Managing the Option to use Refined Analysis in Bridge Design or Bridge Evaluation

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Objective: LL Analysis—Awareness of Options

- Background
  - AASHTO Highway Subcommittee on Bridges/Structures (HSCOBS) T5 Technical Committee for Loads/Load Distribution
  - FHWA/AASHTO scan of European practice
- Levels of analysis
- Caltrans' special study
- Considerations for Managers, Developers of 3D Bridge Analysis Software

Background

- From 1931-2002, "s-over" factors
- 1980's: NCHRP 12-26; 1994 LRFD 1st Ed.
- 2003: NCHRP 12-62; 2006-7 T5 Review
  - Bridge designers 5-yrs later were no longer complaining of complexity.
  - Step back in accuracy; recalibration reqd.
  - Software already available for more refined LL analysis

“Assuring Bridge Safety, Serviceability” (ABSS) International Scan, 2009

- Refined analysis in bridge design
- Refined analysis in bridge rating

Eurocode Background

- Genesis: Commission of European ('75) eliminate technical trade obstacles by "harmonizing technical specifications"
- Nat. Annex: alt. Procedures; values of "Nationally Determined Parameters"
- Load models (LM) calibrated for characteristic, frequent values
  - LM1—tandem + UDL on "unfavorable parts of *influence surface*, both directions"
  - LM2—single axle w/dynamic ampl.
  - LM3—special vehicles
  - LM4—crowd loading

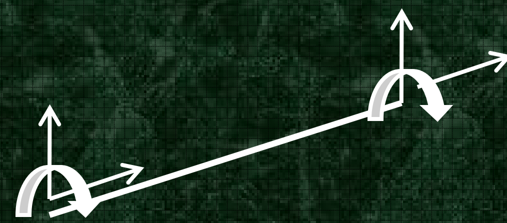
ABSS Scan Team Findings

- Grillage analysis typically used [UK, Finland, Austria, Germany, France]
  - Not that much more time consuming to create grillage vs. girder model
  - Engineer has better “feel” for structure
  - Quicker response to field changes
- Refined analysis used to improve funding decisions wrt rehab/replace
- Use of lower β_T on existing bridges

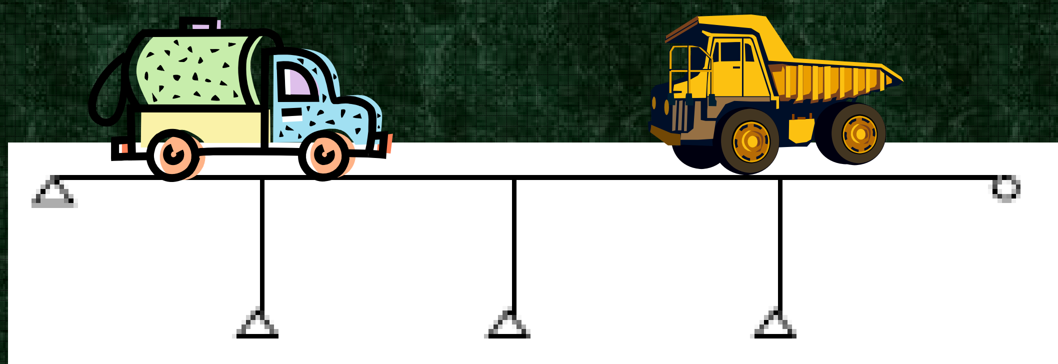
Implementation of Scan-Findings

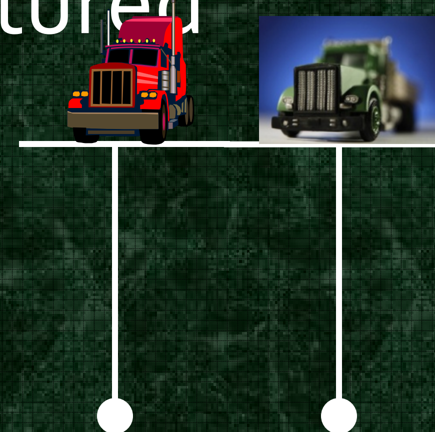
- Work w/AASHTO T5; distribute the report
- USA Survey on Refined Analysis
  - Used in rating, rehab decisions
  - States just getting in to it for design
  - Many different tools
- Training: Tried ½ day theory, ½ day program-specific; really need 3 days
  - Working with software vendors
  - Delivery starting with NC, WV (HOLD)

Level 1 Analysis

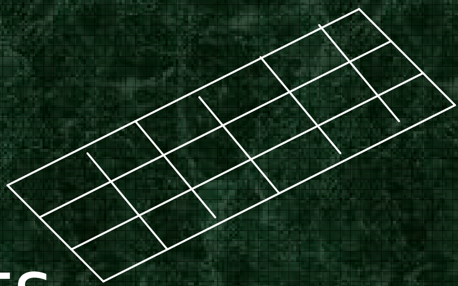


- Beams: 3 DOF at each node; LLdf's
- Single-spline longitudinal analysis
- Separate 2D bent analysis
- "Fanning" of load not captured

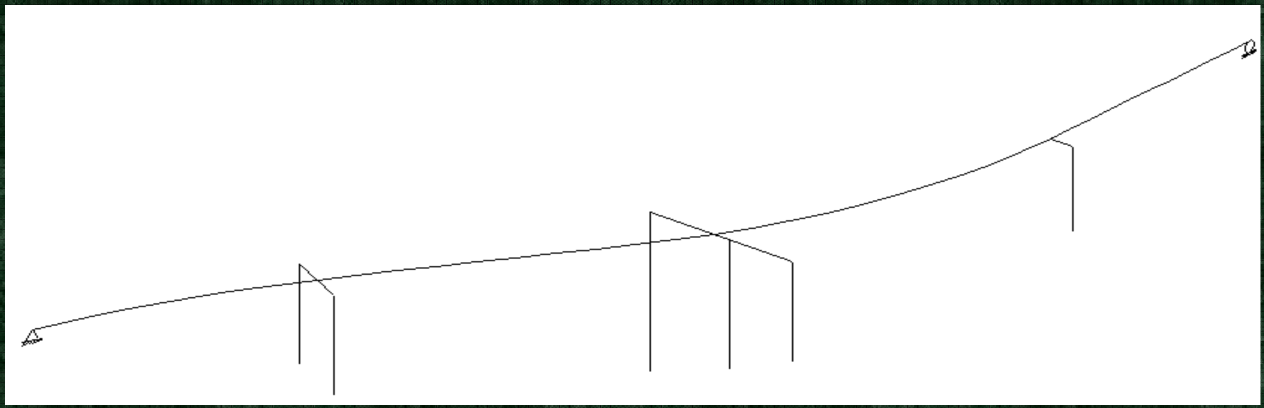




Level 2 Analysis

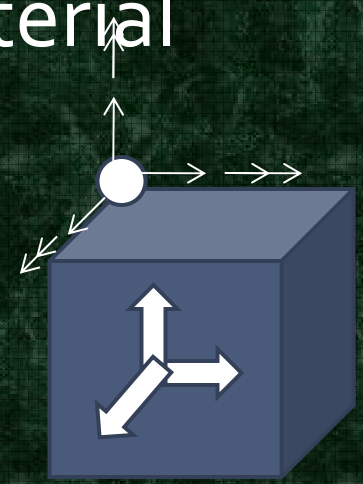


- 2D grillage of beam elements representing girders and deck
- 2.5D single-spline w/addition of substructure elements



