Investigation of the January 19, 2015 collapse of bridge onto southbound interstate I-75 during demolition in Cincinnati, OH

U.S. Department of Labor
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Directorate of Construction

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Report

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Introduction

A construction incident occurred on Monday, January 19, 2015 near downtown Cincinnati at approximately 10:30 p.m. when the center and east spans of a ramp bridge being demolished suddenly fell 15-20 feet onto southbound interstate I-75 south freeway, killing a foreman and injuring the excavator operator. At the time of the incident, concrete slab was being removed from the deck of the ramp as a part of the demolition of the Hopple Street Ramp Bridge. The demolition work began a day earlier but had to be stopped due to concerns about some steel girders lifting off their bearings. Work resumed Monday evening after the remedial measures recommended by the engineers were carried out. Those measures proved inadequate, and the incident occurred.

OSHA Regional Administrator, Region V asked the Directorate of Construction (DOC), OSHA National Office to provide technical assistance to the OSHA Cincinnati Area Office in investigating the incident and determining the cause of the collapse. Two structural engineers from DOC visited the incident site on January 22 to examine the fallen structural girders, and to interview key personnel. Photographs and measurements were taken, and construction documents were obtained to aid in the investigation.

The structural computations performed by the engineers were reviewed and DOC conducted an independent analysis to determine the cause of the collapse.

The Project

The Ohio Department of Transportation (ODOT) contracted with Kokosing Construction Company Inc., (Kokosing) of Columbus, Ohio to demolish the Hopple Street exit ramp situated over the I-75 south freeway. The ramp, called Bridge HAM-25-0356 - Ramp D, was constructed during the early 1960s. It consisted of three spans, a 40 ft. west span, a center span of 92 ft. and a 46 ft. east span. Each span consisted of five steel girders. The east and west span girders rested on bearings over the east and west abutments, respectively, and cantilevered 9 ft. and 9.5 ft. from pier No. 2 and pier No. 1, respectively. The center span of the bridge rested on the cantilevered ends of the east and west spans. The ramp was 28 ft. wide between the concrete curbs. The deck consisted of 8 ½" thick reinforced concrete slab over steel girders. For original design drawings, see figures 1 through 6.

