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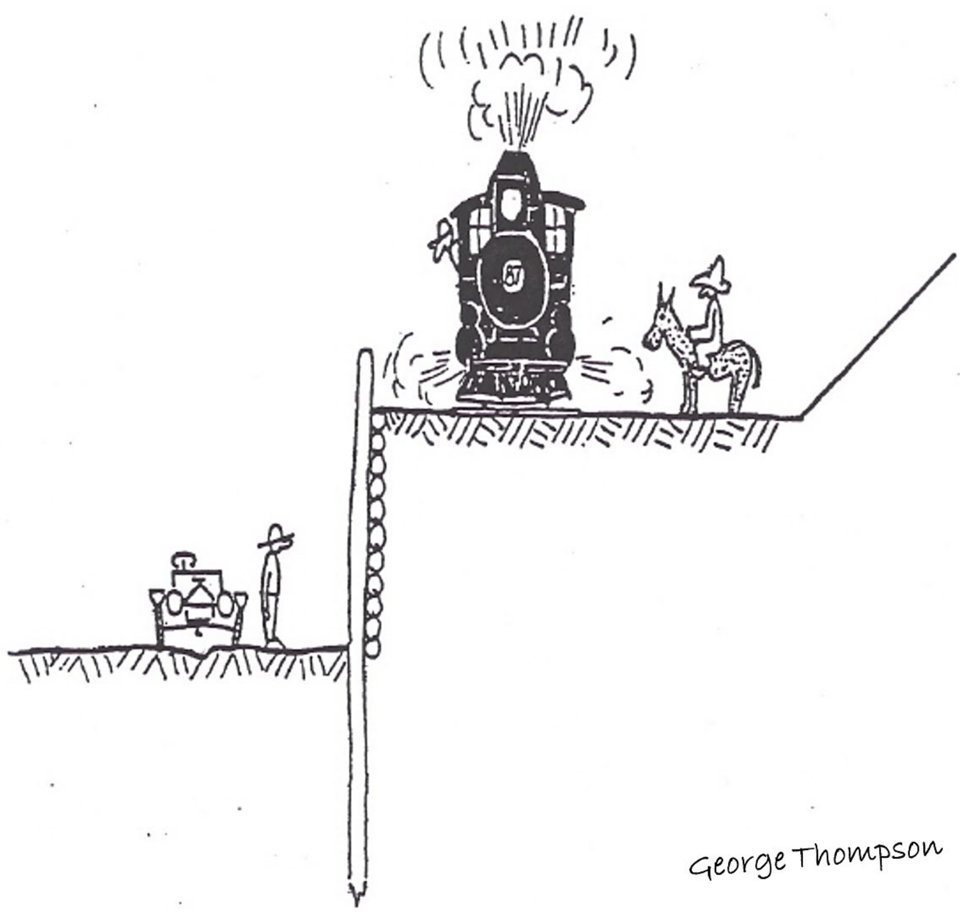
CHAPTER 5

SURCHARGES



Chapter 5: Surcharges

Table of Contents

5-1 Surcharge Loads

This chapter will present how to account for loads on the retained soil. There could be buildings, roadways, railroads, construction equipment, and/or materials adjacent to the excavation. There is a minimum surcharge that must always be applied. It is necessary for the Engineer to always consider a shoring system in relation to its surroundings as well as to the construction methods and equipment that will be implemented. Assumptions made with regards to these additional loads are best recorded on the shop drawings for the protective system.

A surcharge load is any load which is imposed upon the surface of the soil close enough to the excavation to cause a lateral pressure to act on the system in addition to the basic earth pressure. Groundwater will also cause an additional pressure, but it is not a surcharge load. Water is not classified as a surcharge load as it is a force acting against the sheets directly and not as a load acting on the soil retained by the shoring system.

5-1.01 Minimum Construction Surcharge Load

A minimum lateral construction surcharge of 72 psf (σ_h) must be applied to the shoring system. The Cal/OSHA tables account for a similar surcharge. This load must be applied to a minimum depth of 10 feet (**Hs**) below the uppermost level of the soil retained by the shoring system, as illustrated in Figure 5-1. This is the minimum surcharge loading that must be applied to any shoring system regardless of whether or not the system is actually subjected to a surcharge load. Surcharge loads which produce lateral pressures greater than 72 psf would be used in lieu of this prescribed minimum.

