HS20-44 vs HL-93

(Standard Specifications vs LRFD Code)

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KEARNEY,NEBRASKA
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Topics to cover:

- **Topic 1: Comparison of ASD, LFD and LRFD**
- **Topic 2: LRFD Objective and calibration**
- **Topic 3: Comparison of HS20-44 VS HL-93**
- **Topic 4: FHWA SHV's new memo**
- **Topic 5: Husbandry Vehicles and NE Legal Loads**
- **Conclusion and things to consider**

Topic 1

Comparison of ASD, LFD and LRFD

Golden Rule of Engineering

- A. Load > Resistance
- B. Load = Resistance
- C. Load < Resistance

Designs must be safe, therefore?

Uncertainty

- Material dimensions and location
- Material strength
- Failure mode and prediction method
- Long term material performance
- Material weights
- Prediction of potential Live loads
- Load analysis and distribution methods
- General uncertainty associated with structural function

Allowable Stress Design (aka Working Stress Design)

FS: Factor of Safety.
Ru: RESISTANCE

$$\Sigma DL + \Sigma LL \leq Ru / FS$$

Allowable Stress Design

- **Advantages**
- Simplistic

- **Limitations**
- Inadequate account of variability
- Stress not a good measure of resistance
- Factor of Safety is subjective
- No risk assessment based on reliability theory

Load Factor Design (aka Strength Design)

LFD

- γ : **Coefficients Load Factor**
- φ : **Resistance Factor**
- **ΣβDL, ΣβLL :Loads combinations Coefficients**

$$\gamma(\Sigma\beta DL \times DL + \Sigma\beta LL \times LL) \leq \varphi Ru$$

EX: 1.3 (1.0 x DL+ 1.67x LL)

1.3DL + 2.17LL

Load Factor Design

- **Advantages**
- Load factor applied to each load combination
- Types of loads have different levels of uncertainty

- **Limitations**
- More complex than ASD
- No risk assessment based on reliability theory

Load and Resistance Factor Design
(aka Reliability Based Design or Limit State Design)

LRFD

- η : Factor
- φ : resistance Factor
- γDL, γLL : Load Factor
- **η =ηD ηR ηI ≈ 0.95 to 1.050**

$$\eta(\Sigma\gamma DL\ (DL)+\Sigma\gamma LL\ (LL)\ ) \leq \varphi Ru$$

EX: $\eta\ (1.25DL + 1.75LL)$

1.25DL + 1.75LL

Load and Resistance Factor Design

- **Advantages**
- Accounts for variability
- Uniform levels of safety
- Risk assessment based on reliability theory

- **Limitations**
- Requires availability of statistical data
- Resistance factors vary
- Old habits

Topic Wrap Up

1. State the difference between ASD, LFD and LRFD

The three design methods are distinguished by how uncertainty is accounted for.

Topic 2

Fundamentals of LRFD

Objective and calibration

Objective of LRFD

Develop a comprehensive and consistent Load and Resistance Factor Design (LRFD) specification that is calibrated to obtain uniform reliability (a measure of safety) at the strength limit state for all materials.

CALIBRATION

Selection of a set of γ's and φ's to approximate a target level of reliability in an LRFD-format specification.

AASHTO chose this reliability to be 3.5 @ inventory level
And 2.5 @ operating level

Calibration continued

Only the strength limit states of the *LRFD Specifications* are calibrated based upon the theory of structural reliability, wherein statistical load and resistance data are required. The other limit states are based upon the design criteria of the *Standard Specifications*.

Calibration for service limit state is done and implementation is underway.

Calibration cont.