Level 3 Analysis

- Beam elements AND shell elements for deck (6 DOF @ ea. node; stresses at midpoints along sides of elements)
- Level 3+: Further discretization of girders
- Level 3+: With time dependent material properties for construction staging



Caltrans Investigation

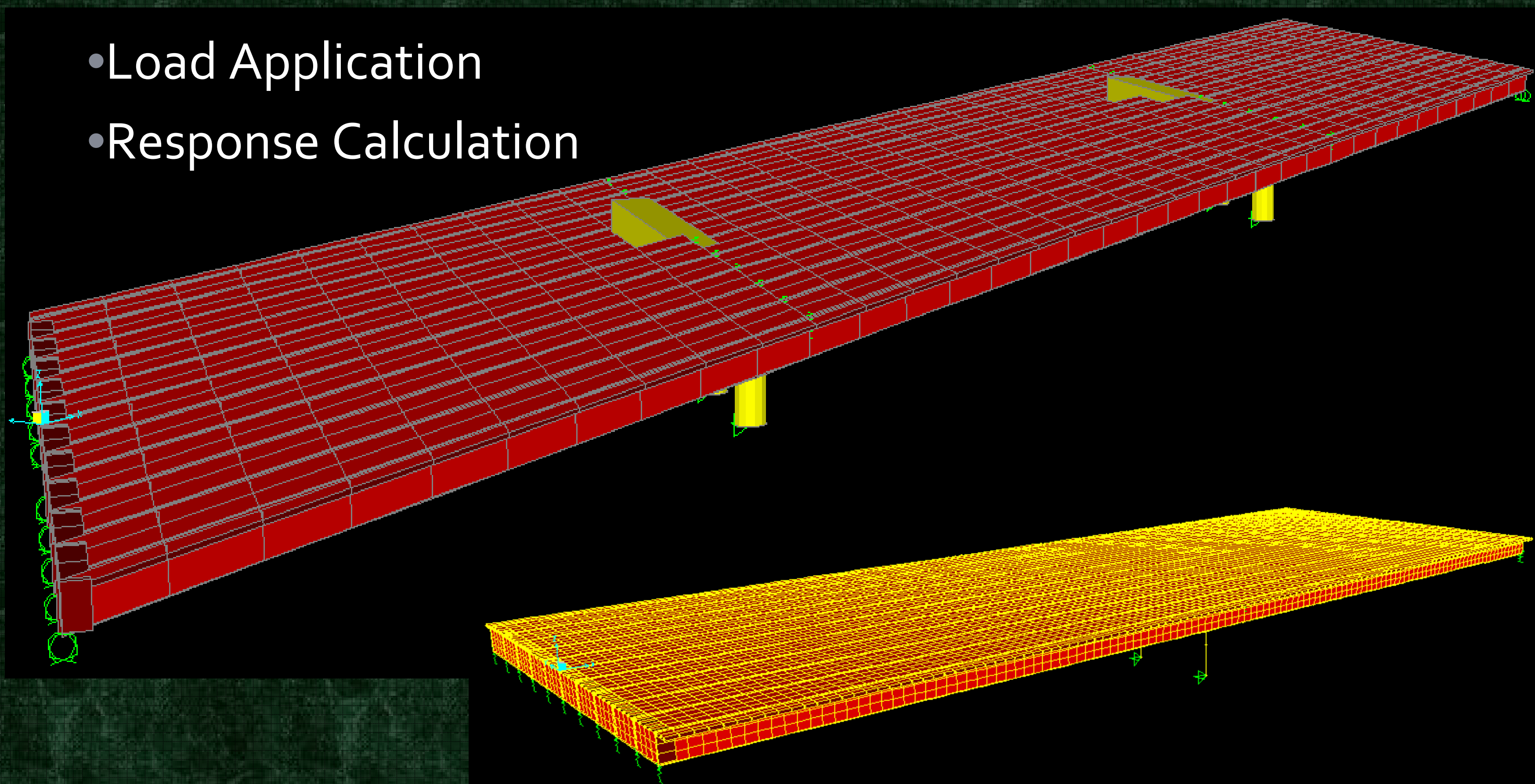
- CIP MC PT Concrete Box Girder w/HIGH force effects per 2.5D analysis

Structure Policy & Innovation
(Barton, Mike, Sue, Toorak)

Structure Design
(Tony, Tom, Marc and 200+)

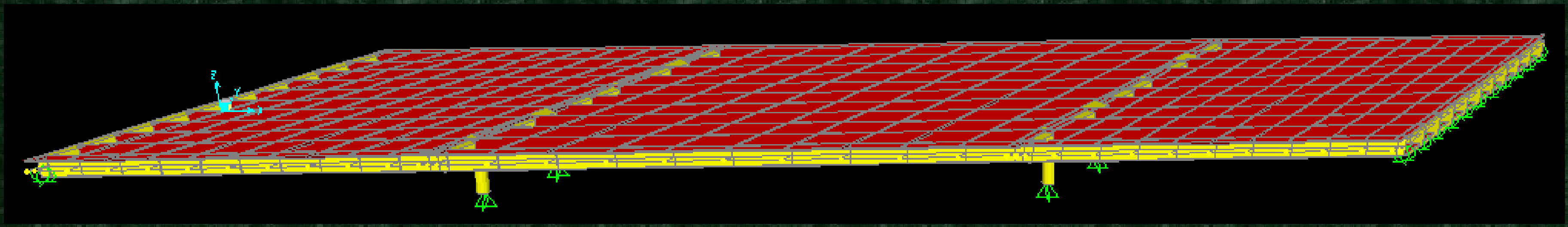
Caltrans Investigation, cont.

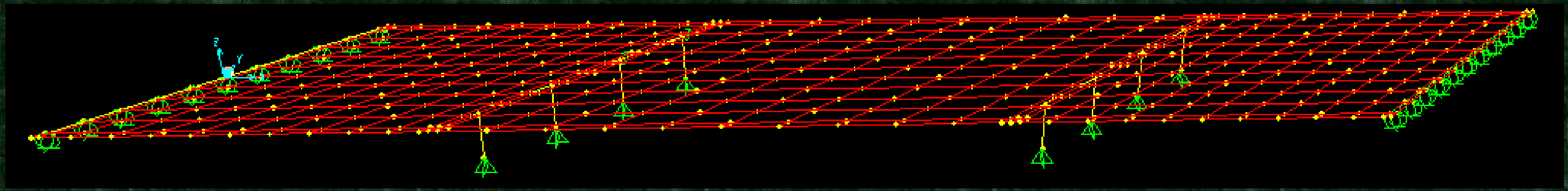
- Modeling Options: Full 3D Plate
  - Mesh Size
  - Load Application
  - Response Calculation



Caltrans Investigation, cont.