This surcharge is intended to provide for the normal construction loads imposed by small vehicles, equipment, materials, and workers in the area adjacent to the trench or excavation and should be added to all basic earth pressure diagrams. This minimum surcharge can be compared to a soil having parameters of γ = 109 pcf and **Ka** = 0.33 for a depth of 2 feet [(0.33)(109)(2) = 72 psf].

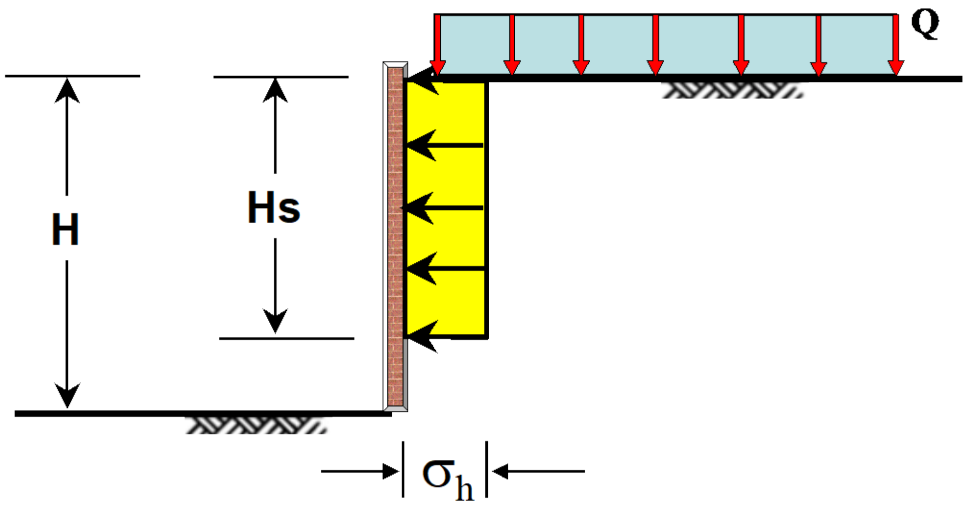


Figure 5-1. Minimum Lateral Surcharge Load

5-1.02 Uniform Surcharge Loads

Where a uniform surcharge is present, a constant horizontal earth pressure must be added to the basic lateral earth pressure. This constant earth pressure may be taken as:

$$\boldsymbol{\sigma_h} = (\mathbf{K})(\mathbf{Q}) \quad (5\text{-}1\text{-}1)$$

Where:

σ_h = Constant horizontal earth pressure due to uniform surcharge.

K = Coefficient of lateral earth pressure due to surcharge for the following conditions:

- Use **K_a** for active earth pressure.
- Use **K_o** for at-rest earth pressure.

Q = Uniform surcharge applied to the wall backfill surface within the limits of the active failure wedge.

5-1.03 Boussinesq Loads

Typically, there are three (3) types of Boussinesq Loads. They are as follows:

5-1.03A Strip Load

Strip loads are loads such as highways and railroads that are generally parallel to the wall.

The general equation for determining the horizontal pressure at distance, **h**, below the ground line may be referred to as the Wayne C. Teng equation (see Figure 5-2):

$$\boldsymbol{\sigma_h = \frac{2Q}{\pi}[\beta_R - \sin\beta\cos(2\alpha)]} \qquad (5\text{-}1\text{-}2)$$

Where $\boldsymbol{\beta_R}$ is in radians.

