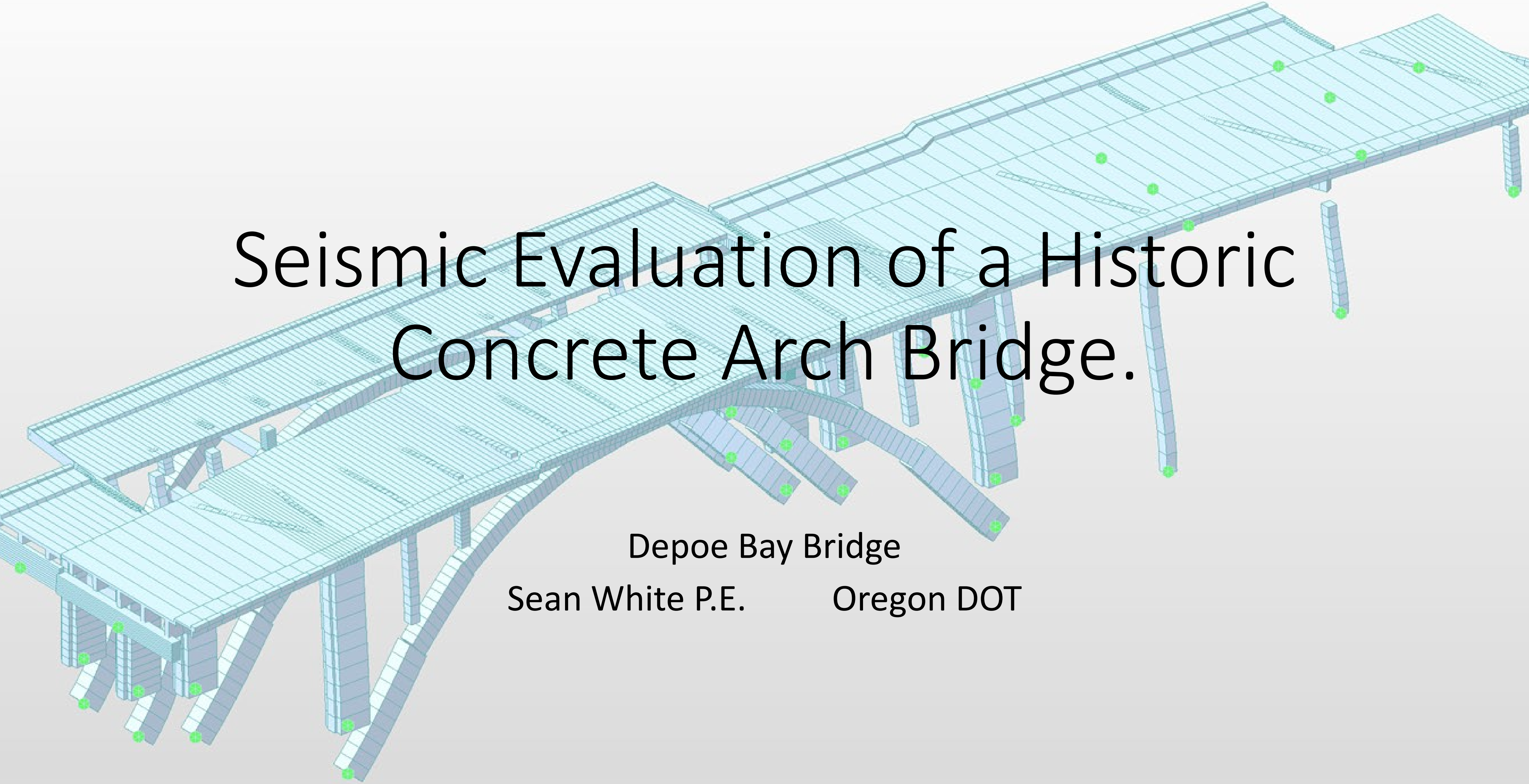


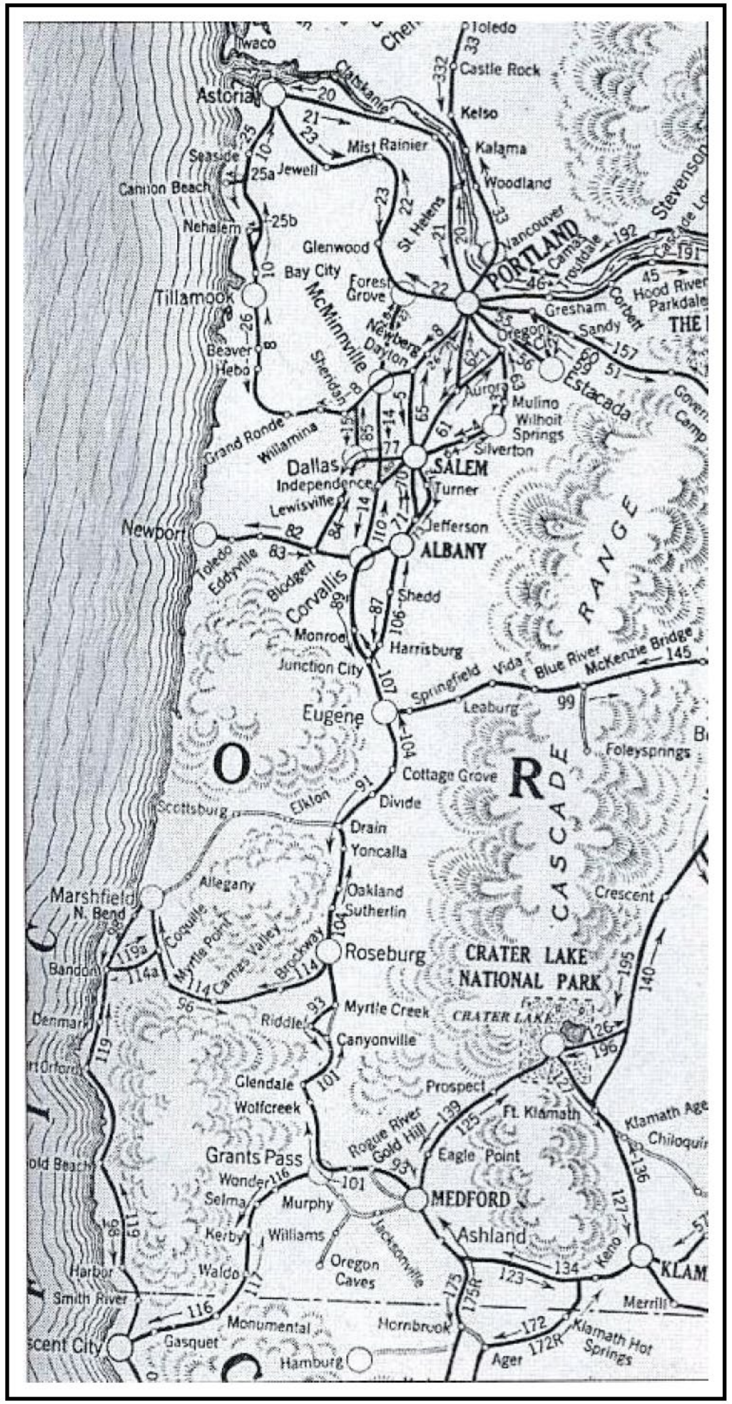
Seismic Evaluation of a Historic Concrete Arch Bridge.

Depoe Bay Bridge

Sean White P.E. Oregon DOT

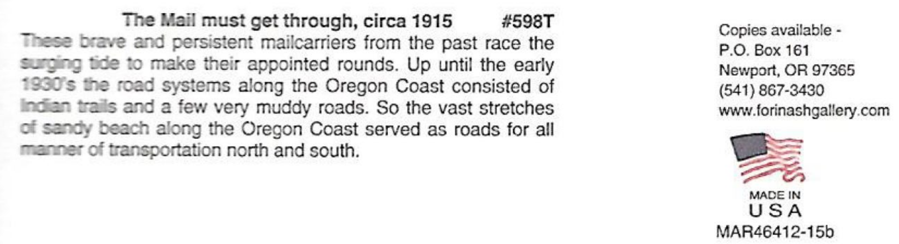
A little historical background:

- Coastal communities accessed by highways from the Willamette Valley or the Sea.
- In 1913 the entire Oregon beach established as a public highway.
- Although the Oregon coast highway (Roosevelt Highway) was envisioned, it was not largely developed.
- A 1918 trip from Marshfield (Coos Bay) to Crecent City took over 50 hours.



ODOT Map Adapted from Book "Lifting Oregon Out of the Mud"

The mail must get through!



The Mail must get through, circa 1915 **#598T**

These brave and persistent mailcarriers from the past race the surging tide to make their appointed rounds. Up until the early 1930's the road systems along the Oregon Coast consisted of Indian trails and a few very muddy roads. So the vast stretches of sandy beach along the Oregon Coast served as roads for all manner of transportation north and south.

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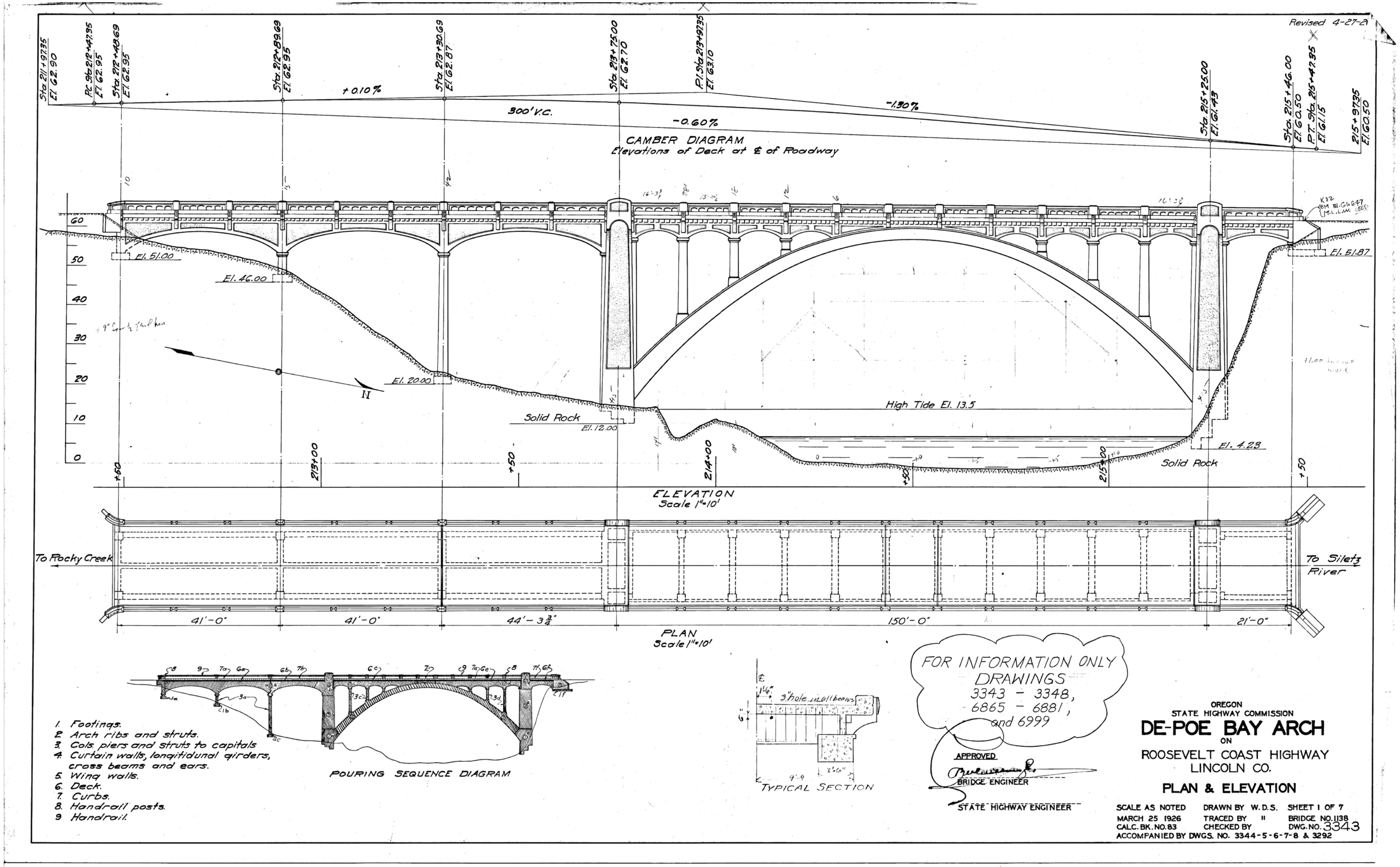
MADE IN
USA
MAR46412-15b

