Maximizing the Flexibility of Precast Concrete to Accommodate Unusual Bridge Geometry in a Constrained Urban Environment

Yuling Teo, PE
Seattle Department of Transportation

Hong Guan, PhD, PE, SE
CH2M

Western Bridge Engineers' Seminar
September 10, 2015
Reno, Nevada

SDOT
Seattle Department of Transportation

ch2m

East Marginal Way Grade Separation (EMWGS)

SDOT
Seattle Department of Transportation
ch2m

Purpose and Benefits

- FAST (**F**reight **A**ction **ST**rategy) Corridor project
- Move nation's freight through major NW trade corridor
- Fix freight and general bottlenecks
- Increase competiveness of Puget Sound ports
- Improve safety at rail/road crossings

Congestion at Existing Grade Crossing

SDOT
Seattle Department of Transportation
ch2m

Purpose and Benefits

- Provide N-S grade separation for traffic from railroads
- Improves freight mobility (roads and rails)
- Improves safety and circulations for all modes
- Reduces delays, improves air quality
- Improves access to and fro local business

East Marginal Way Grade Separation (EMWGS)

SDOT
Seattle Department of Transportation
ch2m

Project Funding Partners and Funding Source

Port of Seattle

City of Seattle

State Freight Mobility Strategic Investment Board (FMSIB)

Transportation Improvement Board (TIB)

BNSF & UPRR Railroads

FAST Partnership (TEA-21 Borders & Corridors)

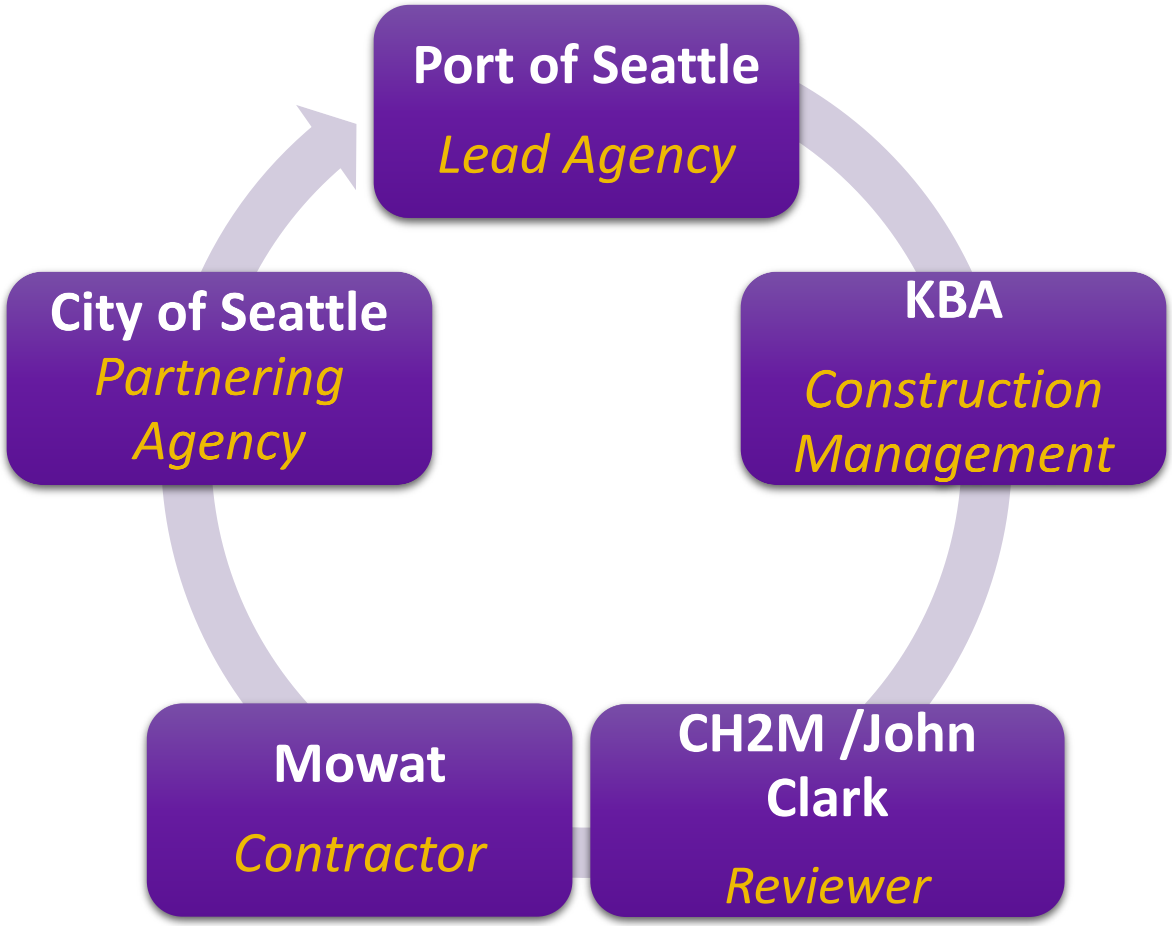
Federal Surface Transportation grants

ARRA Federal Stimulus Funding

PSRC (ISTEA Regional; TEA-21 Regional)

