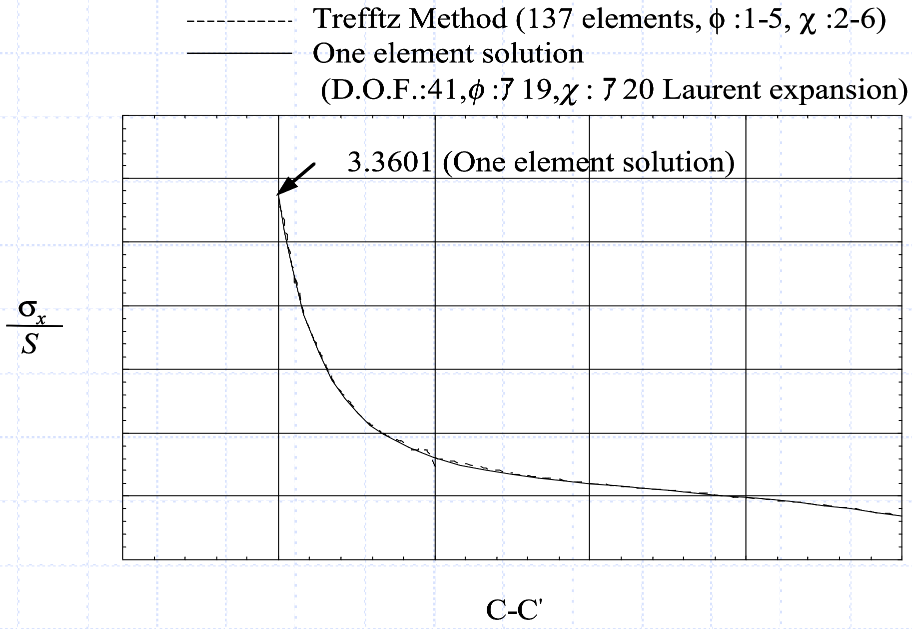
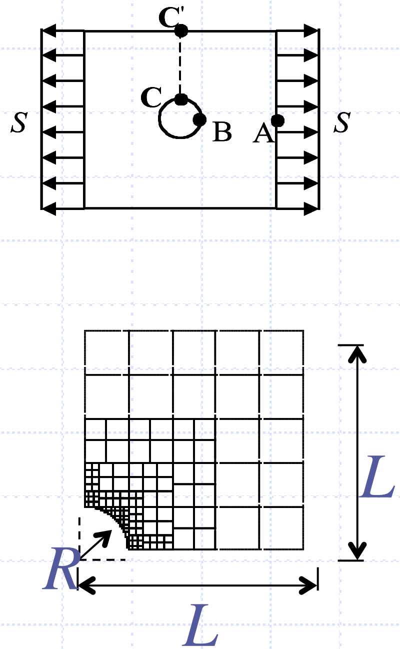
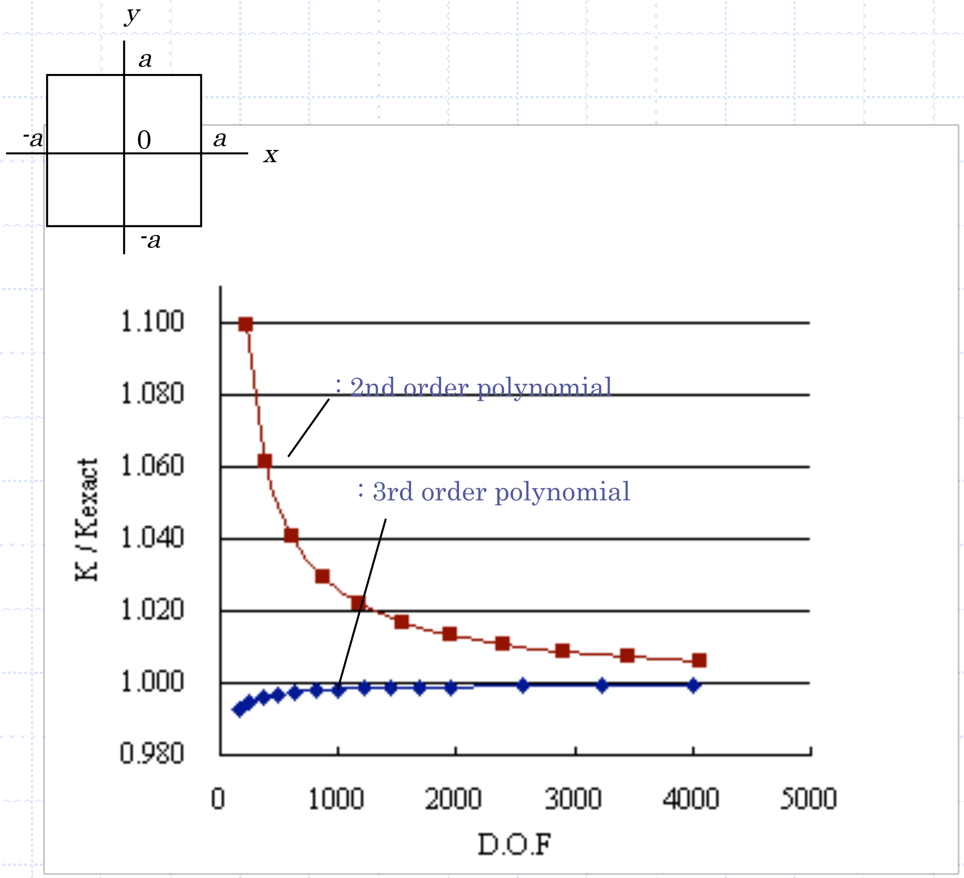
Stress distribution on section C-C' of a perforated square plate under uniaxial uniform loading





$R = 10\text{mm}, \quad L = 50\text{mm}, \quad S = 100\text{kgf/mm},$
$E = 20000\text{kgf/mm}^2, \quad \nu = 0.3$

