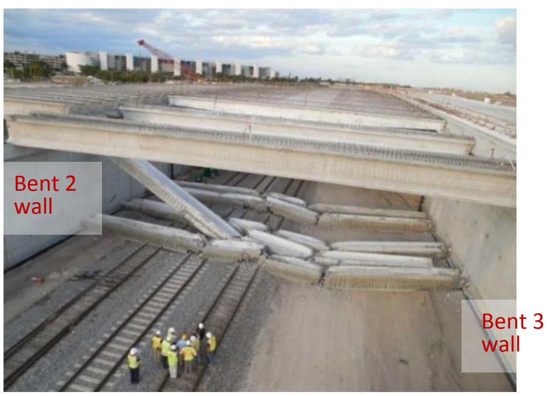


Fig. 7 Fallen beams

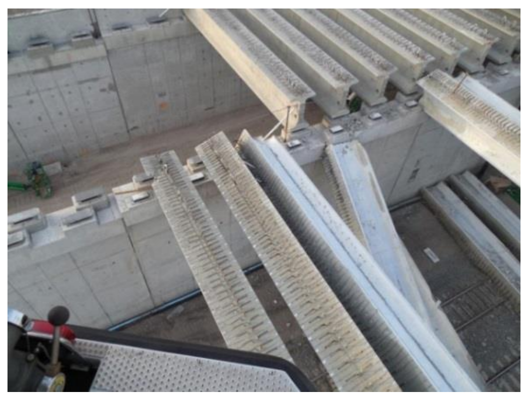


Fig. 8 Fallen and displaced beams

Fig. 9 Fallen beams

Fig. 10 Fallen beams

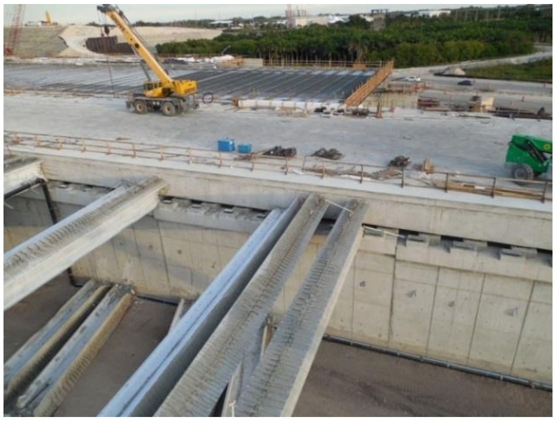


Fig. 11 Displaced beams

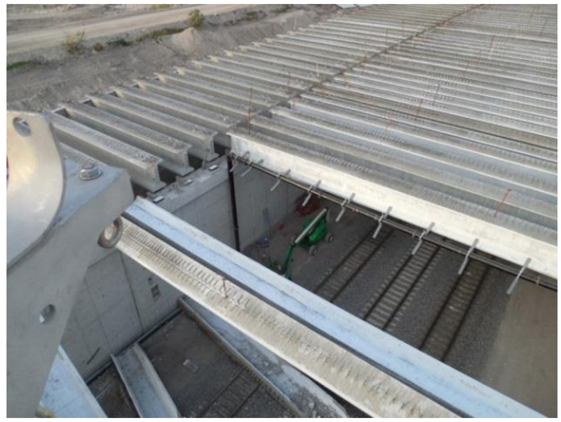


Fig. 12 Displaced beams

As beam 84 fell off the bearing, the channels supporting the pipe lost their support but were hanging in an inclined manner, still connected to the pipe. The pipe lost its support as the channels were no longer supported at both ends. The pipe did not fall off as it gained support by the risers placed over the grade, see Fig.s 13 thru 17, below. The pipe was anchored to the bent walls with U straps which also failed, see Fig.s 16 and 17. The pipe running on grade at the foot of the east and west bents were loosely anchored to the bent walls and fractured at multiple locations, see Fig.s 18, 19 and 20.

