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

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➔ Make a Complicated Question Simple ...

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

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➔ Make a Simple Question Complicated …
**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

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”? 

\[ q = 2.5 \text{ ft} (125 \text{ psf}) = 250 \text{ psf} \]

\[ F_2 = q \cdot h \cdot b = 250 \text{ psf} (2 \text{ ft}) (0.360) = 2.81 \text{ ksf} \]
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.

Common Cases
Conventional Construction Equipment
Common Cases
Conventional Construction Equipment

Special Cases
Self Propelled Modular Transporter (SPTM)
Methodology of Design Analysis

Rigorous Analytical (High-Tech) Approach
- Model Traffic Surcharge as an actual 3-Dimensional 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
Semi- Rigorous Approach

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

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 \( (DD) = \left(\frac{1}{2}\right) \frac{(A)}{(BC)} \) …… Why \( \left(\frac{1}{2}\right) \)?
• IF DD ≤ 250 psf, OK

Effects of Live / Traffic Surface Surcharge?

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

\[ \Delta \sigma_z = q_0 \frac{(BxL)}{(B+z)(L+z)} = \frac{P}{(B+z)(L+z)} \]

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

- Adopting similar concepts modeling the anchor load in 2-D

Stability Analysis:
- Use a factor of (\%5) to distribute the 3-D Loading for a 2-D analysis

References:
• 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 ft²
• Projection Surcharge = (72 kips/ 168 ft²) = 428 psf
• Equivalent Surcharge = \( \frac{1}{2} \times 428 \text{ psf} \) = 214 psf \( \approx 250 \text{ psf} \)

<table>
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<th>Surcharge Conditions</th>
<th>FOS (Global Stability)</th>
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<td>(Slope 20'-High, 2H:1V, ( \gamma ) = 120 pcf)</td>
<td>( c=0 ) ( \varphi=34^\circ ), ( c=100 \text{ psf} ) ( \varphi=30^\circ ), ( c=500 \text{ psf} ) ( \varphi=0^\circ )</td>
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<tr>
<td>No Surcharge</td>
<td>1.43 (+1%) 1.82 (+4%) 1.35</td>
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<td>Infinite Uniform</td>
<td>1.42 1.74 1.23</td>
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<td>Overall Contact</td>
<td>1.41 (-1%) 1.69 (-3%) 1.28</td>
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<td>( \frac{1}{2} ) Overall Contact</td>
<td>1.43 (+1%) 1.75 (+1%) 1.31</td>
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<tr>
<td>Infinite Strips (Overall Contact)</td>
<td>1.38 (-5%) 1.70 (-2%) 1.27</td>
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<td>1.35 (-5%) 1.64 (-6%) 1.24</td>
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<td>1.38 (-3%) 1.67 (-4%) 1.27</td>
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<td>1.35 (-5%) 1.61 (-7%) 1.27</td>
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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 \( \leq 250 \text{ psf} \), OK

### Table: FOS (Global Stability)

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- **Conclusions**

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

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

### 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 \( DD = \left(\frac{y_2}{y_1}\right)(A)/(BC) \)
- IF \( DD \leq 250 \) psf, OK
- IF \( DD > 250 \) psf, rerun 2-D analysis, assuming an infinite, uniform load of DD
Keep a Simple Question Simple

Thank you!

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Acknowledgement: Atefeh Asoudeh, PE, PhD / AmecFW
Q&A