SDOT Seattle Department of Transportation ch2m

Roles and Responsibilities



Complexity

Geometric Constraints

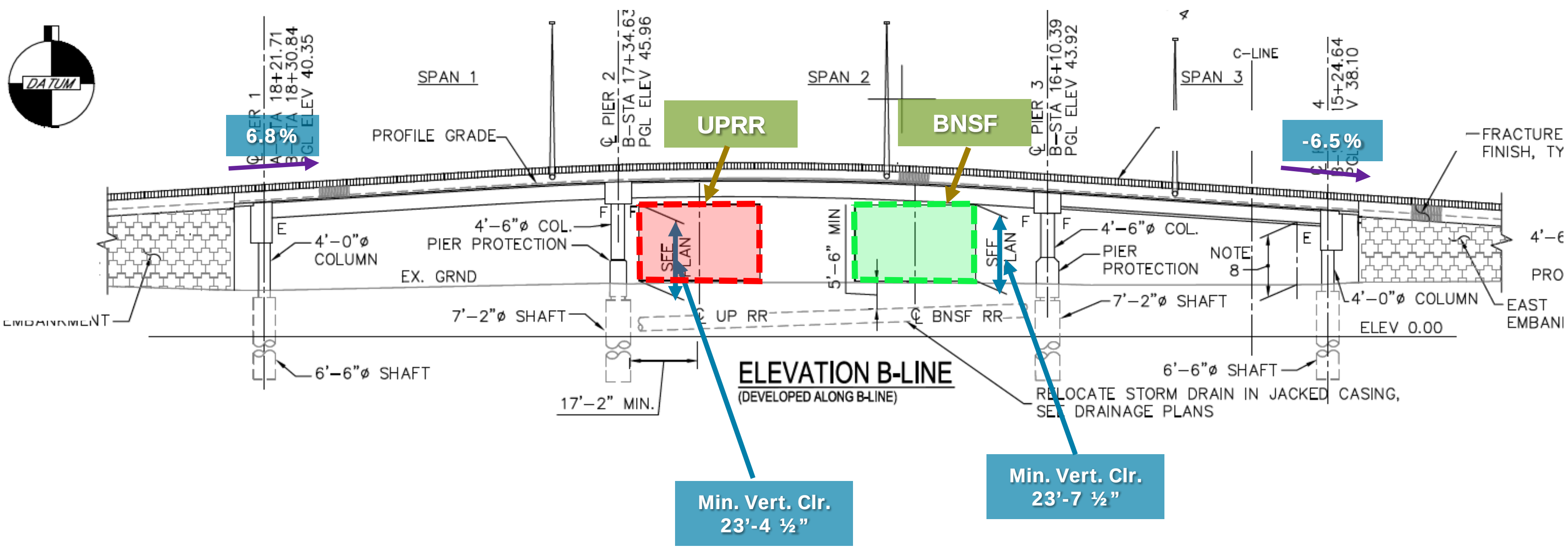
SDOT
Seattle Department of Transportation
ch2m

Cost Reduction Incentive Proposal (C.R.I.P.)

- WSDOT Standard Girders
- Cost Reduction
- Schedule saving
- Meeting AREMA requirements
- Aesthetic – no impact
- Construction Safety

