# Load Rating and Lateral-Torsional Buckling (LTB) in Simply Supported Steel Bridges

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# Presentation Outline

- Load Rating Overview
- Problem Statement (“The Good, The Bad, and The Ugly”)
- What is LTB?
- Research
- LTB Procedure
- Results
- ODOT-OSU Research Project

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# ODOT Load Rating Overview

- What is a Load Rating?
  - Analysis of bridge in current condition
    - Based on latest inspection info
    - Modifications for condition, redundancy, material, ADTT, etc.
  - Rating Factors
    - ≥ 1.00 = Good
    - < 1.00 = Bad
  - Results
    - Posting/restriction
    - Strengthening
    - Replacement

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| LOAD: | R.F. |
|---|---|
| **DESIGN & LEGAL VEHICLES** | |
| HL93 (INVENTORY) | 0.27 |
| TYPE 3 (50K) | **0.83** |
| TYPE 3S2 (80K) | **0.66** |
| TYPE 3-3 (80K) | **0.66** |
| TYPE 3-3 & LEGAL LANE | |
| TYPE 3-3 TRAIN & LEGAL LANE | **0.67** |
| SU4 TRUCK (54K) | **0.70** |
| SU5 TRUCK (62K) | **0.67** |
| SU6 TRUCK (69.5K) | **0.60** |
| SU7 TRUCK (77.5K) | **0.57** |
| EV2 TRUCK (57.5K) | **0.73** |
| EV3 TRUCK (86K) | **0.47** |
| **CTP VEHICLE, MULTI-LANE** | |
| OR-CTP-2A (105.5K) | **0.68** |
| OR-CTP-2B (105.5K) | **0.71** |
| OR-CTP-3 (98K) | **0.62** |
| **STP VEHICLE, MULTI-LANE** | |
| OR-STP-3(120.5K) | **0.65** |
| OR-STP-4A (99K) | **0.62** |
| OR-STP-4B (185K) | **0.56** |
| OR-STP-4C (150.5K) | **0.59** |
| OR-STP-4D (162.5K) | **0.51** |
| OR-STP-4E (258K) | **0.48** |
| OR-STP-5BW (204K) | **0.49** |
| SPECIAL | |

# ODOT Load Rating Overview

- Original Load Ratings (early 1990's)
  - LFR (Tier-1)
  - AASHTO Standard Specs
  - 1989 Guide Specs
  - No LTB check for design or load rating

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# ODOT Load Rating Overview

- Updated Load Ratings (mid 2010's)
  - Switch to LRFR (Tier-2) method
    - AASHTO LRFD
    - AASHTO MBE
  - Re-rate for SHV's
  - Check for LTB required

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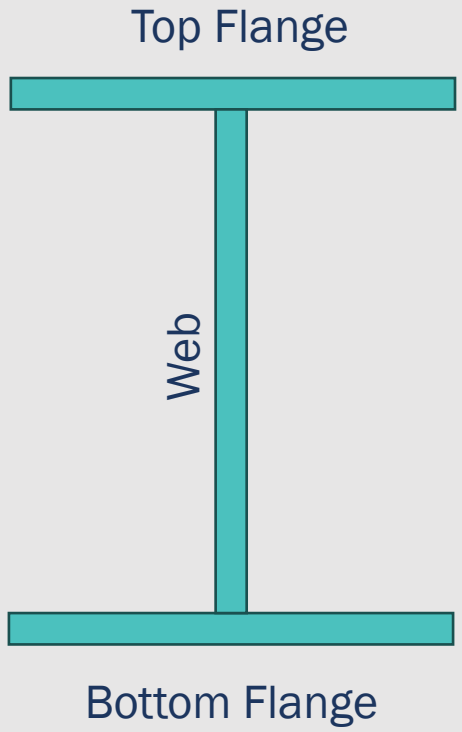
# Steel Bridge Population

- Rural (county roads)
- Short spans
- Rolled I-shapes
- Timber or corrugated steel decking
- Inadequate bracing
  - Deck
  - Cross frames or diaphragms