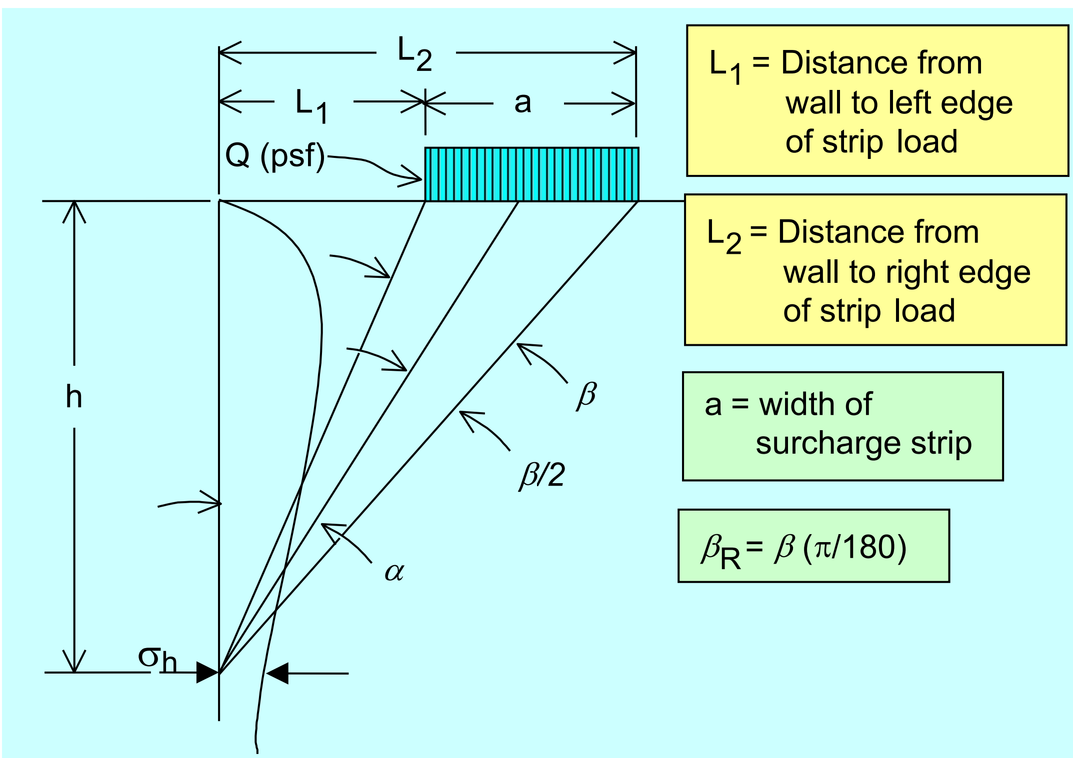


Figure 5-2. Boussinesq Type Strip Load

5-1.03B Line Load

A line load is a load such as a continuous wall footing of narrow width, or a similar load, generally parallel to the wall. K-railing could be considered to be a line load.

The general equation for determining the pressure at distance, **h** = **n·H**, below the ground line is (see Figure 5-3):

For **m** ≤ 0.4:

$$\boldsymbol{\sigma_h = \frac{Q_l}{H}\frac{0.2n}{(0.16+n^2)^2}} \tag{5-1-3}$$

For **m** > 0.4:

$$\boldsymbol{\sigma_h = 1.28\frac{Q_l}{H}\frac{m^2 n}{(m^2+n^2)^2}} \tag{5-1-4}$$

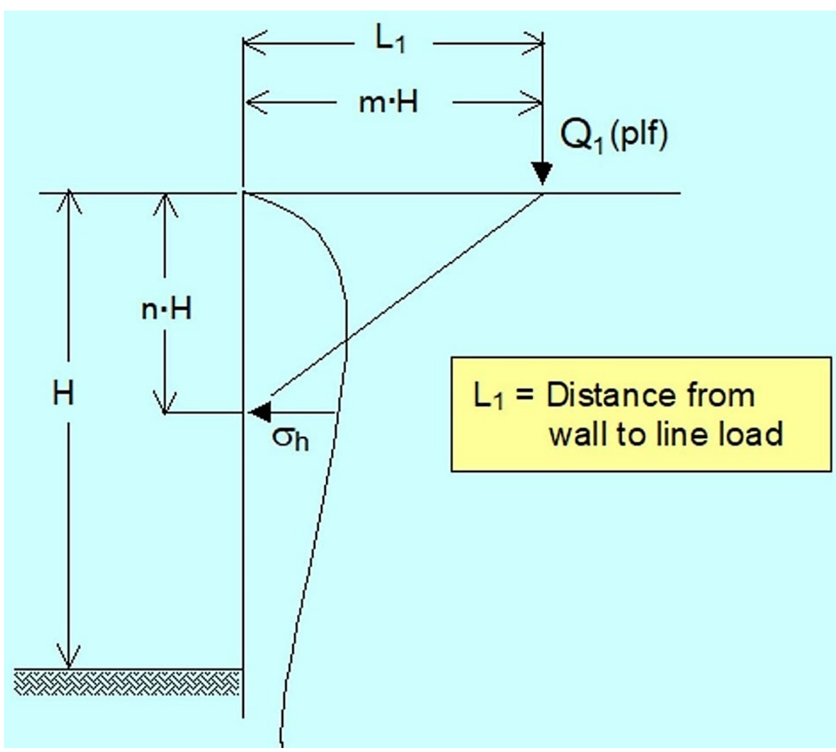


Figure 5-3. Boussinesq Type Line Load

5-1.03C Point Load

Point loads are loads such as outrigger loads from a concrete pump or crane. A wheel load from a concrete truck may also be considered a point load when the concrete truck is adjacent to an excavation and in the process of unloading. The truck could be positioned either parallel or perpendicular to the excavation.

