FOUNDATION ANALYSIS FOR STRUCTURES USED IN RESOURCE MANAGEMENT SYSTEMS

Engineering Field Handbook Amendment IA36 dated October, 1988, and titled "Foundation Analysis for Structures used in Resource Management Systems" presents discussion on the factors involved in determining soil bearing capacity and settlement. It provides simplified methods to estimate these two design considerations.

The information presented in this Amendment has been reviewed and while it is not being updated, it is being re-issued because the discussion and procedures are still valid.

These procedures may be used for low hazard structures. Soil mechanics analysis for moderate or high hazard structures should have a detailed analysis performed by a person with soil mechanics expertise.

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Definitions

Parentheses ( ) will be used to group terms.

A dot "•" will be used to indicate multiplication.

B	Footing width.
Bearing capacity	The maximum footing pressure that can be permitted on a soil, giving consideration to all pertinent factors.
c	Total unit cohesion, psf.
$\bar{c}$,bar c	Effective unit cohesion, psf (sometimes written c').
Cc	Compression index.
Cr	Recompression index.
Consolidation	Reduction in the volume of a <u>soil</u> due to increased loading.
e	Void ratio, volume of voids divided by the volume of solids.
g	Footing shape factor for the shallow bearing capacity equation.
Gs	Specific gravity of the soil grains.
γ,gamma	Unit weight of soil, pcf.
k	Footing shape factor for the shallow bearing capacity equation.
N	Blow count. The number of blows with a 140 lb hammer dropped 30 in required to drive a standard sampler 1 ft.
Nc,Nq,Nγ	Bearing capacity factors from figure 4-3S.
po	The before construction soil load at the center of a strata or increment.
Δp	The increase in load on a soil at the center of a strata or increment.

(EFM, Amend. IA-36, Oct. 1988)

ϕ, phi	Total angle of internal friction of a soil.
$\bar{\phi}$, bar phi	Effective angle of internal friction of soil (Sometimes written ϕ').
q	The overburden pressure at the base of a footing.
qa	Allowable bearing capacity, usually qult/3.
qult	Ultimate bearing capacity. (Computed bearing capacity with no factor of safety).
R/C	Reinforced concrete.
Settlement, S	Downward movement of a structure due to soil consolidation.

Settlement, allowable- The maximum settlement or maximum differential settlement that will not cause structure malfunction.

Settlement, differential- The difference between the settlement at two points on a structure.

Settlement, total- The sum of the immediate and long term settlements at a given point on a structure foundation.

Settlement, uniform- The same total settlement at all points on a structure foundation.

Shallow Footing- A footing whose depth below the ground surface is less than or equal to its width.

W, W' Water table elevation correction factors for use in the shallow bearing capacity equation.

Soil Bearing Capacity and Settlement

When designing animal waste storage and other conservation structures, a foundation's bearing capacity must be determined. Standard structure drawings will often call for a minimum soil bearing capacity, such as, 2,000 pounds per square foot. However, referring to a soil bearing capacity is a gross oversimplification. Structures must be designed so the loadings will not cause the soil beneath the footing to fail by shear, and settlements will not distress the structure. Foundation design is more often controlled by settlement than by soil shear strength.

Bearing capacity is determined by three soil factors;

Shear strength

Compressibility

Water table elevation

And three structure characteristics;

Foundation size and shape

Foundation depth

The structures' ability to settle without distress

Bearing Capacity Equation

Bearing capacity equations have been developed for both sand and clay soils based on theoretical analyses and model tests. The equation described below applies to shallow footings. Foundations for structures used in resource management systems will usually fit the definition for shallow footings. A shallow footing's depth below the ground surface is equal to or less than the footing's width. Footings that do not meet this criteria because their depth is greater than their width may still be conservatively designed by assuming the footing depth equal to the width.

For Class V or smaller structures the shallow bearing capacity equation is recommended when sizing footings for failure against shear. The equation is given below and in the appendix, Part A. Part A includes a sketch and definitions of the terms.

$$q_{ult} = (g \cdot c \cdot N_c) + (q \cdot N_q) + (k \cdot \gamma \cdot B \cdot N_\gamma)$$

qult = Ultimate Bearing Capacity. (The maximum unit loading a soil can support without failing in shear.)

Nc, Nq, and N_γ are bearing capacity factors. They are given in Appendix A, Table 4-3S. They depend on the $\bar{\phi}$ or ϕ soil strength parameter.

The first term in the equation is (g • c • Nc). For continuous linear footings, such as for walls, g = 1.0 and for square and round footings, such as for columns, g = 1.3. the c is the cohesion ($\bar{c}$ or c) soils strength parameter. This term accounts for the cohesive strength of the soil.