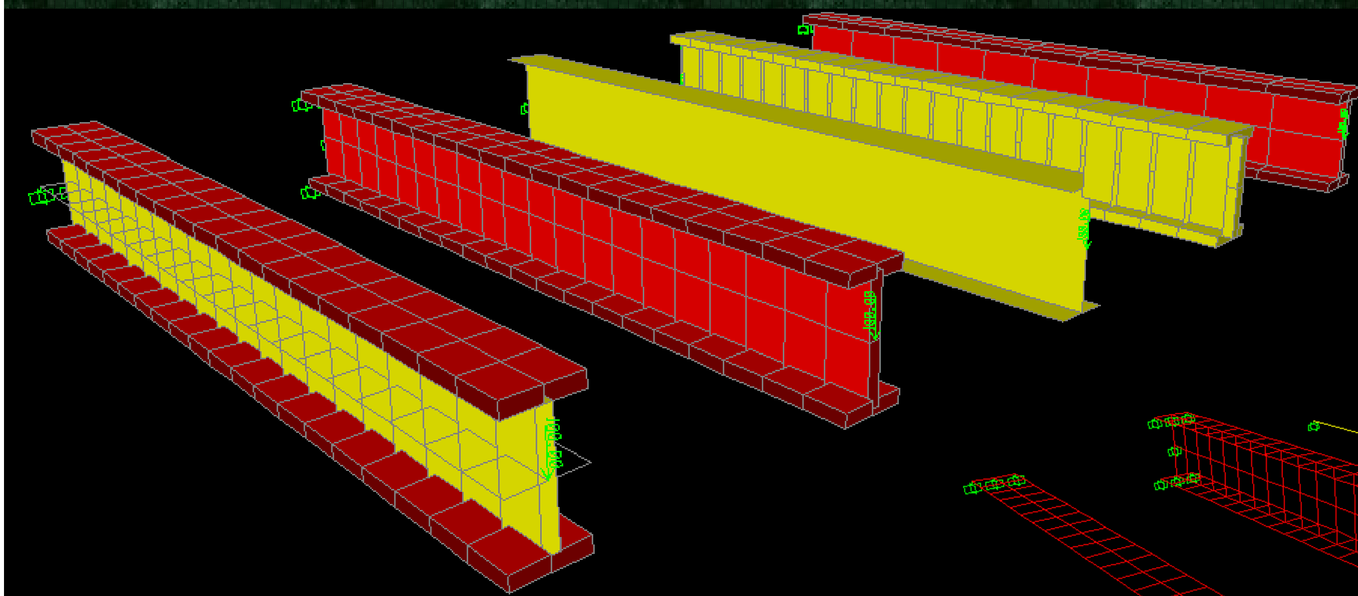
- Modeling Options: 3D Beam &Plate
    - Mesh Size
    - Load Application: Influence Surface
    - Response Calculation
    - Efficiency of Run Time

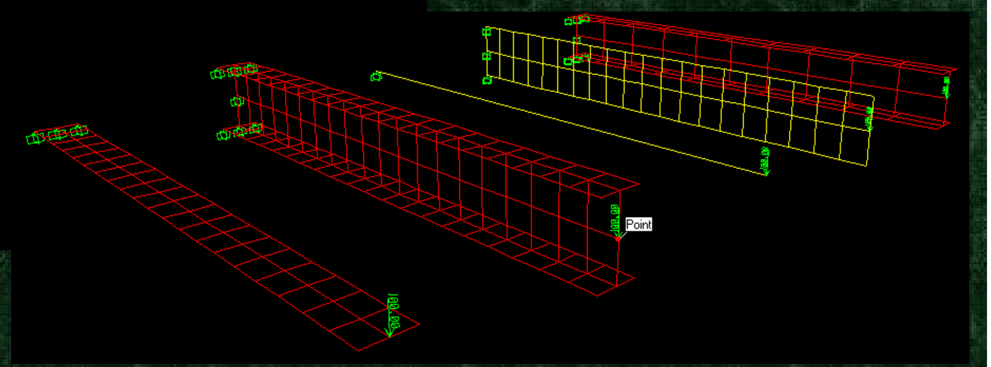




Caltrans Investigation, cont.

- Modeling Options: Verification with Cantilever Beam
  - Beam; Multi-element Beam
  - Plate: Course & Fine Mesh
  - Beam & Plate





Caltrans Investigation, cont.

- Modeling Options: Verification

Model Type	End Displacement	% Difference
Beam with Shear Deformation	1.2091 in	Base
Multi-Element Beam (W/ Rigid Links)	1.220 in	0.90%
Course Mesh Plate (End Offset)	1.2125 in	0.28%
Fine Mesh Plate (Web to CL flange)	1.1316 in	-6.4%
Beam & Plate	1.2164 in	-0.25%

Caltrans Investigation, cont.

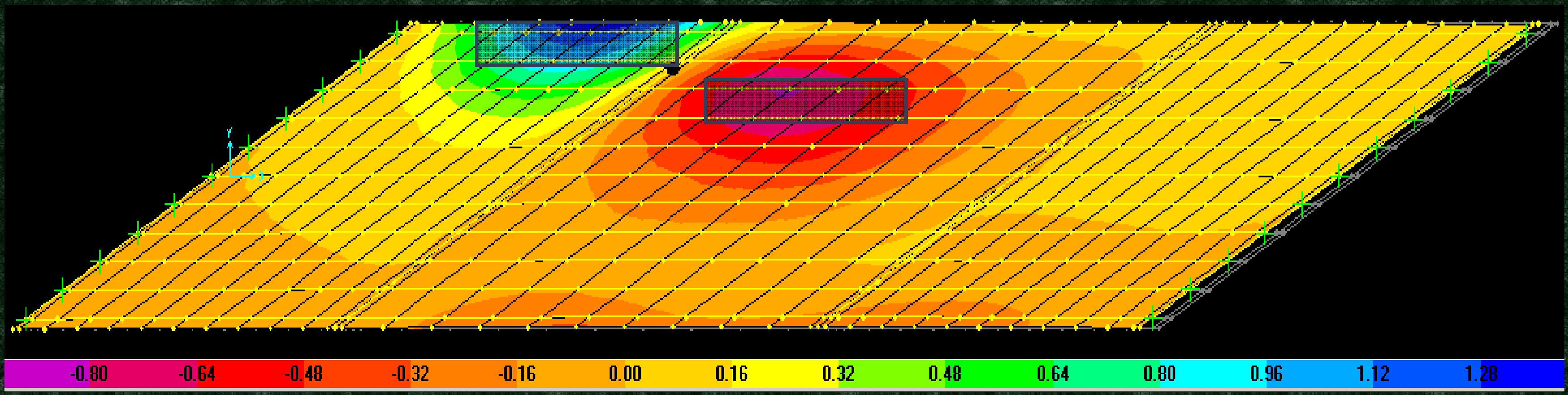
- Response in Question: Column Moment
- Important Parameters:
  - # Spans: 2 (150'-150'), 3 (150'-225'-150')
  - Skew: 0, 45 deg.
  - Width (#Columns): 27' (1), 57' (2), 107' (4)
  - Col. Height: 20', 70'
  - Abutment Fixity: Roller, Slider
  - Column Bot. Fixity: 1-col=Fix, Multi-col=Pin

Caltrans Investigation, cont.

