Surcharge Load Approach

thread255-260153

InDepth (Structural) 1 Dec 09 17:43

Apparently Civil Tech Shoring Suite 8 uses the following methodology (see below). Key in on the fact that they take the strip loading surcharge and modify it to obtain area and point load surcharge. Is this methodolgy typically used in practice? I usually use the Terzaghi equations listed in the USS Steel Manual for point loads (modified by experiment & listed in almost every shoring manual).

I believe that the strip and area loading is based on elastic methods, while the USS Steel Manual equation for point loads accounts for the inelasticity of soil (modified by experiment).

There appears to be great differences between using the Civil Tech methodology and the USS Steel manual (Terzaghi)methodolgy. Any thoughts would be greatly appreciated.

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We use the following equations:

1. Pstrip = k* Q/pi * (beta-sin(beta)*cos(2alpha))

where k=1 for very flexible wall. k=2 for rigid wall

This equation can be found in P16 of USS manual. It is modified Boussinesq equation and widely used for shoring design. It called Wayne & Teng Equation. Wayne & Teng Equation is widely used in shoring design. We found that using Boussinesq equation to calculate Area Loading and Pint Loading do not match the results from strip loading calculation of Wayne & Teng Equation. We have to modify Wayne & Teng Equation for area loading to keep the results consistent.

Following are our equation:

2. Parea = f * Pstrip
Where f is length factor:
f = 1- 1/(0.25 * L/(X+1) +1)
L - length of area loading; X - Distance to the wall.
When L is infinitive, f = 1, Parea=Pstrip

We plotted curve from Boussinesq equation and use this curve to scale down to fit Wayne & Teng Equation. Then we get the above equation.

3. Ppoint = Parea when Length=1 and Width=1.

http://files.engineering.com/getfile.aspx?folder=ee3c1cea-6d03-4a55-bd0b-86

PEinc (Geotechnical) 1 Dec 09 18:44

Why don't you call James Su at CivilTech and discuss this with him?

www.PeirceEngineering.com

fattdad (Geotechnical) 2 Dec 09 9:06

There is not one ? in the OP. Is there some direct question related to other's approach to designing a surcharge?

f-d

¡papá gordo ain't no madre flaca!

InDepth (Structural) 2 Dec 09 13:13

I apologize for not providing a clear question. What I am after is an understanding/confirmation of the assumptions behind surcharge load equations. What are the assumptions behind the equations cited in the texts (USS Steel, Caltrans, NAVFAC, etc..)? Is it only the Terzaghi point load /line load surcharge case that has been modified by experiment? Did the strip load case never get modified by experiment and is it still an elastic solution?

Which equations assume (Point, Line, Strip, Area)
1) elastic medium or inelastic medium
2) rigid wall vs flexible wall
3) equations modified by experiment
4) backfill or natural soil
5) Soil/wall friction (some elastic solutions don't account for wall friction)

Based on my research you'll notice that the USS Sheet Pile Manual, Navfac DM, and Poulous and Davis reference are all the same equation for the strip loading surcharge case(for poulous multiply by 2 to get same result). You'll also note that all these strip load equations are based on elastic theory. To obtain this equation, the Boussinesq elastic solution was superimposed. The assumption was an infinite strip load in an elastic medium.

The point load and line load equation on pg 15&16 of USS Sheet Pile manual have been modified by experiment by Terzaghi. Thus, the modifications changed the shape of the Boussinesq to account for soil inelasticity. Unfortunately the strip loading solution provided in most texts was never modified to reflect soil inelasticity.

With this said, it appears that the Civil Tech software has an underlying assumption that the surcharge provided is based on elastic theory (nothing wrong with their approach).

fattdad (Geotechnical) 2 Dec 09 13:44

I've never used a software to design a surcharge. I have designed surcharges for different cases:

to minimize secondary compression (force aging).
to arrive at 90 percent primary consolidation quicker.
to force elastic compression prior to large areal loading.

In each case, I've used some version of Bousinesq or Westergard elastic solutions to arrive at the change in vertical effective stress with depth. Not sure one is better than the other, just used engineering judgement for that site condition.