Meets and exceeds the original design

C.R.I.P



SDOT Seattle Department of Transportation

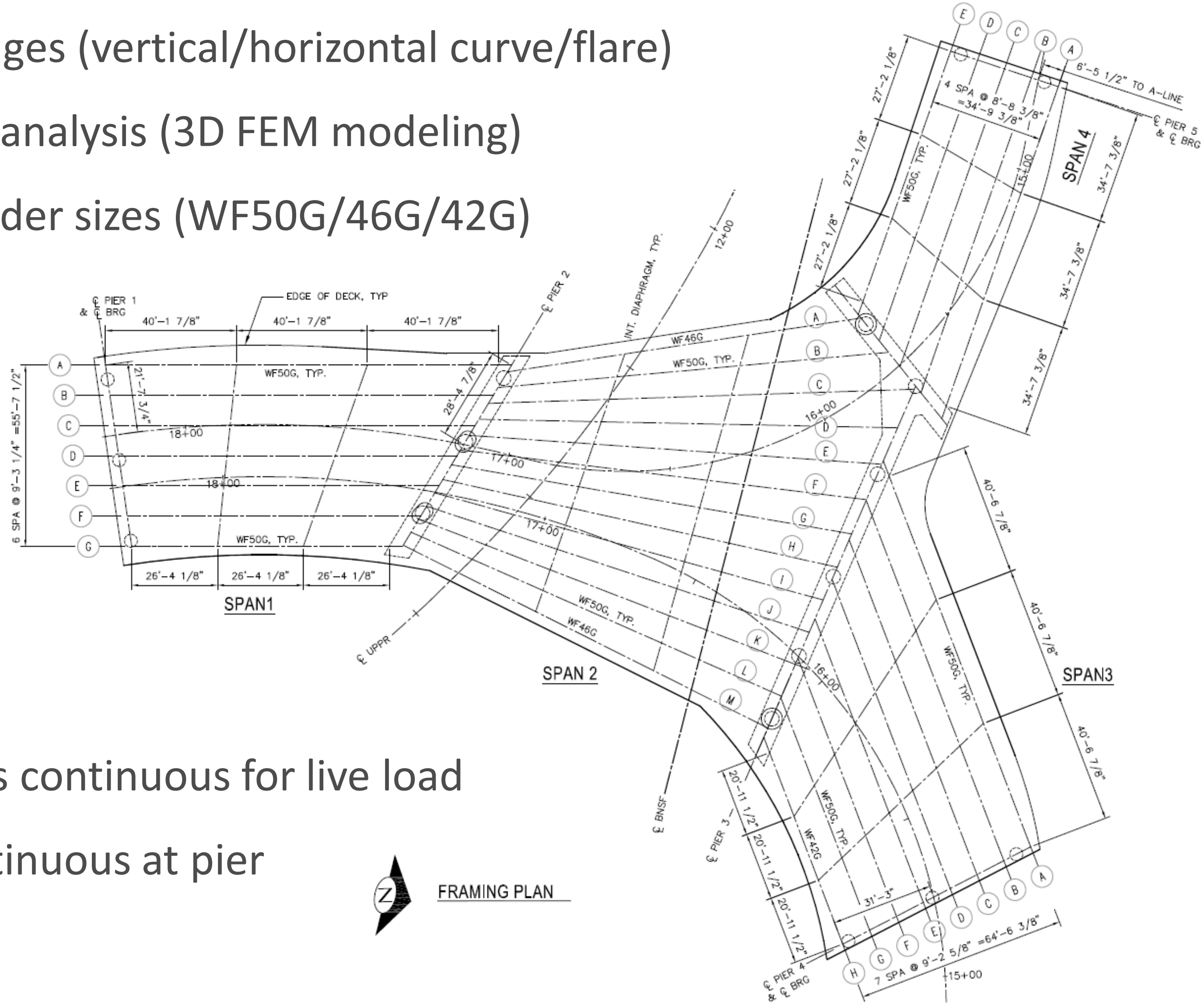
ch2m

C.R.I.P. - Concerns

- Delivery Model
- EOR
- Geometry
- Predicting Camber

Superstructure

- Geometric challenges (vertical/horizontal curve/flare)
- Complex live load analysis (3D FEM modeling)
- Three different girder sizes (WF50G/46G/42G)



- Girder designed as continuous for live load
- Girder line discontinuous at pier

Pre-cambered Prestressed Girders

- Max pre-camber = 13-⅛"
- Predicted additional camber ≈ 6-⅛" , max total camber ≈ 19-¼"
- One of the largest pre-camber for wide-flange I-girder fabricated in State of WA to-date