The general equation for determining the horizontal pressure at distance, **h** = **n·H**, below the ground line is (see Figure 5-4):

For **m ≤ 0.4**:

$$\boldsymbol{\sigma_h = 0.28\frac{Q_p}{H^2}\frac{n^2}{(0.16+n^2)^3}} \qquad (5\text{-}1\text{-}5)$$

For **m > 0.4**:

$$\boldsymbol{\sigma_h = 1.77\frac{Q_p}{H^2}\frac{m^2n^2}{(m^2+n^2)^3}} \qquad (5\text{-}1\text{-}6)$$

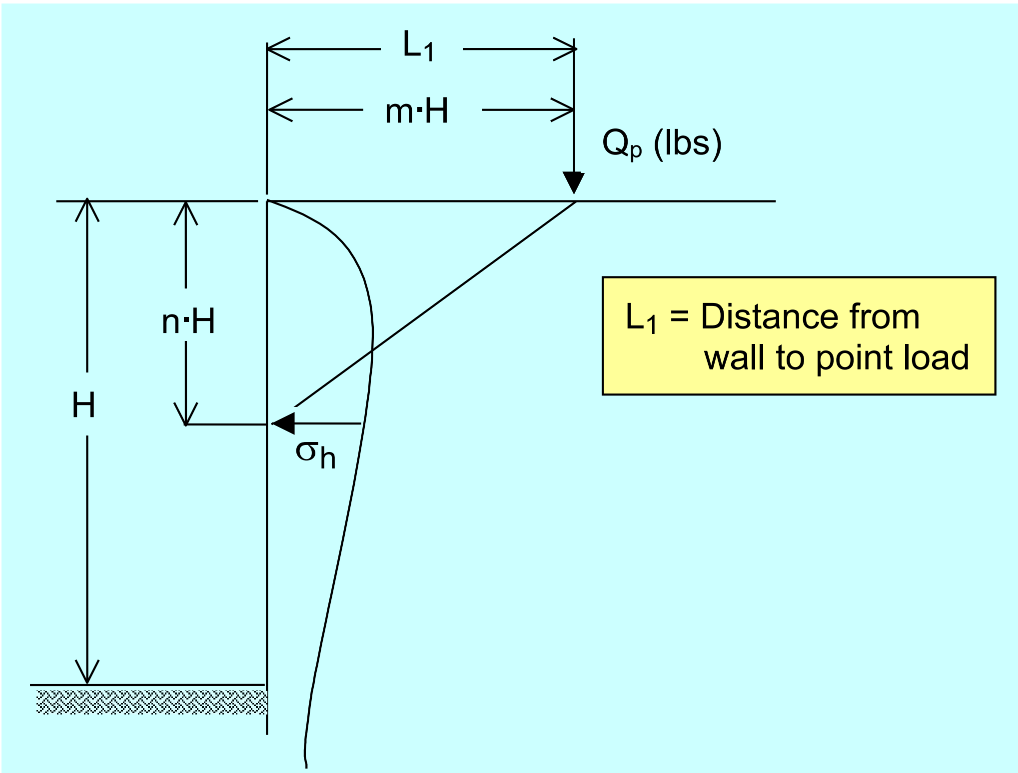


Figure 5-4. Boussinesq Type Point Load

In addition, σ_h is further adjusted by the following when the point is further away from the line closest to the point load (see Figure 5-5):