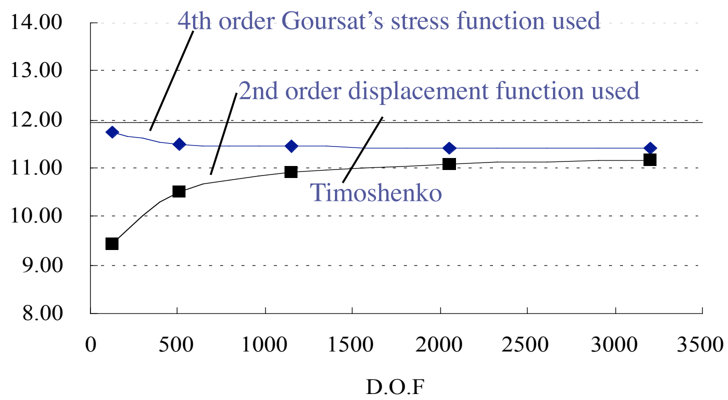
Analysis of torsional rigidity of an elastic bar with the square cross section(divided by square mesh)

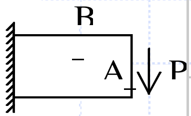


6DOF / element		10 DOF / element	
Mesh Div.	2nd order polynomial	Mesh Div.	3rd order polynomial
2x 2	0.17708	3x 3	0.13951
4x 4	0.16498	4 x4	0.13961
6x 6	0.15456	5x 5	0.13984
8x 8	0.14921	6x 6	0.14002
10x 10	0.14635	7x 7	0.14014
12 x12	0.14469	8x 8	0.14023
14x 14	0.14365	9x 9	0.1403
16x 16	0.14295	10x 10	0.14035
18 x18	0.14247	11x 11	0.14039
20x 20	0.14211	12x 12	0.14041
22x 22	0.14185	13x 13	0.14044
Timoshenko $K=0.1406(2a)^4$			

Inplane bending analysis of a cantilever plate subjected to a boundary shear of parabolic distribution (divided by square mesh)

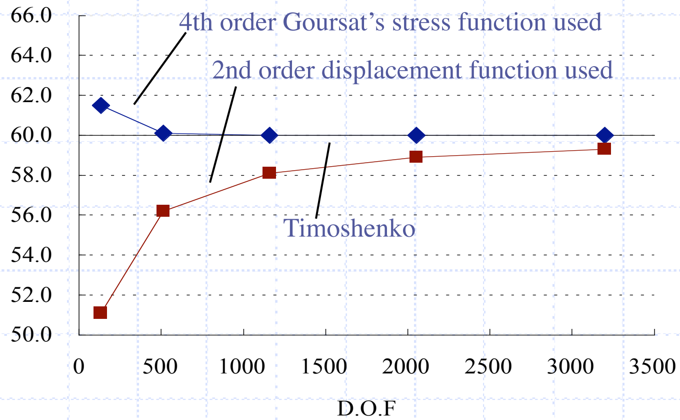
v_A : vertical displacement at the point A

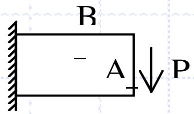




Mesh Div. x NDOF	stress function used	displacement function used
4x 2x 16	11.7195	9.4399
8x 4 x16	11.4996	10.5163
12x 6 x16	11.4347	10.9196
16 x8x 16	11.4063	11.0912
20x 10 x16	11.3909	11.178

$(\sigma_x)_B$: stress at the point B

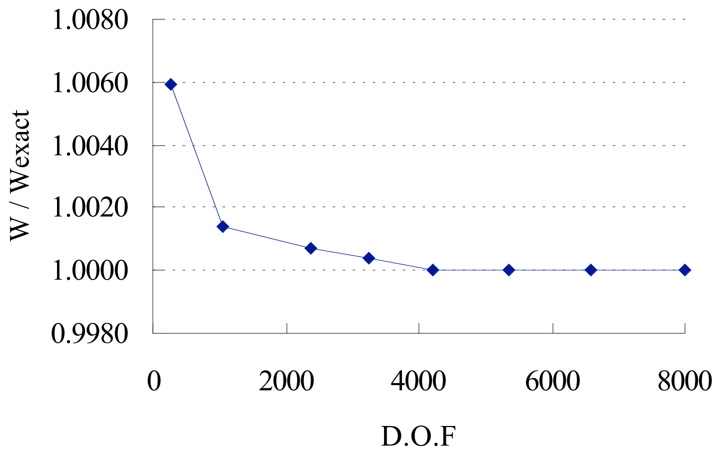


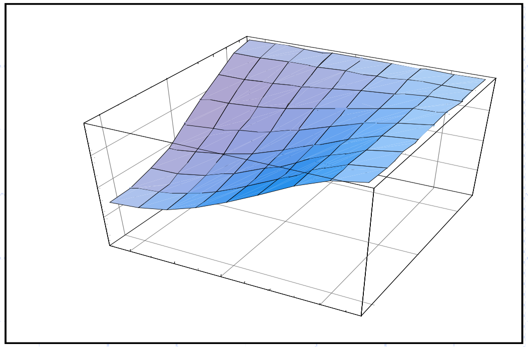


Mesh Div. x NDOF	stress function used	displacement function used
4x 2x 16	61.4766	51.0777
8x 4 x16	60.0641	56.1607
12x 6 x16	60.0287	58.1254
16 x8x 16	60.0138	58.8946
20x 10 x16	60.0071	59.2698

Finite element bending analysis of a square plate under uniformly distributed load using the newly proposed variational method.

Nonequilibrium 10th order polynomials of (x,y) were used for analysis.