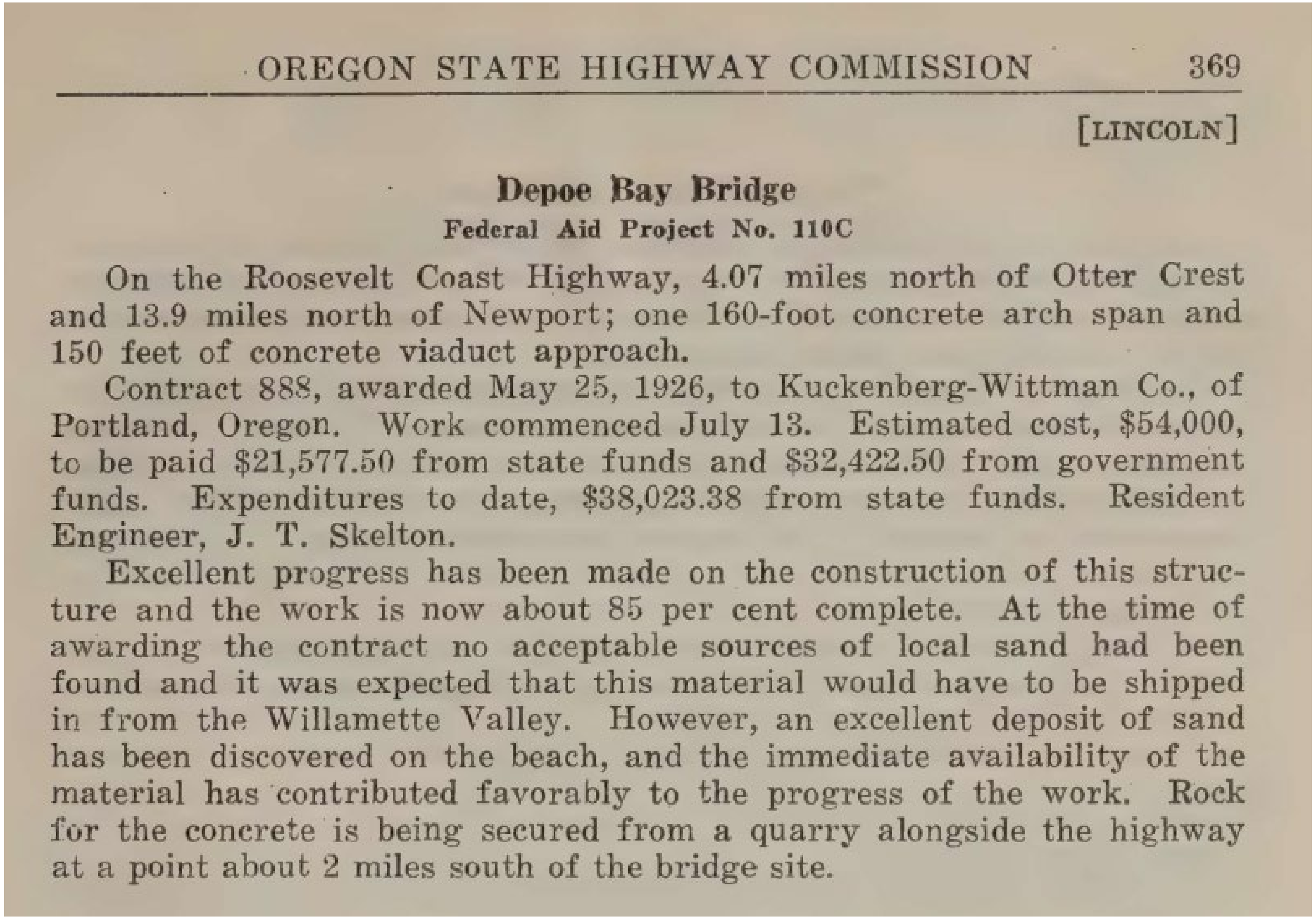
US Mail Stage at High Tide on the Oregon Coast, circa 1915

The original Depoe Bay bridge was designed in 1926, built in 1927.



One of the early Conde McCullough bridges.

1927 biennial report on the original construction.



OREGON STATE HIGHWAY COMMISSION 369

[LINCOLN]

Depoe Bay Bridge

Federal Aid Project No. 110C

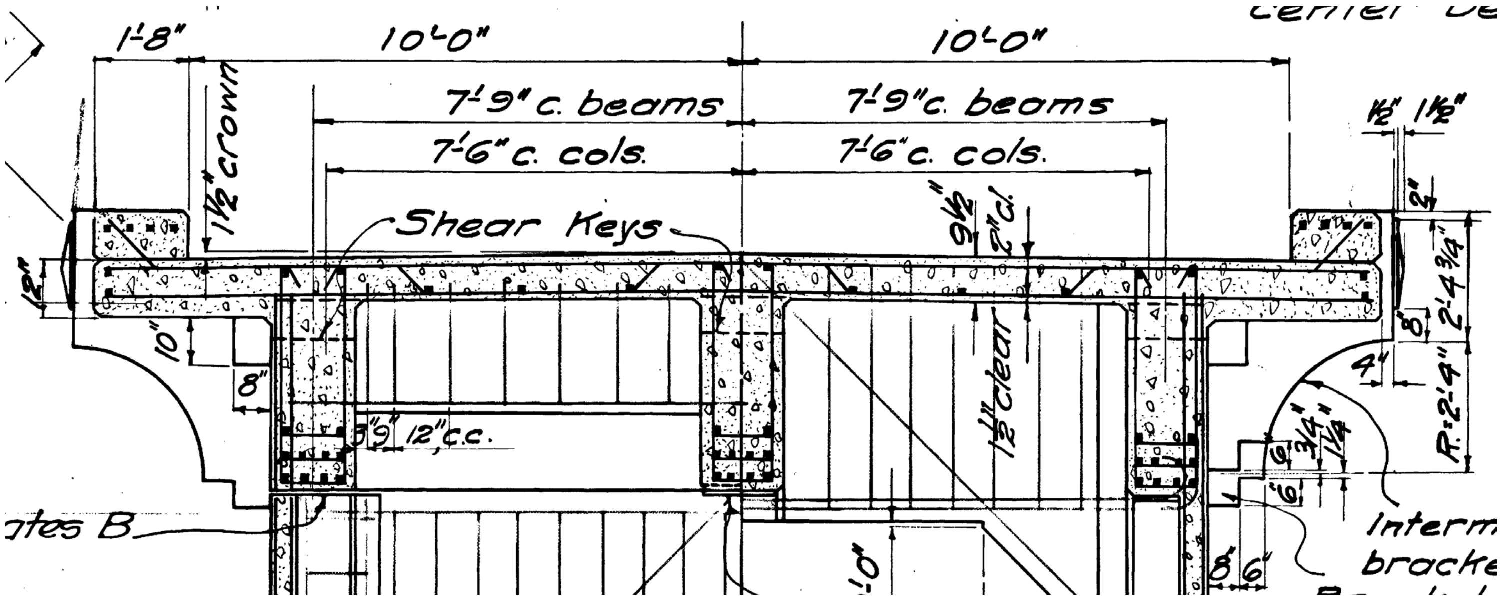
On the Roosevelt Coast Highway, 4.07 miles north of Otter Crest and 13.9 miles north of Newport; one 160-foot concrete arch span and 150 feet of concrete viaduct approach.

Contract 888, awarded May 25, 1926, to Kuckenberg-Wittman Co., of Portland, Oregon. Work commenced July 13. Estimated cost, $54,000, to be paid $21,577.50 from state funds and $32,422.50 from government funds. Expenditures to date, $38,023.38 from state funds. Resident Engineer, J. T. Skelton.

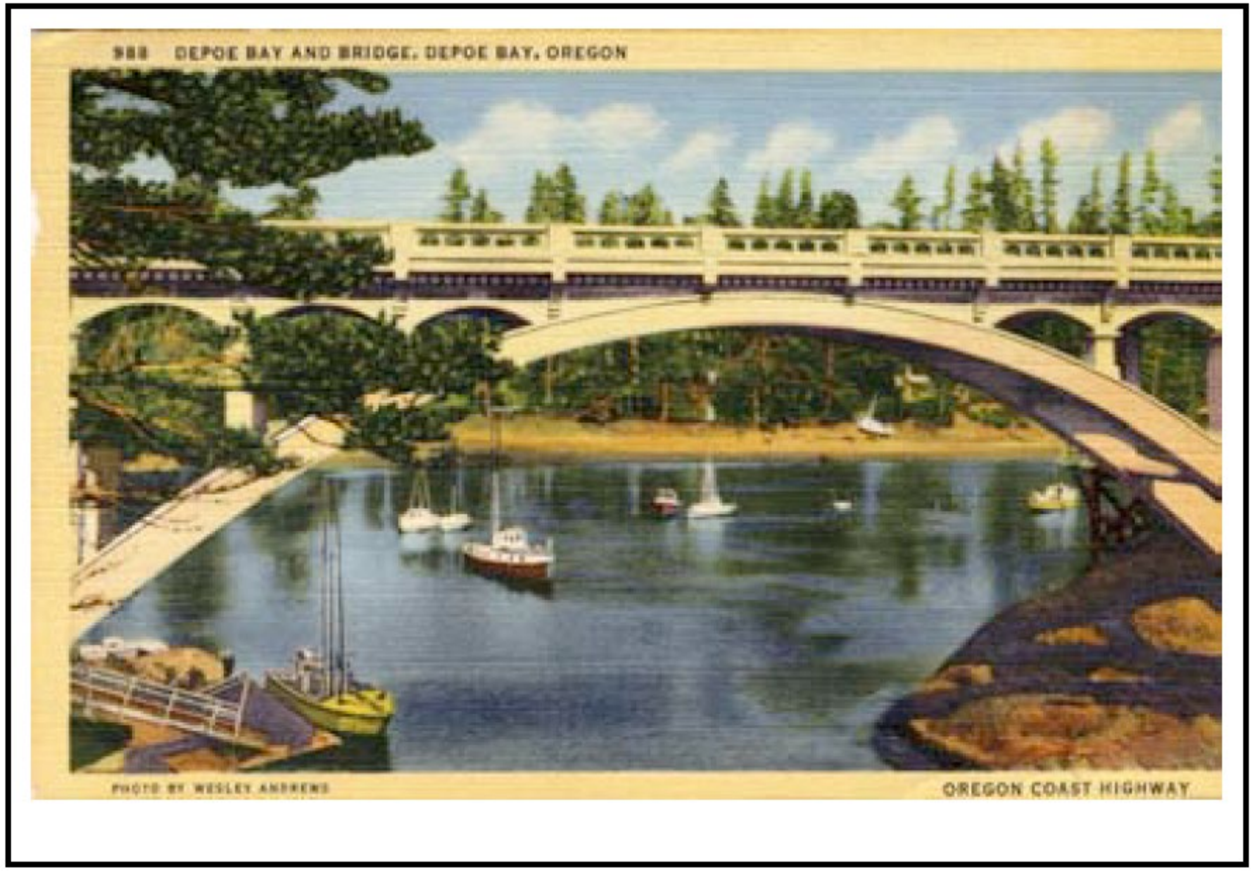
Excellent progress has been made on the construction of this structure and the work is now about 85 per cent complete. At the time of awarding the contract no acceptable sources of local sand had been found and it was expected that this material would have to be shipped in from the Willamette Valley. However, an excellent deposit of sand has been discovered on the beach, and the immediate availability of the material has contributed favorably to the progress of the work. Rock for the concrete is being secured from a quarry alongside the highway at a point about 2 miles south of the bridge site.

