LRFD Bridge Update

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ASHE TRIKO Valley Chapter
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LRFD Bridge Update (Outline)

- Presentation Purpose
  - How LRFD will effect you?
  - Owner's & Consultant's perspective
- Background
- Implementation Costs & Research Efforts
- Major Code Changes
- Status of LRFD Implementation in Ohio
- What about Load Rating?

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LRFD Bridge Update

- How LRFD will effect you?
  - Owners
  - Consultants
  - Bridge Contractors
    - Value Engineering
  - Managers
  - Business Development
  - Marketing
- Training & Learning Curve
- Bridge Design Software
- Updating “in-house” spreadsheets
- Man-hour estimating
  - More work?
- Cost to Implement
  - More cost ($$$$)?
- Staff Capabilities
  - Ohio only & National firms
- Benefits
  - More consistent Factor of Safety

LRFD Bridge Update

Background

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LRFD Bridge Update (Background)

- 2006 marks the 50th anniversary of our Nations interstate system
  - 1944, HS20-44 live load introduced into specifications which is still in use today
- In the last 50 years bridge design methodology has transitioned from allowable stress to load factor design and now LRFD (Limit State Design)
- LRFD publications
  - 1994 1st Edition
  - 1998 2nd Edition
  - 2000 Interim Revisions
  - 2004 3rd Edition (Including 2005 and 2006 Interim Revisions)

LRFD Bridge Update (Background)

- In 2002, AASHTO sunsets Standard Bridge Design Specifications and officially adopts LRFD for future Specification maintenance
- According to FHWA's June 28, 2000 letter, on Oct. 2007 all new bridges utilizing Federal funding shall be designed using the LRFD specifications
  1. All new bridges on which States initiate preliminary engineering after October 1, 2007, shall be designed by the LRFD Specifications.
  2. All new culverts, retaining walls, and other standard structures on which States initiate preliminary engineering after October 1, 2010, shall be designed by LRFD Specifications, with the assumption that the specifications and software for these structures are "mature" at this time.
  3. States unable to meet these dates will provide justification and a schedule for completing the transition to LRFD.
  4. For modifications to existing structures, States would have the option of using LRFD Specifications or the specifications which were used for the original design.

LRFD Bridge Update

- What is LRFD?

  Load Resistance Factored Design

  Supply > Demand

  Resistance > Loads

  $\varphi R > \eta(\lambda Q)$

LRFD methodology is independent of material

- Load factors developed from theory of reliability based on statistical information/knowledge
- Reliability Index (β) = Quantitative assessment of Safety
  - ß ranges btw. 1.5 to 4.5 (3.5 design, 2.5 rating)

LRFD Bridge Update

Implementation Costs & Research Efforts

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Research Efforts

- 1986 AASHTO began research work through NCHRP efforts to implement LRFD
- LRFD research is on-going
  - sections and chapters of the code are either being edited or revised based on current research & practices

date	project	Res. Agency
1987	"20-7 Task 31"	Modjeski and Masters
1988	"12-33"	Modjeski and Masters
1995	"12-42"	Modjeski and Masters
1997	"12-46"	A. G. Lichtenstein & Associates
1999	"12-52"	Modjeski and Masters
2001	"12-55"	D'Appolonia
2001	"12-56"	University of Illinois
2001	"12-57"	Ralph Whitehead Associates
2001	"12-58"	University of Buffalo
2002	"12-60"	Purdue University
2003	"12-61"	University of Illinois
2003	"12-62"	BridgeTech
2003	"12-63"	Lichtenstein Consulting Engineers
2003	"12-64"	North Carolina State University
2004	"12-69"	Construction Technology Laboratories
2004	"12-70"	CH2M Hill
2004	"18-12"	Universite de Sherbrooke
2005	Task 186	Modjeski and Masters

Implementation Costs

date	project	cost
1987	"20-7 Task 31"	annual budget for multiple projects
1988	"12-33"	1,404,167
1995	"12-42"	922,630
1997	"12-46"	390000
1999	"12-52"	700000
2001	"12-55"	250000
2001	"12-56"	650000
2001	"12-57"	240000
2001	"12-58"	359999
2002	"12-60"	600000
2003	"12-61"	250000
2003	"12-62"	249958
2003	"12-63"	350000
2003	"12-64"	600000
2004	"12-69"	500000
2004	"12-70"	500000
2004	"18-12"	449904
2005	Task 186	60000
	total =	**$8,476,658**

