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April 11-12, 2017

9[th] GEOTECHNICAL, GEOPHYSICAL AND GEOENVIRONMENTAL TECHNOLOGY TRANSFER (Geo^3T^2) CONFERENCE AND EXPO

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Modeling Traffic and Construction Equipment Surcharges for Geotechnical Analysis: 2-D or 3-D?

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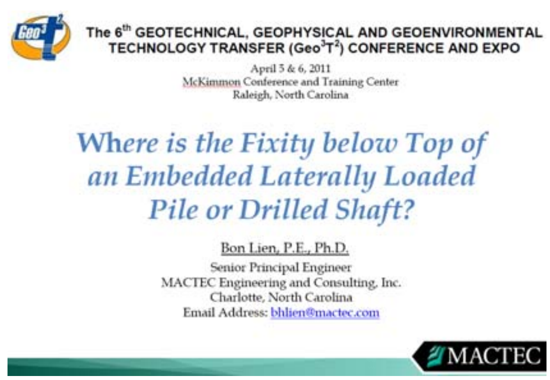
- Make a Complicated Question Simple ...


The 6[th] GEOTECHNICAL, GEOPHYSICAL AND GEOENVIRONMENTAL TECHNOLOGY TRANSFER (Geo^3T^2) CONFERENCE AND EXPO
April 5 & 6, 2011
McKimmon Conference and Training Center
Raleigh, North Carolina

Where is the Fixity below Top of an Embedded Laterally Loaded Pile or Drilled Shaft?

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MACTEC

- ***Make a Simple Question Complicated …***

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Question

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

Answer #1: 250 PSF; Typically

Answer #2: Conventionally,

- 100 psf for light traffic and parking
- 250 psf for highway traffic

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Answer #3:

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

Traffic Load

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.

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

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

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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 …..

Question

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

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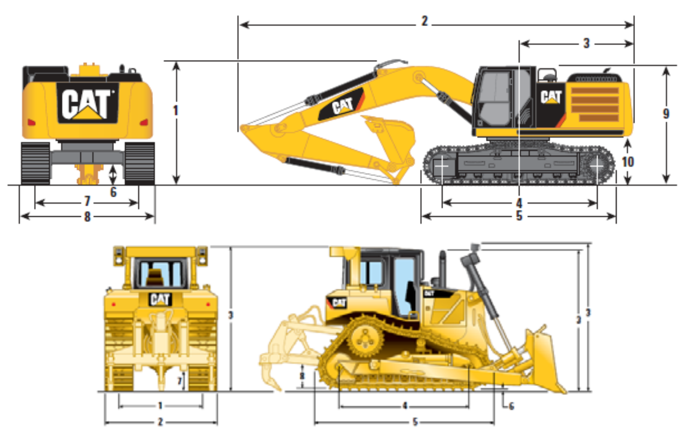
Common Cases

Conventional Construction Equipment



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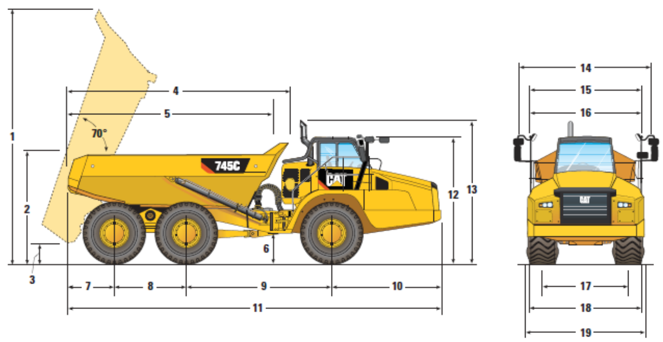
Common Cases

Conventional Construction Equipment



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Special Cases

Self Propelled Modular Transporter (SPTM)