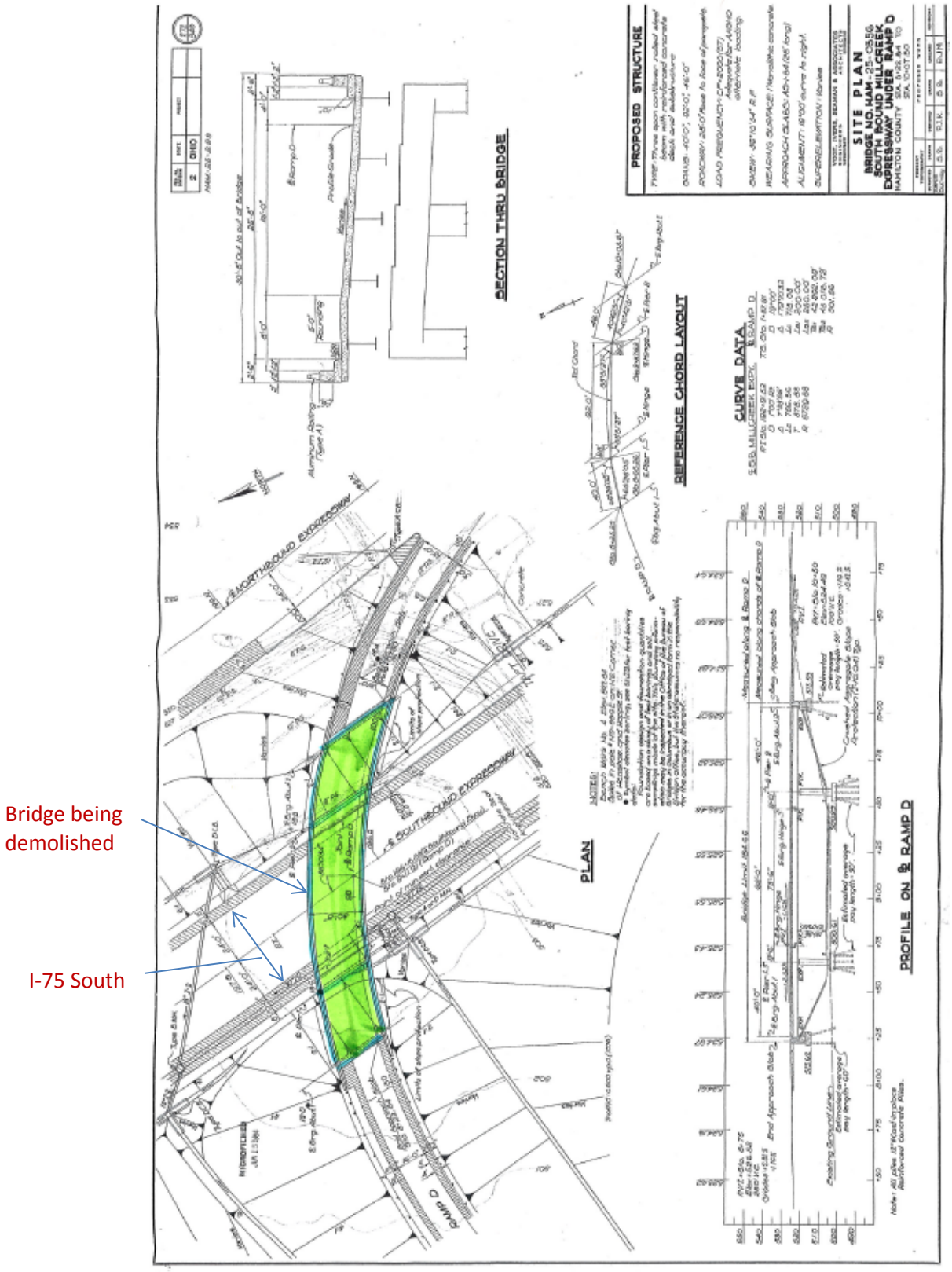


Figure 1 – Site plan, section and profile (original design drawing)

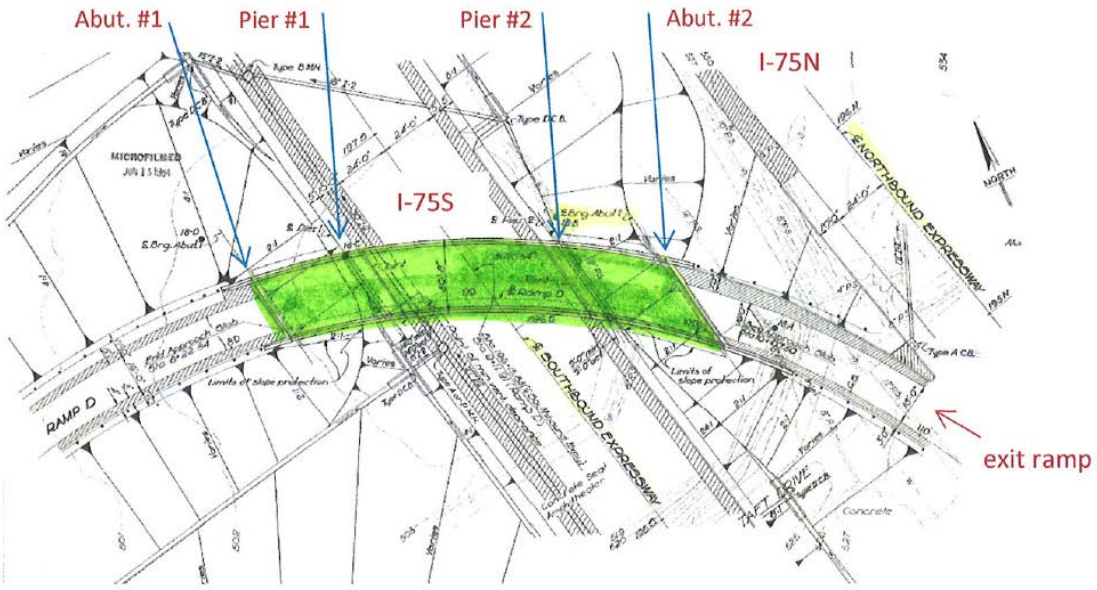


Figure 2 – Site plan showing the left exit ramp from I-75N over I-75S (taken from design drawing)

