



AECOM

SR 519 Design Build Project

Atlantic Street Ramp Innovative Design

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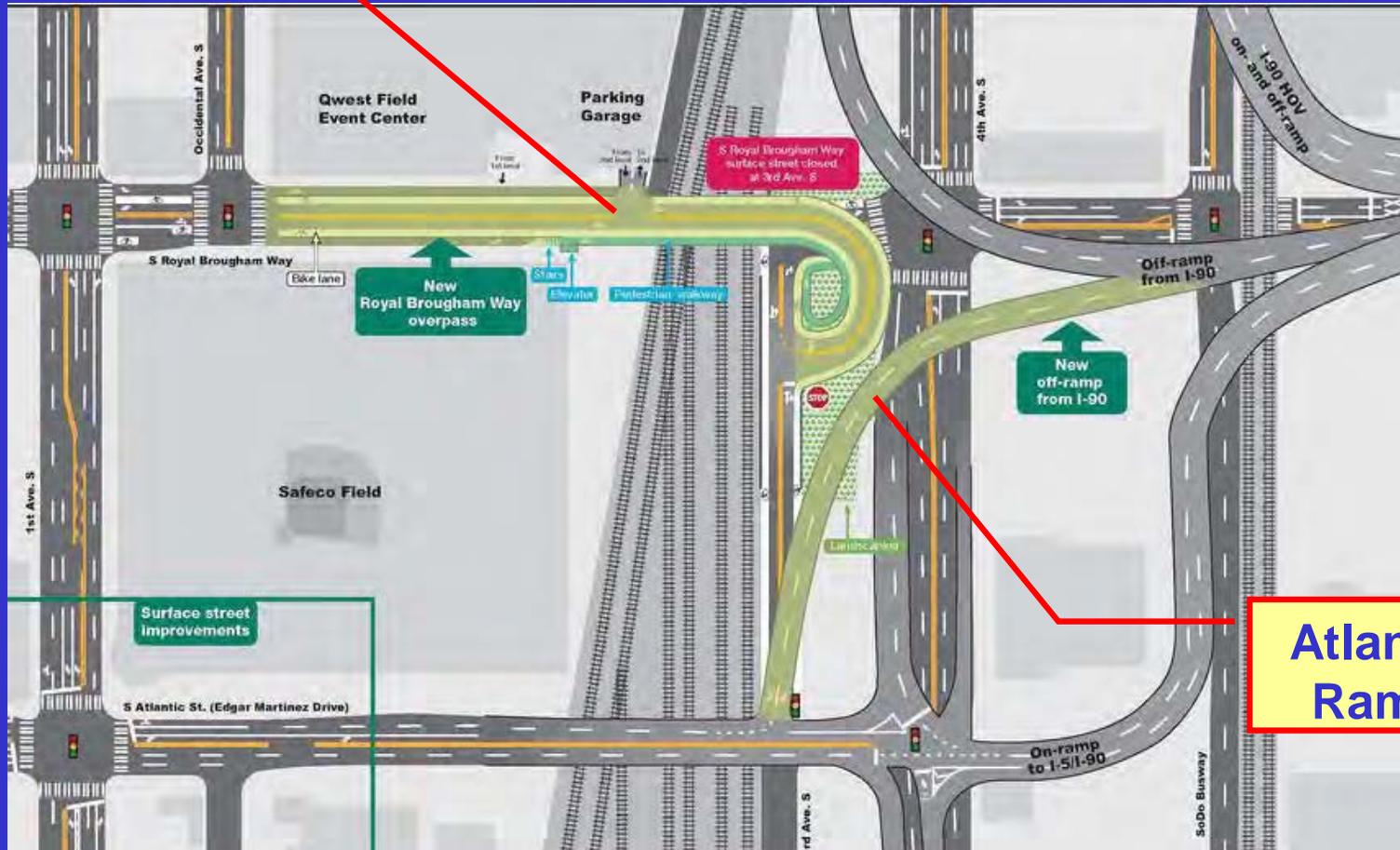
Design Build - Project Partners



Project Delivery Method – Allowed for Innovations

**RBW
Bridge**

Project Overview



**Atlantic
Ramp**

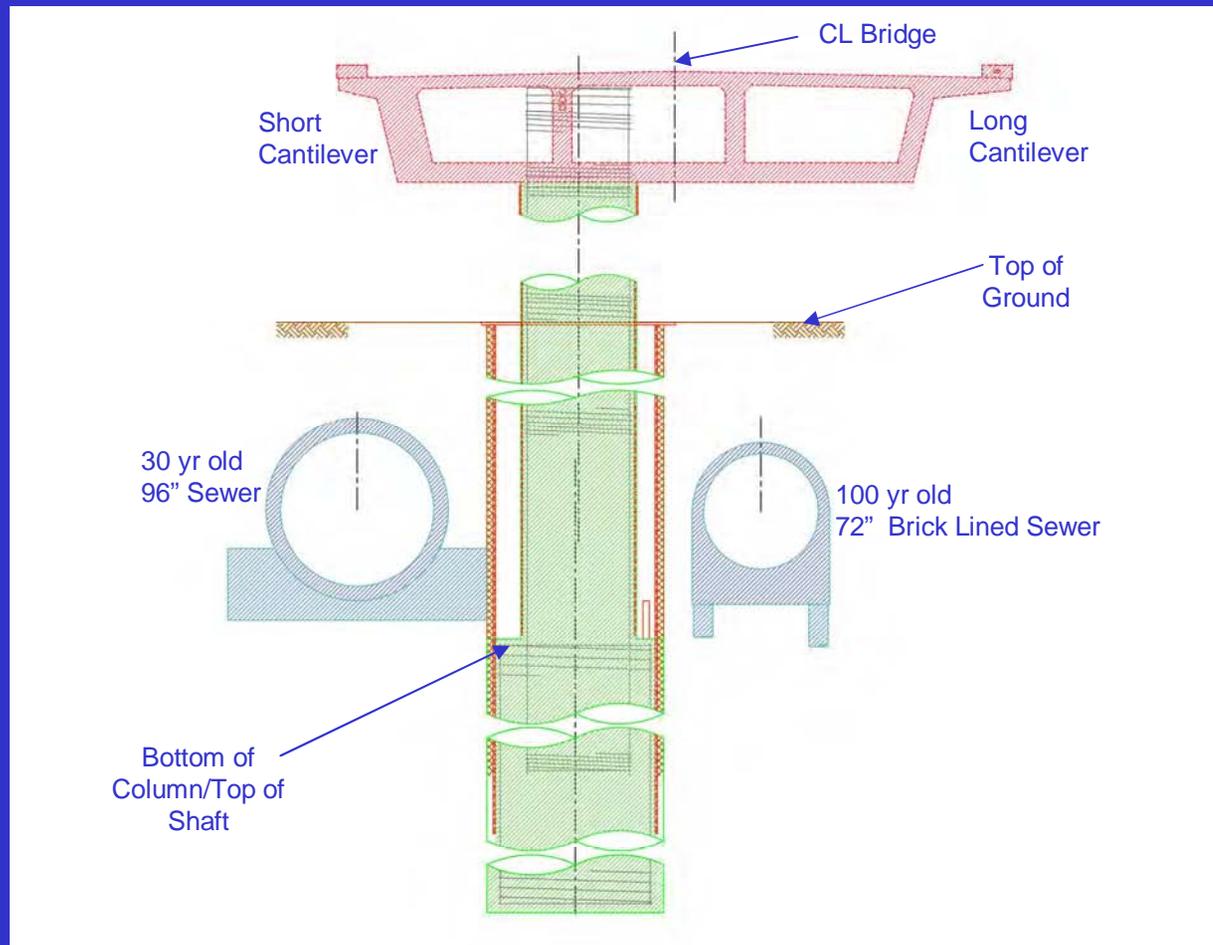
Project Schedule

- ❖ Bid Design – June/July 2008 (6 weeks)
- ❖ Begin Final Design – October 2008
- ❖ Complete All Major Design Elements – July 2009
- ❖ Open to Traffic – RBW Winter 2010, A. Ramp June 2010

