OptumG3

Bearing capacity of strip footing on sand

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1 Introduction

The bearing capacity of a strip footing may be assessed by Terzaghi's bearing capacity equation:

$$q_u = cN_c + qN_q + \tfrac{1}{2}\gamma BN_\gamma \tag{1.1}$$

where:

q_u = bearing capacity

c = cohesion

q = surcharge

γ = soil unit weight

B = footing width

N_c, N_q, N_γ = bearing capacity factors

The bearing capacity factors all depend on the soil friction angle ϕ. In addition, N_γ depends on the soil-foundation interface roughness, usually specified in terms of the interface friction angle δ.

For the special case of a surface footing on sand ($c = 0$ and $q = 0$), the bearing capacity is given by

$$q_u = \tfrac{1}{2}\gamma BN_\gamma \tag{1.2}$$

Numerous approximate expressions for N_γ are listed in textbooks and codes of practice. However, the definite and exact N_γ was determined by Martin (2005). It is listed in the table below, along with N_c and N_q, for various friction angles and soil-foundation interface roughnesses, δ/ϕ.

In the following, the problem where $\phi = 30°$ is solved for various soil-interface roughnesses.

Exact bearing capacity factors for strip footings

Martin, C.M. (2005), http://www2.eng.ox.ac.uk/civil/people/cmm/download/ncnqngamma.xls

ϕ	N_c	N_q	N_γ				
(°)	δ/ϕ = any	δ/ϕ = any	δ/ϕ = 0	δ/ϕ = 1/3	δ/ϕ = 1/2	δ/ϕ = 2/3	δ/ϕ = 1
0	5.14159	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000
1	5.37926	1.09390	0.0106339	0.0110586	0.0112596	0.0114539	0.0118240
2	5.63160	1.19666	0.0242179	0.0257878	0.0265319	0.0272506	0.0286045
3	5.89977	1.30919	0.0408212	0.0443525	0.0460261	0.0476371	0.0506295
4	6.18504	1.43250	0.0607622	0.0672331	0.0702954	0.0732293	0.0785916
5	6.48882	1.56770	0.0844649	0.0950574	0.100057	0.104821	0.113371
6	6.81264	1.71604	0.112443	0.128586	0.136180	0.143368	0.156020
7	7.15820	1.87892	0.145304	0.168723	0.179693	0.190002	0.207770
8	7.52736	2.05790	0.183757	0.216532	0.231807	0.246050	0.270054
9	7.92217	2.25475	0.228629	0.273262	0.293945	0.313066	0.344540
10	8.34493	2.47144	0.280879	0.340379	0.367775	0.392867	0.433164
11	8.79814	2.71019	0.341627	0.419603	0.455253	0.487578	0.538175
12	9.28461	2.97351	0.412173	0.512957	0.558674	0.599689	0.662191
13	9.80746	3.26423	0.494036	0.622817	0.680737	0.732111	0.808259
14	10.3701	3.58556	0.588986	0.751982	0.824616	0.888264	0.979939
15	10.9765	3.94115	0.699096	0.903758	0.994049	1.07216	1.18139
16	11.6309	4.33511	0.826793	1.08205	1.19345	1.28852	1.41748
17	12.3381	4.77215	0.974928	1.29147	1.42803	1.54291	1.69393
18	13.1037	5.25764	1.14685	1.53753	1.70397	1.84190	2.01746
19	13.9336	5.79771	1.34653	1.82673	2.02861	2.19325	2.39600
20	14.8347	6.39939	1.57862	2.16686	2.41065	2.60618	2.83894
21	15.8149	7.07076	1.84869	2.56721	2.86050	3.09162	3.35737
22	16.8829	7.82112	2.16332	3.03892	3.39057	3.66260	3.96449
23	18.0486	8.66119	2.53035	3.59535	4.01573	4.33468	4.67604
24	19.3235	9.60339	2.95919	4.25262	4.75384	5.12649	5.51080
25	20.7205	10.6621	3.46108	5.03017	5.62641	6.06038	6.49131
26	22.2544	11.8542	4.04956	5.95158	6.65942	7.16328	7.64467
27	23.9422	13.1991	4.74097	7.04550	7.88433	8.46773	9.00358
28	25.8033	14.7199	5.55510	8.34686	9.33941	10.0132	10.6076
29	27.8605	16.4433	6.51599	9.89841	11.0713	11.8475	12.5050
30	30.1396	18.4011	7.65300	11.7527	13.1371	14.0294	14.7543
31	32.6711	20.6308	9.00208	13.9744	15.6069	16.6306	17.4275
32	35.4903	23.1768	10.6074	16.6437	18.5673	19.7393	20.6131
33	38.6383	26.0920	12.5237	19.8603	22.1254	23.4649	24.4203
34	42.1637	29.4398	14.8188	23.7485	26.4145	27.9427	28.9849
35	46.1236	33.2961	17.5771	28.4643	31.6012	33.3421	34.4761
36	50.5855	37.7525	20.9049	34.2044	37.8947	39.8748	41.1059
37	55.6296	42.9199	24.9357	41.2180	45.5591	47.8083	49.1416
38	61.3518	48.9333	29.8388	49.8224	54.9296	57.4811	58.9219
39	67.8668	55.9575	35.8302	60.4242	66.4339	69.3250	70.8787
40	75.3131	64.1952	43.1866	73.5471	80.6214	83.8937	85.5656
41	83.8583	73.8969	52.2656	89.8703	98.2022	101.902	103.697
42	93.7064	85.3736	63.5316	110.280	120.100	124.280	126.203
43	105.107	99.0143	77.5929	135.943	147.525	152.243	154.300
44	118.369	115.308	95.2519	168.401	182.075	187.396	189.592
45	133.874	134.874	117.576	209.715	225.876	231.874	234.213
46	152.098	158.502	145.996	262.657	281.784	288.541	291.026
47	173.640	187.206	182.449	330.993	353.662	361.270	363.907
48	199.259	222.300	229.584	419.882	446.795	455.359	458.150
49	229.924	265.497	291.056	536.469	568.482	578.119	581.067
50	266.882	319.057	371.967	690.752	728.912	739.755	742.863
51	311.752	385.982	479.523	896.883	942.480	954.679	957.947
52	366.660	470.304	624.024	1175.14	1229.77	1243.49	1246.92
53	434.421	577.496	820.392	1554.95	1620.59	1636.04	1639.63
54	518.805	715.074	1090.56	2079.65	2158.80	2176.18	2179.93
55	624.924	893.484	1467.23	2814.00	2909.77	2929.35	2933.25
56	759.793	1127.44	2000.05	3856.36	3972.74	3994.80	3998.85
57	933.170	1437.96	2765.60	5358.81	5500.86	5525.73	5529.93
58	1158.83	1855.52	3884.45	7560.90	7735.20	7763.26	7767.58
59	1456.54	2425.08	5550.24	10847.9	11063.0	11094.7	11099.1
60	1855.10	3214.14	8081.21	15853.6	16120.6	16156.5	16161.0

