Method for Predicting Foundation Stability for Equipment Placed on Grade in a Seafloor Environment

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Abstract – When a piece of equipment is placed directly on the seafloor, it is often important that its position and orientation remain stable. Depending on its characteristics and the seafloor soil properties, the item might slide, tilt or settle excessively. The analytical tools currently available in geotechnical engineering practice do not fully address the behavior of such an object in the seafloor environment, especially regarding the unusually soft and varied surface soils commonly found there.

A method was developed to predict this behavior. It incorporates elastic and plastic (bearing capacity failure) soil deformations, and includes accounting for a varying soil shear strength profile. It requires only knowledge of the shear strength profile, using an approximation for the soil's elastic modulus that was developed from published data. Results appear reasonable, but remain to be confirmed by comparisons with actual observations. The method is particularly useful for predicting the tilting stability of items placed on a very soft surface layer overlying stronger deeper layers.

I. INTRODUCTION

A. Settlement

Excessive settlement (sinkage into the seafloor) might create a problem for the function of bottom-placed equipment, or might make locating and recovering it difficult. The total settlement might be elastic only, but for heavy objects on weak soil, it can also include plastic settlement due to bearing capacity failure. Elastic settlement occurs by continuous elastic deformation of the soil, with no slip planes and no sinkage of the object relative to the immediately adjacent soil. For objects having a comfortably high safety margin against on-grade bearing capacity failure, elastic settlement is relatively low, and its prediction is normally not of primary importance. In contrast, plastic settlement (after bearing capacity failure) involves slip planes and significant downward displacement of the object relative to the adjacent soil. When plastic settlement occurs or is imminent, the possibilities of excessive tilting and sliding also should be addressed..

The basic principle used to estimate plastic settlement is the bearing capacity relationship for the object on/in the soil. The bearing capacity of soil to support a given object depends on soil strength, buoyant density, and the depth of the base of the object. The depth effect acts to increase the bearing capacity, and the soil strength typically increases with depth, also increasing the bearing capacity. If the object weight is great enough and the soil strength is small enough, bearing capacity failure will occur as the object weight is applied to the soil on grade, and will continue as the bearing capacity increases due to increasing depth of penetration until it is sufficient to support the weight.

B. Tilting

A single object (as opposed to a foot of a structure such as a tripod, e.g.) placed on a seafloor that is soft enough to allow sinkage due to bearing capacity failure will be unstable in tilting when its center of gravity is high enough and the strength of the seafloor soil does not increase fast enough with depth of penetration. Similarly, when on-grade bearing capacity is adequate, but with a relatively low safety margin, such an object might be unstable against elastic tilting. Furthermore, potential for tilting is exacerbated by the actions of currents and non-horizontal seafloors (especially important when the center of gravity is high relative to the base width). As the toppling of an object might impair its functioning or associated operations, the prediction of stability against tilting due to elastic and plastic soil deformations is often of primary importance.

The basic principle used to estimate tilting stability is the balance of forces and moments applied by the object to the seafloor with the soil reactions produced by combined settlement and tilting displacements. The object base is divided into small strip footing elements running perpendicular to the tilting direction, strip settlements are related to a trial object settlement-tilt combination, soil reactions to the strip settlements are calculated, and a combined reaction force and moment are calculated from the strip soil reactions. The calculated combined reactions are used to adjust the trial object settlement-tilt combination and the process is repeated until the calculated reactions match the trial inputs. For a stable configuration, the soil reaction moment builds as the trial tilt angle is increased, until a match is found. Significantly, this process includes accounting for the effect of a high center of gravity adding to the overturning moment as the trial tilt is increased; when this causes the overturning moment to build faster than the soil reaction moment, the configuration is predicted to be basically unstable.

C. Sliding

On a slope and/or in a current, an object might slide. Depending upon the object, such sliding might impair its function or associated operations, so prediction and prevention become important.