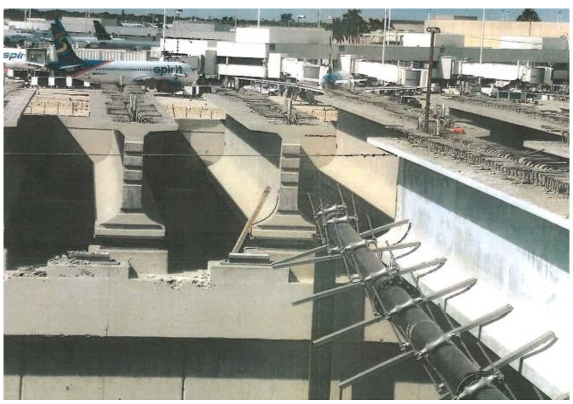


Fig. 13 Water pipe and steel channels support

Fig. 14 Water pipe and steel channels support

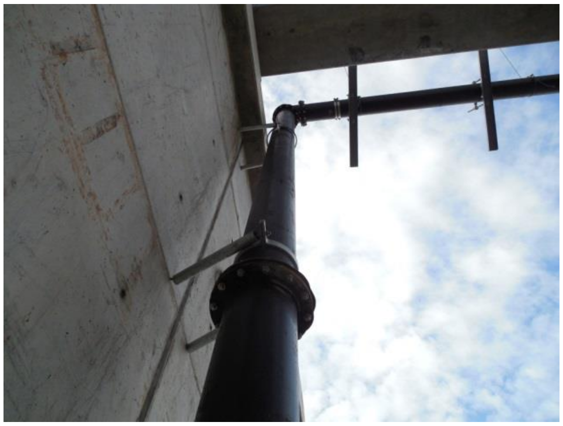


Fig. 15 Water pipe and steel channels support

Fig. 16 Failed clamp for water pipe

Fig. 17 Failed clamp for water pipe

Fig. 18 Fractured 12" Water pipe

Fig. 19 Fractured 12" Water pipe

Fig. 20 Fractured 12" Water pipe

After the incident, the site was cleared quickly due to the operation of trains. There were extensive marks on the stainless steel finish on the bottom of the sole plate. The fractured concrete appeared to be in good condition, free of any voids, honeycombing, etc.

Post-incident observations indicated that there were no horizontal bracings placed over the top flange of the exterior pair of beams at the center of the span, as had been directed by the specialty engineer retained by the concrete beam erector. Horizontal braces over the top flange of the beams at each end of the exterior pair of beams were also not provided. However, there are indications that the last beam (93) might have been provided with a diagonal brace at each end. HNTB required that all beams be provided with a horizontal brace at the center of the span to reduce their unbraced length, see Fig. 21. Such braces were not provided. Furthermore, the bearings were not provided with any retainers to restrict their transverse movement. Also, beam 84 was not provided with any diagonal braces to prevent its movement.

TABLE OF TEMPORARY BRACING VARIABLES

CELL NO.	Lb. MAXIMUM UNBRACED LENGTH (FT)	HORIZONTAL FORCE AT EACH BEAM END AND ANCHOR BRACE (KIP)	HORIZONTAL FORCE AT EACH INTERMEDIATE SPAN BRACE (KIP)	OVERTURNING FORCE AT EACH BEAM END AND ANCHOR BRACE (KIPxFT)	OVERTURNING FORCE AT EACH INTERMEDIATE SPAN BRACE (KIPxFT)	BRACE ENDS PRIOR TO CRANE RELEASE?	TOTAL NUMBER OF BRACES
1	45.00	6.43	N.A.	33.36	N.A.	No	---
2	55.17	6.71	18.03	37.70	29.37	No	---
3	37.88	4.61	12.38	31.35	24.70	No	---
4	58.00	7.06	18.96	38.68	29.70	No	---
5	45.50	6.50	N.A.	34.95	N.A.	No	---

BEAM TEMPORARY BRACING NOTES:

Based on investigation of the beam stability, temporary bracing as shown in the 'TABLE OF TEMPORARY BRACING VARIABLES' and Design Standard Index No. 20005 is required. The Table and following information is provided to aid the Contractor in design of beam temporary bracing:

1. Design the bracing members and connections to transfer both compressive and tensile forces equal to the horizontal forces given in the 'TABLE OF TEMPORARY BRACING VARIABLES'. Also design bracing members and connections to be capable of resisting the overturning forces given in the Table, non-simultaneously with horizontal forces. Assume that horizontal bracing forces are applied perpendicular to the beam web at mid-height of the beam, and assume that overturning bracing forces are applied at the centerline of the beam at the top of the top flange.
2. The horizontal brace forces have been determined by application of the Construction Inactive Wind Load as listed in the 'TABLE OF WIND LOAD VARIABLES'. The overturning brace forces have been determined by application of the Construction Active Wind Load as listed in the 'TABLE OF WIND LOAD VARIABLES' plus the assumed construction loads shown in the 'TABLE OF ASSUMED CONSTRUCTION LOADS'. It is the Contractor's responsibility to re-calculate the bracing requirements if the actual construction loads exceed the assumed loads shown, or if the finishing machine wheel location from the edge of the deck overhang exceeds the value listed.
3. The temporary bracing at the ends of the beams shall be installed prior to crane release if indicated in the 'TABLE OF TEMPORARY BRACING VARIABLES'. Beams shall not be left un-braced during non-work hours. Bracing at the ends of the beams shall remain in place until the diaphragm concrete reaches 2500 psi. The temporary intermediate bracing, if required, shall remain in place until bridge deck concrete reaches 2500 psi.
4. The exposure period (defined as the time period for which temporary load cases of the superstructure exist) is assumed to be less than one year. Horizontal bracing forces, as specified in the 'TABLE OF TEMPORARY BRACING VARIABLES', are not valid if the exposure period is more than one year; for this case the Contractor shall re-calculate bracing requirements.
5. Horizontal and overturning forces are factored per the Strength III limit state for construction.