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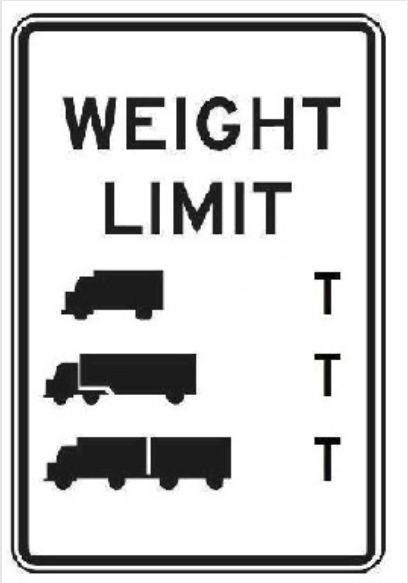
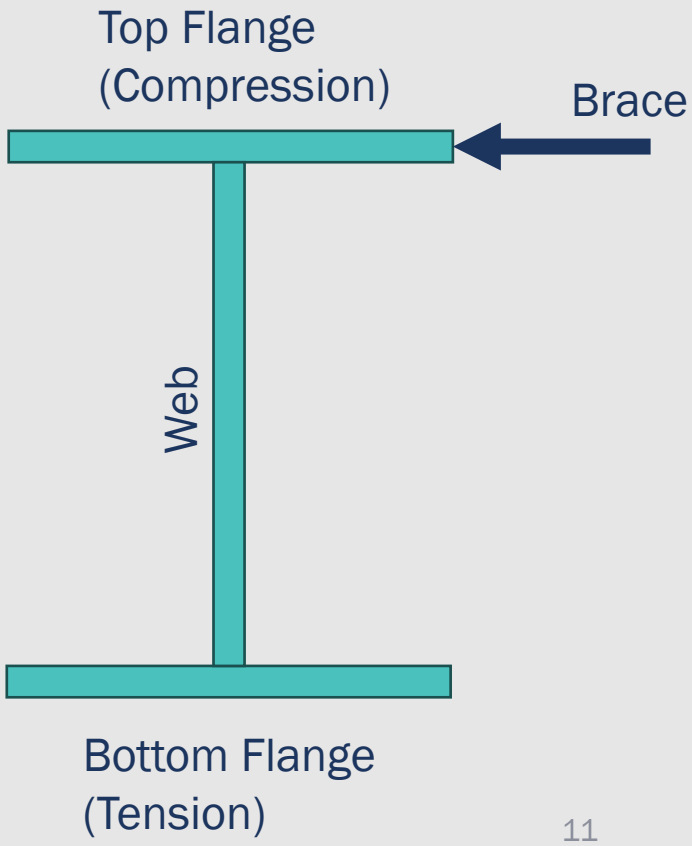
Lateral bracing
Cross bracing

# Problem Statement - “The Good”

- Adequate original load ratings
  - Yielding/buckling of top flange failure mode controls capacity
  - Minimal load postings if in good condition

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# Problem Statement - “The Bad”

- Inadequate updated load ratings
  - LTB controlled when bracing inadequate
  - SHV’s
- Field investigation
- More load postings


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# Problem Statement - “The Ugly”

- Confusion among bridge owners
  - Why?
  - 30 days to make and install posting signs
- Anger from truckers and industry
  - Costly detours
  - Strained relationships
- More work for everybody
  - ODOT: Detailed review, letters, outreach
  - Owners: Posting signs, outreach to stakeholders
  - Users: Detours, delays

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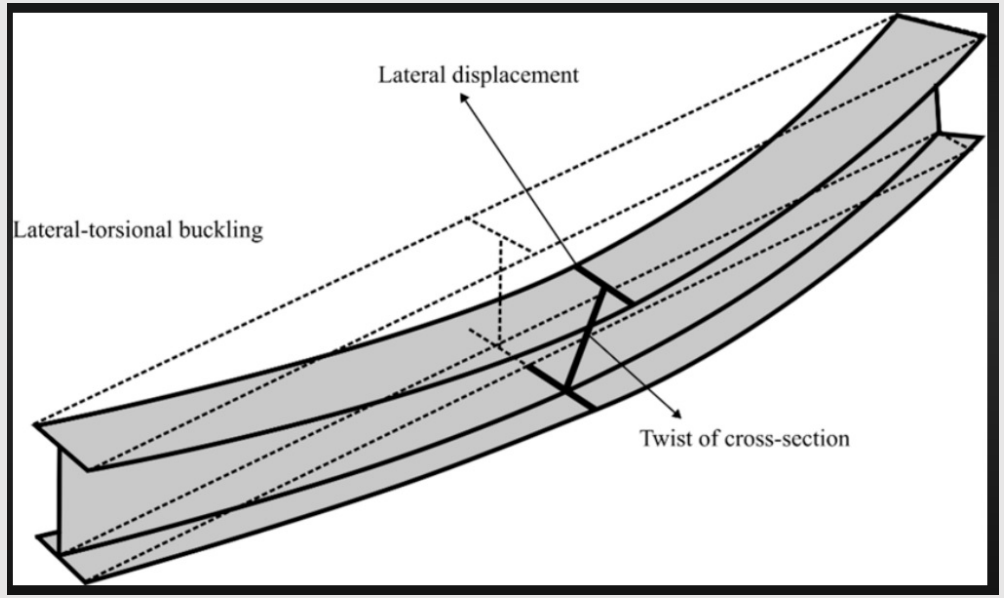
# What is Lateral-Torsional Buckling (LTB)?

