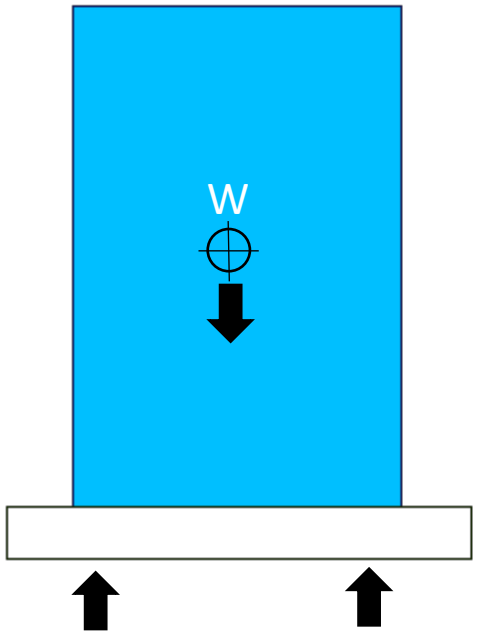
FOUNDATION ROCKING

IT7 – Soil-Foundation Interface

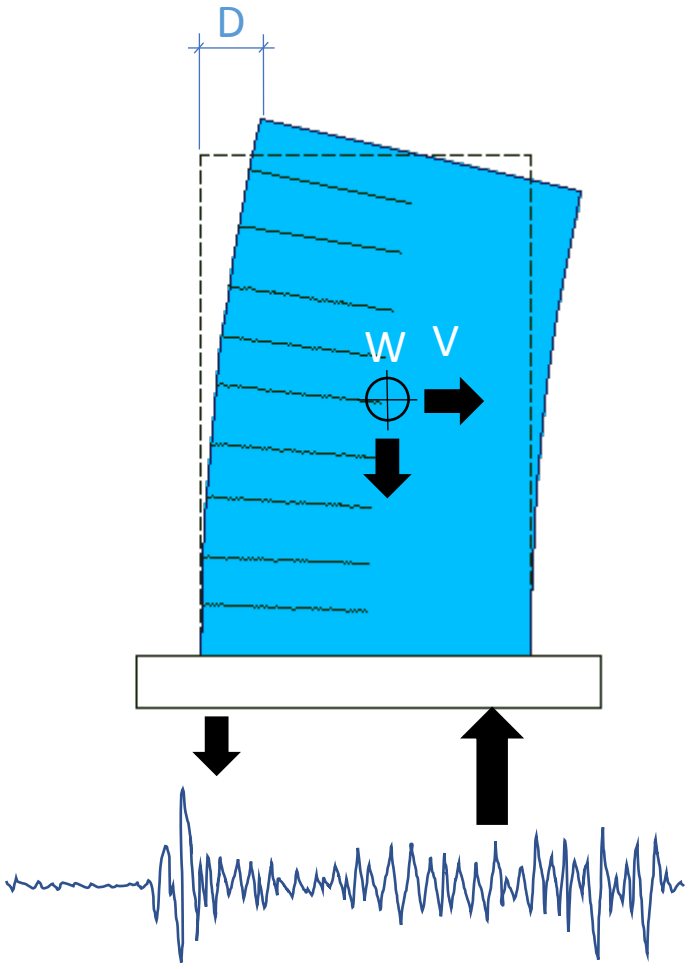
16 August 2018

Rocking Behavior

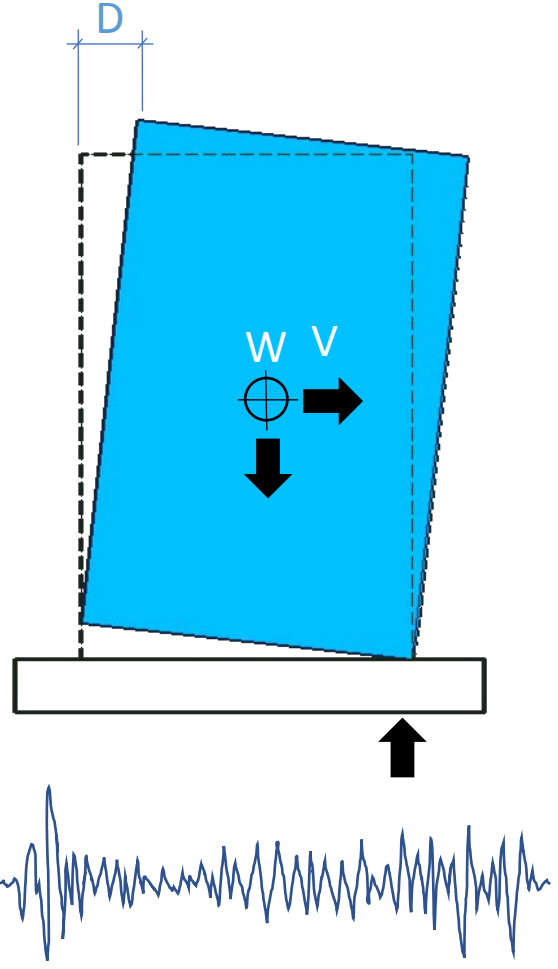
Undeformed structure



Conventional structural response



Rocking structural response



Rocking Behavior

- Behavior of structures on shallow foundations can be controlled by rocking rather than by structural yielding.
- The load at which rocking can occur safely may be less than the load resulting from the use of the R factor.
- If behavior is controlled by rocking, structural demands are limited and ductility requirements are different
  - The resulting loads are the “real” loads, not loads reduced with the expectation of ductility
  - For example, shear walls with loads so limited may not need confinement
  - However, coupling beams or other connecting elements may have increased demands

Limitation of Rocking per ASCE 41

- Section 8.4.2.3.1 limits rocking
  - Foundation shape
  - Ratio of gravity load to effective area
- Bearing Capacity
