**HS20-44 vs HL-93**
*(Standard Specifications vs LRFD Code)*

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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**

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**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
- Material weights
- Failure mode and prediction method
- Long term material performance
- Load analysis and distribution methods
- General uncertainty associated with structural function

Allowable Stress Design (aka Working Stress Design)

FS: Factor of Safety.
Ru: RESISTANCE

\[ \Sigma DL + \Sigma LL \leq \frac{Ru}{FS} \]

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

\[ \gamma(\Sigma DL x DL + \Sigma LL x LL) \leq \phi Ru \]

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
  - Risk assessment not based on reliability theory

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

- $\eta$: Factor
- $\phi$: resistance Factor
- $\gamma_{DL}$, $\gamma_{LL}$: Load Factor
- $\eta = 0.95$ to 1.050

$$\eta \left[ \sum \gamma_{DL} (DL) + \sum \gamma_{LL} (LL) \right] \leq \phi \cdot Ru$$

$Ru$: $1,25DL + 1,75LL$

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.
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 $\gamma$'s and $\phi$'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.
CONCLUSIONS (continued)

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

Tandem and Lane Load
LRFD– HL-93 Loading

(a) Truck and Uniform Load

(b) Tandem and Uniform Load

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.
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 FACTORS

- 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 reduction 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-lumber deck
  - 47 County steel girder-lumber 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

Distribution of OR ratio AV3

Distribution of OR ratio AV4
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???