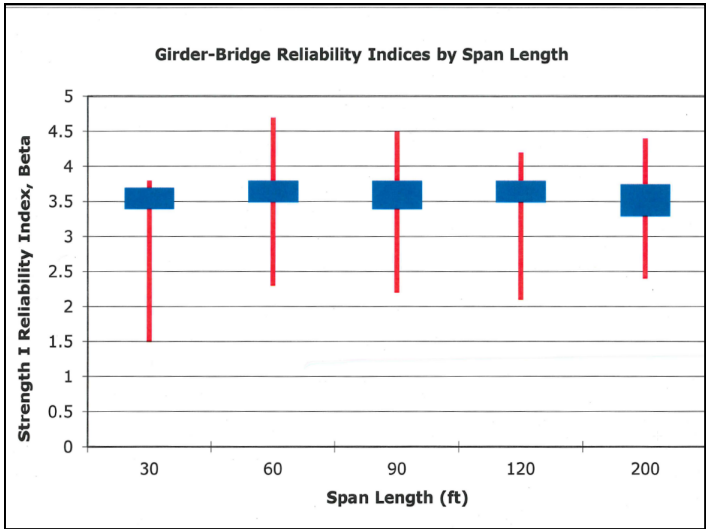
- Calibration consists of up to three steps:

1. Reliability-based calibration,
2. Calibration or comparison to past practice, and,
3. Liberal doses of engineering judgment.

CONCLUSIONS

The reliability-based LRFD design methodology is not perfect, but it represents an improvement over the ASD and LFD methodologies.

LRFD utilizes structural reliability to help us select improved load and resistance factors, and it provides a framework for future improvement.



limit-state load combination	strength I		service III	service II
component type	steel & concrete I-girders	longer steel trusses, concrete boxes & steel tubs	prestressed concrete components	compact steel sections
increased live load	✓	✓	✓	✓
Reduced live-load load factor	✓ (1.75/2.17)	✓ (1.75/2.17)	✓ (0.8/1.0)	✓ (1.3/1.67)
improved distribution	✓	✗	✓	✓
increased force effect=more safety or reliability	✗	✓	✗	✗

CONCLUSIONS (continued)

Most of the features which designers dislike about the LRFD Specifications have little, if anything, to do with the LRFD design methodology.

FHWA MEMO

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
Director of Bridge Technology

Live Loads

All new bridge projects will meet the requirements of AASHTO LRFD Bridge Design Specifications HL93 for live load. Live load distribution factors will be as specified by AASHTO LRFD Bridge Design Specifications.

For all bridges on the State highway system, the load factor for vehicular live load (LL) and vehicular dynamic load allowance (IM) for Strength I in Table 3.4.1-1, Load Combinations and Load Factors, of the AASHTO LRFD Bridge Design Specifications shall be increased from 1.75 to 2.0.

Existing Superstructures

When the entire superstructure is being replaced, the new superstructure will be designed for HL93 using AASHTO LRFD Bridge Design Specifications.

The following procedures will apply to widening projects.

A. WIDEN ONLY – The widening portion shall be designed to match the existing superstructure capacity.

B. WIDEN AND REDECK
   1. If the inventory rating of the existing superstructure is above HS20, design the widened superstructure to match the existing superstructure.
   2. If the inventory rating of the existing superstructure is less than HS20, investigate the feasibility of strengthening the existing superstructure to a minimum of:
      a. HS20 for bridges on the Interstate, Expressway, or Commercial Priority systems.
      b. HS15 for all other bridges.
   3. If strengthening is feasible, the widening shall be designed to match the maximum attainable capacity of the existing superstructure. If the existing superstructure cannot be strengthened to the above requirements, the superstructure must be replaced.

If it has been determined to widen a bridge that has an inventory rating less than HS20, a Justification Sheet shall be attached to the Bridge Design Data Sheet.

Existing Substructures

For all bridges that are to be widened or remodeled, the Designer will evaluate each bridge substructure to insure that it is capable of supporting the design load required in the superstructure. The substructure must be capable (by strengthening if necessary) of supporting the following design live loads:

a. HL-93 for existing substructures supporting new superstructures designed for HL-93 loading. If existing substructures cannot be strengthened to meet the HL-93 loading but yet meets the following requirements, a design exception to the "Nebraska Minimum Design Standards" needs to be obtained in order to use the existing substructures.

b. HS20 for bridges on the Interstate, Expressway or Commercial Priority systems.

c. HS15 for all other bridges.