The basic principle in predicting stability against sliding is that the soil shear strength acting on the base and, for embedded objects, the soil passive resistance acting against the leading edge (bulldozing resistance) must be sufficient to resist the forces acting to cause sliding. For an object that is embedded, and especially when its base is textured to key into the seafloor, the soil shear strength at the depth of the base is assumed to act on the entire base area. On the other hand, for an object on grade and preceding bearing capacity failure, the unevenness of the seafloor is assumed to preclude full contact, so the contact area and hence the sliding resistance are proportional to the applied normal force, with an effective friction coefficient typically near 0.2. Such predictions may be made relatively independently from settlement and tilting predictions, except insofar as the latter are needed to determine the embedment depth (which determines the soil strength and bulldozing depth).

II. RELATIONSHIPS USED IN CALCULATIONS

A. Elastic Settlement

Elastic settlement is obtained using the expression given in [1], as

$$s_e = \{F_b{*}C_s/L\} * \{(1-\nu^2)/E\} \qquad (1a)$$

where s_e = elastic settlement, ft
F_b = footing bearing force, lb (commonly equal to wet weight)
L = footing length, ft
C_s = shape factor, a function of L/B
B = footing width, ft
ν = Poisson's ratio
= 0.5, a constant value for most saturated soils
E = elastic secant (Young's) modulus, psf

Values of C_s given in [1] for rigid rectangular footings on an elastic half-space for L/B = 1, 2, 5 & 10 are 0.82, 1.12, 1.6 & 2.0, respectively. They may be approximated by the expression

$$C_s = 1.46 * \log(L/B + 2/3) + 0.5 \qquad (1b)$$

Because it is usually difficult to obtain elasticity data for seafloor soils, an expression for Young's modulus was sought in terms of shear strength and strain. Data from [1] and [2] were fitted with a curve given by the expression

$$E = S_u / \{C_o + \varepsilon^{p\varepsilon}\} \qquad (2a)$$

where S_u = cohesive soil shear strength, psf
C_o = initial value of S_u/E,
ε = soil strain
$p\varepsilon$ = exponent of strain

The best conservative fit is for an initial S_u/E value and an exponent of

$$C_o = 0.00625 \quad \text{and} \quad p\varepsilon = 4/3 \qquad (2b)$$

In these expressions, the modulus and the strain are taken as effective average values, as affecting footing behavior, representative of the strain field beneath the footing. The strain was determined as a multiple of footing displacement, with a proportionality constant chosen to match the elastic reaction force at failure with the portion of bearing capacity (Equation 5) due to soil strength. The resulting proportionality is

$$\varepsilon = s_e / (R_\varepsilon * B * C_s * N_e) \qquad (3)$$

where $R_\varepsilon = \{C_o/(p\varepsilon-1)+C_o\}*(1-\nu^2) / (C_o/(p\varepsilon-1))^{(1/p\varepsilon)}$
$= (0.00625{*}3 + 0.00625){*}(0.75) / (0.00625{*}3)^{3/4}$
$= 0.37$
L = footing length, ft
N_e = effective S_u-related bearing capacity factor for cohesive soils
$= Q_{bs} / (S_u{*}B{*}L)$
Q_{bs} = bearing capacity due to soil strength acting on base and sides

The corresponding conditions at bearing capacity failure (where the slope of the F_b vs ε curve is zero) are

$$\varepsilon_f = \{C_o / (p\varepsilon-1)\}^{(1/p\varepsilon)} = (0.00625 * 3)^{3/4} = 0.0507 \qquad (4a)$$

$$s_{ef} = \varepsilon_f * R_\varepsilon * B * C_s * N_e = 3 * C_o * B * C_s * N_e = 0.01875 * B * C_s * N_e \qquad (4b)$$

These relationships are explicit for determining bearing force, but implicit for determining elastic settlement. That is to say, one can enter Equation 3 with a specified settlement to obtain a strain and then use Equations 2 to obtain a modulus and a rearrangement of Equations 1 to obtain the bearing force. On the other hand, one must know the modulus to obtain a settlement from the force using Equations 1, and one must know the strain to obtain the modulus from Equations 2, and one must know the settlement (which is being sought) to obtain the strain from Equation 3. If the force is known and the elastic settlement is sought, the latter process may be used iteratively. If, however, one is specifying settlement as part of the tilting analysis process (as described below in "Combined Settlement and Tilting"), these equations are usable for obtaining soil reactions explicitly.