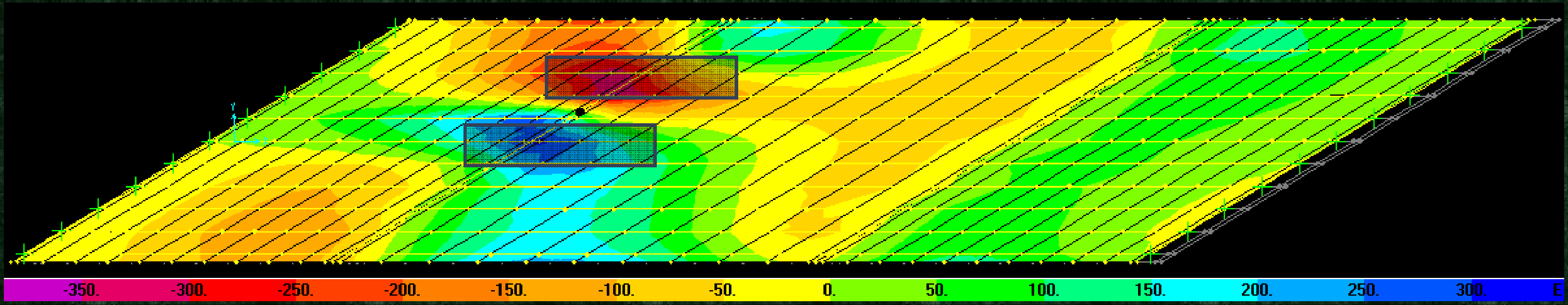
- Loading and Analysis
- 3D:
  - Create Influence Surface for Longitudinal and Transverse Moments
  - Position HS20 Truck to Maximize moment (MT and ML and their corresponding ML and MT)
  - Calculate Mmax: Resultant of ML and MT

Caltrans Investigation, cont.

- 3D Loading and Analysis



- Influence Surface for Longitudinal Column Moment



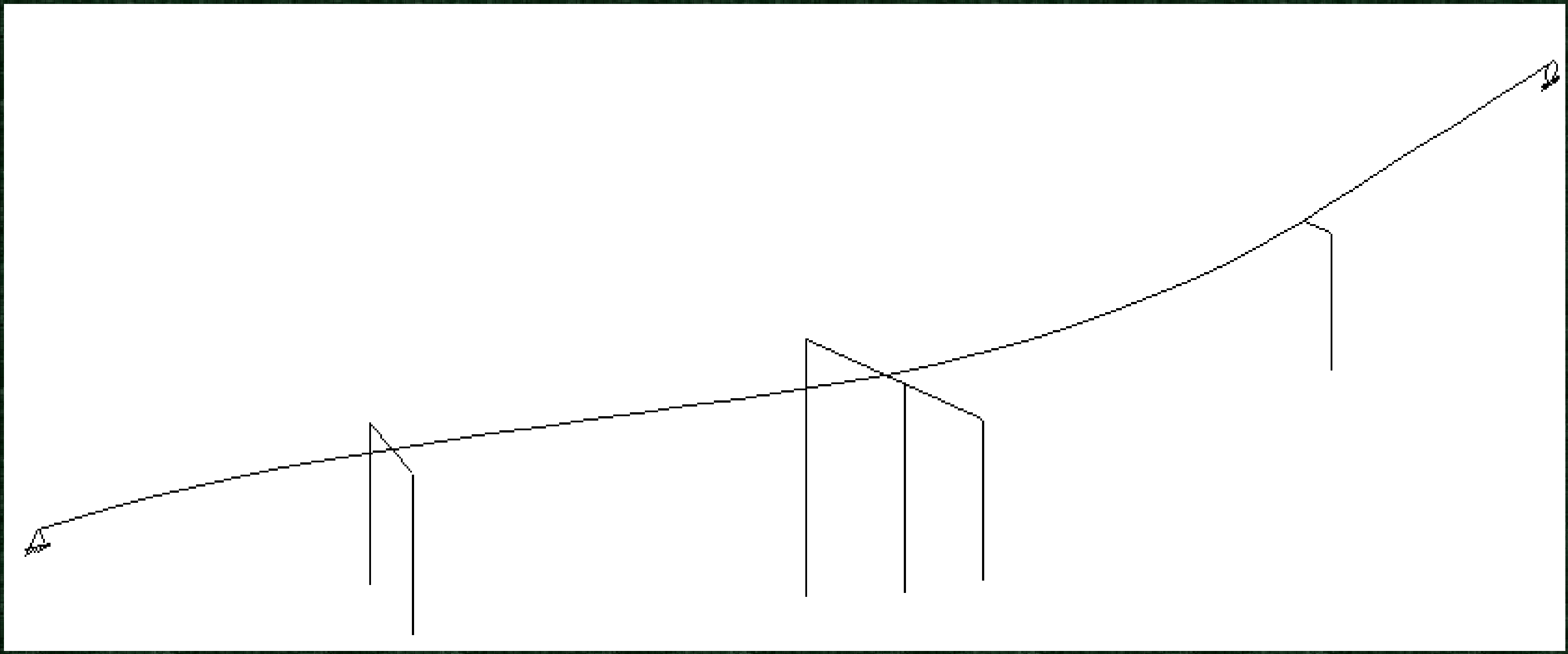
- Influence Surface for Transverse Column Moment

Caltrans Investigation, cont.

- Loading and Analysis
- 2D:
  - Create spine model, calculate reaction from HS20 truck: P, ML (ignore MT)
  - Move P over Pier model, find MT
  - Distribute ML to columns
  - Calculate Mmax: Resultant of MT and ML

Caltrans Investigation, cont.

