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STGEC 2019
Southeastern Transportation
Geotechnical Engineering Conference

Modeling Traffic and Construction Equipment Surcharges for Geotechnical Global Stability Analysis

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Savannah, Georgia, December 11 -14, 2017

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Clarifications of Determining Pile Tip Fixity in Geotechnical and Structural Analyses of Laterally Loaded Piles Supporting Highway Structures

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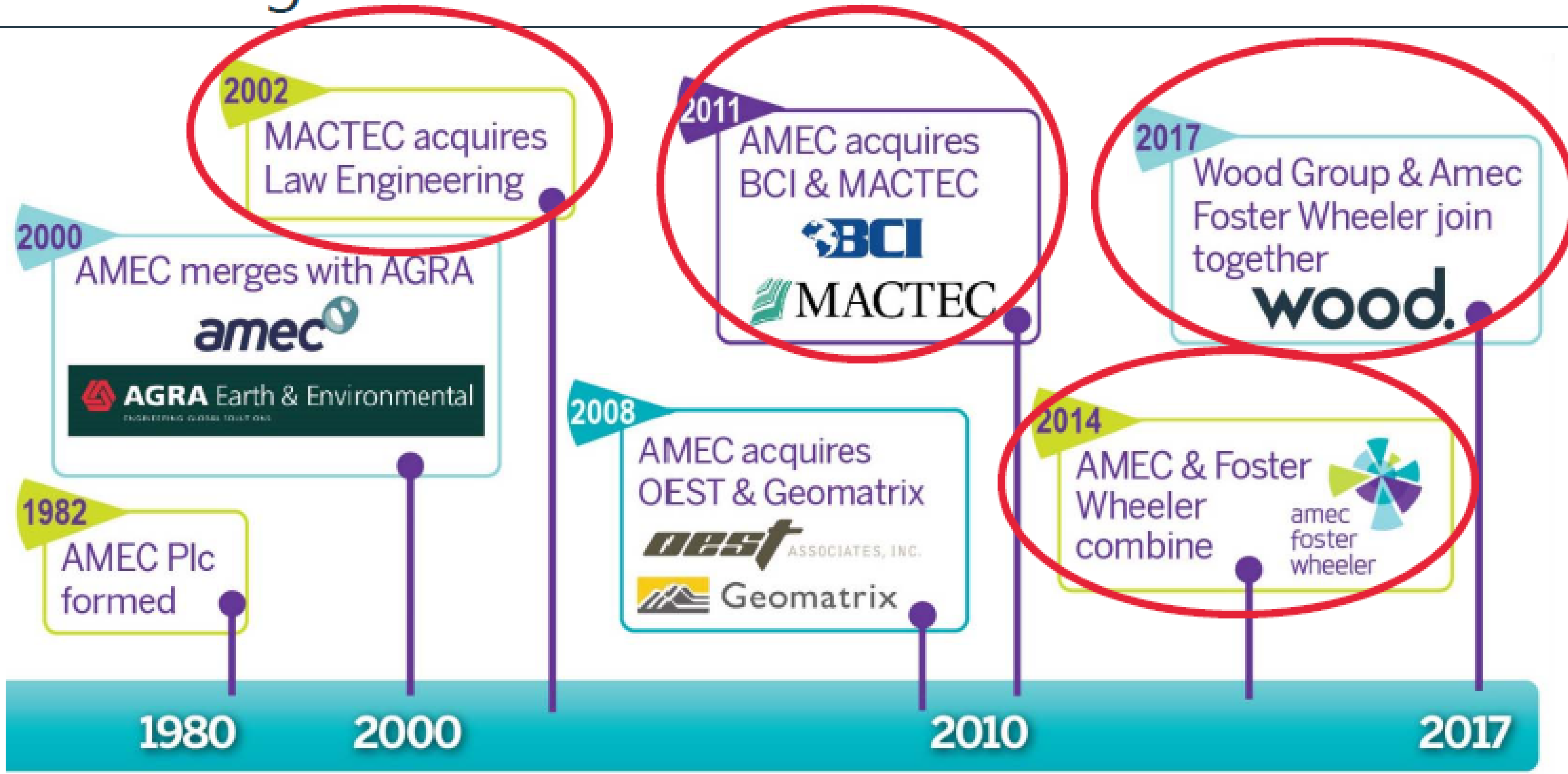
Our Lineage



2002
MACTEC acquires Law Engineering
2011
AMEC acquires BCI & MACTEC
BCI
MACTEC
2017
Wood Group & Amec Foster Wheeler join together
wood.
2000
AMEC merges with AGRA
amec
AGRA Earth & Environmental
2008
AMEC acquires OEST & Geomatrix
oest ASSOCIATES, INC.
Geomatrix
2014
AMEC & Foster Wheeler combine
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1982
AMEC Plc formed
1980
2000
2010
2017

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Design, Analysis, and Testing of Laterally Loaded Deep Foundations that Support Transportation Facilities

FHWA GEC 009

April 2018

U.S.Department of Transportation
Federal Highway Administration

Sponsored by
Federal Highway Administration
Office of Infrastructure
FHWA-HIF-18-031

Question

What is the Typical Highway Live/Traffic Surcharge Load in Geotechnical Designs?

Should actual tire/track contact pressures be used? …. Which appear very high; intuitively.

Answer: NO!

Question

What is the Typical Highway Live/Traffic Surcharge Load in Geotechnical Designs?

Answer #1: Typically … *"Everyone Know"!*

250 PSF; Uniform Loading

<u>Question</u>

What is the Typical Highway Live/Traffic Surcharge Load in Geotechnical Designs?

<u>Answer #2</u>: Conventionally, for commercial or Industrial projects:

- **100 psf for light traffic and parking areas**
- **250 psf for heavy equipment loading**

<u>Answer #3</u>:

According to 2014 AASHTO LRFD Article 11.19.10.2,
"***Traffic loads shall be treated as uniform surcharge loads in accordance with the criteria outlined in Article 3.11.6.2. The live load surcharge pressure shall not be less than 2.0 ft of earth.***"

Q: What is the unit weight of the "earth"?

FHWA NHI-10-025 Example E1 – Broken Backslope & Traffic
MSE Walls and RSS – Vol II E1 – 5 November 2009

<u>Traffic Load</u>

The traffic load is on the level surface of the retained backfill. For external stability, traffic load for walls parallel to traffic have an equivalent height of soil, h_{eq} equal to 2.0 ft.

$$q = 2.0\text{ ft }(125\text{ pcf}) = 250\text{ psf}$$

$$F_2 = q\,h\,K_{ab} = 250\text{ psf }(29\text{ ft})(0.360) = 2.61\text{ k/lft}$$

Question

Where was the 250 psf Uniform Surcharge originated from?