From HNTB drawing S 3.56

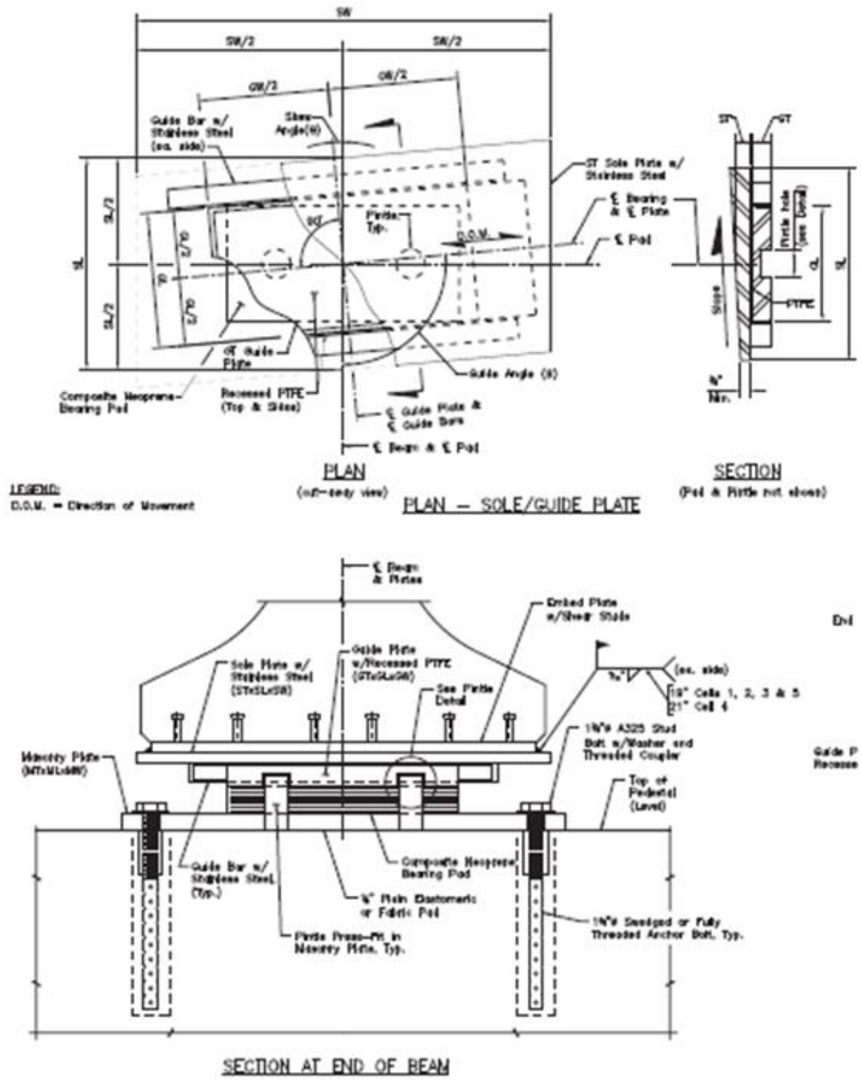
Fig. 21 Table of temporary bracings prepared by Engineer of Record

Discussion

The following is a discussion of the pertinent issues involved in the incident.

1. <u>Bearings</u>:

For beams No. 84 thru 93, there were two types of bearings, identified as Type III and Type IV. All beams bearing on Bent 2 had Type IV bearings. Beams bearing on Bent 3 were also Type IV except for beams 85, 89 and 93. Type IV bearings permitted both transverse and longitudinal movements of the beams, whereas Type III bearings prevented longitudinal movements but permitted transverse movements. Both bearings were of similar construction except for the guide plates of Type III to prevent longitudinal movements. Typical details for Type III and IV are provided below (see Fig.s 22 and 23).