B. Plastic Settlement

Plastic settlement (sinkage into the seafloor, when object weight exceeds on-grade bearing capacity) is determined as the depth at which the bearing capacity is just sufficient to support the submerged weight of the object. The bearing capacity of a soil for an object is calculated in accordance with standard geotechnical engineering practice according to the expression given in [1] as

$$\begin{aligned} Q_b = {} & S_u{*}B{*}L{*}N_c{*}S_c{*}d_c \\ & + S_u/S_t{*}2{*}(B+L){*}(s_p+s_o) \\ & + \gamma_b{*}(s_p+s_o){*}B{*}L{*}N_q{*}S_q{*}d_q \\ & + 0.5{*}\gamma_b{*}B{*}B{*}L{*}N_\gamma{*}S_\gamma{*}d_\gamma \end{aligned} \qquad (5)$$

where S_u = soil shear strength
B = object base width
L = object base length
N_c, N_q, N_γ = bearing capacity factors for cohesion, overburden, and density
S_c, S_q, S_γ = shape factors for cohesion, overburden, and density
d_c, d_q, d_γ = depth factors for cohesion, overburden, and density
S_t = soil sensitivity = ratio of undisturbed to remolded strength
s_p = plastic settlement
γ_b = buoyant density of soil

For purely cohesive soils, these parameters have the following values, per [1]:

N_c = 2 + pi = 5.14
N_q = 1
N_γ = 0
S_c = 1 + (N_q/N_c)*(B/L) = 1 + (B/L)/5.14
S_q = 1
S_γ = 1 – 0.4*(B/L)
d_c = 1 + 0.4 * arctan{$(s_o+s_p)/B$}
d_q = 1
d_γ = 1

where s_o = initial depth of object base

For soft cohesive seafloor soils, the following approximate values may be used:

S_t = 3
γ_b = 20 pcf

These relationships allow the bearing capacity to be determined explicitly, given a specified value of plastic settlement. However, they are implicit in plastic settlement, and cannot be easily rearranged to obtain an explicit form for determining plastic settlement. When required, they may be solved iteratively to obtain plastic settlement for a given value of bearing force.

C. Combined Settlement and Tilting

As discussed in the introduction, the analysis of stability against tilting is addressed in an iterative process involving:

- the specification of trial values of object settlement and tilting,
- the calculation of individual settlements for small strips comprising the object base,
- the determination of soil reactions on these strips using the relationships given above for elastic and plastic settlements,
- the calculation of the combined soil reaction force and moment on the object, and
- the adjustment of the input settlement and tilt values in repeat trials until the calculated reactions match the applied loads.

The tilting stability analysis process is detailed in Table 1. Also in this table are numerical calculations and results for example objects on soft cohesive seafloors, selected to illustrate the nature of tilting stability, as discussed below.

An object having its center of gravity located high relative to its base width can exhibit adverse stability behavior on soft seafloors. Behavior varies from the most stable, stiffest seafloor to unstable seafloors as follows:

- For a stiff seafloor, the elastic modulus is so high that the restoring moment caused by elastic tilting quickly builds to exceed the moment produced by the weight being off-center due to the elastic tilting, as well as any applied tilting moment.
- For a more compliant seafloor, the elastic reaction (restoring) moment builds more slowly, making it less capable of sustaining applied moments.
- For an even more compliant seafloor, having a modulus that is too small, the elastic reaction moment builds too slowly to sustain even the moment caused by eccentricity due to elastic tilting.

