# AASHTO LRFD Bridge Design Specifications

Josh Beakley
August, 2010

# AASHTO

- Standard Specifications for Highway Bridges (LFD) – 17th Edition - 2002
  - Load Factor Design
- LRFD Bridge Design Specifications
  - Load Resistance Factor Design

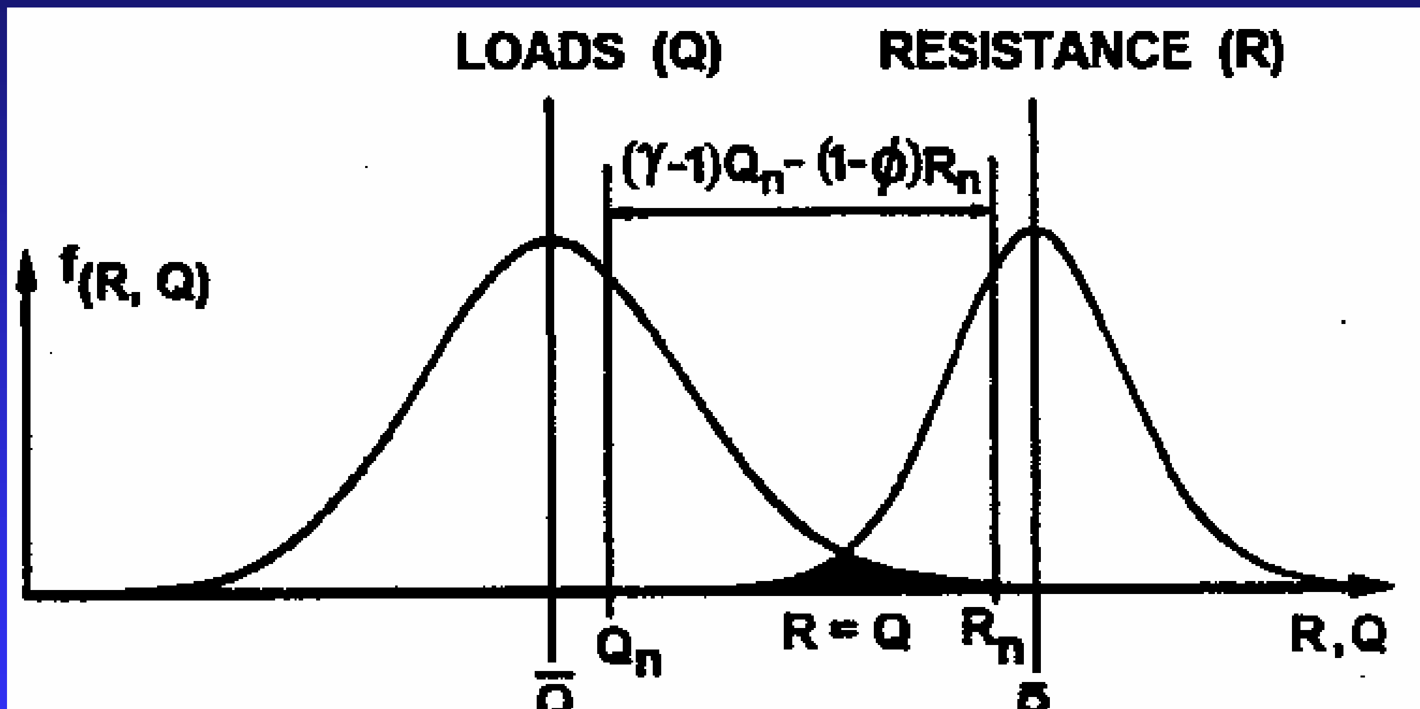
# AASHTO LRFD Bridge Design Specifications – First Edition - 1994

- "In 1987, the Subcommittee submitted a request to the AASHTO Standing Committee on Research to undertake an assessment of the U.S. Bridge design specifications, review foreign design specifications and codes, consider design philosophies alternative to those underlying *Standard Specifications*, and to render recommendations based on these investigations."

# AASHTO LRFD Bridge Design Specifications – First Edition - 1994

- LRFD – Load and Resistance Factor Design
- “A further philosophical extension results from considering the variability in the properties of structural elements, in similar fashion to load variabilities.”
- “LRFD relies on extensive use of statistical methods, but sets forth the results in a manner readily usable by bridge designers and analysts.”

# Statistically Based Design



# Load and Resistance Factor Design (LRFD)

- "A reliability-based design methodology in which force effects caused by factored loads are not permitted to exceed the factored resistance of the components."

# AASHTO LRFD Bridge Design Specifications – First Edition - 1994

- "The body of knowledge related to the design of highway bridges has grown enormously since 1931 and continues to do so. Theory and practice have evolved greatly, reflecting advances through…."
- "The pace of advances in these areas has, if anything, stepped up in recent years."

U.S. Department of Transportation
Federal Highway Administration

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## Bridge Technology

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FHWA > Infrastructure > Bridge > LRFD

1200 New Jersey Avenue SE
Washington, D.C. 20590

U.S. Department of Transportation
**Federal Highway Administration**

June 28, 2000

Refer to: HIBT

David H. Pope, P.E.
Chairman, Highway Subcommittee on Bridges and Structures
Wyoming Department of Transportation
5300 Bishop Boulevard
Cheyenne, WY 82009-3340

Dear Mr. Pope:

Thank you for the letter of June 20, 2000. We appreciate receiving the advice and recommendation of the AASHTO Highway Subcommittee on Bridges and Structures and its member State bridge engineers on the time frame goals for the use of Load and Resistance Factor Design (LRFD) for the design of bridges. We concur in recommended time frames and would be pleased to work in partnership with the States to attain the listed four goals which, to repeat, are:

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.

A copy of this letter and yours are being provided to the State bridge engineers and our FHWA field offices so that they are aware of FHWA's decision on this matter.

Sincerely yours,

*/s/ original signed by*
David H. Densmore

# LRFD is Coming

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.