- 2.5D Loading and Analysis



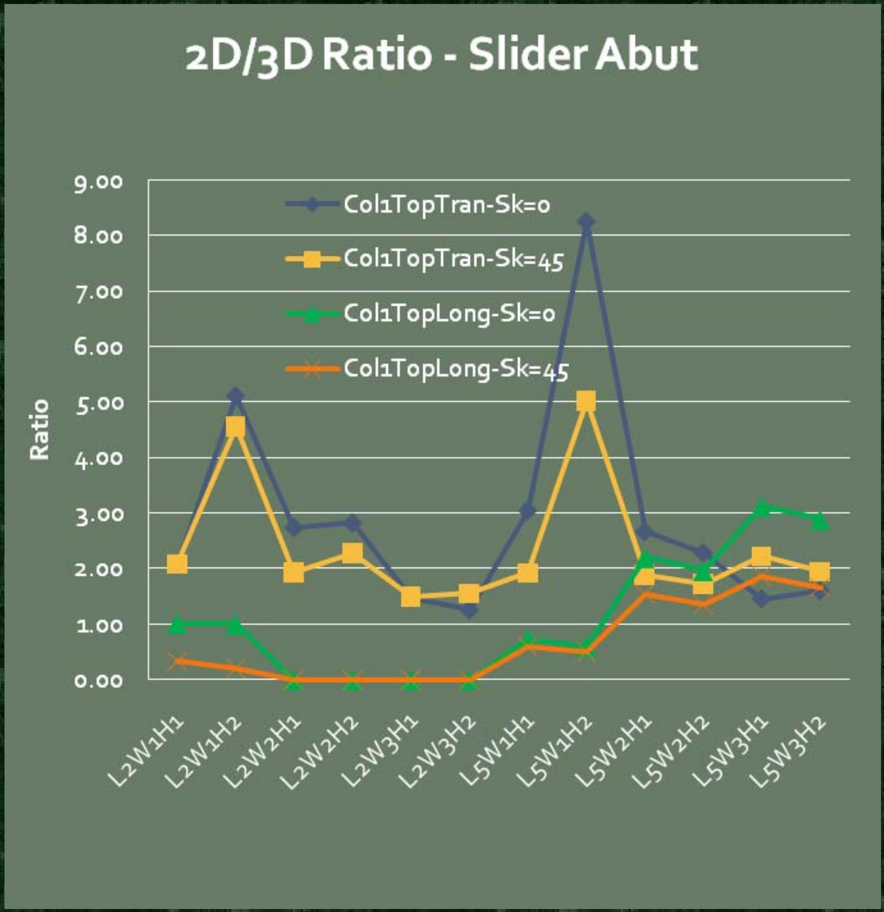
- Spine Model of Bridge

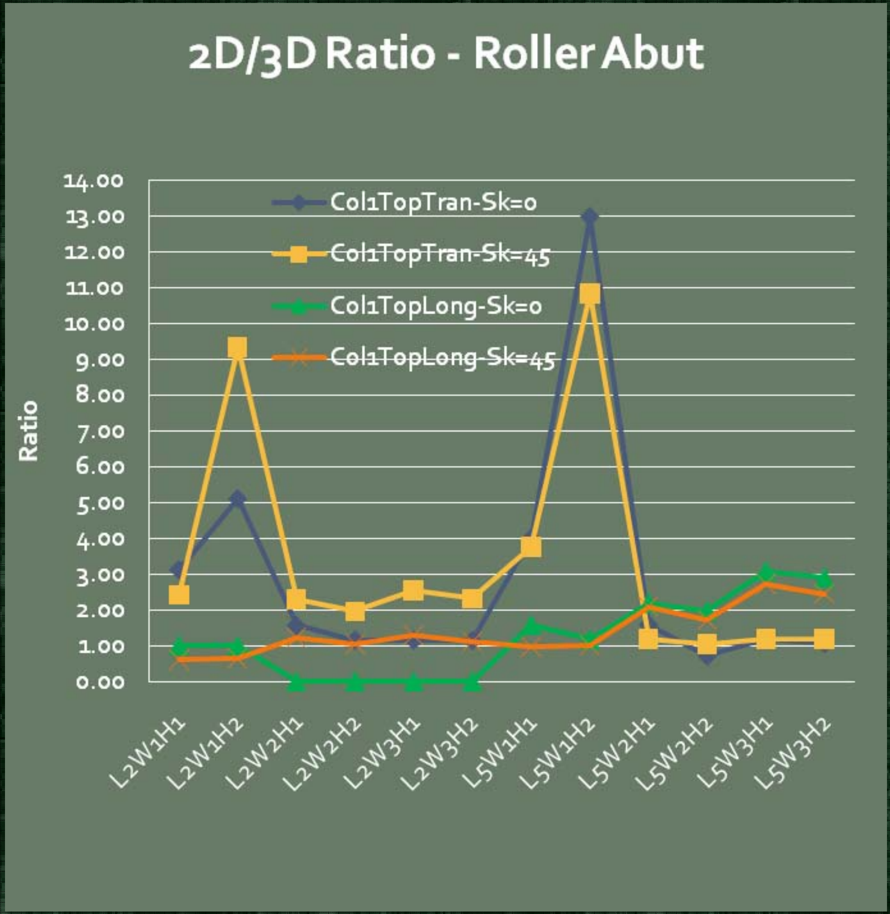
Caltrans Investigation, cont.

- Loading and Analysis
- 2.5-D:
  - Create spine model, calculate reaction from HS20 truck: P, ML, MT1
  - Move P over Pier model, find MT2
  - Distribute ML & MT1 to columns
  - MT = MT1+MT2
  - Calculate Mmax: Resultant of MT and ML

Caltrans Investigation, cont.

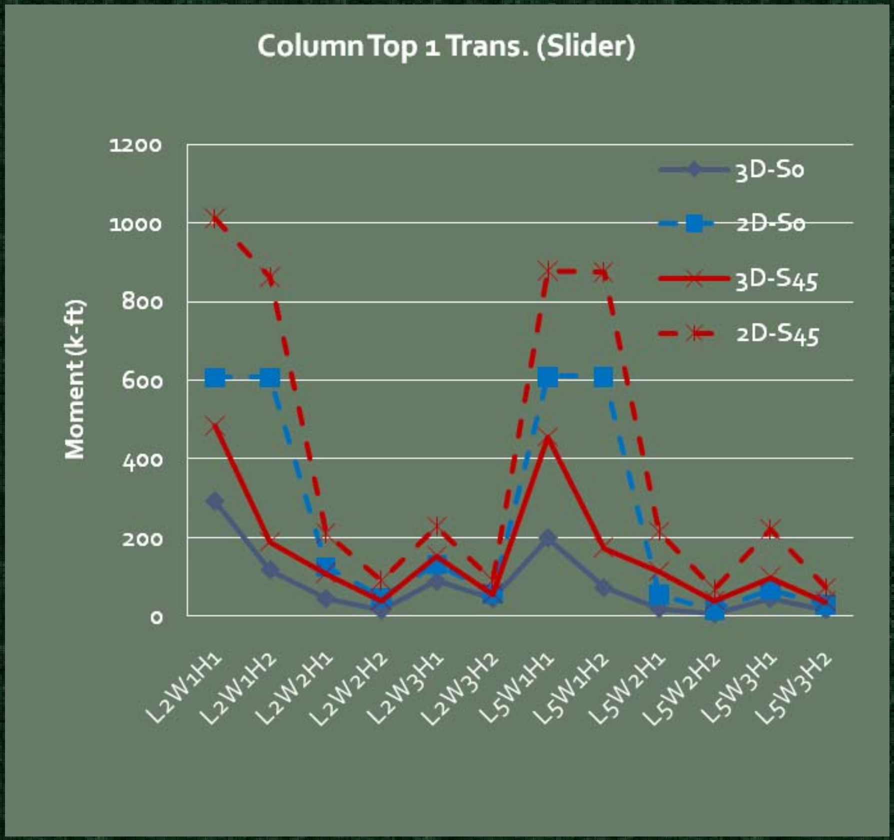
- 2.5D/3D Moment Ratios
  - Single Column Bents are highly overestimated

