In Service Replacement of Box Girder Bottom Slab

WSDOT Bridge No. 5/537S - Span 11

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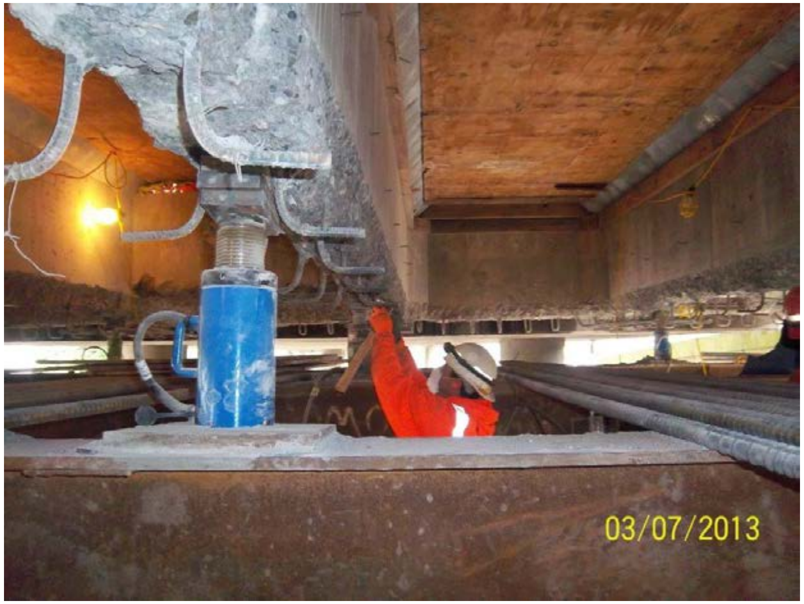
Lynn Peterson
Secretary of Transportation



2015 Western Bridge Engineers' Seminar
Reno, Nevada
September 9-11, 2015

Washington State
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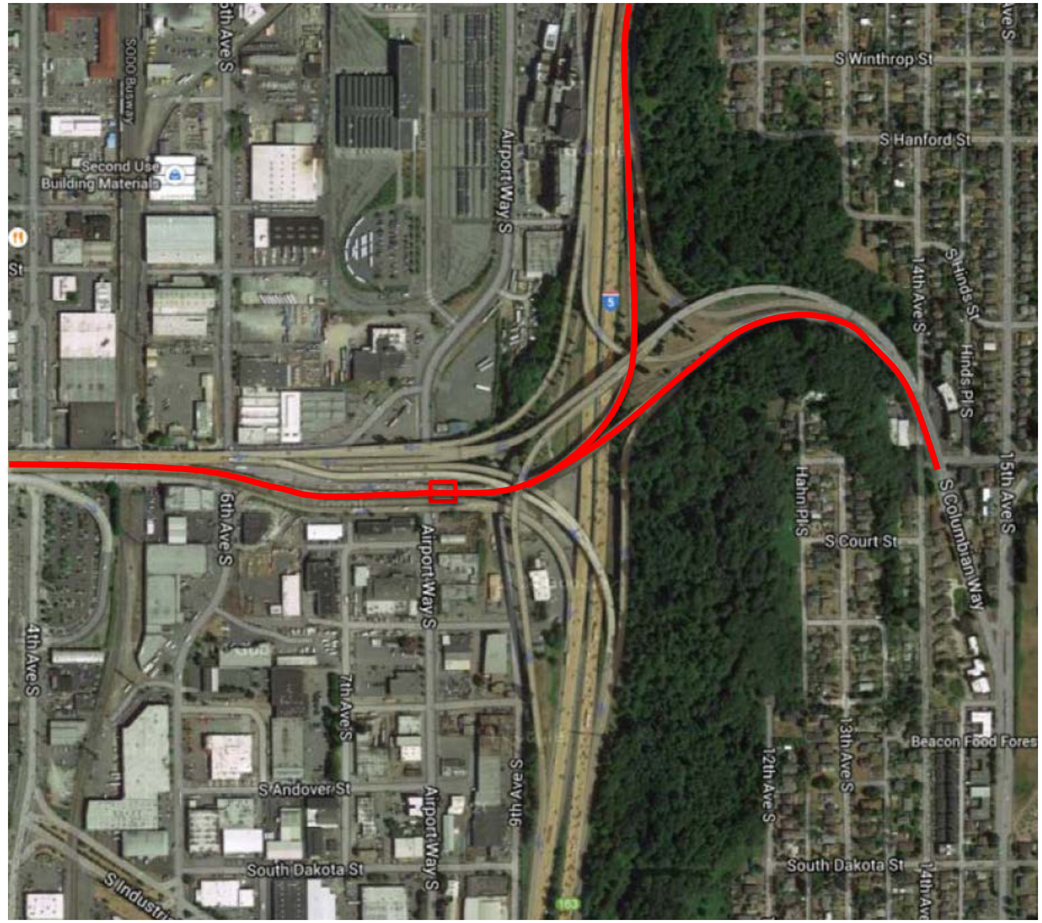
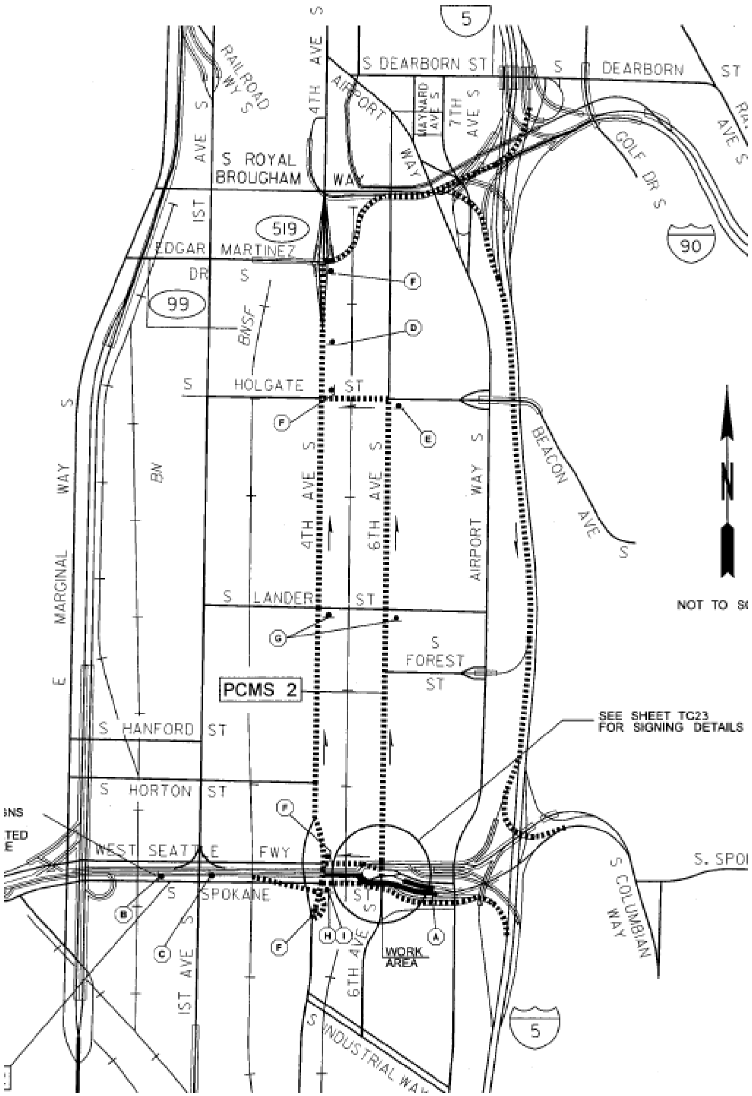
Location And Function