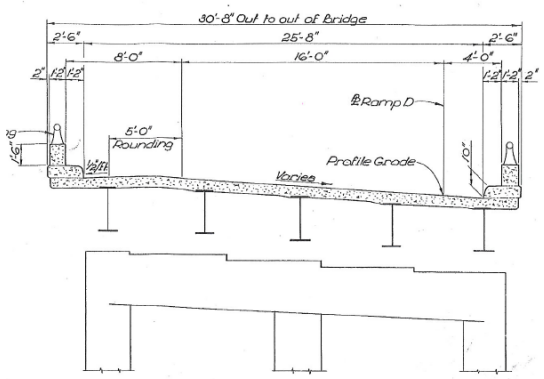


Figure 3 – Section through bridge

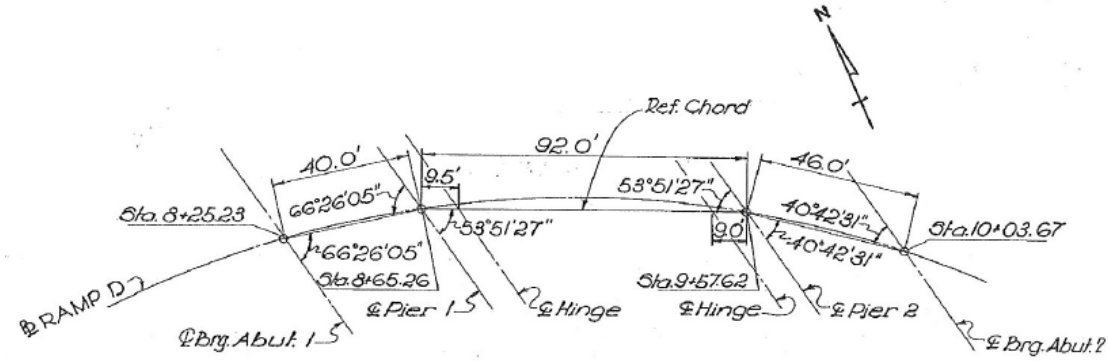


Figure 4 – Reference chord layout for the left exit ramp from I-75N ((taken from design drawing)