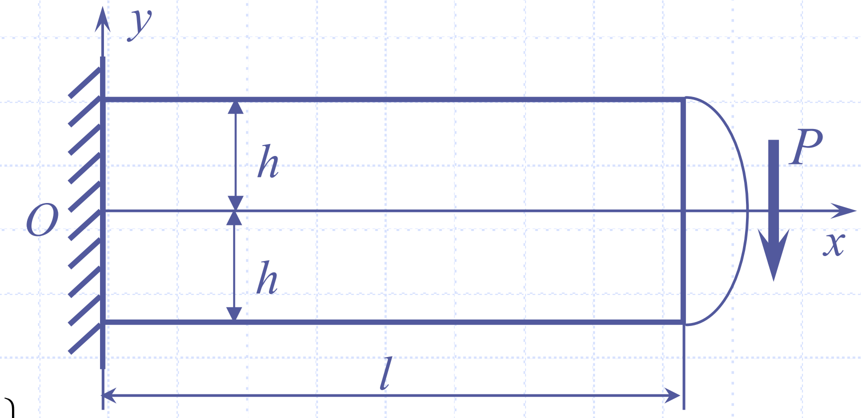


deflection (Mesh Div. NDOF = 8866)

Central deflection $w(0,0)$

Mesh Div NDOF	$w(0,0)$	w/w_{exact}
2 2 66	1.0059	1.27247
3 3 66	1.0014	1.26676
4 4 66	1.0014	1.26675
5 5 66	1.0006	1.26576
6 6 66	1.0007	1.26587
7 7 66	1.0004	1.26555
8 8 66	1.0000	1.26524
9 9 66	1.0000	1.26502
10 10 66	1.0000	1.26531
11 11 66	1.0000	1.26531

先端に垂直せん断力を受ける片持矩形板の面内曲げ問題のTK解析



平衡条件式:

$$\left.\begin{aligned}\nabla^2 u+\frac{(1+\nu)}{2}\frac{\partial}{\partial x}\left(-\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)+f_x=0\\ \nabla^2 v+\frac{(1+\nu)}{2}\frac{\partial}{\partial y}\left(\frac{\partial u}{\partial y}-\frac{\partial v}{\partial x}\right)+f_y=0\end{aligned}\right\} \quad (1)$$

境界条件:

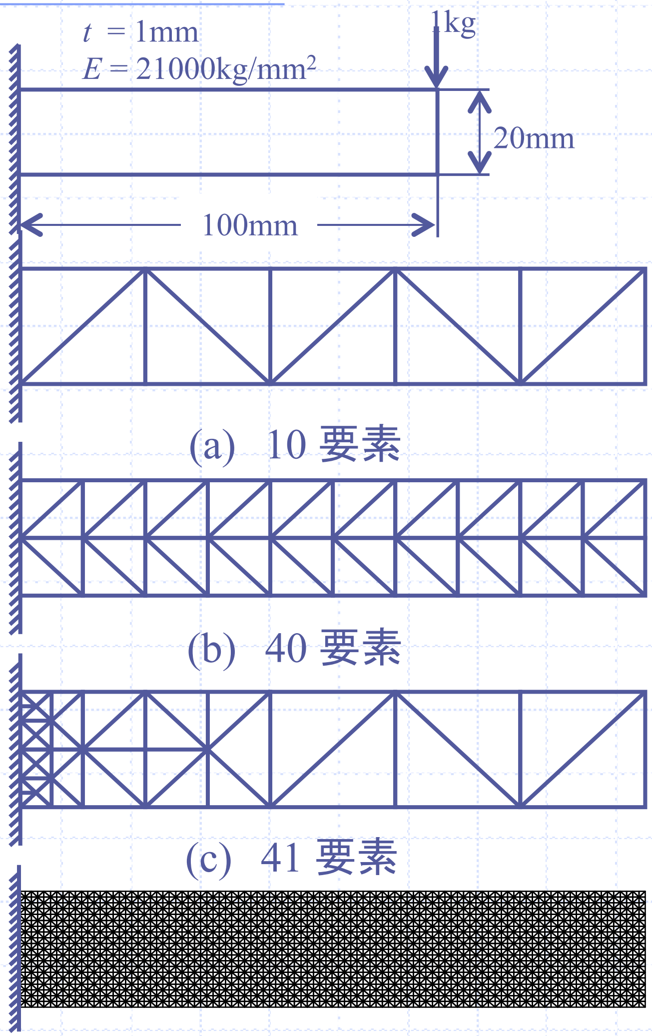
$$\left.\begin{aligned}&x=0\ :\text{固定端} && u(0,y)=v(0,y)=0\\ &y=\pm h:\text{自由端} && \tau_{xy}(x,\pm h)=0\ ,\ \sigma_y(x,\pm h)=0\\ &x=l\ :\text{荷重端} && \sigma_y(l,y)=0\ ,\ \tau_{xy}=-\frac{P}{2I}\left(h^2-y^2\right)\end{aligned}\right\} \quad (2)$$

近似固定条件に対するTimoshneko解:

$$u(0,0)=v(0,0)=\frac{\partial v}{\partial x}(0,0)=0 \quad (3)$$

$$\left.\begin{aligned}u(x,y)&=-\frac{Px^2y}{2EI}-\frac{\nu Py^2}{6EI}+\frac{Py^3}{6GI}+\left(\frac{Pl^2}{2EI}-\frac{Ph^2}{2GI}\right)y\\ v(x,y)&=\frac{\nu Pxy^2}{2EI}+\frac{Px^3}{6EI}-\frac{Pl^2x}{2EI}+\frac{Pl^3}{3EI}\end{aligned}\right\} \quad (4)$$