- Load-induced out-of-plane twisting due to:
  - Diminished strength in weak axis (I-shapes)
  - Insufficient bracing to prevent lateral movement
- Tight-rope analogy
- First discovered in 1960's
- Not codified until early 1990's
  - Used for design only
  - Primarily concern for new girder erection

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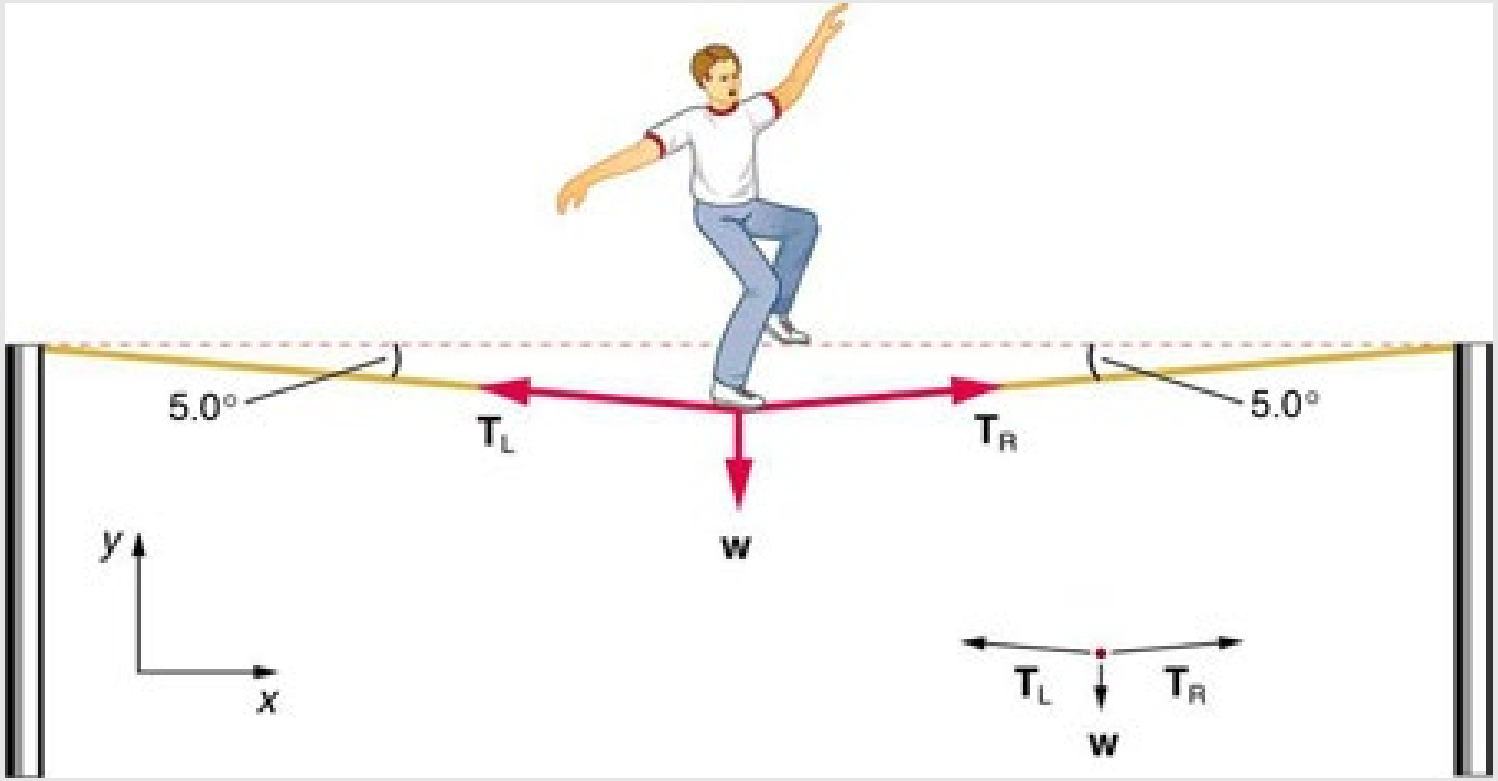
# LTB: Tight-rope Analogy



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# LTB: Single I-Shape Girder