RBW – Design Innovations

Preliminary Design	Innovative Approach	Benefit
Steel Superstructure	Concrete Superstructure	Less Maintenance/Lower Cost
Bridge for West Approach	Geofoam Fill	Less Maintenance/Lower Cost
Asymmetrical Piers	Asymmetrical Box/Thickened Web	Better Balanced Structure
6 foot columns with Crash Walls	Stretch Columns to 30 sf	No Crash Walls/Keep RBW Open to Traffic
Steel Superstructure over BNSF	Pre-cambered PS Girders over BNSF	No Future Painting over BNSF/Lower Cost
Ground Improvement and Fill at East Approach	Geofoam Fill	Less Risk/Lower Cost

RBW – Asymmetrical Piers

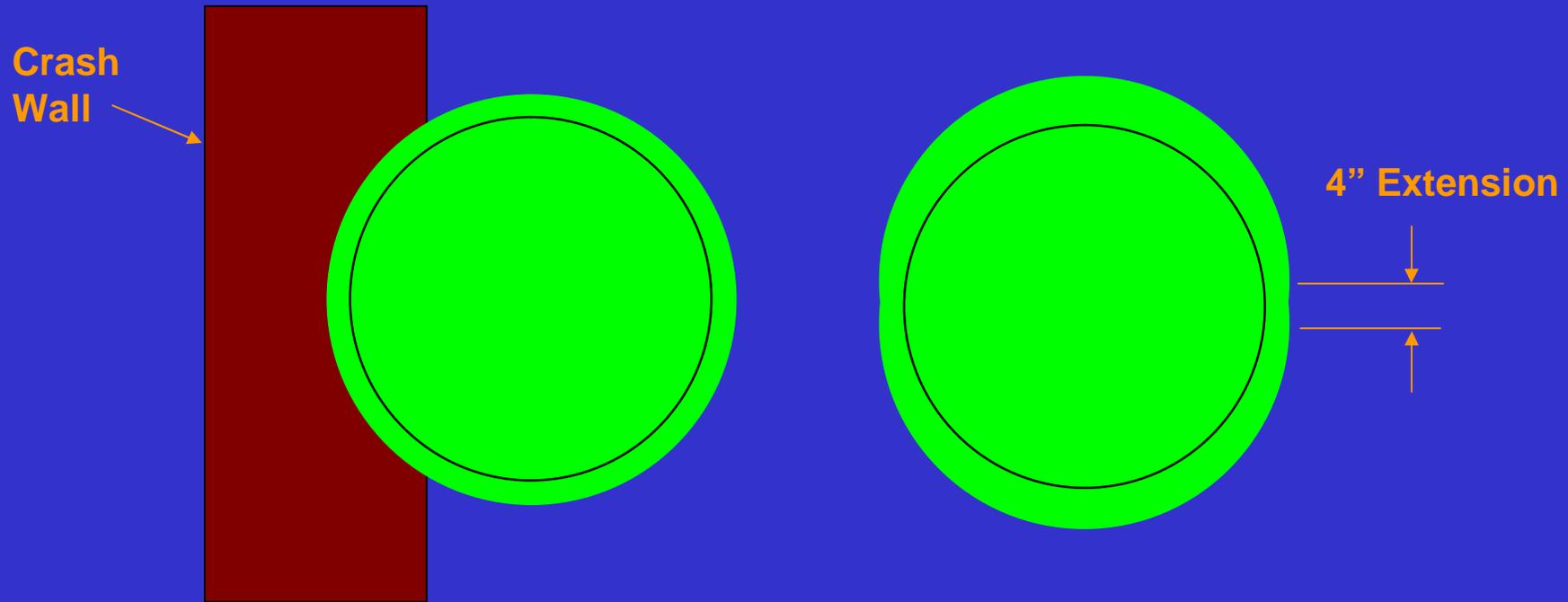


RBW – Pre-Cambered WF Girders

- First Pre-cambered highway girders in Washington
- Limited Structural Depth – Girders must following roadway profile



RBW – Piers 3 & 4 Columns 15 feet from C.L. BNSF Tracks



6' diameter shaft = 28 sf
Requires Crash Walls

6' diameter shaft with
4" extension = 30 sf
No Crash Walls

Atlantic Ramp – Design Innovations

Preliminary Design	Innovative Approach	Benefit
Steel Superstructure	Concrete Superstructure	Less Maintenance/Lower Cost
12 foot Conventionally Drilled Shafts	10 foot Oscillated Shafts	Less Risk/Faster/Lower Cost
6 foot Standard Columns	7 foot Reduced Moment Section (RMS) Columns	Less EQ Load to Shafts/7 foot Columns/Less Shaft Cost
Standard Fixed Closure at Existing Bridge	Seismic Fuse at Existing Bridge	Less Risk to Existing Bridge/Concrete Superstructure

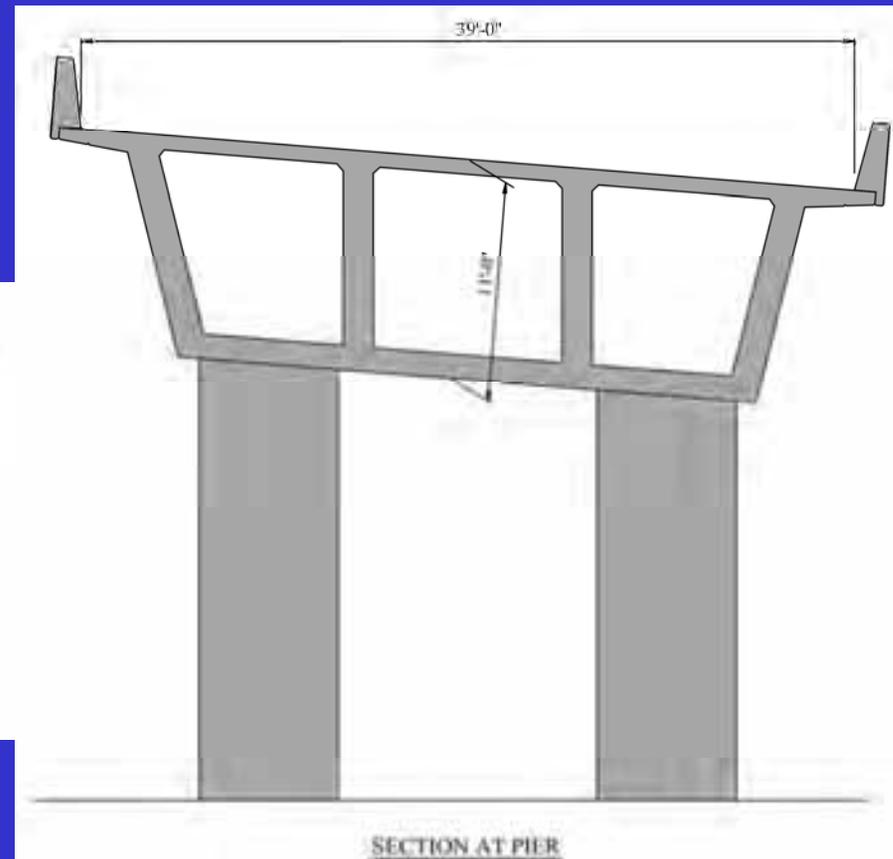
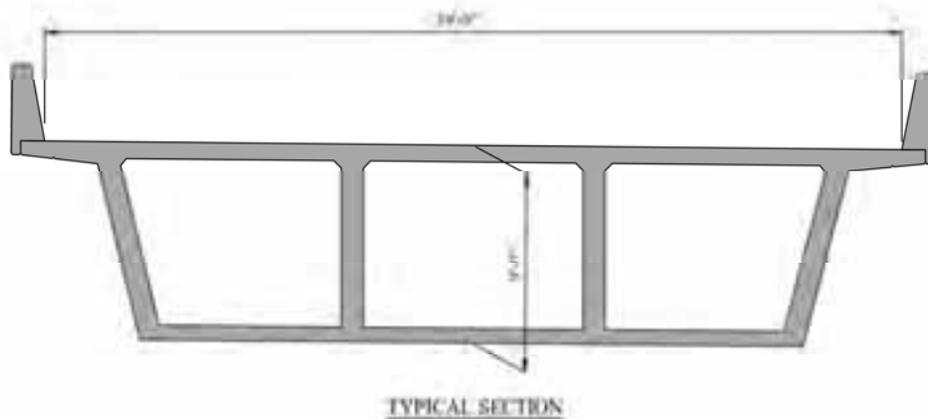
Bridge Layout

