Plate Mesh©
Convergence Study

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OVERVIEW

For a finite element analysis, “convergence” must be achieved for an accurate result. In other words, the number of elements must be sufficient such as provide a relatively accurate solution. Increasing the number of elements (for the same element type) reduces the error between the actual solution and the FEA solution. However, increasing the number of elements also increases computational time.

This document evaluates various cases, the mesh density, and the possible element types (QUAD4 versus QUAD8). Based on these results, recommendations to achieve convergence are provided. The user can also choose their own settings, which can be aided by the information provided in this document.

As an additional point of reference, the validation document has 27 cases that use the “High Accuracy” setting (although stretch elements is not allowed for that document).

RECOMMENDATIONS FOR CONVERGENCE

Default settings for **HIGH ACCURACY**:

QUAD8

Reduced Integration (R)

Elements on short edge = 16

Allow stretch? = Y

Max known error with these settings is 1.8%. Most cases are accurate to within 1%.

Default settings for **MEDIUM ACCURACY**:

QUAD8

Reduced Integration (R)

Elements on short edge = 10

Allow stretch? = Y

Max known error with these settings is 4.5%. Most cases are accurate to within 1%.

NOTES:

If QUAD4 is used, it is recommended to use at least 30 elements along the shortest edge. Max known error with this setting is 4.6%.

If QUAD8 is used, it is recommended to use at least 10 elements along the shortest edge (for either Full or Reduced integration).

If QUAD8 is used, Reduced (R) Integration = “R”, converges with few elements than full integration “F” (Full Integration).

The setting “Allow Stretch = Y” has a minor effect to solution accuracy, but can dramatically reduce the run time.

The QUAD4 with reduced integration is not available because the results are very inaccurate.

CONVERGENGE STUDY

For the following figures, the far left column represent the number of elements along the short edge. The second column is the result predicted by the FEA solution. The third column is the error for the FEA solution (based on the assumption that the classical solution is exact).

Case 1:

W=10, H=10
Isotropic material, E = 10.0E6, v = 0.30, t = 0.05
All edges simply supported
Nx – Uniaxial running load
Stretch not allowed

Classical Solution :
Fx,cr = 903.5psi (Kc = 4.0)
Nx,cr = 45.17

QUAD4, F	Nx, cr	% Error
10	71.8	58.9
16	49.3	9.1
20	46.8	3.6
30	45.5	0.7
50	45.2	0.1

QUAD8, F	Nx, cr	% Error
2	1816	3920.1
4	61.9	37.0
6	46.9	3.8
8	45.7	1.2
12	45.3	0.3
18	45.4	0.5

QUAD8, R	Nx, cr	% Error
2	42.4	-6.1
4	45.2	0.1
6	44.7	-1.0
8	44.9	-0.6
12	45	-0.4
18	45	-0.4

