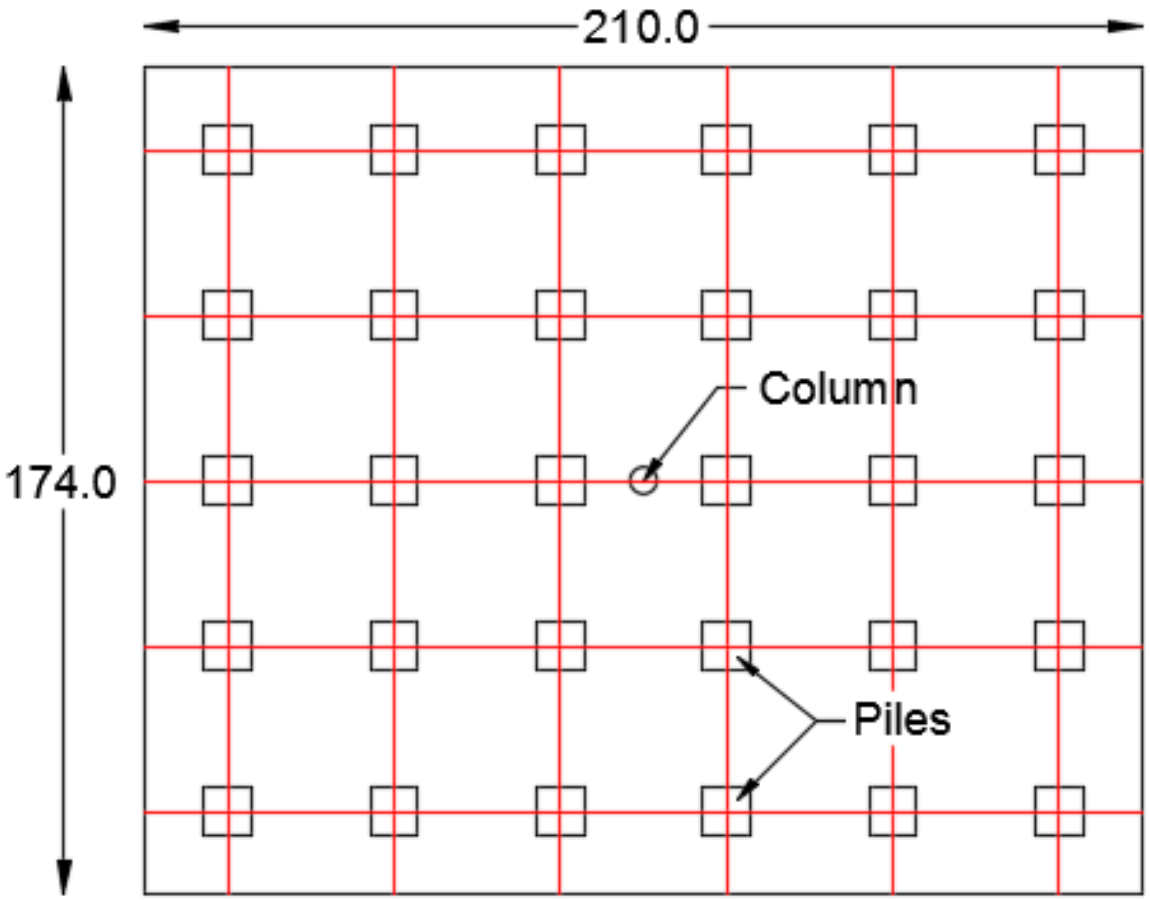
PILE REACTIONS DISTRIBUTION IN PILE CAP FOUNDATION

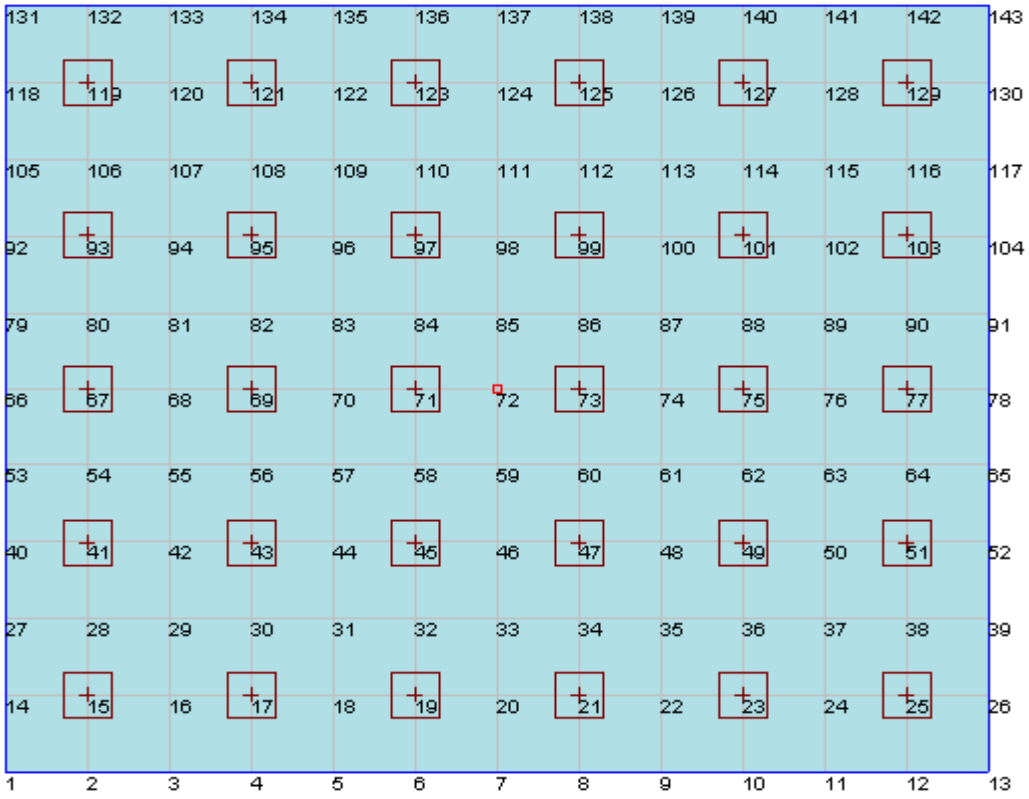
A Comparison of the CRSI Design Guide with spMats Program

Investigate the column load distribution to each pile of a 59 in thick pile cap foundation with the arrangement shown in the figure below. In this foundation, 30 - 10 in square piles are used to support a center column carrying 5000 kips. The piles are 40ft long and spaced approximately 1.45' apart with axial stiffness of 1200 kips/in (14400 kips/ft).

Pile cap foundation material is 4.0 ksi concrete with a modulus of elasticity of 3834.25 ksi, poisson's ratio 0.2, and density of 150 pcf.



Pile Cap Foundation Arrangement



Pile Cap Foundation Analytical Model spMats Program

Results: The table summarizes the percentage of applied loads resisted by each pile. The total loads (including the self-weight of the pile cap) = 5187.141 kips

Node	Reaction	% of Total	Proportion		Node	Reaction	% of Total	Proportion
15	157.333	3.03	1/32.97		73	191.92	3.70	1/27.03
17	169.559	3.27	1/30.59		75	179.068	3.45	1/28.97
19	177.617	3.42	1/29.2		77	164.29	3.17	1/31.57
21	177.617	3.42	1/29.2		93	162.241	3.13	1/31.97
23	169.559	3.27	1/30.59		95	176.015	3.39	1/29.47
25	157.333	3.03	1/32.97		97	186.381	3.59	1/27.83
41	162.241	3.13	1/31.97		99	186.381	3.59	1/27.83
43	176.015	3.39	1/29.47		101	176.015	3.39	1/29.47
45	186.381	3.59	1/27.83		103	162.241	3.13	1/31.97
47	186.381	3.59	1/27.83		119	157.333	3.03	1/32.97
49	176.015	3.39	1/29.47		121	169.559	3.27	1/30.59
51	162.241	3.13	1/31.97		123	177.617	3.42	1/29.2
67	164.29	3.17	1/31.57		125	177.617	3.42	1/29.2