SDOT Seattle Department of Transportation ch2m

Pre-cambered Prestressed Girders

SDOT
Seattle Department of Transportation
ch2m

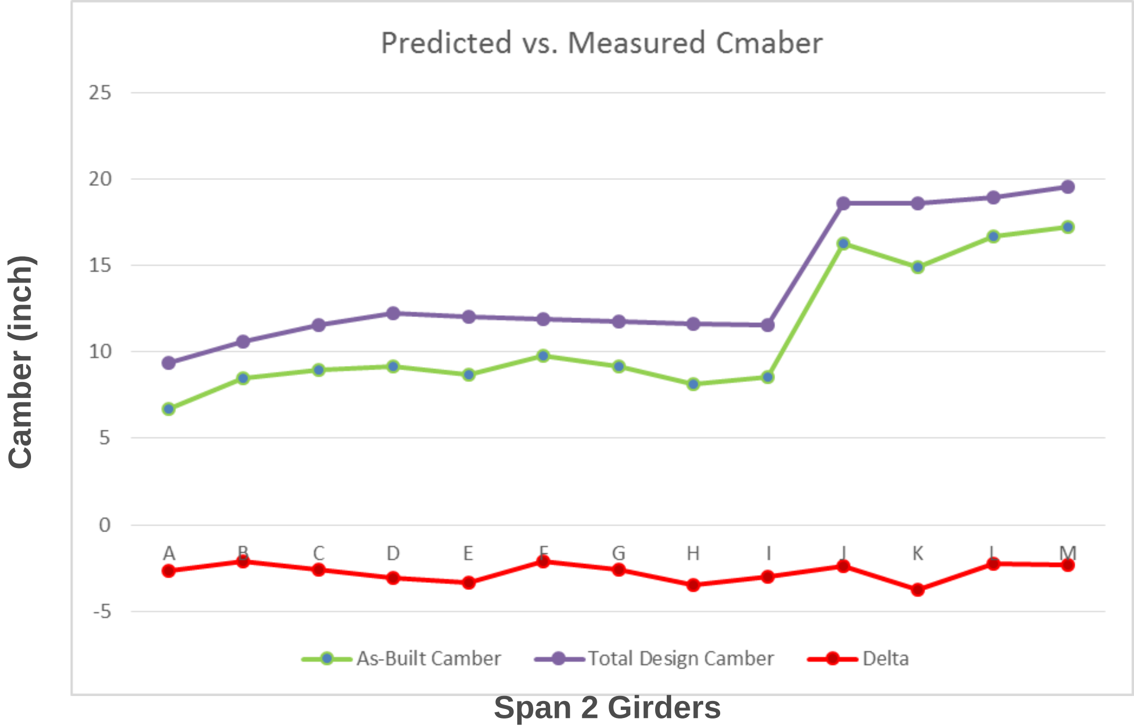
Erected Pre-cambered Girders

SDOT
Seattle Department of Transportation
ch2m

Erected Pre-cambered Girders

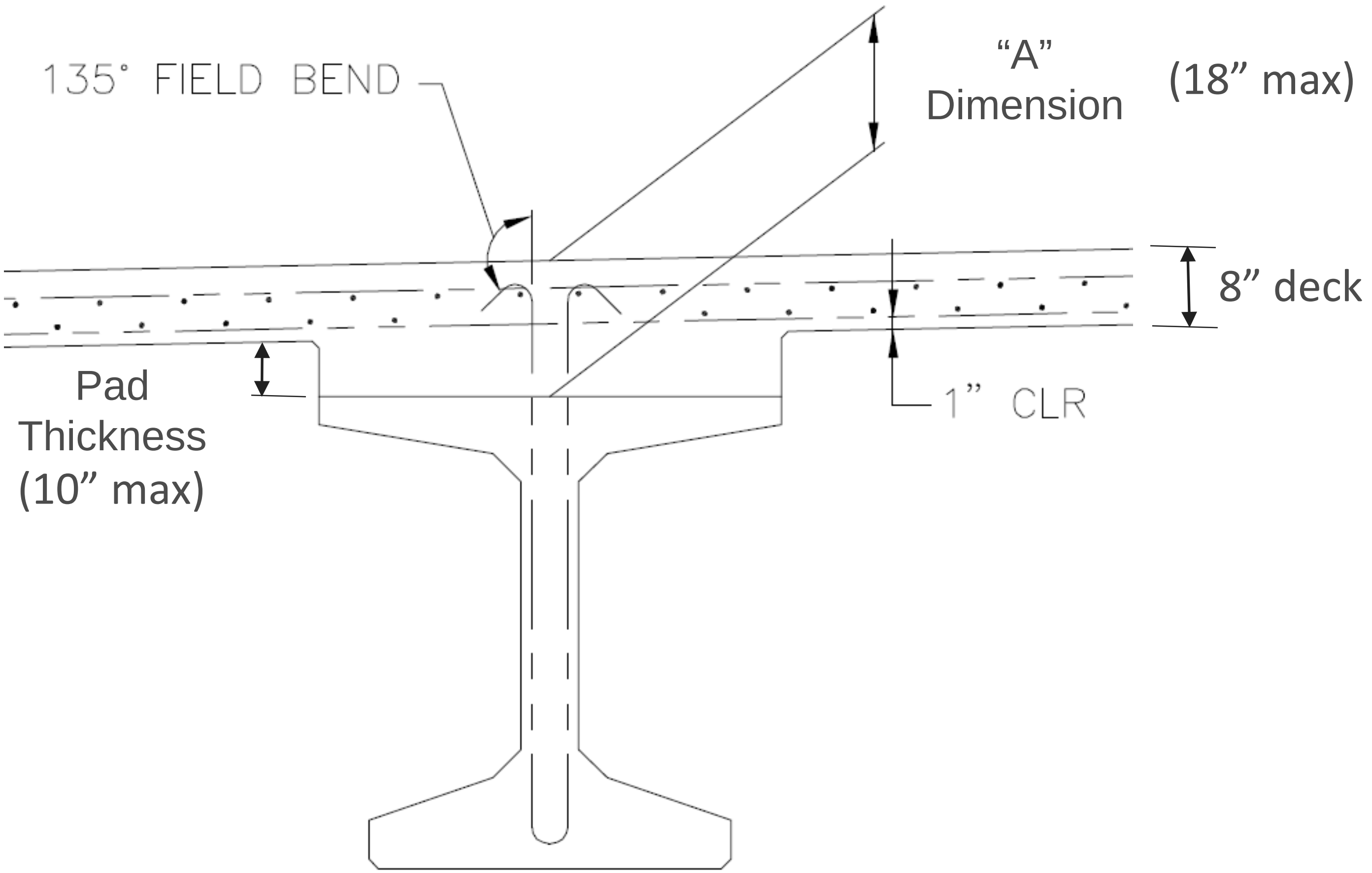
Actual Measured Camber

- Up to 3.7” less than predicted
  - Girder 2K: Predicted Total = 18.6” vs. Actual Measured = 14.9”
- Implications
  - Girder haunch/pad thicker than expected
  - Did not affect vertical clearance