Answer

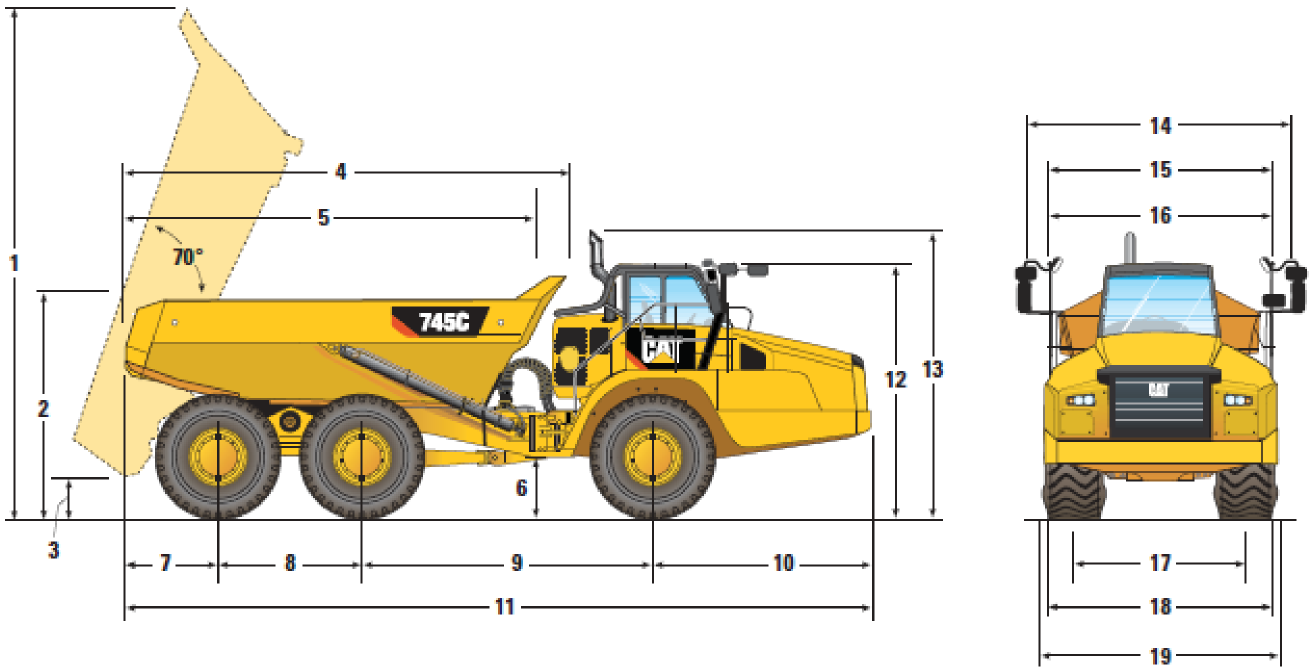
- **Civil Engineering Handbook (1940) refers to the Equivalent Surcharge and shows a 2 foot (scaled; not specified) fill on top of a retaining wall backfill.**
- **Elsewhere .....**

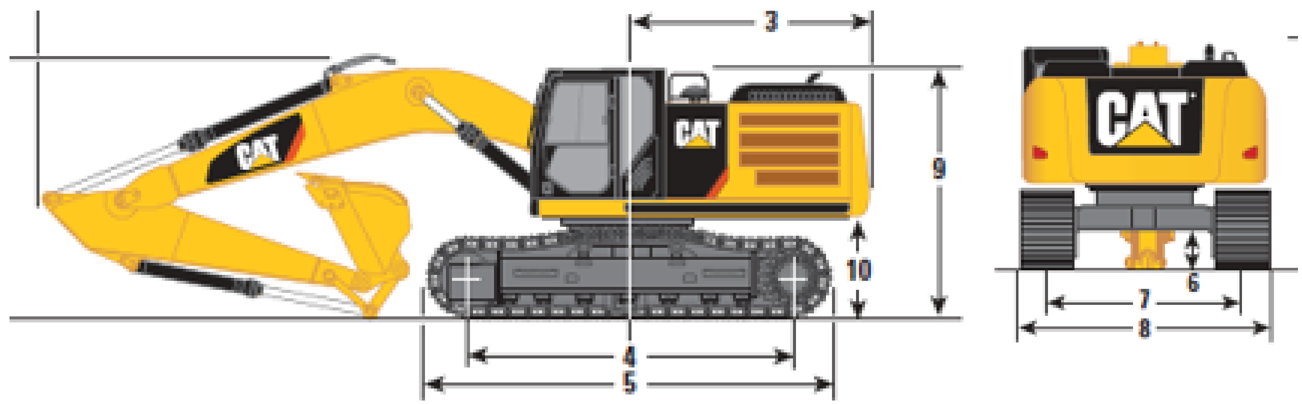
Remark

Practically, in reality, there is no such a Uniform, Infinite Long Strip Load of 250 psf.