$$\sigma_h' = \sigma_h \cos^2[(1.1)\theta] \tag{5-1-7}$$

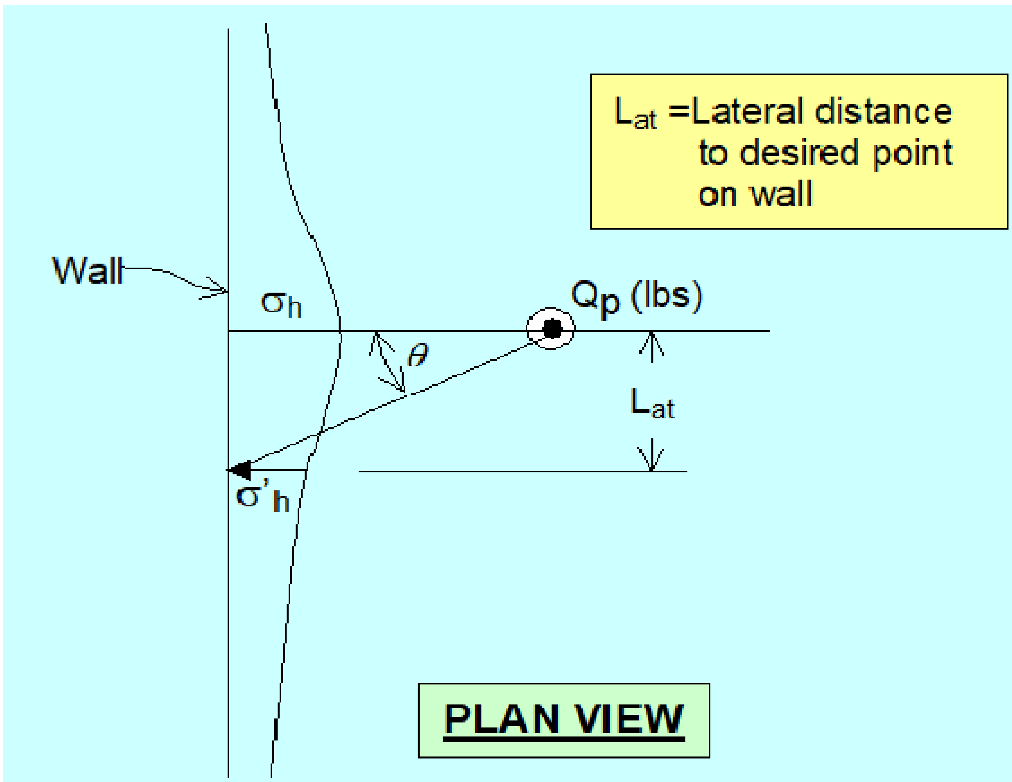


Figure 5-5. Boussinesq Type Point Load with Lateral Offset

5-1.04 Traffic Loads

Traffic near an excavation is one of the more commonly occurring surcharge loads. Trying to analyze every possible scenario would be time consuming and not very practical. For normal situations, a vertical surcharge load of 300 psf spread over the width of the traveled way should be sufficient.

The following example compares the pressure diagrams for a **Q** = 300 psf load (using the Boussinesq Strip method) and that of an HS-20 truck, using individual point loads from the tires centered in a 12-foot lane adjacent to the shoring, as illustrated in Figure 5-6. The total depth of excavation is 10 feet.

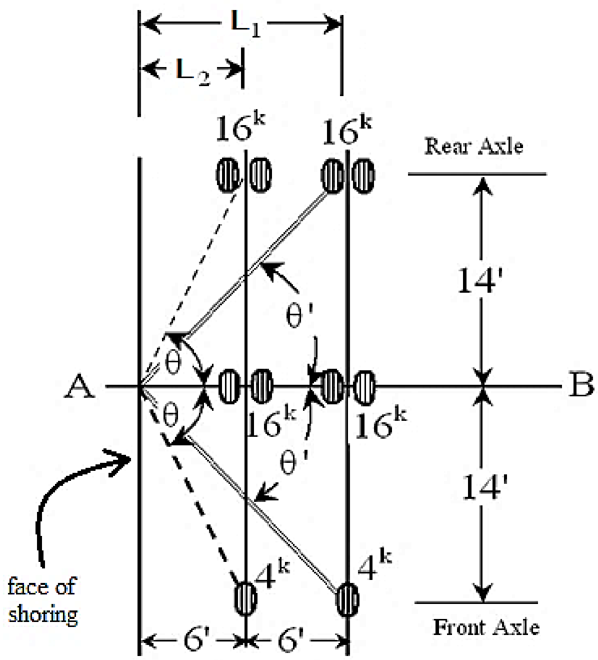


Figure 5-6. Example problem of HS-20 traffic loads adjacent to excavation

Solving to determine **n** for various depths (Table 5-1):

n = depth/H

Table 5-1. Values of 'n' for various depths

Depth	n
2'	0.2
4'	0.4
6'	0.6
8'	0.8
10'	1.0

$$\mathbf{L_1 = m_1 H \therefore m_1 = \frac{L_1}{H} = \frac{12}{10} = 1.2} \qquad (5\text{-}1\text{-}8)$$

$$\mathbf{L_2 = m_2 H \therefore m_2 = \frac{L_2}{H} = \frac{6}{10} = 0.6} \qquad (5\text{-}1\text{-}9)$$