- ❖ Post-tensioned, CIP concrete box girder
- ❖ 5 Spans: 177' – 221' – 241' – 276' – 211'
- ❖ Total Structure length = 1155'
- ❖ Tie into WB I90 (north)
- ❖ Tie into EMW (south)



Cross Section

- ❖ 9' deep box girder
- ❖ 50' length haunched girders to 11' deep box girder at piers
- ❖ 7' columns typical
- ❖ 6' column at pier 6



Drilled Shafts

- ❖ 10' drilled shafts (8' at Pier 6)
- ❖ Constructed using oscillator method



Drilled Shafts

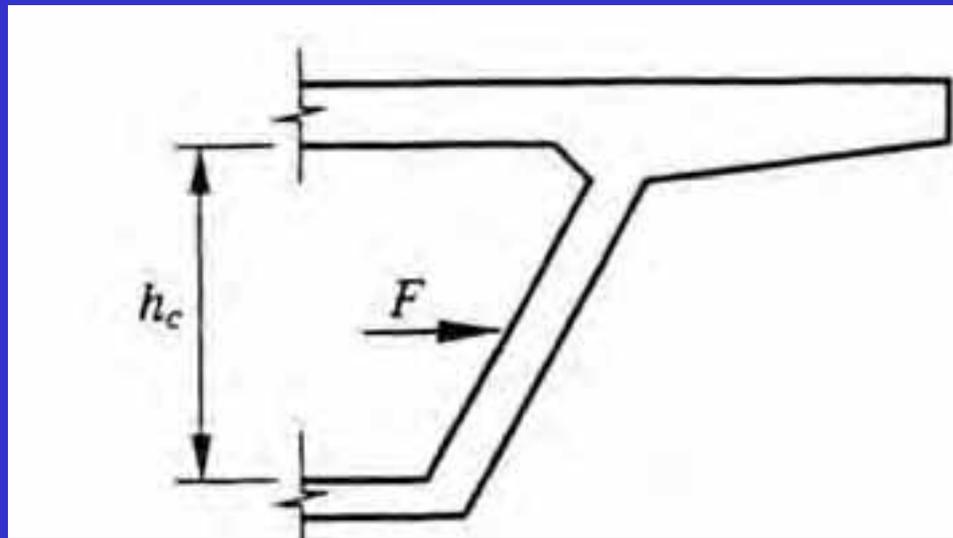
❖ Pier 6 construction constraints



Web Design Due to Horizontal PT

❖ Caltrans' Practice

1. Check regional bending

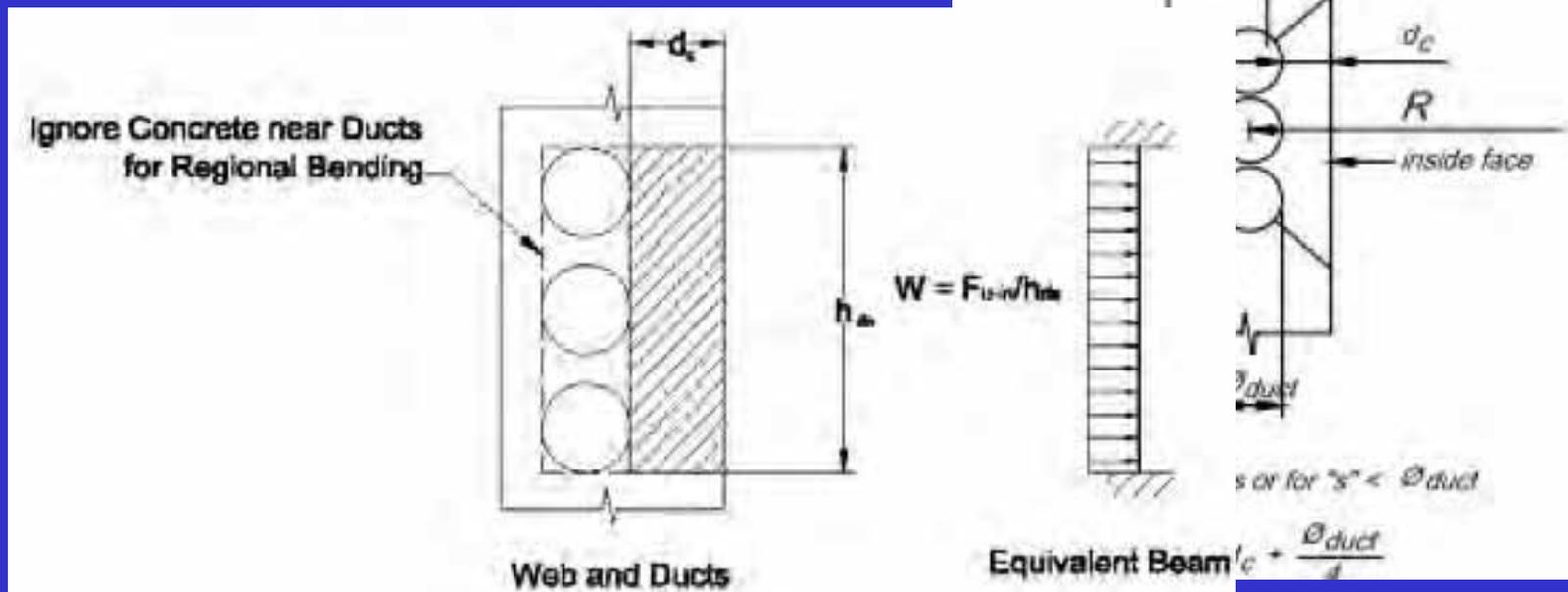


2. Stresses induced by shear and regional bending are not additive

Web Design Due to Horizontal PT

❖ NCHRP Report 620

1. Shear resistance to pullout
2. Cracking of concrete cover

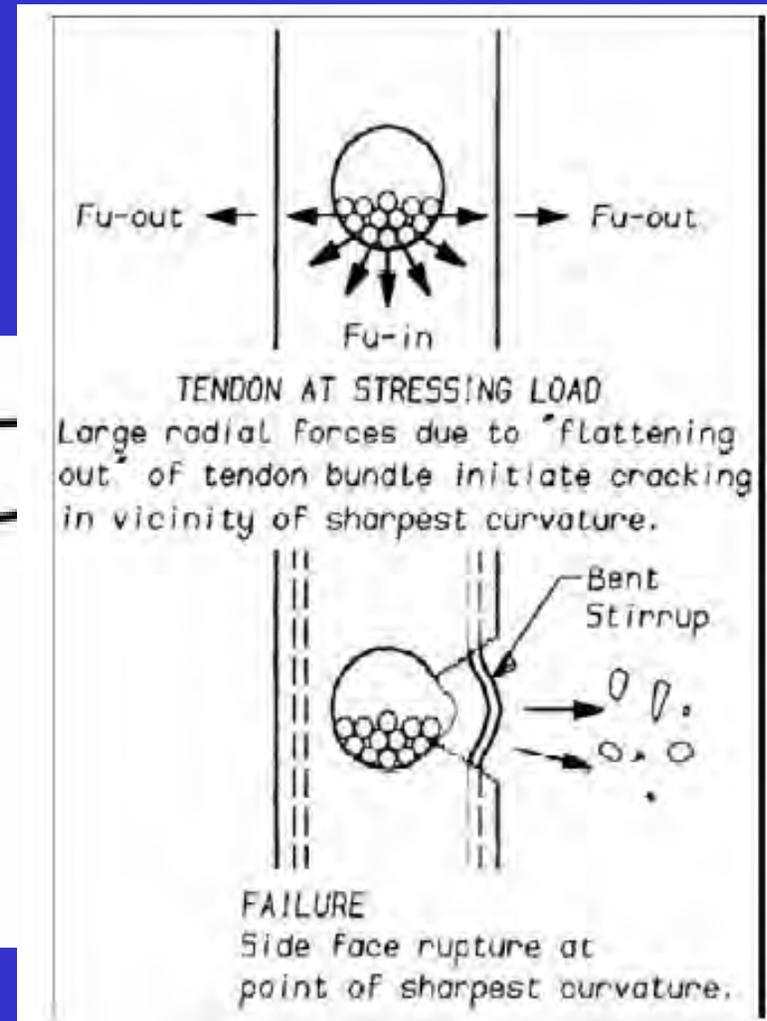
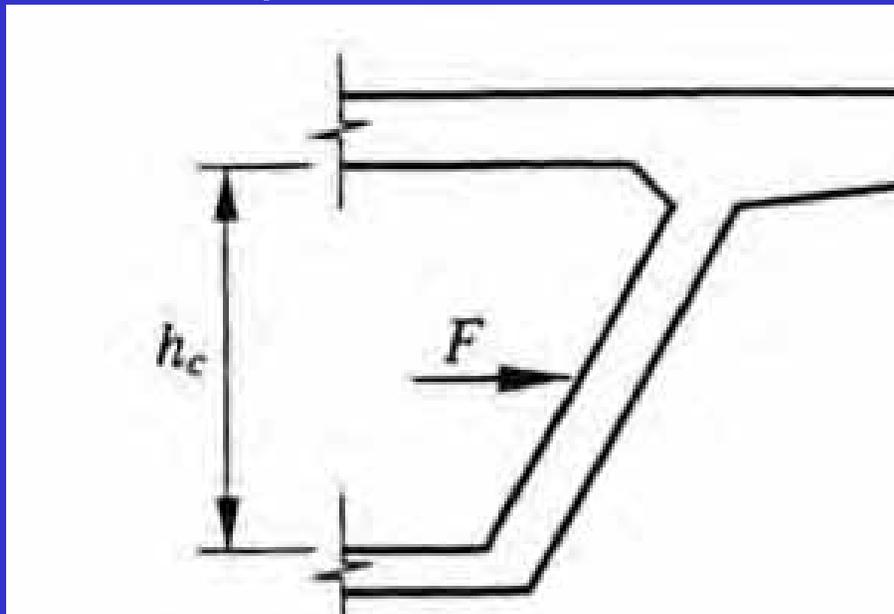