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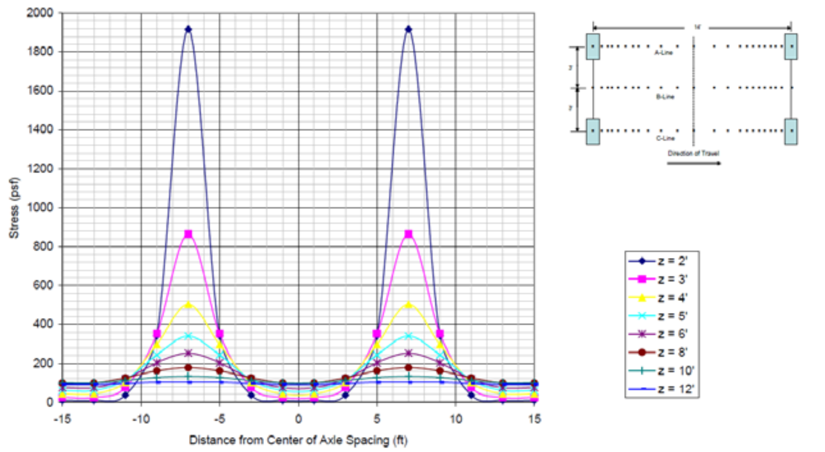

Reference:
Fig. 3-8 in *Design of Live Loads on Box Culverts*. Report No. BC354 RPWO #47 – Part 2, published by University of Florida (2002)

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Methodology of Design Analysis

Rigorous Analytical (High-Tech) 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**.
- Global Slope Stability of Roadway Embankment; using a 2-D Computer Software; e.g., SLOPE/W

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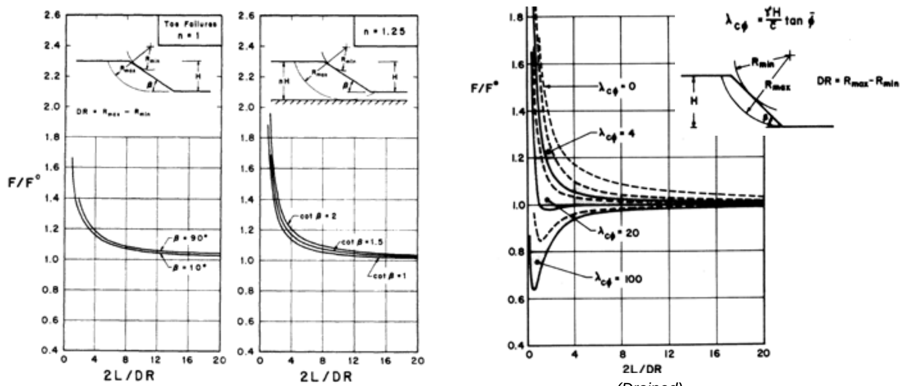
Semi- Rigorous Approach

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



(Undrained) (Drained)

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

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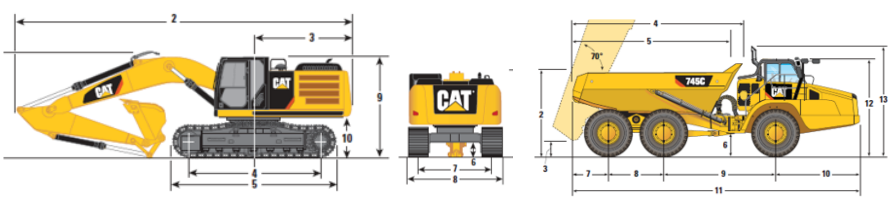
Proposed practically "Quick" (Low-Tech) Evaluation

- 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 distance (C) … Front-to-Rear
- **Equivalent Surcharge** (DD) = (½)(A)/(BC) …… ***Why (½)?***
- **IF DD ≤ 250 psf, OK**



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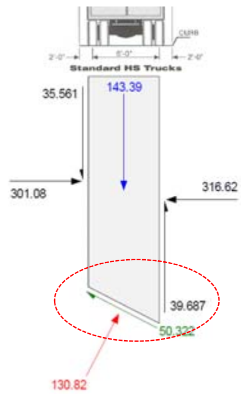
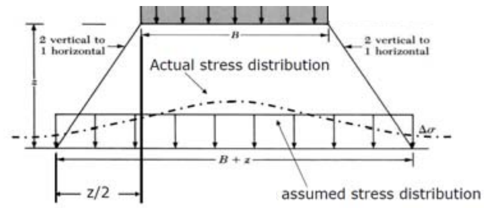
Effects of Live / Traffic Surface Surcharge?





