2011 Coastal Construction Manual (CCM) - Calculator

The equations in this spreadsheet are equations in Volume 2 of the CCM

In order to avoid the user from accidentally erasing the formula in a cell, all the cells in each of the worksheets, except those requiring user input, are protected (with no password).

On each of the worksheets, the material on the right-hand side (Column J - Q) are reference material to help the user with input to the equation.

Each of the worksheets is set to print only the left hand side (Columns A-I).

List of equations included in this workbook is given in the "LIST" Worksheet.

List of Equations - CCM Volume 2

Equation 8.1 Design Stillwater Flood Depth

Equation 8.1

$$d_s = E_{sw} - GS$$ Eq. 8.1

where:

d_s = design stillwater flood depth (ft)

E_{sw} = design stillwater flood elevation in ft above datum (e.g., NGVD, NAVD)

GS = lowest eroded ground elevation, in ft above datum, adjacent to a building, excluding effects of localized scour around the foundation

Calculation

Input:

E_{sw}	=	10.10	ft
GS	=	5.50	ft

Output:

d_s	=	**4.60**	ft	Eq. 8.1

Equation 8.2. Design Flood Velocity

Equation 8.2

Lower bound $V = \frac{d_s}{t}$ Eq. 8.2A

Upper bound $V = (gd_s)^{0.5}$ Eq. 8.2B

where:

V	=	design flood velocity (ft/sec)
d_s	=	design stillwater flood depth (ft) - from Eq. 8.1
t	=	1 sec.
g	=	gravitational constant (32.2 ft/sec^2)

Calculation

Input:

d_s	=	4.60	ft
g	=	32.20	ft/sec^2

Output:

V	=	**4.60**	ft/sec	Eq. 8.2A	Lower bound
V	=	**12.17**	ft/sec	Eq. 8.2B	Upper bound

Equation 8.3. Lateral Hydrostatic Load

Equation 8.3

$$f_{sta} = (1/2)\,\Upsilon_w d_s^{\,2}$$ Eq. 8.3 A

$$F_{sta} = f_{sta}\,(w)$$ Eq. 8.3 B

where:

f_{sta}	=	hydrostatic force per unit width (lb/ft) resulting from flooding against vertical element
γ_w	=	specific weight of water (62.4 lb/ft^3 for fresh water and 64.0 lb/ft^3 for saltwater)
d_s	=	design stillwater flood depth (ft) - from Eq. 8.1
F_{sta}	=	total equivalent lateral hydrostatic force on a structure (lb)
w	=	width of vertical element (ft)

Calculation

Input:

d_s	=	4.60	ft
γ_w	=	64.00	lb/ft^3
w	=	0.67	ft

Output:

$\boldsymbol{f_{sta}}$	=	**677.12**	lb/ft	Eq. 8.3 A
$\boldsymbol{F_{sta}}$	=	**453.67**	lb	Eq. 8.3 B

(flood load on only one side of vertical component)

Equation 8.4. Vertical (Buoyant) Hydrostatic Force

Equation 8.4

$$F_{buoy} = \gamma_w (Vol) \qquad \text{Eq. 8.4}$$

where:

F_{buoy}	=	vertical hydrostatic force (lb) resulting from the displacement of a given volume of floodwater
γ_w	=	specific weight of water (62.4 lb/ft^3 for fresh water and 64.0 lb/ft^3 for saltwater)
Vol	=	Volume of floodwater displaced by a submerged object (ft^3)

Calculation

Input:

γ_w	=	64.00	lb/ft^3
Vol	=	20.00	ft^3

Output:

$\boldsymbol{F_{buoy}}$	=	**1280.00**	lb	Eq. 8.4

Equation 8.5. Breaking Wave Load on Vertical Piles

Equation 8.5

$$F_{brkp} = (1/2)\, C_{db}\, \gamma_w\, D H_b^{\,2}$$ Eq. 8.5

where:

F_{brkp}	=	drag force (lb) acting at the stillwater elevation
C_{db}	=	breaking wave drag coefficient (recommended value are 2.25 for square piles and 1.75 for round piles)
γ_w	=	specific weight of water (62.4 lb/ft^3 for fresh water and 64.0 lb/ft^3 for saltwater)
D	=	pile diameter (ft) for a round pile or 1.4 times the width of the pile or column for a square pile
H_b	=	breaking wave height (0.78 d_s) in ft. where d_s = design stillwater depth in ft

Calculation

Input:

"round" or "square" pile ?	square	
if round pile, enter diameter of pile		ft
if square, enter the width of pile	0.67	ft

γ_w	=	64.00	lb/ft^3	
d_s	=	4.60	ft	stillwater depth (From Eq 8.1)

Output:

C_{db}	=	2.25		square pile
D	=	0.94	ft	(pile diameter or 1.4 * width of pile)
H_b	=	3.59	ft	(0.78 * design stillwater depth, d_s)
$\boldsymbol{F_{brkp}}$	**=**	**869.44**	lb	Eq. 8.5
		(on one pile)		

Equation 8.6. Breaking Wave Load on Vertical Walls

Equation 8.6a (enclosed dry space behind wall)

$$f_{brkw} = 1.1\, C_p\, \Upsilon_w\, d_s^{\,2} + 2.4\, \Upsilon_w\, d_s^{\,2} \qquad \text{Eq. 8.6a}$$

Equation 8.6b (equal stillwater elevation on both sides of the wall)

$$f_{brkw} = 1.1\, C_p\, \Upsilon_w\, d_s^{\,2} + 1.9\, \Upsilon_w\, d_s^{\,2} \qquad \text{Eq. 8.6b}$$

Equation 8.6c

$$F_{brkw} = f_{brkw}\,(w) \qquad \text{Eq. 8.6c}$$

where:

f_{brkw}	=	total breaking wave per unit length of wall (lb/ft) acting at the stillwater elevation
C_p	=	dynamic pressure coefficient from Table 8-1
γ_w	=	specific weight of water (62.4 lb/ft^3 for fresh water and 64.0 lb/ft^3 for saltwater)
d_s	=	design stillwater flood depth in ft (From Eq. 8.1)
F_{brkw}	=	total breakwater wave load (lb) acting at the stillwater elevation
w	=	width of wall in ft

Calculation

Input:

C_p	=	2.8		
γ_w	=	64	lb/ft^3	
d_s	=	4.60	ft	(From Eq 8.1)
w	=	2.00	ft	

Output:

f_{brkw}	=	**7,421.24**	lb/ft	Eq. 8.6a	enclosed dry space behind wall
f_{brkw}	=	**6,744.12**	lb/ft	Eq. 8.6b	equal stillwater elevation both sides
F_{brkw}	=	**14,842.47**	lb	Eq. 8.6c	enclosed dry space behind wall
F_{brkw}	=	**13,488.23**	lb	Eq. 8.6c	equal stillwater elevation both sides

Equation 8.7. Lateral Wave Slam

Equation 8.7

$$F_s = f_s w = (1/2)\,\Upsilon_w C_s d_s h w \qquad \text{Eq. 8.7}$$

where:

F_s	=	lateral wave slam (lb)
f_s	=	lateral wave slam (lb/ft)
C_s	=	slam coefficient incorporating effect of slam duration and surface stiffness for typical residential structure (recommended value is 2.0)
γ_w	=	specific weight of water (62.4 lb/ft^3 for fresh water and 64.0 lb/ft^3 for saltwater)
d_s	=	design stillwater flood depth in ft (From Eq. 8.1)
h	=	vertical distance (ft) the wave crest extends above the bottom of the floor joist or floor beam
w	=	length (ft) of the floor joist or floor beam struck by wave crest

Calculation

Input:

γ_w	=	64.00	lb/ft^3
C_s	=	2.00	
d_s	=	7.00	ft
h	=	0.90	ft
w	=	50.00	ft

Output:

$\boldsymbol{f_s}$	=	**403.20**	lb/ft	
$\boldsymbol{F_s}$	=	**20,160.00**	lb	Eq. 8.7

Equation 8.8. Hydrodynamic Load (for All Flow Velocities)

Equation 8.8

$$F_{dvn} = (1/2)\, C_d \rho V^2 A \qquad \text{Eq. 8.8}$$

where:

F_{dyn}	=	horizontal drag force (lb) acting on the stillwater mid-depth (half way between the stillwater level and the eroded ground surface)
C_d	=	drag coefficient (recommended coefficient are 2.0 for square or rectangular piles and 1.2 for round piles; for other obstructions, see Table 8-2)
ρ	=	mass density of fluid (1.94 slugs/ft^2 for fresh water and 1.99 slugs/ft^2 for saltwater)
V	=	Velocity of water (ft/sec); see Equation 8.2
A	=	surface area of obstruction normal to flow (ft^2) = (w)(d_s) if object is not fully immersed, see figure 8-13 or (w)(h) if the object is completely immersed
h	=	the height of the object (ft) if the object is completely immersed in water
d_s	=	stillwater flood depth of the water (ft) if the object is not fully immersed

Calculation

Input:

C_d	=	2.00		
ρ	=	1.99	slugs/ft^2	
V	=	12.20	ft/sec	from Eq. 8.2
w	=	0.67	ft	
h	=		ft	Leave blank if object is not completely immersed.
d_s	=	4.60	ft	

Output:

A	=	3.082	ft^2	(A = d_s*w or h*w)
$\mathbf{F_{dyn}}$	**=**	**912.86**	lb	Eq. 8.8

Equation 8.9. Debris Impact Load

Equation 8.9

$$F_i = WVC_D C_B C_{Str}$$ Eq. 8.9

where:

F_i	=	impact force acting at the stillwater elevation (lb)
W	=	weight of the object (lb)
V	=	velocity of water (ft/sec), approximated by $1/2(gd_s)^{1/2}$
C_D	=	depth coefficient (see Table 8-3)
C_B	=	blockage coefficient (taken as 1.0 for no upstream screening, flow path greater than 30 ft; see below for more information)
C_{Str}	=	Building structure coefficient (sec/ft)
		0.2 for timber pile and masonry column supported structures 3 stories or less in height above grade
		0.4 for concrete pile or concrete or steel moment resisting frames 3 stories or less in height above grade
		0.8 for reinforced concrete foundation walls (including insulated concrete forms)

Calculation

Input:

W	=	1000.00	lb
V	=	12.20	ft/sec
C_D	=	0.75	
C_B	=	1.00	
C_{Str}	=	0.20	sec/ft

Output:

F_i	=	**1830.00**	lb	Eq. 8.9

Equation 8.10. Localized Scour Around a Single Vertical Pile

Equation 8.10

$$S_{max} = 2.0a$$ Eq. 8.10

where:

S_{max} = maximum localized scour depth (ft)

a = diameter of a round foundation element or the maximum diagonal cross-section dimension for a rectangular element

Calculation

Input:

a = 0.88 ft

Output:

S_{max} = **1.76** ft Eq. 8.10

Equation 8.11. Total Localized Scour Around Vertical Piles

Equation 8.11

$S_{TOT} = 6a + 2\,ft$	(if grade beam and/or slab-on-grade present)	Eq. 8.11a
$S_{TOT} = 6a$	(if no grade beam or slab-on-grade present)	Eq. 8.11b

where:

S_{TOT}	=	total localized scour depth (ft)
a	=	diameter of a round foundation element or the maximum diagonal cross-section dimension for a rectangular element
$2\,ft$	=	allowance for vertical scour due to presence of grade beam or slab-on-grade

Calculation

Input:

a = 0.88 ft

Output:

S_{TOT} =	**7.28**	ft	Eq. 8.11a
S_{TOT} =	**5.28**	ft	Eq. 8.11b

Equation 8.12. Total Scour Depth Around Vertical Walls and Enclosures

Equation 8.12

$$S_{TOT} = 0.15L$$ Eq. 8.12

where:

S_{TOT} = total localized scour depth (ft), maximum value is 10 ft

L = horizontal length (ft) along the side of the building or obstruction exposed to flow and waves

Calculation

Input:

L = 10.00 ft

Output:

S_{TOT} = **1.50** ft Eq. 8.12

Check **Total localized scour depth is less than 10 ft - OK**

Equation 8.13. Velocity Pressure

Equation 8.13

$$q_z = 0.00256\, K_z K_{zt} K_d V^2$$ Eq. 8.13

where:

q_z	=	Velocity pressure evaluated at height z (psf)
K_z	=	velocity pressure exposure coefficient evaluated at height z
K_{zt}	=	topographic factor
K_d	=	wind directionality factor
V	=	basic wind speed (mph) (3-sec gust speed at 33 ft above ground in Exposure Category C)

Calculation

Input:

K_z	=	1.00	
K_{zt}	=	1.00	
K_d	=	0.85	
V	=	150.00	mph

Output:

$\boldsymbol{q_z}$ **=** **48.96** psf Eq. 8.13

Equation 8.14. Design Wind Pressure for Low-Rise Buildings

Equation 8.14

$$p = q_h \, [GC_{pf} - GC_{pi}]$$ Eq. 8.14

where:

P	=	design wind pressure (psf)
q_h	=	Velocity pressure (psf) evaluated at mean rood height h, (see Fig 8-18 for an illustration of mean roof height)
GC_{Pf}	=	External pressure coefficient for C & C loads or MWFRS loads per low-rise building provisions, as applicable
GC_{Pi}	=	External pressure coefficient based on exposure classification as applicable, GC_{Pi} for enclosed building is +/- 0.18

Calculation

Input:

q_h	=	29.38	psf
GC_{Pf}	=	-0.69	
GC_{Pi}	=	0.18	

Output:

P	=	**-25.56**	psf	Eq. 8.14

Equation 8.15. Seismic Base Shear by Equivalent Lateral Force Procedure

Equation 8.15

$$V = C_s W$$ Eq. 8.16a

$$C_s = \frac{S_{DS}}{(R/I)}$$ Eq. 8.16b

where:

V	=	Seismic base shear (lb)
C_s	=	Seismic response coefficient
S_1	=	the mapped maximum considered earthquake spectral response acceleration parameter
S_{DS}	=	design spectral response acceleration parameter in the short period range, 5 percent damped
S_{D1}	=	the design spectral response acceleration parameter at a period of 1.0 second
R	=	response modification factor
I	=	occupancy importance factor
W	=	effective seismic weight, kip
T	=	the fundamental period of the structure(s)
T_L	=	long-period transition period(s)

Calculation

Input:

S_1	=	0.2	g
S_{DS}	=	0.33	g
S_{D1}	=	0.13	g
R	=	6.00	
I	=	1.00	
W	=	6816.00	kips
T	=	0.35	sec
T_L	=	8.00	sec

Output:

C_s	=	0.055	Eq. 8.15b

Use **Check C_s (see right hand side)**

C_s	=	**0.055**		
V	=	**374.88**	kips	Eq. 8.15a

Equation 8.16. Vertical Distribution of Seismic Forces

Equation 8.16

$$F_x = C_{vx} V$$ Eq. 8.16a

$$C_{VX} = \frac{w_x h_x{}^k}{\sum_{i=1}^{n} w_i\, h_i{}^k}$$ Eq. 8.16b

where:

F_x	=	lateral seismic force induced at any level
C_{vx}	=	vertical distribution factor
V	=	seismic base shear (kips)
w_i and w_x	=	portion of the total effective seismic weight of the structure (w) located or assigned to level i or x
h_i and h_x	=	height (ft) from the base to Level *i* or *x*
k	=	exponent related to the structure period; for structures having a period of 0.5 sec or less, k =1
n	=	Number of storys (assume not more than 2 storys in this worksheet)