Since **m** is greater than 0.4 in both cases, use Equation 5-1-6.

Since we are checking for the added load at the AB line, the adjustment for the horizontal angle must be calculated. For loads at an angle to AB, see Equation 5-1-7.

Horizontal adjustment:

Front and rear right wheels:

$$\theta = 66.8°, \therefore \cos^2[(1.1)(66.8°)] = 0.08 \qquad (5\text{-}1\text{-}10)$$

Front and rear left wheels:

$$\theta' = 49.4°, \therefore \cos^2[(1.1)(49.4°)] = 0.34 \qquad (5\text{-}1\text{-}11)$$

Now create the equations for each of the six-point loads:

Right rear wheels:

$$\sigma_h = \frac{(0.08)(1.77)(16{,}000)(0.6^2)(n^2)}{10^2(0.6^2 + n^2)^3} = 8.16n^2/(0.36 + n^2)^3 \qquad (5\text{-}1\text{-}12)$$

Left rear wheels:

$$\sigma_h = \frac{(0.34)(1.77)(16{,}000)(1.2^2)(n^2)}{10^2(1.2^2 + n^2)^3} = 138.7n^2/(1.44 + n^2)^3 \qquad (5\text{-}1\text{-}13)$$

Right center wheels:

$$\sigma_h = \frac{(1.77)(16{,}000)(0.6^2)(n^2)}{10^2(1.2^2 + n^2)^3} = 102.0n^2/(0.36 + n^2)^3 \qquad (5\text{-}1\text{-}14)$$

Left center wheels:

$$\sigma_h = \frac{(1.77)(16{,}000)(1.2^2)(n^2)}{10^2(1.2^2 + n^2)^3} = 407.8n^2/(1.44 + n^2)^3 \qquad (5\text{-}1\text{-}15)$$

Right front wheels:

$$\sigma_h = \frac{(0.08)(1.77)(4{,}000)(0.6^2)(n^2)}{10^2(0.6^2 + n^2)^3} = 2.04n^2/(0.36 + n^2)^3 \qquad (5\text{-}1\text{-}16)$$

Left front wheels:

$$\sigma_h = \frac{(0.34)(1.77)(4{,}000)(1.2^2)(n^2)}{10^2(1.2^2 + n^2)^3} = 34.7n^2/(1.44 + n^2)^3 \qquad (5\text{-}1\text{-}17)$$

Combine and simplify similar equations:

a) $$\sigma_H = \frac{8.16n^2}{(0.36 + n^2)^3} + \frac{102.0n^2}{(0.36 + n^2)^3} + \frac{2.04n^2}{(0.36 + n^2)^3} = \frac{(112.2)n^2}{(0.36 + n^2)^3}$$

$$\sigma_H = \frac{(112.2)(n^2)}{(0.36 + n^2)^3} \qquad (5\text{-}1\text{-}18)$$

$$\sigma_H = \frac{138.7n^2}{(1.44 + n^2)^3} + \frac{407.8n^2}{(1.44 + n^2)^3} + \frac{34.7n^2}{(1.44 + n^2)^3} = \frac{581.2n^2}{(1.44 + n^2)^3}$$

$$\sigma_H = \frac{(581.1)(n^2)}{(1.44 + n^2)^3} \qquad (5\text{-}1\text{-}19)$$

The following Table 5-2 will sum up the point load values at the 2-foot increments. The last column in the table uses the 300 psf surcharge tables in Appendix C, *Surcharges – Tabular Values*. The HS-20 truck was centered on the lane, thus the near edge of the lane is 3 feet away from the shoring. Hence the beginning of the 300 psf load is 3 feet away, and the far edge is 15 feet away. The resultant pressures at 2-foot increments are also illustrated in Figure 5-7.