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

- Mobilization of soil base resistance (Limitations of limiting equilibrium analysis)
- Local stability concerns (sloughing, ground bearing, deflections); rather than global.
- Run 3D FEM/FLAC ……

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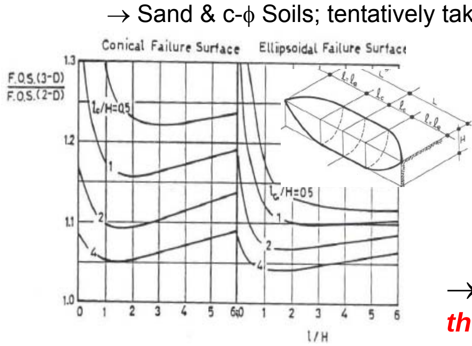
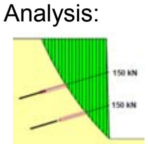
- Embankments on Homogeneous undrained clay;
  - → $FS_{3D} \cong (114\%)*FS_{2D}$ .... (Ref.1)
  - → $(l_c/H) \geq 4$; 3-D failure close to plane-strain; i.e., $FS_{3D} \cong FS_{2D}$ .... (Ref.2)
- 3-D effect for cohesive soils is more than for cohesionless soils .... (Ref.2)
  - → Sand & c-ϕ Soils;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

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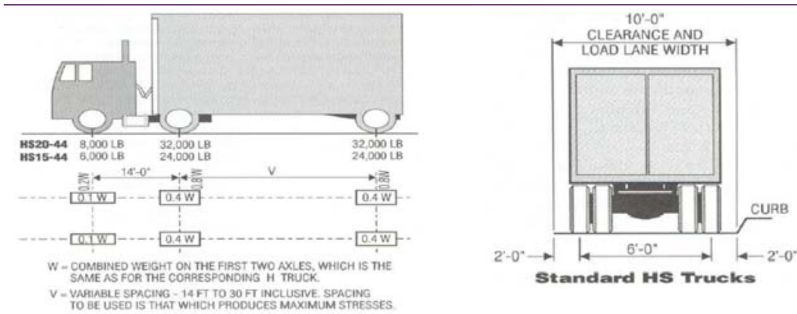

- HS20-44: Minimum AASHTO recommended design load for bridges on Interstate Highways
- Axle Loads: (1) 8-Kip & (2) 32-Kips; i.e., total 72 Kips
- Max. Overall contact projection =(6')*(14'+14')= 168 ft^2
- Projection Surcharge = (72kips/ 168 ft^2) = 428 psf
- Equivalent Surcharge = **(½)**(428 psf) =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

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COMPARISONS

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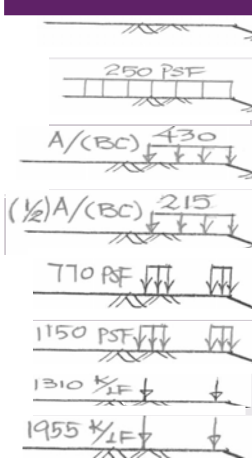