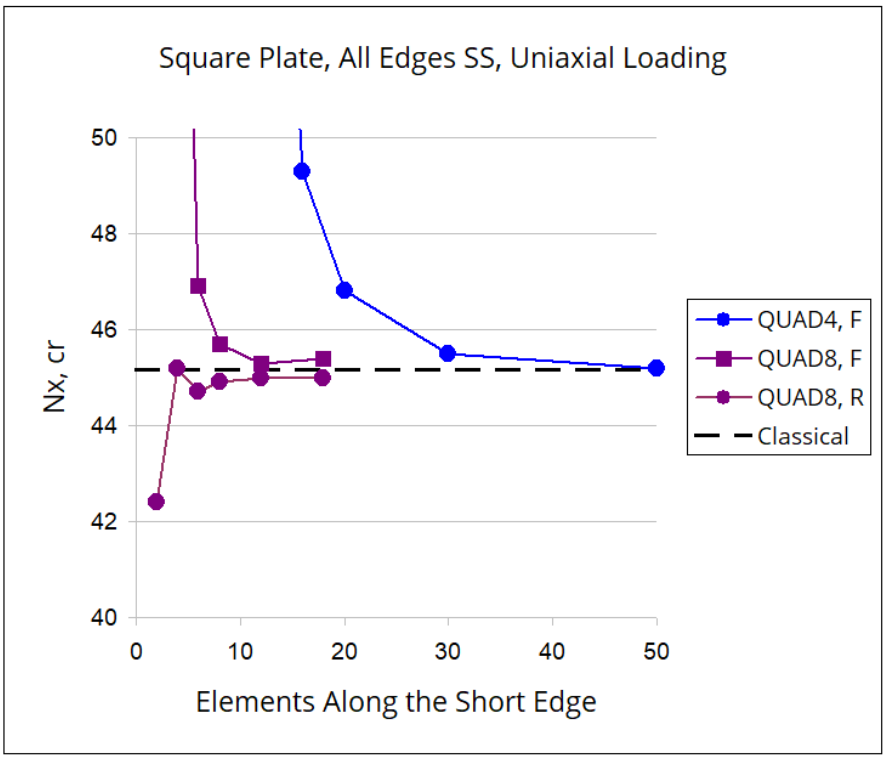

Figure 1 : Convergence for Case 1

Case 1L:

Same as case 1, but Width=50 (aspect ratio of 5:1).

QUAD4, F	Nx, cr	% Error
10	69.6	54.1
16	49.3	9.1
20	46.9	3.8
30	45.5	0.7
50	45.2	0.1

QUAD8, F	Nx, cr	% Error
2	-	-
4	58.1	28.6
6	46.9	3.8
8	45.7	1.2
12	45.3	0.3
18	45.2	0.1

QUAD8, R	Nx, cr	% Error
2	-	-
4	46.5	2.9
6	44.9	-0.6
8	45.0	-0.4
12	45.0	-0.4
18	45.1	-0.2

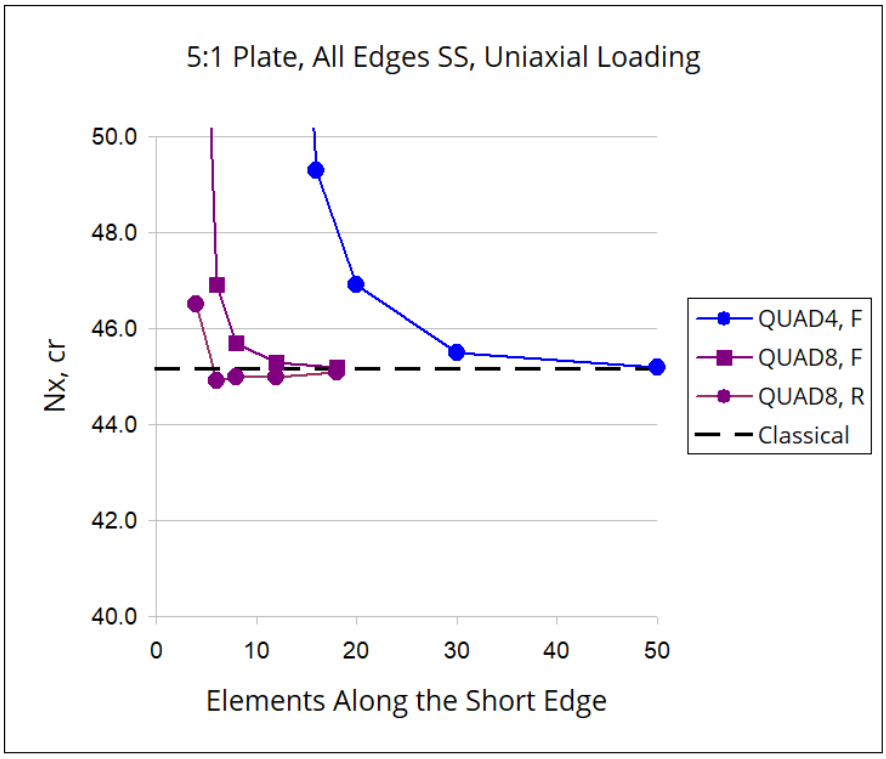

Figure 2 : Convergence for Case 1L

Case 1LS:

Same as case 1L, but allow stretching is set to "Y". This means the elements can be stretched to have an aspect ratio of about 2:1.