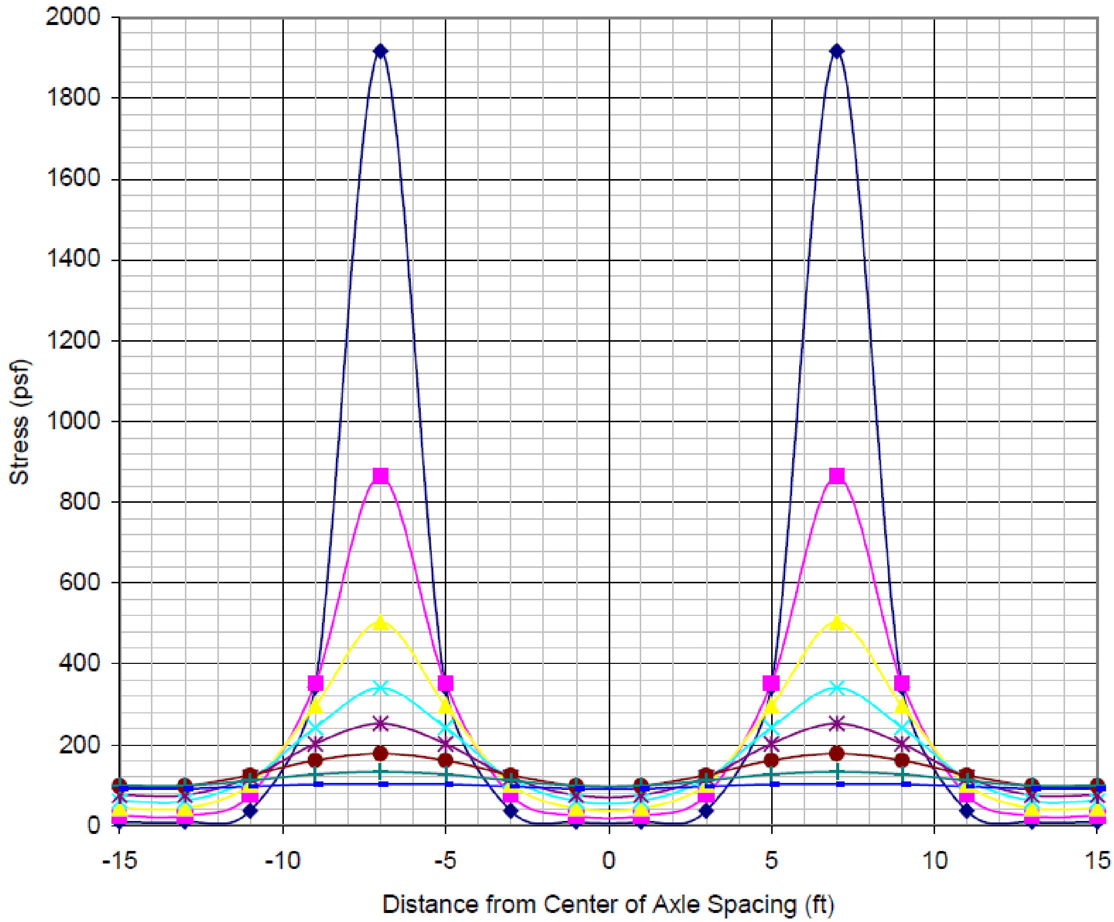
Specific Cases

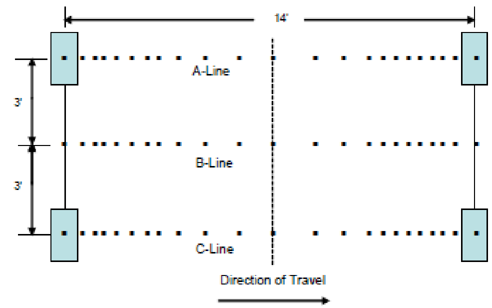
Use of Heavy-Duty Construction Equipment





Special Cases
Self Propelled Modular Transporter (SPMT)





Reference:
Fig. 3-8 in *Design of Live Loads on Box Culverts*. Report No. BC354 RPWO #47 – Part 2, published by University of Florida (2002)

Methodology of Design Analysis

Rigorous Analytical Approach

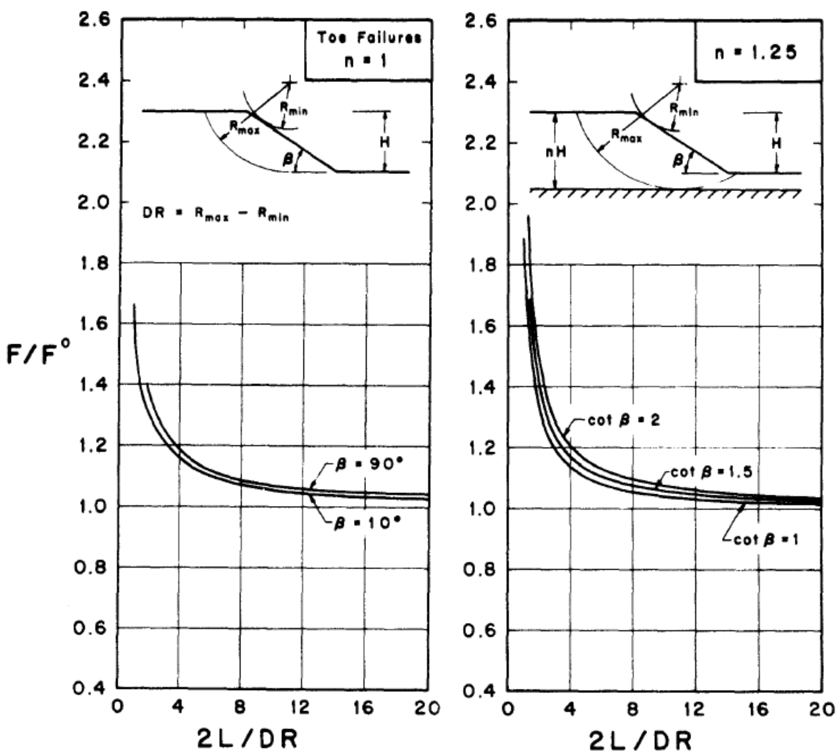
- Model Traffic Surcharge as an actual 3-Dimensinal loading
- Run Roadway Embankment Global Slope Stability; using a 3-D Computer Software

Conventional Analytical Approach

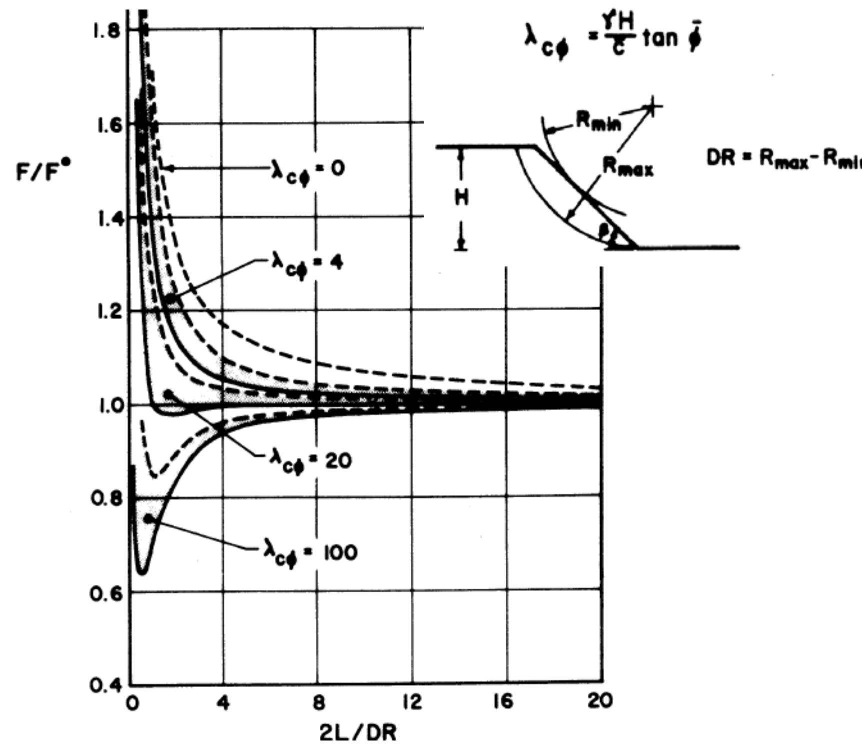
- Model Traffic Surcharge as a Uniform, Infinite Long Strip Load of 250 PSF over the entire crest.
- Global Slope Stability of Roadway Embankment; using a 2-D Computer Software; e.g., SLOPE/W, Slide2

Semi- Rigorous Approach

- **Correlations between results of 2-D and 3-D**



(Undrained)



(Drained)

Reference: "Three-Dimensional Analysis of Slope, by Amr Sayed Azzouz (1977)

Three Dimensional End Effects (in Cohesive Soil Slopes)

Conventional slope stability analyses assume a 2-D plane strain condition

$$FS(3D)/FS(2D) = 1 + 0.7\ (D/L) \qquad (7.3)$$

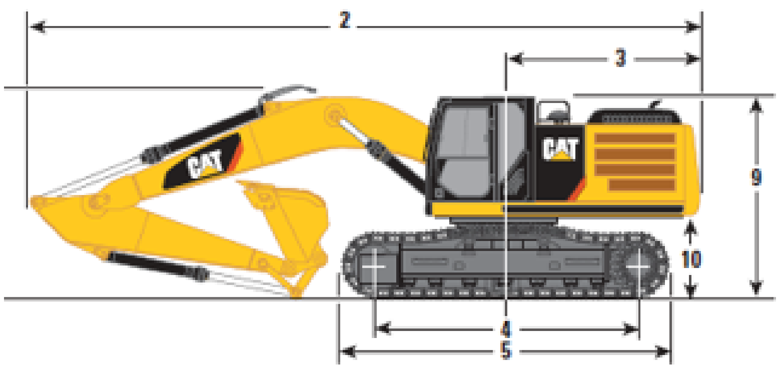
where D = maximum thickness of the failure zone and L = maximum longitudinal length of the zone of failure.

