HDR

Comparison of FEE vs. SEE

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HDR

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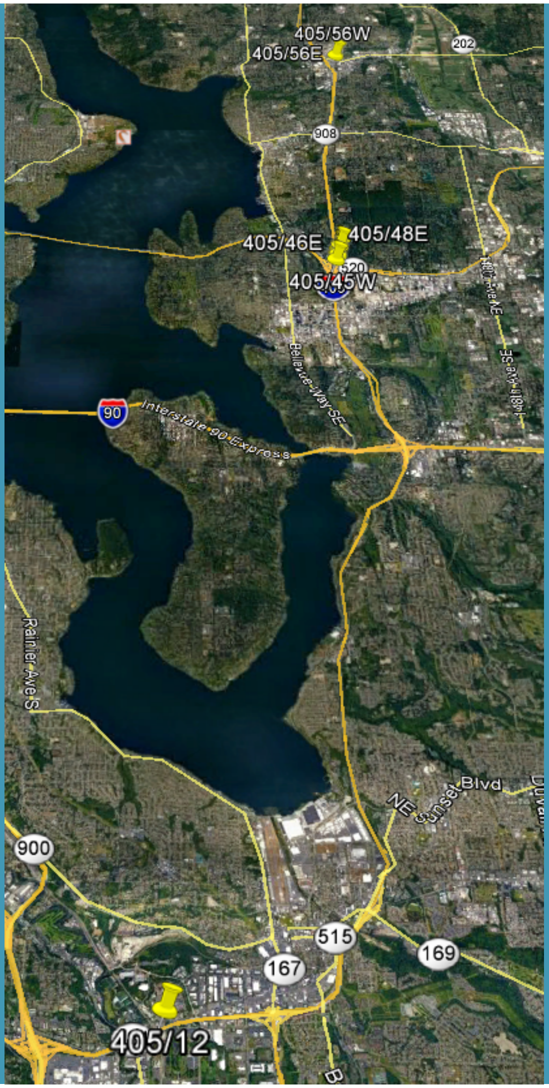
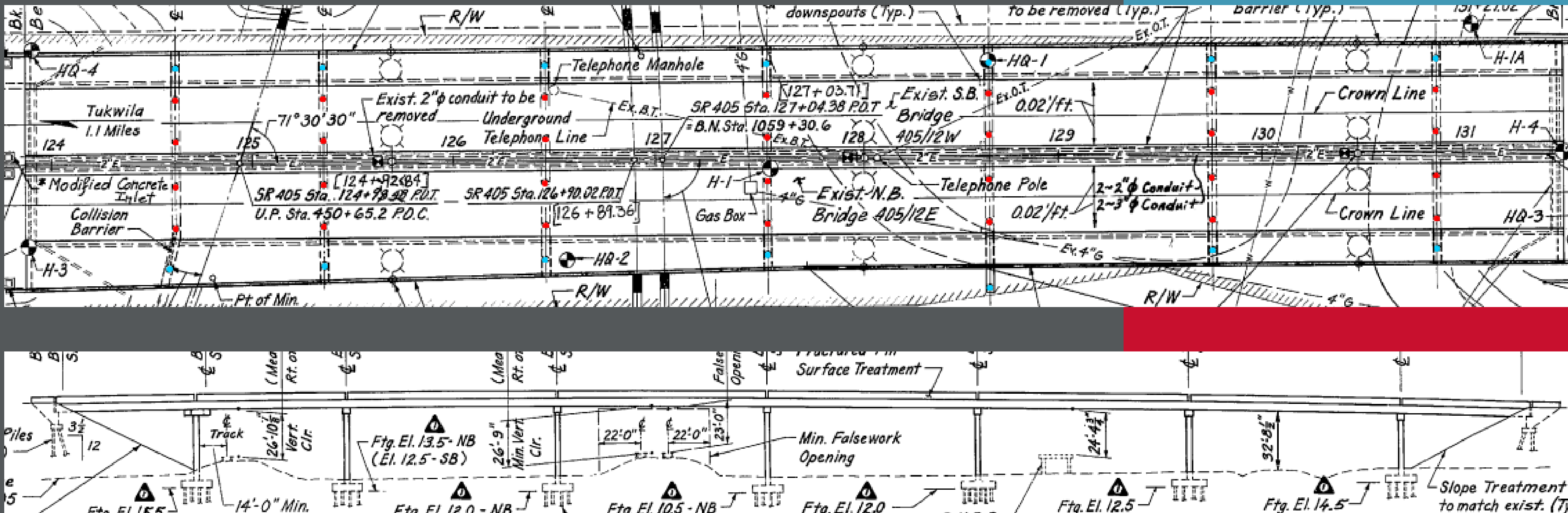
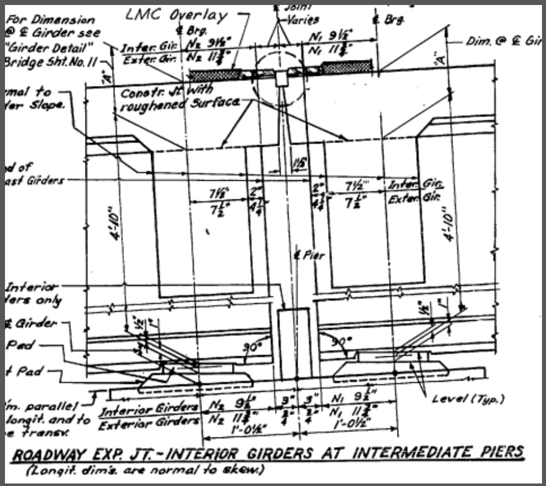
10 Bridges
- **405/12**
- **405/45W**
- **405/46E**
- **405/46W**
- **405/47E**
- **405/47W**
- **405/48E**
- **405/48W**
- **405/56E**
- **405/56W**