CST要素を用いた有限要素解とTimoshenko解の比較

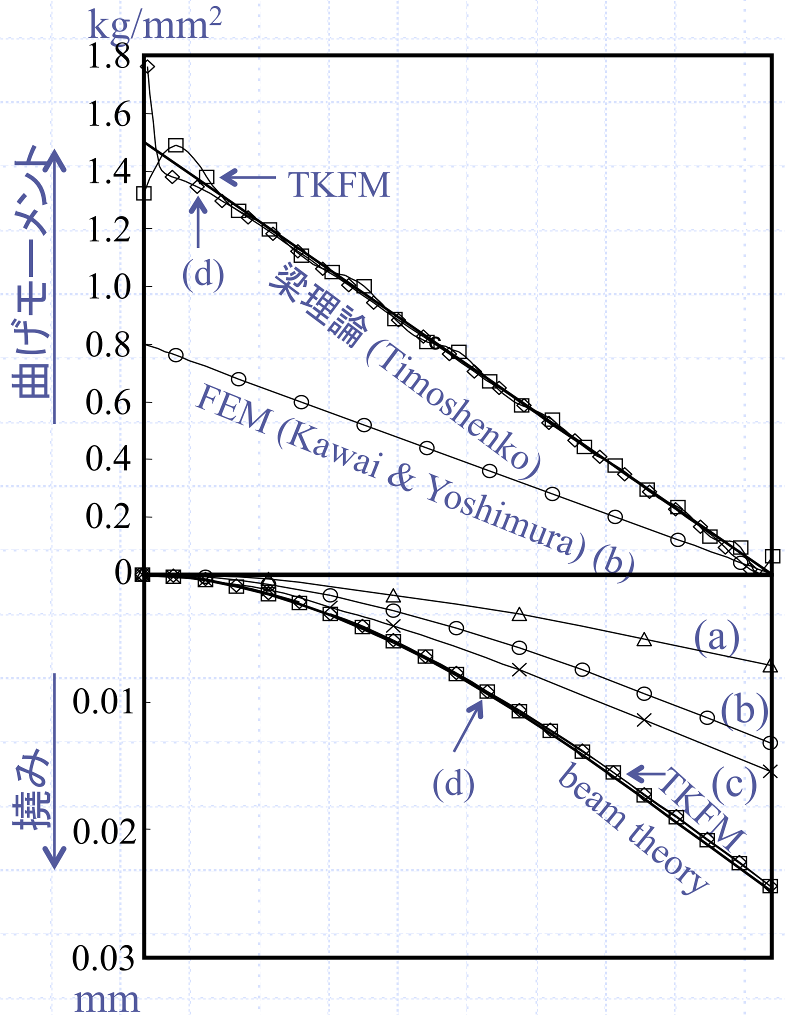


(a) 10 要素

(b) 40 要素

(c) 41 要素

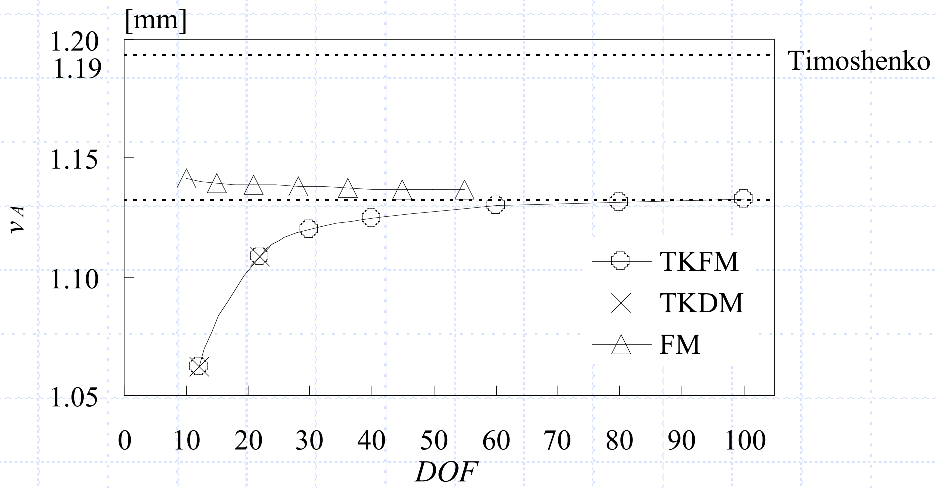
(d) 4000 要素 (2121 節点)



平衡法(FM)解と100項近似のTKFMとTKDM解の比較

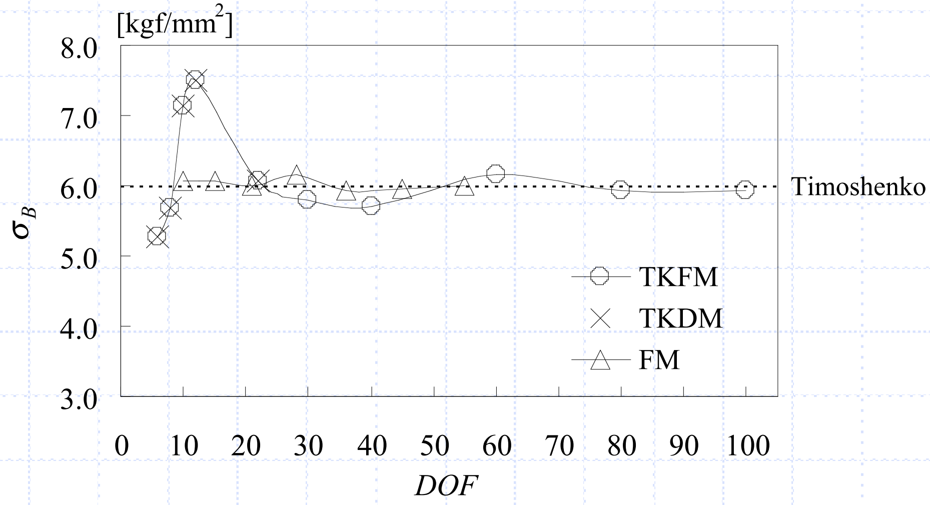
The deflection of point A [mm]

DOF	TKFM	TKDM	DOF	FM
6	0.7377	0.7377	10	1.1417
8	0.7812	0.7812	15	1.1398
10	0.9815	0.9815	21	1.1387
12	1.0621	1.0621	28	1.1379
22	1.1088	1.1088	36	1.1373
30	1.1202		45	1.1369
40	1.1247		55	1.1365
60	1.1302			
80	1.1312			
100	1.1324			