69	179.068	3.45	1/28.97		127	169.559	3.27	1/30.59
71	191.919	3.70	1/27.03		129	157.333	3.03	1/32.97

Additional tests were carried out varying the piles vertical stiffness as provided in table 3.1 of CRSI Design Guide. The results are listed below.

Vertical Pile stiffness (kips/in)	CRSI Manual		spMats Program	
	P_{center} (2 piles)	P_{corner} (4 piles)	P_{center} (2 piles)	P_{corner} (4 piles)
100	1/30	1/30	1/30	1/30
400	1/28	1/32	1/29	1/31
800	1/27	1/33	1/28	1/32
1200	1/25	1/34	1/27	1/33

Conclusions & Observations:

Based on the study above the following can be concluded:

1. CRSI's Design Guide reports the two piles closest to the column resist approximately 1/27 of the overall column demand while the 4 corner piles resist approximately 1/33. Results from spMats software model at nodes 71 and 73 indicate 1/27.03 for the center piles and 1/32.97 for the corner piles which shows very close agreement between the two sources.
2. As noted from the table above, as the piles become stiffer the portion of applied vertical loading as presented in Table 3.1 of the CRSI manual deviates from that calculated from spMats. Piles with stiffness of 800 kips/in in the CRSI manual coincide better with results from the 1200 kips/in stiff piles instead.
3. In general FEA programs such as spMats should be used carefully by the engineer when it comes making choices of load application, mesh density and aspect ratio, pile stiffness, and pile location.

References

[1] spMats v8.12 – Analysis and Design of Foundation Mats, Combined Footings, and Slabs on Grade, STRUCTUREPOINT 2016

[2] CRSI Design Guide for Pile Caps, 1st Edition