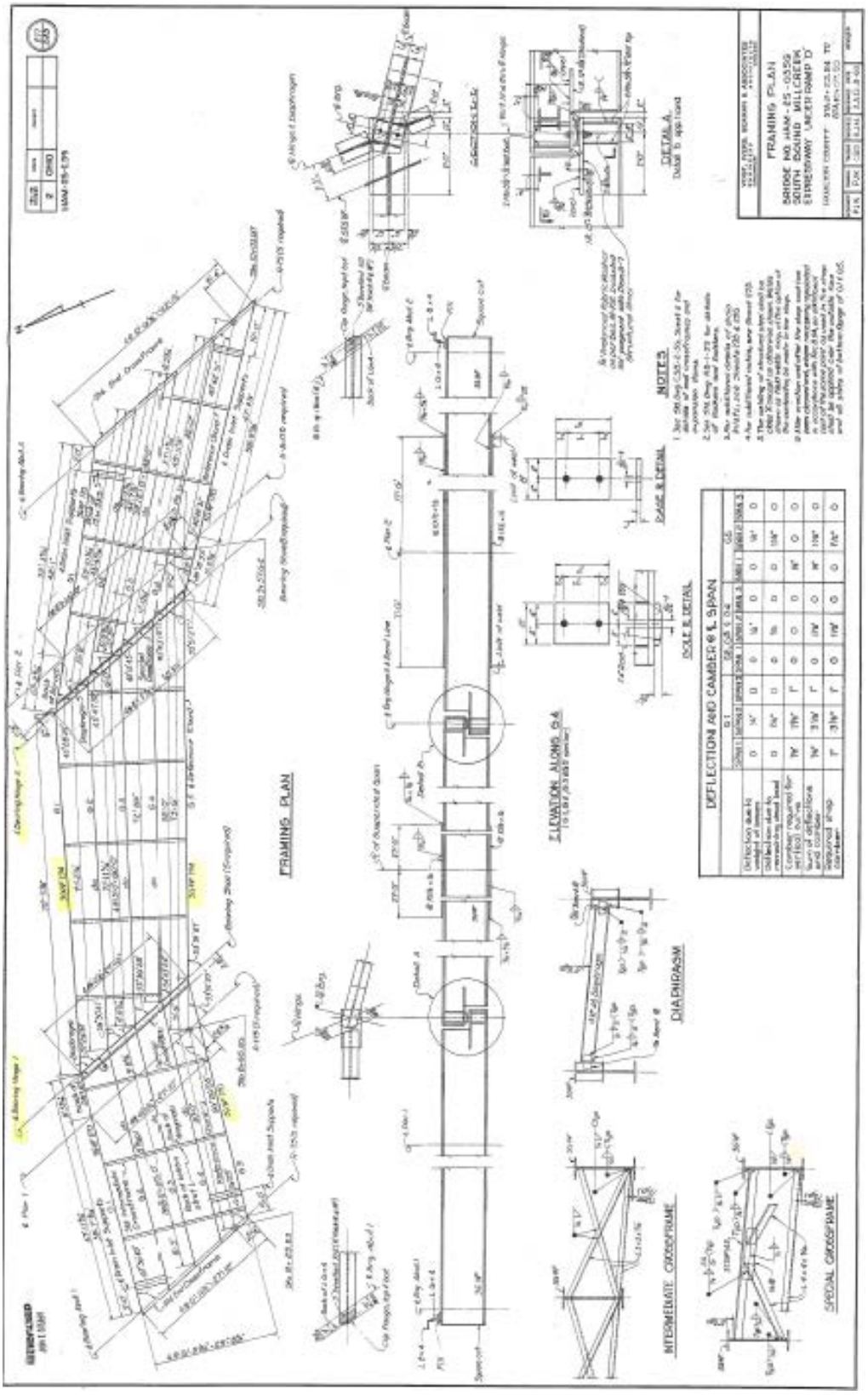


Figure 5 – Framing plan and elevation (original design drawing)