SDOT Seattle Department of Transportation
ch2m

Girder Pad/Haunch

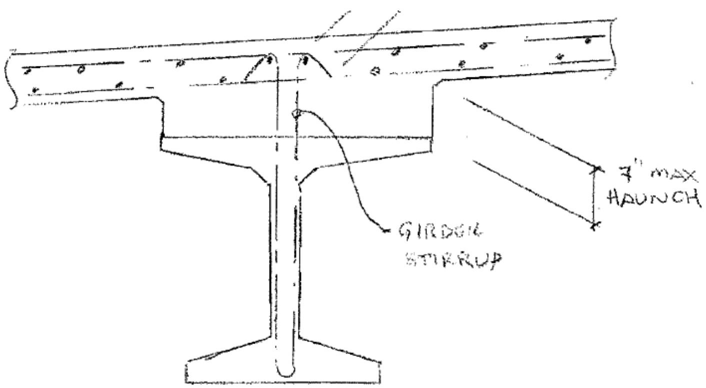


Girder Pad/Haunch

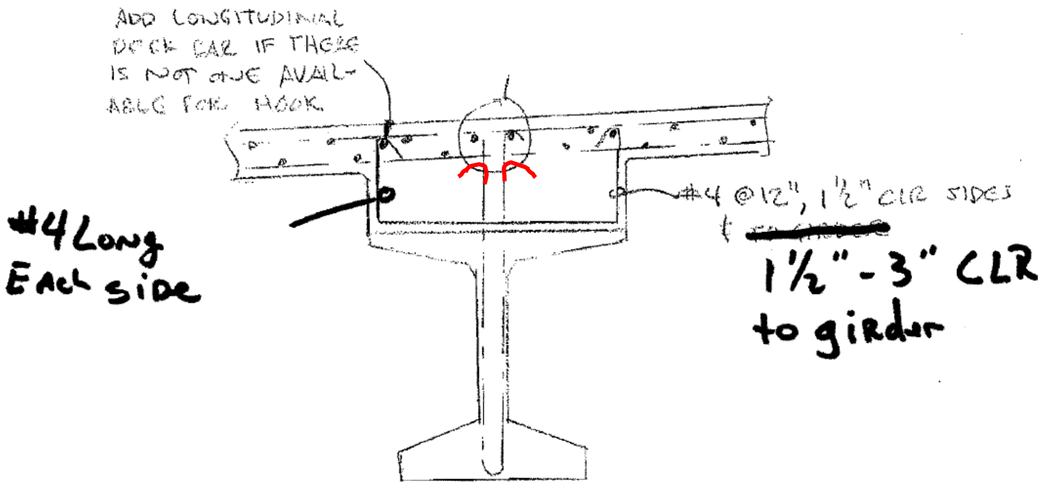
- Pad thickness varies between 2” to 10”
- Max near mid-span

Deck Haunch/Girder Pad

- Less camber than predicted – additional haunch thickness – additional weight
- Girder stirrup not long enough to hook around deck rebar