From HNTB drawing S 2.51

Fig. 22 Typical detail of bearing type III

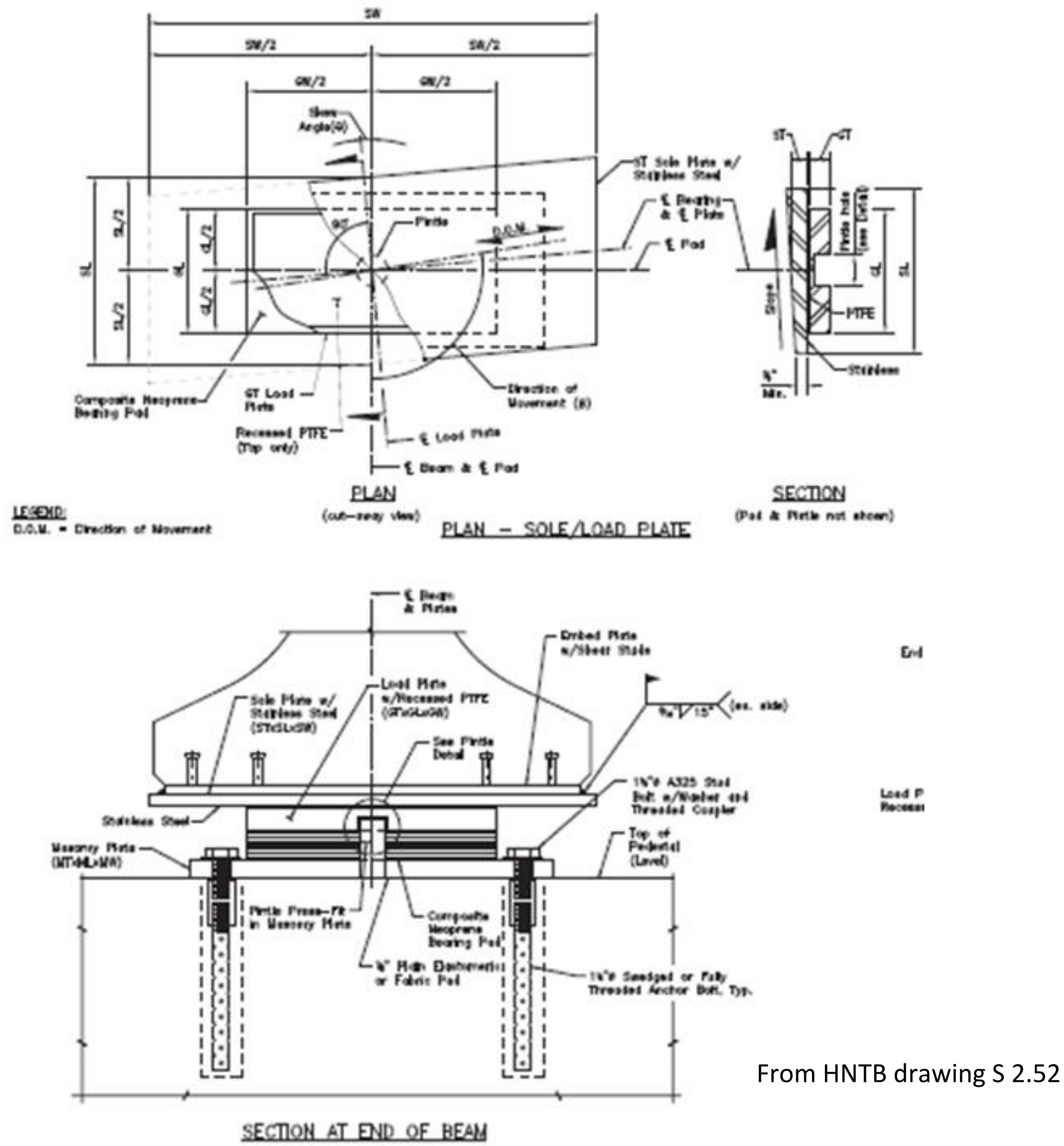


Fig. 23 Typical detail of bearing type IV

There were five parts of the bearing, i.e., masonry plate, composite neoprene bearing pad, load plate with recessed polytetrafluoroethylene (PTFE), sole plate with stainless steel backing having #8 mirror finish, and steel plates embedded in the precast beams. Masonry plates were anchored to the bents by anchors embedded in the concrete walls of the bents. On the center of the masonry plates were composite neoprene pads 12" x 24", approximately 3" thick consisting of five layers of neoprene. The pads were secured to the masonry plates with two pintles. On top of the neoprene pads were the steel load plates bonded with recessed PTFE at the top with silicone grease. On the top of the PTFE was the sole plate with a stainless steel mirror finish at the bottom to mate with the PTFE for ease of sliding with a coefficient of friction no higher than 4%. The sole plate was welded to the embedded plate which is cast in the concrete beams.

Type IV bearings provide movement in multiple directions. Type III bearings are restricted to transverse movements only. The longitudinal movements are contained by welding guide bars to the sole plate, see Fig. 22 above.

The use of PTFE and a mating stainless steel with a mirror finish are well recognized and accepted in bridge construction where longitudinal or transverse movements are desired. All bearings were manufactured by D S Brown Company of Ohio, and were individually shipped with all five pieces of the bearings bundled together. The bearings were not opened until they were placed when the sole plate was ready to be welded to the embeded plate of the concrete beams, see Fig. 24.

Fig. 24 Typical bundled bearings

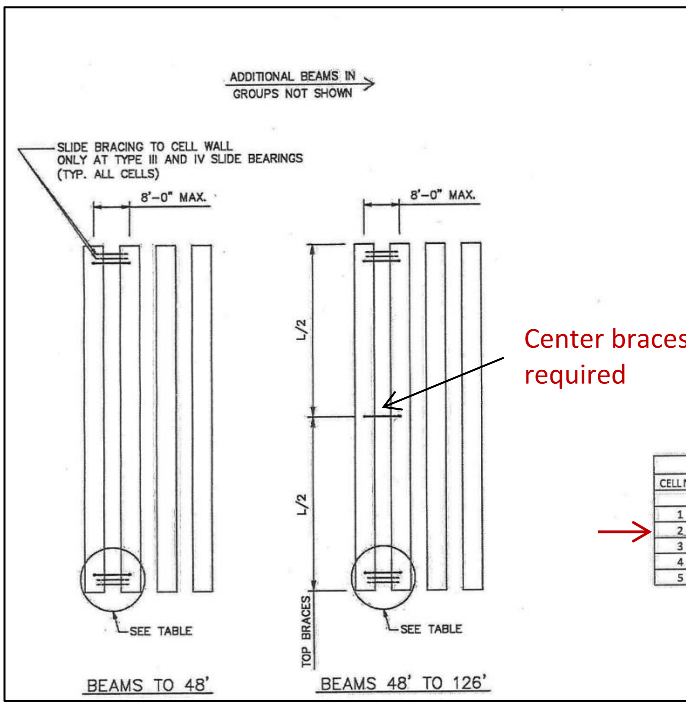
As stated earlier, the coefficient of friction, as per the construction documents was required to be no higher than 4%. However, the actual coefficient of friction as per the tests of the bearings conducted by the fabricator indicated an average coefficient of friction of only 1.1%. If the four highest and two lowest test values are ignored, the average comes to 0.93%, see Fig. 25, which would indicate that a meager lateral force of only 725 pounds could slide the concrete beam.