Web Design Due to Horizontal PT

❖ NCHRP Report 620

3. Regional bending

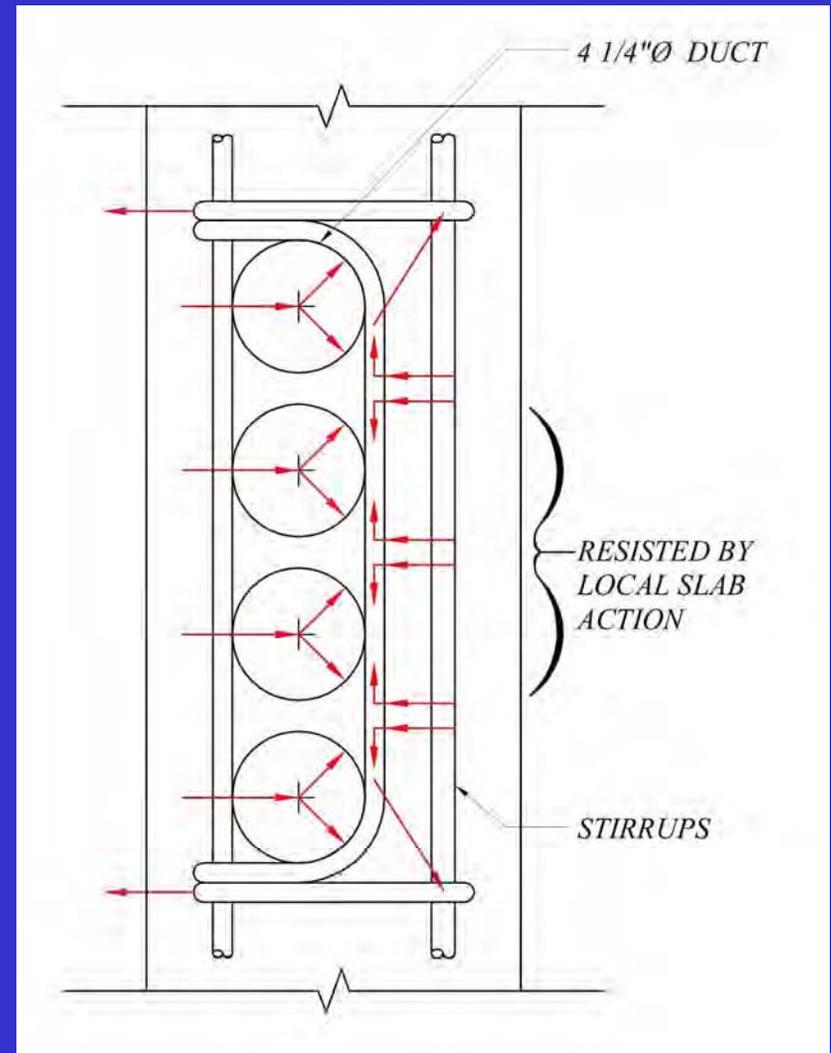
4. Out of plane force effect



Web Confinement Reinf. Design

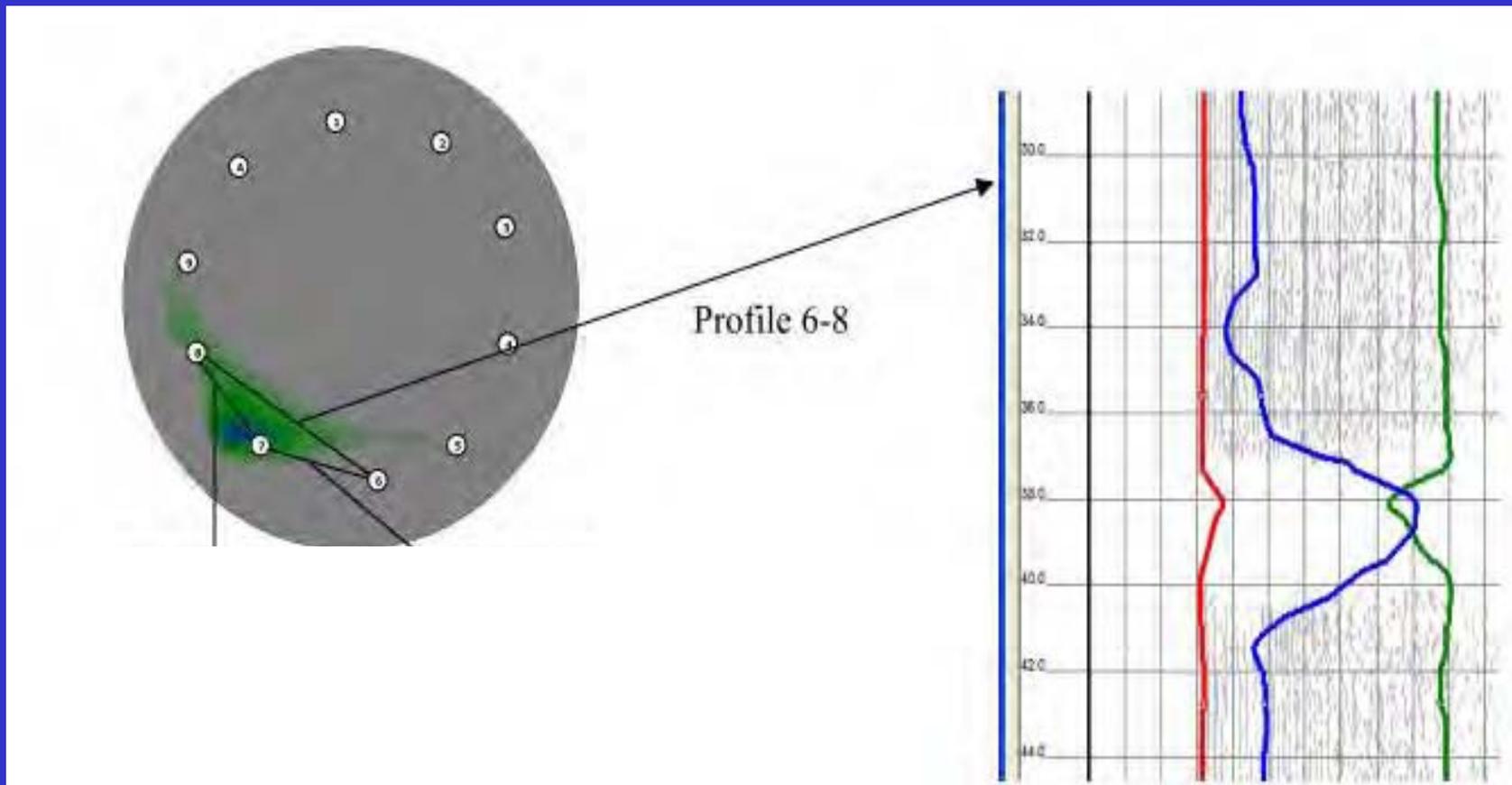
Strut-and-tie method

When sizing the web stirrups, the effect of regional bending should be added to the effect of global flexural and torsion shear