# AASHTO Design and Installation

- AASHTO Standard Specifications for Highway Bridges
  - Division I – Design
  - Division II – Construction
- AASHTO LRFD Bridge Design Specifications
- AASHTO LRFD Bridge Construction Specifications

# AASHTO Design Specifications

# AASHTO Standard Specifications for Highway Bridges

- Section 3 – Loads
- Section 6 – Culverts
- Section 8 – Reinforced Concrete
- Section 12 – Soil-Corrugated Metal Structure Interaction Systems
- Section 16 – Soil-Reinforced Concrete Structure Interaction Systems
- Section 17 – Soil-Thermoplastic Pipe Interaction Systems

# AASHTO LRFD Bridge Design Specifications

- Section 3 – Loads and Load Factors
- Section 4 – Structural Analysis and Evaluation
- Section 5 – Concrete Structures
- Section 12 – Buried Structures and Tunnel Liners

# Structures Designed Per Section 12

- Section 12.7 - Metal Pipe, Pipe Arch, and Arch Structures
- Section 12.8 - Long-Span Structural Plate Structures
- Section 12.9 - Structural Plate Box Structures
- Section 12.12 – Thermoplastic Pipes
- Section 12.13 – Steel Tunnel Liner Plate

# Structures Designed Per Section 12

- Section 12.10 – Reinforced Concrete Pipe
- Section 12.11 - Precast Box Culverts, Cast-in-place Box Culverts, Cast-in-place Arches
- Section 12.14 - Precast Three-Sided Structures

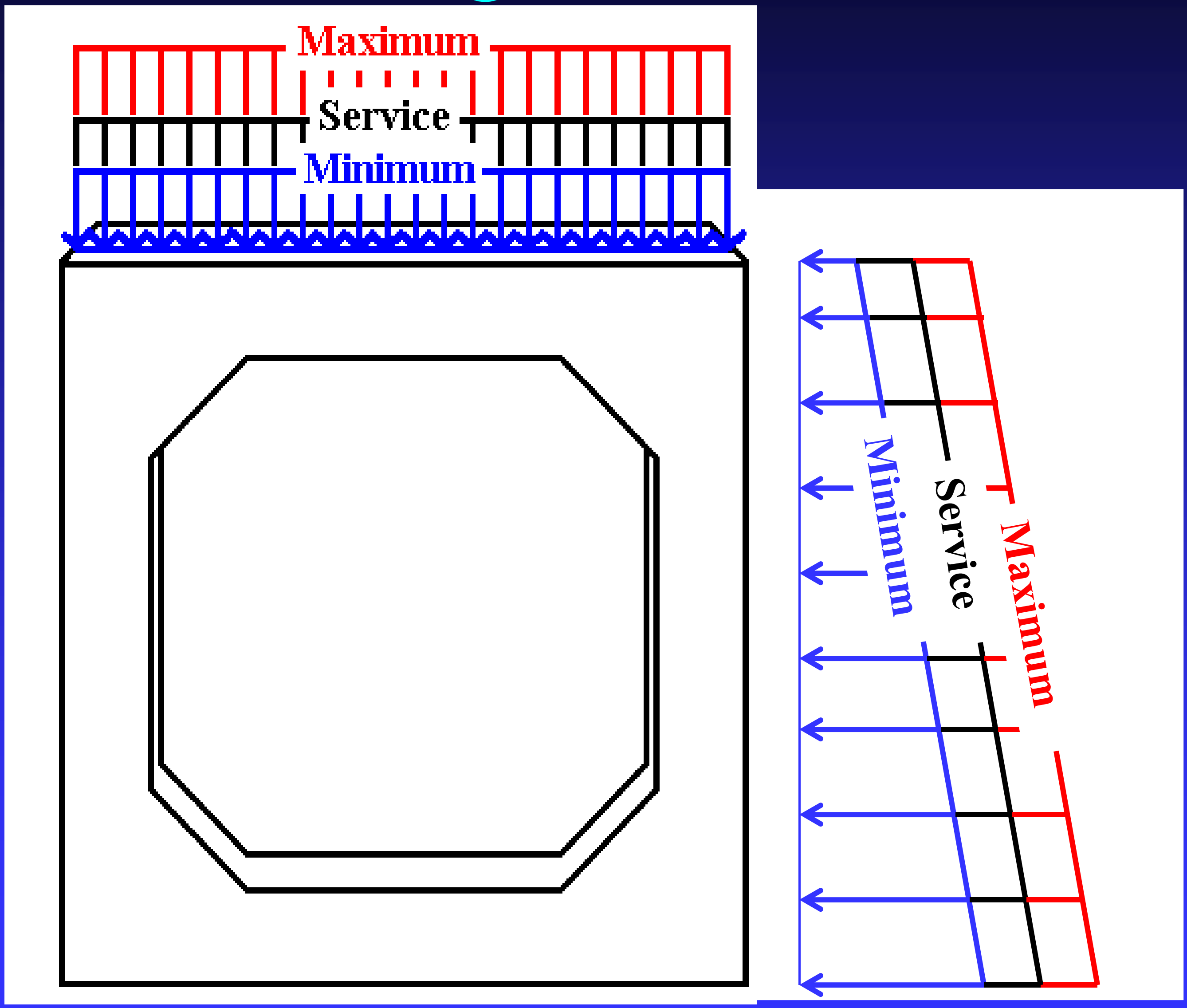
# Load Factors

# Load Factors

| Load | Load Factor | | |
|---|---|---|---|
| | Standard | LRFD | |
| | | Minimum | Maximum |
| Dead | 1.3 | 0.90 | 1.25 |
| Water | 1.3 | 1.0 | 1.0 |
| Earth – Vertical | 1.3 | 0.90 | 1.30 |
| Earth - Horizontal | 1.3 | 0.90 | 1.35 |
| Live | 1.3 x 1.67 = 2.17 | 0.0 | 1.75* |