LRFD Bridge Update

Major Code Changes

+ Parallel Commentary

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Dead Loads

AASHTO Standard		LRFD
Deck slab	DL=1.3	DC=1.25/0.9
Self Wt.	DL=1.3	DC=1.25/0.9
FWS & Utilities	DL=1.3	DW=1.50/0.65

Live Loads

AASHTO Standard (HS25)

- Max. (HS20 truck or lane) x 1.25
- Alternate military (24 K)
- HS20 lane (26 K rider for shear) x 1.25
- Impact = 50/L+125

LRFD (HL-93)

- Design truck (HS20 truck) + design lane (HS20 lane minus the 26 K rider)
- Design tandem (alternate military (25 K))
- 0.9*(double truck + design lane) interior pier reactions
- Impact (dynamic load allowance)= 1.33 truck, 1.00 lane

Multiple Presence Factors (MPF)

# Lanes	LRFD	AASHTO STND.
1	1.20	1.00
2	1.00	1.00
3	0.85	0.90
4	0.65	0.75

Based on ADTT of 5000; C3.6.1.1.2 allows up to 10% reduction of MPF

Live Load Distribution Factors

Range of Applicability (Art. 4.6.2.2.1):

- Constant deck width
- # beams >= 4
- Parallel Beams
- Roadway part of overhang (de) <= 3.0 ft.
- Curvature <= limits specified in Art. 4.6.1.2
- Structure Types consistent with Table 1

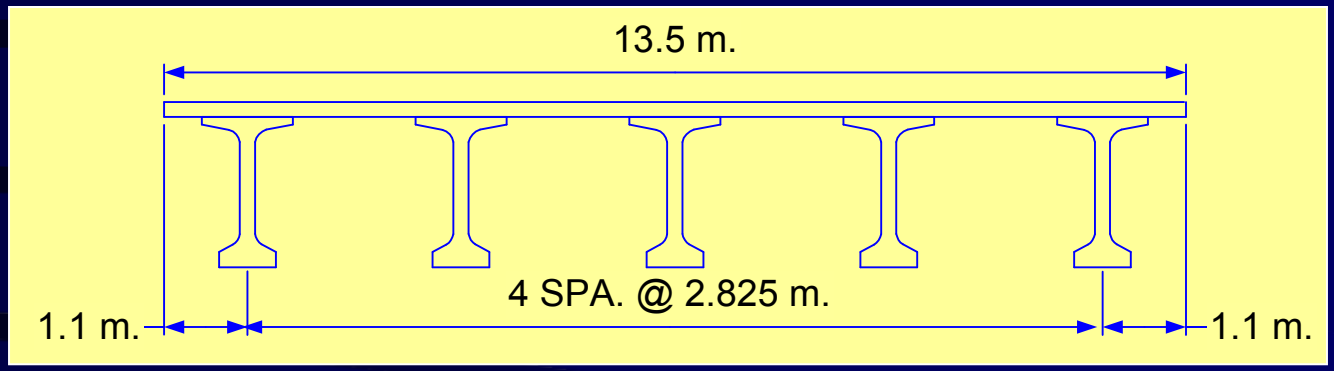
Moment Distribution Factors – Prestressed Concrete I-Girder (2+ lanes)