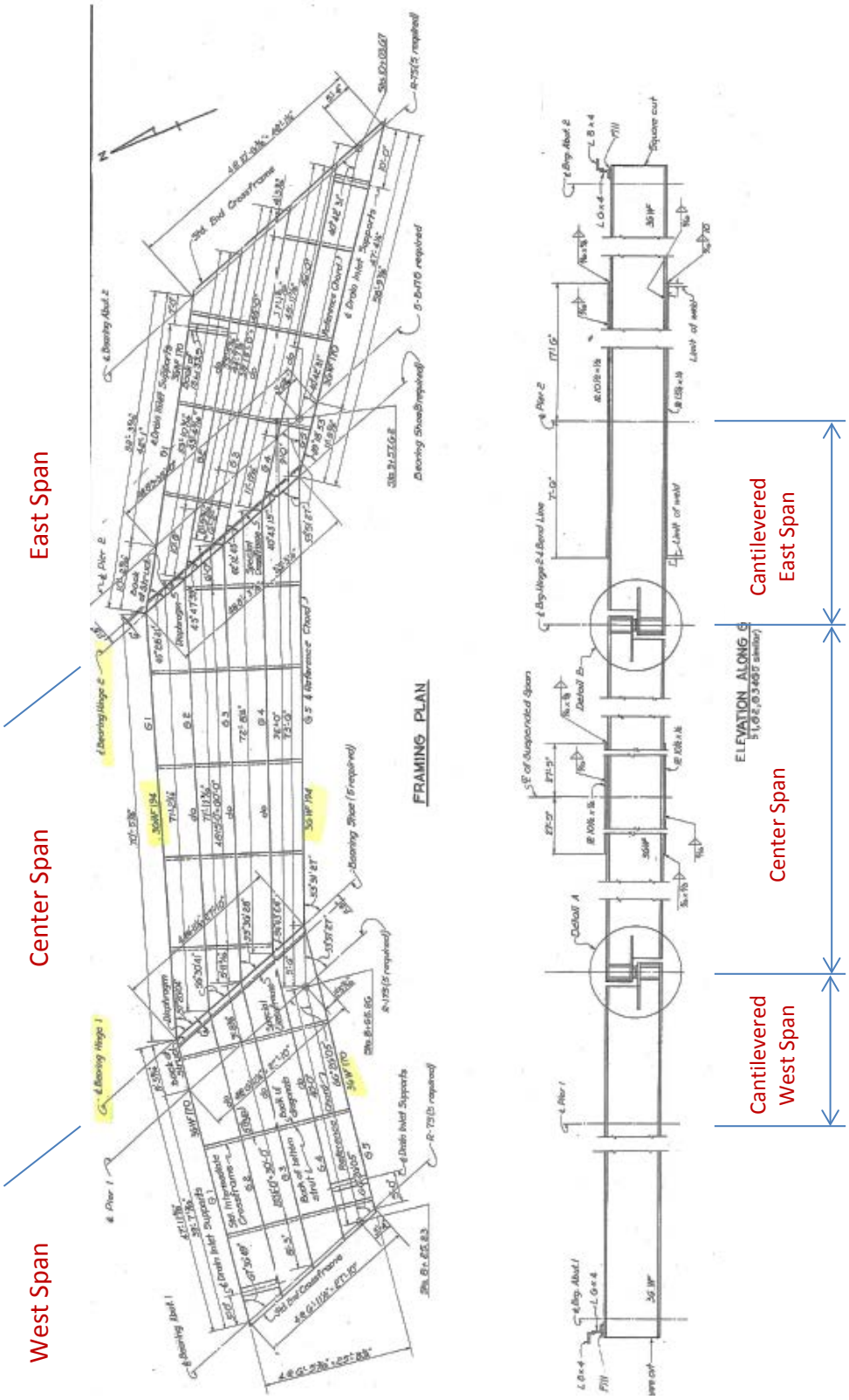


Figure 6 – Framing Plan and Elevation along G4 (original design drawing)

On December 16, 2014 Kokosing prepared a demolition plan for the ramp that included drawings and calculations. On December 19, 2014, Kokosing submitted the plan to ODOT for their records. A telephone number was provided for ODOT to contact Kokosing's engineer in case ODOT had any questions. The plan was signed and sealed by two professional engineers, Mr. Bret Murray and Mr. Burgess L. Decker. This plan called for removing the concrete deck by saw cutting the slab longitudinally in 6 ft. widths and transporting them by loaders from the west span. However there was a change in the plan. A new demolition plan was developed on January 16, 2015 using a different set of equipment to "chew" the concrete deck instead of saw cutting it, and to drop the chewed concrete pieces down below from where it would be scooped up later. This new plan resulted in a reduction of some 25,000 pounds in equipment and concrete haul weight. A copy of the January 16 plan was submitted to ODOT. This plan was also signed and sealed by the same two engineers.

Kokosing decided to demolish the concrete deck beginning from the east abutment, and gradually proceeding towards the west. Steel beams along with diaphragm members were to be left intact until it was time to remove the steel girders. Steel girders were to be removed first from the center span followed by removing the steel girders from the east and west spans as shown in demo plan. The demo plan did not specify the sequence and direction of removal of the concrete deck. However, it was in the knowledge of the Kokosing engineers that the field personnel were removing the concrete deck from east to west.

