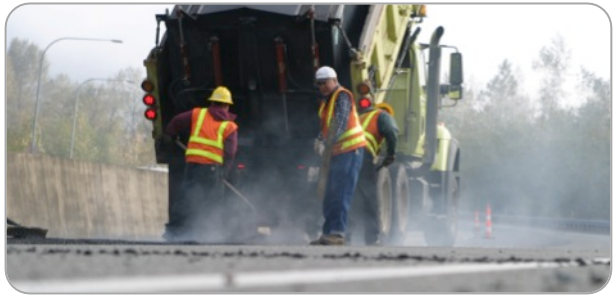
Precast-Prestressed Bridge Girders Damaged by High Load Impacts







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Introduction

- Case Studies
  - High Load Impact Events resulting in Minor, Moderate, and Severe Damage
  - Damage assessment, repair method, and repair cost
- Design Criteria and Guidelines
  - Review of WSDOT's design criteria for improving impact resistance
  - Review of WSDOT's repair and replacement guidelines

SR 3 – Trigger Avenue Undercrossing

- Hit by excavator on low boy trailer
- Minor damage
- Spall was repaired with concrete patching and repair mortar
- Repaired by WSDOT maintenance personnel

SR 14 – Lieser Road Bridge

- Hit by an excavator on flat bed trailer, 2005
- 7 of 8 girders damaged
- 5 interior girders – minor spalls repaired by WSDOT crews
- 2 exterior girders – severe damage. Girders were removed and replaced under contract
- $623,000 = $6,184 per ft of girder
- Hit again 2008 – one girder moderately damaged, 4 severed strands, repaired by WSDOT

I-90 – Easton Road Bridge

- Hit by wind turbine support column
- All 6 girders damaged beyond repair
- 45 day repair challenge by Secretary of Transportation
- Accelerated Bridge Construction (ABC)
- Non-standard configuration of pre-decked bulb-tee girders
- Located in mountain pass (late fall)
- Repaired under contract
- $703,000 = $2,379 per ft of girder

I-5 – Chuckanut Drive Overcrossing

- Hit by excavator (17 ft load, 15’-5” clearance)
- Exterior girders on both sides where damaged.
- All but one interior girder were not hit
- Several strands were severed
- WSDOT crews made temporary repairs by splicing strands
- Final repair was total span replacement
- $723,000 = $2,939 per ft of girder

I-5 – South 178th Street Bridge

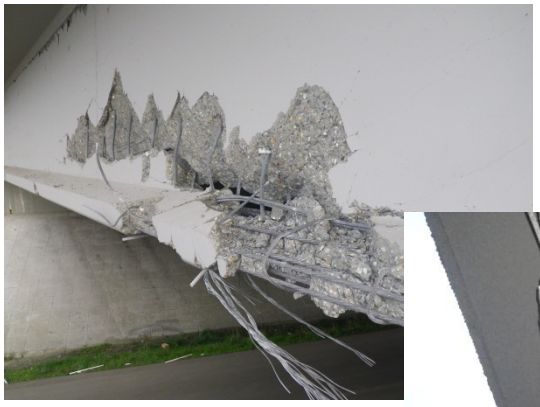
- Hit by high load transformer
- Vehicle traveling on ascending grade beneath structure
- Impacted last exterior girder
- Extensive damage to web
- Several strands were severed
- Remove and replace girder, deck, and railing
- $895,000 = $8,861 per ft of girder

I-5 – 113th Avenue Bridge

- Hit by fork lift on flat bed trailer
- Single girder damaged because mast was torn from fork lift
- Exposed and severed strands
- X-Section – 4 girders at 8ft
- Closed bridge due to lack of redundancy and high volume of heavy truck traffic (nearby quarry)
- Replaced girder, deck and barrier
- $488,519 = $8,246 per ft of girder

SR16 – Olympic Road Bridge

- Hit by fork lift on lowboy trailer
- Mast impacted last girder, pulling it away from bridge
- Pried girder away from diaphragms
- 3” permanent lateral displacement of bottom flange
- 1½” separation between bottom flange and pier
- $851,318 = $8,643 per ft of girder



SR167 – 24th Street Bridge

- Side impact by errant tanker truck
- Bottom flange permanently displaced 3¼“”
- Bottom flange spalled at abutment – loss of bearing
- 6 strands exposed and untensioned
- Broken and bent stirrups
- $1,113,791 = $8,328 per ft of girder