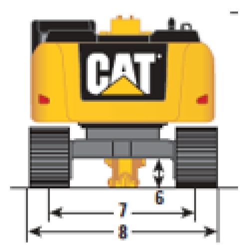
Reference: Ladd and DeGroot (2003), *"Recommended Practice for Soft Ground Site Characterization: Arthur Casagrande Lecture"*

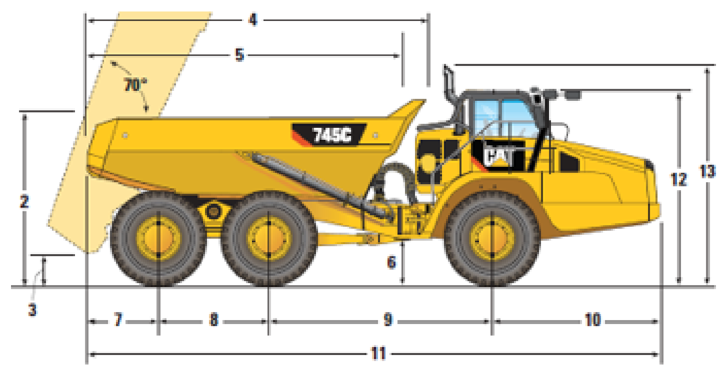
Proposed practically “Quick” Evaluation

- Perform the Conventional 2-D Analysis, using 250 psf infinite uniform loading
- Max. operating weight (A)
- Overall width of the contact footprint (B) … Edge-to-Edge
- Overall wheelbase ground contact distance (C) … Front-to-Rear
- Equivalent Surcharge (DD) = (½)(A)/(BC)
- IF DD ≤ 250 psf, OK

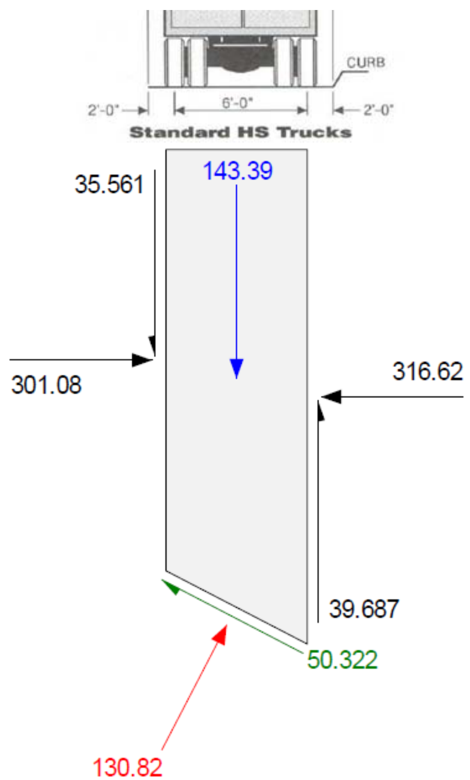
…… *Why (½)?*

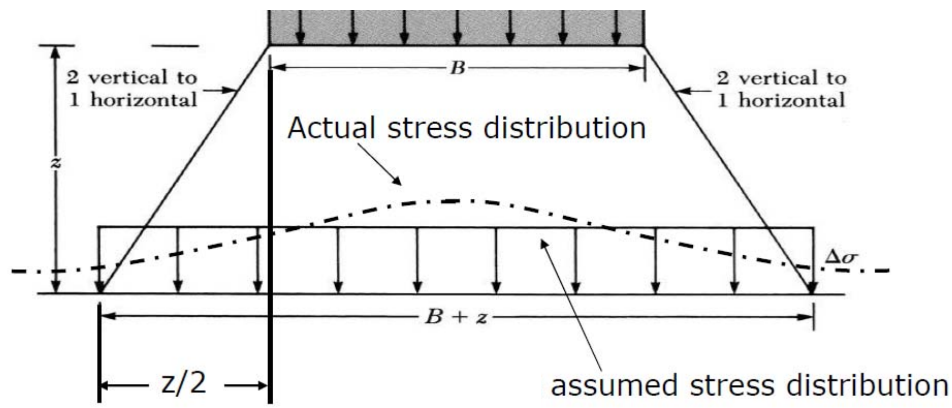






Effects of Live / Traffic Surface Surcharge?

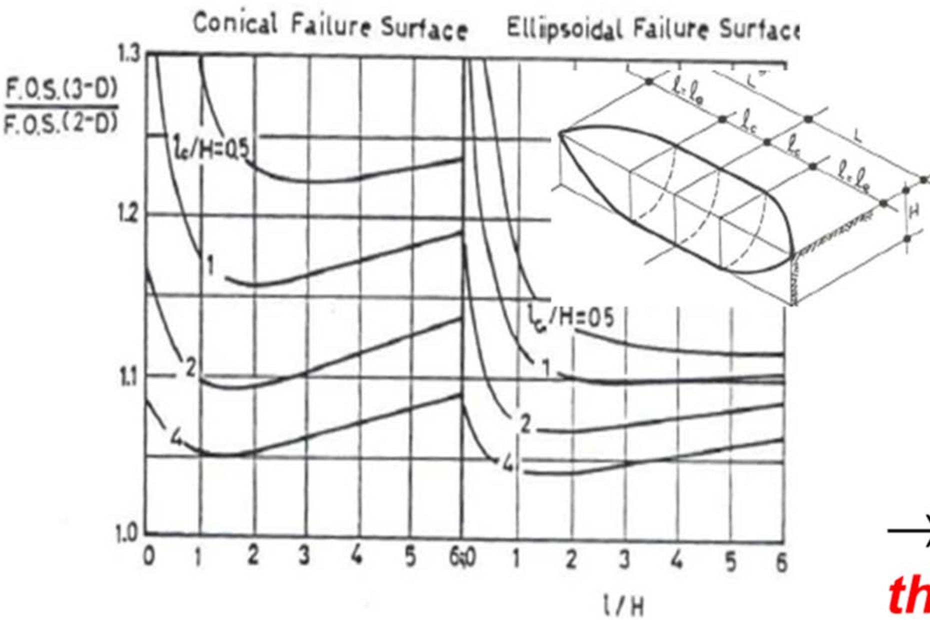




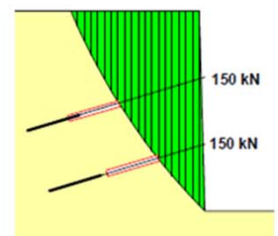
$$\Delta\sigma_z = q_o(BxL)/(B+z)(L+z)=P/(B+z)(L+z)$$