Hope this helps.

f-d

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jdonville (Geotechnical) 2 Dec 09 15:55

InDepth,

The elastic solution (Boussinesq, Westergaard, etc) is conservative (assuming that you have your flexible vs rigid assumptions right), therefore safe.

BTW, when using ctShoring, I always use an area load - that way I can be sure that the loading area matches the pile spacing. Based on the proximity of the load to the top of the wall, you may also want to modify the elastic loading so that loads outside of the assumed failure wedge don't penalize you unduly.

J

rowingengineer (Structural) 3 Dec 09 2:09

sorry don't have the time to read everything so i may just be posting something stupid, but I believe the problem could be half space, take all at this link.

http://www.ejge.com/iGEM/Articles/FactorOf2/FactorOf2.htm

Arguing with an engineer is like wrestling with a pig in mud. After a while you realize that they like it

rowingengineer (Structural) 3 Dec 09 2:15

why is when you want to do things fast they always take a heap of time, PDF for those who want it.

Arguing with an engineer is like wrestling with a pig in mud. After a while you realize that they like it

http://files.engineering.com/getfile.aspx?folder=f11dd3e0-2f4d-4618-abc6-93

InDepth (Structural) 3 Dec 09 14:44

It's interesting, because EM 1110-2 indicates 1 for yielding walls and 2 for non-yielding walls. See attached.

jdonville, I like your points. I usually select elastic solutions for stiff shoring systems like diaphragm walls or secant walls with tightly spaced tiebacks. I select the Terzaghi (modified by experiment solutions) when dealing with soldier pile and lagging. i.e. Surcharge selection (and even earth pressure selection) should be stiffness based. Are there any papers or reserach on this?

Some engineers/softwares seem to use:
Boussinesq elastic solutions multiplied by 0.5 for flexible wall and 0.75 for semi-flexible walls and 1 for rigid.

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fattdad (Geotechnical) 3 Dec 09 16:39

If you are using an elastic solution to derive the change in horizontal effective stress and if you are then using these values to design loads acting on a retaining wall, you need to double the values.

My professor (J. M. Duncan) was clear on this and there was no wiggle room for whether it was the active case or whether it was the at-rest case. I'm talking about retaining walls, not temporary shoring systems.

f-d

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InDepth (Structural) 4 Dec 09 11:51

2 Questions:

1) Elastic solutions also have a shear component. Would you also double this shear component?

2) If the elastic solution provides stresses (horizontal and shear) that exceed the soils ultimate capacity, what would you do? Would you cap the elastic stress levels at the ultimate soil capacity....but then how would you achieve force equilibrium?

fattdad (Geotechnical) 7 Dec 09 9:48

You'd double the horizontal component of the shear force.

Not sure what you mean by "the soils ultimate capacity." Not trying to be dense, but the soil's ultimate capacity is determined by shear strength and if you are designing a shoring system or a retaining wall, you are already dealing with soil strength and shear capacity. Your structure will make up any force deficate and allow for the safety factor.

f-d

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EJGE/Magazine *i*GEM Article

The *Factor of Two* Question

by

Mete Oner

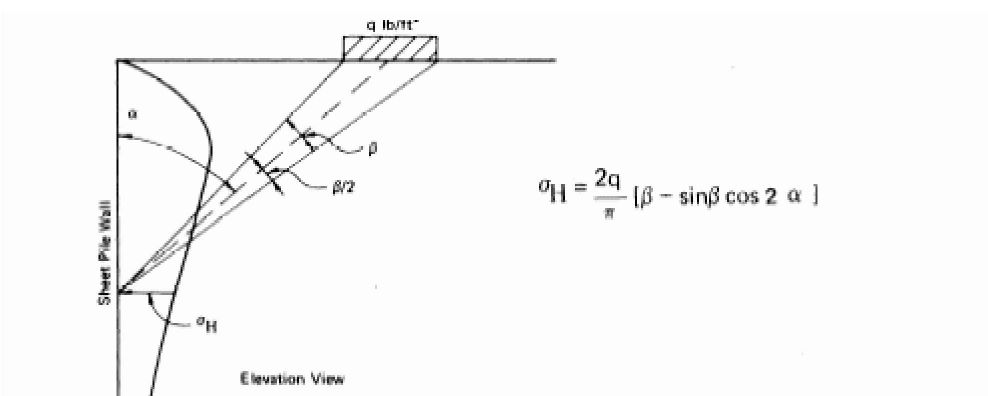
In designing a retaining wall, the engineer naturally considers all the likely forces that will affect it. One of these forces is the additional lateral earth pressure due to surcharge loads acting over the backfill soil (whether it is actually *backfilled* or not we still call it that).