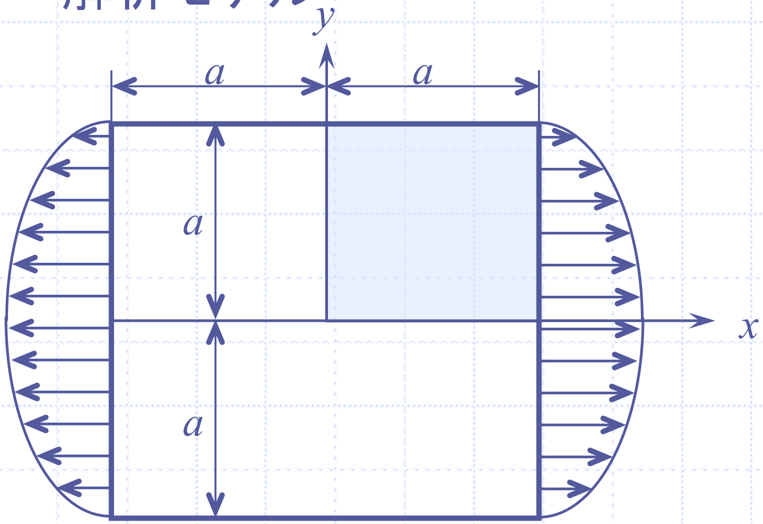
The bending stress at point B σ_x [kgf/mm^2]

DOF	TKFM	TKDM	DOF	FM
6	5.2647	5.2647	10	6.0781
8	5.6759	5.6759	15	6.0657
10	7.1358	7.1358	21	6.0113
12	7.4969	7.4969	28	6.1516
22	6.0718	6.0718	36	5.9345
30	5.7907		45	5.9479
40	5.7008		55	5.9899
60	6.1502			
80	5.9393			
100	5.9286			

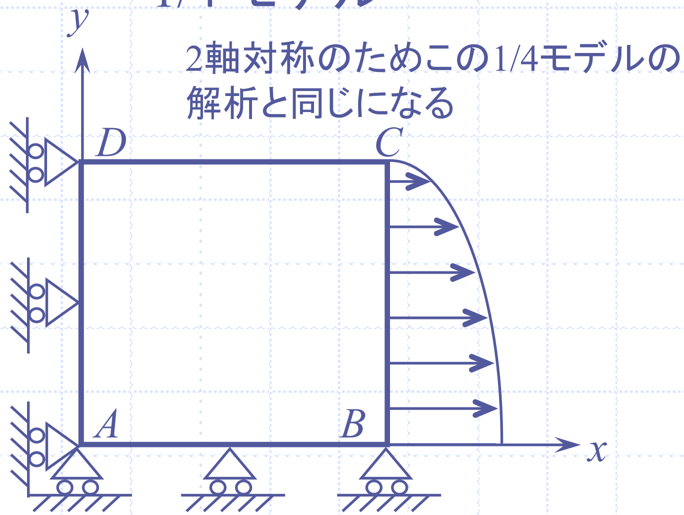


一方向に放物線状分布引張荷重を受ける矩形板の面内変形解析

解析モデル



1/4 モデル



境界条件

$$\left.\begin{array}{l} x = \pm a : \quad \tau_{xy} = 0, \quad \sigma_x = S\left(1 - \dfrac{y^2}{a^2}\right) \\ y = \pm a : \quad \tau_{xy} = 0, \quad \sigma_y = 0 \end{array}\right\}$$