  - The prescriptive expected bearing capacity, q_c, for a spread footing is
    - $q_c = 3\ q_{allow}$
  - where q_{allow} = allowable bearing pressure for the gravity load design.
- m-Factors (Table 8-3)
  - For LS performance level, m-factors for typical wall- or mat-footings range from about 1 to 5, depending on gravity load area ratio, A_c/A_f
  - More complex for flanged foundations

Limitation of Rocking per ASCE 41

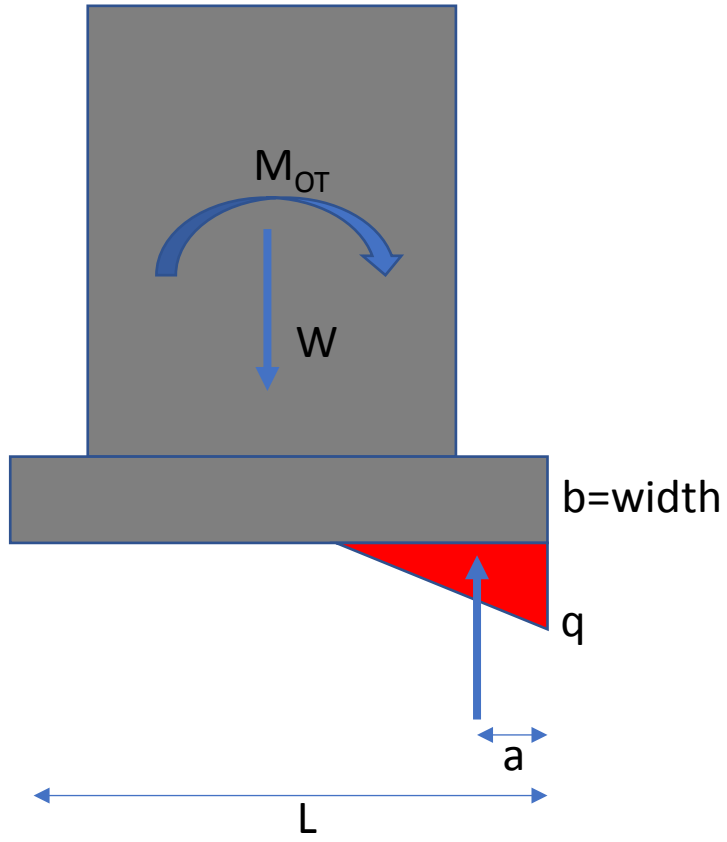
- A_c = critical contact area, P/q_c, where P is the gravity load
- A_f = actual area of footing
- Consider b/Lc of 0.3 for long footings relative to width

Table 8-3. Modeling Parameters and Numerical Acceptance Criteria for Linear Procedures

Footing Shape			*m*-Factors[a] Performance Level IO	LS	CP
i. Rectangle[b]					
$\frac{b}{L_c}$	$\frac{A_{rect} - A_f}{A_{rect}}$	$\frac{A_c}{A_f}$			
≥ 10	0	0.02	3	7	10
		0.13	2	6	9
		0.5	1	1	1
		1	1	1	1
3	0	0.02	3	7	10
		0.13	2	5	8
		0.5	1	1	1
		1	1	1	1
1	0	0.02	3	6	9
		0.13	1.5	3	6
		0.5	1	1	1
		1	1	1	1
0.3	0	0.02	2.5	5	8
		0.13	1.5	3	5
		0.5	1	1	1
		1	1	1	1