The second term is (q • Nq). q is the load per unit area (lb per sq. ft) on a horizontal plane beside the footing at the footing bottom elevation. This term accounts for the effect of overburden confining the soil beneath the footing. In some cases this term accounts for a major portion of the computed ultimate bearing capacity. Even small, 1 to 2-foot, backfill depths can be significant with noncohesive soils. In the case of eccentric loadings caused by a backfilled wall with an empty tank or a loaded tank with little backfill, both empty tank and full tank conditions may need to be checked to find the most critical case.

The third term is ($k \cdot \gamma \cdot B \cdot N\gamma$). k is dependent on the footing shape. γ is the unit weight of soil below the footing. Use moist soil weights. B is the footing width. Notice the value of the third term is directly proportional to the footing width. This term represents the frictional shearing strength of the soil beneath the footing.

Footing size for the soil bearing equation is measured on each structurally independent unit. The "B" for precast retaining wall units used as structure walls with a poured concrete floor is the B of each unit. Units set in line to form a continuous wall should be treated as a continuous footing rather than separate rectangular footings. However, when estimating settlement, the total loaded area must be considered because part of the load from one unit is spread to the soil beneath adjacent units and contributes to their settlement.

If the water table is at a distance of more than "B" below the footing bottom, then it does not affect bearing capacity. If the water table is between the bottom and depth B below the footing, the $(k \bullet \gamma \bullet B \bullet N\gamma)$ factor must be modified by adding a water table correction factor W'. The third term is then $(W' \bullet k \bullet \gamma \bullet B \bullet N\gamma)$. If the water table is above the bottom of the footing, then the term $(q \bullet Nq)$ must also be corrected by adding W. The second term is then $(W \bullet q \bullet Nq)$. W' and W can be read from figure 4-1S.

WATER TABLE CORRECTION FACTORS

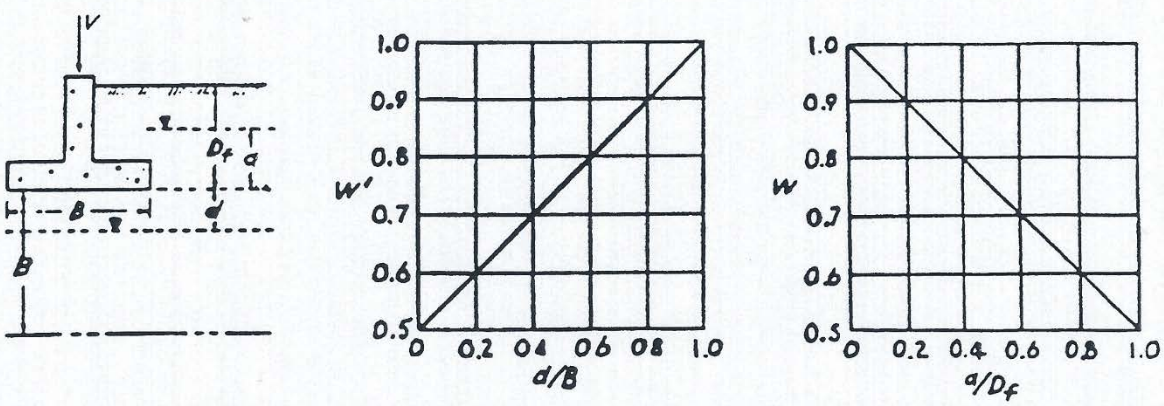


FIGURE 4-1S

(EFM, Amend. IA-36, Oct. 1988)

Settlement

Two settlement conditions must be considered. They are uniform settlement and differential settlement.

Total settlement is the sum of immediate and long-term settlements at a given point on the structure foundation. If all points in the foundation have the same total settlement, the structure settles uniformly. Since settlement is uniform, uneven stresses are not created in the structure.

Most structures can withstand fairly large uniform settlement, especially if the potential settlement is anticipated and provisions are made for it in design. Uniform settlement can cause problems such as: shearing or malfunction of loading and unloading conduits and fixtures and disruption of surface and subsurface drainage.

Even very small differential settlements can cause structural damage such as cracking of concrete, opening of joints, and bending and dimpling of steel structures. Part B of the Appendix contains a chart of allowable settlements for various structure types.

Any loading of the soil causes settlement due to (a) relocation and consolidation of the soil particles, and (b) movement of water and/or air from the void spaces. Conversely, any excavation or structure removal unloads the underlying soil so that new loads will cause only small settlements until the reloading exceeds the previous load. Soils that have not been previously loaded greater than at present are called "normally consolidated." Soils previously subjected to greater loadings than present are called "overconsolidated" or "preconsolidated".