* A multiple presence factor is included in the total load

# LRFD Design

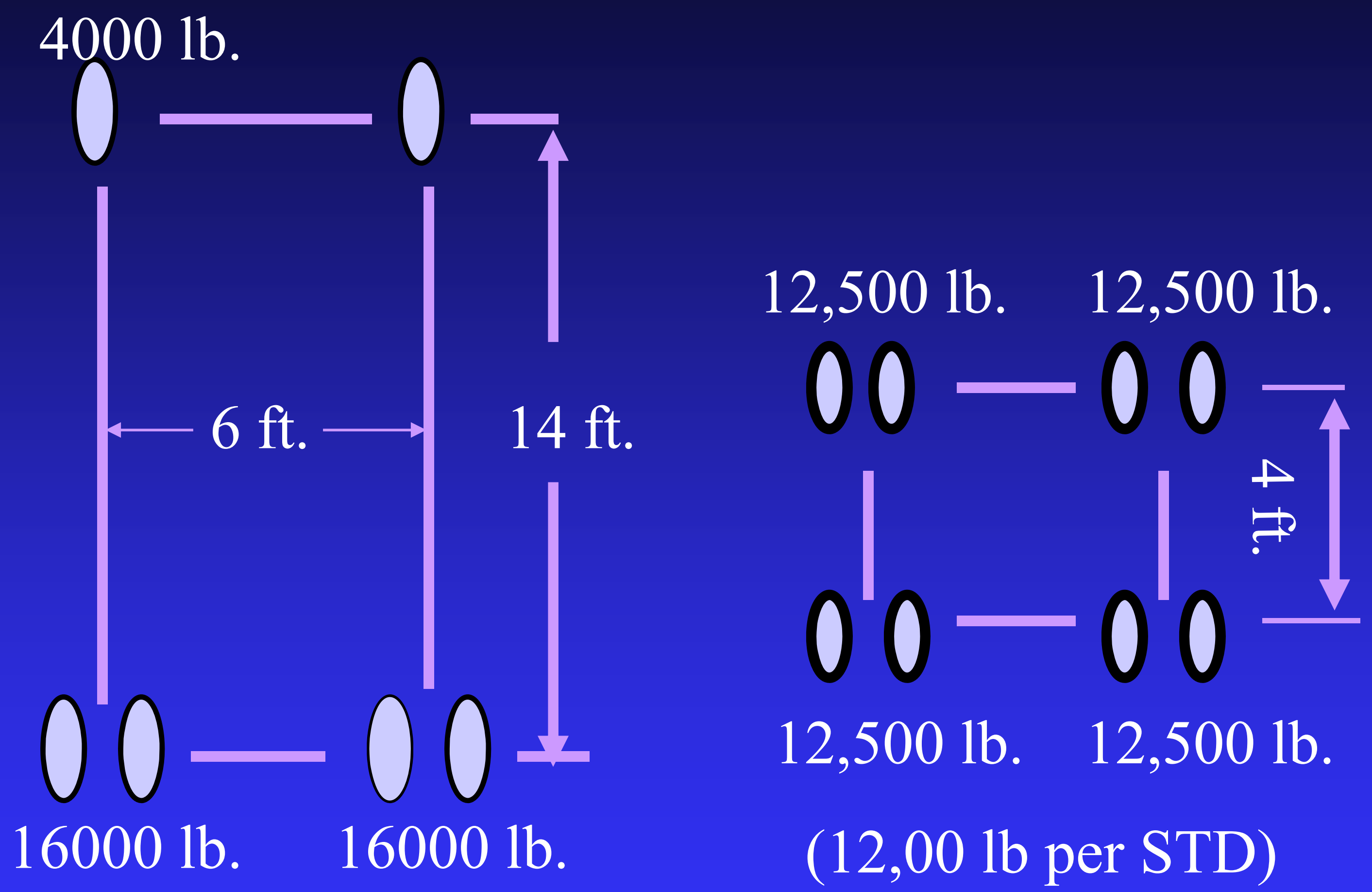


# Live Load

# Live Load

- 3.6.1.2 Design Vehicular Live Load
  - 3.6.1.2.1 General
  - "Vehicular live loading on the roadways of bridges or incidental structures, designated HL-93, shall consist of a combination of:
    - Design truck or design tandem, and
    - Design lane load