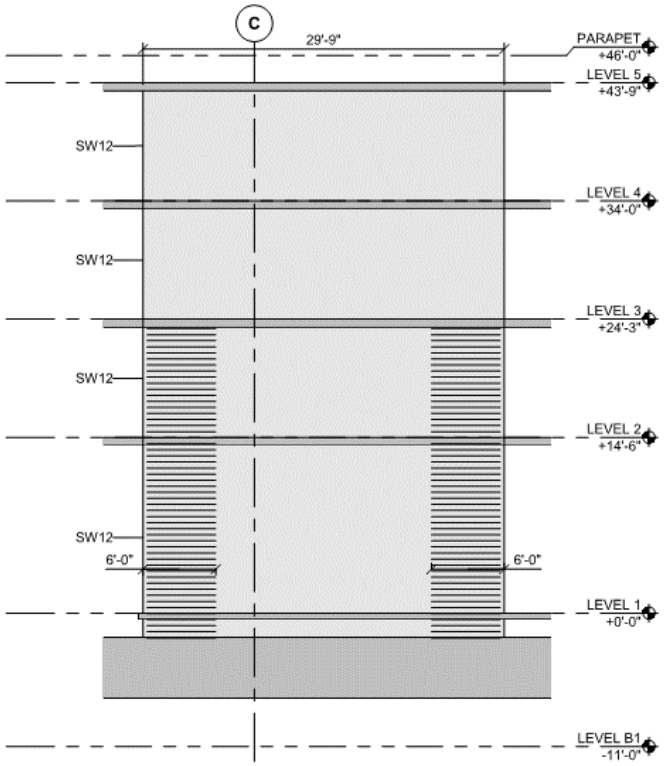
Soil Pressure due to Overturning

- Resisting Moment, M_R=WL/2
- $a = (M_R - M_{OT})/W$
- $q = \frac{2W}{3ab} = \frac{2W^2}{3b(M_R - M_{OT})}$
- Solving for the overturning moment that produces a pressure, q:
  - $M_{OT} = \frac{WL}{2} - \frac{2W^2}{3qb}$
- Set soil pressure to maximum allowed by ASCE 41 for LS performance
- Determine M_{OT} at various values of L
- Compare to unreduced demand
  - Compute effective reduction, μ_{OT}