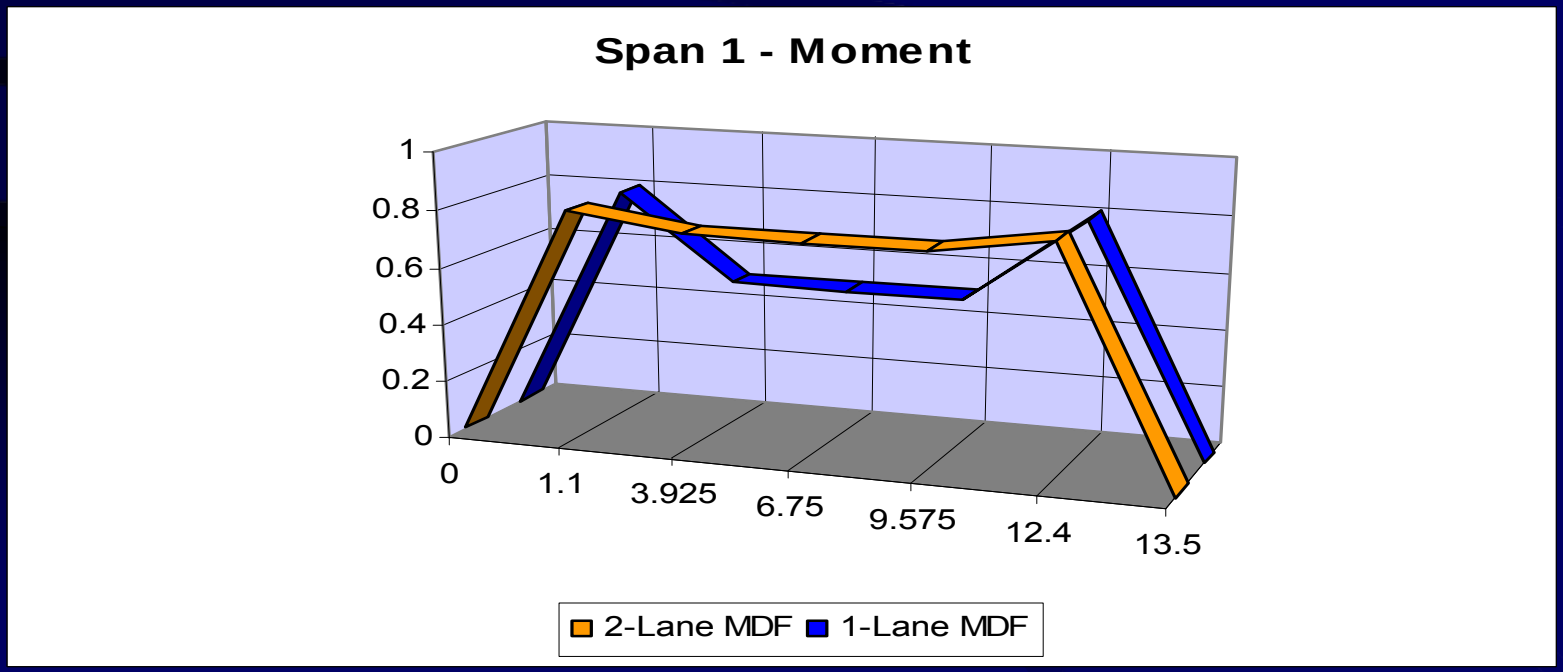
LRFD	AASHTO Stnd.
Skew	
Longitudinal Stiffness	Beam Spa. (S/D)
Beam Spa.	
Deck Thick.	
Length of Span	

$$g = 0.075 + \left(\frac{S}{9.5}\right)^{0.6}\left(\frac{S}{L}\right)^{0.2}\left(\frac{K_g}{12.0Lt_s^3}\right)^{0.1}$$