1927 Bridge

- Original bridge had two 10-foot travel lanes and no sidewalks.



Photograph and Postcard of the early bridge.

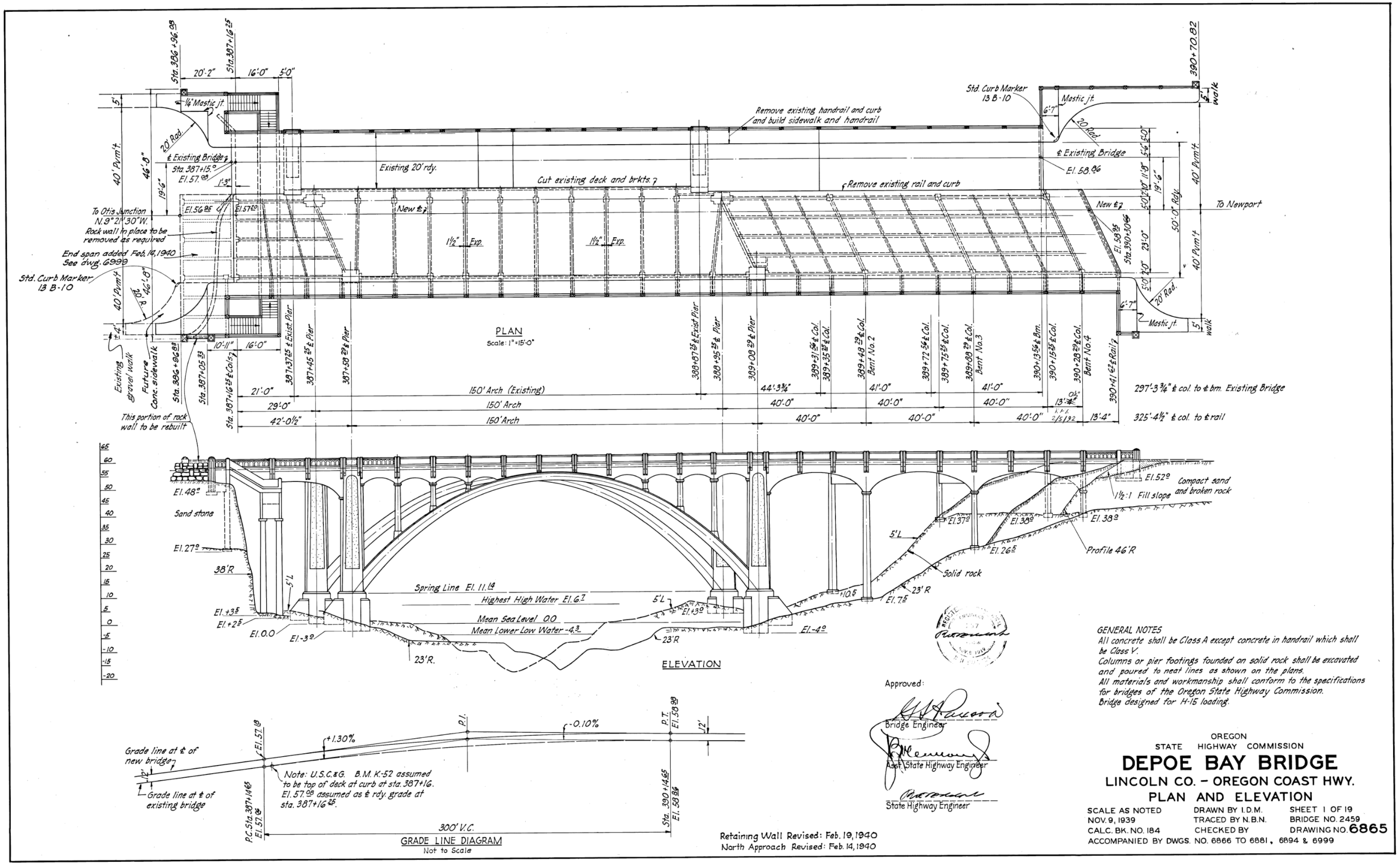


The world’s smallest navigable harbor.

Some is good, more is better!

- After the major river crossings were built during the Depression, the need for more capacity was clear. Yaquina Bay bridge (Newport) was completed in 1936.
- Widening designed for Depoe Bay Bridge in 1939, built in 1940.
- Widening structure was twice the width of the original, 20-foot roadway became 50-foot, plus two 5-foot sidewalks, for a total of 60 feet.
- The widening is a separate structure. The two are adjacent but not attached.
- McCullough had left the State Bridge Engineer’s position in 1936, but his influence is clear.

1940 widened bridge. BR # 2459



GENERAL NOTES
All concrete shall be Class A except concrete in handrail which shall be Class V.
Columns or pier footings founded on solid rock shall be excavated and poured to neat lines as shown on the plans.
All materials and workmanship shall conform to the specifications for bridges of the Oregon State Highway Commission.
Bridge designed for H-15 loading.

Approved:
G S Paxson
Bridge Engineer
Asst. State Highway Engineer
State Highway Engineer

NOV. 9, 1939

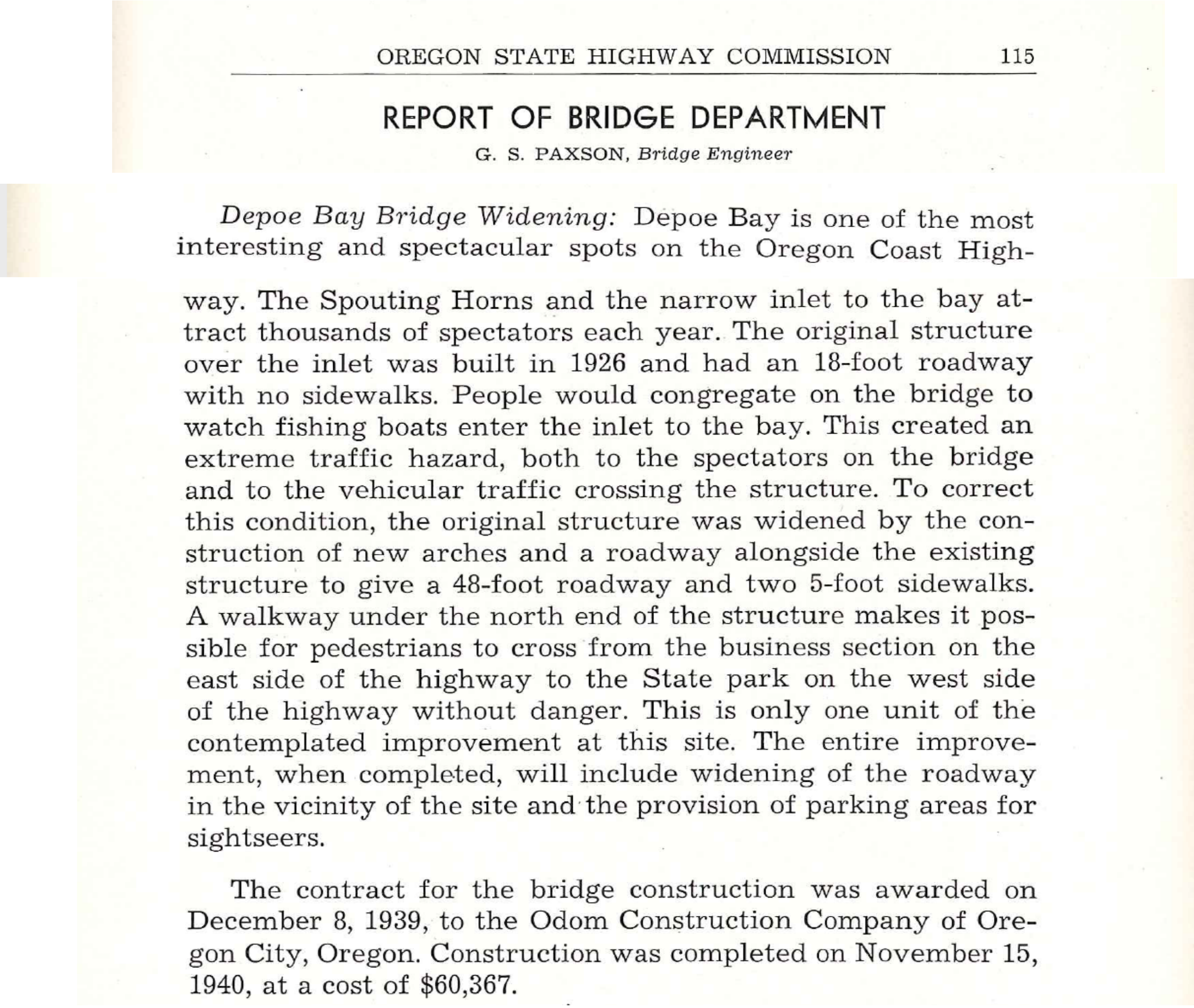
Retaining Wall Revised: Feb. 19, 1940
North Approach Revised: Feb. 14, 1940

OREGON
STATE HIGHWAY COMMISSION
DEPOE BAY BRIDGE
LINCOLN CO. – OREGON COAST HWY.
PLAN AND ELEVATION

SCALE AS NOTED	DRAWN BY I.D.M.	SHEET 1 OF 19
NOV. 9, 1939	TRACED BY N.B.N.	BRIDGE NO. 2459
CALC. BK. NO. 184	CHECKED BY	DRAWING NO. 6865

ACCOMPANIED BY DWGS. NO. 6866 TO 6881, 6894 & 6999

1940 biennial report on the widening construction



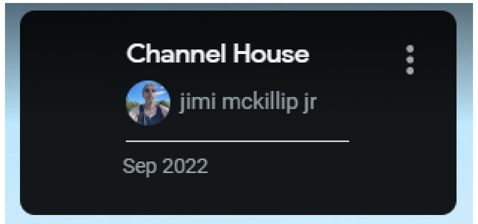
REPORT OF BRIDGE DEPARTMENT

G. S. PAXSON, *Bridge Engineer*

Depoe Bay Bridge Widening: Depoe Bay is one of the most interesting and spectacular spots on the Oregon Coast Highway. The Spouting Horns and the narrow inlet to the bay attract thousands of spectators each year. The original structure over the inlet was built in 1926 and had an 18-foot roadway with no sidewalks. People would congregate on the bridge to watch fishing boats enter the inlet to the bay. This created an extreme traffic hazard, both to the spectators on the bridge and to the vehicular traffic crossing the structure. To correct this condition, the original structure was widened by the construction of new arches and a roadway alongside the existing structure to give a 48-foot roadway and two 5-foot sidewalks. A walkway under the north end of the structure makes it possible for pedestrians to cross from the business section on the east side of the highway to the State park on the west side of the highway without danger. This is only one unit of the contemplated improvement at this site. The entire improvement, when completed, will include widening of the roadway in the vicinity of the site and the provision of parking areas for sightseers.

