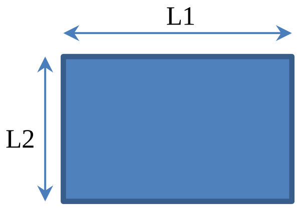
FINITE ELEMENT ASPECT RATIO INFLUENCE IN CONCRETE FOUNDATION MODELS

The aspect ratio "a" of an element is defined by, $a = \frac{r2}{r1}$, where r_2 is the radius of the largest circle containing the element and r_1 is the radius of the smallest circle contained in the element. For rectangular elements as are used in spMats, aspect ratio can be simply defined as the ratio of the largest to the smallest length of the sides of the element.



Aspect Ratio, $a = \frac{L1}{L2}$

Figure 1 – Aspect Ratio for a rectangular element

Finite Element Analysis (FEA) theories state that local variation in cell sizes should be minimal citing that large aspect ratios can result in interpolation errors of unacceptable magnitudes and loss of computational accuracy. The best possible value of the aspect ratio for a rectangular element therefore, is 1. A rough guideline suggests that elements with aspect ratios exceeding 3 should be viewed with caution. However, it should be understood that numerous elements based on different interpolation functions exist in the market today. Aspect ratios might affect the solutions produced by some elements more than others.

spMats utilizes a 4 noded rectangular element with 3 degrees of freedom at each node. Rectangular elements make it easy to define structured grids and facilitate regular connectivity. There have been studies showing that large aspect ratios (100-100,000) do not result in loss of computational accuracy for rectangular elements [1]. Furthermore, various literatures concur that the performance of these elements are generally best when they are used without distortions; for example, best results are obtained when rectangular elements are truly rectangular [2].

Parametric Study

The influence of element aspect ratios in spMats results was investigated in two parts. The first part dealt with establishing a maximum element size which would then yield resulting deflections that converged to the second decimal place in case of use of smaller sized elements. This was done to prevent the effect of aspect ratio on results being cross contaminated by the effects of increasing mesh density. Also three different load cases were used; uniform load throughout the foundation, concentrated load at foundation center and concentrated loads at 4 corners of the foundation.

Part 1:
It was seen that, elements equal to or smaller than 0.5ft sides with aspect ratio 1 produced resulting deflections that converged to the second decimal place. The second part of the study was then conducted using 0.5ft sided elements with aspect ratio 1 as the control.

Part 2:
Design Data
Mat Foundation Plan Dimensions: 4 ft x 4 ft
Mat Foundation Thickness: 12 in

With

1. Uniform Area Load 2000 psf acting throughout the foundation
2. Center Concentrated Load 75 kips
3. Concentrated loads of 20 kips acting on four corners

In every step, new elements were created by dividing only the left and right most 0.5ft grid in the x-direction to progressively generate elements with higher aspect ratios. The average effects of increasing aspect ratios compared to the control and percentage change in results due to decrease in element size are summarized in the tables below.

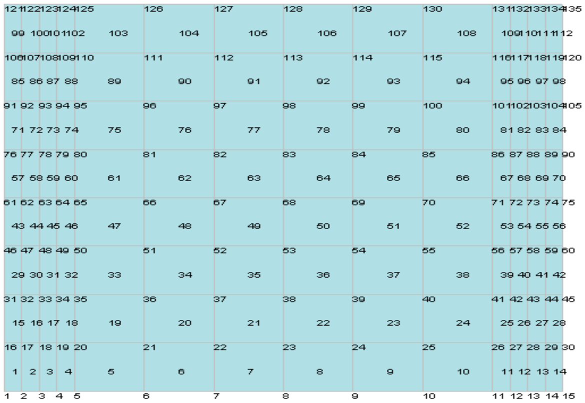
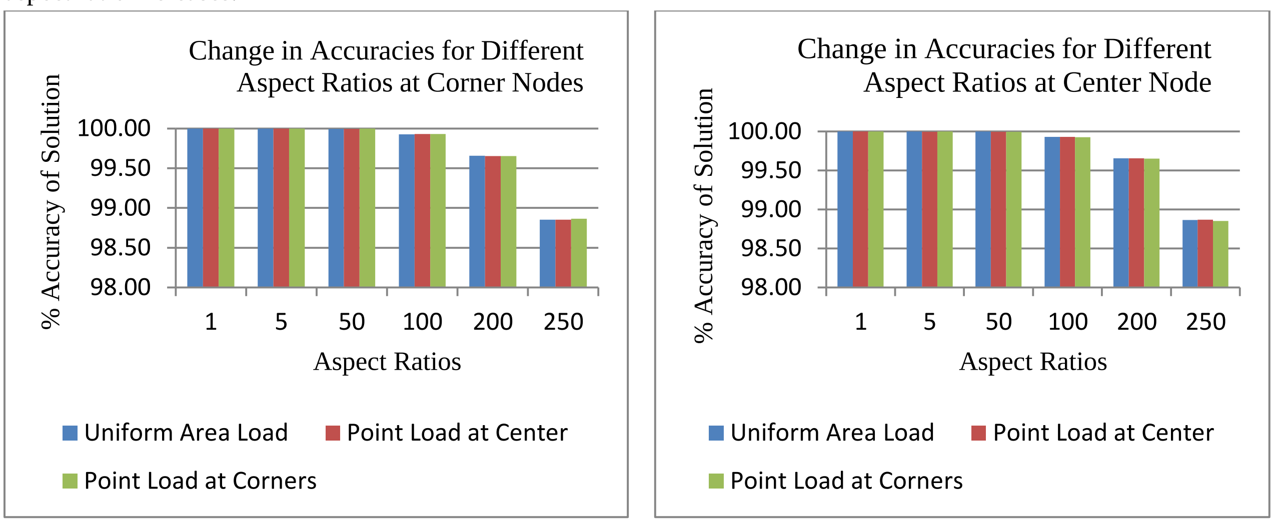


Figure 2 – Mesh example for study of aspect ratio

Element Size (ft)	Percentage deflection deviation in each step
3	0
1.5	3.21
0.75	0.862
0.5	0.164
0.25	0.0979
0.15	0.0227
0.075	0.00873
0.05	0.00175

Aspect Ratio	Average % deviation in deflection results
1	0
2	0.0024
4	0.0030
5	0.0030
10	0.0073
100	0.1261
200	1.5913
250	1.5050

It can be seen from the study that aspect ratios of up to 10 have a negligible effect on the results. Subtle differences in solutions can be seen when the aspect ratio is in the order of 100 with the differences getting more pronounced as the aspect ratio increases.



Figures 3 – Graphs showing change in solution accuracy with aspect ratio at center and corner loads

Conclusions

1. Increasing the aspect ratio makes a difference in the accuracy of the solution obtained.
2. It is recommended that elements with aspect ratios less than 10 be used during modelling.
3. In cases where elements with aspect ratios greater than 10 are difficult to avoid, it is suggested that users try to reduce the aspect ratio by increasing the mesh density.
4. It is suggested that elements with aspect ratios close to or greater than 100 be avoided entirely
5. The spMats manual and References below provide the user with additional background on using Finite Element Analysis methods to help prepare efficient models and enhance validity of results.

References

1. Rice, J. (1985). Is the aspect ratio significant for finite element problems? No. 85-535) Department of Computer Science, Purdue University.
2. Bathe, K. (1982). Finite element procedures in engineering analysis (1st Ed). New Jersey: Prentice-Hall, Inc.