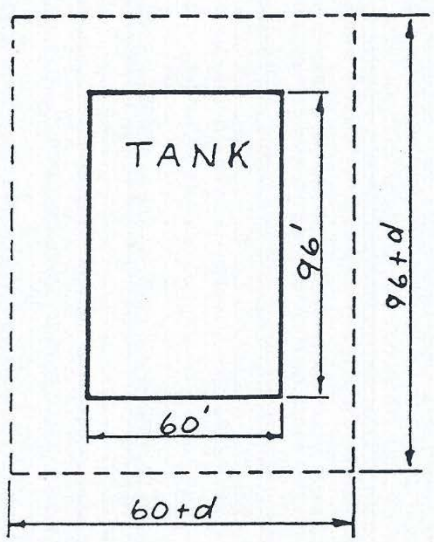
Loads on certain compressible soils can cause significant consolidation to a depth where the weight of the imposed load is 10% of the existing overburden pressure. This can be quite deep. Figure 4-2S page 4-46 gives an example of the computation of this depth. Settlements will be large in soft fine grained soils and in low density sands. Rock, dense tills, gravels, and highly overconsolidated fine grained soils will have few or no settlement problems.

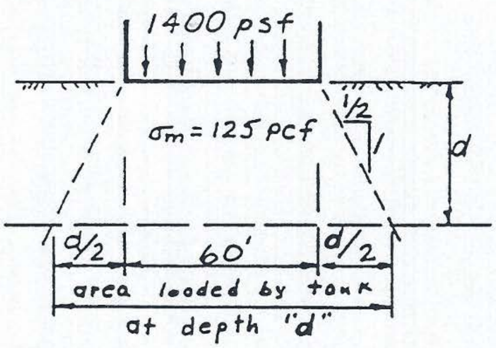
Extensive geologic investigation, sampling, and testing are required to reliably estimate settlement. However, depending on the soil and the characteristics of the structure, settlement may be reasonably estimated using the methods and guidelines described in the Appendix. These methods should not be applied to high hazard structures or where soil characteristics outlined in the Appendix can not be reasonably estimated. Rationale for determining the significance of the settlement and estimated values should be documented in the design file.

Differential settlements occur when foundation soils are not uniform and/or when loadings are nonuniform and under large flexible foundations and floors on compressible foundations. Relatively small differential settlements (1 to 2 inches) will cause distress in many structures especially concrete structures. When total settlement is large, a high potential for large differential settlement usually exists. It is important to select uniform foundation soil conditions and to keep loading uniform. For example, it would be poor practice to place a structure partially on rock and partially on a compressible soil. Also, a foundation should not be constructed partially on a dense till and partially on a compressible alluvium. Where compressible soils occur in a foundation, an investigation must be adequate to assure the compressible material is of uniform depth. In some situations sampling and testing may be required. Examples of loadings and resultant settlements are given in the Appendix.

Depth of Significant Consolidation

A 60 ft by 96 ft rectangular animal waste storage tank sets on the ground surface. When loaded, it exerts 1400 pounds per square foot (psf) on the foundation soil. The foundation soil weighs 125 pcf. It is deep to the water table. Assume the load spreads at a slope of 1/2:1. At what depth is the load imposed by the loaded tank less than 10% of the existing over-burden pressure?





Compute the total Wt. of the tank and contents.

Wt = Area • Wt/unit area

= (60'•96')•1400 psf

Wt = <u>8,064,000</u> lb

Compare the imposed load and existing overburden pressure at depth "d".

try d = 45 ft

Compute imposed load

$\Delta\sigma$ = Wt / area

$\Delta\sigma$ = 8064,000/(60+d)•(96+d)

$\Delta\sigma$ = <u>545 psf</u>

Compute overburden pressure at "d"

σ_o = 125 pcf • 45 ft

σ_o = <u>5625 psf</u>

Compare $\Delta\sigma$ with σ_o

$(\Delta\sigma/\sigma_o)\cdot 100 = (545/5625)\cdot 100$

$(\Delta\sigma/\sigma_o)\cdot 100$ = <u>9.7% < 10%</u>

<u>At 45 ft depth the imposed load becomes less than 10% of the overburden</u>

Figure 4-2S

(EFM, Amend. IA-36, Oct. 1988)