This information on the low coefficient of friction was available to the Joint Venture but was not forwarded to other contractors for their consideration during construction. This was a serious lapse of judgment on the part of the Joint Venture. Parsons, as the construction manager, should have taken the initiative in a proactive role to ask the Joint Venture to provide such information to the contractors engaged in erecting the beams. Parsons was in a unique situation to assist as they were fully aware of the actual site conditions prevailing in Cell # 2 as their inspectors closely examined the progress of the construction.

Test ID	Cofficient of Friction %	Select if within Mean+- SD
63	1.76	
64	0.81	0.81
65	1.91	
66	1.66	1.66
67	1.15	1.15
68	2.66	
69	1.33	1.33
71	0.83	0.83
72	1.01	1.01
73	0.96	0.96
74	0.76	0.76
75	0.86	0.86
76	0.71	0.71
77	0.51	0.51
78	0.53	0.53
79	0.37	
80	0.62	0.62
81	0.47	
82	1.11	1.11
83	0.8	0.80
84	0.79	0.79
85	1.18	1.18
87	1.14	1.14
88	2.59	
Average	1.105	**0.9311**

Fig. 25 Test results of coefficient of friction

2. Contex retained a specialty engineer, Construction Engineering Consultants (CEC), to design temporary bracings for the precast concrete beams. CEC produced three drawings with varying dates, the original date being July 29, 2013. A table of bracing requirements was prepared, see Fig. 26, below. For cell No. 2, braces were required for the end locations and at the center of the span for the exterior pair of beams only. Interior beams were exempted by CEC from having any temporary bracings on the premise that they would be shielded by adjoining beams, and would not be subjected to any appreciable wind loads. These beams were 6 ft. deep, spaced at 8 ft. on center with a top flange 4′-4" wide. CEC's drawings called for a pair of horizontal bracings at the center of the two exterior beams see Fig. 26 and 27**.** These bracings were not installed by Contex. CEC also called for horizontal braces between the two exterior beams at their ends. These braces were also not installed. The lack of braces mentioned above is significant, but this is not believed to have contributed to the incident of November 2, 2013. However, it would have prevented beams 92 and 93 from sliding and overturning.



GENERAL NOTES:

1. THIS BRACING IS FOR WIND LOADS ONLY. LOADS TO BEAMS FROM THE DECK FORMING OPERATION WILL BE COVERED IN A SEPARATE SUBMITTAL.
2. FACTORED DESIGN LOAD FOR WIND IS 0.286 K/FT. MAXIMUM UNBRACED LENGTHS ARE THOSE GIVEN ON SHEET S 07.51 OF THE CONTRACT PLANS.
3. WIND BRACING IS REQUIRED AT THE NORTH AND SOUTH ENDS OF ANY GROUP OF BEAMS PLACED ON THE BRIDGE. BRACING MUST BE INSTALLED AND FUNCTIONAL DURING NON-WORK PERIODS

   A GROUP OF BEAMS IS DEFINED AS A SERIES OF ERECTED BEAMS IN WHICH ALL BEAMS ARE AT THEIR NOMINAL SPACING WITH NO GAPS OR BEAMS OMITTED. BRACING IS REQUIRED ONLY BETWEEN THE TWO PAIRS OF EXTERIOR BEAMS IN A GROUP.
4. BRACING TO THE CELL WALL TO PREVENT SLIDING FROM WIND (SLIDE BRACING) IS REQUIRED AT ANY EXTERIOR BEAM END WHERE THERE IS A TEFLON/STAINLESS SLIDE BEARING THAT ALLOWS TRANSVERSE MOVEMENT (BEARING TYPES III AND IV). SEE DETAILS S-1, S-2 AND S-3.
5. CENTER TOP BRACE ANCHOR BOLTS BETWEEN K-BARS TO AVOID BARS 4M. LOCATE BARS IN BEAM AND CAP BY DIMENSIONS OR OTHER MEANS BEFORE DRILLING.
6. REMOVE POWERS WEDGE BOLTS AFTER USE AND PATCH HOLES PER STANDARD SPECIFICATIONS.

TABLE OF BRACING REQUIREMENTS

CELL No.	BEAM LENGTHS	TOP BRACE DETAIL		SLIDE BRACE DETAIL	Lb MAX.
		INTERMEDIATE BRACES	END BRACES		
1	46'-11 1/2"	N/A	T-1	S-1	45'-0"
2	112'-4 3/4" to 112'-5"	T-2	T-1	S-2 (*)	55'-2"
3	PLAN PREVIOUSLY SUBMITTED	N/A	N/A	N/A	N/A
4	118'-1" TO 125'-3 3/4"	T-2	T-1	S-2 (*)	58'-0"
5	47'-5 1/2"	N/A	T-1	S-1	45'-6"