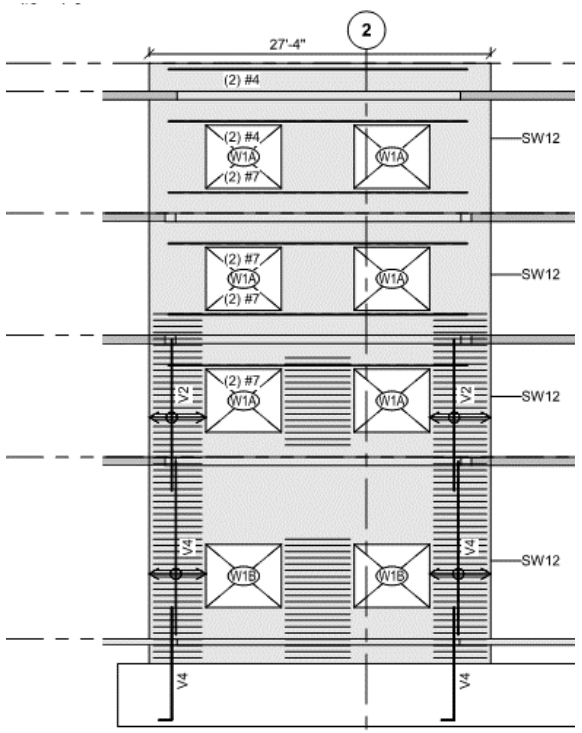


Examples

- Lightly loaded, higher shear



Heavily Loaded, lower shear

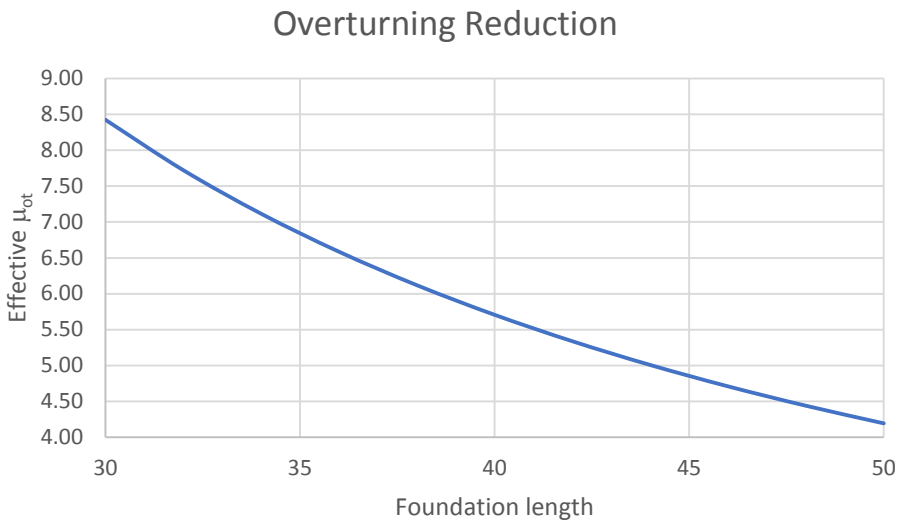


Example 1

- Lightly loaded Foundation A_c/A_f = 0.14; high shear

b	14	ft	A_c	86.67	sf		
L	44	ft	A_f	616.00	sf		
t	4	ft	A_c/A_f	0.14			
W=(0.9D)	1040.04	k	m	2.94			
q_c	12	k/sf					
mq_c	35.31	k/sf					
M_{ot}	107260	k-ft	unreduced				
M_{ot}	21422	k-ft	reduced to provide maximum permissible pressure				
M_r	22881	k-ft					
μ_{ot}	5.01	effective reduction					
a	1.40	ft					
P	35.31	k/sf					

Length	μ_{ot}
	5.01
30	8.43
32	7.72
34	7.12
36	6.59
38	6.12
40	5.71
42	5.34
44	5.01
46	4.71
48	4.44
50	4.19



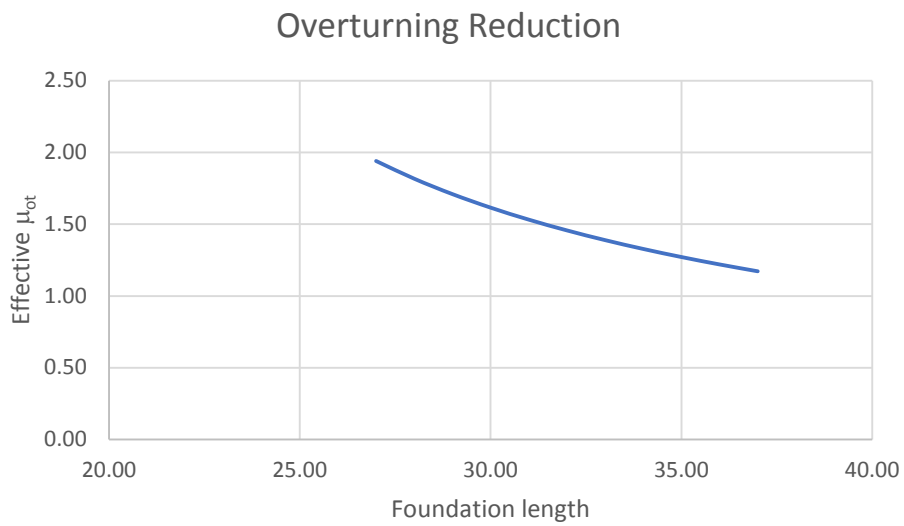
- Effective reduction could be over 8 – more than actual R=5

Example 2

- Moderately loaded Foundation A_c/A_f = 0.36; low shear

b	4	ft	A_c	39.42	sf		
L	27	ft	A_f	109.32	sf		
t	4	ft	A_c/A_f	0.36			
W=(0.9D)	473.03	k	m	1.75			
q_c	12	k/sf					
mq_c	21.04	k/sf					
M_{ot}	8905	k-ft	unreduced				
M_{ot}	4692	k-ft	reduced to provide maximum permissible pressure				
M_r	6464	k-ft					
μ_{ot}	1.90	effective reduction					
a	3.75	ft					
P	21.04	k/sf					

Length	μ_{ot}
	1.90
27	1.94
28	1.82
29	1.71
30	1.62
31	1.53
32	1.46
33	1.39
34	1.33
35	1.27
36	1.22
37	1.17



- Effective reduction is small – well less than actual R =5

Concluding thoughts

- For any building, the effective rocking reduction at maximum safe soil pressure can be computed for each wall and foundation
- The lowest reduction factor in each direction could be used for the design of all elements, including diaphragms, collectors, etc.
- The loads reduced in this manner can be considered as E_m
- Most effective in light buildings