Three selected examples show this succession of behaviors for increasingly compliant seafloors. They are based on a rectangular prismatic solid block (centers of gravity and buoyancy at its geometric center) weighing 13,000 lb in seawater, with dimensions 4 ft wide by 8 ft long, by 6 ft high. The density of seawater is assumed to be 64 pcf, and the hydraulic drag coefficient is assumed to be 1.0. In all cases, the soil is assumed to have a shear strength gradient of 10 psf/ft and a submerged density of 40 pcf. The elastic modulus varies with the surface shear strength. The results of the stability analysis process for these examples are in Figure 1.

In the first case, the highest surface shear strength of 1 psi (144 psf) renders the block stable on slopes up to 12.5 deg with no current and up to 10.1 deg with a current of 2 kt, and on flat seafloors with currents up to 4.6 kt. In the second case, the surface shear strength of 0.75 psi (108 psf) supports the lesser slope of 8.3 deg with no current and 5.9 deg with a current of 2 kt, and the maximum current on a flat seafloor is 3.7 kt. In the third case, the surface shear strength of 0.47 psi (68 psf) is just sufficient for elastic stability with no slope or current (or any other perturbations), and any lesser surface shear strength renders the block elastically unstable (i.e. it will topple with infinitesimal perturbation, much as if it were sitting on a knife edge). Note that the factors of safety against bearing capacity failure (nonzero plastic settlement) for these on-grade examples are approximately 2.3, 1.8 and 1.2 for Cases 1 through 3 respectively; i.e. the block is stable against bearing capacity failure in all three cases, as well as for soils slightly weaker than Case 3.

The determination of these maxima involves multiple trials involving the balance between overturning and restoring moments. Under less-than-maximum conditions, the iteration process proceeds from a small trial elastic tilt angle and converges to the elastic tilt angle at equilibrium. If successively greater angles are tried, the restoring moment exceeds the overturning moment by an amount that first increases, then peaks, and then decreases; it eventually reaches zero again at a second equilibrium position, beyond which the block tilts catastrophically. (Also, there is a negative value of tilt angle that produces equilibrium, with the weight eccentricity balancing the applied moments.) As the maximum condition (current speed, e.g.) is approached, the two equilibrium points become increasingly close together, and at the maximum condition, they are one point. If the maximum condition is exceeded, equilibrium cannot be achieved at any positive value of elastic tilt angle. Thus, in all cases, the determination of maxima must be confirmed by repeating the calculation process for a slightly larger value of either the seafloor slope or the current speed and obtaining a negative value for the elastic tilt angle at equilibrium.

These results show that, even though the block does not cause a bearing capacity failure, a tilting instability is to be expected due to the moderately high center of gravity and the low modulus of the soil at a loading nearing bearing capacity failure. A lower center of gravity, with the same submerged weight and base dimensions, would produce stability on a weaker seafloor.

D. On-Grade Sliding

For an object that has a substantial margin of safety against plastic settlement, the area of soil in contact with the base is approximately proportional to the bearing force, as

$$A_c = B * L * F_b / Q_b$$

Also, the sliding resistance is a direct function of the soil shear strength and the contact area, as

$$Q_{so} = S_u * A_c$$

Combining these expressions with Equation 5, evaluated on-grade with so = sp = 0 and d_c = 1, and for purely cohesive soil with N_γ = 0, gives the sliding resistance as

$$Q_{so} = F_b / \{ N_c * S_c \} \qquad (6)$$

Thus, on-grade sliding may be viewed as a frictional phenomenon, with the friction coefficient equal to the ratio of Q_s/F_b; its value for a long strip footing (S_c=1) is nearly 0.20 (=1/5.14), and for a square footing is nearly 0.13 (=1/(1.5*5.14)). The resistance given by Equation 6 is compared with the applied lateral loads to determine the stability of an object against sliding in a specified environment of current and slope (irrespective of seafloor shear strength, so long as bearing capacity has not been exceeded).