The contract for the bridge construction was awarded on December 8, 1939, to the Odom Construction Company of Oregon City, Oregon. Construction was completed on November 15, 1940, at a cost of $60,367.

Depoe Bay Bridge today (Google Maps).



Channel House

jimi mckillip jr

Sep 2022

View from the water.

A pretty little Bridge.

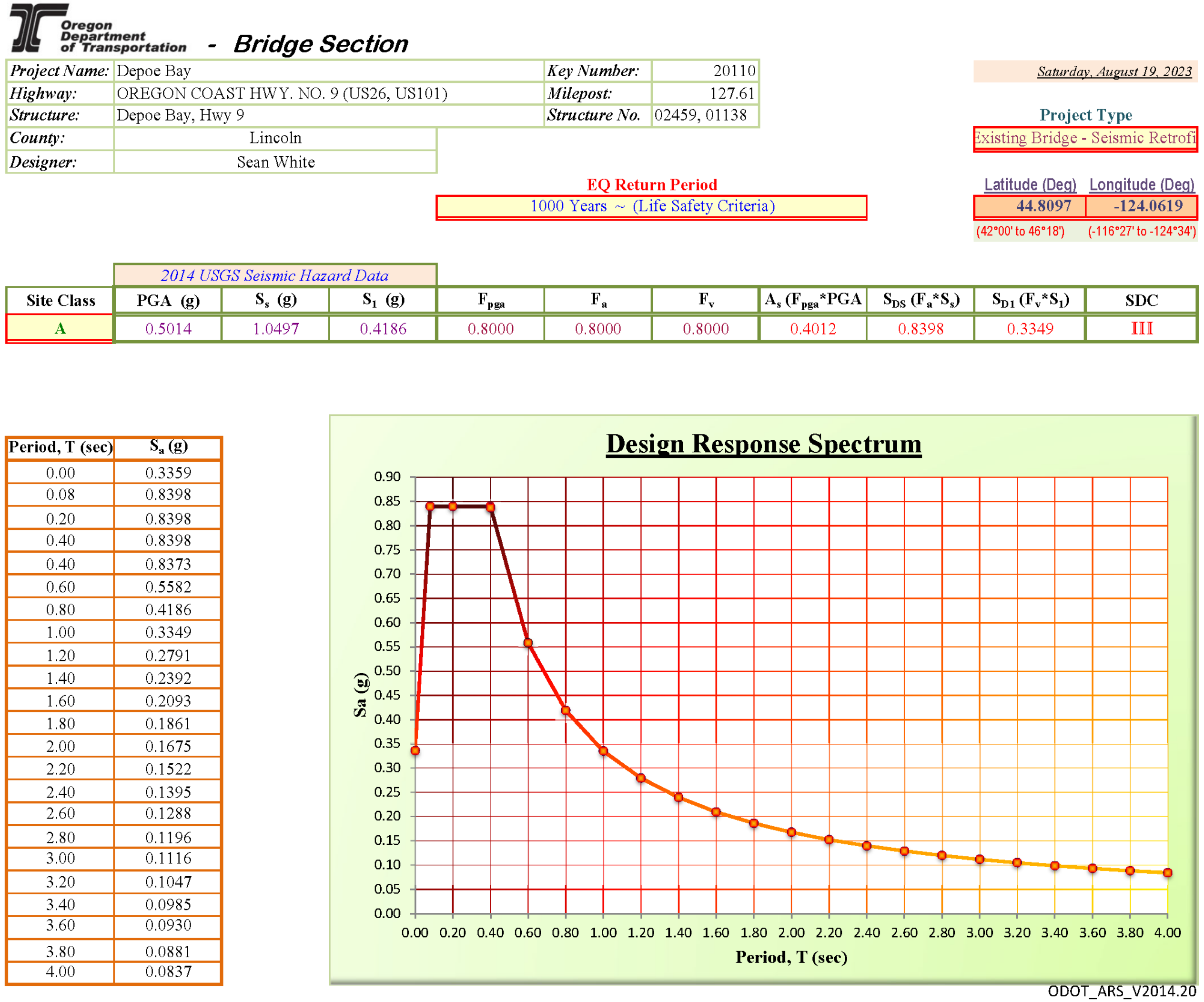
The need for seismic evaluation.

- The primary work on this bridge is to update of the Cathodic Protection system and repair the bridge railing.
- The need to replace existing seismic restrainers provided an opportunity to revisit the design.
- The scope of the seismic work is limited to Phase 1 life safety retrofit.

Figure 1: Example of corroded seismic restraint cables.

Figure 2: Example of corroded nuts and anchors

Life Safety Criteria.



Oregon Department of Transportation - *Bridge Section*

Project Name:	Depoe Bay	*Key Number:*	20110
Highway:	OREGON COAST HWY. NO. 9 (US26, US101)	*Milepost:*	127.61
Structure:	Depoe Bay, Hwy 9	*Structure No.*	02459, 01138
County:	Lincoln		
Designer:	Sean White		

Saturday, August 19, 2023

Project Type

Existing Bridge - Seismic Retrofi

EQ Return Period

1000 Years ~ (Life Safety Criteria)

Latitude (Deg)	Longitude (Deg)
44.8097	**-124.0619**
(42°00' to 46°18')	(-116°27' to -124°34')

2014 USGS Seismic Hazard Data

Site Class	PGA (g)	S_s (g)	S_1 (g)	F_{pga}	F_a	F_v	A_s (F_{pga}*PGA	S_{DS} (F_a*S_s)	S_{D1} (F_v*S_1)	SDC
A	0.5014	1.0497	0.4186	0.8000	0.8000	0.8000	0.4012	0.8398	0.3349	III

Period, T (sec)	S_a (g)
0.00	0.3359
0.08	0.8398
0.20	0.8398
0.40	0.8398
0.40	0.8373
0.60	0.5582
0.80	0.4186
1.00	0.3349
1.20	0.2791
1.40	0.2392
1.60	0.2093
1.80	0.1861
2.00	0.1675
2.20	0.1522
2.40	0.1395
2.60	0.1288
2.80	0.1196
3.00	0.1116
3.20	0.1047
3.40	0.0985
3.60	0.0930
3.80	0.0881
4.00	0.0837

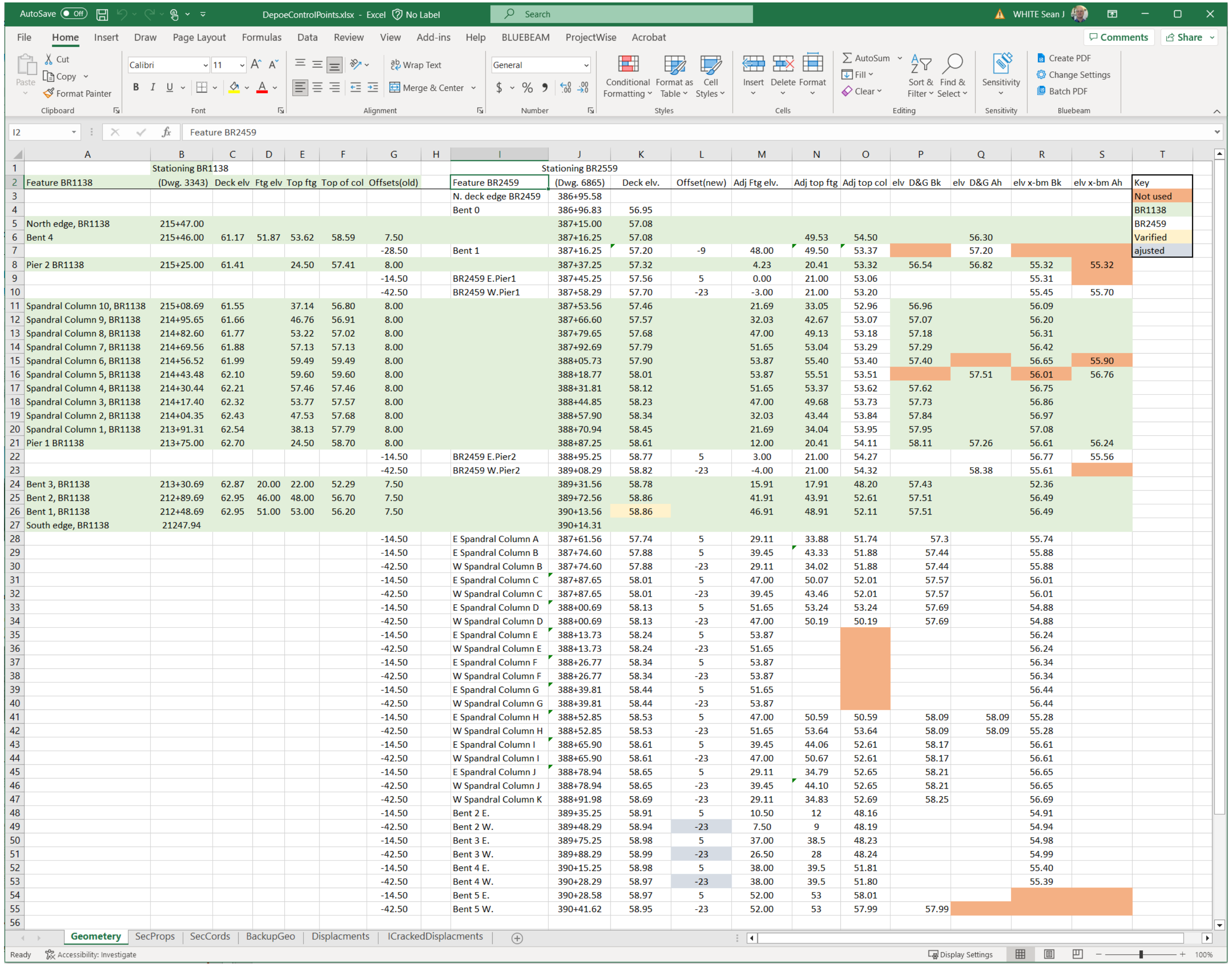
ODOT_ARS_V2014.20

Building the model.

Coordination:

Control lines parallel but running in different directions.

Two different elevation datum.