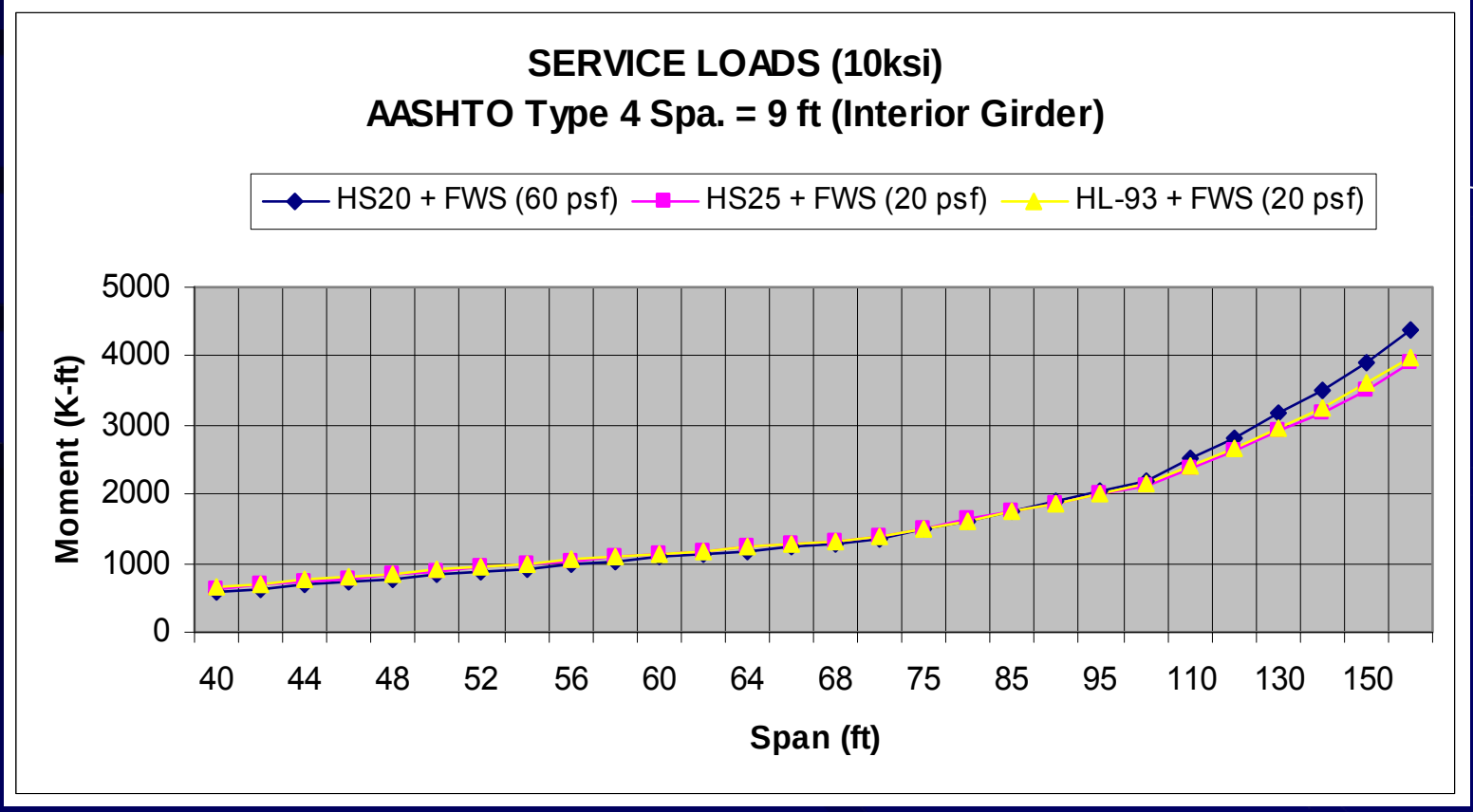
Note: Equations are dependent on Structure Type!