Although it is generally agreed that elastic solutions can be used for calculating these additional lateral earth pressures, there is a controversy about how this should be done. Specifically, should we use the equations given by the theory directly or apply a factor of two as some think?

Why is there such a question in the first place? It is because there are both theoretical and experimental facts about it. This article intends to clarify these and provide the answer once and for all.

Controversy?

Is there really such a wide discrepancy for such a simple question? USS (US Steel) uses the factor of two in their sheet pile design manual (Figure 1).



Lateral pressure due to strip load (Boussinesq equation modified by experiment) (after Teng[1])

Figure 1. USS (US Steel) sheet pile design manual recommendation

On the other hand the popular sheet pile design/analysis program CWALSHT by W. P. Dawkins does not apply the two factor (Figure 2). This program is distributed by US Army Engineer WES. He follows the recommendation found in the last edition of the (otherwise excellent) Foundation Engineering book by J. Bowles.

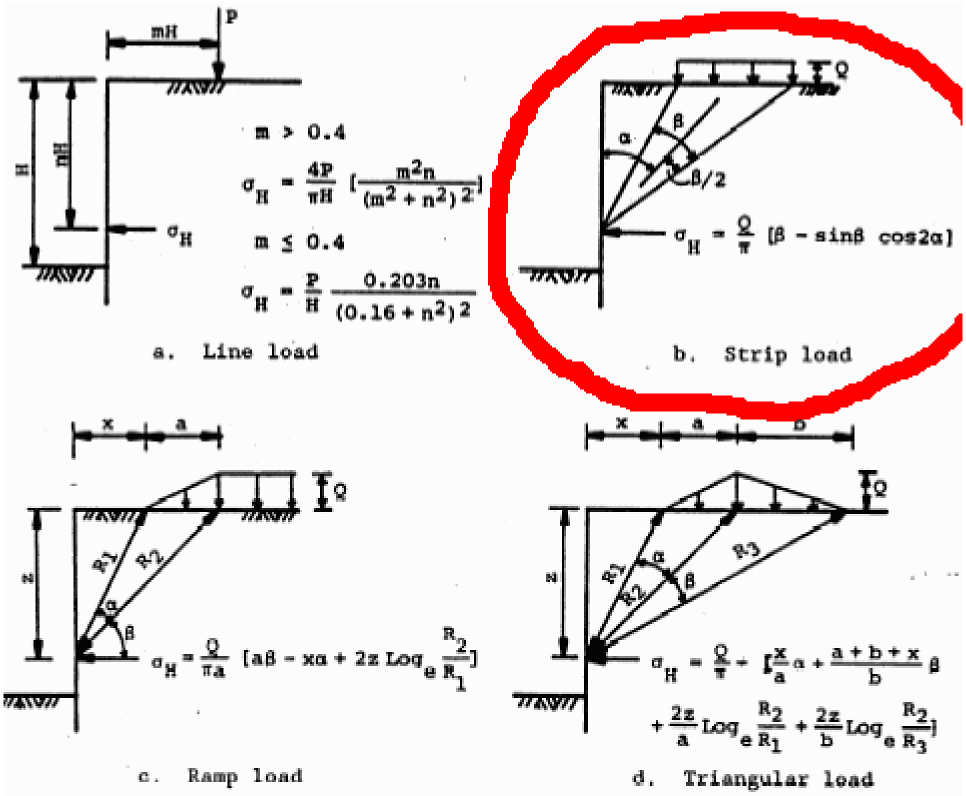


Figure 4. Theory of elasticity equations for pressures on wall due to surcharge loads

Figure 2. The original elastic stresses are used by the CWALSHT *without the factor of two*.