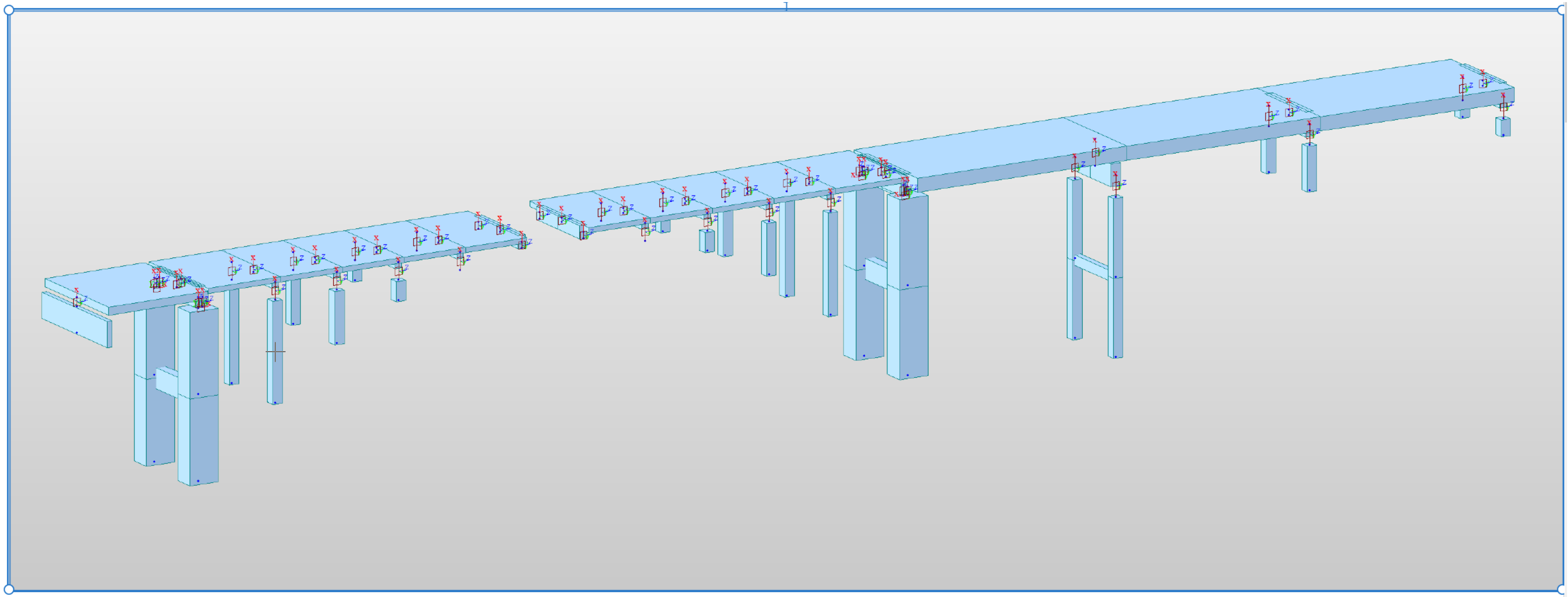


I2 Feature BR2459

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1		Stationing BR1138								Stationing BR2559										
2	Feature BR1138	(Dwg. 3343)	Deck elv	Ftg elv	Top ftg	Top of col	Offsets(old)		Feature BR2459	(Dwg. 6865)	Deck elv.	Offset(new)	Adj Ftg elv.	Adj top ftg	Adj top col	elv D&G Bk	elv D&G Ah	elv x-bm Bk	elv x-bm Ah	Key
3									N. deck edge BR2459	386+95.58										Not used
4									Bent 0	386+96.83	56.95									BR1138
5	North edge, BR1138	215+47.00								387+15.00	57.08									BR2459
6	Bent 4	215+46.00	61.17	51.87	53.62	58.59	7.50			387+16.25	57.08			49.53	54.50		56.30			Varified
7							-28.50		Bent 1	387+16.25	57.20	-9	48.00	49.50	53.37		57.20			ajusted
8	Pier 2 BR1138	215+25.00	61.41		24.50	57.41	8.00			387+37.25	57.32		4.23	20.41	53.32	56.54	56.82	55.32	55.32	
9							-14.50		BR2459 E.Pier1	387+45.25	57.56	5	0.00	21.00	53.06			55.31		
10							-42.50		BR2459 W.Pier1	387+58.29	57.70	-23	-3.00	21.00	53.20			55.45	55.70	
11	Spandral Column 10, BR1138	215+08.69	61.55		37.14	56.80	8.00			387+53.56	57.46		21.69	33.05	52.96	56.96		56.09		
12	Spandral Column 9, BR1138	214+95.65	61.66		46.76	56.91	8.00			387+66.60	57.57		32.03	42.67	53.07	57.07		56.20		
13	Spandral Column 8, BR1138	214+82.60	61.77		53.22	57.02	8.00			387+79.65	57.68		47.00	49.13	53.18	57.18		56.31		
14	Spandral Column 7, BR1138	214+69.56	61.88		57.13	57.13	8.00			387+92.69	57.79		51.65	53.04	53.29	57.29		56.42		
15	Spandral Column 6, BR1138	214+56.52	61.99		59.49	59.49	8.00			388+05.73	57.90		53.87	55.40	53.40	57.40		56.65	55.90	
16	Spandral Column 5, BR1138	214+43.48	62.10		59.60	59.60	8.00			388+18.77	58.01		53.87	55.51	53.51		57.51	56.01	56.76	
17	Spandral Column 4, BR1138	214+30.44	62.21		57.46	57.46	8.00			388+31.81	58.12		51.65	53.37	53.62	57.62		56.75		
18	Spandral Column 3, BR1138	214+17.40	62.32		53.77	57.57	8.00			388+44.85	58.23		47.00	49.68	53.73	57.73		56.86		
19	Spandral Column 2, BR1138	214+04.35	62.43		47.53	57.68	8.00			388+57.90	58.34		32.03	43.44	53.84	57.84		56.97		
20	Spandral Column 1, BR1138	213+91.31	62.54		38.13	57.79	8.00			388+70.94	58.45		21.69	34.04	53.95	57.95		57.08		
21	Pier 1 BR1138	213+75.00	62.70		24.50	58.70	8.00			388+87.25	58.61		12.00	20.41	54.11	58.11	57.26	56.61	56.24	
22							-14.50		BR2459 E.Pier2	388+95.25	58.77	5	3.00	21.00	54.27			56.77	55.56	
23							-42.50		BR2459 W.Pier2	389+08.29	58.82	-23	-4.00	21.00	54.32		58.38	55.61		
24	Bent 3, BR1138	213+30.69	62.87	20.00	22.00	52.29	7.50			389+31.56	58.78		15.91	17.91	48.20	57.43		52.36		
25	Bent 2, BR1138	212+89.69	62.95	46.00	48.00	56.70	7.50			389+72.56	58.86		41.91	43.91	52.61	57.51		56.49		
26	Bent 1, BR1138	212+48.69	62.95	51.00	53.00	56.20	7.50			390+13.56	58.86		46.91	48.91	52.11	57.51		56.49		
27	South edge, BR1138	21247.94								390+14.31										
28							-14.50		E Spandral Column A	387+61.56	57.74	5	29.11	33.88	51.74	57.3		55.74		
29							-14.50		E Spandral Column B	387+74.60	57.88	5	39.45	43.33	51.88	57.44		55.88		
30							-42.50		W Spandral Column B	387+74.60	57.88	-23	29.11	34.02	51.88	57.44		55.88		
31							-14.50		E Spandral Column C	387+87.65	58.01	5	47.00	50.07	52.01	57.57		56.01		
32							-42.50		W Spandral Column C	387+87.65	58.01	-23	39.45	43.46	52.01	57.57		56.01		
33							-14.50		E Spandral Column D	388+00.69	58.13	5	51.65	53.24	53.24	57.69		54.88		
34							-42.50		W Spandral Column D	388+00.69	58.13	-23	47.00	50.19	50.19	57.69		54.88		
35							-14.50		E Spandral Column E	388+13.73	58.24	5	53.87					56.24		
36							-42.50		W Spandral Column E	388+13.73	58.24	-23	51.65					56.24		
37							-14.50		E Spandral Column F	388+26.77	58.34	5	53.87					56.34		
38							-42.50		W Spandral Column F	388+26.77	58.34	-23	53.87					56.34		
39							-14.50		E Spandral Column G	388+39.81	58.44	5	51.65					56.44		
40							-42.50		W Spandral Column G	388+39.81	58.44	-23	53.87					56.44		
41							-14.50		E Spandral Column H	388+52.85	58.53	5	47.00	50.59	50.59	58.09	58.09	55.28		
42							-42.50		W Spandral Column H	388+52.85	58.53	-23	51.65	53.64	53.64	58.09	58.09	55.28		
43							-14.50		E Spandral Column I	388+65.90	58.61	5	39.45	44.06	52.61	58.17		56.61		
44							-42.50		W Spandral Column I	388+65.90	58.61	-23	47.00	50.67	52.61	58.17		56.61		
45							-14.50		E Spandral Column J	388+78.94	58.65	5	29.11	34.79	52.65	58.21		56.65		
46							-42.50		W Spandral Column J	388+78.94	58.65	-23	39.45	44.10	52.65	58.21		56.65		
47							-42.50		W Spandral Column K	388+91.98	58.69	-23	29.11	34.83	52.69	58.25		56.69		
48							-14.50		Bent 2 E.	389+35.25	58.91	5	10.50	12	48.16			54.91		
49							-42.50		Bent 2 W.	389+48.29	58.94	-23	7.50	9	48.19			54.94		
50							-14.50		Bent 3 E.	389+75.25	58.98	5	37.00	38.5	48.23			54.98		
51							-42.50		Bent 3 W.	389+88.29	58.99	-23	26.50	28	48.24			54.99		
52							-14.50		Bent 4 E.	390+15.25	58.98	5	38.00	39.5	51.81			55.40		
53							-42.50		Bent 4 W.	390+28.29	58.97	-23	38.00	39.5	51.80			55.39		
54							-14.50		Bent 5 E.	390+28.58	58.97	5	52.00	53	58.01					
55							-42.50		Bent 5 W.	390+41.62	58.95	-23	52.00	53	57.99	57.99				
56																				