E. Embedded Sliding

For an object base that has reached bearing capacity failure, either at the surface or with some penetration, the entire base area acts against the shear strength of the soil (a rough surface with full adhesion is assumed). To this force must be added the passive soil resistance (bulldozing resistance) of the leading edge of the object, which is computed as twice the product of the swept area and average soil shear strength; the result, for sliding perpendicular to the long axis of the object, is

$$Q_{sh} = S_{uh} * B * L + 2 * S_{ua} * L * h \qquad (7)$$

where S_{uh} = soil shear strength at object base
S_{ua} = soil shear strength average over leading face
h = depth to object base = $s_o + s_p$

The resistance given by Equation 7 is compared with the applied lateral loads to determine the stability of an object against sliding in a specified environment of current, slope, and seafloor shear strength.

References

[l] Fang, H.-Y. (ed.), Foundation Engineering Handbook, 2^{nd} ed. Van Nostrand Reinhold, New York, 1991.

[2] Lambe, T.W. and Whitman, R.V., Soil Mechanics. John Wiley & Sons, New York, 1969.

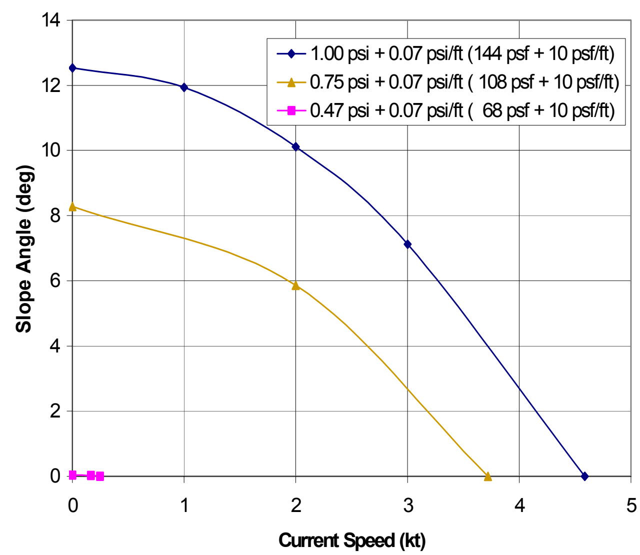

Figure 1. Maxima for 40 pcf Soil.

Table 1. Calculation Flow: a. main flow.

Parameter	Symbol	(units)	Relationship	Example
---OBJECT CHARACTERISTICS:				
Overall Height	H	(ft)	input	6
Overall Width	B	(ft)	input	4
Overall Length	L	(ft)	input	8
Number of Strip Footing Elements	ns		input	10
Strip Footing Element Width	Bs	(ft)	=B/ns	0.4
LOAD PARAMETERS:				
Wet Weight	Wb	(lb)	input	13000
CG Height	hc	(ft)	input	3
Current CP Height	hh	(ft)	input	3
Current Speed	v	(kt)	input	2
Slope Angle	be	(deg)	input	5.8655
Hydraulic Drag Coefficient	Cd		input	1
Current Force	Fh	(lb)	=gamw/2/g*v^2*H*L	531.789
Equiv Nor Force	Fn	(lb)	=Wb*cos(be)	12931.9
Equv Tang Force	Ft	(lb)	=Fh+Wb*sin(be)	1328.52
---SOIL PROPERTIES & PARAMETERS:				
Surface Shear Strength	Suo	(psf)	input	108
Shear Strength Gradient	Suz	(psf/ft)	input	10
Sensitivity Strength Ratio Undisturbed/Remolded	St		input	3
Friction Angle	phi	(deg)	input	0
Poisson Ratio	nu		input	0.5
Buoyant Density	gm	(pcf)	input	40
Cohesion BC Factor	Nc		input	5.14159
Burden BC Factor	Nq		input	1
Friction BC Factor	Ngm		input	0
Depth Burden Factor	dq		input	1
Depth Friction Factor	dgm		input	1
Elastic Strain Power	pe		input	1.33333
Elastic Strain Constant	Co		input	0.00625
Failure Strain	epsf		={Co/(pe-l)}^(l/pe)	0.05067
Elastic Strain Factor	Rep		=(epsf^pe+Co)*(l-nu^2)/epsf	0.37004
Elastic Shape Factor	Cs		= 1.46*log(L/B+2/3)+0.5	1.12191
Shape Cohesion Factor	Sc		= 1 +(Nq/Nc) *(B/L)	1.09725
Shape Burden Factor	Sq		=1+(B/L)*tan(phi)	1
Shape Friction Factor	Sgm		=1-.4*(B/L)	0.8
Stress from Friction	Sgg	(psf)	=.5*B*gm*Ngm*Sgm*dgm	0
Effective Cohesion BC Factor, Initial	Neo		= Nc*Sc	5.64159
Overall Failure Depth, Initial	Defo	(ft)	= epsf *B*Cs*Rep*Neo	0.4747

