FINITE ELEMENT MESH DENSITY INFLUENCE ON spMats MODEL RESULTS

Structural engineers routinely ask us about the influence of mesh density on the results obtained from spMats models. In any Finite Element Analysis (FEA), individual finite elements can be visualized as small pieces of a structure and particular arrangements of these elements is known as a mesh. Mesh density in FEA is defined as the number of elements used in modeling a given structure. According to FEA theory, high density models (small element size and a fine mesh) yield results with higher accuracy but may take longer computing time compared to low density models (large element size and a coarse mesh). Computational power required increases exponentially with increase in mesh density and slows down the analysis. Therefore, it is not always practical or necessary to simply decrease the element size in order to increase accuracy.

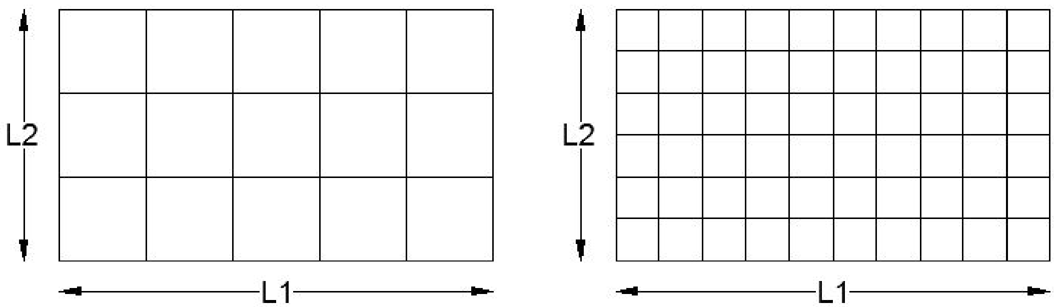

Figure 1 – Coarse mesh (low density) and Fine mesh (high density) for the same model

spMats uses the Finite Element Method for the structural modeling and analysis of reinforced concrete slab floor or foundation systems. The slab is idealized as a mesh of rectangular elements interconnected at the corner nodes. The same mesh applies to the underlying soil with the soil stiffness concentrated at the nodes. Slabs of irregular geometry are idealized to conform to geometry with rectangular boundaries. Rectangular elements make it easy to define structured grids and make the model more space efficient and contribute to better solution convergence.

Parametric Study

To assess the influence of mesh density in spMats, a simple slab model using progressively decreasing element sizes was investigated and the corresponding results provided in this article.