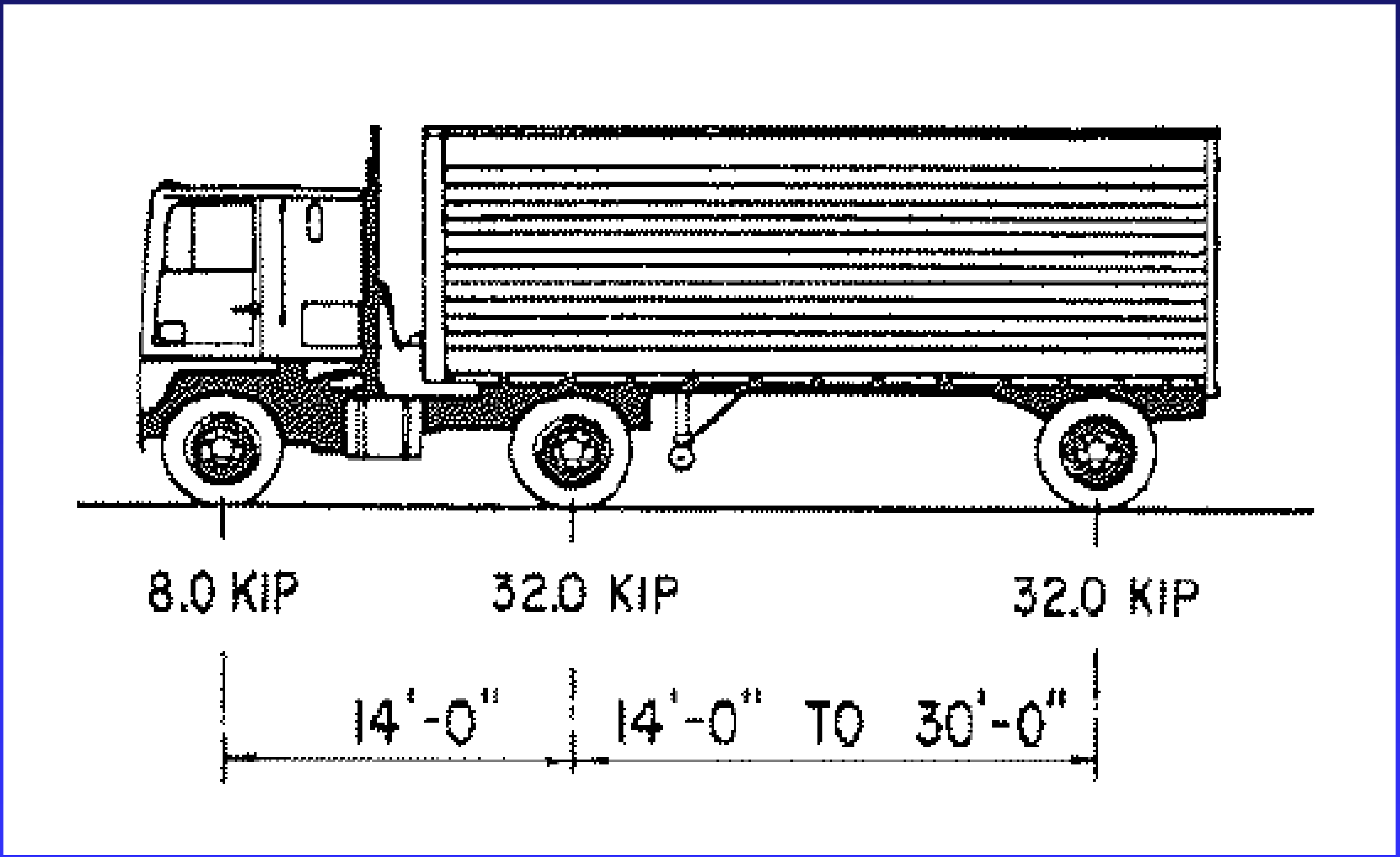
# Live Load Spacing – HL-93



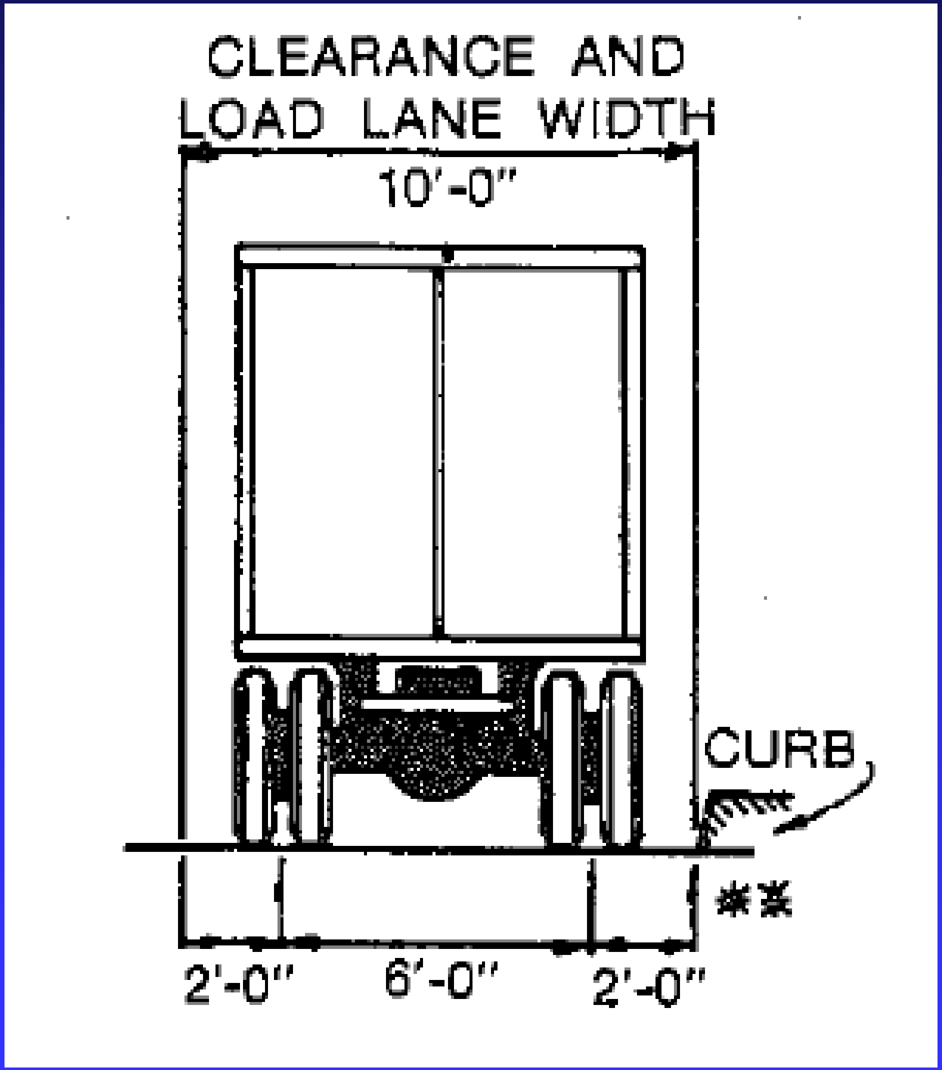

**AASHTO HS 20 LOAD**

**AASHTO ALTERNATE LOAD**

# HS20 or HL 93 Single Axle



# Axle Width



# Applied Live loads

- 3.6.1.3.3 Design Loads for Decks, Deck Systems, and the Top Slabs of Box Culverts
  - Where the slab spans primarily in the longitudinal direction:
  - For top slabs of box culverts of all spans and for all other cases, including slab-type bridges where the span does not exceed 15.0 ft, only the axle loads of the design truck or design tandem of Articles 3.6.1.2.2 and 3.6.1.2.3, respectively, shall be applied.