- **Mobilization of soil base resistance (Limitations of limiting equilibrium analysis)**

- Embankments on Homogeneous undrained clay;
  - → $FS_{3D} \cong (114\%)*FS_{2D}$ .... (Ref.1)
  - → $(l_c/H) \geq 4$; 3-D failure close to plane-strain; i.e., $FS_{3D} \cong FS_{2D}$ .... (Ref.2)
- 3-D effect for cohesive soils is more than for cohesionless soils .... (Ref.2)
  - → Sand & c-ϕ Soils; tentatively taking **$(l_c/H) = 2$** for reaching plane-strain

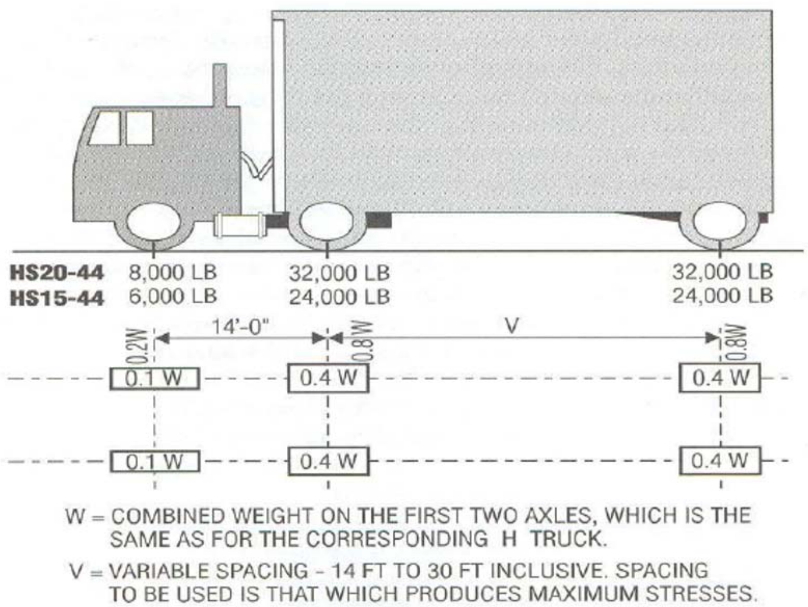


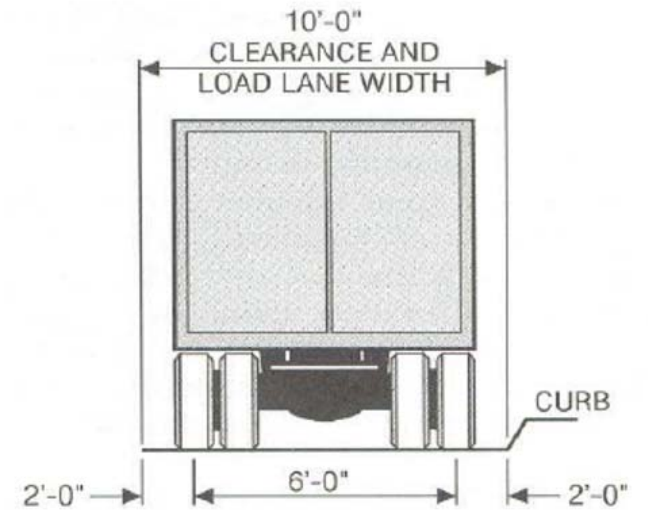
- Adopting similar concepts modeling the anchor load in 2-D Stability Analysis:



→ ***Use a factor of (½) to distribute the 3-D Loading for a 2-D analysis***

References:
1. Z. Habibnezhad (2014), "Stability Analysis of Embankments Founded on Clay - a comparison between LEM & 2D/3D FEM" A Mater Thesis; Royal Institute of Technology, Stockholm.
2. Baligh, M., and Azzouz, A. S., (1975) "End Effects on Stability of Cohesive Slopes," Journal of the Geotechnical Engineering Division, ASCE, Vol. 101, No. GT11, pp.1105-1117.

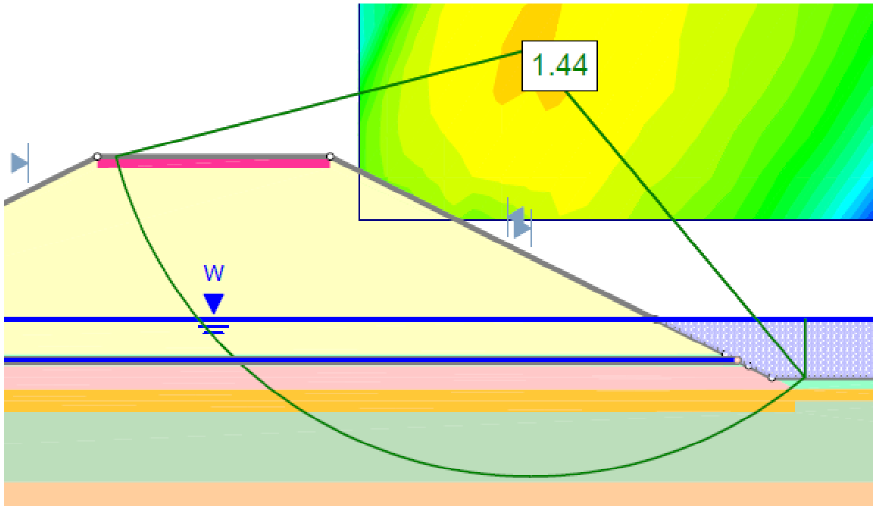




Standard HS Trucks

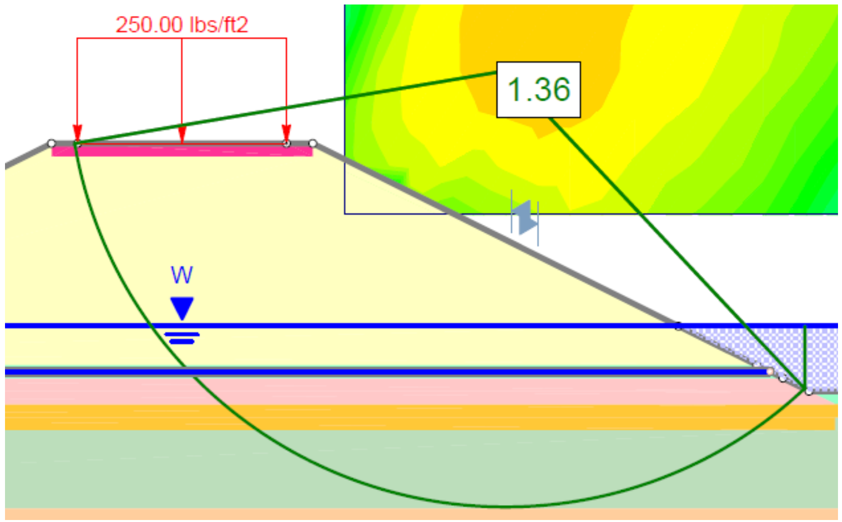
- **HS20-44: Minimum AASHTO recommended design load for bridges on Interstate Highways**
- **Axle Loads: (1) 8-Kip & (2) 32-Kips; i.e., total 72 Kips**
- **Max. Overall contact projection =(6′)*(14′+14′)= 168 ft^2**
- **Projection Surcharge = (72kips/ 168 ft^2) = 428 psf**
- **Equivalent Surcharge = *(½)*(428 psf) = 214 psf ≅ 250 psf**