寸法及び材料定数

$a = 100mm$

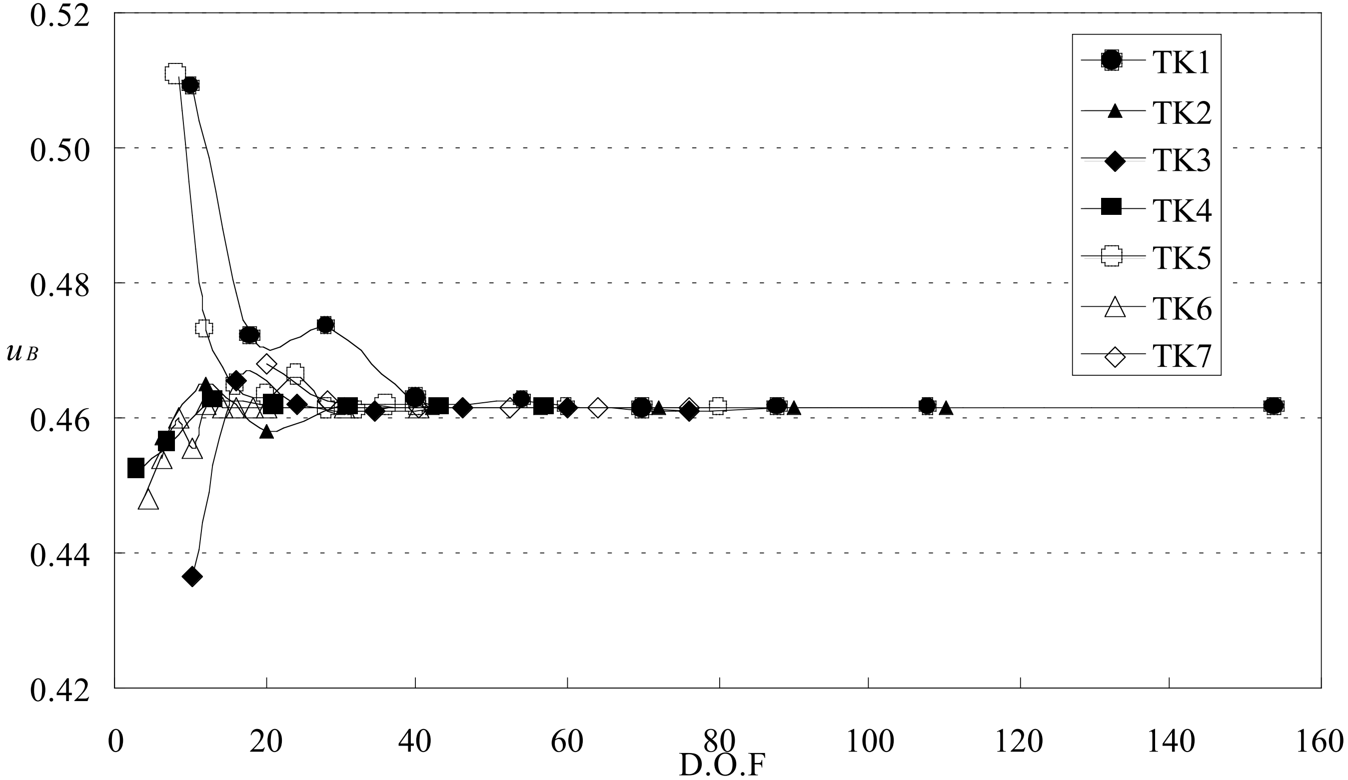
$S = 100$

$E = 20000kgf / mm^2$

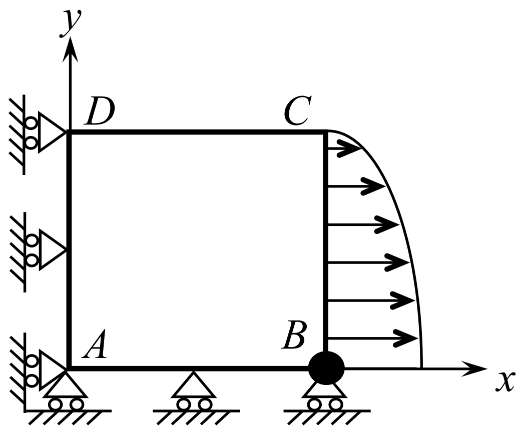
$\nu = 0.3$

解析解的手法（解法8）を除いた7つの解法の解の比較

DOF	TK1	DOF	TK2	DOF	TK3	DOF	TK4	DOF	TK5	DOF	TK6	DOF	TK7
10	0.50918	6	0.45747	10	0.43648	3	0.45237	8	0.51110	4	0.44828	20	0.46833
18	0.47225	12	0.46539	16	0.46598	7	0.45639	12	0.47319	6	0.45434	28	0.46293
28	0.47352	20	0.45823	24	0.46230	13	0.46267	16	0.46482	8	0.46006	40	0.46196
40	0.46285	30	0.46220	34	0.46112	21	0.46181	20	0.46348	10	0.45551	52	0.46166
54	0.46271	42	0.46192	46	0.46192	31	0.46163	24	0.46641	12	0.46238	64	0.46157
70	0.46145	56	0.46165	60	0.46181	43	0.46167	28	0.46135	14	0.46186	76	0.46156
88	0.46153	72	0.46168	76	0.46131	57	0.46168	32	0.46101	16	0.46177		
108	0.46157	90	0.46168					36	0.46174	18	0.46163		
154	0.46171	110	0.46168					40	0.46179	20	0.46178		
								60	0.46170	30	0.46170		
								80	0.46169	40	0.46178		