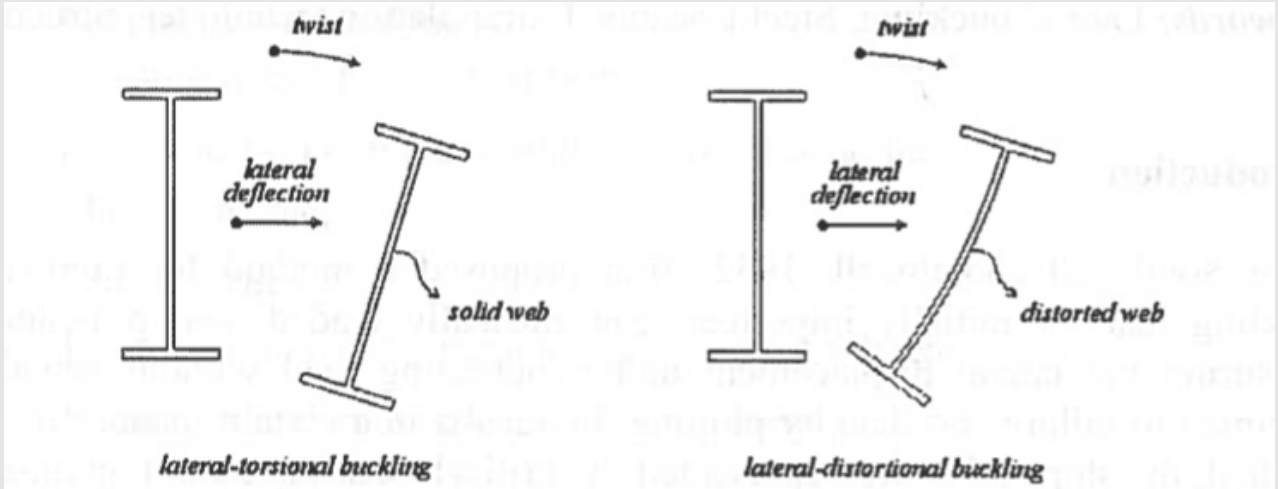
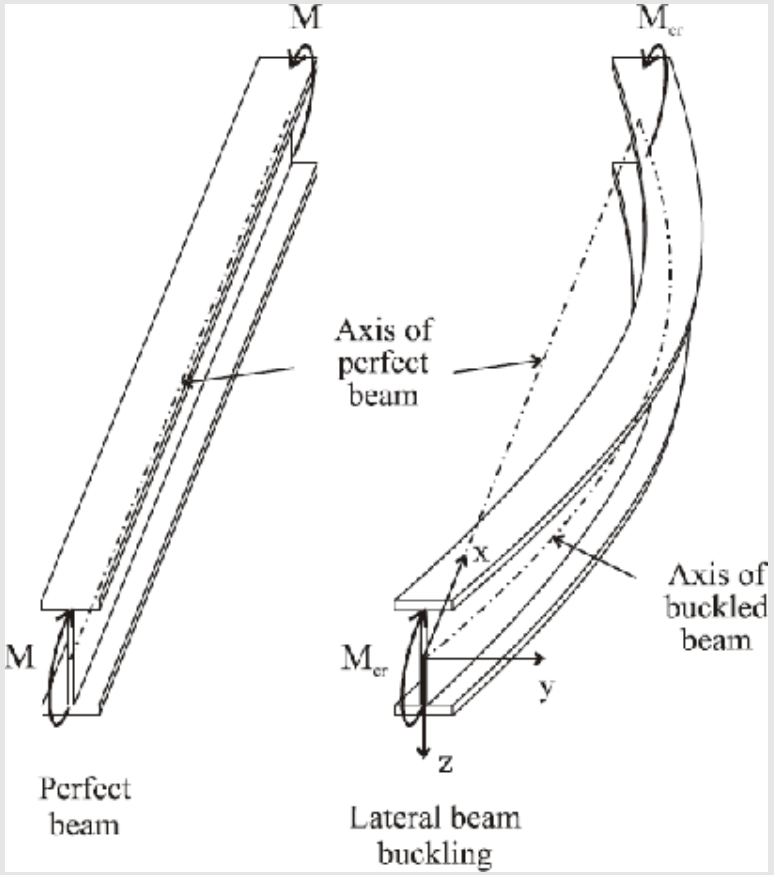



**Figure (1):** Lateral-torsional and lateral-distortional modes of buckling

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# Why is LTB a Problem?

- Design check
  - Bridges built pre-1990's
- Local Bridge Inventory
  - I-shape
  - Inadequate bracing

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# Sanity Check Time!

- Where are the LTB failures?
- How do you fail multiple girders at the same time?
- Is the deck acting as a girder top flange brace?
- How can we prove that this failure mode won't govern?