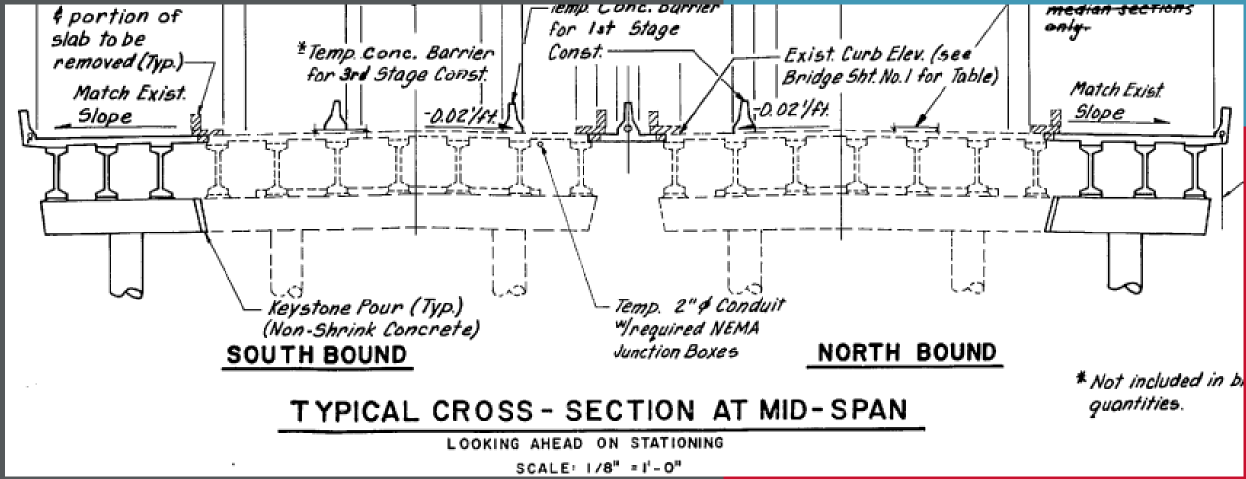




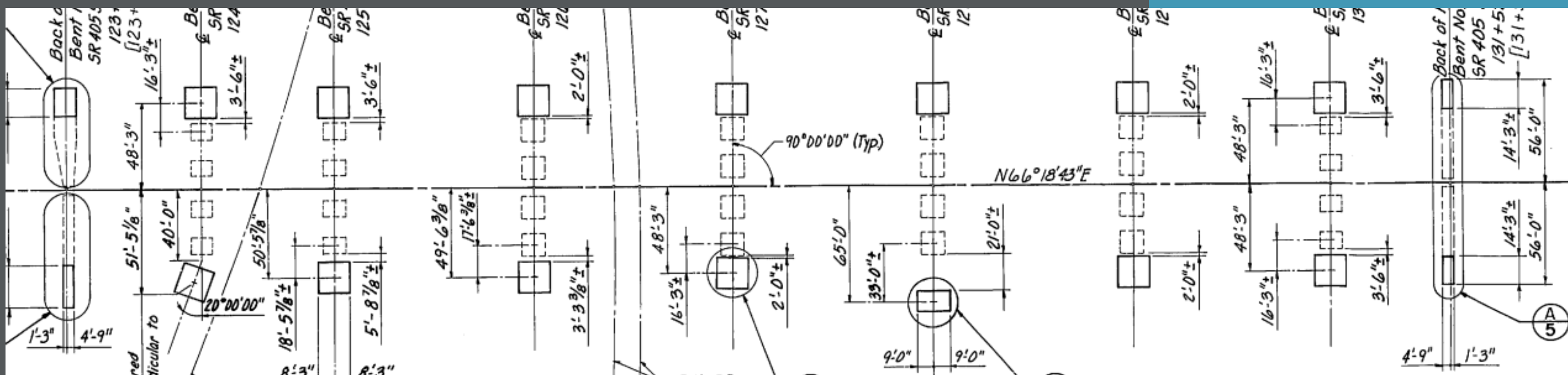
LEGEND
- ORIGINAL COLUMNS
- WIDENING COLUMNS

Bridge 405/12

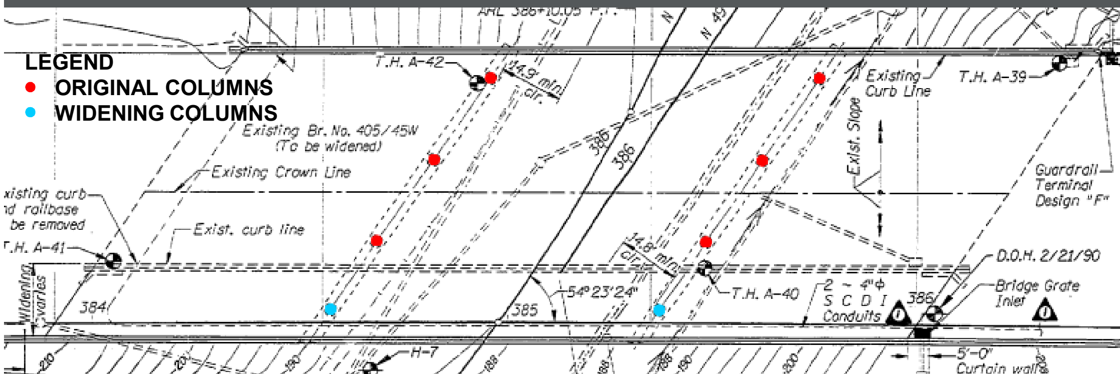


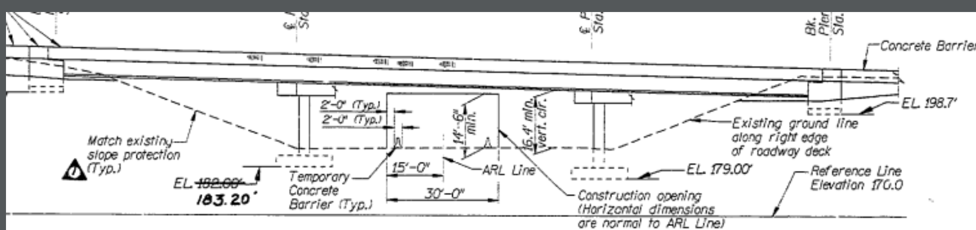


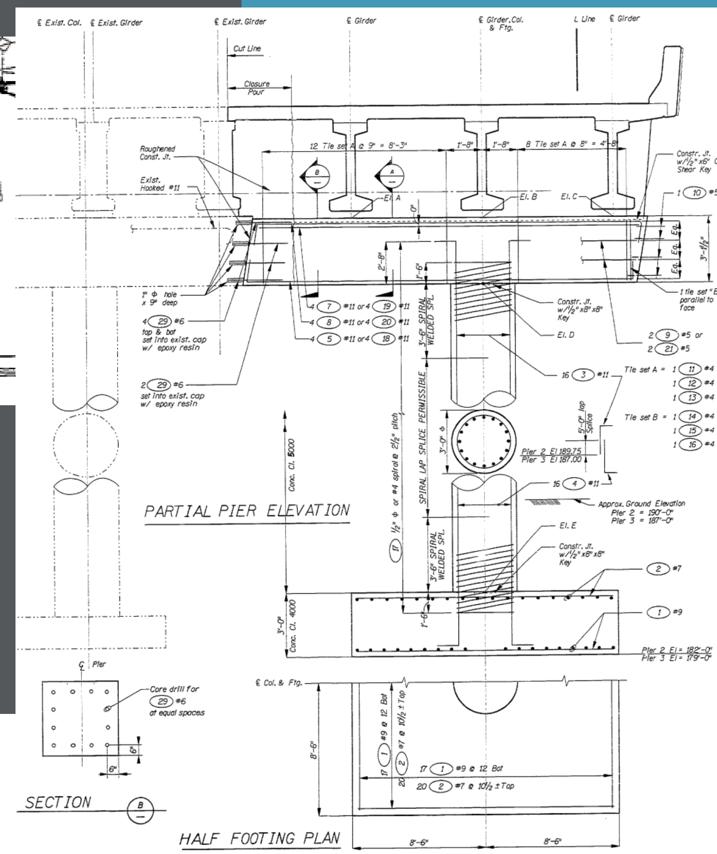
Bridge 405/12



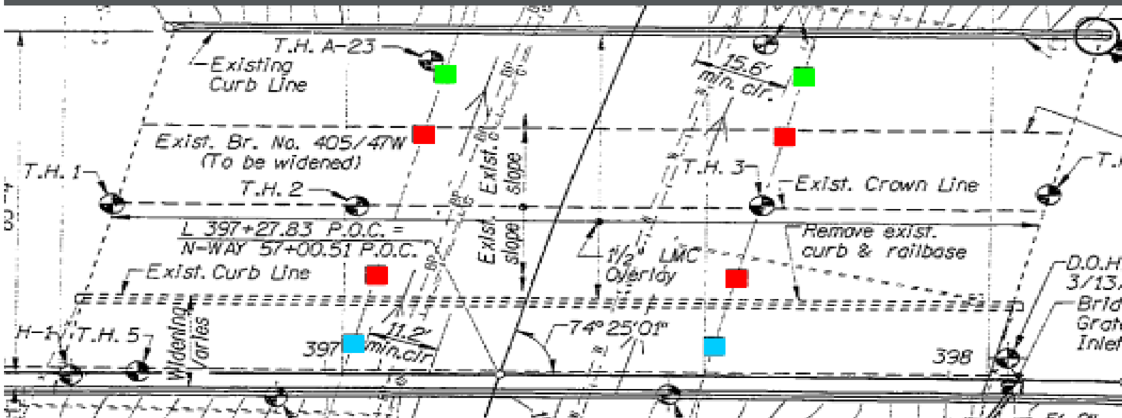
Bridge 405/12