(*) USE DETAIL S–3 AT END OF CELL WALL

Fig. 26 Temporary bracing prepared by consultant for the beams erector

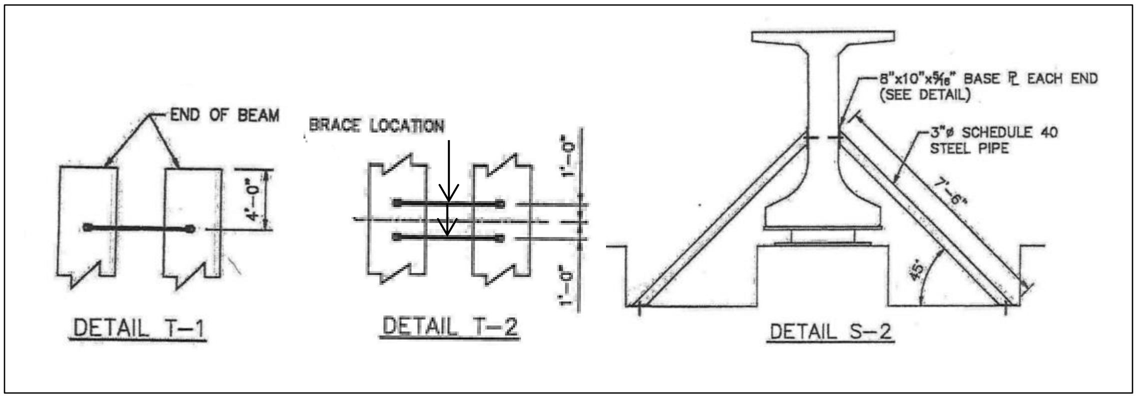


Fig. 27 Bracing details prepared by consultant

HNTB, as the engineer of record (EOR), in compliance with the Florida Department of Transportation (DOT) requirements, and structures design bulletin C10-01, required that contractor design horizontal bracings for the beams in Cell #2 at their mid-span. The specialty engineer, CEC, did not follow the instructions contained in the EOR drawing S 03.56, see Fig. 21. Instead, CEC required that center bracings be provided only at the exterior pair of beams. If center bracings were provided as directed by EOR until the vertical diaphragm was poured, they would have restrained the beams from sliding, and this incident could have been prevented. It was reported that at places, the joint venture (JV) would place the restraints on the bearings but would remove them as soon as the crane unloaded the weight of the beam on the bearings.

3. Six months before the incident, CEC was aware of the fact that the beams in cell # 2 were placed on Teflon with silicone grease/stainless steel bearings, prone to sliding, and recommended to the JV, Contex and others that either the beams be restrained or continuously monitored (see the letter, Fig. 28). At the request of the JV, CEC prepared a drawing for the restraints, and JV did fabricate approximately 50 bearing restraints, but did not actually place all of them on the bearings. JV was responsible to fabricate and place the restraints on the bearings. If JV had provided the bearings with restraints until the vertical diaphragm was poured, this incident could have been prevented. Typical bearings restraints are shown in Fig. 30 at the northern end of cell #2. Pouring of vertical diaphragms was supposed to follow closely the placement of the beams but in Cell #2,

even after 93 beams had been placed, the diaphragm was not yet poured, although forming had started.

Michael Bone

From: Michael Bone
Sent: Friday, May 03, 2013 12:15 PM
To: Olga Contex (omartell@contexflorida.com)
Cc: 'Robert de Leon'; 'jsanz@contexflorida.com'; Bob Demotte; 'Gavin Lichthardt'; Hernandez, Michael; Francis Bain; Kellen Bone
Subject: Girders on Slide Bearings

Tracking:

Recipient	Read
Olga Contex (omartell@contexflorida.com)	
'Robert de Leon'	
'jsanz@contexflorida.com'	
Bob Demotte	
'Gavin Lichthardt'	
Hernandez, Michael	
Francis Bain	Read: 5/3/2013 12:27 PM
Kellen Bone	Read: 5/3/2013 2:20 PM

Olga,

I want to express a word of caution to all regarding those FIB-72 beams that are on Teflon/stainless slide bearings. The Coefficient of Static Friction for these bearings is on the order of 0.08. It is recommended that any beam on a slide bearing be restrained or be continuously monitored for movement until the beam is tied to a fixed bearing by the diaphragms. Experience has shown that beams on Teflon bearings can translate due to vibration (railroad, pile driving), thermal effects, supports out of level or a combination of these.

Our wind bracing calculations have handled the slip bearings by bracing the exterior beams in a group. Interior beams pick up only a slight wind load and are stable without bracing.

Best regards,

Construction Engineering Consultants

Michael C. Bone, P.E.
Phone: (954) 922-6917 Fax: (954) 922-3755
Email: mbone@ceconstruct.com
Web: www.ceconstruct.com

Fig. 28 Letter from consultant warning the possibility of sliding

4. Florida Paving Group retained a specialty engineer, Gator, to design the support system of the 12" water main to be placed between beams 83 and 84. Gator designed the support for the pipe over steel channels spanning between the sloping bottom flanges, see Fig. 29. Gator had no knowledge of the sliding bearings over which the concrete beams were

seated because Gator was not provided with construction drawings. The steel channel with bottom roller was assembled on the ground, and then placed between the concrete beams. A crane dropped the black pipe over the steel channel and connections were made. Then pipe risers were brought in and fastened to the horizontal pipe. The dead load of the pipe was transferred to the sloping bottom flanges of concrete beams through steel channels. Our calculations indicated that a horizontal thrust would be created which could slide the beam horizontally if the coefficient of friction is at the bearing in the low range of 1 to 1.5%. It must be noted here that the bottom horizontal run of the pipe was placed just over the uncompacted grade, and the risers were not supported over concrete pads. Therefore, it is believed that the risers could be hanging from the horizontal pipe, thus adding more loads to the pipe supports.