Calculation

Input:

For two-story structure, 1 is the lowest level

V	=	374.88	kips
k	=	1.00	
w_1	=	0.33	
w_2	=	0.33	
h_1	=	13	ft
h_2	=	26	ft

Output:

$w_1 h_1{}^k$	=	4.29
$w_2 h_2{}^k$	=	8.58

C_{vx1}	=	**0.33**	F_{x1}	=	**124.96**	kips
C_{vx2}	=	**0.67**	F_{x2}	=	**249.92**	kips

Equation 10.1. Sliding Resistance

Equation 10.1

$$F = tan(\phi)\ (N)$$ Eq. 10.1

where:

F = resistance to sliding (lb)

ϕ = angle of internal friction in degrees

N = normal force on the footing (lb)

Calculation

Input:

ϕ	=	10.00	degree
N	=	3000.00	lb

Output:

F	=	**528.98**	psf	Eq. 10.1

Equation 10.2. Ultimate Compression Capacity of a Single Pile

Equation 10.2

$$Q_{ULT} = P_T N_q A_T + \sum K_{HC} P_0 Ds \tan(\delta)$$ Eq 10.2

$\sum$ - summation over the different layers of soil. Set at maximum of 4 in this worksheet

Where:

Q_{ult}	=	ultimate load capacity in compression (lb)
P_T	=	effective vertical stress at pile tip (lb/ft^2)
N_q	=	bearing capacity factor (see Table 10-4)
A_T	=	area of pile tip (ft^2)
K_{HC}	=	earth pressure coefficient in compression (see Table 10-5)
P_0	=	effective vertical stress over the depth of embedment, D (lb/ft^2)
δ	=	friction angle between pile and soil in degrees (see Table 10-6)
s	=	surface area of pile per unit length (ft^2)
D	=	depth of embedment (ft)

Calculation

Input:

P_T	=	975	lb/ft^2
N_q	=	21	
A_T	=	0.79	ft^2

Enter soil information from top layer down. Leave blank if less than 4 layers

Soil Layer	K_{HC}	P_0 (lb/ft^2)	δ (degree)	s (ft^2/ft)	D (ft)	$K_{HC} P_0 Ds\tan(\delta)$
1 (Top)	1.00	975.00	22.50	3.14	15.00	19021.72
2						0.00
3						0.00
4						0.00
					Total =	19021.72

Output:

Q_{ult}	=	**35196.97**	lb	Eq. 10.2
Q_{all}	=	**11732.32**	lb	**Allowable compression capacity with a safety factor of 3**

Equation 10.3. Ultimate Tension Capacity of a Single Pile

Equation 10.3

$$T_{ult} = \sum K_{HT} P_0 Ds\ tan(\delta)$$ Eq. 10.3

$\sum$ - summation over the different layers of soil. Set at maximum of 4 in this worksheet

Where:

T_{ult}	=	ultimate load capacity in tension (lb)
K_{HT}	=	earth pressure coefficient in tension (see Table 10-5)
P_0	=	effective vertical stress over the depth of embedment, D (lb/ft^2)
δ	=	friction angle between pile and soil in degrees (see Table 10-6)
s	=	surface area of pile per unit length (ft^2/ft or ft)
D	=	depth of embedment (ft)

Calculation

Input:

Enter soil information from top layer down. Leave blank if less than 4 layers.