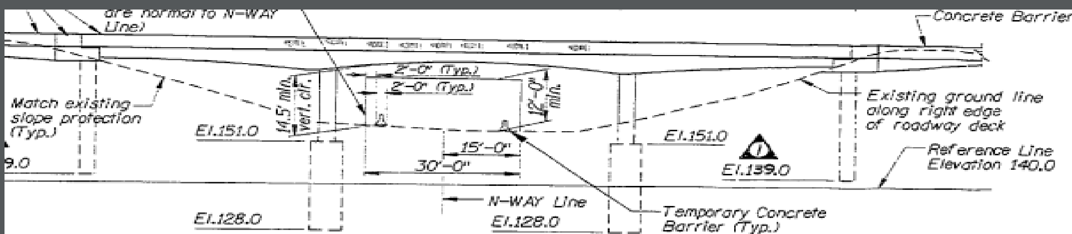


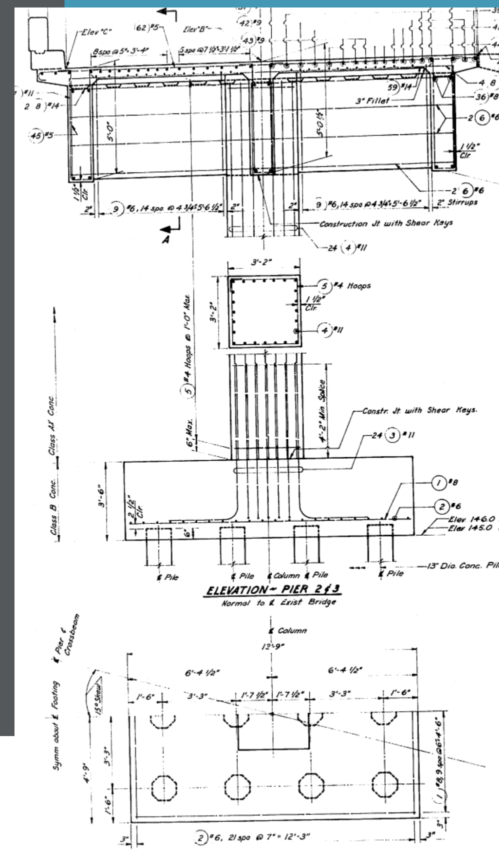




Bridge 405/45W







LEGEND

- ORIGINAL (1953) COLUMNS
- 1965 WIDENING COLUMNS
- 1992 WIDENING COLUMNS

Bridge 405/47W

SEE VS. FEE

- SEE: 7% EXCEEDANCE IN 75 YEARS
- FEE: 30% EXCEEDANCE IN 75 YEARS

DEMAND APPLIED TO FOUNDATION ELEMENTS TAKEN FROM THE ELASTIC DYNAMIC ANALYSIS PROCEDURE (NOT THE TYPICAL COLUMN OVERSTRENGTH FORCES)

Bridge 405/47W

PIER 3 – Original (SEE)			
PILE CAP	C/D	Dem	Cap
Cap M (k-ft)	-	898	-
Cap V (k)	0.52	828	434
Pile Axial (k)	0.72	185	134
Pile Shear (k)	2.58	13	34
Pile Pull Out (k)	0.03	98	2
COLUMN			
Long. Disp. (in)	0.89	14.0	12.5
Transv. Disp (in)	1.13	6.0	6.8
Shear (k)	0.84	196	165
CROSSBEAM			
Moment (k-ft)	0.49	1686	821
Shear (k)	0.51	426	217

PIER 3 – Widening (SEE)			
PILE CAP	C/D	Dem	Cap
Cap M (k-ft)	0.79	1712	1352
Cap V (k)	0.80	1160	930
Pile Axial (k)	0.72	197	142
Pile Shear (k)	1.87	22	41
Pile Pull Out (k)	0.03	86	2
COLUMN			
Long. Disp. (in)	2.36	11.4	27.0
Transv. Disp (in)	2.51	6.0	15.0
Shear (k)	1.66	427	708
CROSSBEAM			
Moment (k-ft)	0.51	1616	821
Shear (k)	0.90	487	437