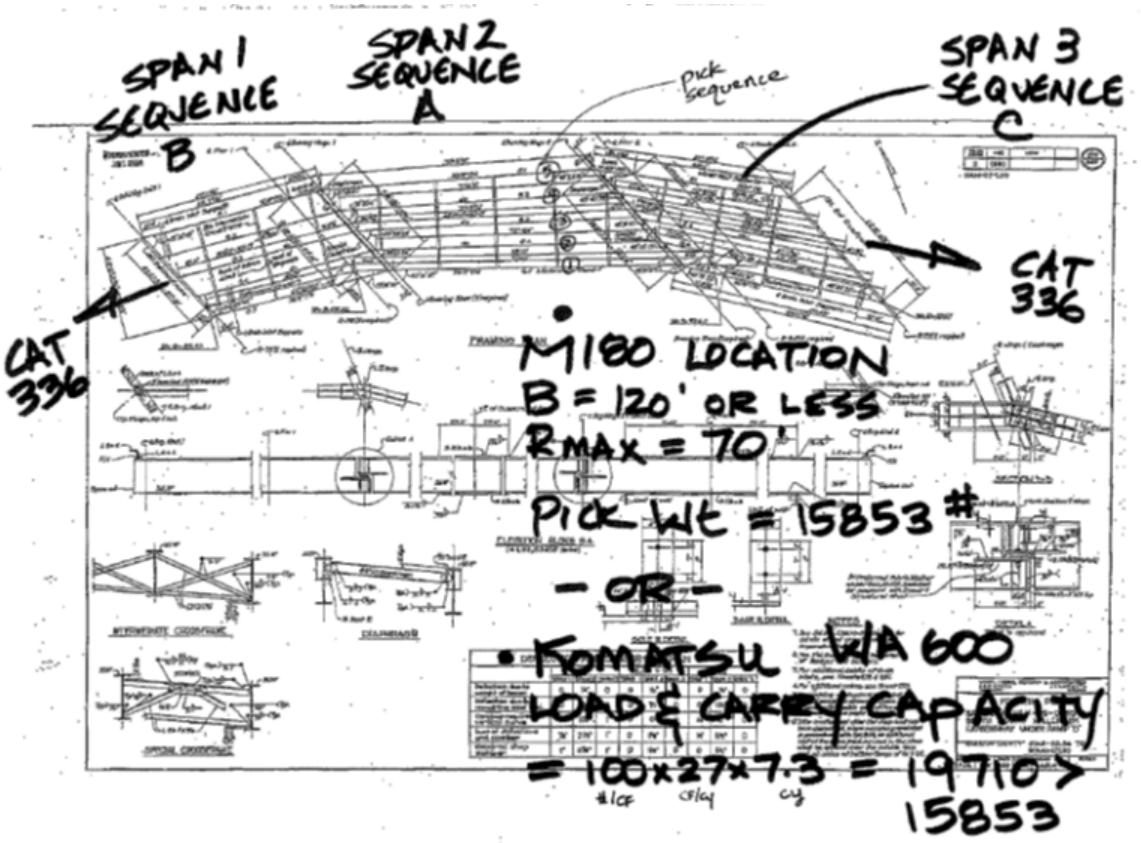
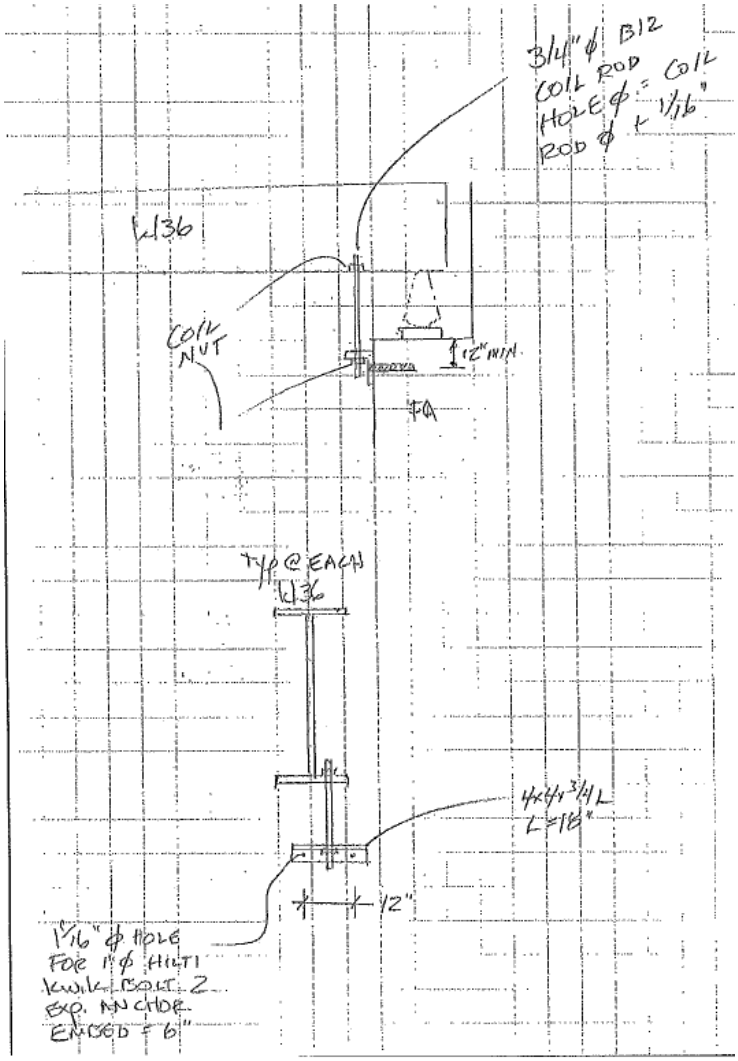