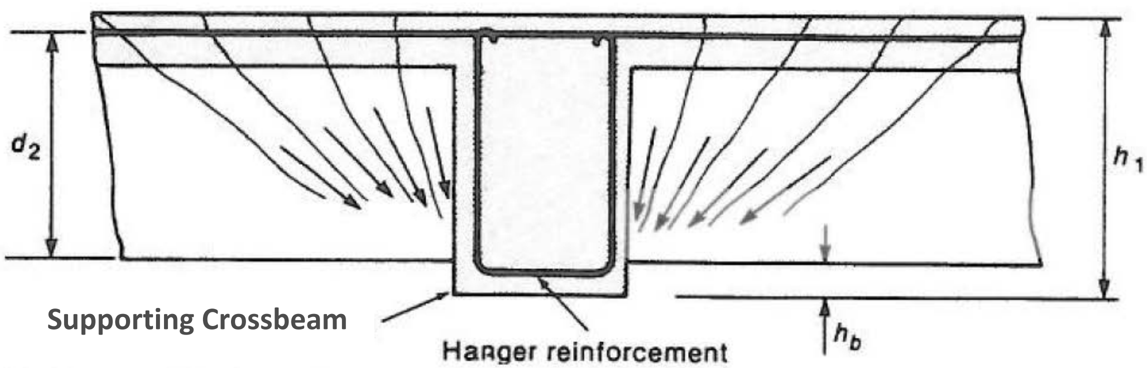


What was specified on the plans

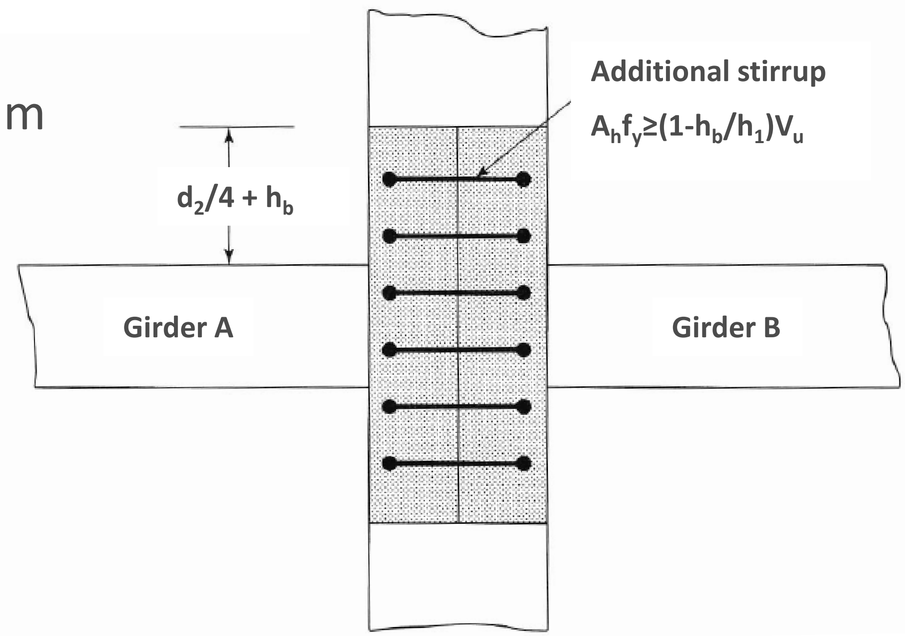


What was actually built

Hanger Reinforcement



Compression fan at girder-crossbeam joint

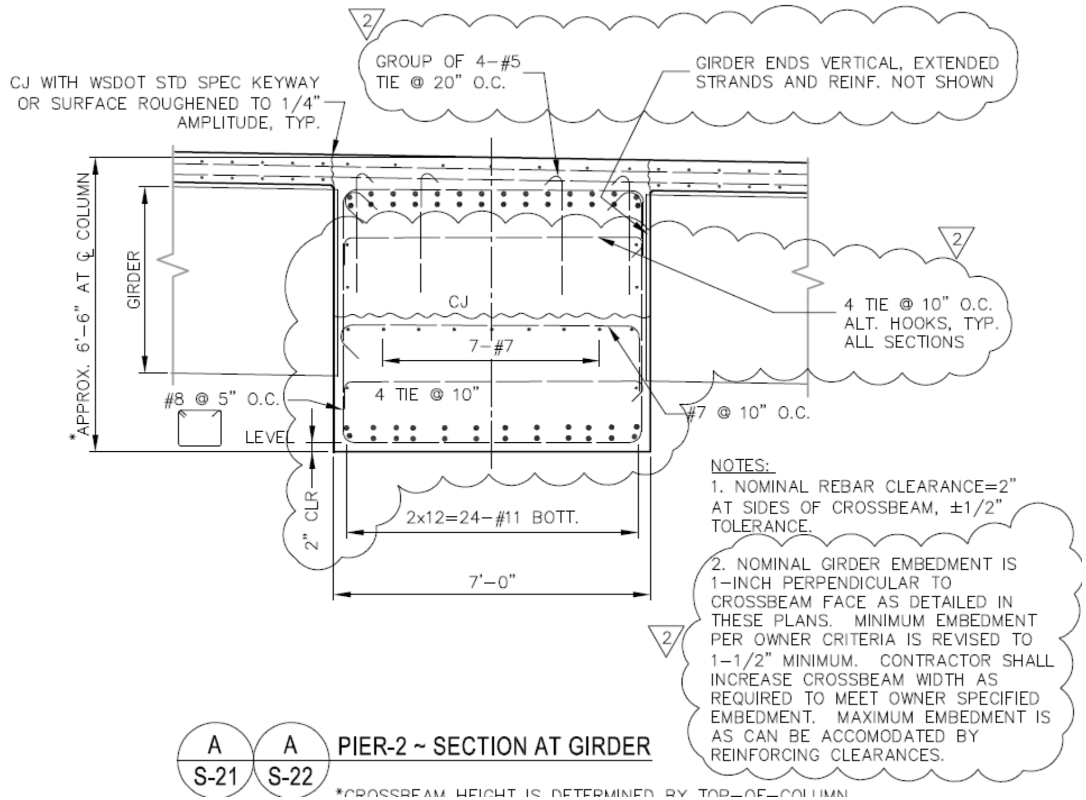


- Applies for girders supported by crossbeam of almost the same depth
- In addition to conventional shear reinforcement
- Waived if $v_u < 3\sqrt{f'_c}$

Ref.: MacGregor, J. G. *Reinforced Concrete: Mechanics and Design (4th Edition)*

Girder Embedment in Crossbeams

- Original CRIP design specified 0” minimum embedment
- What happens if girder is too short?
- Corrected to require 1 ½” minimum embedment
- Actual girders short by as much as 1 ½”. Crossbeam widened by 1”.