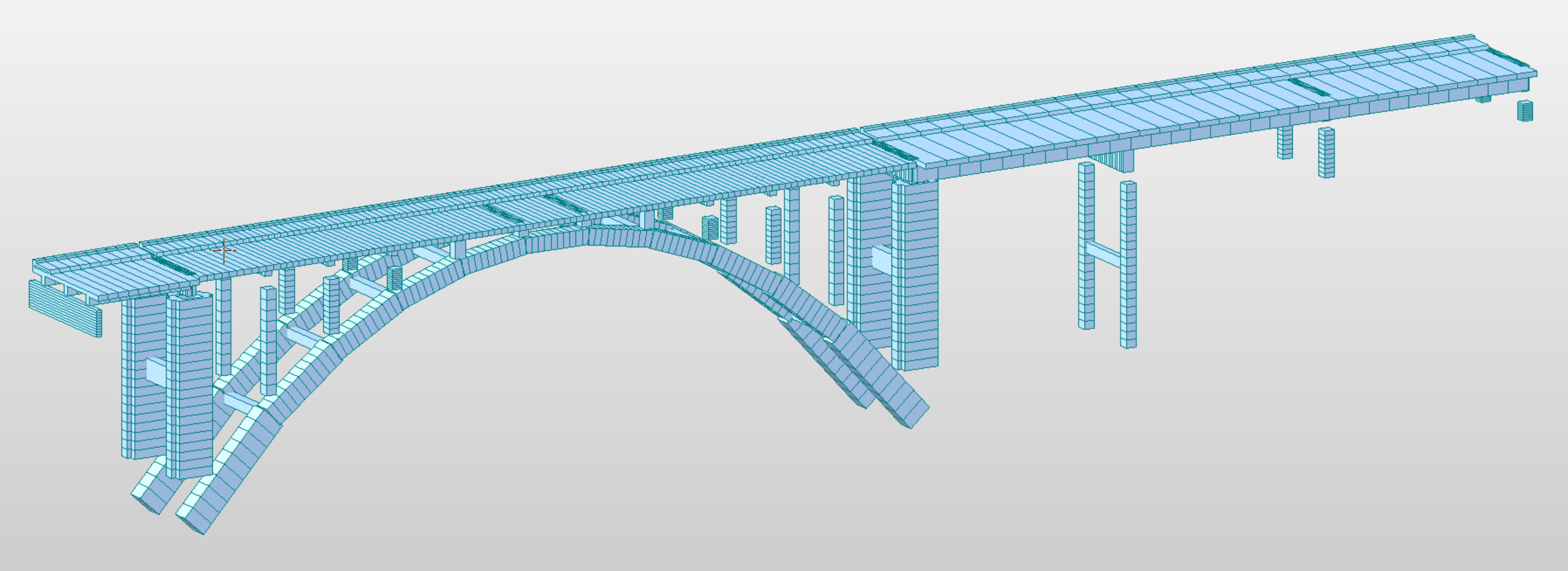
Starting simple:

Simple block elements between control points.
Beam end releases to model joints.
Ridged links to tie sections together.
Section properties overwritten with hand calculated values.



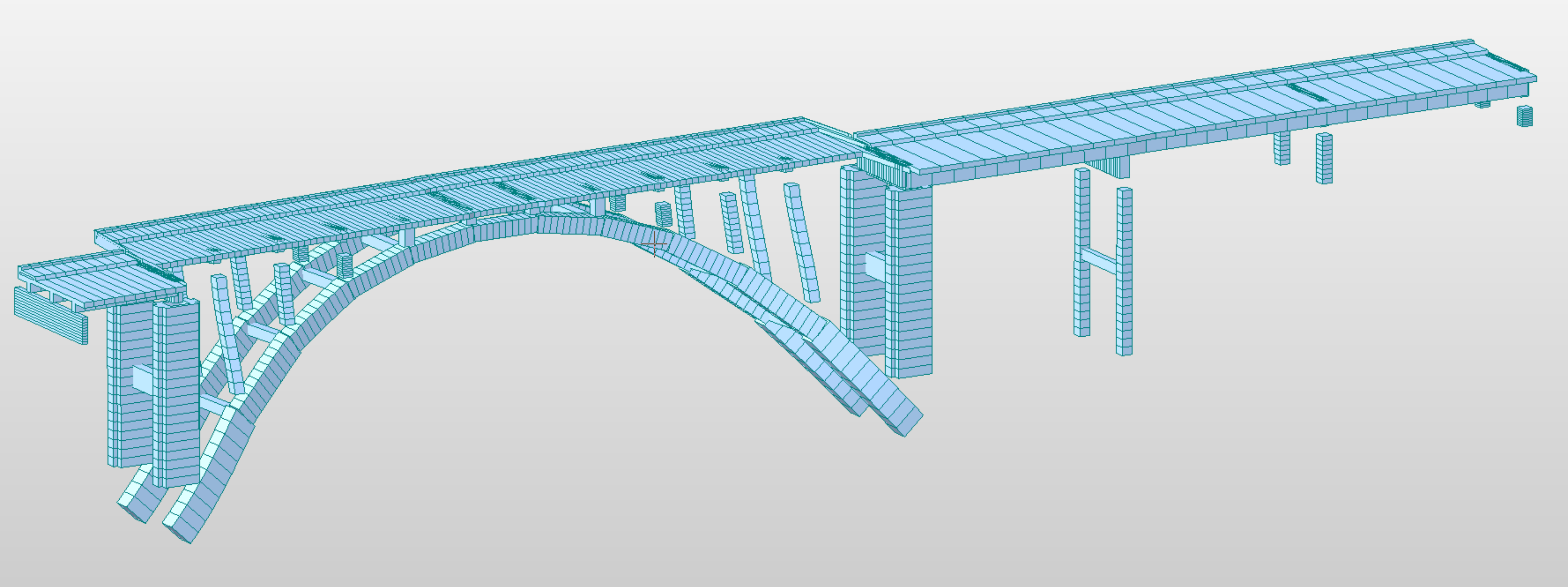
Refining the model:

Adding arch ribs. Entered complex shapes which allowed software to calculate the section properties. Modified concrete stiffness to cracked section properties.

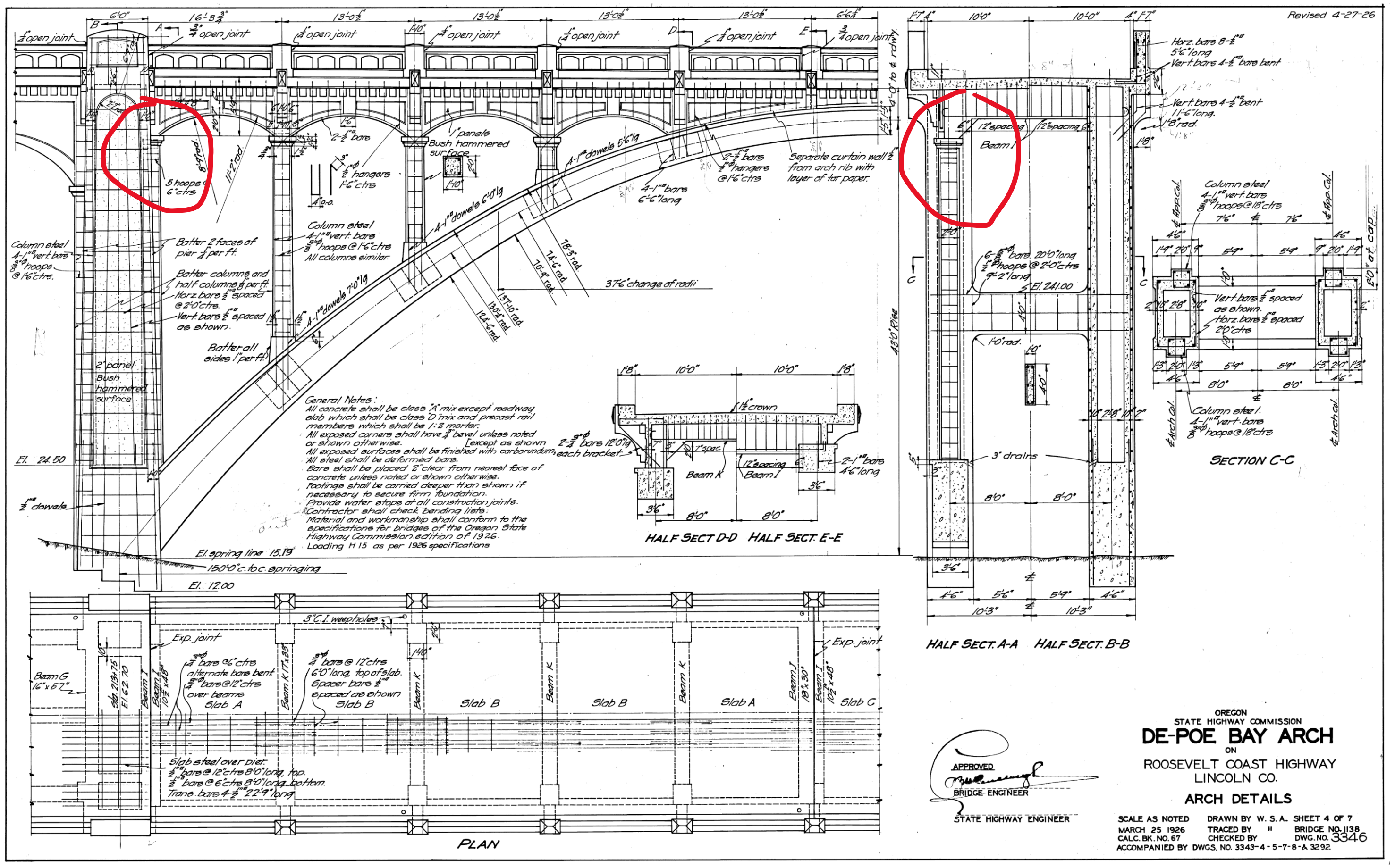


Watching it move.

About 3.5” lateral movement at the Pier Column to Spandrel Column supported deck joint.



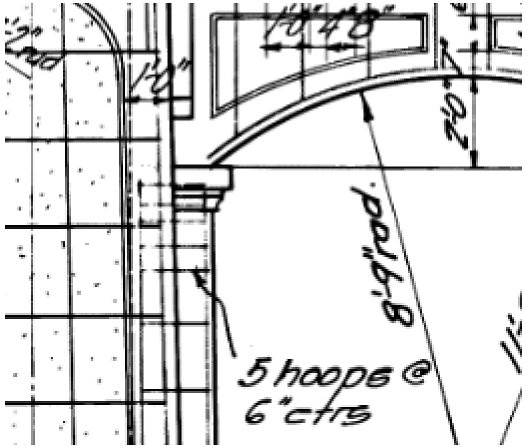
Concrete Hinge (unreinforced concrete pedestal).