Figure 7 – Plan showing sequence of removal of girders (page 26 of demo plan dated 12-16-14)

The Incident

On Sunday, January 18, the work began at approximately 8:00 p.m. according to the method outlined in the January 16 demolition plan using a Komatsu excavator PC-400 with a Genesis LXP400 attached to it. Both together weighed approximately 110,000 pounds. The contractor began to crunch the concrete deck beginning from the east abutment (Abutment #2) and proceeding west towards the pier No.2. When approximately 50% of the concrete deck on the east span was crunched and dropped down, the foreman and the excavator operator noticed that the girders were lifting off their bearings on the east abutment. The foreman and the operating engineer contacted the superintendent of the project, Mr. Michael Schweer of Kokosing, who decided to stop the work until it was cleared by the engineers who had prepared the demolition plan.

The next morning, Mr. Brett Murray, PE, proposed that the girders be tied down to the abutment at the east end (Abutment #2) with Hilti anchors. Mr. Murray prepared a sketch showing a ¾" coil rod through the bottom flange of the steel girder with a 4x4x3/4" angle anchored to the abutment wall with two 1" dia. Hilti anchors, see figure 8 below.



Sketch prepared by Kokosing engineer

Figure 8 – Details of how girders to be tied down to the abutment

The proposed remedial measure was carried out on the afternoon of Monday, January 19. Work began in earnest at approximately 9:00 p.m. on January 19 with the excavator on the cantilevered portion of the east span of the bridge, but soon thereafter, the incident occurred with the center span falling down over the highway underneath. Seconds later, the east span flipped and fell to

the ground as well. The foreman standing on the center span fell and was killed. The excavator operator fell along with the excavator and sustained minor injuries, see figures 9 through 12.

Figure 9 – Bridge center span with excavator collapsed onto I-75S (taken from the web)

Figure 10 – I-75S after the incident (taken from the web)

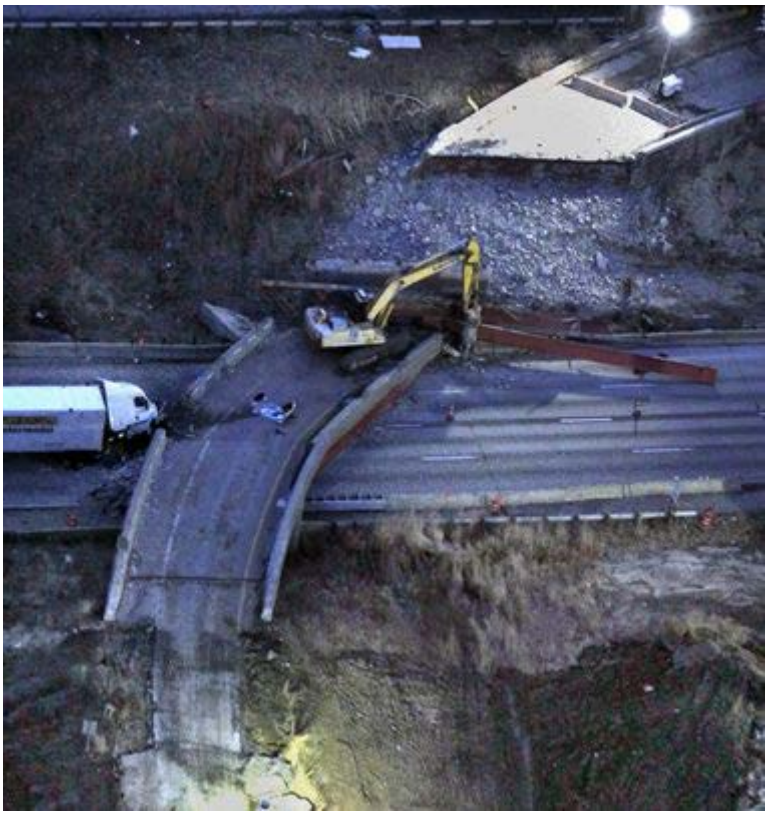


Figure 11 – Collapsed bridge with excavator, abutments and I-75S (taken from the web)

Figure 12 – Excavator after the collapse

Post-incident inspection revealed that the Hilti anchors which secured the bottom flange of the girders from lifting failed either by pulling out of the concrete or by failing in shear. All five girder hold-down measures failed.