Live Load Moment Distribution

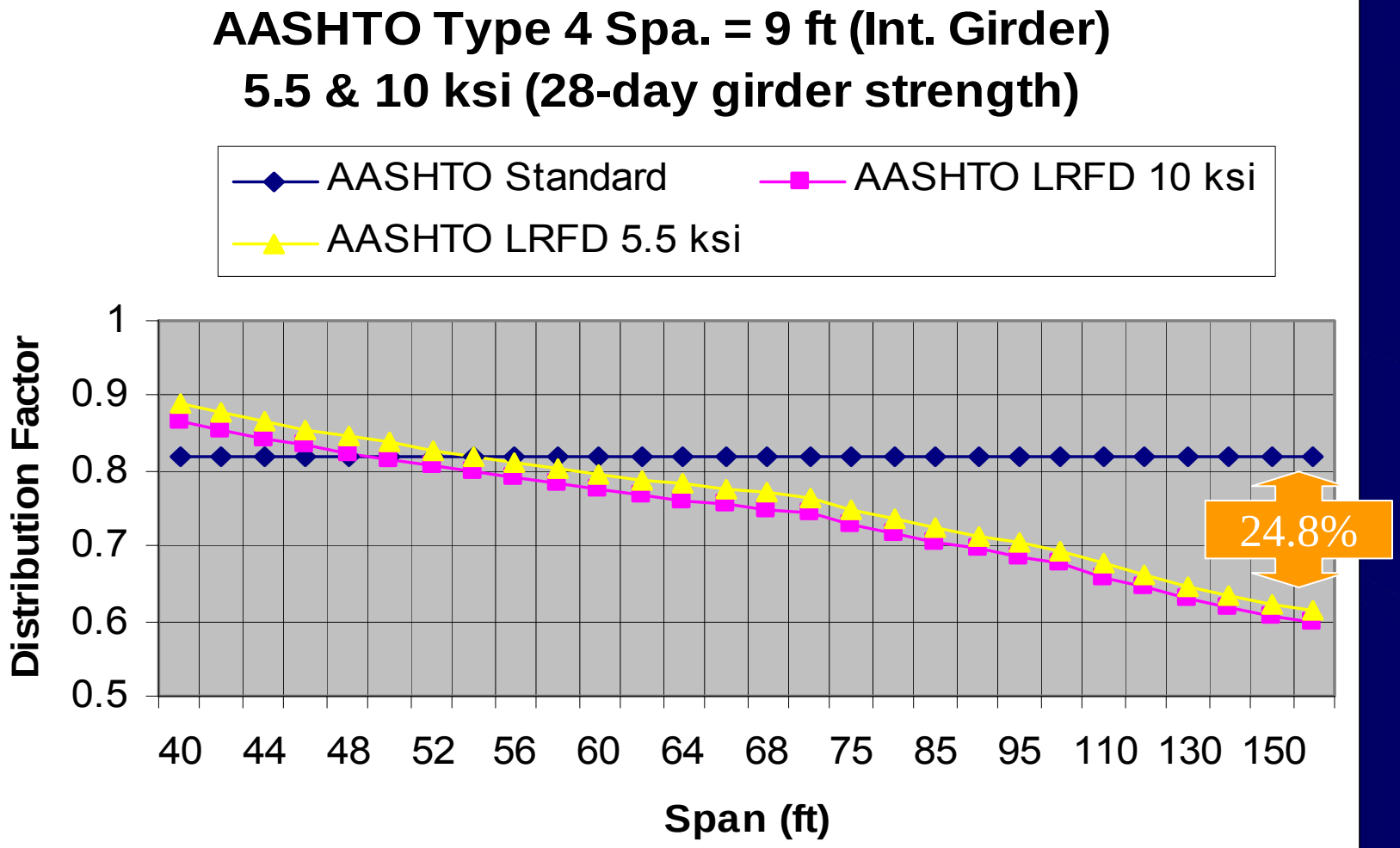




LRFD vs. AASHTO Standard Service Moments



Distribution Factors & HSC



Skew Effects for Live Load Distribution

Shear:

- Applicable if:
  - Dependent on Structure Type
  - adjacent skewed supports <= 10°
  - 30° <= skew <= 60°
  - 3.5’ <= S <= 16.0’
  - 20’ <= L <= 240’
  - Nb >= 4

Moment:

- Applicable if:
  - Dependent on Structure Type
  - adjacent skewed supports <= 10°
  - 30° <= skew <= 60°
  - 3.5’ <= S <= 16.0’
  - 20’ <= L <= 240’
  - Nb >= 4

Shear Capacity

LRFD	AASHTO Standard
$V_n = V_c + V_s + V_p$	$V_n = V_c + V_s + V_p$
$V_c = \beta(f'_c)^{1/2} b_v d_v$	V_c = min. V_{ci} or V_{cw}
$V_s = A_v f_y d_v / s$	$V_s = A_v f_{sy} d / s$

LRFD - Simplified Method ($\theta = 45°$, $\beta = 2.0$)

or

LRFD - Modified Compression Field Theory

Braking Force

AASHTO Standard

- 5% of live load in all lanes (1 lane)
- For L = 276 ft.