APPENDIX

PART SUBJECT

A The Shallow Bearing Capacity Equation................4-48

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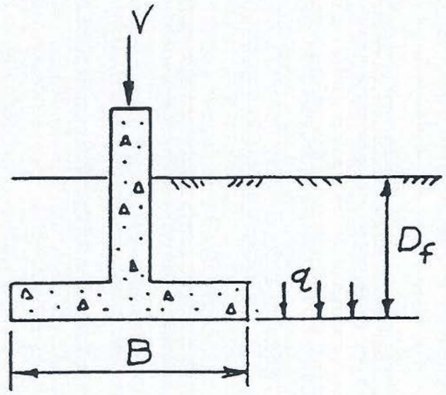
(EFM, Amend. IA-36, Oct. 1988)

PART A

THE SHALLOW BEARING CAPACITY EQUATION



$Df < B$

$$qult = (g \cdot c \cdot N_c) + (W \cdot q \cdot Nq) + (W' \cdot k \cdot \gamma \cdot B \cdot N_\gamma)$$

qult = Ultimate Soil Bearing Capacity

qa = qult/3 = Allowable Bearing Capacity

$\bar{c}$ or c = Soil Cohesion Parameter

$\bar{\phi}$ or ϕ = Soil Friction Parameter

g & k   Footing Shape Factors

Continous Footing	g = 1.0, k = 0.5
Square Footing	g = 1.3, k = 0.4
Round Footing	g = 1.3, k = 0.3

Df= Depth of Footing

γ= Soil Unit Weight

q = $Df \cdot \gamma$, Effective Vertical Soil Pressure

B = Footing Width

Nc, Nq, $N\gamma$ = Bearing Capicity Factors

W, W' = Watertable Correction Factors

(EFM, Amend. IA-36, Oct. 1988)

BEARING CAPACITY FACTORS

ϕ	Nc	Nq	N_γ
0	5.7	1.0	0.0
5	6.7	1.4	0.2
10	8.0	1.9	0.5
15	9.7	2.7	0.9
20	11.8	3.9	1.7
25	14.8	5.6	3.2
30	22.6	11.1	8.5
35	48.0	32.8	35.2
40	95.7	81.3	100.4

Figure 4-3S

This chart lists local shear factors for $\phi < 28^\circ$, general shear factors for $\phi > 38^\circ$, and interpolates between local and general factors between $\phi = 28^\circ$ & $\phi = 38^\circ$.

IA4-33(15)

(EFM, Amend. IA-36, Oct. 1988)

PART B

MAXIMUM ALLOWABLE SETTLEMENT .
for
STRUCTURES USED IN RESOURCE MANAGEMENT SYSTEMS
(Maximum Settlement In Inches) 1/

STRUCTURE TYPE	WIDTH OR DIAMETER FEET 20	40	60	80	100
1	0.5	1.0	1.5	2.0	2.5
2	0.7	1.5	2.0	3.0	3.5
3	1.2	2.5	3.5	5.0	6.0
4	2.5	5.0	7.0	10.0	12.0

1 (a) Masonry walls.
  (b) R/C walls, no cracking permitted.

2 (a) R/C walls, minor cracking may occur.
  (b) Precast R/C units that must remain watertight.
  (c) Steel tanks.

3 (a) Simple wood or steel framed structure.
  (b) Precast R/C units, leakage permitted.

4 Impervious earth lined structures.

1/
If the foundation soils are shown to be uniform through the depth of significant settlement the allowable settlements from the chart may be doubled. *

Estimated allowable settlements are taken from observations and studies on buildings and structures. The maximum allowable settlements in the table are based on the assumption differential settlements may equal total settlement and occur at opposite sides of the structure. This assumption may not be conservative in that maximum and minimum settlement may be at intermediate points. If the foundation is uniform then differential settlements will be less than total settlement and the allowable settlement may be increased.

* Appurtenances (pipes, ramps, etc) must be articulated at their contact with the structure to allow settlement without damage.

(EFM, Amend. IA-36, Oct. 1988)

PART C

ESTIMATED SHEAR STRENGTHS

The following guide may be used to estimate shear strength when test data are not available.

Strength of Sands and Sands with Gravel Based on Estimated Density

$c = 0$

Soil Density	N Blows/ft	$\bar{\phi}$ Deg
Very Loose	2	27
Loose	7	30
Medium	20	35
Dense	40	37
Very Dense	>50	40

Strength of Silts and Sandy Silts with Little or No Plasticity

$c = 0$

Soil Density	$\bar{\phi}$ Deg
Loose	27
Dense	30

Strength of Clays and Silty Clays Based On Consistency

phi = 0

Soil consistency	Cohesion psf	Blowcount N	
Very soft	*	<2	Thumb will penetrate >1"
Soft	250	2-4	Thumb will penetrate about 1"
Firm	500	4-15	Thumb will penetrate about 1/4 "
Hard	2000	15-30	Readily indented with thumbnail
Very hard	4000	>30	Thumbnail will not indent

* Requires special evaluation of shear strength

(EFM, Amend. IA-36, Oct. 1988)

PART D

SETTLEMENT ON SAND

Settlement of structures on sand may be estimated from the results of standand penetration tests with the equation

$$qa = 720 \cdot (N-3) \cdot ((B+1)/2B)^2 \cdot W' \cdot Kd$$

qa= Net increase in soil pressure in psf producing 1 inch of settlement.