Topic 3
H/HS20 TRUCKS USED IN STANDARD SPECS.

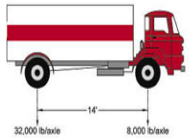


FIGURE 1 H20 TRUCK

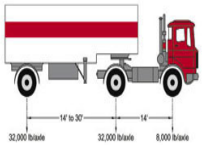


FIGURE 2: HS20 TRUCK

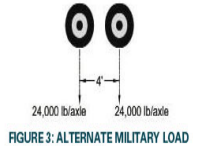
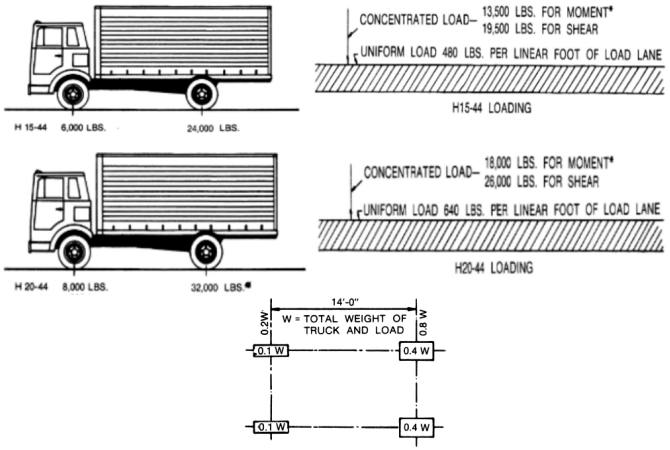
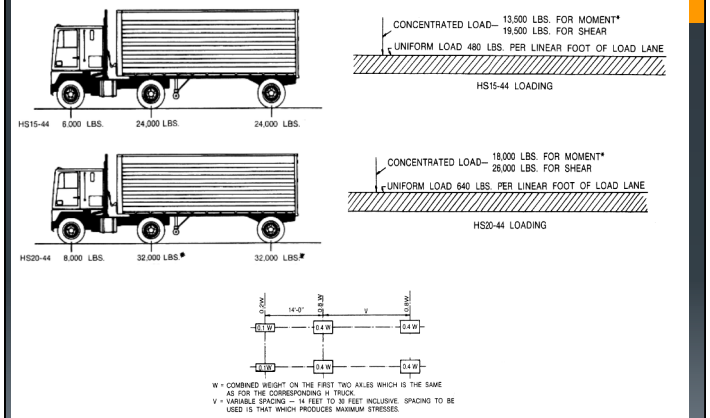


FIGURE 3: ALTERNATE MILITARY LOAD (INTERSTATE LOAD)

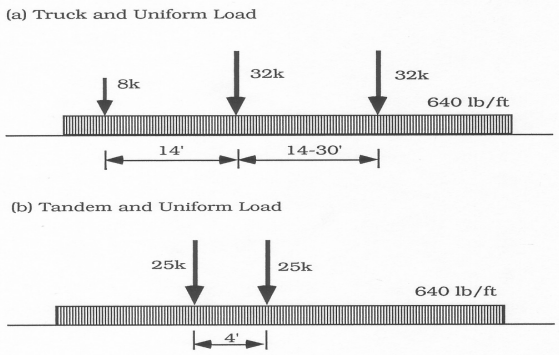
H TRUCK AND LANE LOADING



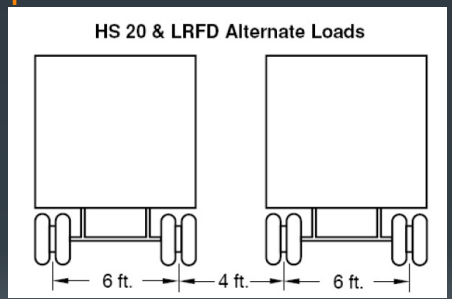
HS TRUCK AND LANE LOADING



Tandem and Lane Load LRFD– HL-93 Loading



Multiple Lanes



4.6.2.10.2—Case 1: Traffic Travels Parallel to Span

When traffic travels primarily parallel to the span, culverts shall be analyzed for a single loaded lane with the single lane multiple presence factor.