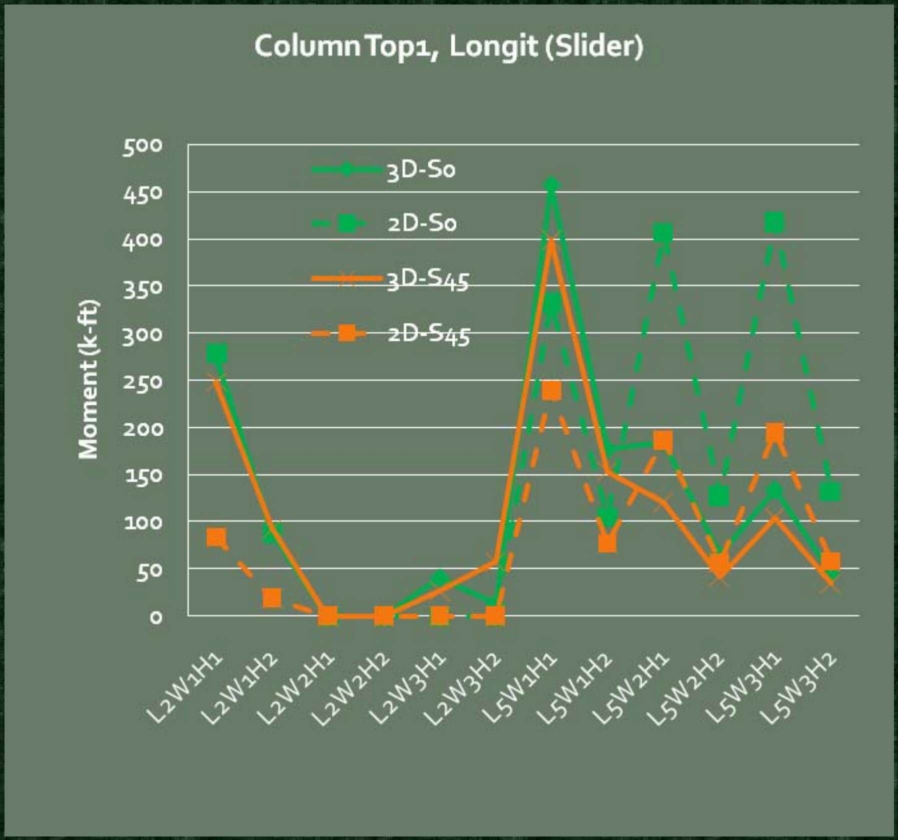




Caltrans Investigation, cont.

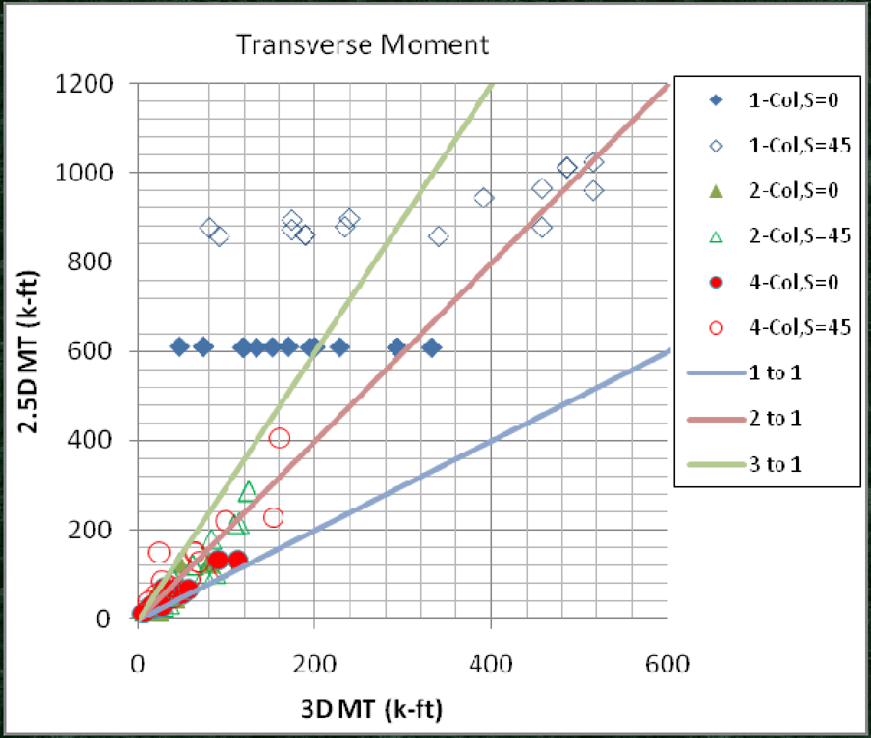
- 2.5D/3D Moment Comparison
  - Approximations are similar in Skewed and Right Bridges

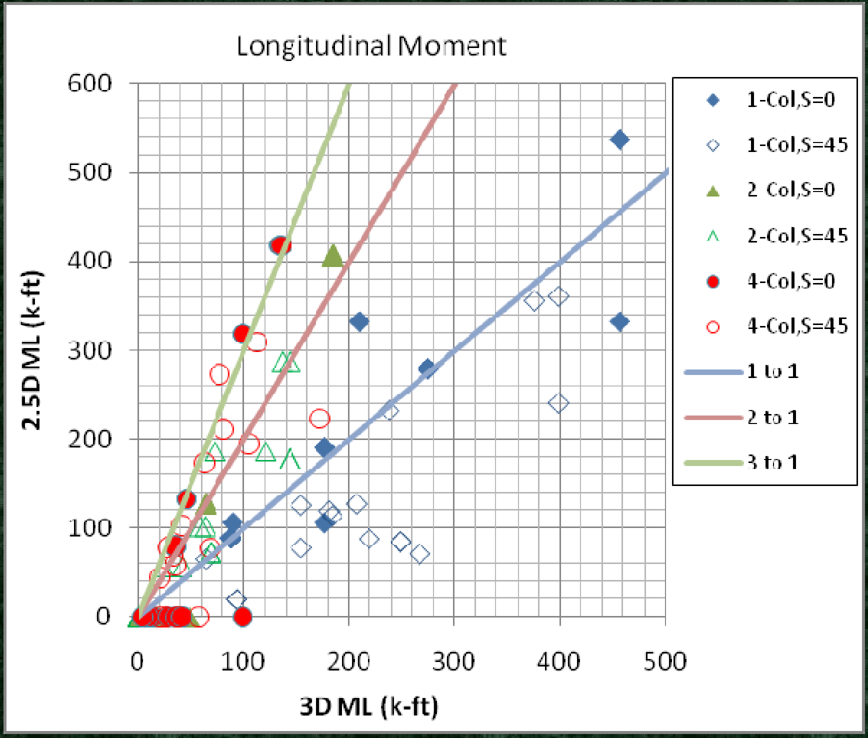




Caltrans Investigation, cont.