# Applied Live loads

- 3.6.1.3.3 Design Loads for Decks, Deck Systems, and the Top Slabs of Box Culverts
  - Where the slab spans primarily in the transverse direction, only the axles of the design truck of Article 3.6.1.2.2 or design tandem of Article 3.6.1.2.3 shall be applied to the deck slab or the top of box culverts.

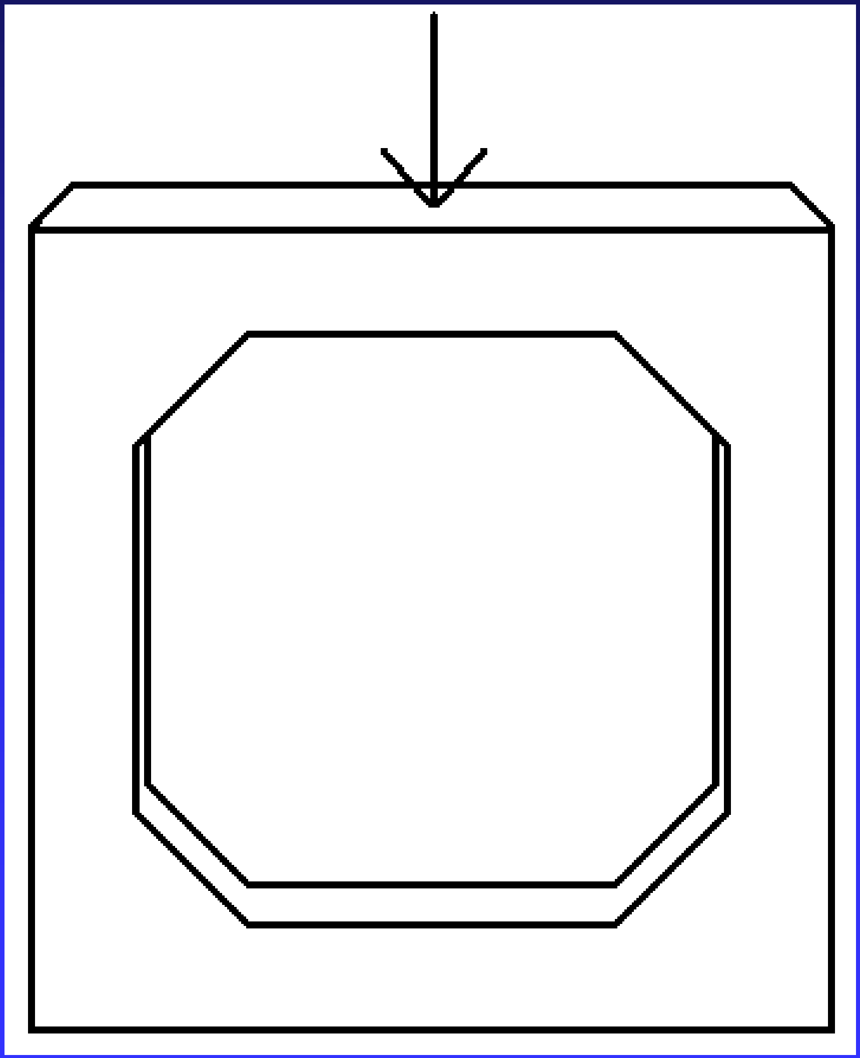
# Lane Load – 3.6.1.3

- LRFD – 2004 – Truck and Lane Load
  - 64 lbs across a 10 ft width
  - DLA not applied
- LRFD – 2005 – Truck only
- LRFD – Future – ?
- Standard Specification – 3.7.1.1
  - Either truck or Lane Load
  - Truck governs for shorter spans