Multiple Presence Factor

	Design Code	
Lanes	AASHTO STD	AASHTO LRFD
1	1.0	1.2
2	1.0	1.0
3	0.90	0.85
4	0.75	0.65

EXEMPTION

- Culverts shall be design only to axle loads of a truck or Tandem (no lane loads)

1. The design truck x 1.2 factored force effect is equivalent to the old Standard Spec. HS-20
2. The tandem x 1.2 factored force effect is equivalent to the old standard Spec. Military loads

LOADS REDUCTION FATORS

- FACTORS WERE DEVELOPED ON THE BASIS OF AN ADTT = 5000

BRIDGE OWNERS MAY REDUCE THE LOADS BY:

- IF 100 <=ADTT<= ,1000,REDUCE THE LOADS BY 5%
- IF ADTT < 100, REDUCE THE LOADS BY 10%
- THE REDUCTUON IS BASED ON THE REDUCED PROBABILITY OF ATTAINING THE DESIGN EVENTS DURING A 75-YEAR DESIGN LIFE WITH REDUCED TRUCK VOLUME.

SYSTEM PRESERVATION

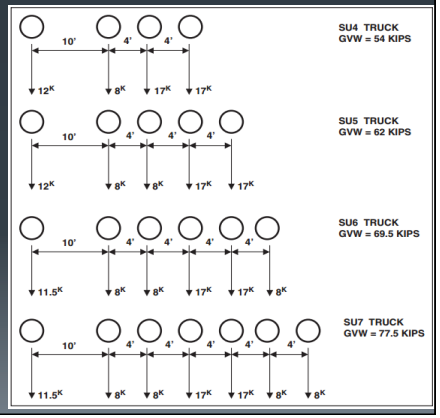
Standard Specifications' 50 to 60-year design life

V.

LRFD Specifications' 75-year design life

Topic 4 : FHWA Single Unit Posting Vehicle

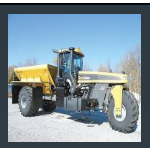
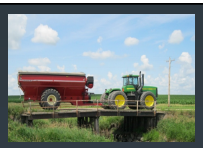
- SHV or Specialized Hauling Vehicles are Legal Loads In NE



Triple axle configurations of single unit vehicles (legal loads in Nebraska) have been observed to have load effects greater than HL-93 tandem axle load.

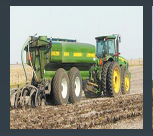
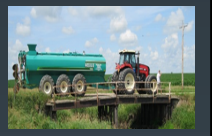
Pooled Fund Study of the Impacts of Implements of Husbandry on Bridges

Topic 5

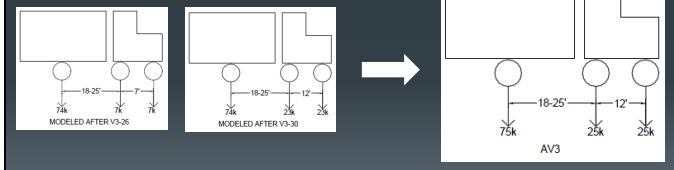
Vehicle and Bridge Data

- 121 Husbandry Vehicles
  - 2 Two Axle Vehicles
  - 37 Three Axle Vehicles
  - 46 Four Axle Vehicles
  - 29 Five Axle Vehicles
  - 7 Six Axle Vehicles
- 174 Bridges
  - 32 County steel girder-concrete deck
  - 43 State steel girder-concrete deck
  - 52 Country timber girder-timber deck
  - 47 County steel girder-timber deck