Case Study Summary

Span Type	Repair Type	Year	Cost	Linear Feet of Girder Replaced	Cost/ft
Simple	Span Replacement (5 girders)	2007	$703,000	295.5	$2,379
Simple	Span Replacement (4 girders)	2008	$723,000	246.0	$2,939
Continuous	Girder Replacement	2005	$623,000	100.8	$6,184
Simple	Girder Replacement	2006	$895,000	101.0	$8,861
Simple	Girder Replacement	2011	$489,000	59.3	$8,246
Continuous	Girder Replacement	2012	$851,318	98.3	$8,643
Continuous	Girder Replacement	2012	$1,114,000	133.8	$8,328

WSU Research Project - High Load Impact

- Evaluate effect of intermediate diaphragms on performance of precast-prestressed I-girders during high-load impact events
- Investigated
  - Location of diaphragms
  - Size of diaphragms (height and width)
  - Girder spacing
  - Aspect ratio of span
  - Impact load contact interface (point load, distributed load)

WSU Research Project - Conclusions

- Most significant factors influencing impact resistance are
  - Location of diaphragms
  - Depth of intermediate diaphragms
- Multiple distributed diaphragms provide better energy dissipation and load sharing between structural elements
- Shallow diaphragms found to be detrimental to girder
- Full depth diaphragms limit rotation of girder and provide better impact protected to the overall bridge system

Guidelines for Improving Impact Resistance

Location of Diaphragms

- No diaphragms required for span length ≤ 40 ft
- Mid-point for 40 ft < L ≤ 80 ft
- 1/3 points 80 ft < L ≤ 120 ft
- 1/4 points for 120 ft < L ≤ 160 ft
- 1/5 points for L > 160 ft

Depth of Diaphragms

- Full depth intermediate diaphragms shall be used for bridge crossings over roadways with ADT greater than 50,000.
- Full depth intermediate diaphragms should also be considered in cases with questionable minimum vertical clearance, previous impact events in the vicinity of the structure, and unusual frequency of over height loads.

Repair Design

- Damage assessment is largely a matter of judgment.
- Where section loss has occurred or strands have been severed, calculations aid in the decision process.
- WSDOT BDM describes general categories of damage and suggests repair procedures
  - Minor Damage
  - Moderate Damage
  - Severe Damage

Minor Damage

- Characteristics
  - Damage is slight and limited to small areas of spalling on the outside surface of the concrete
- Repair
  - Damaged area shall be first thoroughly cleaned of any loose material and dried
  - Patch damaged area with epoxy-based repair product

Moderate Damage

- Characteristics
  - Substantial section loss
  - Severed strands
- Repair
  - Clean and prepare girder for repair
  - Splice strands
  - Apply pre-load sufficient to restore prestressing to original levels
  - Repair section with concrete grout
  - Remove pre-load to restore pre-compression to concrete

Severe Damage

- Characteristics
  - Extreme cracking
  - Considerable loss of prestressing
  - Excessive permanent lateral deformation
  - Loss of structural integrity
  - Yielding of stirrups
  - Separation between girder/deck or girder/pier interface
- Repair
  - Carefully removing deck, diaphragms and railing system to permit removal of girder
  - Preserve adequate reinforcement for splicing and development
  - Replace girder, deck, diaphragms, and railing

WSDOT Guidelines for Repair –vs– Replacement

- Replacement is required when one of the following conditions exist
- Strand Damage
  - More than 25% of strands are damaged/severed
- Displacement
  - Bottom flange permanently displaced more that ½” per 10’ of girder length
- Concrete Damage at Harp Point
  - Severe cracking or loss of section at harp point indicates change in strand geometry and loss of prestress force that cannot be restored
- Concrete Damage at Girder Ends
  - Severe cracking at girder ends resulting in permanent loss of prestress

WSDOT Guidelines for Repair –vs– Replacement

- Other items to consider…
- Capacity of adjacent girders
  - Do adjacent girders have adequate capacity if repair cannot fully restore girder?
  - Where adjacent girders damaged as well?
- Cost
  - Replacement is often warranted if cost of repair reaches 70% of replacement cost

Conclusions

- No two high load impact events are the same
- Minor damage can be easily repaired by maintenance personnel
- Severe damage typically require repairs by experienced bridge builders
- WSDOT design criteria provide a simple solution for improving impact resistance of precast-prestressed girder bridge systems.
- WSDOT guidelines for assessment and repair design provide a rational basis for evaluating repair versus replace options.