w/o Surcharge

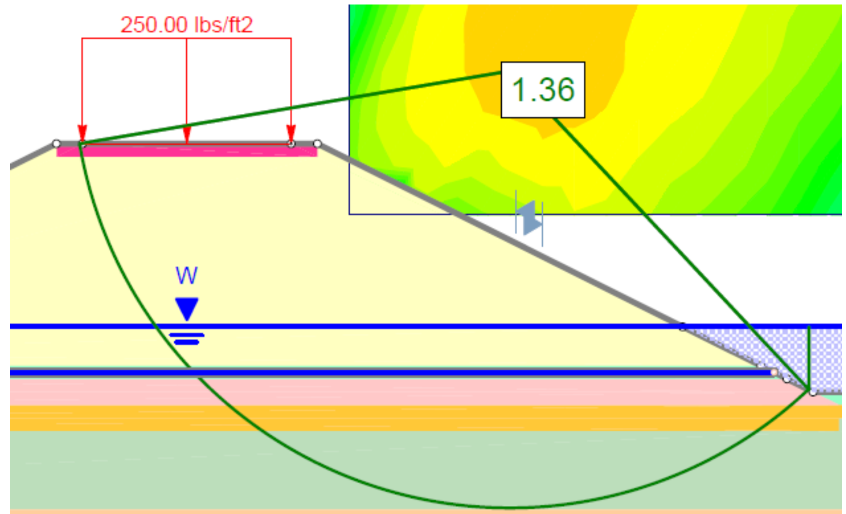


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Embankment Fill		120	Mohr-Coulomb	100	30
Soft Lean Clay		105	Undrained	400	
Medium Stiff Lean Clay		115	Undrained	550	
Blended Soft Lean Clay and Class A rip-rap		120	Mohr-Coulomb	0	32
Class A Rip Rap		110	Mohr-Coulomb	0	40
#57 Stone		110	Mohr-Coulomb	0	37
Weathered Rock		135	Mohr-Coulomb	0	38

w/ 250 PSF Surcharge

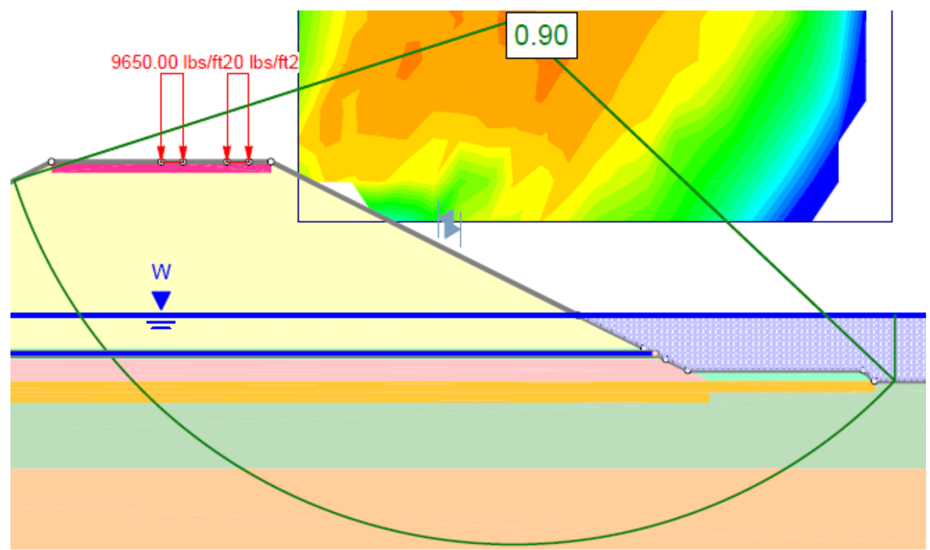


w/ 250 PSF Surcharge

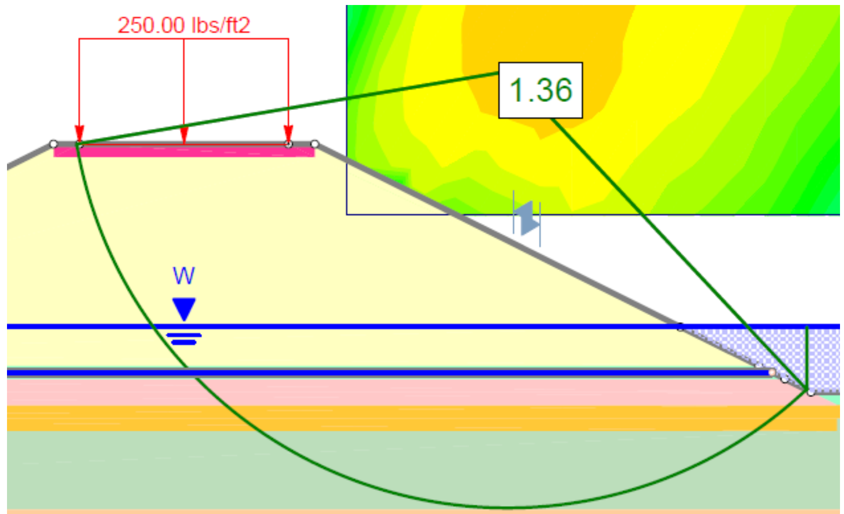


DO NOT use actual tire/track contact pressure as infinite strip loading within specific widths in 2-D analysis.

w/ HS-20 Tire Contact Pressure 67 psi (9650 psf)

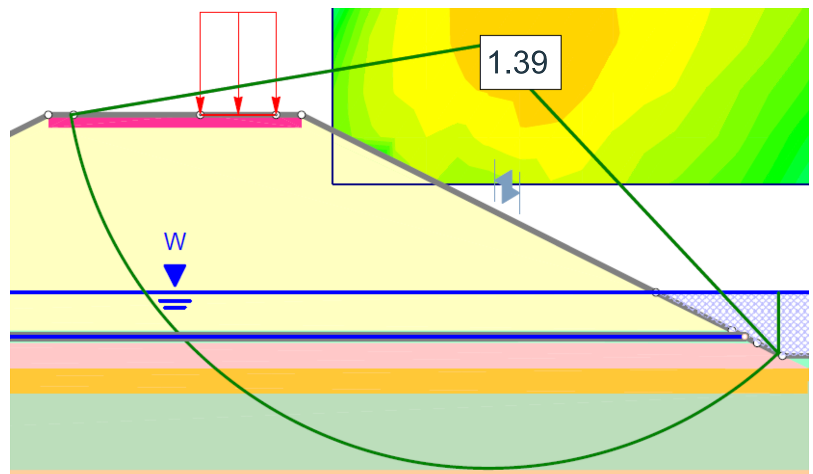


w/ 250 PSF Surcharge



Implying applicability of the "1/2" factor.