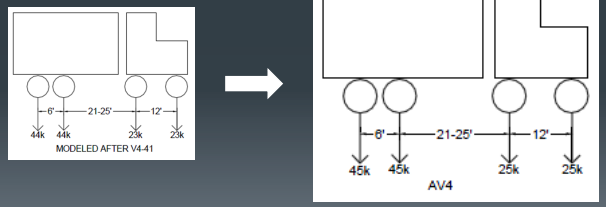

Generic Vehicles

- Generic three axle vehicles



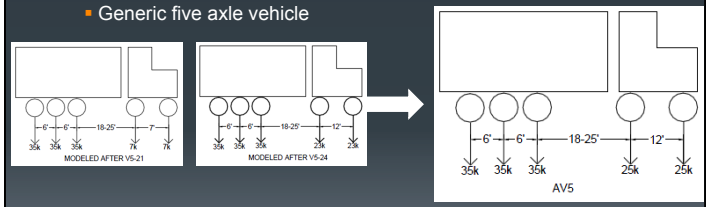
Generic Vehicles *Cont'd*

- Generic four axle vehicle



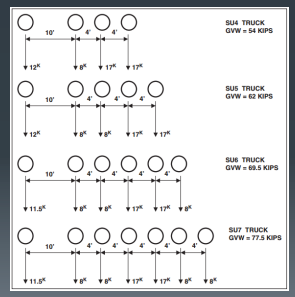
Generic Vehicles *Cont'd*

- Generic five axle vehicle



Comparison of Generic Vehicles and current AASHTO specifications

- Included in comparison
  - HS20
  - HL93
  - SHV
    - Closely-spaced multi-axle single unit trucks



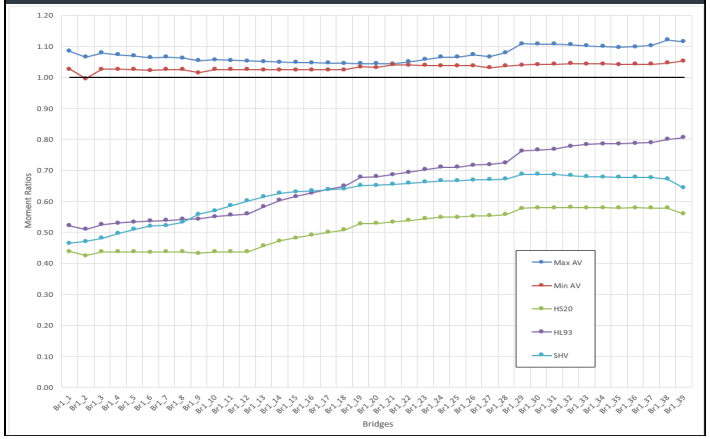
Comparison

- Comparison done by Moment Ratios at critical locations
  - John Kulicki study and development of HL93
- Example Moment Ratio Calculation

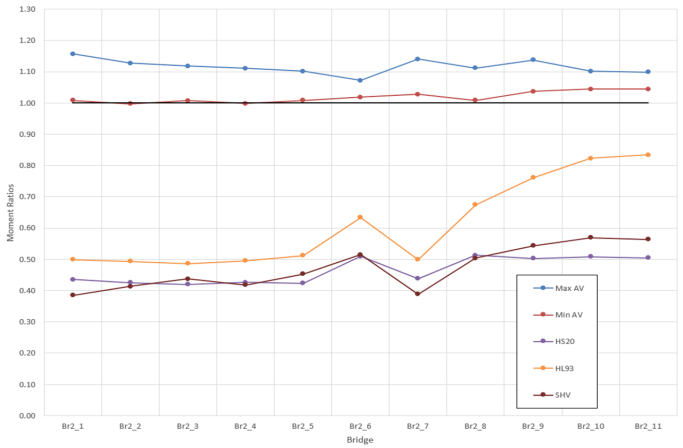
$$\text{Moment Ratio} = \frac{\text{Maximum moment value of AV3 vehicles at 0.4L}}{\text{Maximum moment value of the three axle husbandry vehicles at 0.4L}}$$