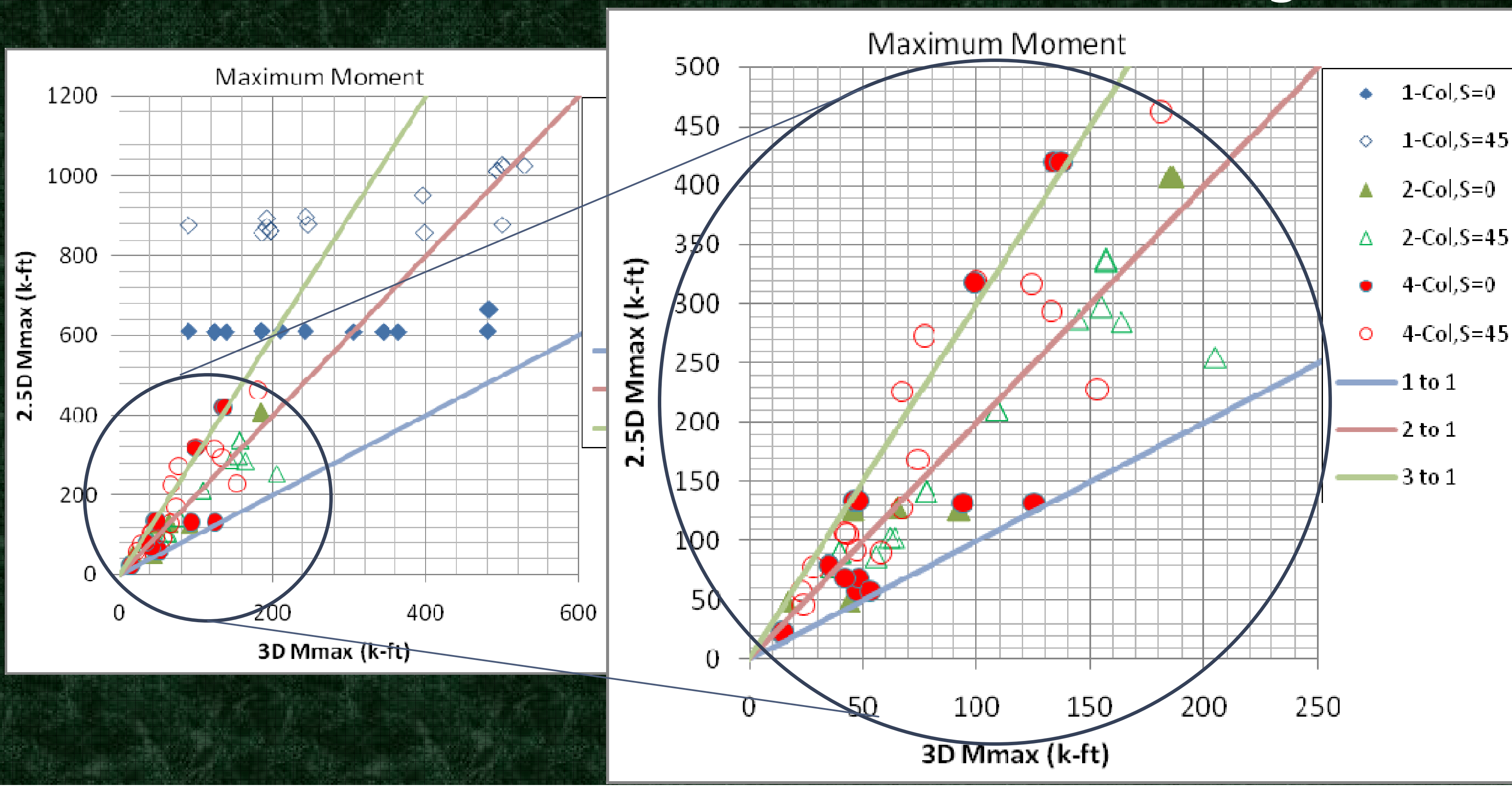
- 2.5D/3D Moment Comparison (MT & ML)
  - MT Overestimated, ML Underestimated





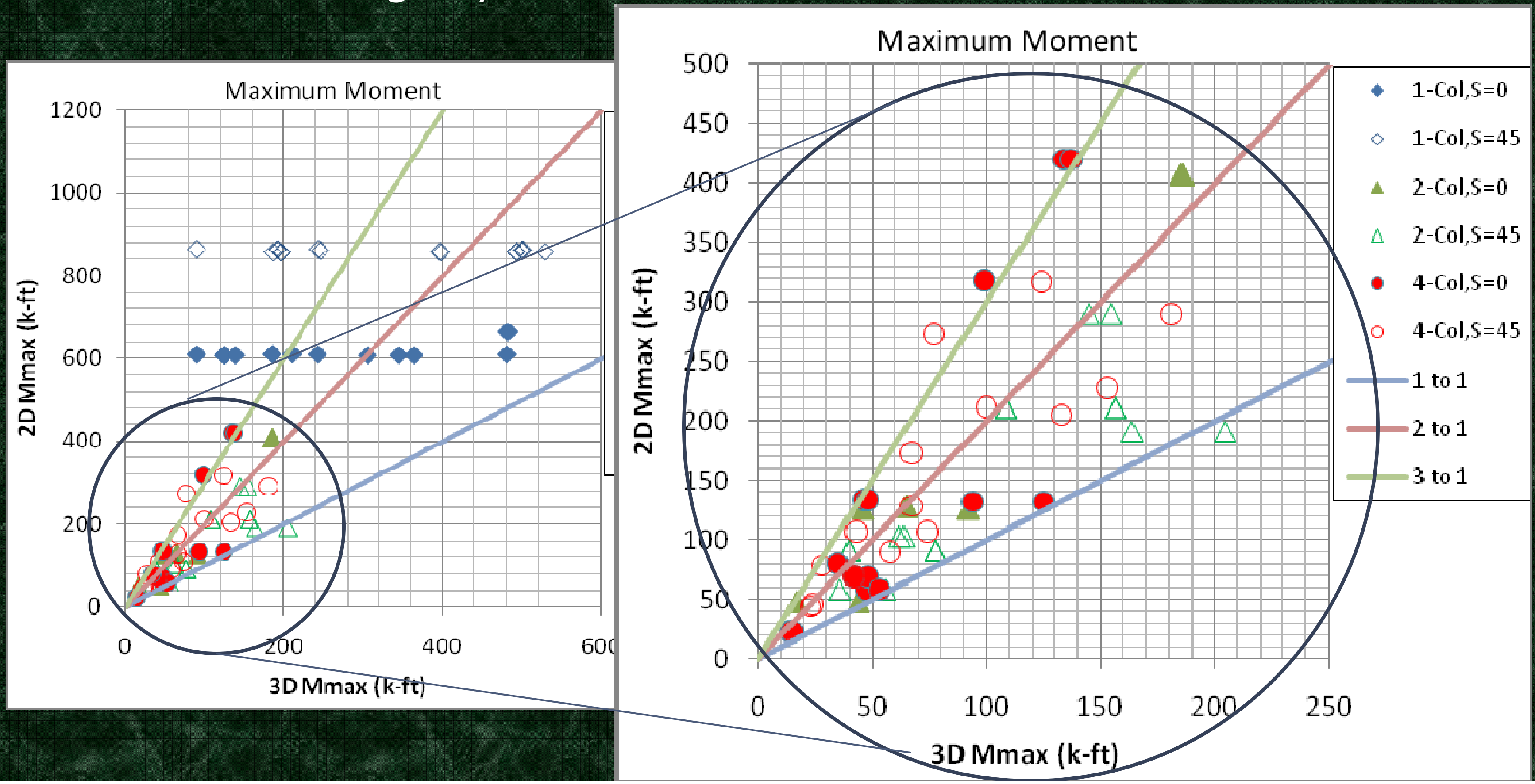
Caltrans Investigation, cont.