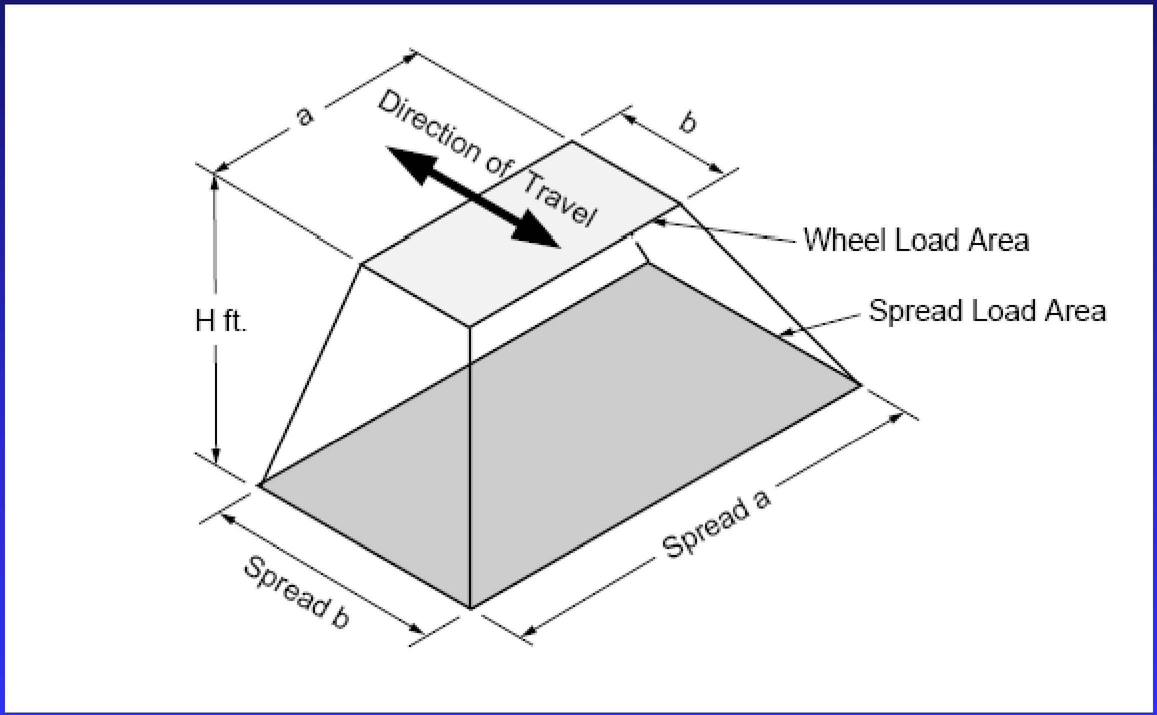
# Tire Footprint

- LRFD – 3.6.1.2.6
  - w=20”
  - l=10”
- Standard Specification – 6.4.1
  - “Concentrated Load”

# Concentrated Load



# Live Load Distribution




STD – Spread a = a + 1.75*H

LRFD – Spread a = a + 1.15*H

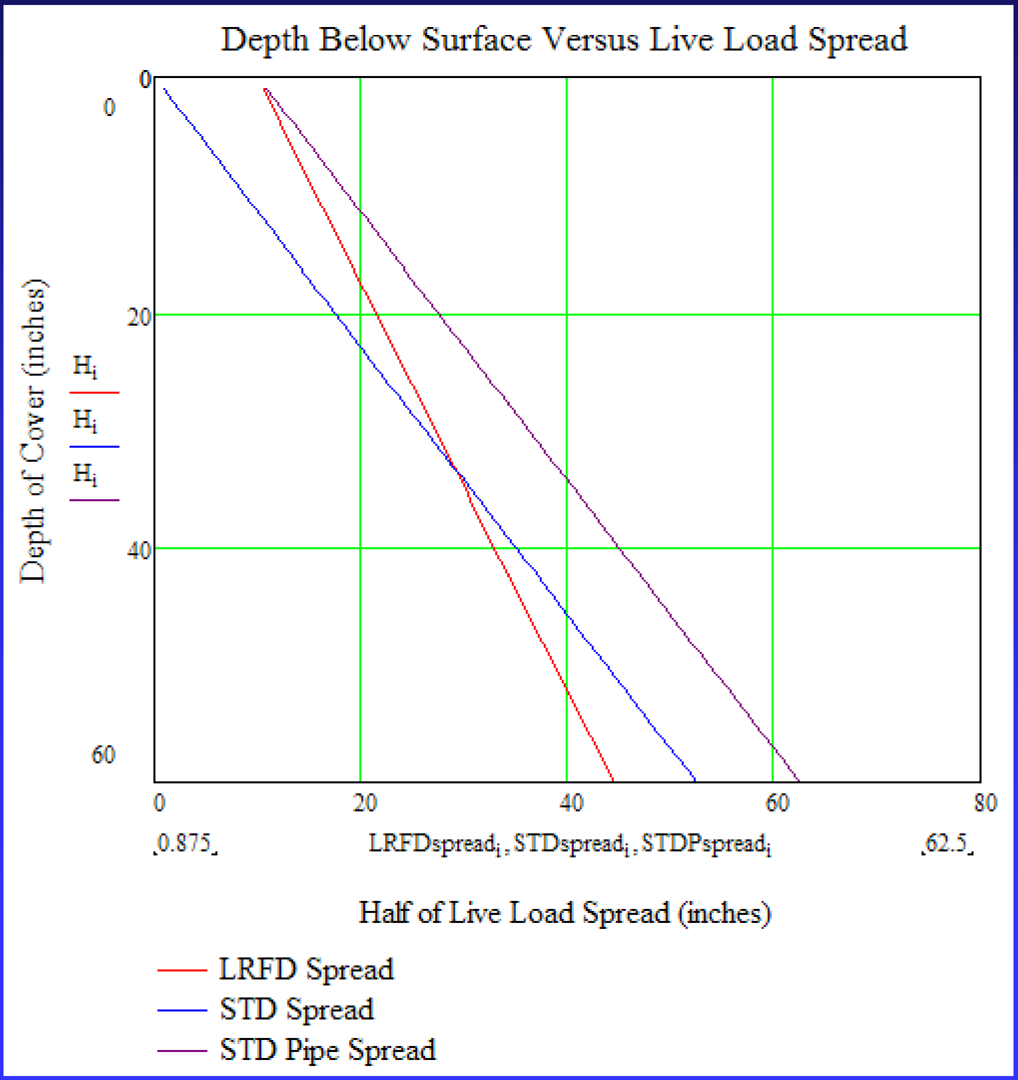
STD – Spread b = b + 1.75*H

LRFD – Spread b = b +1.15*H

# Live Load Area for Depths $\geq$ 2 ft.

- LRFD (3.6.1.2.6)
  - $A_L = (20/12 + 1.15D_E)(10/12 + 1.15D_E)$
    - 1.15 above should be replaced with 1.0 if select granular backfill is not used
- Standard (6.4.1)
  - $A_L = (1.75D_E)^2$