Gator did not consider the lateral thrust of the pipe support on the concrete beams. It is understood that Gator was not provided any information about the bearings. If the bearing information was provided or if Gator had asked for the information, it is believed that Gator would have designed it differently or would have highlighted the need to restrain the bearings against movement.

It is not certain whether HNTB reviewed the design of the pipe support system prior to the incident. The inspector for the construction manager saw the drawing and informed her supervisor about the existence of such a drawing, but no follow-up action was taken by the construction manager. It was certainly known to both, the JV and the construction manager how the pipe was being supported. Neither performed any inquiry to determine if the design had undergone proper review. If that had been done, this incident could have been avoided.

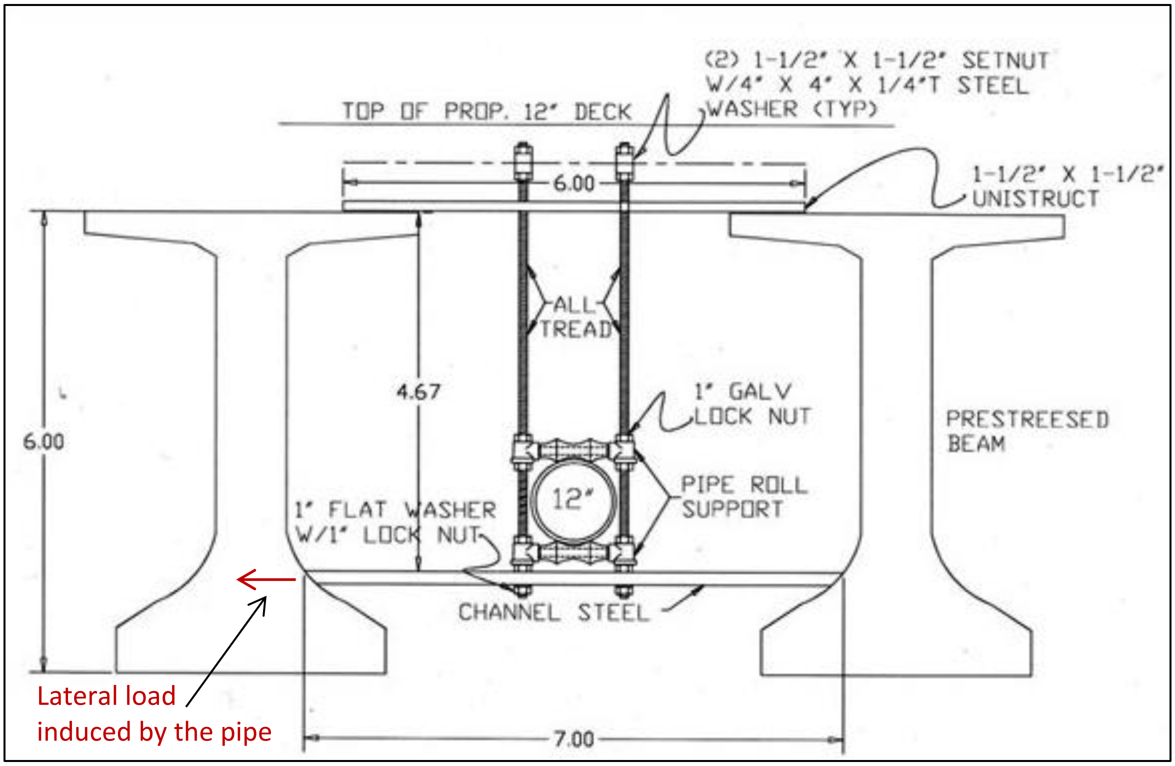


Fig. 29 Drawing prepared by the consultant of Florida Paving Group after the incident

Fig. 30 Pipe support at the north end of cell #2

5. Parson Transportation Group (Parsons) was retained by the owner to be their representative at the site, to manage their contract with the joint venture, and to ensure quality assurance. Parson's inspectors knew of the support of the water pipe over the bottom flanges of the concrete beams, and inspected them. Parsons failed to ensure that

the plan being followed had undergone proper review by the JV and HNTB. Parsons also failed to assure that the plan was signed by the engineer who designed the support system. If Parsons had asked the JV for a proper review, this incident could have been avoided because HNTB would have noticed the lateral load being imposed on the concrete beams on the sliding bearings. Parsons' inspector informed Parsons' main office about the framing of the pipe, and still no action was taken by Parsons. Parsons knew or should have known that the requirement for the pair of bracings at the top flange of the exterior beams was not being followed, and they still failed to raise the issue with the JV. Parsons' inspectors knew of the restraints for the bearings, and still the issue was never raised to the JV. Florida Department of Transportation's Specification 5-1.4.5.7 required that "At a minimum, provide temporary bracings at each end of each beam or girder", see Fig. 31.

Parsons failed to take notice of the above requirements and did not ensure that the above specification was followed at the site. Parsons did not take a proactive role in assuring that the County's interests were safeguarded, and that the construction was carried out as per industry standards. Thus, Parsons was negligent in its duties.