SDOT Seattle Department of Transportation
ch2m:

Girder Embedment in Crossbeam

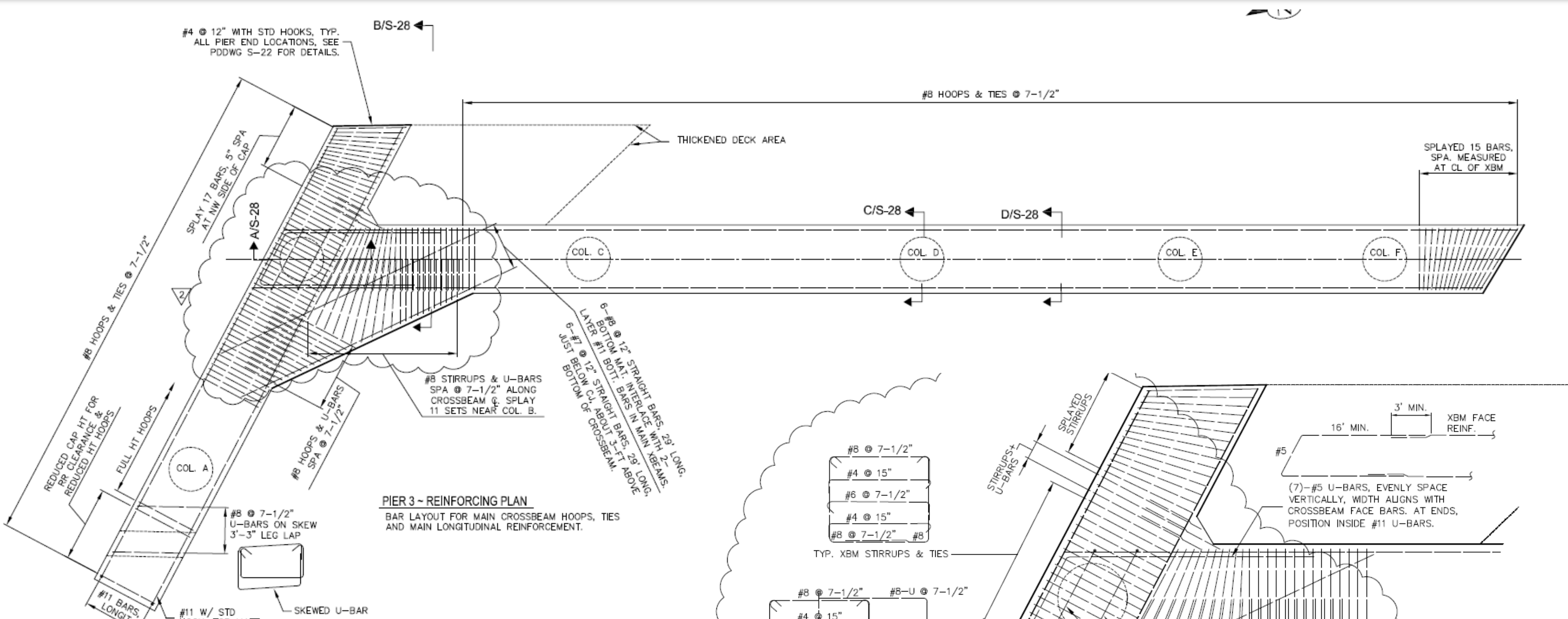
SDOT Seattle Department of Transportation ch2m