N= Blow count from the standard penetration test.

B= Width of footing.

W'= Water reduction factor as defined in Part A.

Kd= 1+Df/B But no greater than 2.

Df= Footing depth below ground surface.

When B becomes very large then $((B+1)/2B)^2$ approaches 0.25

When the footing depth (D) is very shallow in relation to the footing width, then Kd approaches 1.

When d/B > 1, W' = 1

Assuming a load on the foundation soil that is wide and at a shallow depth such as a manure tank set at the soil surface and a deep water table we can compute soil loadings that will produce 1 inch of settlement.

Sand Density	N Blows/ft	Load psf
Very Loose	2	1/
Loose	7	700
Medium	20	3000
Dense	40	6000
Very Dense	50	8000

1/ Even very light loads will produce settlements in excess of 1 inch.

(EFM, Amend. IA-36, Oct. 1988)

Total settlement for any foundation load can be estimated by relating it to the load producing 1 inch of settlement. For example, on a sand of medium density, a 2000 lb load will produce 2/3 the settlement of a 3000 lb load or 2/3 of an inch. If the footing is large and flexible, the loading of the soil under the edge will be about 1/2 the loading under the center and settlements will be about 1/2 as much. On a large structure, a 5 inch thick reinforced concrete floor will act like a flexible floor.

To compute settlement for any load;

Settlement (in) = (actual load psf)/(load producing 1 in of settlement)

(EFM, Amend. IA-36, Oct. 1988)

PART E

SETTLEMENT ON CLAY

The settlement of a structure on a clay soil foundation is estimated using consolidation theory. The void ratio and compression index (Cc) for the soil is needed in order to make the settlement computations.

If the soil has been loaded in the past with a greater load than it now has, it is said to be preconsolidated, overconsolidated or preloaded. Compacted fill has been preloaded by the compaction equipment. In the case of preconsolidated soil the, recompression index (Cr) is used in place of Cc in the computations. Cc and Cr are determined by consolidation testing of undisturbed samples from the foundation. Cc can be estimated from the liquid limit with the formula;

$$Cc = 0.009 \cdot (LL-10)$$

Or from the liquid limit and the void ratio with the formula

$$Cc = (0.0035 \cdot LL \cdot (eo-0.4))^{1/2}$$

Cr is usually 15 to 25% Of Cc.

Void ratio can be computed from the dry density and specific gravity of the soil with the formula;

$$e = (Gs \cdot \gamma w/\gamma d)-1$$

e= void ratio

γd= dry density of the soil in pcf

Gs= the specific gravity of the soil grains Usually between 2.65 and 2.75

γw= 62.4 pcf

The formula for settlement is;

$$S = ((Cc \cdot H)/(1+eo)) \cdot \log 10 ((po+\Delta p)/po)$$

(EFM, Amend. IA-36, Oct. 1988)

S= total settlement

Cc= compression index

H= depth of compressible strata.
Thick strata should be
divided into 4 to 10 foot thick
increments.

po= The existing vertical soil pressure
at the center of the strata or incre-
ment.

eo= The void ratio of the compressable
strata before loading.

Δp= The added load at the center of the strata
or increment.

log10= The logarithm of this number to the
base 10.