- 2.5D/3D Total Moment Comparison
  - Total Moments are overestimated: 1 to 3 times



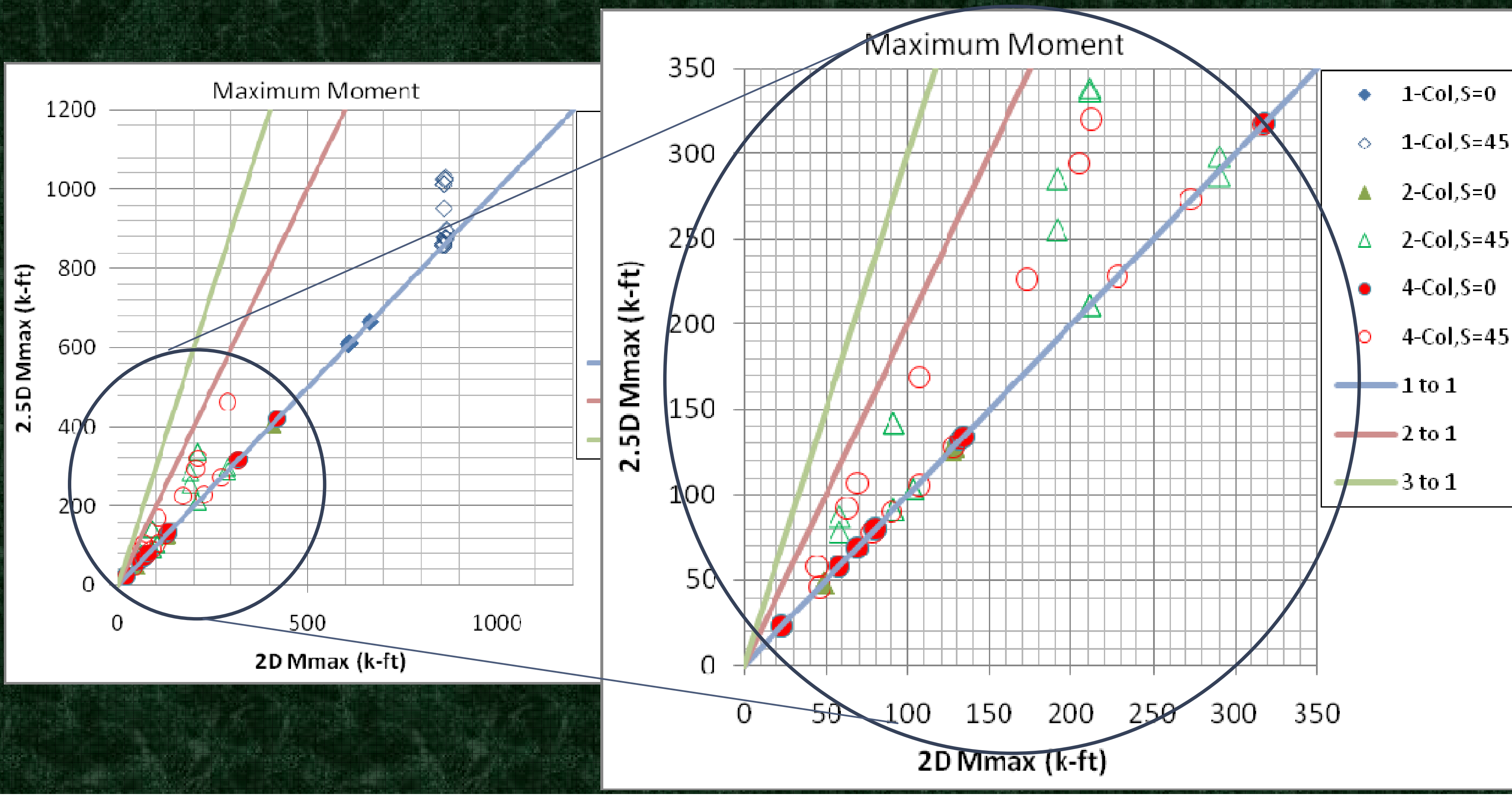
Caltrans Investigation, cont.

- 2D/3D Total Moment Comparison
  - 2D Procedure is conservative but less than 2.5D
  - 2D can be slightly unconservative (one case observed)



Caltrans Investigation, cont.

- 2.5D/2D Total Moment Comparison
  - 2.5D is more conservative than 2D in <u>skewed</u> bridges



Conclusions of Investigation

- 2D or 2.5D Analysis has inherent approximations
- 2D or 2.5D Analysis is highly conservative for single-column bents
- 2D is less conservative than 2.5D and generally not unconservative
- 3D Analysis tools are available; live loading is becoming available in current tools
- 3D Analysis procedures need to be streamlined

Management Considerations

- APPROXIMATE LL analysis methods….
  - Extra "margin" can be +/-, and large!
- 2D "correction factor"—not feasible
- Consider refined analysis when
  - Cross-section is extremely irregular
  - Layout is extremely irregular
  - 2D results are high; cost-savings desired
  - Significantly skewed supports
  - Non-standard vehicular or torsional loads
  - Long-span CR, SH, TU
- **Usage is NOT a clear-cut decision!**

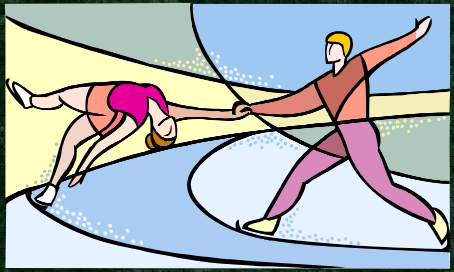
Management Considerations, cont.

- Pro Refined Analysis
  - Potential cost savings (new bridges)
  - Better decisions in rehab (existing)
  - Better "feel" for structural behavior
  - A model to facilitate quick response to field changes, permit requests
- Anti-Refined Analysis
  - Cost; Learning-curve/project time
  - 3D liveloader not totally automated

Overall Conclusions/Recommendations

- Conduct a study of beam-slab bridges similar to that done for CIP Concrete MC PT Box Girders
- Software developers should ask users how to improve 3D live-loader so that it would be used (bought) more often
- Users of 3D live-loaders: talk to developers!

GRACEFULLY partner
Into the future!



Thank you for your attention!

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- Prof. Dennis Mertz, Univ. of Delaware

the ***FHWA/AASHTO ABSS Scan Team***