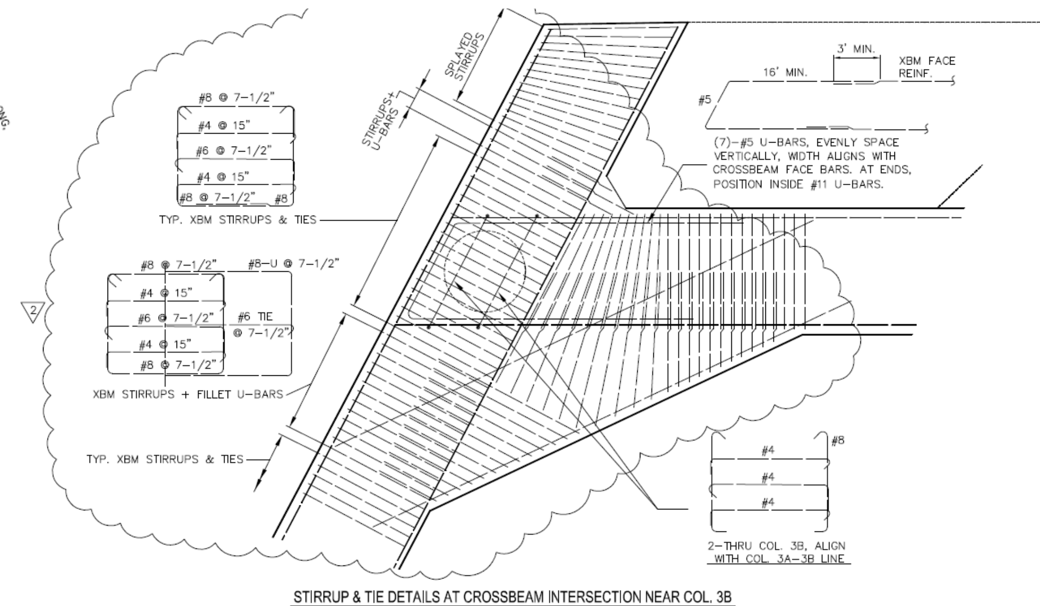
Girder Embedment in Crossbeam

SDOT
Seattle Department of Transportation

ch2m

“T-bone” Crossbeam Detailing

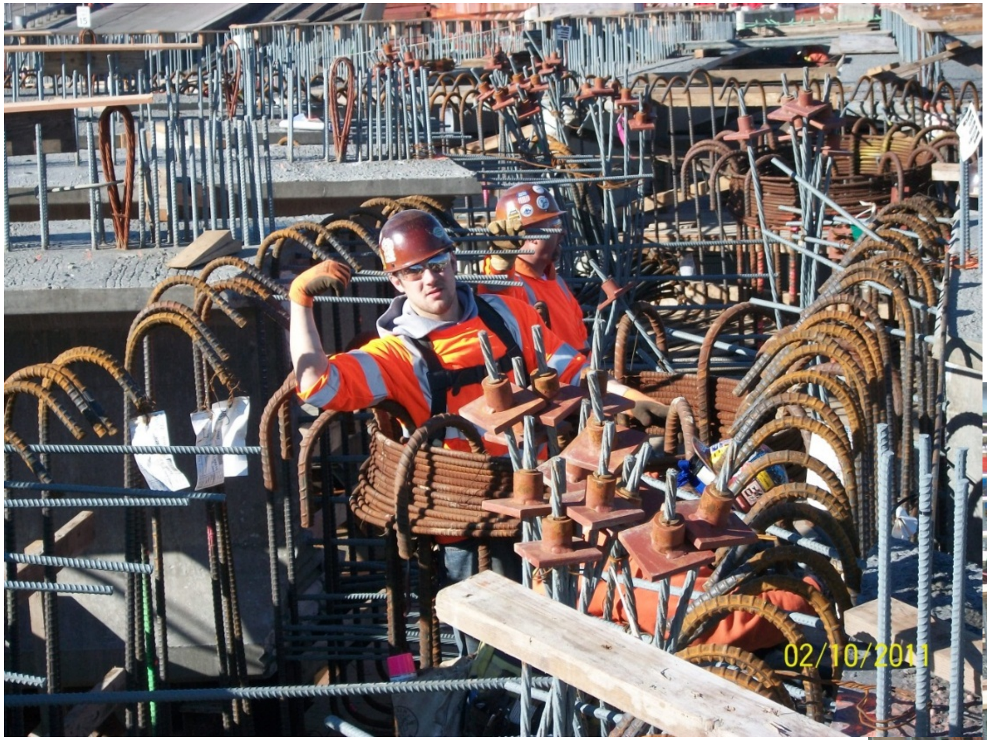




- Large torsional load
- Knee joint detailing

SDOT Seattle Department of Transportation ch2m

Crossbeam Reinforcement



Bridge Foundations

- Superstructure weight reduced by approx. 19% compared with Contract design
- Smaller size column and shafts
- Soft, liquefiable soil
- Relatively long drilled shaft (max shaft length = 150’)
- Savings resulting from smaller shaft diameter are significant

Shaft Cage

Completed Structure

SDOT
Seattle Department of Transportation
ch2m

Lessons Learned

- Precast girders for highly demanding geometry – Can be done!
- But there ARE challenges
- Careful attention to detailing is the key
- Incorporate flexibility into the design – construction tolerances

Acknowledgements

- Gary Wallinder, *Port of Seattle*
- Mike Houlihan, *City of Seattle*
- John Arnesen*, City of Seattle*
- John Clark*, Independent Structural Consultant*
- David Chapman, *Concrete Technology Corporation*
- Ryan Thorne*, Mowat Construction Company*
- Richard Campbell*, Campbell Construction Engineering*

SDOT
Seattle Department of Transportation