- Ideal Moment Ratio is greater than 1.0

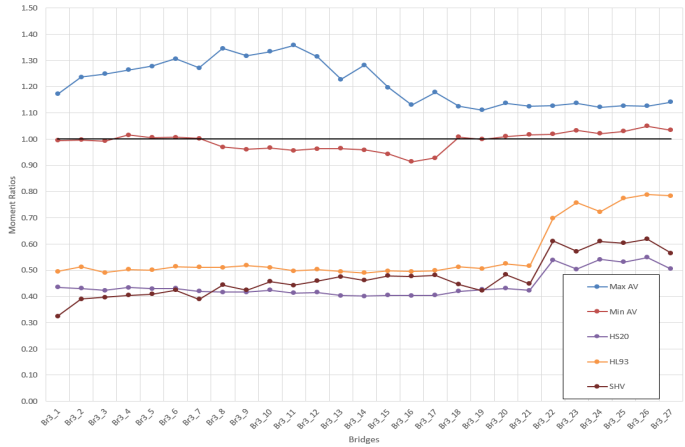
Single Span Moment Ratios

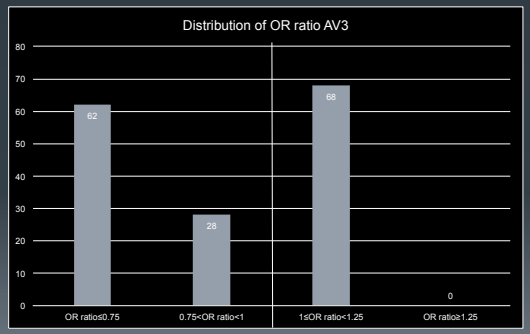


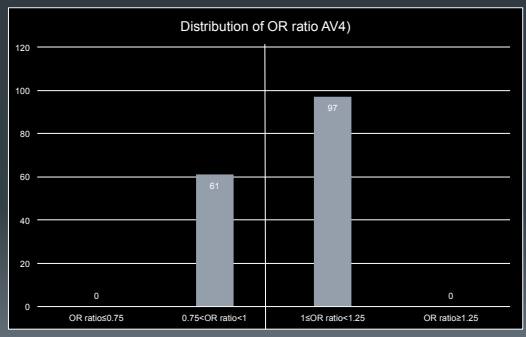
Two Span Moment Ratios

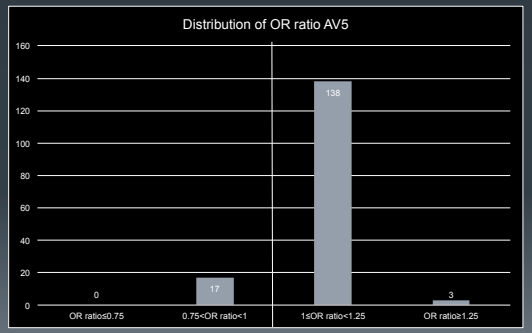


Three Span Moment Ratios









NEBRASKA's Legal Weight Limits

Wheeled grain cart, tank wagons, and fence-line feeder

- Single axle – 20,000 pounds maximum
- Gross weight – 20,000 pounds multiplied by the number of axles
- Maximum gross weight – up to 80,000 pounds on Interstate and Defense highway
- 15% load increase during harvest season and..
- 25% increase for sugar beets will be allowed

- The weight of the farm tractor towing the implement is not included in the gross weight limit
- Taken from Nebraska DOR Truck Information Guide and Nebraska Law

WHAT YOU NEED TO CONSIDER

Using HS20-44 Loading

- Difficult to be used without the Standard spec's.
- Standard Specs was ceased to be updated by AASHTO more than 10 years ago
- Can't be used with New LRFD specs without additional calibration. We can't mix codes.
- New and young designers don't even know what LFD ,ASD and HS20-44 are. They don't teach it in college anymore..
- Moving forward
- Net Load effect difference between HL-93 and HS20-44 loading is very small. Reliability has improved

- Trucks are getting heavier and heavier
- We are designing for 75 years service life

QUESTIONS???