HS-20 Surcharge within Vehicle Overall Footprint 500 psf; i.e., w/o (½) Factor



Question (… not often asked)

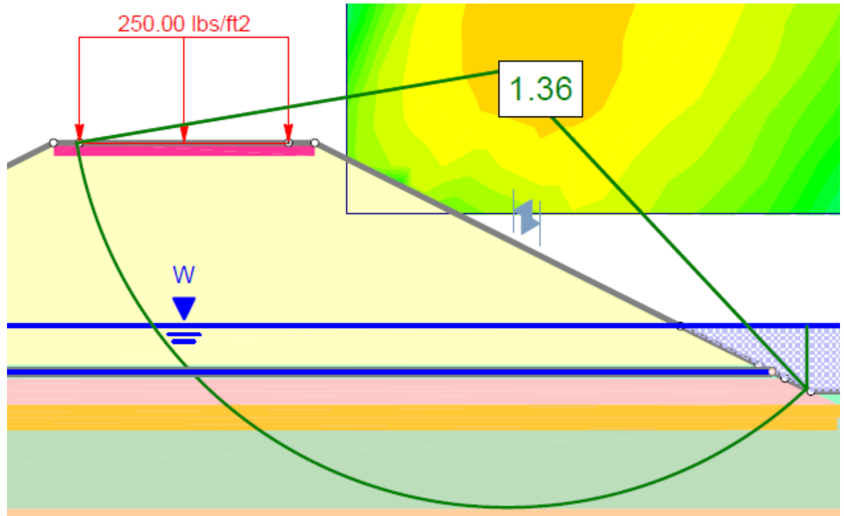
How to evaluate haul truck traffic-induced vibration effects on global stability of an embankment slope?

Method #1

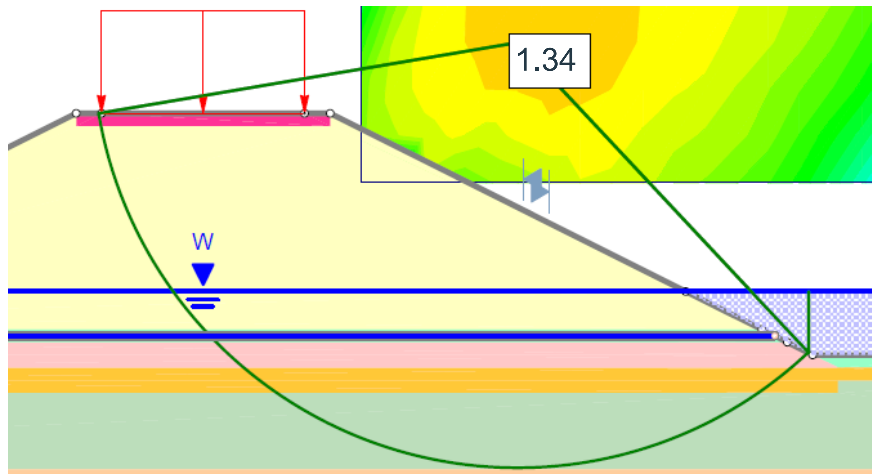
- **2014 AASHTO LRFD, Article 3.6.2; dynamic load allowance (*IM*), an increment applied to the static wheel load to account for wheel load impact from moving vehicle; dynamic effects attributed to vehicular hammering effects due to roughness of the haul road riding surface, dynamic response of the embankment as a whole to the passing haul trucks, and other factors.**

- **Based on Table 3.6.2.1-1 in 2014 AASHTO LRFD, use an IM value of 33% for global stability analysis. Use a surcharge of 335 psf [i.e., (133%)*(250 psf)] to model the haul truck traffic vibration effects.**

w/ 250 PSF Static Surcharge



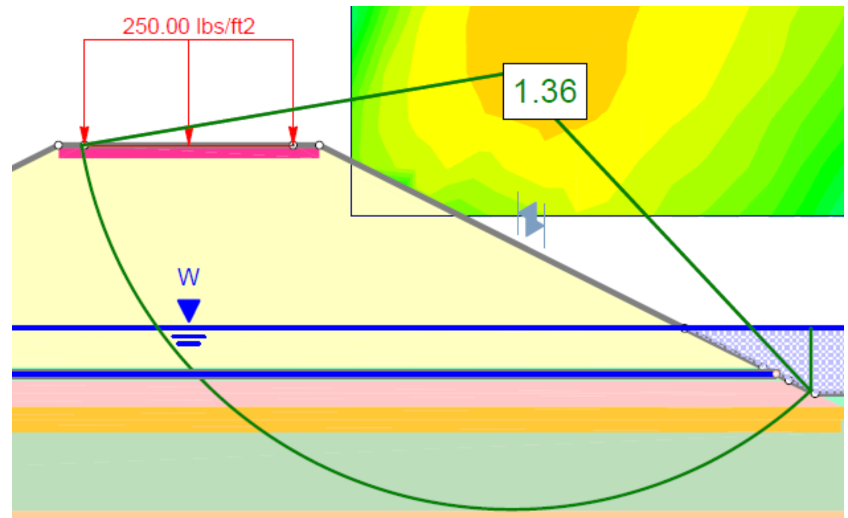
w/ Dynamic Surcharge (250)*(133%)=335 psf



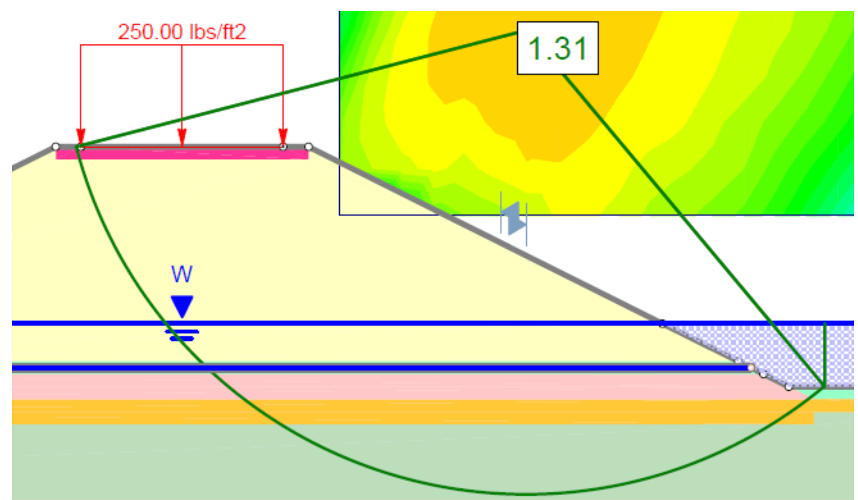
Method #2

- **Caltrans (2013), *Transportation Construction Vibration Guidance Manual*, the highest traffic generated vibrations measured on freeway shoulder have never exceed a peak vertical particle velocity (PPV) of 2.0 mm/sec, with worst combinations of heavy trucks. Assume PPV=1.25 mm/sec.**
- **Vibration frequency from transportation and construction sources typically ranging from 10 to 30 Hz (Avg. 15 Hz)**
- **Corresponding acceleration would equal to 0.012 g [=(0.000641)*(15 Hz)*(1.25 mm/sec)]**
- **Run a pseudo-static analysis, w/ both vertical and horizontal seismic loading coefficients = 0.012g.**