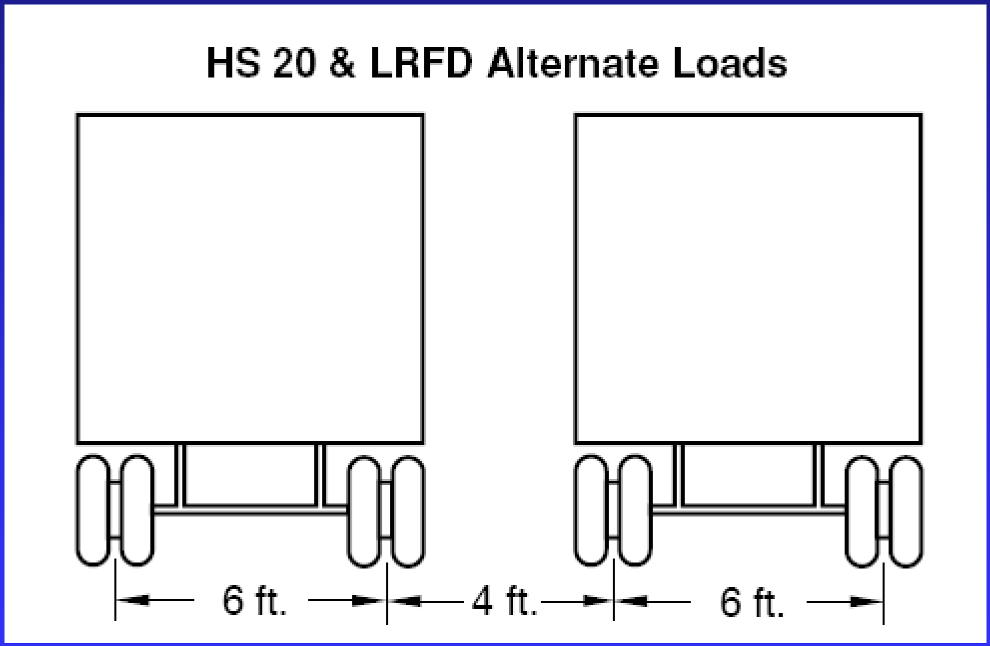
# Live Load Spread



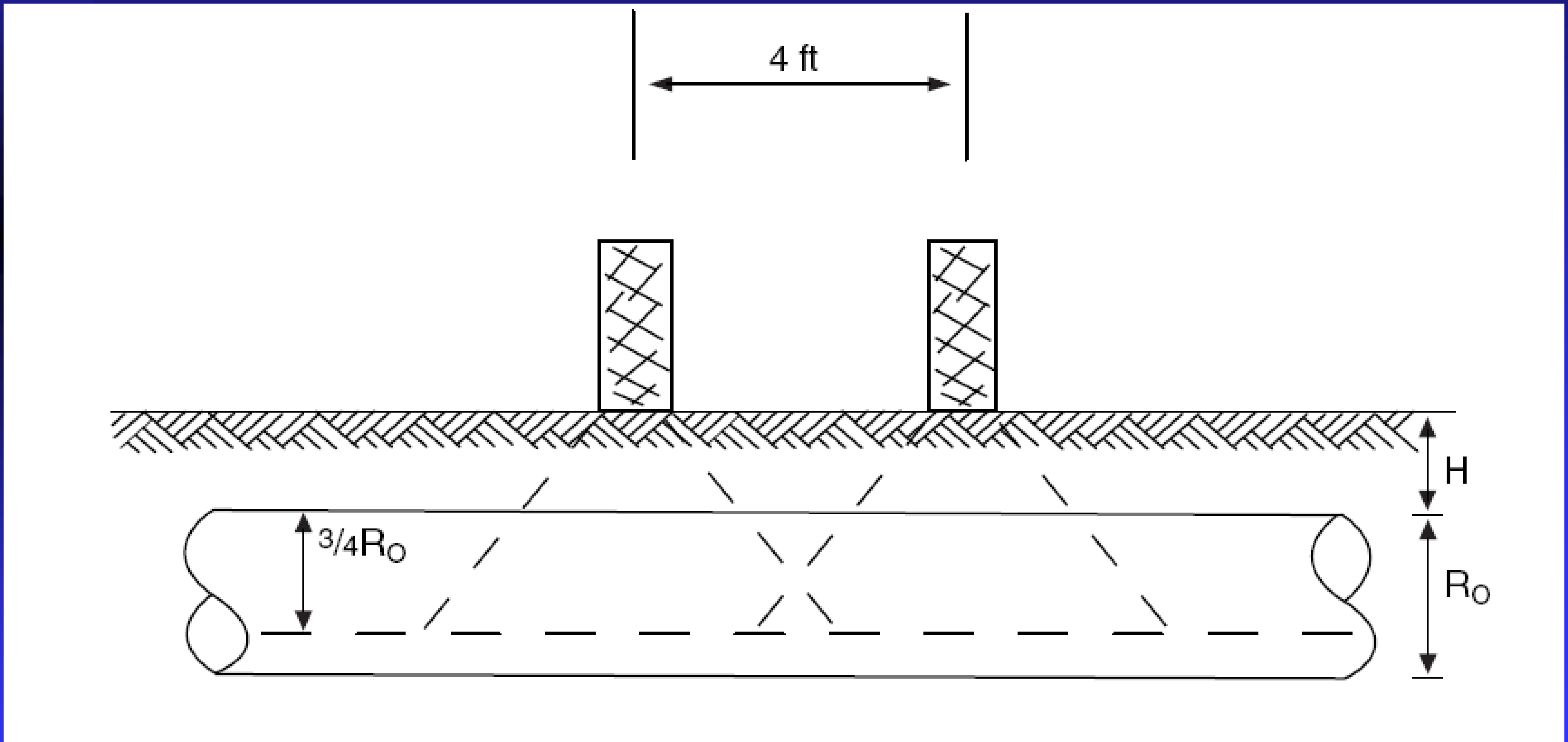
# Dynamic Load Allowance

- LRFD – Dynamic Load Allowance (3.6.2.2)
  - $DLA = 0.33(1.0 - 0.125D_E)$
- Standard – Impact Factor (3.8.2.3)
  - IM = 0.3 – 0'-0" to 1'-0" INCL.
  - IM = 0.2 – 1'-1" to 2'-0" INCL.
  - IM = 0.1 – 2'-1" to 2'-11" INCL.