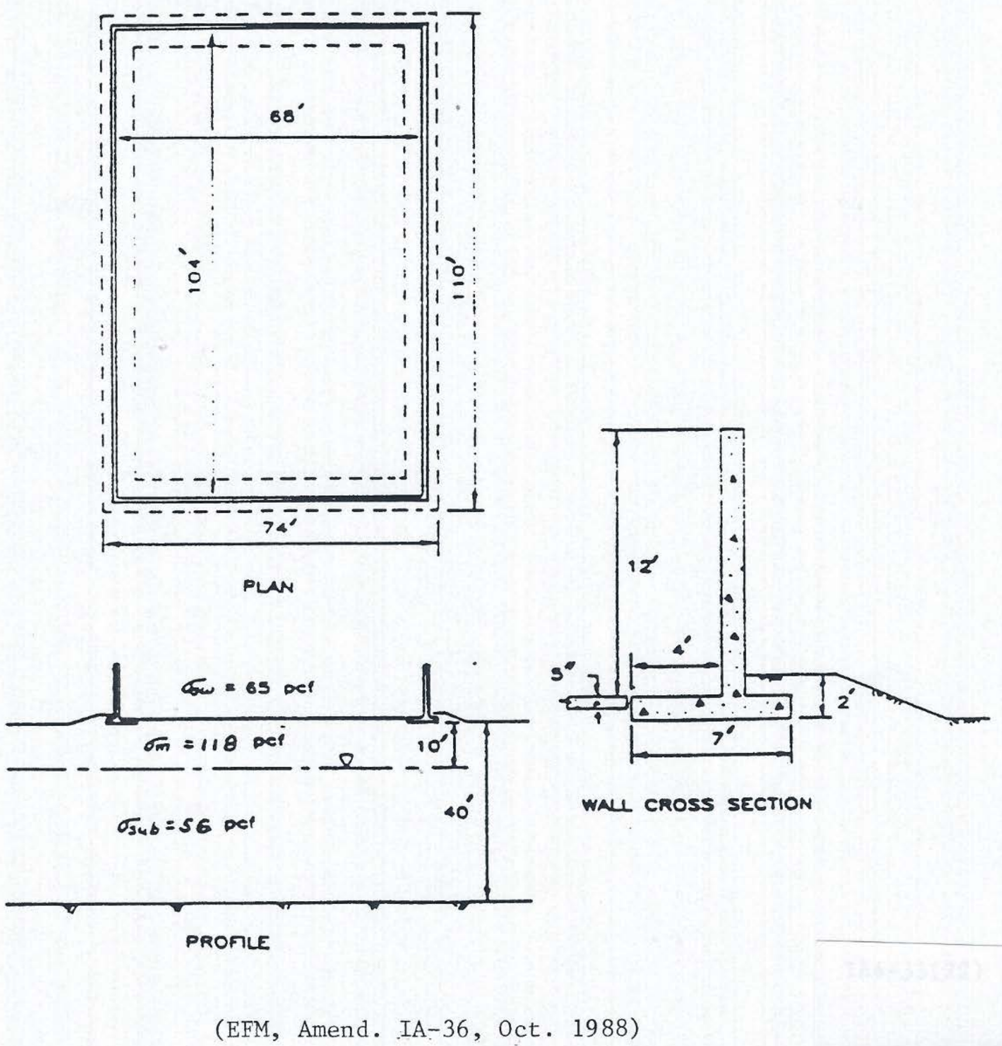
(EFM, Amend. IA-36, Oct. 1988)

PART F

EXAMPLE

An animal waste storage structure with inside dimensions of 68 ft by 104 ft by 12 ft is to be constructed of precast R/C units. The units are 7 ft wide, 12 ft long and produce a 12 ft high wall. They weigh 2800 lb per ft of length. A 5 in thick R/C floor will be cast and all the joints will be sealed to produce a water tight structure. The units will be placed on a smoothed ground surface and backfilled on the outside to a depth of 2 ft. The foundation consists of 40 ft of firm silty clay with a liquid limit of 40. The dry unit weight is 90 pcf and the wet unit weight is 118 pcf. The unit weight of the animal waste is 65 pcf. The water table is 10 ft below the ground surface.

Assess the adequacy of the foundation soil to support this structure when it is full.



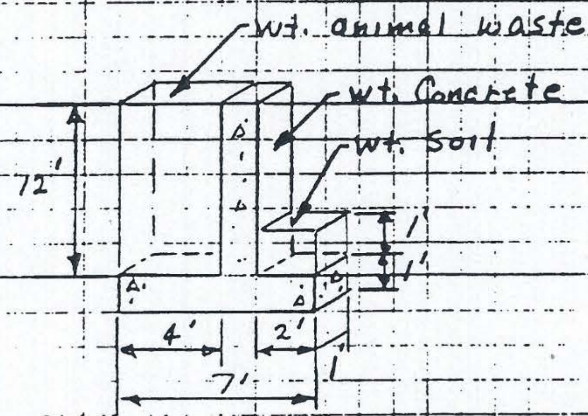
(EFM, Amend. IA-36, Oct. 1988)

NENTC — PROJECT: Example

BY: H W Hall DATE: 7-87 CHECKED BY: DATE: JOB NO.