All of these sources are quite reputable. So Mr. Michael Lecomte of Deerfield Beach, FL, like many other alert engineers before him, asked the question *do I apply the factor of two or not?*

So the question is still there. I have become familiar with it when my good friend Dr. Ergun of METU was building a huge sand box with a wall next to it covered with stress cells. He explained to me that someone reported measuring wall stresses twice as large as the elastic theory predicts. This happened way back in 20th Century in one of the early World Conferences of Soil Mechanics and Foundatiion Engineering (I think the very first one), when Mindlin (who gave us the fundamental point-load solutions for a buried force) jumped up yelling "of course" and explained it with an "imaginary mirror load" model.

Dr. Ergun found the same factor of two with his tests.

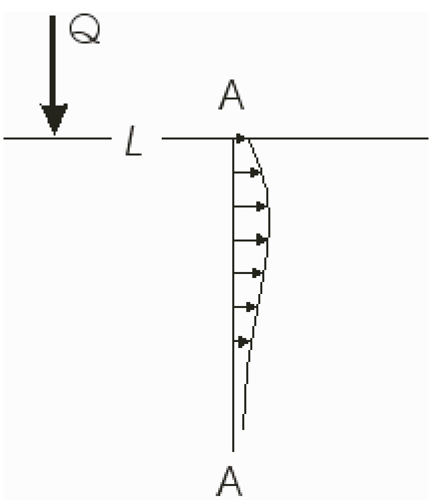
But Why a Factor of Two?

In one of my funny T/F test questions I said "it is because the theory is so wrong, and soils are not even elastic" to which many students agreed! The fact is the theoretical solutions are for an elastic half space (i.e., infinite in both horizontal directions), not one restricted by a wall, especially so close to the load, and where we are interested in the stresses.

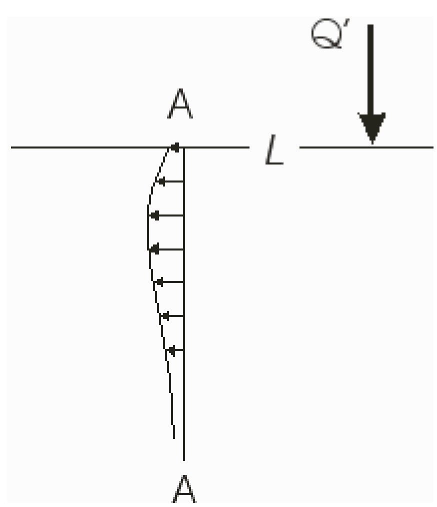
Consider the problem of a point load on an elastic half space Figure 1 (*a*) (Boussinesq problem). The theory of elasticity is based on *linear* differential equations. Before you start yawning, I will tell you that that is exactly what makes superposition possible: In case you forgot, a fundamental theorem is that

> If a function *f* is a solution of a linear differential equation and another function *g* is independently another solution, then any linear combination of *f* and *g*
>
> $$c_1 f + c_2 g$$
>
> is also a solution. This is what makes the integration of Boussinesq solution for any load shape, as well as other superpositions we routinely do, legitimate.

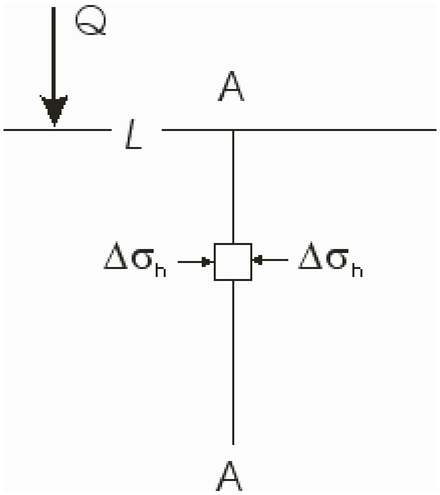
Now, in Figure 3, (*a*) shows the actual point load *Q*, and (*b*) shows another point load, *Q*' as Mindlin imagined. A-A is a vertical plane, at some arbitrary distance *L* from the load, where we consider the stresses and displacements due to these two loads.