QUAD4, F	Nx, cr	% Error
10	135.0	198.8
16	60.4	33.7
20	51.7	14.4
30	46.4	2.7
50	45.4	0.5

QUAD8, F	Nx, cr	% Error
2		-
4	121.0	167.9
6	54.8	21.3
8	48.3	6.9
12	45.7	1.2
18	45.4	0.5

QUAD8, R	Nx, cr	% Error
2		-
4	62.6	38.6
6	47.0	4.0
8	45.3	0.3
12	45.1	-0.2
18	45.1	-0.2

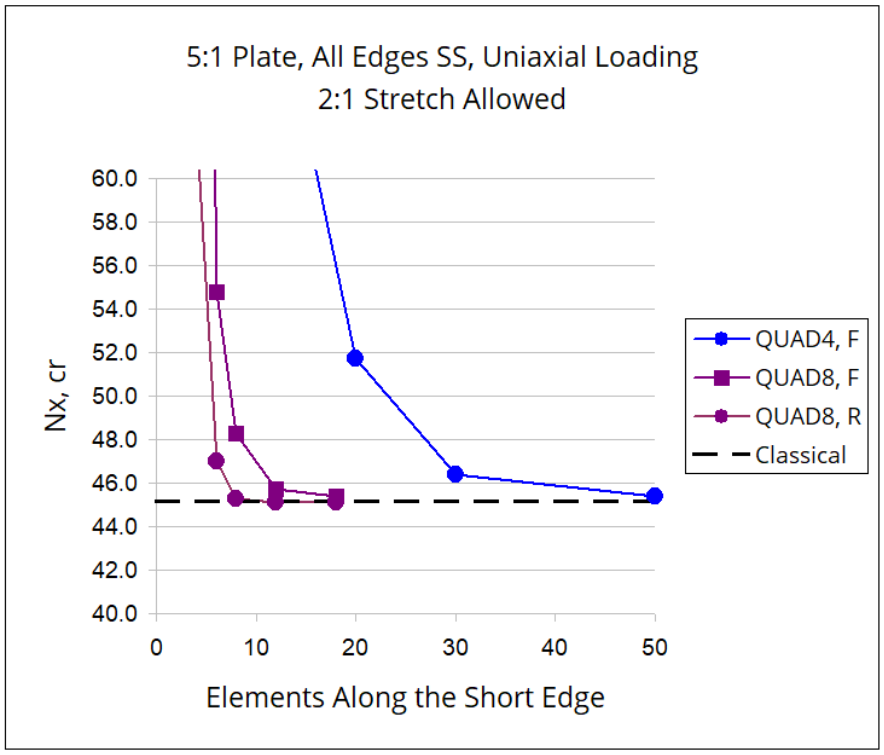

Figure 3 : Convergence for Case 1LS

Case 2:

Same as Case 1, but a shear running load (Nxy) is applied

QUAD4, F	Nxy, cr	% Error
10	266.0	152.2
16	132.8	25.9
20	117.2	11.1
30	107.8	2.2
50	105.6	0.1

QUAD8, F	Nxy, cr	% Error
2	19030.0	17941.3
4	483.5	358.4
6	148.6	40.9
8	115.7	9.7
12	107.4	1.8
18	105.9	0.4

QUAD8, R	Nxy, cr	% Error
2	6225.0	5801.6
4	167.7	59.0
6	112.9	7.0
8	106.4	0.9
12	105.0	-0.5
18	105.0	-0.5