PIER 3 – Original (FEE)			
PILE CAP	C/D	Dem	Cap
Cap M (k-ft)	-	1380	-
Cap V (k)	0.74	589	434
Pile Axial (k)	1.07	125	134
Pile Shear (k)	5.35	6	34
Pile Pull Out (k)	0.06	38	2

PIER 3 – Widening (FEE)			
PILE CAP	C/D	Dem	Cap
Cap M (k-ft)	2.00	2777	5562
Cap V (k)	1.10	825	906
Pile Axial (k)	0.90	158	142
Pile Shear (k)	3.30	12	41
Pile Pull Out (k)	0.07	30	2

Bridge 405/12

PIER 2 – Original (SEE)			
FOOTING	C/D	Dem	Cap
Moment (k-ft)	-	944	-
Shear (k)	0.26	564	149
Overturning (k)	0.69	1612	1115
Sliding (k)	1.30	147	192
COLUMN			
Long. Disp. (in)	1.28	3.5	4.5
Transv. Disp (in)	1.36	1.7	2.3
Shear (k)	0.83	175	146
CROSSBEAM			
Moment (k-ft)	0.40	1132	455
Shear (k)	0.53	370	195

PIER 2 – Widening (SEE)			
FOOTING	C/D	Dem	Cap
Moment(k-ft)	1.04	2988	3111
Shear (k)	1.50	632	949
Overturning (k)	1.14	4980	5686
Sliding (k)	0.87	412	359
COLUMN			
Long. Disp. (in)	3.80	3.2	12.2
Transv. Disp (in)	4.60	1.7	7.6
Shear (k)	1.36	410	558
CROSSBEAM			
Moment (k-ft)	0.32	3794	1198
Shear (k)	0.79	508	401

PIER 2 – Original (FEE)			
FOOTING	C/D	Dem	Cap
Moment (k-ft)	0.93	862	805
Shear (k)	0.28	531	149
Overturning (k)	0.70	1518	1067
Sliding (k)	1.32	137	181

PIER 2 – Widening (FEE)			
PILE CAP	C/D	Dem	Cap
Moment (k-ft)	2.58	1205	3111
Shear (k)	2.76	344	949
Overturning (k)	2.40	2276	5463
Sliding (k)	1.82	189	343