6. The Joint Venture: Six months before the incident, the JV was informed by the specialty engineer of the need to restrain the bearings, but the JV failed to take proper follow-up actions. It is not clear whether the information was passed on to all the subcontractors. The JV failed to get a proper review of the water pipe support drawing which was not even signed by the designer. If a proper review had been conducted, this incident would not have occurred. The JV did not take any steps to assure that the Florida State Department of Transportation's requirement of minimum bracings was followed by the contractors. Thus, the joint venture was negligent.

Florida DOT Standard Specifications for Road and Bridge Construction
http://www.dot.state.fl.us/specificationsoffice/Implemented/SpecBooks/2014/Files/2014eBook.pdf

5-1.4.5.4 Temporary Works: For Construction Affecting Public Safety, submit to the Engineer of Record shop drawings and the applicable calculations for the design of special erection equipment, bracing, falsework, scaffolding, etc. Ensure that each sheet of the shop drawings and the cover sheet of the applicable calculations is signed and sealed by the Specialty Engineer. Transmit the submittal and copies of the transmittal letters in accordance with the requirements of 5-1.4.5.1 through 5-1.4.5.3, as appropriate.

5-1.4.5.7 Beam and Girder Temporary Bracing: The Contractor is solely responsible for ensuring stability of beams and girders during all handling, storage, shipping and erection. Adequately brace beams and girders to resist wind, weight of forms and other temporary loads, especially those eccentric to the vertical axis of the products, considering actual beam geometry and support conditions during all stages of erection and deck construction. At a minimum, provide temporary bracing at each end of each beam or girder. Develop the required bracing designs in accordance with the AASHTO LRFD Bridge Design Specifications (LRFD) and Chapter 11 of the SDG using wind loads specified in the SDG. For information not included in the SDG or LRFD, refer to the AASHTO Guide Design Specifications for Bridge Temporary Works and the AASHTO Construction Handbook for Bridge Temporary Works.

5-1.5.4 Erection: For Construction Affecting Public Safety, submit an erection plan signed and sealed by the Specialty Engineer to the Engineer at least four weeks prior to erection commencing. Include, as part of this submittal, signed and sealed calculations and details for any falsework, bracing or other connection supporting the structural elements shown in the erection plan. Unless otherwise specified in the Plans, erection plans are not required for simple span precast prestressed concrete girder bridges with spans of 170 feet or less.

At least two weeks prior to beginning erection, conduct a Pre-erection meeting to review details of the plan with the Specialty Engineer that signed and sealed the plan, and any Specialty Engineers that may inspect the work and the Engineer. After erection of the elements, but prior to opening of the facility below the structure, ensure that a Specialty Engineer or a designee has inspected the erected member.

Ensure that the Specialty Engineer has certified to the Engineer that the structure has been erected in accordance with the signed and sealed erection plan. For structures without temporary supports but with temporary girder bracing systems, perform, as a minimum, weekly inspections of the bracing until all the diaphragms and cross frames are in place. For structures with temporary supports, perform daily inspections until the temporary supports are no longer needed as indicated in the erection plans. Provide written documentation of the inspections to the Engineer within 24 hours of the inspection.

Fig. 31 Florida state DOT minimum requirement of temporary bracings

Conclusions

1. The concrete beams supporting the water pipe initiated the collapse because they were subjected to lateral loads induced by the 100 ft. long ductile iron pipe supported over the sloping bottom flanges of the precast beams. The beams were not braced properly, nor were the bearings restrained against movement.
2. The specialty engineer recommended in May 2013 to the joint venture, the concrete erector, and others that the sliding bearings be restrained or monitored continuously. Beams that fell or overturned were not provided with any restraints at the bearings. If they had been, the incident could have been prevented.
3. The precast erector did not follow the drawings produced by his consultant to provide horizontal braces between the exterior beams at the center of the span and at the ends. This nonconformance and deficiency, although significant, would not have prevented the incident of November 2, 2013.
4. The joint venture and the construction manager failed to have a proper review conducted of the design prepared by Gator Engineering on the manner in which the 12" ductile iron pipe was to be supported between the concrete beams. If a proper review had been performed, this incident would not have occurred.
5. Gator Engineering, which prepared the design of the support of the pipe, was not furnished structural drawings showing the type of bearings for the concrete beams. It was a case of lack of coordination on the part of the contractors.
6. The Joint Venture and the Construction Manager failed to ensure that the minimum requirements for temporary bracings mandated by the Florida State Department of Transportation were followed.
7. The Joint Venture and the Construction Manager failed to ensure that the temporary bracings designed by the specialty engineer were erected in place.
8. The Joint Venture failed to provide the test results on the bearings to the contractors engaged in erecting the concrete beams. The test results indicated an average coefficient of friction of as low as 1%. This was a serious omission on the part of the Joint Venture.

9. The Construction Manager did not solicit in a proactive manner the information regarding the low coefficient of friction from the Joint Venture, and failed to ensure that the information was forwarded to the contractors engaged in the erection. The Construction Manager was fully aware that the bearings were not restrained, that vertical diaphragms were not poured into Cell # 2, and that bracings were not placed as required.