Figure 13 – Bridge piers after the incident

Figure 14 – West pier (pier #1) and abutment #1

Figure 15 – West span girders and cross frames

Figure 16 – Failed girders after collapse

Figure 17 – Pier #2 and abutment #2

Figure 18 – Another view of Pier #2 and abutment #2

Figure 19 – 4x4x3/4" angle anchored to abutment #2 with Hilti anchors to prevent uplift of the girders

Figure 20 – Failed Hilti anchor

Structural Analysis

OSHA conducted an independent structural analysis of the girders. The excavator was placed on the cantilevered portion close to hinge #2. The weight of the excavator with the genesis was assumed to be spread over 2 girders. This analysis indicated that the entire procedure for removing concrete from the east abutment and proceeding towards the west was flawed. The computations indicated that each of the two girders were subjected to an uplift force of 18,000 pounds at abutment #2, when the entire concrete between the abutment #2 and pier #2 is removed. The analysis confirmed that as the east span was being relieved of the dead load of concrete by crunching the deck, the steel girders would rise from the abutment. The original design did not call for any positive tie-down of the girders at the abutments. The physical tie-down of the girders installed on the day of the incident on the recommendation of the engineer was poorly designed and did not meet industry design standards. The Hilti anchors were subjected to a combination of axial tension and shear in excess of their capacity, and this caused the failure. It is unfortunate that although the remedial measures were designed and reviewed by two professional engineers, neither of them gave due regard to the design that they proposed. The remedy was proposed in haste and ignored basic engineering considerations. The design called for three Hilti anchors with an embedment of 6 inches for each girder. The Hilti anchor provided in the field had an embedment of only 4.5 inches. Even with an embedment of 6 inches, the design would not satisfy industry standards.

Kokosing engineers were fully aware of the sequence of concrete removal by Kokosing field personnel and did not raise any concern. The proper way would have been to remove the

concrete deck from the center span either by saw-cutting or crunching, thus relieving load on the cantilevered segments. This would have precluded any uplift of the girders at the abutment.

Each of the five girders of the center span was bolted with two bolts to each of the five cantilevered east and west girders. As the east span tilted up, exerting undue force on five girders of the center span, the bolts failed. As all five girders, interconnected with the diaphragms and the concrete deck, began to fall down they exerted tension on the bolts on the west side which also failed, prompting the entire center span to fall in one piece to the ground.

Figure 21 – 4x4x3/4" angle used at abutment #2

Figure 22 – Another view of 4x4x3/4" angle used at abutment #2

Figure 23 – ¾" coil rod that was used at abutment #2 to hold down the girder

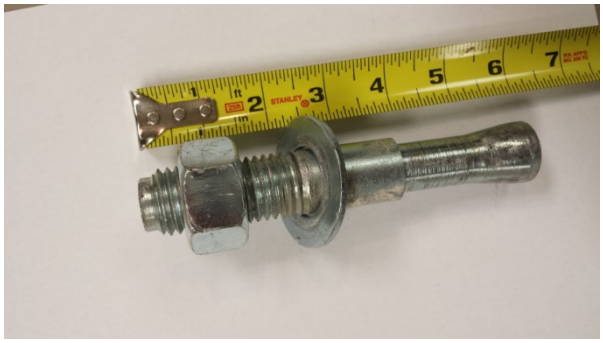


Figure 24 – Hilti anchor used at abutment #2

Conclusions

1. The demolition plan prepared by the contractor's engineers was flawed, and led to the incident. The engineers were provided an opportunity by the field crew to revise their plan, but the engineers' proposed remedies proved to be grossly inadequate and did not meet the standard care of engineering expected from professional engineers.

2. The Ohio Department of Transportation (ODOT), during its review, did not question the contractor about the method and sequence of demolition at the site. ODOT has wide experience in managing and supervising such demolition projects, and its staff includes experienced engineers. It is, however, recognized that the contractor and not ODOT is responsible for the accuracy and completeness of the plan prepared by the contractor.