Bridge 405/45W

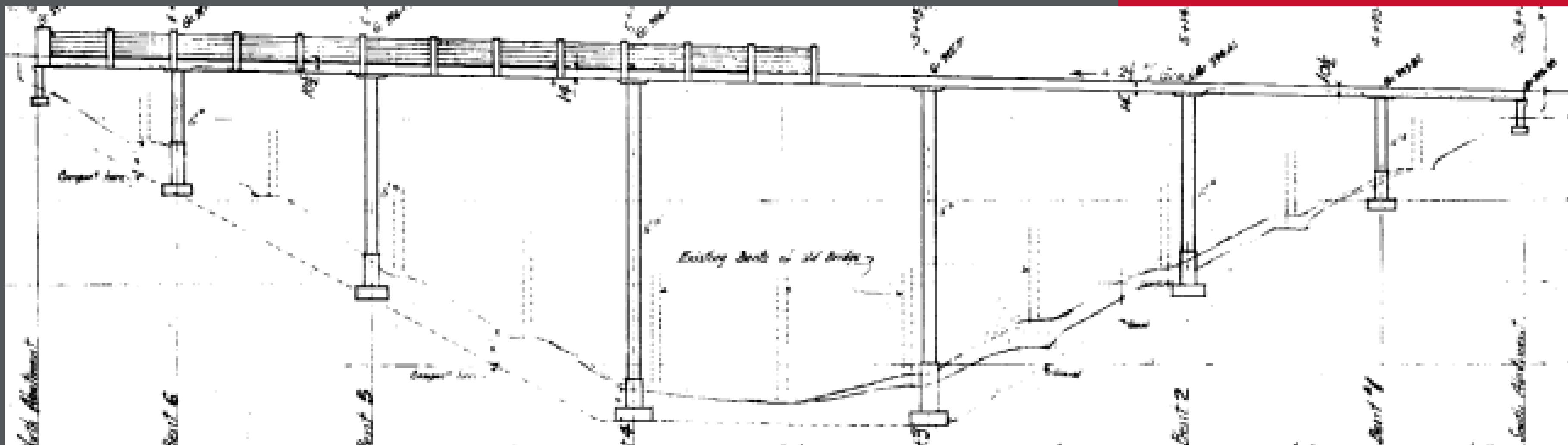
PIER 2 – Original (SEE)			
FOOTING	C/D	Dem	Cap
Moment (k-ft)	-	929	-
Shear (k)	0.65	437	284
Overturning (k)	0.87	1788	1559
Sliding (k)	0.98	102	99
PILE CAP FOOTING			
Pile Cap M (k-ft)	-	656	-
Pile Cap V (k)	0.92	761	703
Pile Axial (k)	0.23	308	70
Pile Shear (k)	4.46	250	1117
Pile Pull Out (k)	0.02	221	4
COLUMN			
Long. Disp. (in)	0.61	3.6	2.2
Transv. Disp (in)	0.72	3.1	2.2
Shear (k)	0.69	245	169
CROSSBEAM			
Moment (k-ft)	0.44	1595	695
Shear (k)	0.67	517	346

PIER 2 – Widening (SEE)			
SHAFT	C/D	Dem	Cap
Moment (k-ft)	1.68	4243	7133
Shear (k)	5.15	375	1928
Axial (k)	5.39	520	2800
COLUMN			
Long. Disp. (in)	4.82	1.6	7.7
Transv. Disp (in)	4.05	1.9	7.7
Shear (k)	2.53	313	792
CROSSBEAM			
Moment (k-ft)	0.45	4736	2121
Shear (k)	1.12	484	602

PIER 2 – Original (FEE)			
FOOTING	C/D	Dem	Cap
Moment (k-ft)	-	824	-
Shear (k)	1.10	258	524
Overturning (k)	2.27	687	1559
Sliding (k)	4.00	25	99
PILE CAP FOOTING			
Pile Cap M (k-ft)	-	425	-
Pile Cap V (k)	1.42	494	703
Pile Axial (k)	0.41	170	70
Pile Shear (k)	10.4	108	1117
Pile Pull Out (k)	0.03	113	4

PIER 2 – Widening (FEE)			
SHAFT	C/D	Dem	Cap
Moment (k-ft)	21.5	767	16462
Shear (k)	19.5	99	1928
Axial (k)	7.3	383	2800

Bridge 405/47W



Short Columns

Slides 1-3 *Introduction*

Slides 4-6 *Bridge 405/12*

- 8 span, PC/PS Concrete I-Girder Bridge 765 feet in length
- Originally constructed in 1965 as two independent structures with dropped crossbeams on 3'-0" diameter columns on pile caps on concrete piles
- Piers are typically perpendicular to the roadway alignment
- Widened in 1987 to both North and South and the deck between the original structures was connected.
    - Cap beams were extended (North and South) but were not connected to one another
    - Intermediate piers founded on 4'-0" diameter columns on pile caps on concrete piles
    - Pier 2 Southern column was angled at 20 degrees to maintain railroad clearance
    - Collision wall added at Pier 2 between the 2 southernmost columns
- Small widening to the South in 2009.
- Expansion Joints located at every pier (simple span beams)
- End Piers are stemwalls connected to concrete pile caps founded on piles

