93 FAST 14
SUBSTRUCTURE DESIGN

ABC-UTC In-depth Web Training
MassDOT's 93FAST14 Project
November 4, 2014

DESIGN DETAILS – SUBSTRUCTURE REHABILITATION

INITIAL EVALUATION

POLICY DECISION BY OWNER REQUIRED

What is the condition of the existing substructure?

Significant deterioration can make reuse questionable

Can it be counted on to provided an acceptable remaining service life?

Should be equal to or greater than the assumed life of the new superstructure

UNDERSTOOD THAT REMAINING SERVICE IS A "GUESTIAMTE" AT BEST

DESIGN DETAILS – SUBSTRUCTURE REHABILITATION

INITIAL EVALUATION

NBIS Inspection Report Item 60 (substructure) = 6 typical for 93Fast14

DESIGN DETAILS – SUBSTRUCTURE REHABILITATION

DESIGN REQUIREMENTS

If it is decided to retain …

Ideally – the existing substructure meets or can easily be modified to meet the current AASHTO LRFD requirements

HL93 Live Load is an increase over HS20, due to the additional lane load that is applied

Often older substructures are not designed to modern seismic code requirements

Even when capacity is satisfied, detailing often is not acceptable to meet current code requirements

DESIGN DETAILS – SUBSTRUCTURE REHABILITATION

MASSDOT PHILOSOPHY towards rehabilitation versus replacement – specifically superstructure replacement

Analysis to determine capacity of substructure for AASHTO LRFD HL93

If it doesn't meet …

Then analyze according to AASHTO Standard Specifications for Highway Bridges (17th Edition) for HS25 using the Load Factor Method

If it still doesn't meet then determine how it could be upgraded to HL93 and what is the cost impact

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Pier Analysis Summary

Bridge Number & Location		Pier Sections	LRFD: HL-93		SS LF: HS-25		SS LF: HS-20		HS-25 Seismic
			Pass	Fail	Pass	Fail	Pass	Fail	
M-12-39	Mystic Valley Parkway	Pier 1 East		N	Y		Y		NG
		Pier 2 East		N	Y		Y		NG
	• Note: Cap beam is split by open joint underneath each bound of I-93								
	• HL-93: Cap beam flexure failure above columns in multiple locations, capacity to demand failure ratio varies from 0.54 to 0.92 (AASHTO 5.7.3.2 - Mr is not greater than ΦMn)								
	• HL-93: Cap beam does not meet minimum longitudinal reinforcement requirement above columns in multiple locations (AASHTO 5.7.3.3.2 - Mr is not greater than lesser of 1.2*Mcr or 1.33*Mu)								
	• HL-93 Columns flexure failure at top and bottom of 4 columns, capacity to demand ratio varies 0.68 to 0.94 (AASHTO 5.7.3.2 - Mr is not greater than ΦMn)								
	• HL-93 Cap beam shear failure outside range of dv away from the face of interior columns in two locations, capacity to demand ratio varies from 0.92 to 0.97 (AASHTO 5.8.3.3 - Vu is not less than ΦVn)								

Courtesy of CME Associates, Inc.

DESIGN DETAILS – SUBSTRUCTURE REHABILITATION

SEISMIC DEMANDS

Massachusetts is predominantly SDC A which typically requires a design for 25% of dead load as the longitudinal and transverse seismic force

MassDOT present policy is to carry these forces down to the foundation and check substructure

MassDOT also uses the "Floating Bridge" concept

- Prefers steel laminated neoprene bearings
- No anchor bolts
- Therefore no FIXED or EXPANSION bearings

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LONGITUDINAL forces are directed to the abutments and are resisted by passive pressure behind the backwall

- Superstructure moves until it impacts the backwall
- Force is "pushing" the abutment into the soil
- Substructures do need to accommodate the "pulling" force associated with the shear in the bearing
- Space between the superstructure and backwall needs to be carefully considered; require enough to address thermal movement and not too much to "tear" bearings
- Multiple spans need to "linked" (Link Slabs) together or made continuous to act as a single unit longitudinally

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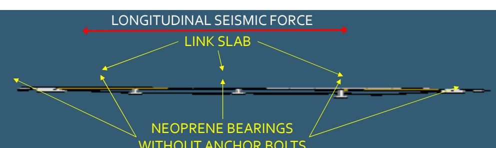

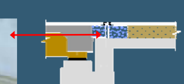

LONGITUDINAL SEISMIC FORCE DIRECTED TO BACKWALL

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TRANSVERSE forces are resisted by all of the substructure units based upon "tributary area"

- This force is typically transmitted to the substructure by concrete shear keys cast into beam seats
- Superstructure moves until it impacts the shear key

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TRANSVERSE FORCE

- Predominantly along strong axis of the substructure unit, where it has higher capacity – strong axis
- Skew is a problem, because resolving the force about the primary axes of the substructure introduces a longitudinal force which may overstress the substructure