- Bridge is located 2-Miles South of downtown Seattle
- Bridge carries traffic from the West Seattle area to North bound Interstate-5
- Average Daily Traffic = 24,638 Vehicles
- Average Daily Truck Traffic = 2,711 Trucks
- Bridge is a critical link for commuters and freight





Detour

- Congested local roadway
- Stop lights
- Industrial area with semi trucks loading and unloading
- Street parking

Congested detour would significantly increase travel time.

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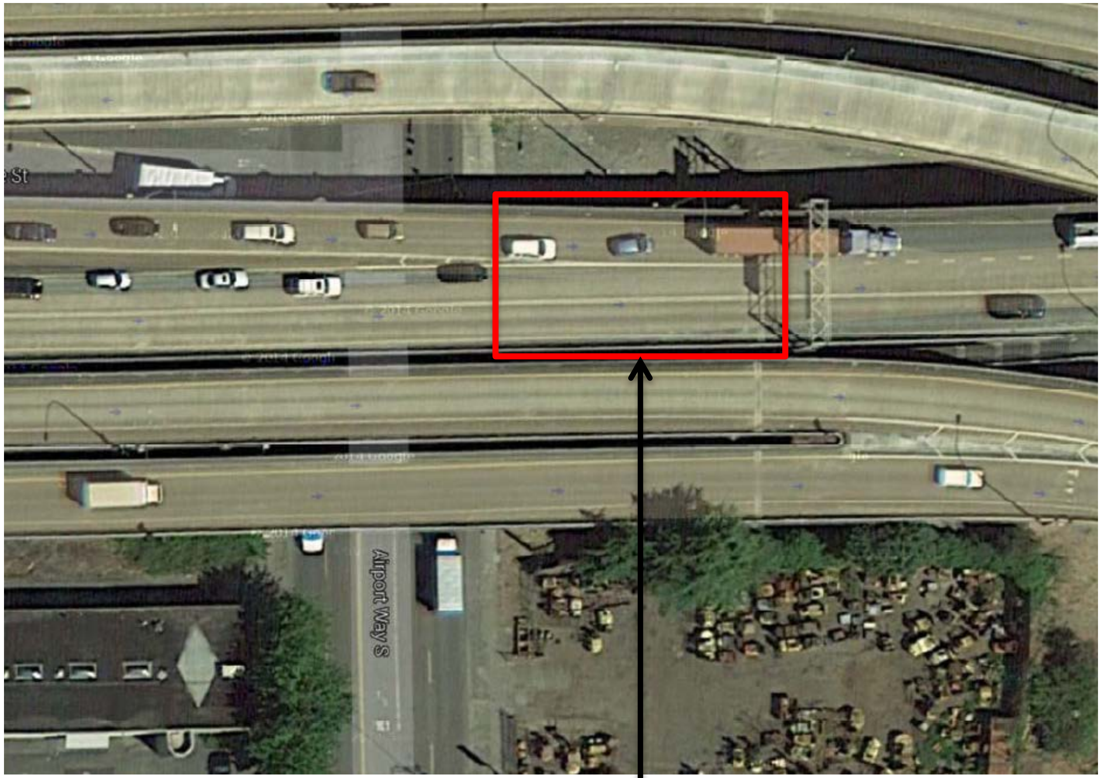
Confined Work Area

- Other bridges located just to the North and South
- Airport Way located at the West end of Span 11
- Interstate-5 located just to the East