2 Bearing capacity

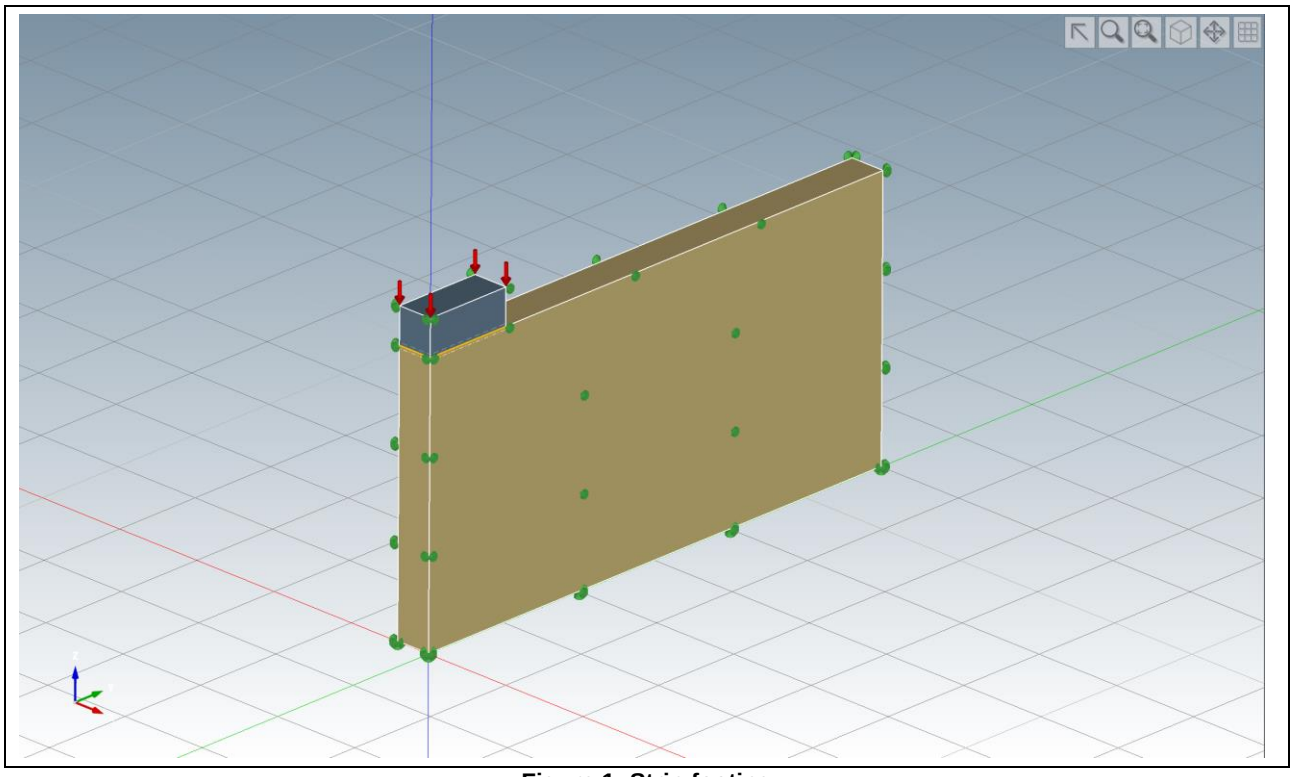

Figure 1: Strip footing

Results

The benchmark solutions are computed using the exact N_γ of Martin (2005) listed in the table above.

δ/ϕ	Limit load	Benchmark	Discrepancy (%)
0	619.913	612.240	1.25
0.3333	943.621	940.216	0.36
0.5	1070.771	1050.968	1.88
0.6667	1127.891	1122.352	0.49
1	1182.357	1180.344	0.17

General description:

Solid domain: 30x15x2m. Foundation: Rigid weightless solid, 5x2x2 m (corresponding to a footing width of *B* = 10m). Interfaces are introduced via a Rigid Shell element between the soil and the foundation. Sides are supported normally to reproduce plane strain and symmetry conditions. The bottom is fully fixed. A distributed multiplier load of -1kPa is applied to the top of the foundation. The soil is modelled as a Mohr-Coulomb material with ϕ = 30° and γ = 16 kN/m^3. Limit Analysis is used to determine the limit loads (collapse multipliers).