Construction Issues

- ❖ Shaft anomaly detected with CSL
- ❖ Repair procedure: 5" cored holes with rebar



Construction Issues

- ❖ Pier 1 – relocated shaft

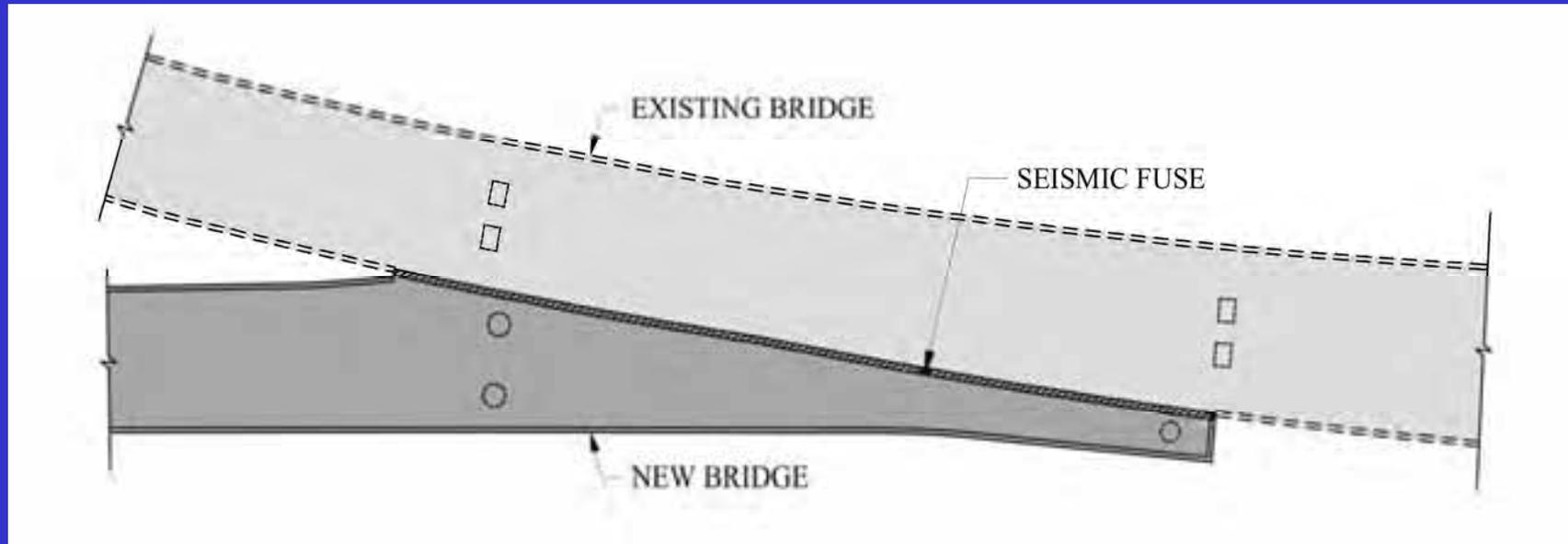


Construction Issues

- ❖ Span 5 constructed over Sound Transit LR power line



Seismic Fuse – Introduction

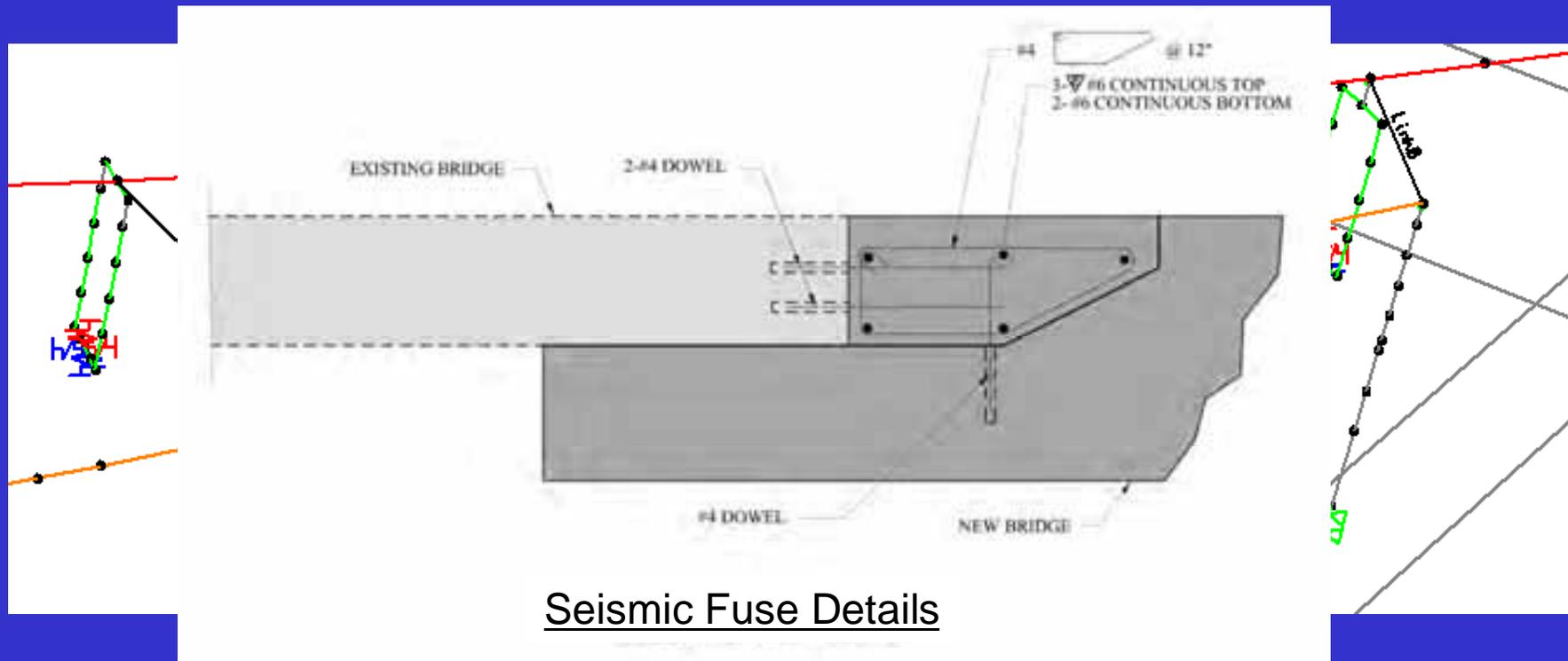


- ❖ 2ft wide and 250 ft long connecting existing I90 off ramp and proposed Atlantic ramp;
- ❖ different from conventional expansion joint to improve traffic safety, especially for motorcycles;