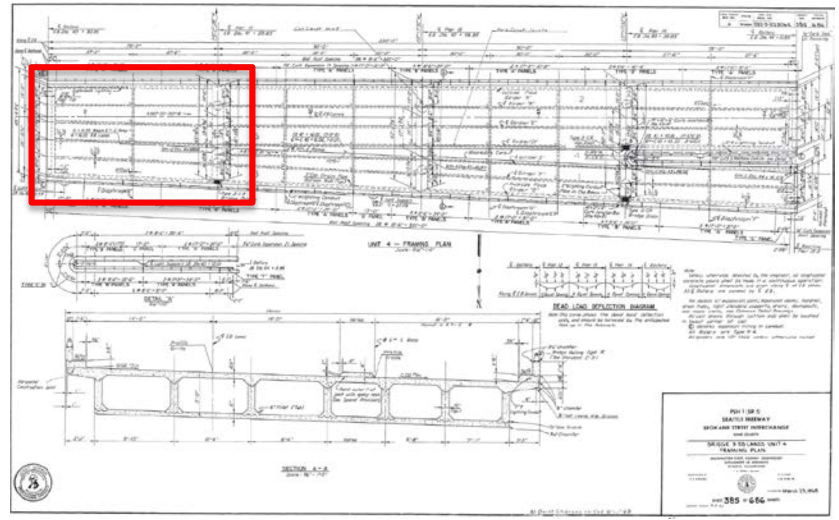


Bridge 5/537S – Span 11

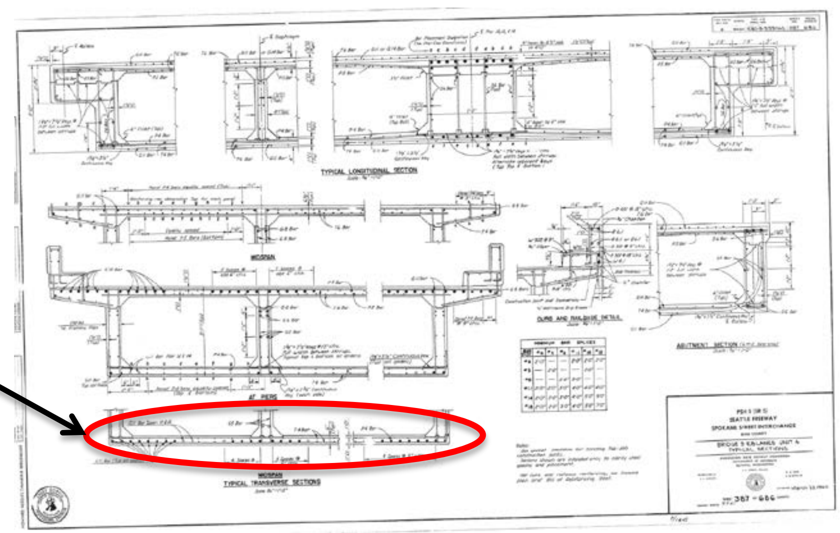
- Real estate under Span 11 is wide open

Original Construction

- Bridge was originally constructed in 1966
- Standard reinforced concrete box girder
- In-Span hinge located near Pier 11



Positive reinforcement to be removed and replaced
((8) #11 bars at each web)



BRIDGE INSPECTION REPORT

	WO	CC	WE	PD			
BAM	0	1	0	2	Status: Released	Ver Date 9/10/2010 Printed on: 9/10/2010	Agency: Washington State Program Mgr: Harvey L. Coffman

Bridge No.	5/537S	Page 4 of 7		**Structure Type**	CBox
Bridge Name	SPOKANE ST EB OVER I-5	**Route**	00005	**Location**	5.5 N JCT SR 900
Structure ID	0007741T	**MilePost**	163.00	**Intersecting**	I-5

Notes 0 to 694

105 Concrete Box has vertical and diagonal hairline cracks in the webs with hairline transverse and longitudinal cracks in the bottom. Some of the cracks are leaching and a few have rust stains. Most spans have small areas of minor spalling with some delamination and short lengths of exposed reinforcement. Span 11 has a heavy concentration of spalls and delamination with exposed rusty reinforcement. Many areas in Spans 11 and 12 have deteriorated, soft and easily broken concrete. These areas, in general, have dark stains and hairline map cracks. See photo #60.

Span 2 bottom of the box, near midspan, has two short lengths of exposed rusty rebar up to 4" long due to lack of cover.
Span 4 bottom of the box, near the hinge, has approximately 4 sq. ft. of delamination and a 2 sq. ft. area of small spalls up to 8" in diameter with short lengths of exposed rebar up to 3" long due to lack of cover.
Span 5 bottom of the box has a few short lengths of exposed rebar up to 4" long due to lack of cover.
Span 6 bottom of the box, near Piers 6 and 7, has a few small spalls with exposed rebar up to 4" long.
Span 10 bottom of the box has a few areas of scattered spalls and delaminations with short lengths of exposed rebar up to 6" long. Total area is approximately 7 sq. ft.
Span 11 bottom of the box has areas of soft and deteriorated concrete of approximately 2,340 sq. ft. and areas of scattered spalling with exposed rusty rebar up to approximately 62 sq. ft. Deteriorated areas are primarily concentrated and heaviest on and near the west side of the Span 11 hinge. See photos #13, #61, #10, #43, #53, #54 and #55. REPAIR #11918. The north web, at the west side of the hinge, has a 12" long spall with exposed rebar. See photo #73. Near the west end of Span 11 numbered plaques have been epoxied to the surface in correlation to previous sampling and documentation.
Span 12 bottom of the box has approximately 110 sq. ft. of soft and deteriorated concrete and 10 sq. ft. of scattered spalling. See photo #57. REPAIR #11918.
Span 13, south edge near Pier 13, has 10 lineal feet of shallow edge spalling with short lengths of exposed ties and rebar.
Span 14 bottom of the south box, west of the hinge, has about 18 sq. ft. of spalls with lengths of exposed rusty rebar up to 24" long. See photo #25. East of the hinge there is a 4" diameter hole in the soffit where water appears to leak into the box. See photos #58 and #59. REPAIR #11919
Span 14 bottom of the north box, near mid span, has transverse hairline leaching cracks concentrated along the centerline.
Span 17 bottom of box, east of the hinge, has a 3 ft. length of exposed longitudinal rebar and a few other short lengths of exposed rebar up to 6" long. See photo #27. Just west of the hinge, along the centerline between the access hatches, there is a heavy concentration of interconnected longitudinal and transverse hairline leaching cracks. Cracking covers a 15 ft. x 30 ft. area with rust staining present. See photo #74.
Span 18 bottom of the box, between Columns 18B and 18C, has two exposed rebar up to 33" long, due to lack of cover.
Span 19 bottom of the box, north edge at Pier 19, has a 1 sq. ft. delamination. On the south edge there is a 5 ft. long x 12" area of delamination and shallow spalling with short lengths of exposed rebar.
Span 21 bottom of box at the hinge, near Pier 21 on the north end, has a 12" length of exposed longitudinal rebar.