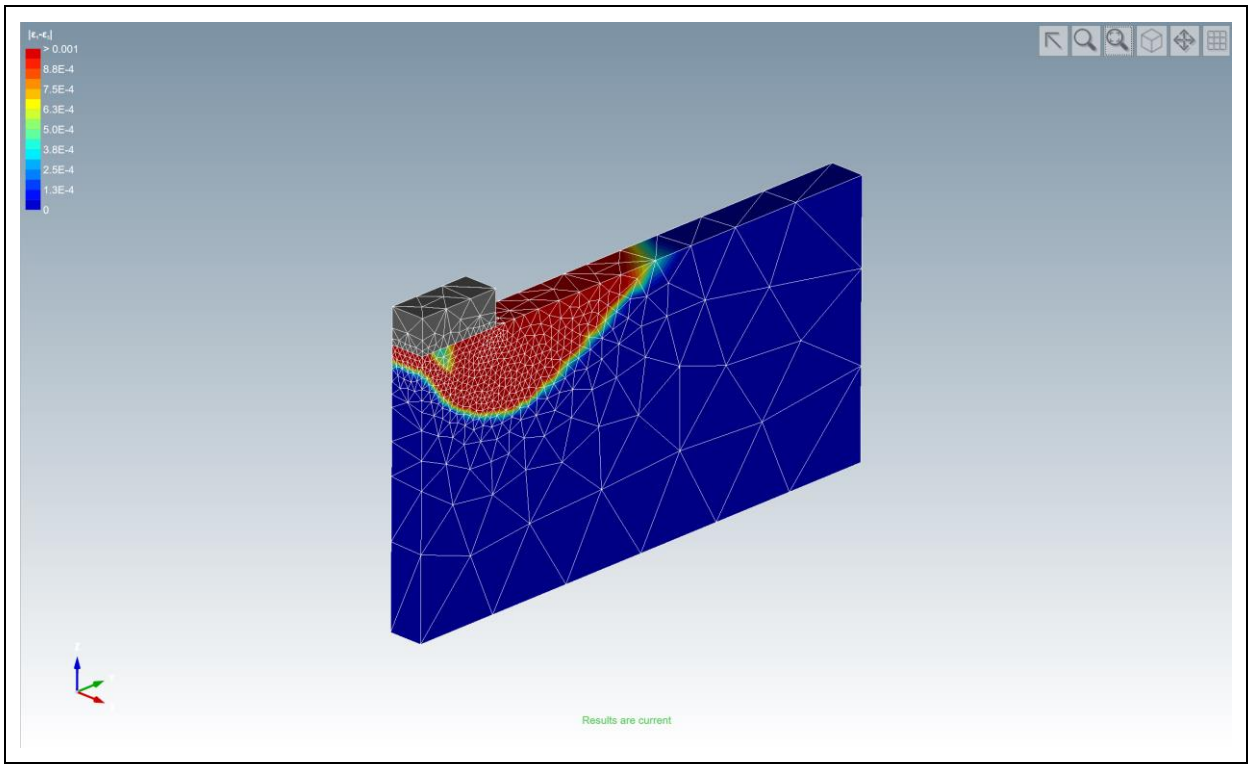

Figure 2: Shear strain field for $\delta l \phi$ = 0

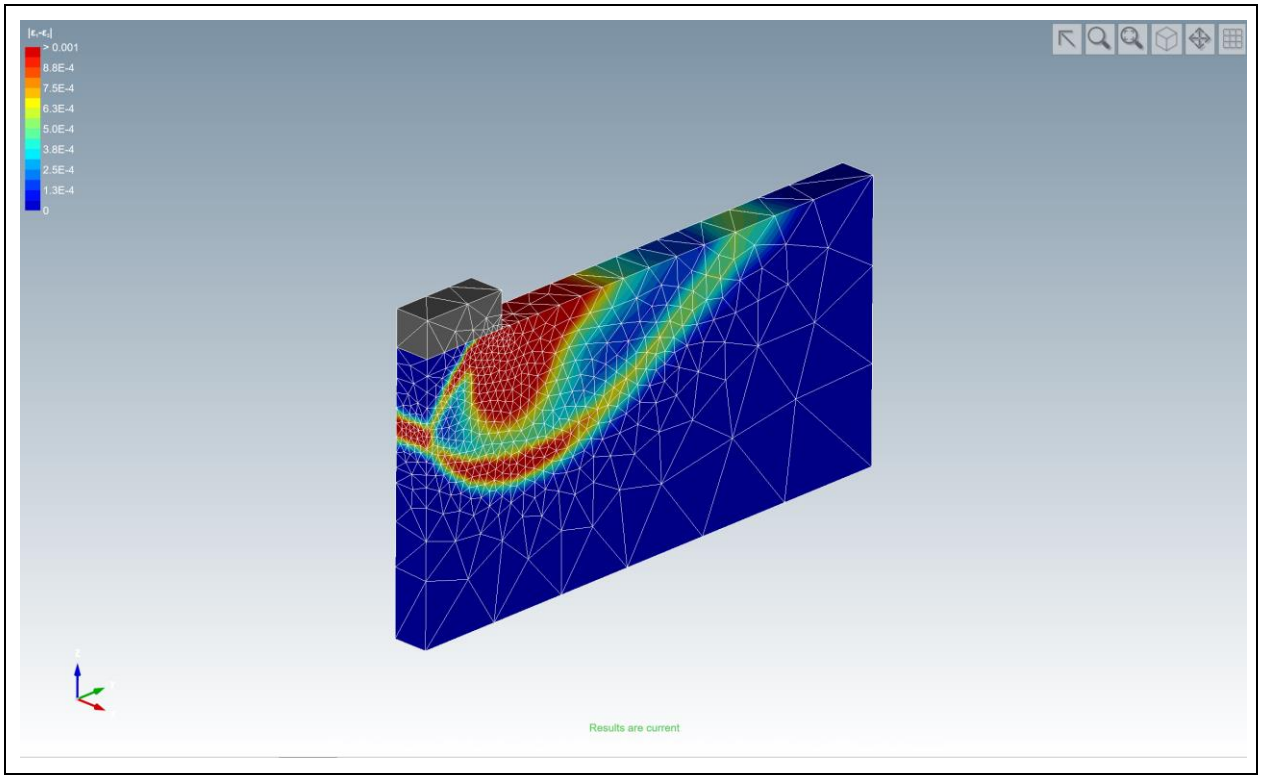

Figure 3: Shear strain field for $\delta l \phi$ = 1

Material properties:

Strength	
c (kPa)	0
ϕ (°)	35

Unit Weight	
γ (kN/m^3)	18

Stage settings:

Settings	
Element Type	Mixed
No of Elements	1E+04

Mesh	
Mesh Adaptivity	Yes
Adaptive Iterations	3
Start Elements	1000

Reference:

Martin C.M. 2005. Exact bearing capacity calculations using the method of characteristics, Proc. IACMAG, Turin, 2005. http://www2.eng.ox.ac.uk/civil/people/cmm/download/iacmag05_cmm.pdf