Seismic Fuse – *Design Philosophy*

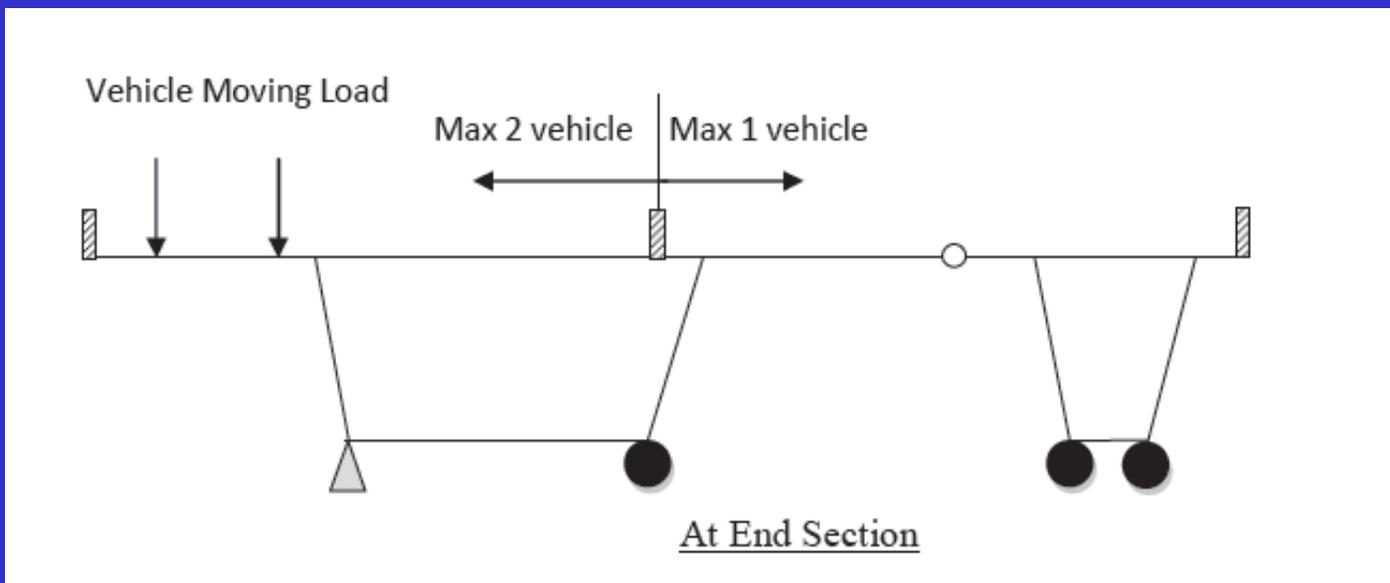
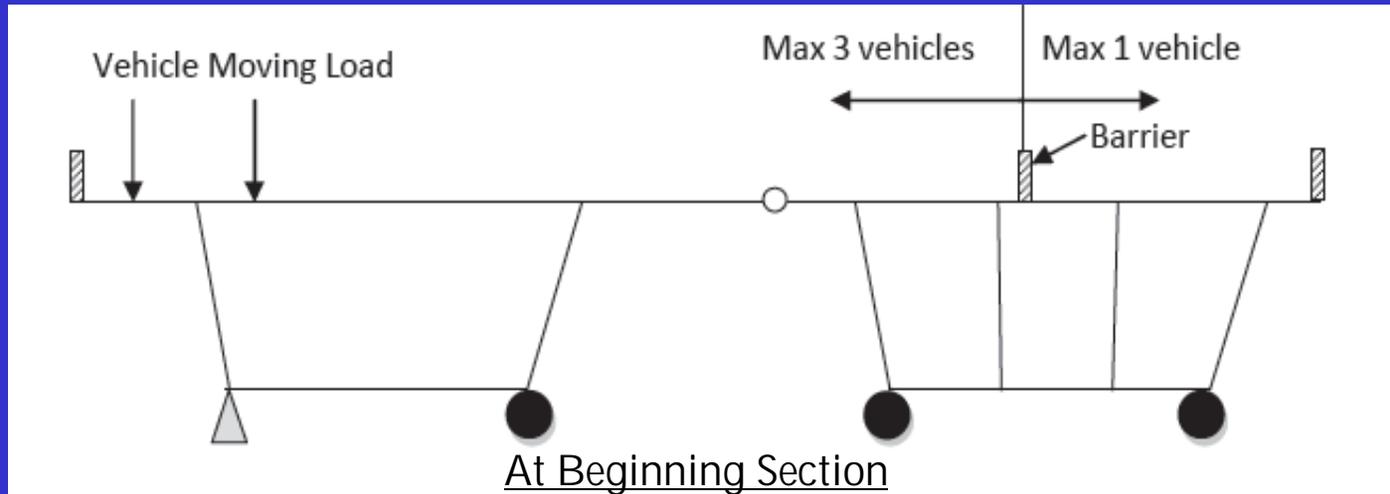
1. Service condition – combined structures behave as a unit
2. Seismic condition – before more than 5% seismic demands transferred from new structure to existing structure, combined structure separate and behave independently

Seismic Fuse – Link Modeling

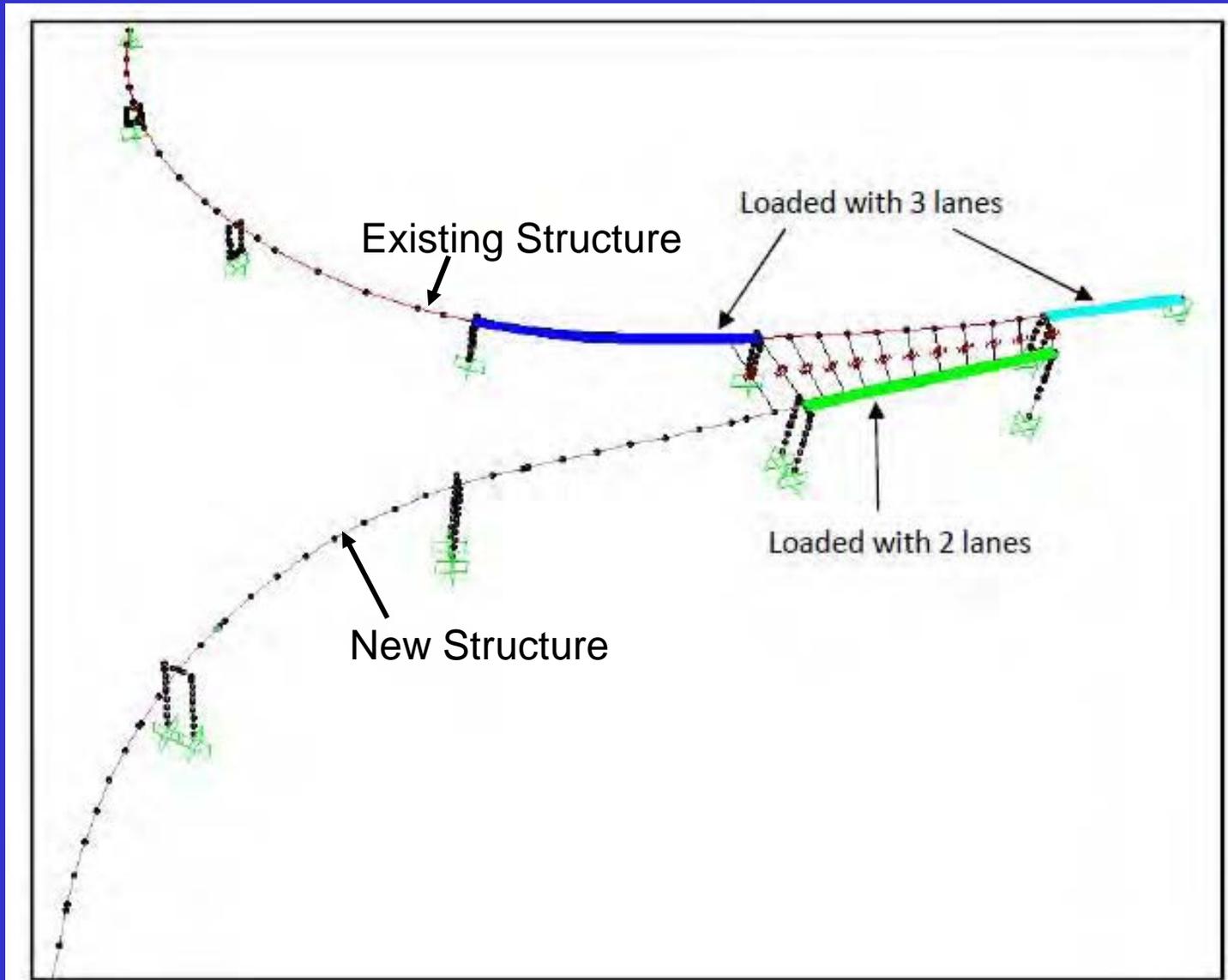


- ❖ Linear elastic links at 20ft ± spacing to represent seismic fuse
- ❖ Stiffness determined in each directions