  LF = 0.05 * [(L x 0.8) + 22.5] = 12.17 k (HS25)

LRFD

- 25% of design truck or tandem

  0.25 * 72 k = 18 k

  Apply multiple presence factor (MPF)
- BR = 1.2 * 18 = 21.6 k

Load Combinations/Limit States

LRFD	AASHTO STND.
Service 1-3	Service 1-10
Strength 1-5	Load Factor 1-10
Extreme Event 1-2	N/A
Fatigue	N/A

Bridge Decks

- Traditional Method (Art. 9.7.3)
  - Similar to AASHTO Standard Specs.
  - Applies to deck overhang design (Art. 3.6.1.3.4)
- Approximate Method/Equivalent Strip Method (Art. 4.6.2.1)
  - ODOT indicated they will use this method
  - Deck Slab design provided in Appendix, Table A4-1

Bridge Decks

- Empirical Design Method (Art. 9.7.2)
  - Crossframes/diaphragms
  - Steel/Concrete supporting components
  - Cast-in-place deck & water cured
  - Uniform deck thickness
  - Ratio of effective L to design depth does not exceed 18.0 and is not less than 6.0
  - Effective length as specified in Art. 9.7.2.3, does not exceed 13.5 ft.
  - Minimum slab depth >= 7.0 inches (excluding sacrificial wearing surface)
  - F'c >= 4.0 ksi
  - Composite Deck
  - Minimum Reinforcing (Art. 9.7.2.5)
    - As = 0.27 in^2/ft (bottom)
    - As = 0.31 in^2/ft (#5 @ 12" c/c)
    - As = 0.18 in^2/ft (top)
    - As = 0.20 in^2/ft (#4 @ 12" c/c)

LRFD will effect various Bridge Structure Types Differently vs. AASHTO Standard

LRFD Bridge Update

Status of LRFD Implementation in Ohio

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Status of LRFD Implementation in Ohio

- ODOT is performing:
  - "in-house" training
  - Performing design comparisons between AASHTO Standard and LRFD codes
  - Changes to Bridge Design Manual
  - LRFD Article Exceptions
  - Changes to Standard Drawings
  - Consultant LRFD Training, Fall 2006 & Spring 2007
    - LRFD training material on website
    - University of Cincinnati
    - University of Akron, and Ohio University
- Project scopes will contain LRFD requirements beginning in Jan./2007

Vertical Profile set!

- Projects-in-Process (MUST USE LRFD) if not completed through July 20, 2007:
  - Step 6 (Major PDP)
  - Step 3 (Minor PDP)
  - Step 1 (Minimal PDP)
- Local Projects-in-Process (MUST USE LRFD) if not completed through October 1, 2007:
  - Step 6 (Major PDP)
  - Step 3 (Minor PDP)
  - Step 1 (Minimal PDP)

Status of LRFD Implementation in Ohio

- Owners will have to address the applicability of LRFD:
  - Project Types:
    - Consulting Services
    - Construction Services
      - Value Engineering
      - Sheeting Design
  - Scope Documents
  - Bridge Widenings specific to what Code and/or live load model to use
  - Existing structures/rehabilitation
    - Live load application
    - Live load distribution

LRFD Bridge Update

Load Rating

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LRFR…Load Rating ….It's Coming

NCHRP Project 12-46, FY 1997

Manual for Condition Evaluation and Load Rating of Highway Bridges Using Load and Resistance Factor Philosophy

- Research Agency: A. G. Lichtenstein & Associates, Inc.
  Principal Investigator: Charles M. Minervino
- Completion Date: September 30, 2000

Objective: To develop a manual, with supporting commentary and illustrative examples, for the condition evaluation of highway bridges that is consistent with the design and construction provisions of AASHTO LRFD bridge specifications, but with calibrated load and resistance factors appropriate for bridge evaluation and rating.

Additional References

"*Designing Bridges for the Vehicular Demands of Today and Tomorrow*", Structural Engineer Magazine (May, 2001)

by

Myint Lwin, P.E., S.E.

John Minor, Ph.D., P.E.

David Tomley, P.E.

"*LRFD Bridge Pier Design Study*"

by

David Tomley, P.E.

at

2004 OTEC

2004 OCEA/CCAO