# Two Trucks Passing



# Live Load Distribution through Pipe and Soil



# Multiple Presence Factor

| | Design Code | | |
|---|---|---|---|
| Lanes | AASHTO STD | AASHTO LRFD | CHBDC |
| 1 | 1.0 | 1.2 | 1.0 |
| 2 | 1.0 | 1.0 | 0.90 |
| 3 | 0.90 | 0.85 | 0.80 |
| 4 | 0.75 | 0.65 | 0.70 |

# Load Factor or Presence Factor?

- Standard Specification
  - Load Factor is 1.3 x 1.67 = 2.17
  - Ultimate Load One Lane =$W_L$ x 2.17
  - Ultimate Load Two Lanes = $W_L$ x 2.17
- LRFD Specification
  - Load Factor is 1.75
  - Ultimate Load One Lane = $W_L$ x (1.2 x 1.75 = 2.1)
  - Ultimate Load Two Lanes = $W_L$ x 1.75

# Factors in Live Load Design

| One Lane Example | | | |
|---|---|---|---|
| AASHTO Spec. | Live Load (lbs/ft) | D-Load (indirect design) value (lbs/ft) | Ultimate Load (direct design) value (lbs/ft) |
| STD | 1,000 | 1,000 | 2,170 |
| LRFD | 1,000 | 1,200 | 2,100 |

| Two Lane Example | | | |
|---|---|---|---|
| AASHTO Spec. | Live Load (lbs/ft) | D-Load (indirect design) value (lbs/ft) | Ultimate Load (direct design) value (lbs/ft) |
| STD | 1,000 | 1,000 | 2,170 |
| LRFD | 1,000 | 1,000 | 1,750 |

# Affect of Multiple Presence Factor

- If live load from one lane controls, the LRFD design is more conservative for indirect design and crack control design.
- If two or more lanes control, the Standard Specifications have a more conservative ultimate load design (flexure, shear, and radial tension).

# NCHRP 647 – Recommended Design Specifications for Live Load Distribution to Buried Structures

- **Multiple presence.** For a single loaded lane, the LRFD Specification includes a 20% increase in service load to account for the likelihood of overloaded trucks. However, because of a reduced load factor in the LRFD code, the factored loads in the two codes are approximately the same. The code comparisons below are on the basis of service loads. To provide a common basis for comparison, loads computed using the Standard Specification are increased by 20%.

# NCHRP Report 647

Table 2-22. Comparison of proposed and current live loads on 8-ft-span box culvert.

| Depth* (ft) | Proposed (lb/ft) | Current | | Ratios | |
|---|---|---|---|---|---|
| | | LRFD (lb/ft) | Modified Stnd** (lb/ft) | Proposed /LRFD | Proposed / Modified Stnd |
| 1 | 5523 | 5523 | 5523 | 1.00 | 1.00 |
| 1.001 | 5523 | 5523 | 5523 | 1.00 | 1.00 |
| 1.999 | 5347 | 5347 | 5347 | 1.00 | 1.00 |
| 2 | 5387 | 6038 | 6844 | 0.89 | 0.79 |
| 2.001 | 5385 | 6036 | 6840 | 0.89 | 0.79 |
| 2.999 | 4139 | 4528 | 4012 | 0.91 | 1.03 |
| 3 | 4138 | 4526 | 4412 | 0.91 | 0.94 |
| 4 | 3510 | 3647 | 3442 | 0.96 | 1.02 |
| 5 | 3105 | 3216 | 2675 | 0.97 | 1.16 |
| 6 | 2763 | 2854 | 1920 | 0.97 | 1.44 |
| 7 | 2223 | 2291 | 1431 | 0.97 | 1.55 |
| 8 | 1765 | 1815 | 1097 | 0.97 | 1.61 |
| 9 | 1485 | 1525 | 949 | 0.97 | 1.56 |
| 10 | 1268 | 1300 | 830 | 0.98 | 1.53 |
| 11 | 1096 | 1121 | 732 | 0.98 | 1.50 |
| 12 | 978 | 1000 | 650 | 0.98 | 1.50 |

*Incremental depths included to show steps in load due to stepwise function for Standard Specification impact

**Modified to negate differences in multiple presence and impact (= actual Standard * 1.2* (LRFD impact/Standard impact)

# Phi Factors

- Strength Reduction Factors
  - $\phi_f = 1.0$
  - $\phi_v = 0.9$
  - LRFD – 12.5.5-1
  - Standard – 16.7.4.6

# "Basis of LRFD Methodology"

- $\Sigma \eta_i \gamma_i Q_i \leq \phi R_n$
  - $\gamma_i$ = a statistically based load factor
  - $\phi$ = a statistically based resistance factor
  - $Q_i$ = force effect
  - $R_n$ = nominal resistance
  - $\eta_i$ = load modifier relating to ductility, redundancy, and operational importance

# Load Modifier - Culverts

- LRFD 12.5.4
  - "Load modifiers shall be applied to buried structures and tunnel liners as specified in Article 1.3, except that the load modifiers for construction loads shall be taken as 1.0"

# Load Modifiers

- LRFD C 1.3.2.1
  - “Ductility, redundancy, and operational importance are significant aspects affecting the margin of safety of bridges.”

# Load Modifiers (LRFD) For Culverts

- Standard = N/A
- LRFD (1.3.2)
  - Ductility = $\eta_D$ = 1.0
  - Redundancy = $\eta_R$ = 1.05 or 1.0
  - Importance = $\eta_I$ = 1.0 or 1.05

# Load Modifier Culverts

- LRFD 1.3.3 – Ductility
  - "The structural system of a bridge shall be proportioned and detailed to ensure the development of significant and visible inelastic deformations at the strength and extreme event limit states before failure."

# Load Modifier - Culverts

- LRFD 12.5.4 - Redundancy
  - "For strength limit states, buried structures shall be considered nonredundant (1.05) under earth fill and redundant (1.0) under live load and dynamic load allowance."

# Load Modifier - Culverts

- LRFD 12.5.4 - Importance
  - "Operational importance shall be determined on the basis of continued function and/or safety of the roadway."

# The End

This presentation can be downloaded at:

http://xfer.concrete-pipe.org/

Password:
"LRFD"