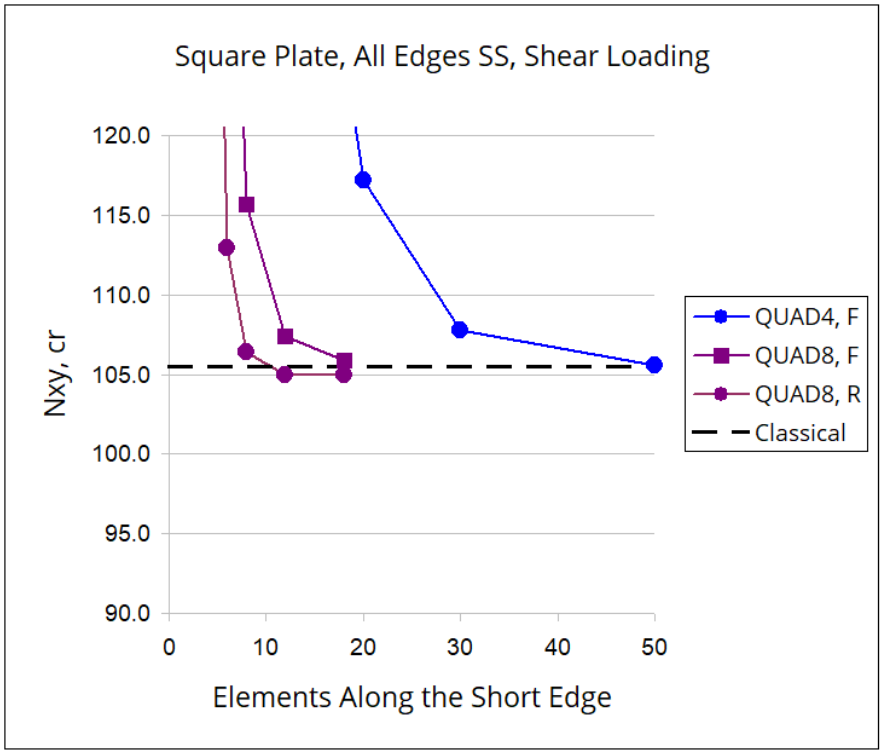

Figure 4 : Convergence for Case 2

Case 3:

Same as Case 1, but all edges are clamped.

QUAD4, F	Nxy, cr	% Error
10	252.8	116.2
16	135.7	16.1
20	123.0	5.3
30	115.8	-0.9
50	114.1	-2.4
70	113.9	-2.6

QUAD8, F	N, cr	% Error
2	18972.1	-
4	1124.3	-
6	188.9	61.6
8	132.9	13.7
10	123.1	5.3
12	119.8	2.5
16	117.2	0.3
20	116.1	-0.7

QUAD8, R	N, cr	% Error
2	155.8	-
4	238.7	104.2
6	129.8	11.1
8	118.6	1.5
10	116.7	-0.2
12	116.0	-0.8
16	115.3	-1.3
20	115.0	-1.6