SUBJECT: Foundation Analysis SHEET 1 OF 8

Compute the Actual Load on the Soil Under the Precast Units With 12 ft of Waste in the tank.



$$\frac{\text{Load}}{\text{Area}} = \frac{\text{wt. Concrete} + \text{wt. animal waste} + \text{wt. soil}}{1' \cdot 7'}$$

$$= \frac{2800^{lb} + (65\,pcf \cdot 1' \cdot 4' \cdot 12') + (118\,pcf \cdot 1' \cdot 1' \cdot 2')}{7\ ft^{sq}}$$

$$= \frac{2800 + 3120 + 236}{7} = \frac{6156}{7}$$

$$= 880\ psf$$

(EFM, Amend. IA-36, Oct. 1988)

NENTC Example
HWH 7-87
Foundation Analysis SHEET 2/8

Compute Allowable Bearing Capacity

From part A

$q_{ult} = (q \cdot c \cdot N_c) + (W \cdot q \cdot N_q) + (W' \cdot K \cdot \gamma_m \cdot B \cdot N_\gamma)$

From part C

Silty clay - firm gives, $\phi = 0$ and $c = 500$ psf
(Figure 4-35)

From Part A, Table 1, @ $\phi = 0$ gives

$N_c = 5.7$, $N_q = 1.0$, $N_\gamma = 0.0$

$q = (2^{ft})(118\,pcf)$

$= 236$ psf Effective Vertical Pressure

Assume the precast units act like a Continous footing with $B = 7^{ft}$

$g = 1.0$, $K = 0.5$, $\gamma_m = 118$ pcf

From Page 4-42, d=10' which is greater tha B=7'

Therefore $W' = 1.0$ & $W = 1.0$

$q_{ult} = (1.0 \cdot 500 \cdot 5.7) + (1 \cdot 236 \cdot 1.0) + (1 \cdot 0.5 \cdot 118 \cdot 7 \cdot 0.0)$

$= 2850 + 236 + 0 = 3086$ psf

$q_a = q_{ult}/3$ (allowable bearing capacity)

$q_a = \frac{3086}{3} = 1028$ psf

$1028^{psf} < 880^{psf}$

Allowable bearing capacity exceeds actual

Therefore Bearing Capacity is O.K.

(EFM, Amend. IA-36, Oct. 1988)

Estimate Actual Settlement

Compute total wt. on foundation

wt. walls	= 2800 #/ft · 2 · (69' + 105') =	974,400
wt. Floor	= 150 pcf · 5/12' · (60 · 96) =	360,000
wt. waste	= 65 pcf · 68 · 104 · 12	= 5,516,160
wt. soil	= 118 pcf · 1' · 2' · (2(72' + 108')) =	84,960
	Total	6935,520 lbs

Compute the increased loading (Δp) from the loaded tank at the surface and at 5, 15, 25 and 35 foot depths. Assume the load spreads at a ½:1 slope.

$$\text{Loading, } \Delta p = \frac{\text{Total Load}}{\text{Area}}$$

$$\text{surface} = \frac{6935{,}520}{74' \cdot 110'} = 852 \text{ psf}$$

$$5' \text{ depth} = \frac{6935{,}520}{79' \cdot 115'} = 763 \text{ psf}$$

$$15' \text{ depth} = \frac{6935{,}520}{89' \cdot 125'} = 623 \text{ psf}$$

$$25' \text{ depth} = \frac{6935{,}520}{99' \cdot 135'} = 519 \text{ psf}$$

$$35' \text{ depth} = \frac{6935{,}520}{109' \cdot 145'} = 439 \text{ psf}$$

(EFM, Amend. IA-36, Oct. 1988)

Compute the existing vertical soil pressures (p_o) at 5, 15, 25 and 35 foot depth.

$p_o\ (5^{ft}) = (5')(118\text{ pcf}) = 590\text{ psf}$

$p_o\ (15^{ft}) = (10')(118\text{ pcf}) + (5')(56^{1/}\text{ pcf}) = 1460\text{ psf}$

$p_o\ (25^{ft}) = (10')(118\text{ pcf}) + (15')(56^{1/}\text{ pcf}) = 2020\text{ psf}$

$p_o\ (35^{ft}) = (10')(118\text{ pcf}) + (25')(56^{1/}\text{ pcf}) = 2580\text{ psf}$

Estimate the void ratio

$$e = \frac{G_s \gamma_w}{\gamma_d} - 1$$

$\gamma_d = 90$ pcf

G_s (estimated) $= 2.65$

$$e = \frac{2.65 \cdot 62.4}{90} - 1$$

$e = \underline{\underline{0.84}}$

Estimate the compression index

From part E

$C_c = [0.0035 \cdot LL \cdot (e_o - 0.4)]^{1/2}$

$C_c = [0.0035 \cdot 40 \cdot (0.84 - 0.4)]^{1/2}$

$C_c = \underline{\underline{0.25}}$

1/ Bouyant weight of soil below the water table $118^{\text{pcf}} - 62.4^{\text{pcf}} \approx 56^{\text{pcf}}$