Moving Vehicle Loading – Local Analysis



Moving Vehicle Loading – Global Analysis



Seismic Fuse – Seismic Analysis

- ❖ linear elastic response spectrum analysis can capture the displacement resulting from inelastic response of a bridge;
- ❖ link forces are determined by the relative displacement between the two structures;
- ❖ Response spectrum input at every 15° due to highly curved geometry
- ❖ Foundation stiffness envelop both soft foundation case (liquefied soil + $0.85f'_c$) and stiff foundation (non-liquefied soil + $1.50f'_c$) case as per BDM requirements

Seismic Fuse – Capacity

- ❖ Similar to shear key concept at abutment, seismic fuse is a sacrificial element;
- ❖ Recent seismic events have shown that shear key capacity are underestimated if determined by current codes;
- ❖ Recent research by UCSD was adopted

$$V_o = \phi_o \bar{V}_n = \frac{\phi_o (\bar{\mu}_f \cos \bar{\alpha} + \sin \bar{\alpha}) A_{vf} \left(\frac{\bar{f}_{su}}{\bar{f}_y} \right) \bar{f}_y}{1 - \bar{\mu}_f \tan \beta}$$

which is equivalent to $1.48 A_{vf} f_{ye}$;

Seismic Fuse – Conclusions

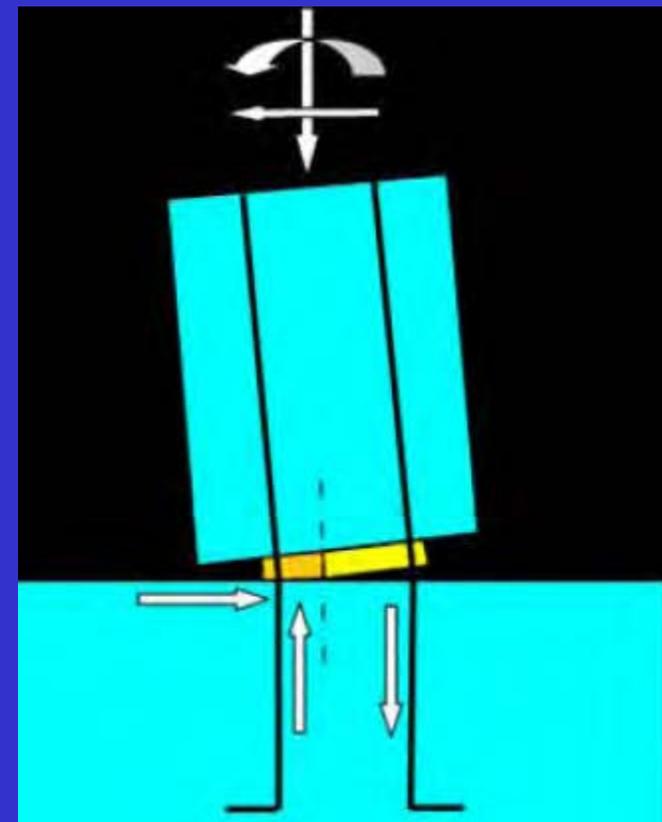
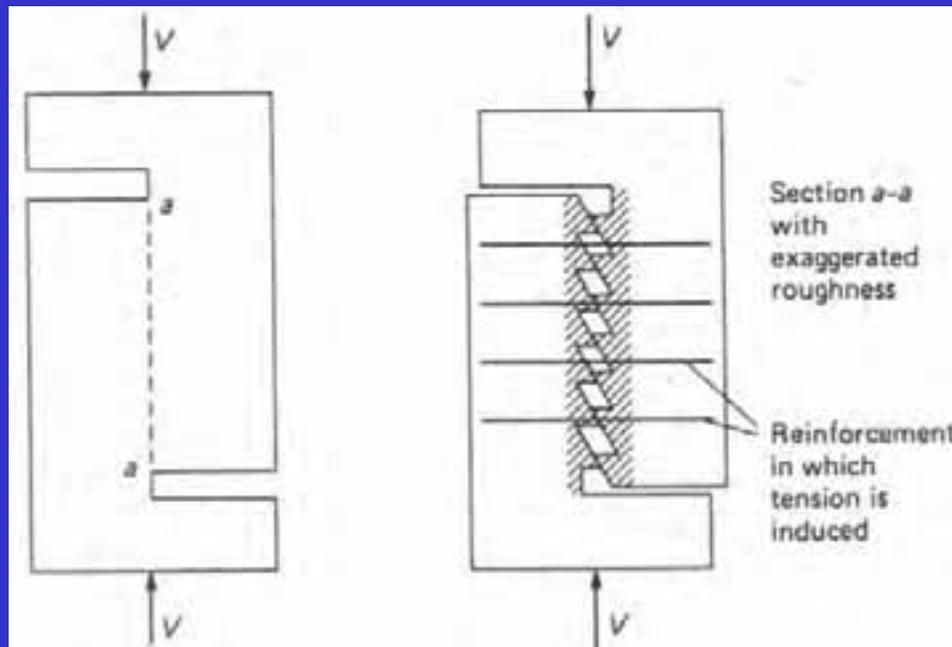
- ❖ More dowels are needed at the end segments to meet the service requirements;
- ❖ Seismic fuse will break off at $75\% \pm$ of the current earthquake design magnitude;
- ❖ With the seismic fuse's "protection", the additional displacement imposed to the existing I-90 off ramp from the proposed Atlantic Ramp can be controlled within 5%;

Reduced Moment Section – Concepts

- ❖ Reduce demands to the capacity-protected member – drilled shaft under seismic condition
- ❖ Maintain continuity between column and drilled shaft under service condition
- ❖ Different from typical two-way hinges used in California

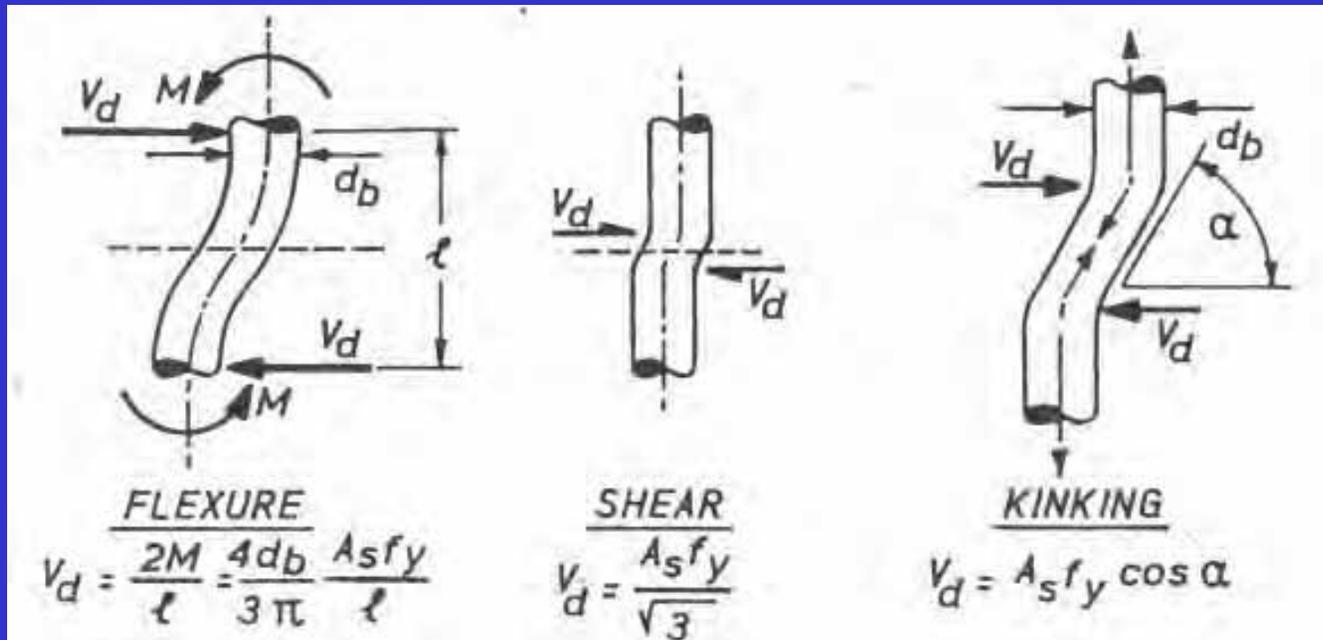
Reduced Moment Section –Shear Design

- ❖ Conventionally shear friction method may not valid due to extensive flexural cracks (*after UNR report*)