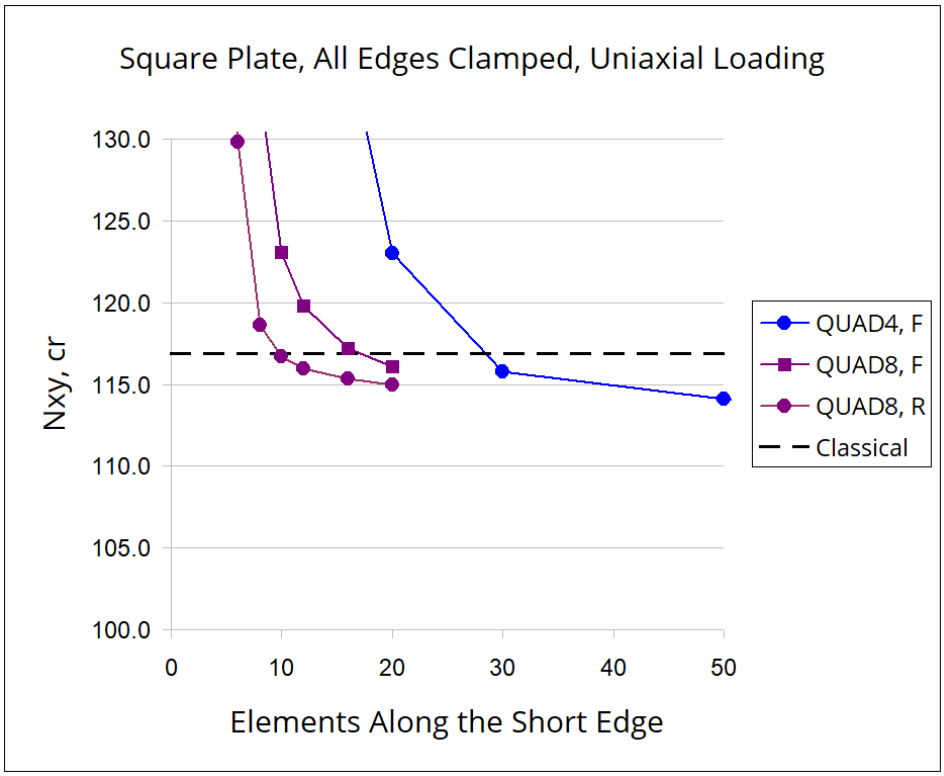

Figure 5 : Convergence for Case 3

Case 4:

Same as Case 1, but all edges are clamped and a shear running load is applied.

QUAD4, F	Nxy, cr	% Error
10	595.5	261.7
16	236.3	43.5
20	196.1	19.1
30	172.2	4.6
50	166.5	1.1
70	165.7	0.6

QUAD8, F	N, cr	% Error
2	-	-
4	-	-
6	551.0	234.6
8	243.3	47.7
10	193.4	17.5
12	179.8	9.2
16	172.0	4.5
20	169.5	2.9

QUAD8, R	N, cr	% Error
2	-	-
4	401.0	143.5
6	245.2	48.9
8	183.9	11.7
10	172.1	4.5
12	169.2	2.8
16	167.7	1.8
20	167.1	1.5

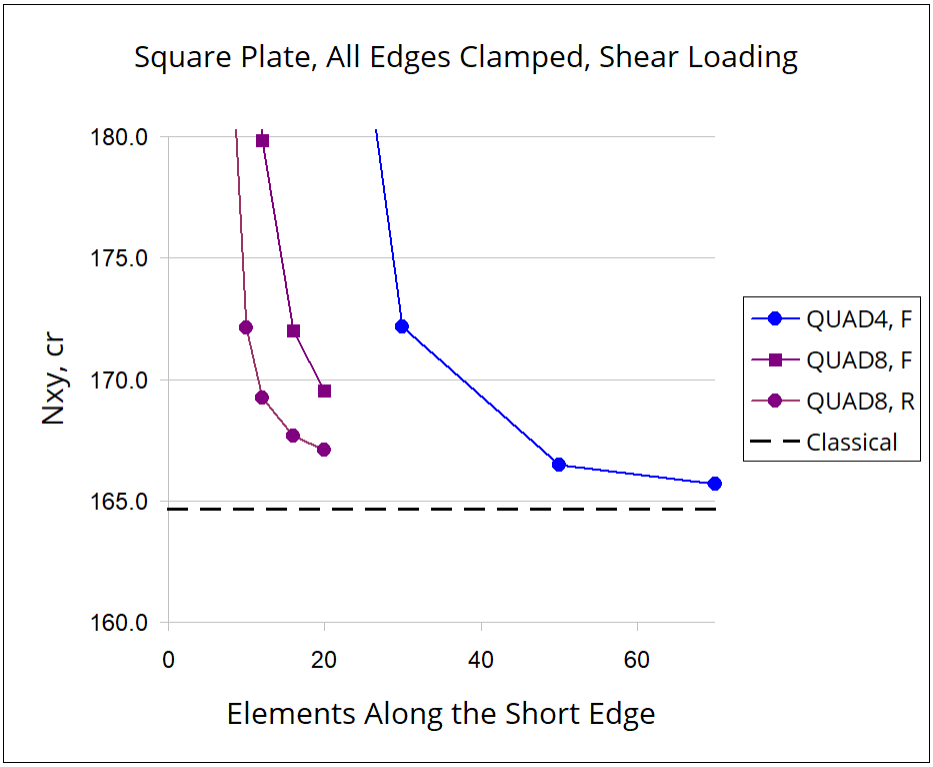

Figure 6 : Convergence for Case 4