NOTE: 9/24/2002
Dick Stoddard visited the site with maintenance crew members on 9/24/2002. Regional maintenance crews were attempting to perform repairs for the Span 11 spalls. Concrete was found to be punky, having a powder consistency. Large areas of concrete were easily removed up to a depth of 6". Longitudinal rebar and the bottom and top mats of transverse rebar were exposed during this operation. The Span 11 soffit was sounded with a rock hammer and estimated to have concrete delamination covering 70 percent of the full span width extending between 55 and 65 ft. west of Pier 11. Samples of the spalled concrete were recovered, examined, and returned to the BPO office. The exposed rebar in Span 11 has pack rust that is creating the concrete delaminations.

205 Concrete Columns have hairline pattern cracks.

207 Steel Jacketed Columns at Piers 2, 3, 4, 15, 16, and 21 were part of a seismic retrofit in 2004.

215 Concrete Abutments have a few diagonal and vertical hairline cracks.
West abutment is shared with Bridge 5/537E-E at the west end of Span 14. The furthest west end, Span 1, joins with Span 21 of Bridge 5/537N.

234 Concrete Pier Cap at Pier 20 has a few diagonal hairline cracks.

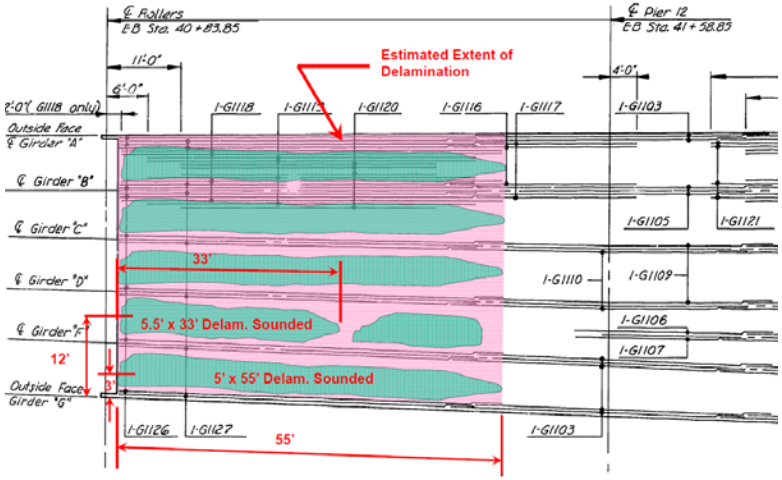
266 Concrete Sidewalk, on the south side from Span 1 to Span 10, has transverse hairline leaching cracks throughout the soffit with a few traffic impact spalls in the curbs up to 12" x 4" x 1" deep.
Stairs, leading off the sidewalk at Spans 2 and 10, have vertical, diagonal, and transverse hairline leaching cracks.

Deficiency

- Span 11 bottom slab had areas of soft and deteriorated concrete (2,340 sf) and areas of spalling with exposed rusty rebar
- Concrete was found to be punky, having a powder consistency
- Large areas of concrete were easily removed up to a depth of 6-inches

Deficiency Continued

- Sounding of the soffit with a rock hammer found that approximately 70% of the Span 11 bottom surface was delaminated



Resulting NBI Coding

- NBI Superstructure Code = 4 (Poor condition. Advanced deficiencies such as section loss, deterioration, cracking, spalling, or scour.)
- Sufficiency Rating: 34.00
- Structurally Deficient

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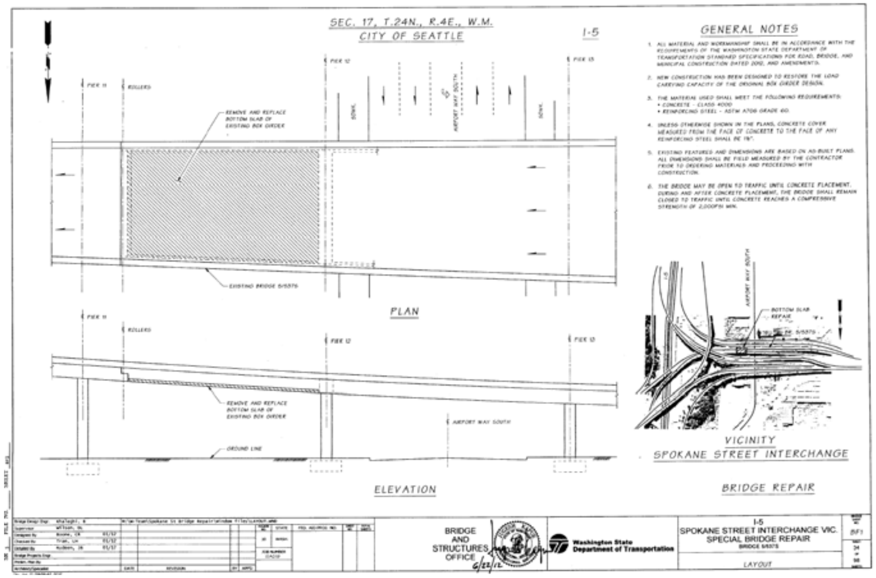
The decision was made to repair the span rather than replace it.

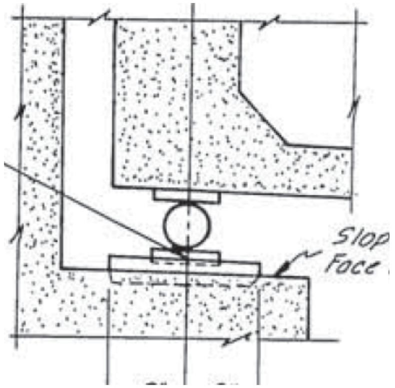
Major Considerations

- With the exception of this deficiency, the bridge is in good condition overall.
- Given the location and function of the bridge, maintaining traffic on the bridge was highly desired.
- Replacement of the span would mean substantial bridge closure time. Accelerated Bridge Construction techniques for replacement would not work well due to the continuous superstructure and congested surroundings.