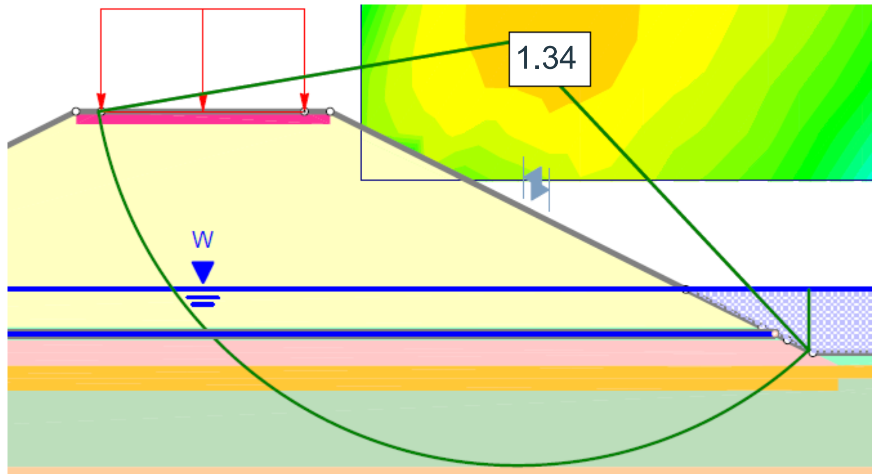
w/ 250 PSF Static Surcharge



w/ 250 PSF, plus Dynamic Surcharge; $a_v = a_h = 0.012g$

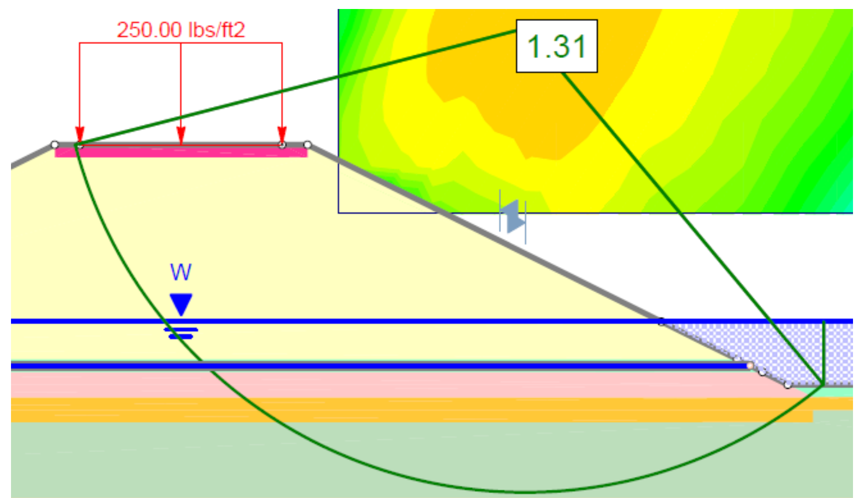


Method #1
w/ Dynamic Surcharge (250)*(133%)=335 psf



Comparable/Similar Results

Method #2
w/ 250 PSF, plus Dynamic Surcharge; $a_v=a_h=0.012g$



CONCLUSION / Proposed Methodolgy

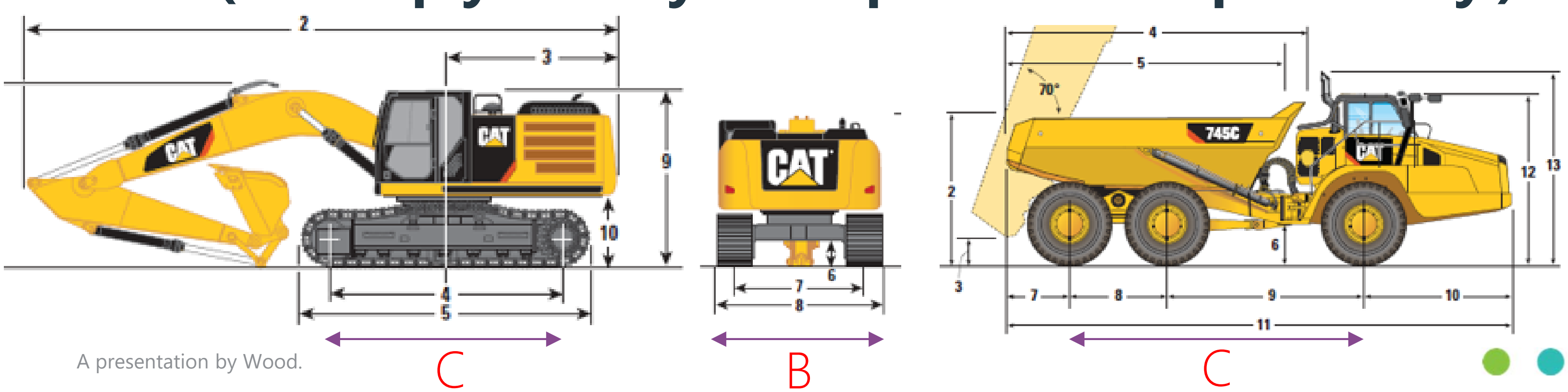
Modeling Hwy Traffic Surcharge
For Embankment Global Stability

- **As Required, perform a Conventional 2-D Analysis using 250 PSF infinite uniform loading over the entire crest to satisfy AASHTO LRFD Provision requirements.**
- **... IF traffic vibration effects need to be considered, run 2-D Analysis using 335 PSF infinite uniform loading over the entire crest.**

CONCLUSION / Proposed Methodolgy

Acceptability of a Specific Construction Equipment

- **DO NOT** use actual tire/track contact pressure as infinite strip loading within specific widths in 2-D analysis.
- **Check Equivalent Surcharge (DD) = (½)(A)/(BC); w/ A = max. operating weight; B & C (see Figure below)**
  - IF DD ≤ 250 psf, OK
  - IF DD > 250 psf, rerun 2-D analysis, assuming an infinite, uniform load of DD over the entire crest (…. simply modify the input file used previously.)



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Questions?