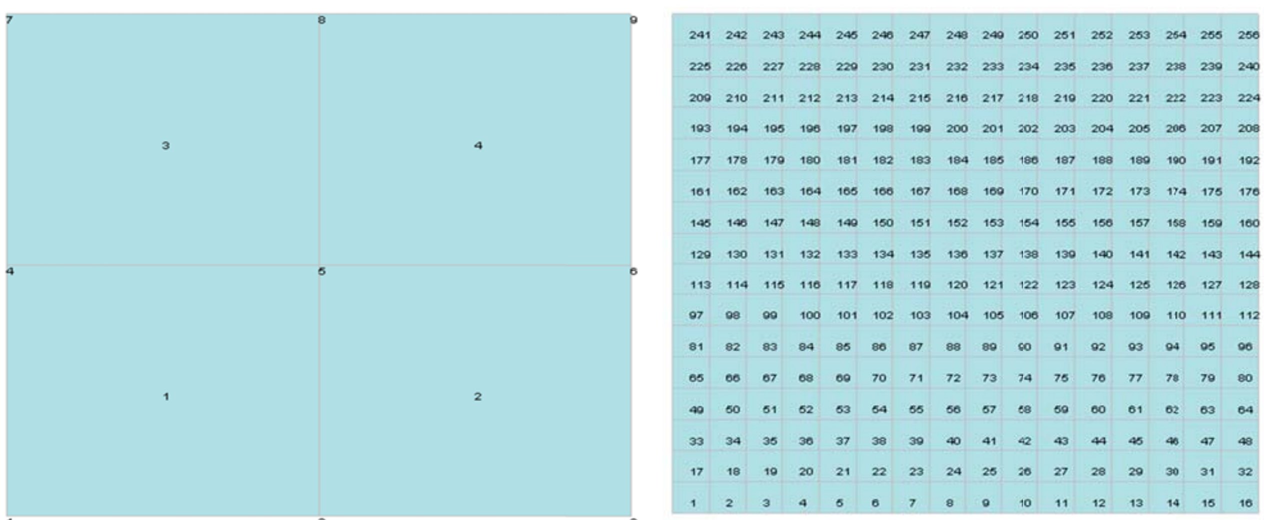

Figure 2 – Example of coarse and fine meshes for the same slab as modeled in spMats

Case 1: Concentrated load
Mat Foundation Plan Dimensions: 8 ft x 8 ft
Mat Foundation Thickness: 12 in
Applied Load: 75 kips concentrated at center acting downwards

Element Size (ft)	Number of Elements	Corner Nodes		Central Node	
		Deflection (in)	Successive Difference (%)	Deflection (in)	Successive Difference (%)
4x4	4	-0.14945	N/A	-0.17096	N/A
2x2	16	-0.1496	0.1	-0.16775	1.87
1x1	64	-0.14973	0.08	-0.16230	3.24
½x½	256	-0.14977	0.02	-0.16677	2.75
¼x¼	1024	-0.14978	0.0067	-0.16671	0.036

Table 1 – Deflection convergence as a function of element size/mesh density

Case 2: Surface load
Mat Foundation Plan Dimensions: 8 ft x 8 ft
Mat Foundation Thickness: 12 in
Applied Load: 5 kips/ft^2 surface area load acting downwards

Element Size (ft)	Number of Elements	Corner Nodes		Central Node	
		Deflection (in)	Successive Difference (%)	Deflection (in)	Successive Difference (%)
8x8	1	-0.61800	N/A	-0.618	N/A
4x4	4	-0.60697	1.78	-0.629	1.78
2x2	16	-0.61449	1.23	-0.6201	1.42
1x1	64	-0.61707	0.42	-0.61848	0.26
½x½	256	-0.61777	0.11	-0.61812	0.05
¼x¼	1024	0.61794	0.02	-0.61803	0.01
0.1x0.1	4096	0.61799	0.008	-0.618	0.004

Table 2 – Deflection convergence as a function of element size/mesh density

Conclusions

1. Increasing mesh density (number of elements) improves the convergence of nodal deflections for concentrated and surface loads
2. The resulting deflections under concentrated loads converge slower than other nodes (case 1). When possible, large concentrated loads can be distributed over multiple nodes with smaller load magnitude or replaced completely with a surface load. This helps to even out the nodal displacements and corresponding soil pressures.
3. The resulting deflections under surface loads (case 2) converge faster than deflections under concentrated loads (case 1)
4. Slabs analyzed with FEA exhibit a cupping effect as the loaded slab corners deflect or lift slightly upwards. Cupping effect is more pronounced with a higher mesh density (increasing number of elements)
5. While there are no rules for selection, solution convergence within 1% can be reasonably achieved starting with elements size equal 10% of the slab least lateral dimension. The user can always try smaller sized elements to achieve higher convergence keeping in mind the practical usefulness of the result. Note that in tables 1 and 2 the resulting deflections with smaller elements are essentially the same from a structural foundation design point of view
6. The spMats manual and References below provide the user with additional background on using spMats and Finite Element Analysis methods to help prepare efficient models and enhance judgment to obtain best possible results.

References

1. Aparico, Christian. The best FEA Mesh Density For Accuracy and Speed 2013
2. Cook, Robert D., Malkus, David S., Plesha, Michael E. and Witt, Robert J. Concepts and Applications of Finite Element Analysis 2002
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4. Kanapady, R., Bhatia S. K. and Tamma K. K. Determination of Initial Mesh Density for Finite Element Computations via Data Mining 2001
5. StructurePoint spMats v8.12 Software Manual