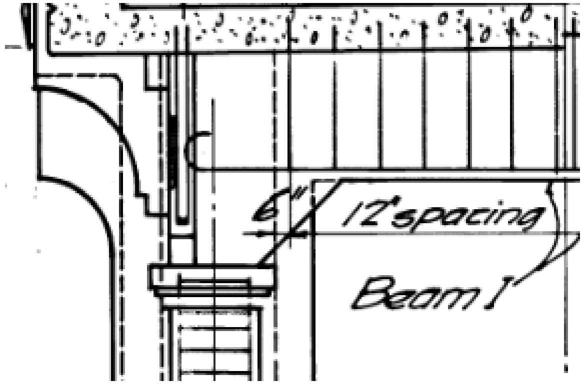


General Notes:
All concrete shall be class "A" mix except roadway slab which shall be class "D" mix and precast rail members which shall be 1:2 mortar.
All exposed corners shall have 3/4" bevel unless noted or shown otherwise.
All exposed surfaces shall be finished with carborundum, [except as shown
All steel shall be deformed bars.
Bars shall be placed 2" clear from nearest face of concrete unless noted or shown otherwise.
Footings shall be carried deeper than shown if necessary to secure firm foundation.
Provide water stops at all construction joints.
Contractor shall check bending lists.
Material and workmanship shall conform to the specifications for bridges of the Oregon State Highway Commission edition of 1926.
Loading H 15 as per 1926 specifications

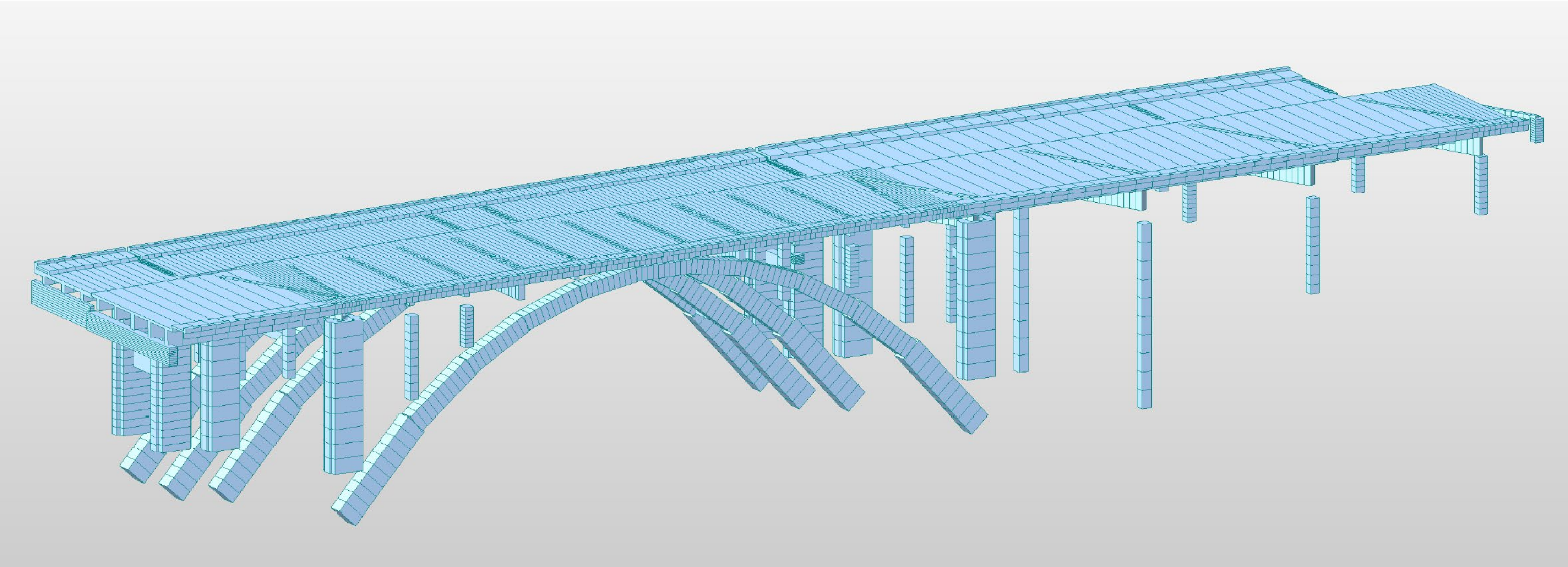
OREGON
STATE HIGHWAY COMMISSION
DE-POE BAY ARCH
ON
ROOSEVELT COAST HIGHWAY
LINCOLN CO.
ARCH DETAILS

SCALE AS NOTED DRAWN BY W. S. A. SHEET 4 OF 7
MARCH 25 1926 TRACED BY " BRIDGE NO. 1138
CALC. BK. NO. 67 CHECKED BY DWG. NO. 3346
ACCOMPANIED BY DWGS. NO. 3343-4-5-7-8-& 3292

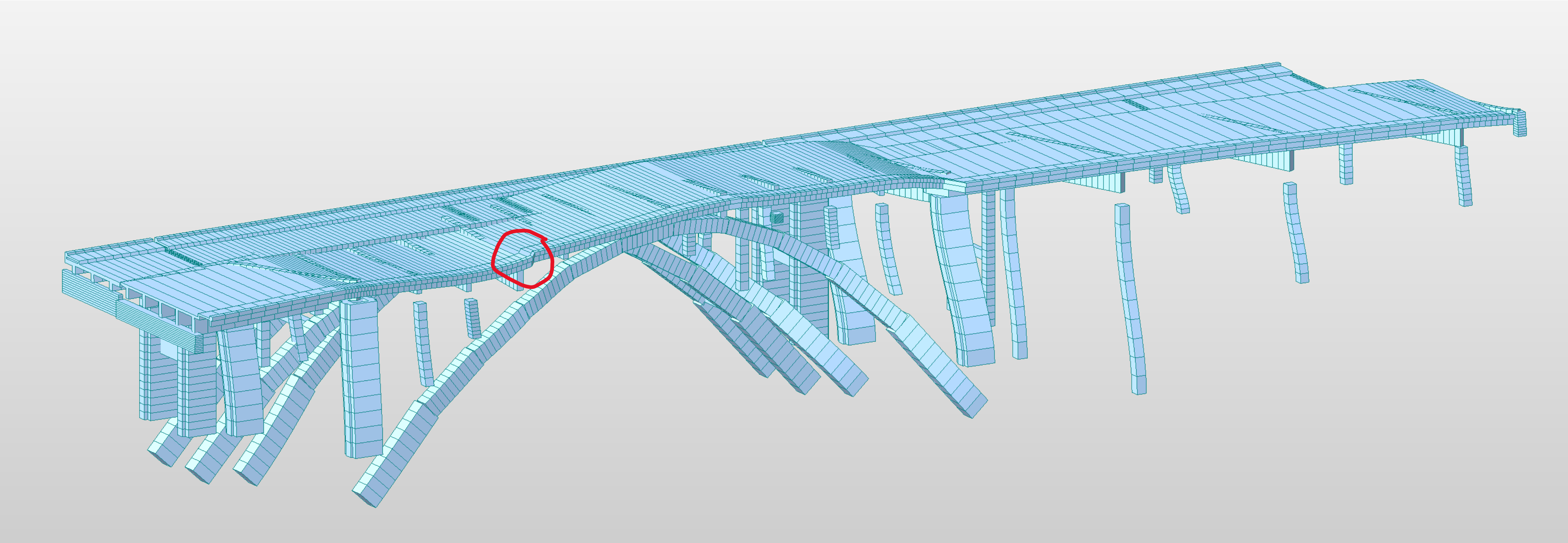




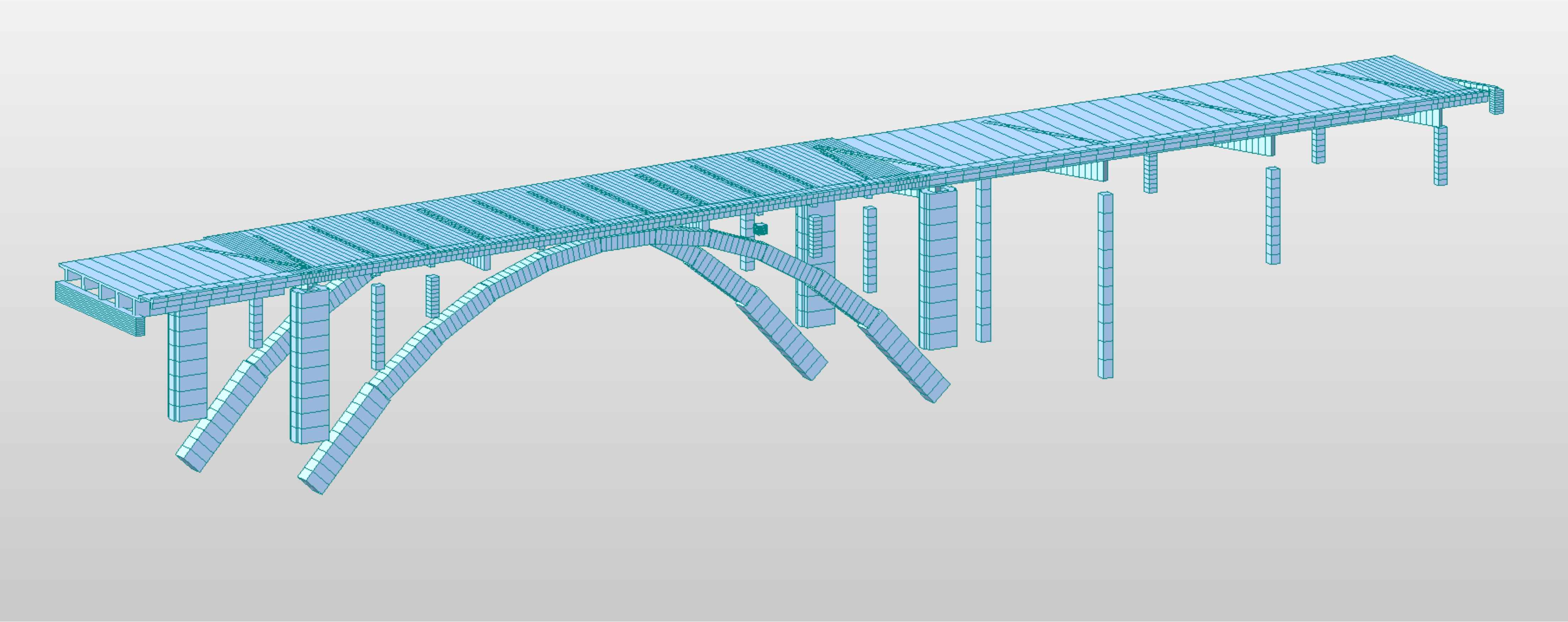
Adding complexity:



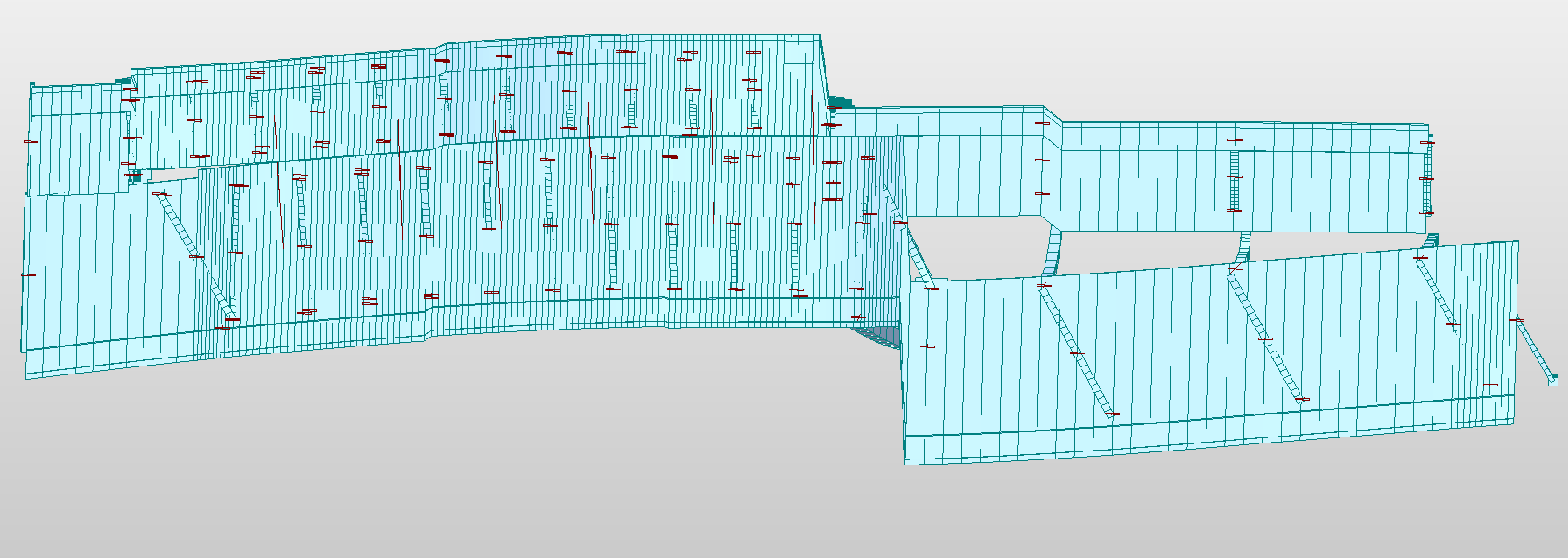
Looking at displacement at the restrainers.