Soil Layer	K_{HT}	P_0 (lb/ft^2)	δ (degree)	s (ft^2/ft)	D (ft)	$K_{HT} P_0\ Dstan(\delta)$
1 (Top)	0.60	975.00	22.50	3.14	15.00	11413.03
2						0.00
3						0.00
4						0.00
					Total =	11413.03

Output:

T_{ult}	=	**11413.03** lb	Eq. 10.3
T_{allow}	=	**3804.34** lb	**Allowable tension capacity with a safety factor of 3.0**

Equation 10.4. Load Application Distance for an Unbraced Pile

Equation 10.4

$$L = H + d/12$$ Eq 10.4

where:

L	=	distance between the location where the lateral force in applied and the point of fixity (i.e., moment arm) (ft)
d	=	depth from grade to inflection point (in); $d = 1.8\left[\frac{EI}{n_h}\right]^{1/5}$
E	=	modulus of elasticity of the pile material, (lb/in^2)
I	=	moment of inertia of pile material (in^4)
n_h	=	modulus of subgrade reaction (lb/in^3), see Table 10-8
H	=	distance above grade where the lateral load is applied (ft)

Calculation

Input:

E	=	1500000	lb/in^2
I	=	322	in^4
n_h	=	700	lb/in^3
H	=	11.3	ft

Output:

d	**=**	**26.49**	in	
L	**=**	**13.51**	ft	Eq. 10.4

Equation 10.5. Determination of Square Footing Size for Gravity Loads

Equation 10.5

$$L = \left[\frac{P_a + (h_{col} + x - t_{foot}) W_{col} t_{col} w_c}{q - t_{foot} w_c}\right]^{0.5}$$ Eq. 10.5

where:

L	=	square footing dimension (ft)
P_a	=	gravity load on pier (lb)
h_{col}	=	height of pier above grade (ft)
x	=	distance from grade to bottom of footing (ft)
W_{col}	=	column width (ft)
t_{col}	=	column thickness (ft)
w_c	=	unit weight of column and footing material (lb/ft^3)
q	=	soil bearing pressure (psf)
t_{foot}	=	footing thickness (ft)

Calculation

Input:

P_a	=	500.00	lb
h_{col}	=	12.00	ft
x	=	5.00	ft
W_{col}	=	2.00	ft
t_{col}	=	2.00	ft
w_c	=	150.00	lb/ft^3
q	=	2000.00	psf
t_{foot}	=	1.00	ft

Output:

L	=	**2.34**	ft	Eq. 10.5

Equation 10.6. Determination of Soil Pressure

Equation 10.6

$$q = \frac{P_l}{L^2} \pm 6\frac{M}{L^3}$$ Eq. 10.6

where:

q	=	minimum and maximum soil bearing pressures at the edges of the footing (lb/ft^2)
P_t	=	total vertical load for the load combination being analyzed (lb)
M	=	applied moment P_l (h_{col}+ x) (ft-lbs) where x and h_{col} are as defined in Figure 10-21 and P_l is the lateral load applied at the top of the column

Calculation

Input:

P_t	=	10710.00	lbs	input negtive for uplift load (↑)
P_l	=	989.00	lbs	lateral force
L	=	8.50	ft	footing dimension
h_{col}	=	13.30	ft	height of pier above grade
x	=	1.50	ft	length below grade

Output:

M	=	**14637.20**	ft-lbs	(P_l * (h_{col}+x))
q_{max}	=	**291.24**	lb/ft^2	Eq. 10.6
q_{min}	=	**5.23**	lb/ft^2	Eq. 10.6

Check eccentricity

$$e = \frac{M}{P_t}$$ (see Figure 10-21)

e = eccentricity, cannot exceed L/6

Output:

e	=	**1.37**	ft	
L/6	=	1.42	ft	**e < L/6 - acceptable**

downward load, no need to check uplift resistance

Equation 13.1. Pile Driving Resistance for Drop Hammer Pile Drivers

Equation 13.1

$$Q_{all} = \frac{2WH}{(S+1)} \qquad \text{Eq. 13.1}$$

Where:

Q_{all} = allowable pile capacity (lb)

W = weight of the striking parts of the hammer (lb)

H = effective height of the fall (ft)

S = average net penetration, given as in per blow for the last 6 in. of driving

Calculation

Input:

W	=	1000.00	lb
H	=	5.00	ft
S	=	1.00	ft

Output:

$\boldsymbol{Q_{all}}$	=	**5000.00**	lb	Eq. 13.1