Reduced Moment Section –Shear Design

- ❖ Research done by UNR on two-way hinges



$$V_n = \mu(P + T_s)$$

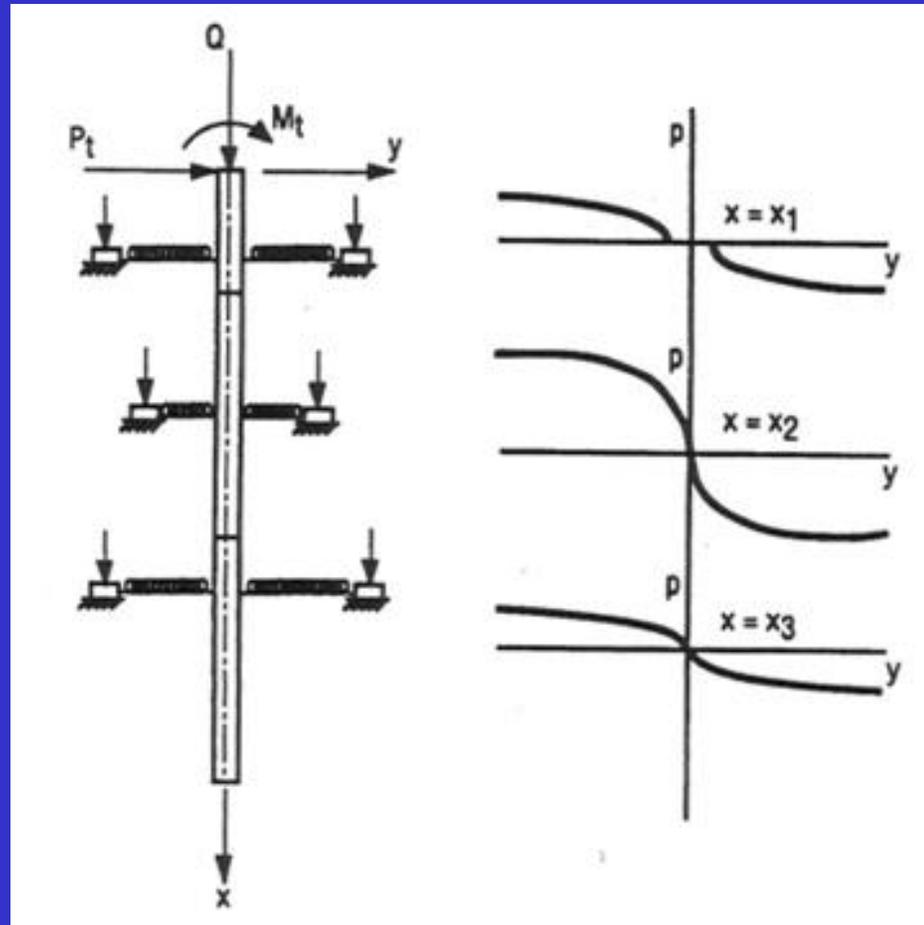
where μ = shear friction factor;

P = applied axial load;

T_s = tension force in rebars

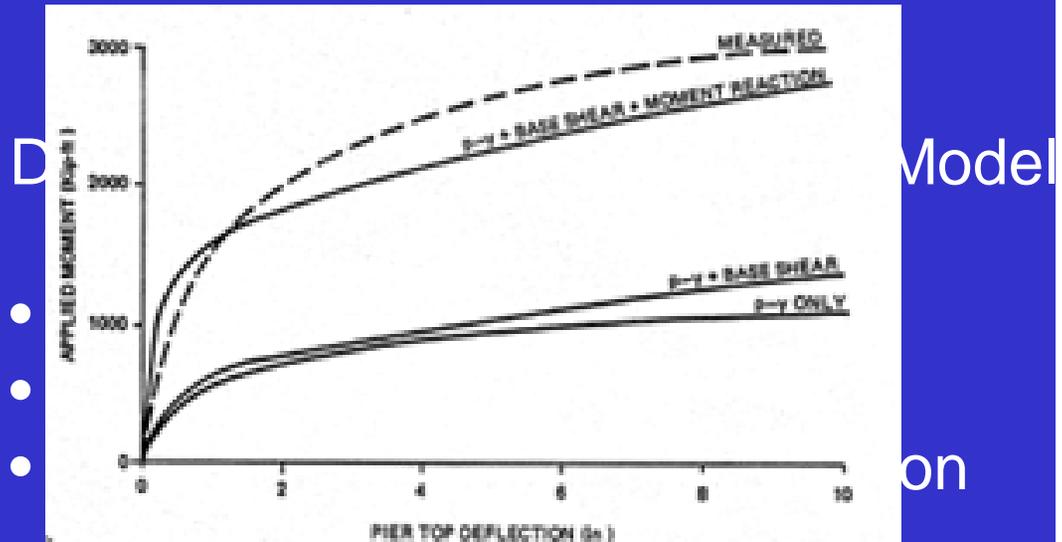
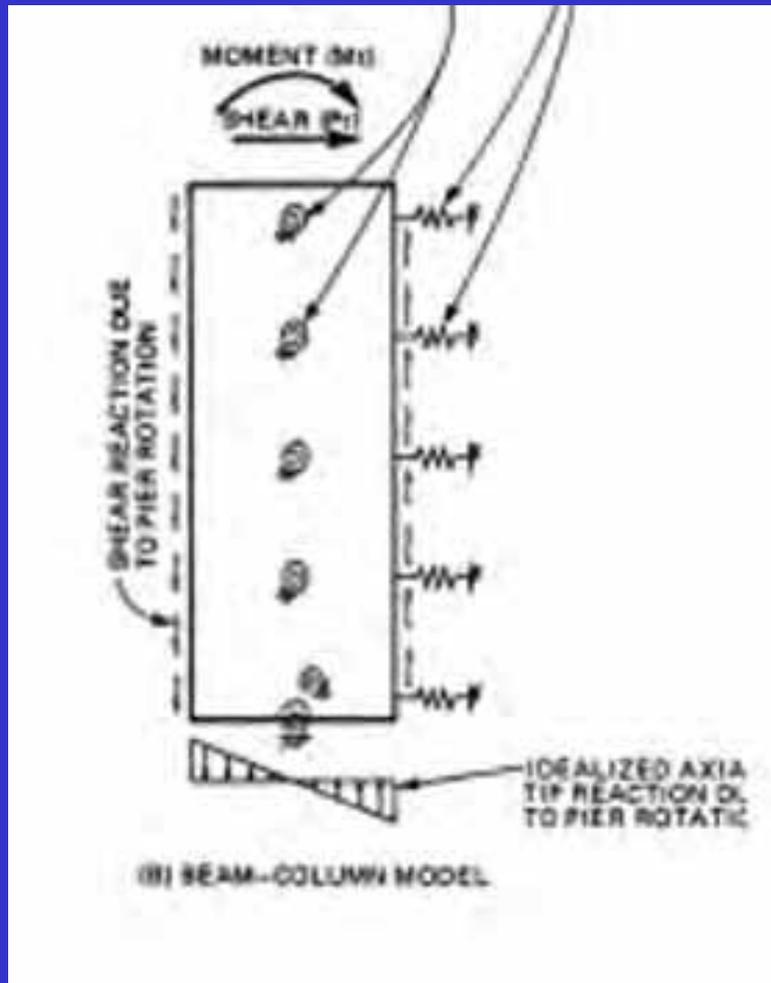
Diameter Effect on Drilled Shaft Design

❖ Conventional Pile Lateral Analysis



Diameter Effect on Drilled Shaft Design

- ❖ Large Diameter Drilled Shaft (after Lam I.P.)



Diameter Effect on Drilled Shaft Design

❖ Recommendations from Lam I.P.

Apply a scale factor of Diameter/2 to the P-Y curve to make up the modeling defects

Questions?