Parameter	Symbol	(units)	Relationship	Example
---START OF ITERATION CALCULATIONS:				
Initial Assembly Depth	Do	(ft)	input	0.1176
Previous Assembly Depth	Dh	(ft)	=Di, control=1, Di not=Dh	0.11764
Previous Force Excess	delFh	(lb)	=delFi, control=1, delFi>0	-9E-11
Current Assembly Depth	Di	(ft)	=Dj, control=1, Di not=Dh	0.11764
Initial Assembly Tilt	To	(deg)	input	4.8199
Previous Assembly Tilt	Th	(deg)	=Ti control=1, Ti not=Th	4.81994
Previous Moment Excess	delMh	(ft*lb)	=delMi, control=1, delMi>0	-2E-07
Current Assembly Tilt	Ti	(deg)	=Tj, control=1, Ti not=Th	4.81994
---IMPOSED MOMENT CALCULATIONS:				
Weight Moment	Mw	(ft*lb)	=hc*sin(Ti+be)*Wb	7231.26
Hydraulic Moment	Mh	(ft*lb)	=Fh*hh	1595.37
Total Tilt Moment	Mt	(ft*lb)	=Mw+Mh	8826.63

---ELEMENT CALCULATIONS ARE INSERTED HERE				

---END OF ITERATION CALCULATIONS:				
Current Reaction Force	Fi	(lb)	=sum(Fe)	12931.9
Current Force Excess	delFi	(lb)	=Fi-Fn	-9E-11
New Assembly Depth	Dj	(ft)	=Di-delFi*(Di-Dh)/delFi-delFh), Di not=Dh	0.11764
Current Restoring Moment	Mi	(ft*lb)	=sum(Me)	8826.63
Current Moment Excess	delMi	(ft*lb)	=Mi-Mt	-2E-07
New Assembly Tilt	Tj	(deg)	=Ti-delMi*(Ti-Th)/(delMi-delMh), Ti not=Th	4.81994
Total BC Force	Qb	(lb)	=sum(Qbe)	22988.6
FS for BC	FSbc		=Qb/Fn	1.77766

Table 1. Calculation Flow: b. element flow.