Table 5-2. Summary of wheel point loads versus 300 psf traffic load

Depth (ft)	**n** from above	a) σ_H	b) σ_H	$\sum \sigma_H$	300 psf (from App. C)
0	0.0	0.0	0.0	0.0	0.0
2	0.2	70.1	7.2	77.3	150.1
4	0.4	127.7	22.7	150.4	171.5
6	0.6	108.2	35.9	144.1	149.3
8	0.8	71.8	41.3	113.1	121.4
10	1.0	44.6	40.0	84.6	96.4

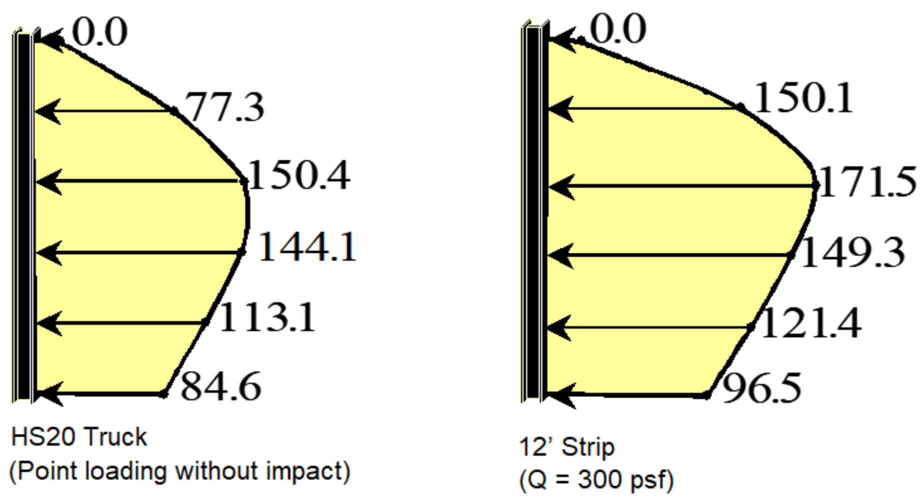


Figure 5-7. Plotted comparision of point loads versus 300 psf for traffic

Conclusion: Strip load of **Q** = 300 psf compares favorably to a point load evaluation for HS-20 truck loadings.