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# Research

- FHWA/TxDOT/UT
- Yura, Phillips, Raju, Webb (1992) – “Bracing of Steel Beams in Bridges”
- Webb, Yura (1991) – “Evaluation of Stiffness of Bridge Decks”
- Vegnesa, Yura (1991) – “An Ultimate Load Test to Study Bracing Effects of Bridge Decks”
- Yura, Phillips (1992) – “Bracing Requirements for Elastic Steel Beams”

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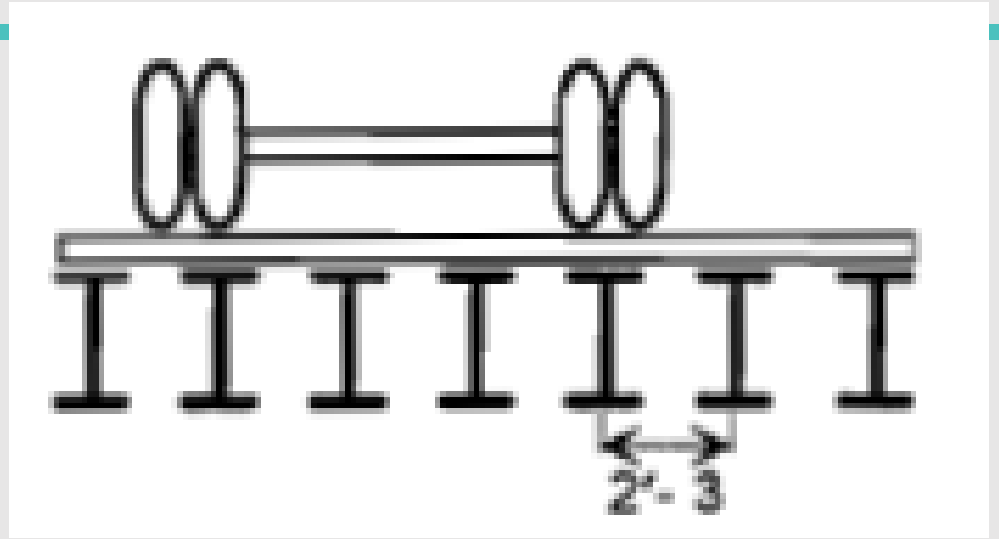
# Research Conclusions

- Decks can act as a lateral brace
  - Must pass stiffness requirement
  - Concrete = stiff
  - Timber = maybe?
  - Corrugated steel not evaluated
- Take sum of LTB capacities under truck limits
- Code checks for AASHTO

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# Gather Information

- Determine if LTB controls capacity
- Ensure DF's are not conservative
- Site visits to determine:
  - Bracing type and locations
  - Positive connection between deck and top flange
  - Measure/verify dimensions

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# ODOT's LTB Procedure

- Based on findings of TxDOT research
  - Assume timber/corr. steel not stiff
- Only concrete decks can be considered as brace
  - Add brace at mid-span or between existing braces
  - Re-run girder analysis
- Timber and corrugated steel decks with unknown stiffness
  - Consider LTB failure of multiple girders
  - Adjust distribution factors
  - Re-run girder analysis

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# ODOT's LTB Procedure Results

**Beneficial**

- For concrete decks
- Closely spaced girders
- LTB capacity is close to yield
- Some cross bracing
- ~20% of cases

**Not Beneficial**

- For timber/corr. steel decks
- Widely spaced girders
- LTB capacity is very low
- Little or no cross bracing
- ~80% of cases

# ODOT-OSU Research Project

- “New Methods for Improving Load Rating of Existing Steel Bridges for Torsional Buckling”
  - Oregon State University
    - Principal Investigator - Christopher Higgins, Ph.D., P.E.
  - Technical Advisory Committee:
    - 5 ODOT Engineers
    - 1 Consultant Engineer
    - 1 Local Agency Engineer
- Timeline: Fall 2023 – Fall 2026
- Budget: $360K

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# ODOT-OSU Research Project

- Objectives
  - Is LTB a legitimate failure mode?
    - If yes, explain to bridge owners why
  - Why aren't these bridges failing in LTB?
    - Perform analysis
    - Develop new rating methods
- Benefits
  - Determine accurate bridge load capacity
  - Reduce or eliminate unnecessary posting
  - ODOT's mission

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# ODOT-OSU Research Project

- Key Tasks:
  - TAC meetings
  - Literature review
  - Database of LTB bridges
  - Lab experiments
  - Field instrumentation and load testing
  - Compare results
  - Develop rating and retrofit guidance
  - Final report

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# Questions?

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