Parameter	Symbol	(units)	Relationship	Example									
---ELEMENT CALCULATIONS:													
Element Number	ne		input	1	2	3	4	5	6	7	8	9	10
Standoff to Center	x	(ft)	={ne-(ns +1)/2} *B/ns	-1.8	-1.4	-1	-0.6	-0.2	0.2	0.6	1	1.4	1.8
Elastic Tilt Displacement	he	(ft)	=x*sin(Ti)	-0.1512	-0.1176	-0.084	-0.0504	-0.0168	0.0168	0.05041	0.08402	0.11763	0.15124
Element Depth	De	(ft)	=Di+he	-0.0336	1.6E-06	0.03361	0.06722	0.10083	0.13444	0.16805	0.20166	0.23527	0.26888
Plastic Element Displacement	Dep	(ft)	=max(0,De-Def)	0	0	0	0	0	0	0	0	0	0
Strength Ratio	Rs		=Su(Dep)/Su(Dep+B)	0.72973	0.72973	0.72973	0.72973	0.72973	0.72973	0.72973	0.72973	0.72973	0.72973
Effective Depth Ratio for Strength Mobilization	Rz		=0.243*{1+(Rs+0.0025)^(1/3)}	0.46202	0.46202	0.46202	0.46202	0.46202	0.46202	0.46202	0.46202	0.46202	0.46202
Effective Bearing Depth	Ds	(ft)	=Dep+B*Rz	1.84809	1.84809	1.84809	1.84809	1.84809	1.84809	1.84809	1.84809	1.84809	1.84809
Shear Strength	Su	(psf)	=Suo+Suz*Ds	126.481	126.481	126.481	126.481	126.481	126.481	126.481	126.481	126.481	126.481
Depth Cohesion Factor	dc		=1+0.4*atan(Dep/B)	1	1	1	1	1	1	1	1	1	1
Equivalent Soil Stress on Side	Sss	(psf)	=(Su/St)*(Dep/B)*2*(1+B/L)	0	0	0	0	0	0	0	0	0	0
Equivalent Soil Stress on Base	Ssb	(psf)	=Su*Nc*Sc*dc	713.554	713.554	713.554	713.554	713.554	713.554	713.554	713.554	713.554	713.554
Tot Equiv Base Soil Stress fm Shear Strength	Ss	(psf)	=Sss(>0)+Ssb	713.554	713.554	713.554	713.554	713.554	713.554	713.554	713.554	713.554	713.554
Base Soil Stress fm Burden	Sd	(psf)	=De*gm*Nq*Sq*dq	0	6.4E-05	1.34446	2.68885	4.03325	5.37764	6.72203	8.06643	9.41082	10.7552
BC Force	Qbe	(lb)	=(Ss+Sd+Sgg)*Bs*L	2283.37	2283.37	2287.67	2291.98	2296.28	2300.58	2304.88	2309.18	2313.49	2317.79
Effective Shear Strength-Related BC Factor	Ne		=Ss/Su	5.64159	5.64159	5.64159	5.64159	5.64159	5.64159	5.64159	5.64159	5.64159	5.64159
Element Failure Depth	Def	(ft)	=epsf*B*Cs*Rep*Ne	0.4747	0.4747	0.4747	0.4747	0.4747	0.4747	0.4747	0.4747	0.4747	0.4747
Element Elastic Displ	Dee	(ft)	=min(De,Def); >0	0	1.6E-06	0.03361	0.06722	0.10083	0.13444	0.16805	0.20166	0.23527	0.26888
Elastic Strain	epse		=Dee/B/Cs/Rep/Ne	0	1.7E-07	0.00359	0.00718	0.01076	0.01435	0.01794	0.02153	0.02511	0.0287
Elastic Modulus	E	(psf)	=Su/(Co+epse^pe)	20236.9	20236.9	18602.2	16568.3	14662.3	12989.4	11555.4	10335.3	9297.28	8411.21
Current Element Force	Fe	(lb)	=Dee*L/Cs*E/(1-nu^2)/ns+(Sd+Sgg)*Bs*L	0	0.03121	598.761	1067.5	1418.52	1677.52	1867.78	2007.4	2109.78	2184.65
Current Element Moment	Me	(ft*lb)	=Fe*x	0	-0.0437	-598.76	-640.5	-283.7	335.505	1120.67	2007.4	2953.69	3932.38