Design Details

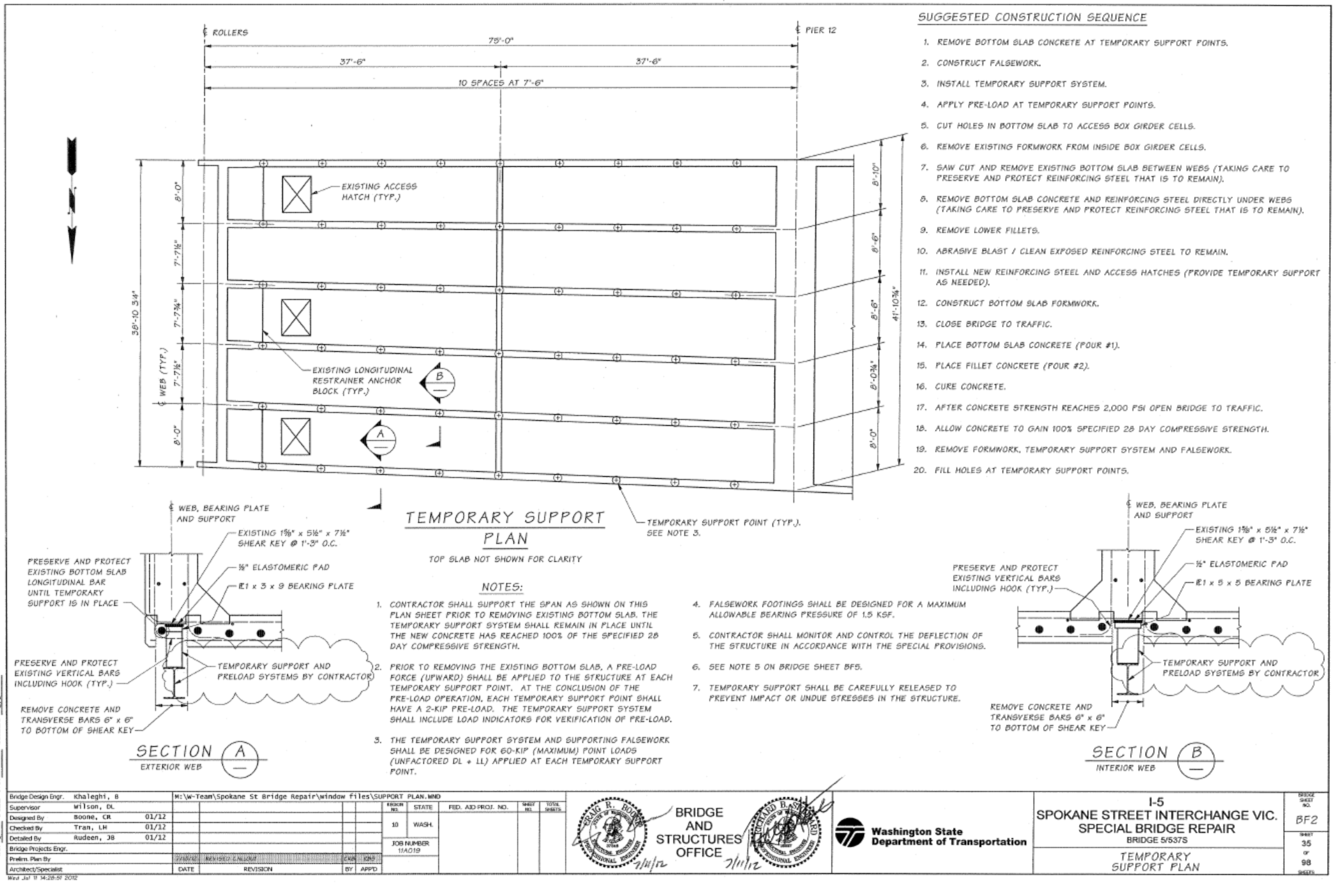
- Our goal was to restore the load carrying capacity of the original design
- With a continuous superstructure, we had to be mindful of the effects this work would have on adjacent spans
- With the in-span hinge located near the repair, we had to consider the effects of the repair on the roller bearings at the in-span hinge