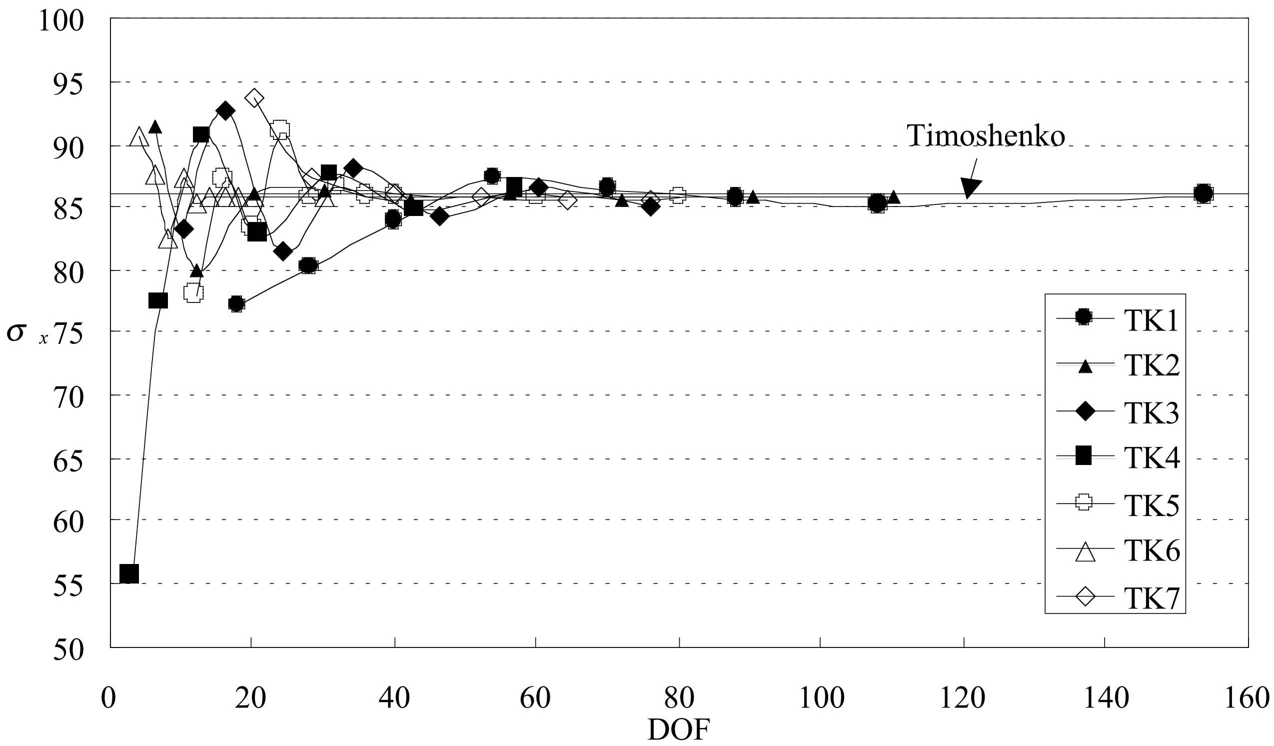


B点の水平変位u_B
の計算値の比較

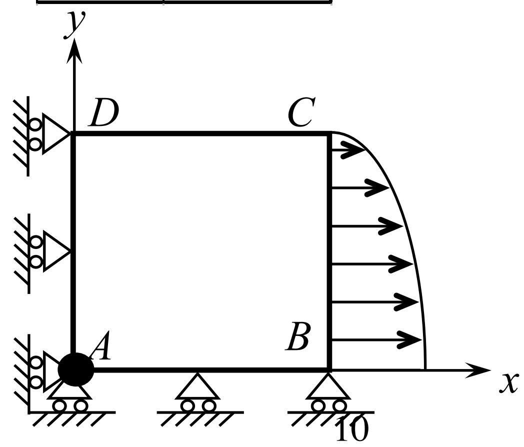


A点の引張応力s_xの計算値の比較

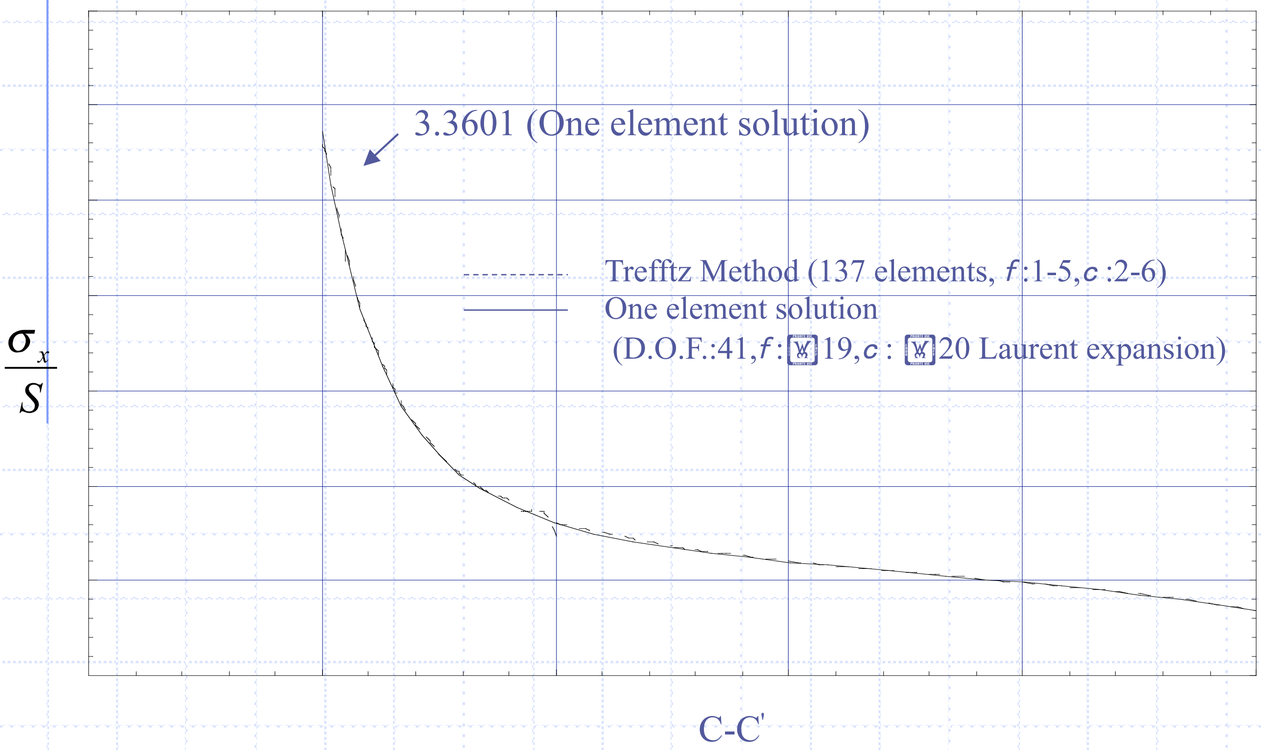
DOF	TK1	DOF	TK2	DOF	TK3	DOF	TK4	DOF	TK5	DOF	TK6	DOF	TK7
10		6	91.49	10	83.51	3	55.67	8		4	90.82	20	93.75
18	77.22	12	80.16	16	92.89	7	77.42	12	78.16	6	87.81	28	87.50
28	80.30	20	86.12	24	81.52	13	90.72	16	87.28	8	82.74	40	86.21
40	83.91	30	86.55	34	88.32	21	82.92	20	83.44	10	87.46	52	85.84
54	87.40	42	85.56	46	84.45	31	87.67	24	91.11	12	85.39	64	85.72
70	86.48	56	86.12	60	86.62	43	84.88	28	85.86	14	86.05	76	85.70
88	85.78	72	85.78	76	85.18	57	86.50	32	86.74	16	85.89		
108	85.29	90	85.97					36	86.07	18	85.83		
154	86.01	110	85.87					40	86.00	20	85.95		
								60	85.94	30	85.93		
								80	85.88	40			

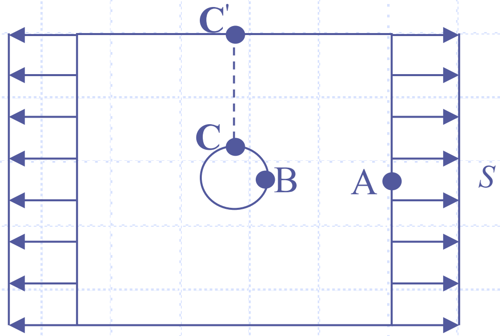


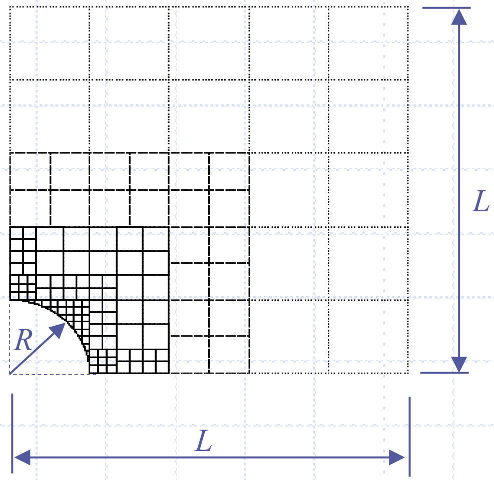
DOF	Timoshenko
1	82.99
3	86.18
5	86.10
7	86.10
9	86.10
11	86.10
17	86.10



一方向に一様分布引張荷重を受ける有孔正方形板の応力集中解析（C−C’ 断面）







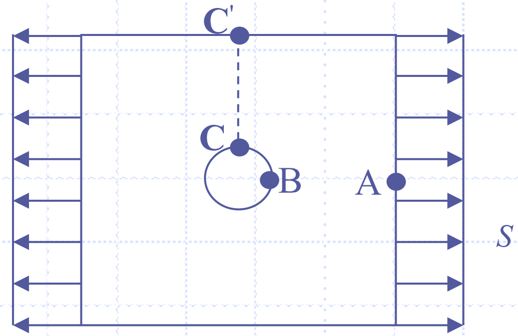
Trefftz法では右図のごとくサイズの異なるメッシュ分割の重ね合せが自由に行える.