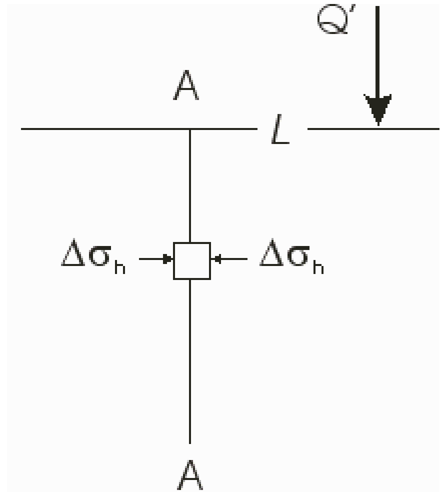
(*a*) Displacement of the vertical plane A-A due to load Q



(*b*) Displacement of the vertical plane A-A due to load Q'



(*c*) Stresses on the vertical plane A-A due to load Q



(*d*) Stresses on the vertical plane A-A due to load Q'

Figure 3. The horizontal stresses and displacements over a vertical plane in an elastic half space due to a vertical load on the surface.

Now compare the effects of the actual load *Q* and the imaginary mirror load *Q*'. Notice that

- The displacements are in the opposite direction, comparing (*a*) and (*b*), but
- Both stresses are *compression*, comparing (*c*) and (*d*).

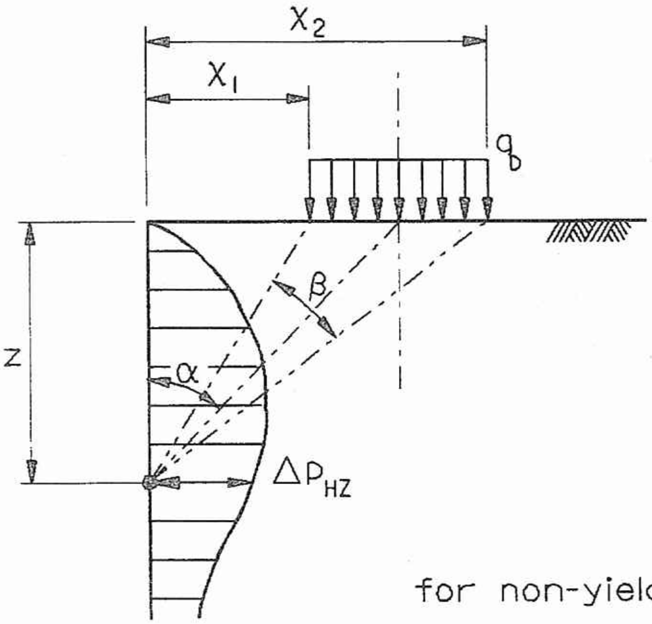
This means that if the two forces were acting together, solutions could be superposed leading to a condition where the displacements would cancel each other, while the stresses would double. Therefore, if the two loads were acting together, our plane A-A would not move. It means that if we were to remove all the material from the right side of the plane A-A, while still maintaining its position, the material on the other side of the plane would not even "know" about it. To maintain the A-A plane in position though, we would have to provide the support equal to twice the stresses due to *Q* alone. So this represents a rigid boundary simulating a rigid retaining wall.

Again by virtue of the *linearity* of the differential equation as explained above, this conclusion is valid not just for a point-load, but to all other load shapes for which solutions are obtained by integration of the point-load solution.

One Last Note

To correct the blunder in CWALSHT you have to apply the factor of two yourself, before feeding it to the program.

And if you have designed a wall with CWALSHT and it is still standing, thank God for his grace.



$$q = \frac{V}{(X_2 - X_1)}$$

for non-yielding walls:

$$\Delta P_{HZ} = \frac{2q}{\pi}\left(\beta - \sin\beta \ \cos 2\alpha\right)$$

for yielding walls,
(walls at failure):

$$\Delta P_{HZ} = \frac{q}{\pi}\left(\beta - \sin\beta \ \cos 2\alpha\right)$$

β in radians

$$\beta = \tan^{-1}\left(\frac{X_2}{z}\right) - \tan^{-1}\left(\frac{X_1}{z}\right)$$

$$\alpha = \tan^{-1}\left(\frac{X_2 + X_1}{2z}\right)$$

Figure 3-27. Increase in pressure due to strip load