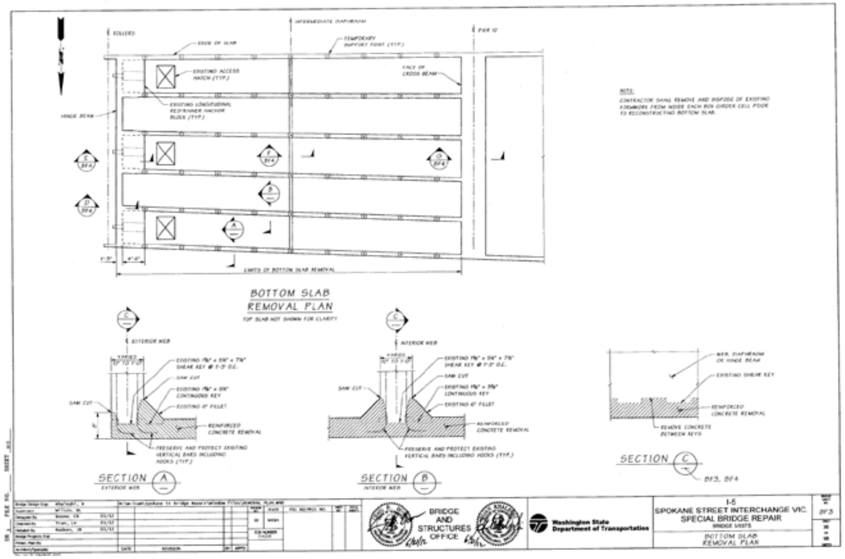


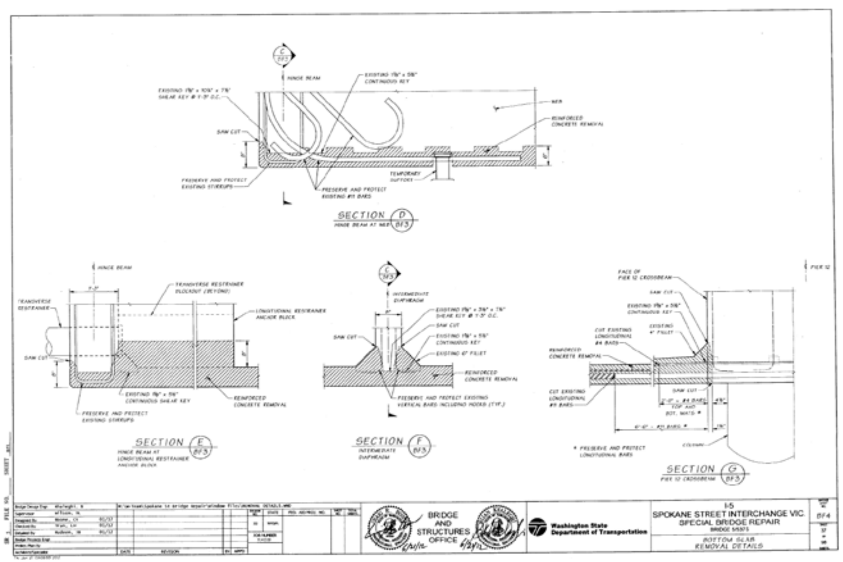
SUGGESTED CONSTRUCTION SEQUENCE

1. REMOVE BOTTOM SLAB CONCRETE AT TEMPORARY SUPPORT POINTS.
2. CONSTRUCT FALSEWORK.
3. INSTALL TEMPORARY SUPPORT SYSTEM.
4. APPLY PRE-LOAD AT TEMPORARY SUPPORT POINTS.
5. CUT HOLES IN BOTTOM SLAB TO ACCESS BOX GIRDER CELLS.
6. REMOVE EXISTING FORMWORK FROM INSIDE BOX GIRDER CELLS.
7. SAW CUT AND REMOVE EXISTING BOTTOM SLAB BETWEEN WEBS (TAKING CARE TO PRESERVE AND PROTECT REINFORCING STEEL THAT IS TO REMAIN).
8. REMOVE BOTTOM SLAB CONCRETE AND REINFORCING STEEL DIRECTLY UNDER WEBS (TAKING CARE TO PRESERVE AND PROTECT REINFORCING STEEL THAT IS TO REMAIN).
9. REMOVE LOWER FILLETS.
10. ABRASIVE BLAST / CLEAN EXPOSED REINFORCING STEEL TO REMAIN.
11. INSTALL NEW REINFORCING STEEL AND ACCESS HATCHES (PROVIDE TEMPORARY SUPPORT AS NEEDED).
12. CONSTRUCT BOTTOM SLAB FORMWORK.
13. CLOSE BRIDGE TO TRAFFIC.
14. PLACE BOTTOM SLAB CONCRETE (POUR #1).
15. PLACE FILLET CONCRETE (POUR #2).
16. CURE CONCRETE.
17. AFTER CONCRETE STRENGTH REACHES 2,000 PSI OPEN BRIDGE TO TRAFFIC.
18. ALLOW CONCRETE TO GAIN 100% SPECIFIED 28 DAY COMPRESSIVE STRENGTH.
19. REMOVE FORMWORK, TEMPORARY SUPPORT SYSTEM AND FALSEWORK.
20. FILL HOLES AT TEMPORARY SUPPORT POINTS.

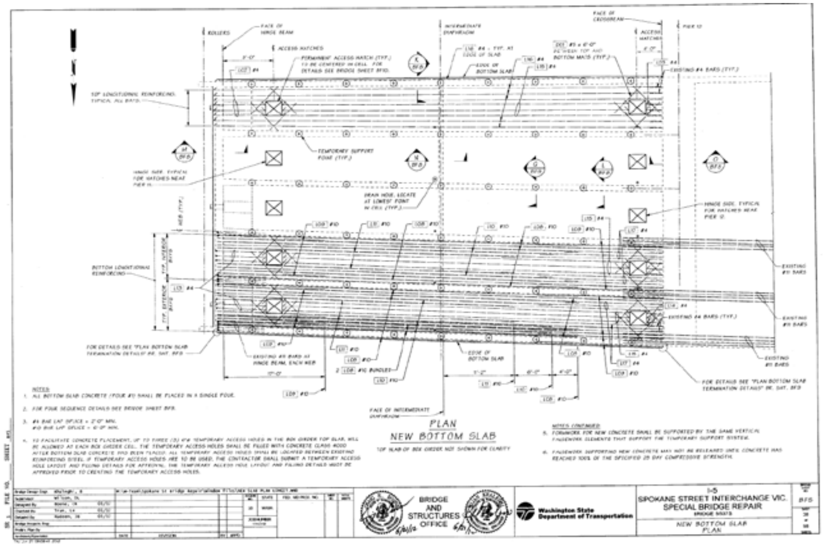


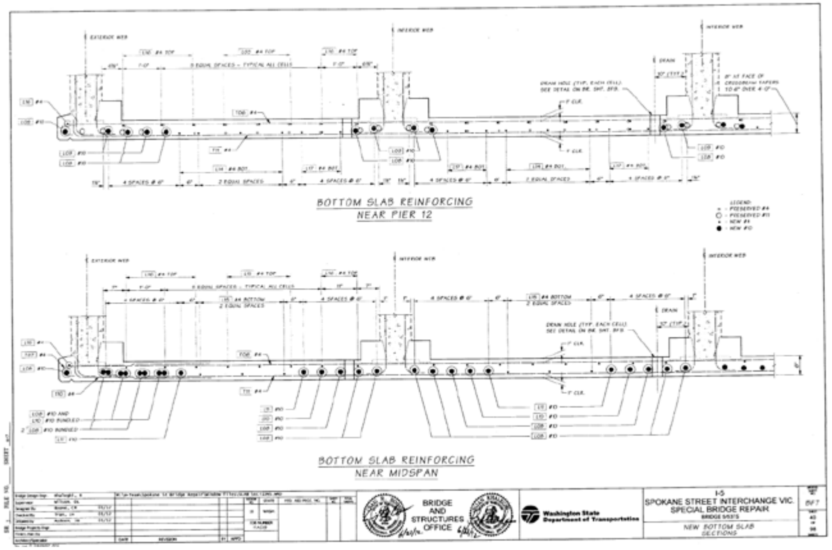
- Removing positive moment reinforcement, thus temporary support required
- (54) support points
- 2-kip pre-load instead of measuring displacements