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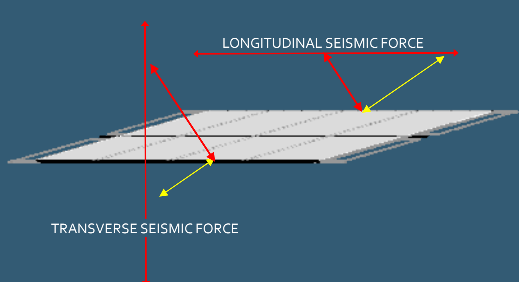

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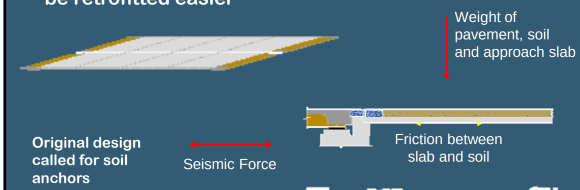
To address this issue:

- Eliminate transvers shear keys at the piers – therefore similar to longitudinal force; all of the transverse force is directed to the abutments
- Abutments are better able to handle force and/or can be retrofitted easier



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- Use PTFE sliding surfaces on top of the neoprene bearing
- This reduces the force transmitted to the coefficient of friction between the Teflon and the polished stainless steel plate, typically a value between 6% and 10%

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This introduces a new concerns:

- While the deck is continuous through out the superstructure via link slabs and extremely stiff in the transverse direction, the beams are not linked
- The superstructure needs to function as a simple span from abutment to abutment in the transverse direction
- Need to add Seismic Connectors, “link plates” between all beams at the piers
- These plates are stiff transversely, like a flange, but are bolted using slotted holes to allow for expansion and contraction

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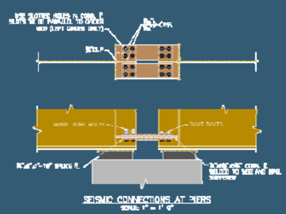
This was only required at bridges where the skew was excessive



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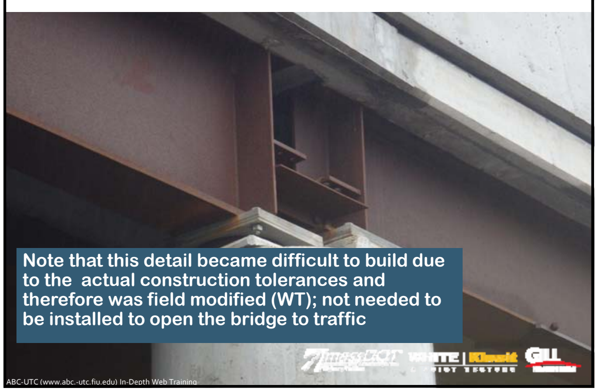

Note that this detail became difficult to build due to the actual construction tolerances and therefore was field modified (WT); not needed to be installed to open the bridge to traffic

DESIGN DETAILS – SUBSTRUCTURE REHABILITATION

<u>Other "Design" Options to Consider</u>

Take concrete cores to determine actual concrete strength

Ideally three cores per concrete pour in the critical elements – columns and pier caps

Or use of other non destructive methods with limited coring

γ_{EQ} = 0 for live load based upon research at University of Nevada Reno

EXPERIMENTAL INVESTIGATION OF INFLUENCE OF LIVE LOAD ON SEISMIC RESPONSE OF A HORIZONTALLY CURVED BRIDGE
Hartanto Wibowo1, Danielle M. Smith1, Ian G. Buckle, and David H. Sanders

DESIGN DETAILS – SUBSTRUCTURE REHABILITATION

PREPARING FOR THE CONSTRUCTION

Construction of new beam seats:

In order to improve the vertical clearance at most of the bridges it was determined by MassDOT to reduce the depth of the beams.

Also the thickness of the deck and wearing surface increased

	EXISTING	PROPOSED
WEARING SURFACE	2.5"	3.0"
DECK	7.0"	8.0"
HAUNCH	-0.75	1.5"
TOTAL	8.75"	12.5"

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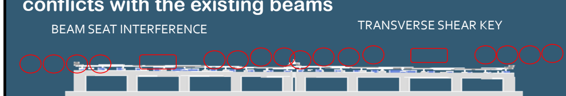
Increased vertical clearance varied, anywhere from a couple of inches to almost a foot

The new beam seats elevations were often significantly higher than the existing beam seats

Note, beam seats at a lower elevation than the existing is not really practical due to interference with reinforcing steel

Even with a revised beam seat spacing there were many conflicts with the existing beams



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It was decided to construct the new beam seats prior to the rapid weekend

Required working around the existing beams

- Shoring/support required to make the modifications while keeping the bridge in service
- Remove portions of the end of the beam for conflicts

DESIGN DETAILS – SUBSTRUCTURE REHABILITATION

- An alternative concept utilizing an adjustable steel bolster underneath the bearing was briefly discussed however, due to schedule and procurement issues was not advanced
- In certain locations used existing beam seat and added shim plates between the bearing and the beam to account for elevation difference.

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QUESTIONS

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