(EFM, Amend. IA-36, Oct. 1988)

NENTC | Example
HWH 7-87
Foundation Analysis
SHEET 5/8

Compute settlement by 10 foot thick foundation strata

From part E

$$S = \frac{C_c \cdot H}{1+e_o} \log 10 \frac{P_o + \Delta P}{P_o}$$

$$= \frac{0.25 \cdot 10}{1+0.84} \log 10 \frac{P_o + \Delta P}{P_o}$$

$$= 1.36 \log 10 \frac{P_o + \Delta P}{P_o}$$

Representative from (ft)	Strata to (ft)	P_o psf	ΔP psf	S feet
0	10	590	763	0.49
10	20	1460	623	0.21
20	30	2020	519	0.14
30	40	2580	439	0.09

Total Estimated Actual Settlement 0.93 ft

or $0.93^{ft} \cdot 12^{in}/ft$ = 11.1 inches

Determine allowable settlement and compare with estimated settlement

From part B

Structure type 2, width 74', use 80'

Maximum Allowable Settlement = 3.0 inches

11.1 inches is much greater than 3.0 inches

Foundation is not adequate

(EFM, Amend. IA-36, Oct. 1988)

Assume the silty clay is overconsolidated with a dry density of 105 pcf

Estimate the settlement,

From part E.

The recompression index, C_r is usually 15 to 25% of C_c, use 20%

From page 4-60, $C_c = 0.25$

$C_r = 0.2 \cdot 0.25 = 0.05$

$$e = \frac{G_s \gamma_w}{\gamma_d} - 1 = \frac{2.65 \cdot 62.4}{105} - 1$$

$= 0.57$

$$S = \frac{0.050 \cdot 10}{1 + 0.57} \log_{10} \frac{P_o + \Delta P}{P_o}$$

$$= 0.32 \log_{10} \frac{P_o + \Delta P}{P_o}$$

Representative from (ft)	Strata to (ft)	P_o psf	ΔP psf	S feet
0	10	625	763	0.11
10	20	1570	623	0.05
20	30	2220	519	0.03
30	40	2860	439	0.02
			Total	0.21 feet

or $0.21^{ft} \cdot 12^{in/ft} = 2.5$ inches

2.5 < 3.0 settlement O.K.

(EFM, Amend. IA-36, Oct. 1988)

NENTC Example

HWH 7-87

CHECKED BY DATE JOB NO.

Foundation Analysis SHEET 7 OF 8

Assume the structure is to be placed on a loose sand foundation with $\gamma_m = 125\ lb/ft^3$. Compute allowable bearing capacity.

From part C

Loose sand, $N = 7$, $\bar{\phi} = 30$, $c = 0$

From part A, table 1

$N_c = 22.6$, $N_q = 11.1$, $N_\gamma = 8.5$

$$q_{ult} = (g \cdot c \cdot N_c) + (W \cdot q \cdot N_q) + (W \cdot K \cdot \gamma \cdot B \cdot N_\gamma)$$

$$q_{ult} = (1.0 \cdot 0 \cdot 22.6) + (1 \cdot 250 \cdot 11.1) + (1 \cdot .5 \cdot 125 \cdot 7 \cdot 8.5)$$

$$= 0 + 2780 + 3720$$

$$q_{ult} = 6500$$

$q_a = q_{ult}/3 = 2170$ psf (allowable bearing)

2170 psf > 880 psf

Bearing Capacity is Adequate

Notice that 43% of the computed bearing capacity comes from the second term in the equation and is dependent on the two feet of backfill.

(EFM, Amend. IA-36; Oct. 1988)

Estimate Actual Settlement

From part D

$qa = 720 \cdot (N-3) \cdot ((B+1)/2B)^2 \cdot W' \cdot Kd$

$N = 7, B = 74,$

$K_d = 1 + D/B = 1 + 2/74$

$= 1.0$

W' from page 4-42, $d/B = 10/74 = 0.14$

$W' = 0.57$

$qa = 720 \cdot (7-3) \cdot ((74+1)/(2 \cdot 74))^2 \cdot 0.57 \cdot 1.0$

$= 420$ psf produces 1 inch of Settlement

$s =$ Actual ground pressure / qa

$s = \frac{860}{420} = 2.0$ inches

2.0 inches < 3.0 inches allowable

Foundation soil is adequate