Surcharge Conditions (Slope 20'-High, 2H:1V, γ_s=120 pcf)	FOS (Global Stability)		
	c=0 ϕ=34°	c=100 psf ϕ=30°	c=500 psf ϕ=0°
No Surcharge	1.43 (+1%)	1.82 (+4%)	1.35
Infinite Uniform	**1.42**	**1.74**	**1.23**
Overall Contact	1.41 (-1%)	1.69 (-3%)	1.28
(½) Overall Contact	**1.43 (+1%)**	**1.75 (+1%)**	**1.31**
Infinite Strips (Overall Contact)	1.38 (-5%)	1.70 (-2%)	1.27
Infinite Strips (Max. Contact)	1.35 (-5%)	1.64 (-6%)	1.24
Infinite Line (Overall Contact)	1.38 (-3%)	1.67 (-4%)	1.27
Infinite Line (Max. Contact)	1.35 (-5%)	1.61 (-7%)	1.27

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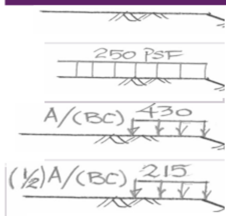

Surcharge Conditions (Slope 20'-High, 2H:1V, γ_s=120 pcf)	FOS (Global Stability)		
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Conclusions

Evaluate acceptability of a specific construction equipment based on results of stability analyses with 250 psf infinite, uniform strip load -

- **Reduce the Overall Contact Pressure by a factor of 2 (i.e., Considering extending the footprint 2x along the longitudinal direction of the slope), if ≤ 250 psf, OK**

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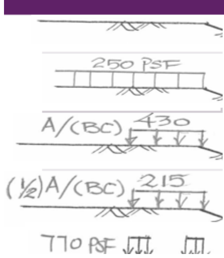

Surcharge Conditions (Slope 20'-High, 2H:1V, γ_s=120 pcf)	FOS (Global Stability)		
	c=0 ϕ=34°	c=100 psf ϕ=30°	c=500 psf ϕ=0°
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(½) Overall Contact	1.43 (+1%)	1.75 (+1%)	1.31
Infinite Strips	1.38 (-5%)	1.70 (-2%)	1.27

Conclusions

- **In determining the equipment acceptability, the factor of 2 reduction is applicable to c=0, c-ϕ, and ϕ=0 (conservative) Soils.**

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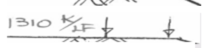
Surcharge Conditions (Slope 20'-High, 2H:1V, γ_s=120 pcf)		FOS (Global Stability)		
		c=0 ϕ=34°	c=100 psf ϕ=30°	c=500 psf ϕ=0°
	Infinite Strips (Overall Contact)	1.38 (-5%)	1.70 (-2%)	1.27
	Infinite Line (Overall Contact)	1.38 (-3%)	1.67 (-4%)	1.27

Conclusions

- **Not to apply extending the footprint 2x along the transverse direction of the slope.**

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CONCLUSION

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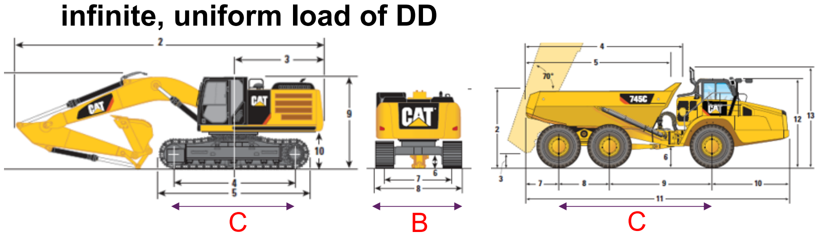
Modeling Hwy Traffic Surcharge

Perform a Conventional 2-D Analysis, using 250 psf infinite uniform loading to satisfy Provision requirements.

Acceptability of a Construction Equipment

- Max. operating weight (A)
- **Equivalent Surcharge** (DD) = (½)(A)/(BC)
- **IF DD ≤ 250 psf, OK**
- **IF DD > 250 psf, rerun 2-D analysis, assuming an infinite, uniform load of DD**



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➢ ***Keep a Simple Question Simple***

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Thank you!

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Acknowledgement: Atefeh Asoudeh, PE. PhD / AmecFW

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Q&A

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