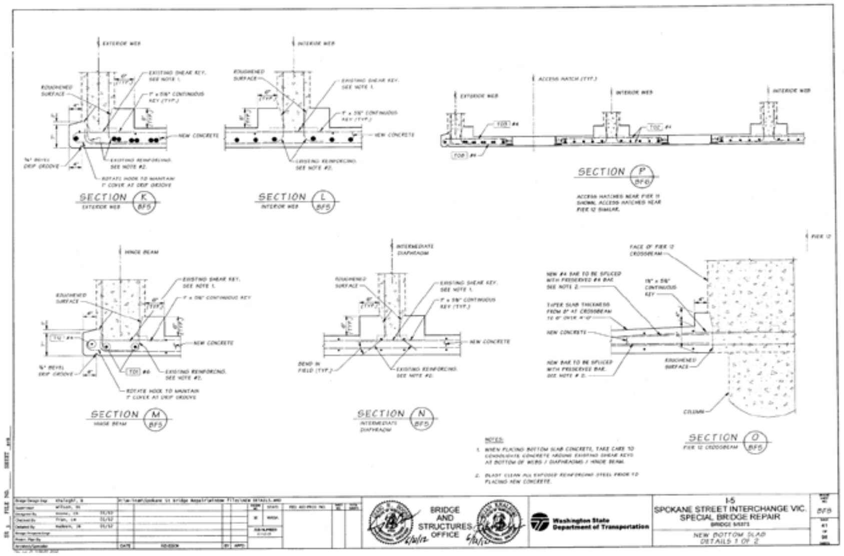


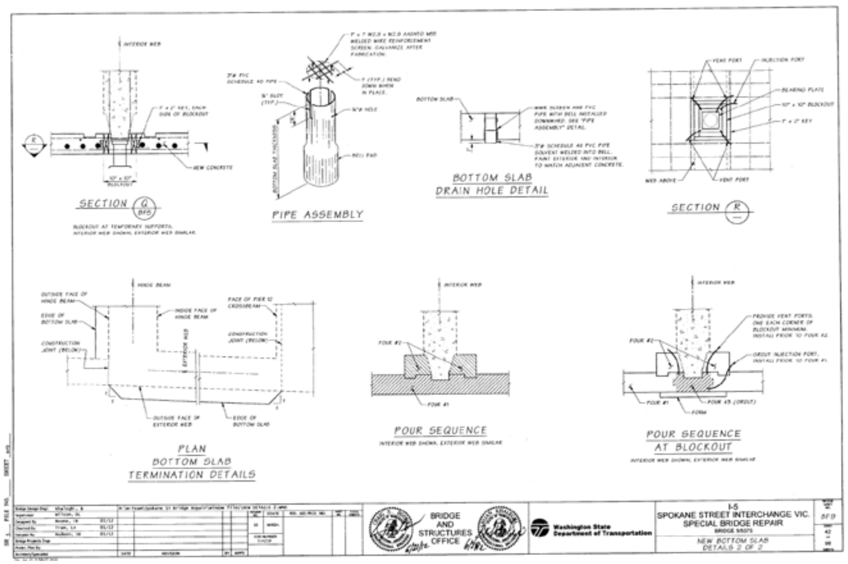
- Formwork for existing top slab had to be removed
- Contractor had to remove bottom slab concrete while preserving existing reinforcing steel that was to remain
- We limited the size of equipment that could be used for concrete removal, so as to not damage concrete that was to remain
- We had to restore shear keys between the bottom slab and webs





- Access hatch required for each cell
- Had to place new bottom slab reinforcement steel around access hatches
- Using higher grade bars (60 ksi vs 40 ksi) allowed us to use slightly smaller bars
- We were a little concerned about cracking that could happen due to the restraint the existing webs provided against shrinkage. Turned out to be a non issue





- Details at the interface between existing and new concrete aimed to gain good consolidation and minimize voids.
- The bridge was closed to traffic during and after concrete placement. Traffic was to be kept off the bridge until concrete gained compressive strength of 2,000 psi. Within 1 ½ days concrete compressive strength was at 3,690 psi.
- Temporary support was to remained in place until concrete gained full design compressive strength of 4,000 psi. Temporary support was left in place for 28-days.

Creating holes at temporary support points

Constructing temporary support structure

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Temporary support structure

- To minimize settlement, the allowable soil bearing pressure was kept very low (1,500 psf)

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Temporary support jacks

- Each support point had to be capable of supporting a minimum of 60,000 lbs.

Temporary support structure
and work platform

Temporary support structure

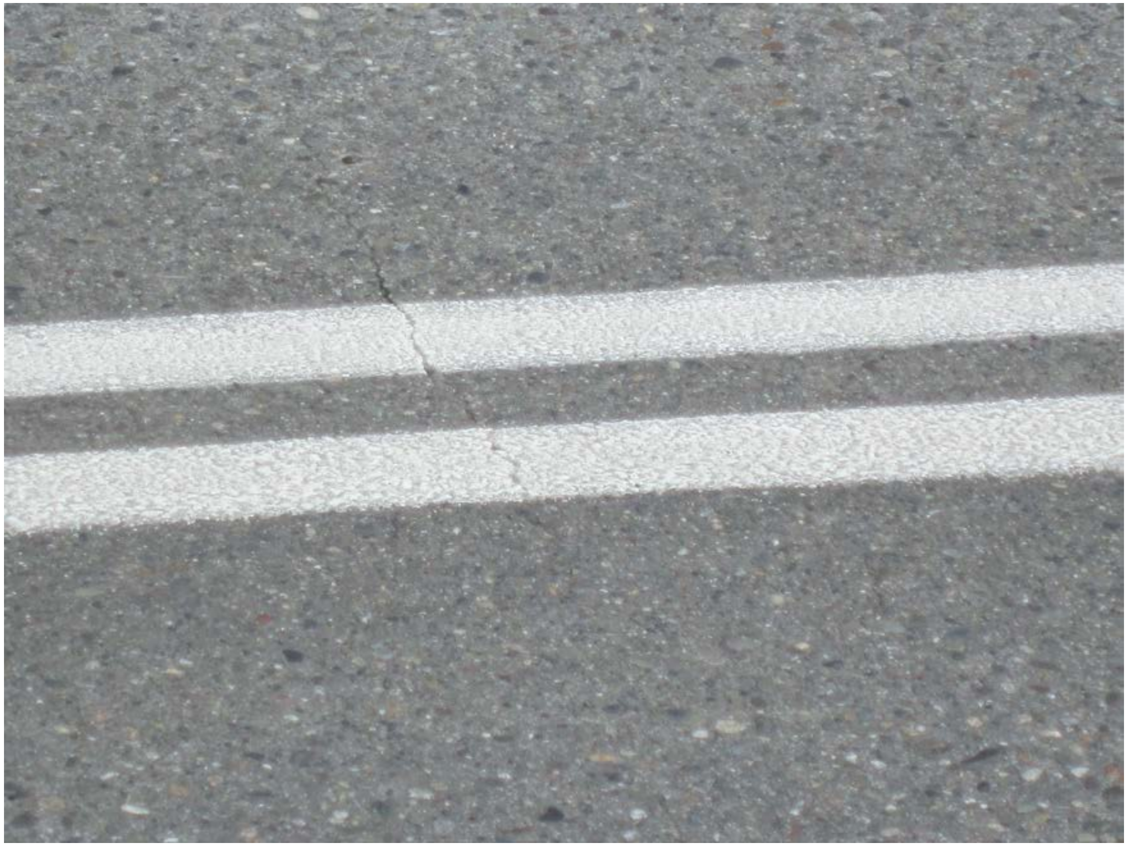
Size of equipment used for removal was limited to 30-lb pneumatic hammers, so as to not damage concrete that was to remain