5-1.04A Example 5-1 Sample Problem – Surcharge Loads

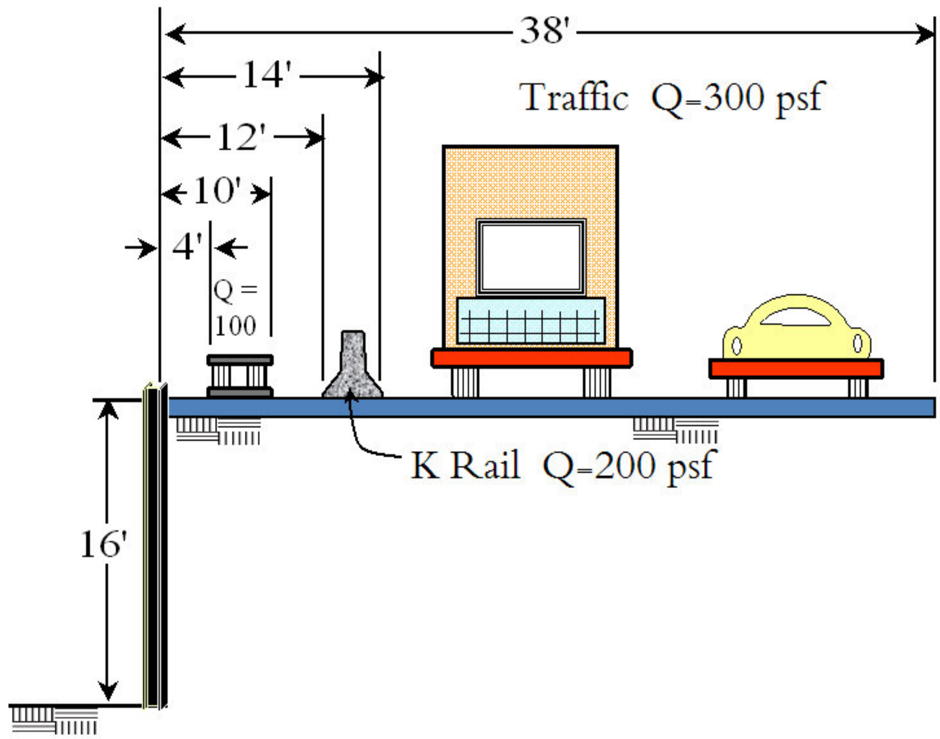


Figure 5-8. Surcharge Loads

Use the surcharge tables in Appendix C to determine the loading on the shoring at 2-foot increments for the three loadings illustrated above in Figure 5-8. The tables are set for a 300 psf surcharge; thus for the K-rail load of 200 psf, use 2/3 of the value in the table, and for the 100 psf load, use 1/3 of the tabulated value, as illustrated in Table 5-3.

Table 5-3. Surcharge Lateral Pressures (psf)

Depth (ft)	**Q** = 100	**Q** = 200	**Q** = 300	Sum
0.1	1.9	0.3	1.7	72*
2	30.2	5.8	33.8	72*
4	35.7	10.1	63.7	109.5
6	29.5	12.3	87.1	128.9
8	21.9	12.7	103.3	137.9
10	15.9	11.9	112.6	140.4
12	11.5	10.5	116.4	138.4
14	8.5	9.0	116.1	133.6
16	6.3	7.6	112.9	126.8

* Minimum construction surcharge load.

5-1.05 Alternate Surcharge Loading (Traffic)

An acceptable alternative to the Boussinesq analysis described above consists of imposing estimated surcharges behind the shoring system, such that the resulting pressure diagram is a rectangle extending to the computed depth of the shoring system and of a uniform width of 100 psf, as illustrated in Figure 5-9. Generally, alternative surcharge loadings are limited to traffic and light equipment surcharge loads. Other loadings due to structures, stockpiles of soil, materials, or heavy equipment will need to be considered separately.

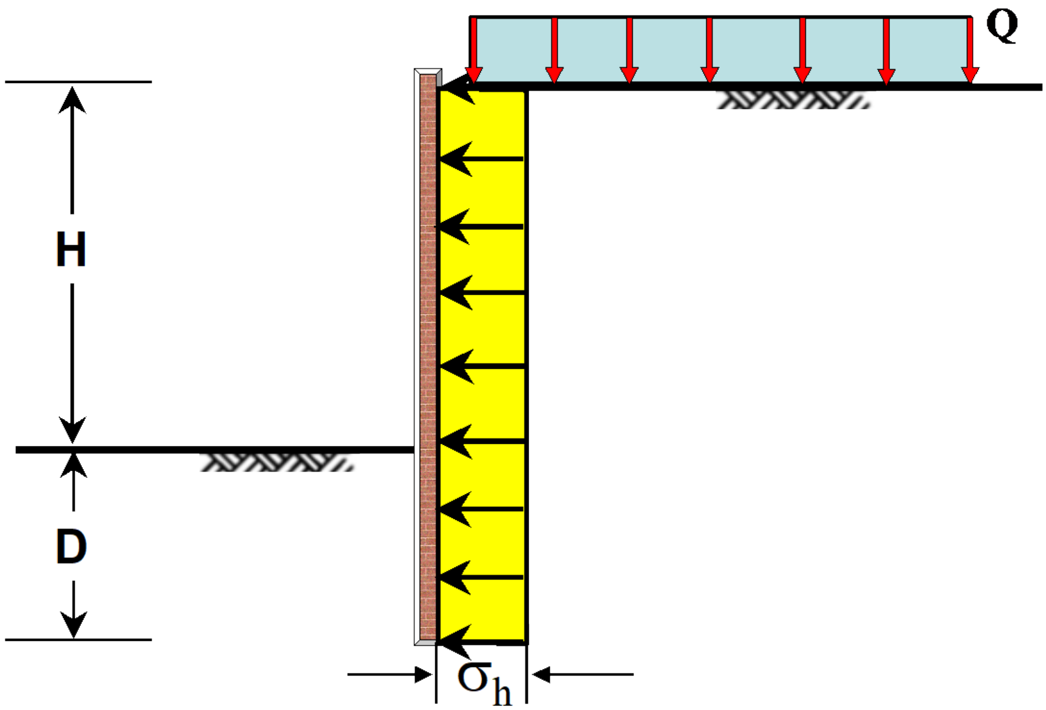


Figure 5-9. Alternate Traffic Surcharge Loading