Isolating the widening structure.



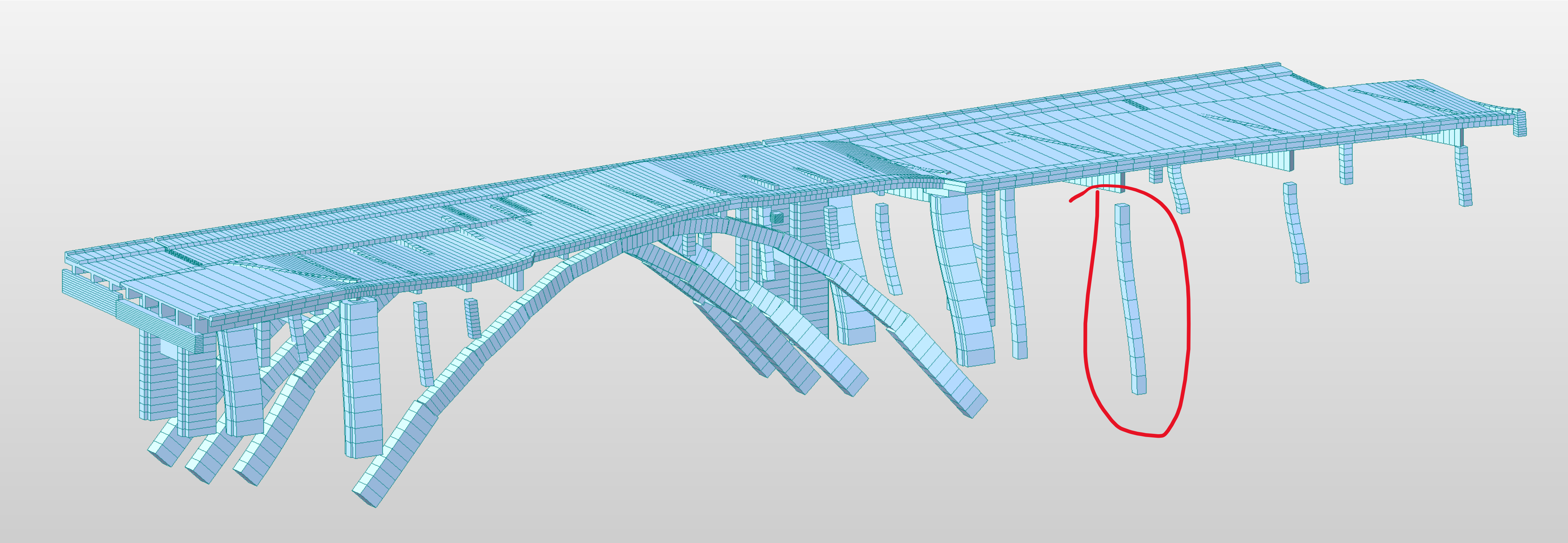
Tying the two together.



As long as we are here...

Take a look at the displacement demand on the lightly reinforced columns.

Full scale tests give data to compare to.



Full scale laboratory research of similar details.

SEISMIC PERFORMANCE DESIGN CRITERIA FOR BRIDGE BENT PLASTIC HINGE REGIONS

Final Report

SPR 802

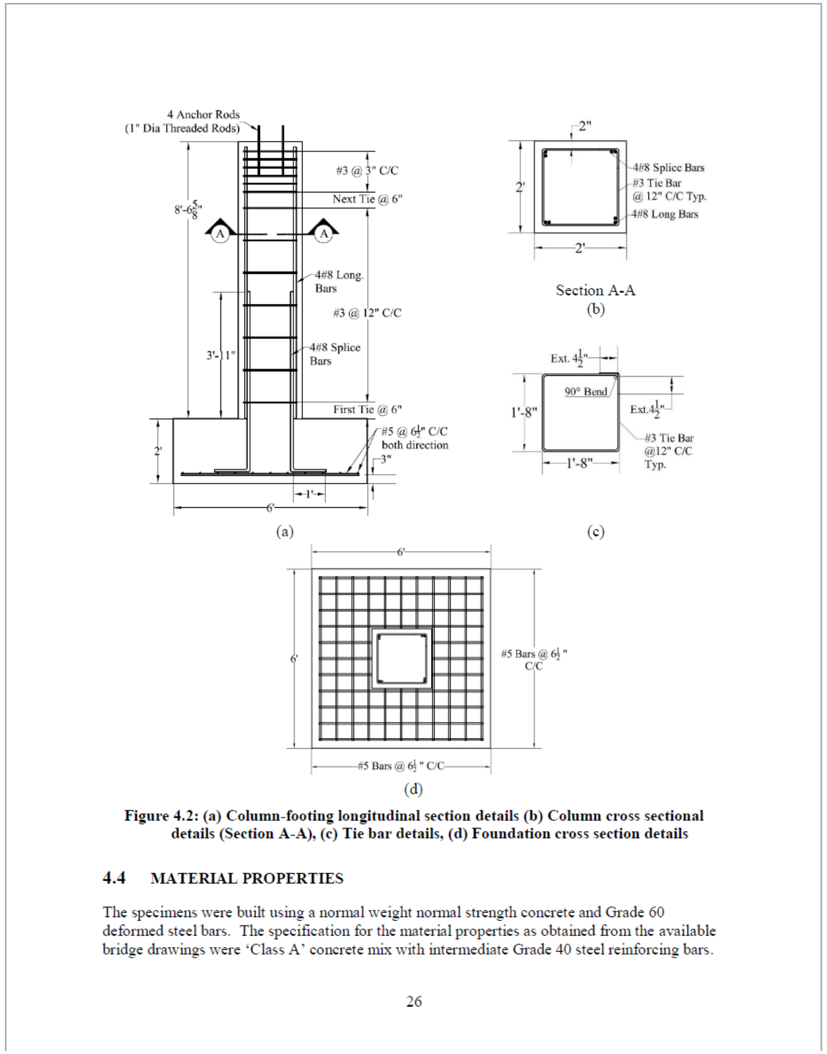


Figure 4.2: (a) Column-footing longitudinal section details (b) Column cross sectional details (Section A-A), (c) Tie bar details, (d) Foundation cross section details

4.4 MATERIAL PROPERTIES

The specimens were built using a normal weight normal strength concrete and Grade 60 deformed steel bars. The specification for the material properties as obtained from the available bridge drawings were 'Class A' concrete mix with intermediate Grade 40 steel reinforcing bars.

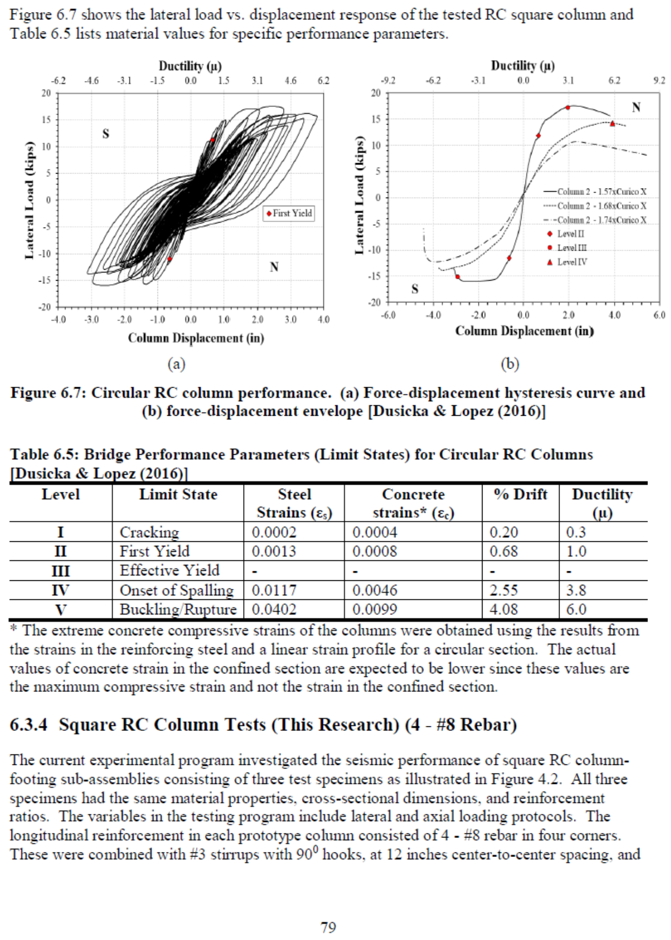


Figure 6.7 shows the lateral load vs. displacement response of the tested RC square column and Table 6.5 lists material values for specific performance parameters.

Figure 6.7: Circular RC column performance. (a) Force-displacement hysteresis curve and (b) force-displacement envelope [Dusicka & Lopez (2016)]

Table 6.5: Bridge Performance Parameters (Limit States) for Circular RC Columns [Dusicka & Lopez (2016)]

Level	Limit State	Steel Strains (ε_s)	Concrete strains* (ε_c)	% Drift	Ductility (μ)
I	Cracking	0.0002	0.0004	0.20	0.3
II	First Yield	0.0013	0.0008	0.68	1.0
III	Effective Yield	-	-	-	-
IV	Onset of Spalling	0.0117	0.0046	2.55	3.8
V	Buckling/Rupture	0.0402	0.0099	4.08	6.0

* The extreme concrete compressive strains of the columns were obtained using the results from the strains in the reinforcing steel and a linear strain profile for a circular section. The actual values of concrete strain in the confined section are expected to be lower since these values are the maximum compressive strain and not the strain in the confined section.

6.3.4 Square RC Column Tests (This Research) (4 - #8 Rebar)

The current experimental program investigated the seismic performance of square RC column-footing sub-assemblies consisting of three test specimens as illustrated in Figure 4.2. All three specimens had the same material properties, cross-sectional dimensions, and reinforcement ratios. The variables in the testing program include lateral and axial loading protocols. The longitudinal reinforcement in each prototype column consisted of 4 - #8 rebar in four corners. These were combined with #3 stirrups with 90^0 hooks, at 12 inches center-to-center spacing, and

Conclusions:

- The existing restrainers are unneeded as the movement demand at the joint is less then the capacity of the beam seats. Deleting the restrainers simplifies the Cathodic Protection system.
- Tying the two structures together will reduce the predicted lateral deck displacement, but not enough to affect the results.
- The concrete hinges will be damaged by the deck displacement but are unlikely to fail to support the span. If span drops enough to block traffic the widening structure can accommodate.
- Based on ‘drift’ alone, it is likely that the columns will survive the design earthquake.

Questions?