$R = 10mm, L = 50mm, S = 100kgf / mm$

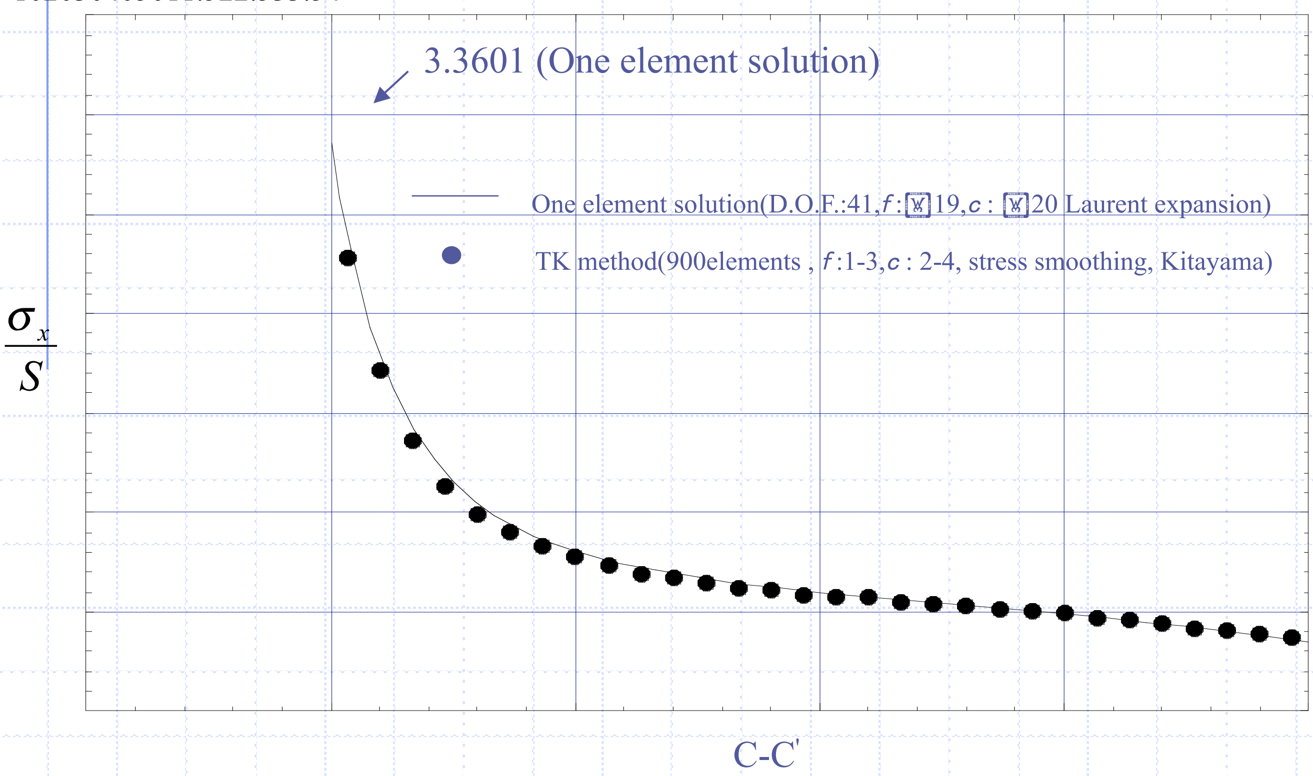
$E = 20000kgf / mm^2, \nu = 0.3$

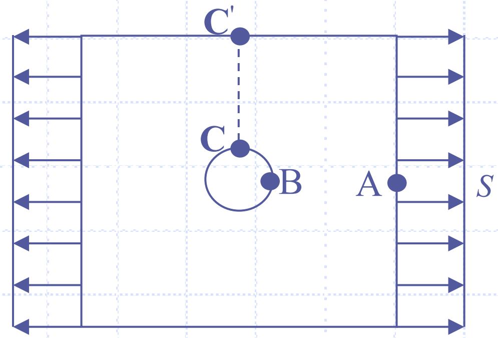
一軸引張を受ける有孔正方形板の応力及び変位の 計算値の収束性

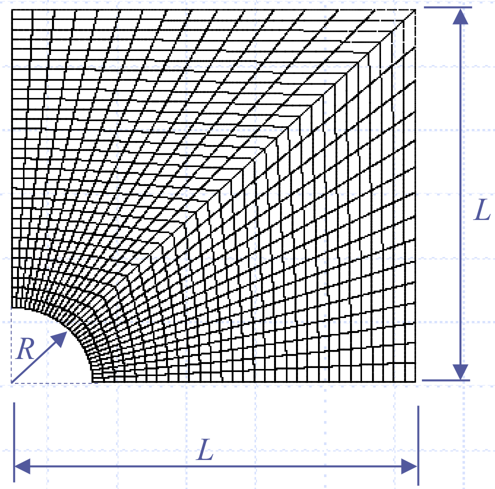
D.O.F	$(\sigma_x)_{max}/S$	u_A	u_B
17	3.351535	0.3048718	0.1682909
21	3.358187	0.3054907	0.1686762
25	3.359322	0.3061321	0.1687509
29	3.359656	0.3066006	0.1687975
33	3.360086	0.3064086	0.1687917
37	3.360099	0.3063427	0.1687925
41	3.360115	0.3064508	0.1687930



通常のメッシュ分割によるTK法の計算結果







$R = 10mm,\ L = 50mm,\ S = 100kgf / mm$

$E = 20000kgf / mm^2,\ \nu = 0.3$