Original reinforcing steel exposed.

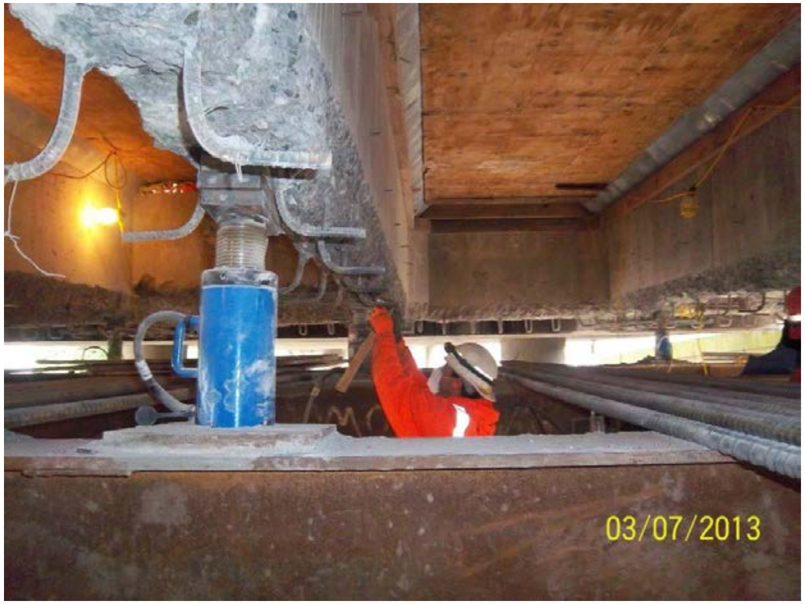
- Contractor chose to remove all concrete with small pneumatic tools

Temporary support

Existing top slab formwork was removed



The scary phone call….



Bottom slab and reinforcing steel completely removed

Placing new reinforcing steel

Placing new reinforcing steel

- Notice the shear keys chipped in to the bottom of the webs.

New reinforcing steel in place. Starting to place formwork for square fillets

- Confined space
- Limited head room

Formwork for new concrete had to be supported by the same vertical elements that supported the temporary support system

Formwork for square fillets

Placing concrete

- Everything had to go up through access hatches
- All bottom slab concrete was required to be placed in a single pour

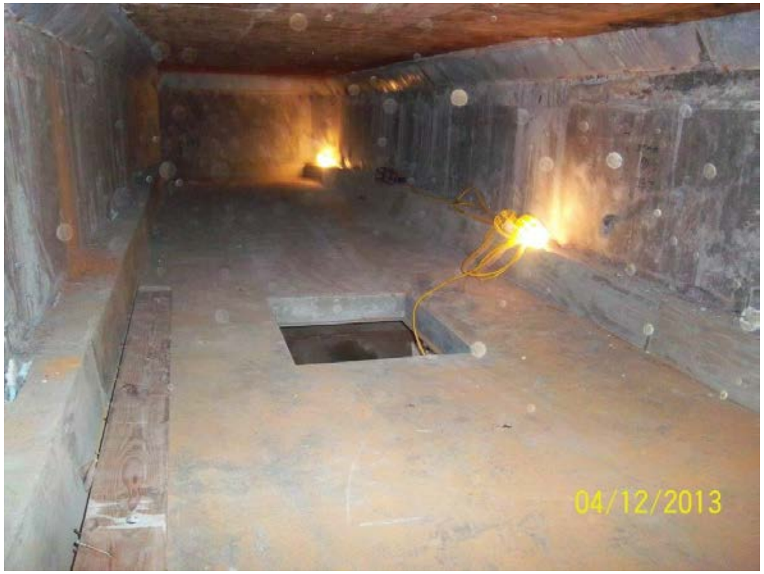
New concrete in place

- Notice the Contractor choose to place the bottom slab and fillets in one pour

Finished bottom slab

- Access hatches
- Filled blockouts at temporary support points

Inside box with new bottom slab.



Summary

- Contractor was Mowat Construction Company
- This repair was combined with expansion joint replacements on multiple nearby bridges. Mobilization, traffic control, and other similar items were combined, so it's hard to say exactly what the total cost of this repair was. However, the two lump sum bid items for removing and replacing the bottom slab totaled $615,000. The total cost for the repair was likely around $1 million.
- The estimated cost of replacing the span was $2.2 million.
- The real savings was in the minimized impact to the users. The bridge closure time required for the concrete to gain strength of 2,000 psi was less than two days. If the span had been replaced, the bridge would likely have been closed for several months.
- Total time to complete the repair: 3-Months

Questions?