Slide 7 *Bridge 405/45W*

- 3 span, PC/PS Concrete I-Girder Bridge 207 feet in length
- Originally constructed in 1966
- Piers are skewed ~34 degrees
- Dropped crossbeams on 3'-0" diameter columns founded on spread footings
- Widened in 1993 to the East
    - Cap beams were extended (East)
    - Intermediate piers founded on 3'-0" diameter columns on spread footings
    - L-shaped end piers extended and supported on new spread footings
- Expansion Joints located at every pier (simple span beams)
- L-shaped end piers are supported on spread footings

Slide 8 *Bridge 405/47W*

- 3 span, cast-in-place T-beam Bridge ~149 feet in length
- Originally constructed in 1953
- Piers are skewed ~15 degrees
- Integral diaphragms on 3'-2" square columns founded on spread footings
- Widened in 1965 to the East and West
    - Longitudinal Joint placed between East Widening and the existing deck (no diaphragm connection). Beam added to west was integral though later removed.
    - Intermediate piers founded on 3'-2" square columns on pile caps on concrete piles
- Widened in 1992 to the West
    - Integrally connected diaphragm
    - Intermediate piers founded on 3'-2" square columns on drilled shafts
- Integral end piers are supported on a row of concrete piles

Slide 9 *SEE vs. FEE*

Safety Evaluation Earthquake (SEE) considers a spectrum based on a 7% exceedance in 75 years (975-year return period)

Functional Evaluation Earthquake (FEE) considers a spectrum based on a 30% exceedance in 75 years (210-year return period)

These bridges are all on a designated lifeline route and are considered "Essential"

Slide 10-12 *Selected Results*

Selected results for one pier at each of the 3 bridges analyzed to show a comparison of the SEE vs. FEE results.

Findings:

The results were similar between all three bridges, though the foundations for bridge 47W did have better C/D ratios.

Our analysis found the FEE event typically resulted in displacements that exceed the column yield capacity and result in column plastic hinging. Therefore, the reduction in force is typically lower than hoped for. It should be noted that these results include a 1.4 overstrength factor when the column yield strains are exceeded (consistent with the FHWA Seismic Retrofitting Manual).

1950's and 1960's construction lacked a top mat of reinforcement in spread footings and pile cap foundations. Therefore, they are deficient for both the SEE and FEE events. We also attempted to use the cracked capacity of unreinforced concrete to check the vulnerability. Unfortunately there is inadequate strength and this deficiency is still present.

The bottom mat of reinforcement is typically inadequate for the SEE and FEE as are the shear and overturning.

The spread footings had many instances where they were adequate for the sliding demands.

Pile foundations showed several deficiencies for the SEE event. Piles were modeled with the best information as could be determined based on existing data. The pile foundations did not fare much better than the spread footings for the SEE event. The pile foundations shown for 405/47W are indicative of all the pile foundations analyzed (including later widenings). Typically several deficiencies were found at each pier including Axial, Shear, Bending, and Pull Out.

The largest deficiency shown is pile pull out. However, the C/D Ratios are likely higher than what is shown. Positive connection details could not be located. Therefore, the connection is assumed to be based on bond between the footing and the pile.

Frequently the 1950s and 1960s columns had inadequate shear capacity. The example pier chosen for Bridge 45W shows that there is adequate displacement capacity, however, this was not the typical result.

The crossbeams were typically detailed for a strength load case and were frequently vulnerable to column plastic hinging forces.

Slide 13 *Alternate Project*

A cautionary tale regarding upper level vs. lower level. There are instances where the geometry of an existing bridge does not lend itself to retrofit for the lower level event. This bridge has very short columns and very long columns. The scope for this project was to find retrofit solutions that would remove all vulnerabilities for both upper and lower events. Utilizing traditional methods (column jackets, pier strengthening, etc.) the upper level could meet a no collapse criteria. The lower level was incredibly challenging and a solution was ultimately found with concrete column wraps that met an essentially elastic criteria. Scenarios like this may require construction of new concrete columns and/or foundations.