

TABLE OF CONTENTS

	Page
TABLE OF CONTENTS	i
LIST OF TABLES	ii
LIST OF FIGURES	iii
LIST OF ABBREVIATIONS	vi
INTRODUCTION	1
LITERATURE REVIEW	3
Theoretical Methods	8
MATERIALS AND METHODS	20
Materials	20
Methods	20
RESULTS AND DISCUSSION	21
CONCLUSION	73
RECOMMENDATION	74
LITERATURE CITED	75
APPENDIX	76

LIST OF TABLES

Table		Page
1	Comparison of stress resultants of slab on simply support that are subjected to uniform load between Levy's method and program STAAD.Pro 2002	22
2	Comparison of stress resultants of slab on fixed support that are subjected to uniform load between Levy's method and program STAAD.Pro 2002	23
3	Percentage of maximum stress resultants change of flat plate with opening in each location compared to flat plate without opening	25
4	Percentage of maximum stress resultants change of flat plate with opening at interior column and located at interior side	35
5	Percentage of maximum stress resultants change of flat plate with opening at interior column and located at exterior side	44
6	Percentage of maximum stress resultants change of flat plate with opening at edge column	53
7	Maximum lateral deflection of flat plate	62
8	Comparison of opening size and different location	63
9	Percentage of maximum bending moment M_x change of flat plate with opening at "all-edge" and "all-in"	65
10	Percentage of maximum bending moment M_y change of flat plate with opening at "all-edge" and "all-in"	67
11	Percentage of maximum shear stress Q_x change of flat plate with opening at "all-edge" and "all-in"	69
12	Percentage of maximum shear stress Q_y change of flat plate with opening at "all-edge" and "all-in"	71
 Appendix Table		
1	Maximum stress resultants in flat plate without opening	79
2	Maximum stress resultants in flat plate with opening at "in-in" (Location D)	79
3	Maximum stress resultants in flat plate with opening at "in-ex" (Location D)	80
4	Maximum stress resultants in flat plate with opening at "edge" (Location B)	81
5	Maximum stress resultants in flat plate with opening at "all-edge"	81
6	Maximum stress resultants in flat plate with opening at "all-in"	82

LIST OF FIGURES

Figure		Page
1	Critical perimeter for shear	4
2	Critical perimeter for shear	6
3	Notation for rotation components of a midsurface-normal and slope of a plate surface	8
4	A plate element with corner nodes, showing typical nodal d.o.f	9
5	A deformed plate cross section, view in the + y direction. Thickness-direction is assumed to remain straight	10
6	Stresses and distributed lateral force q on a differential element of plate	10
7	Moment and transverse shear forces associated with stresses	11
8	Plane stress action	16
9	Plate bending action	17
10	Displacement compatibility	17
11	Element local coordinate system	19
12	Sign convention of element forces	19
13	Plan of rectangular slab on simple support and fixed support	21
14	Cross section of rectangular slab on simple support	22
15	Cross section of rectangular slab on fixed support	23
16	Plan of flat plate (without opening)	24
17	Nine locations of openings in the area of column strip	25
18	Location of maximum stress resultant with opening number 1	27
19	Location of maximum stress resultant with opening number 2	27
20	Location of maximum stress resultant with opening number 3	28
21	Location of maximum stress resultant with opening number 4	28
22	Location of maximum stress resultant with opening number 5	29
23	Location of maximum stress resultant with opening number 6	29
24	Location of maximum stress resultant with opening number 7	30
25	Location of maximum stress resultant with opening number 8	30
26	Location of maximum stress resultant with opening number 9	31
27	Flat plate with opening at “ <i>in-in</i> ”	32
28	Flat plate with opening at “ <i>in-ex</i> ”	33
29	Flat plate with opening at “ <i>edge</i> ”	33
30	Size of the opening at “ <i>in-in</i> ”	34
31	Relationship between size of openings at “ <i>in-in</i> ” and percentage of maximum bending moment M_x change	36
32	Relationship between size of openings at “ <i>in-in</i> ” and percentage of maximum bending moment M_y change	37
33	Relationship between size of openings at “ <i>in-in</i> ” and percentage of maximum shear stress Q_x change	38
34	Relationship between size of openings at “ <i>in-in</i> ” and percentage of maximum shear stress Q_y change	39
35	Bending moment M_x concentration when opening $a = 0.4$ m and $b = 1.6$ m at “ <i>in-in</i> ”	41

LIST OF FIGURES (Continued)

Figure		Page
36	Bending moment M_y concentration when opening $a = 0.4$ m and $b = 1.6$ m at “ <i>in-in</i> ”	41
37	Shear stress Q_x concentration when opening $a = 0.4$ m and $b = 1.6$ m at “ <i>in-in</i> ”	42
38	Shear stress Q_y concentration when opening $a = 0.4$ m and $b = 1.6$ m at “ <i>in-in</i> ”	42
39	Size of the opening at “ <i>in-ex</i> ”	43
40	Relationship between size of openings at “ <i>in-ex</i> ” and percentage of maximum bending moment M_x change	45
41	Relationship between size of openings at “ <i>in-ex</i> ” and percentage of maximum bending moment M_y change	46
42	Relationship between size of openings at “ <i>in-ex</i> ” and percentage of maximum shear stress Q_x change	47
43	Relationship between size of openings at “ <i>in-ex</i> ” and percentage of maximum shear stress Q_y change	48
44	Bending moment M_x concentration when opening $a = 0.4$ m and $b = 1.6$ m at “ <i>in-ex</i> ”	50
45	Bending moment M_y concentration when opening $a = 0.4$ m and $b = 1.6$ m at “ <i>in-ex</i> ”	50
46	Shear stress Q_x concentration when opening $a = 0.4$ m and $b = 1.6$ m at “ <i>in-ex</i> ”	51
47	Shear stress Q_y concentration when opening $a = 0.4$ m and $b = 1.6$ m at “ <i>in-ex</i> ”	51
48	Size of the opening at “ <i>edge</i> ”	52
49	Relationship between size of openings at “ <i>edge</i> ” and percentage of maximum bending moment M_x change	54
50	Relationship between size of openings at “ <i>edge</i> ” and percentage of maximum bending moment M_y change	55
51	Relationship between size of openings at “ <i>edge</i> ” and percentage of maximum shear stress Q_x change	56
52	Relationship between size of openings at “ <i>edge</i> ” and percentage of maximum shear stress Q_y change	57
53	Bending moment M_x concentration when opening $a = 0.4$ m and $b = 0.4$ m at “ <i>edge</i> ”	59
54	Bending moment M_x concentration when opening $a = 0.4$ m and $b = 0.8$ m at “ <i>edge</i> ”	59
55	Bending moment M_x concentration when opening $a = 0.4$ m and $b = 1.2$ m at “ <i>edge</i> ”	60
56	Bending moment M_x concentration when opening $a = 0.4$ m and $b = 1.6$ m at “ <i>edge</i> ”	60
57	Bending moment M_y concentration when opening $a = 0.4$ m and $b = 1.6$ m at “ <i>edge</i> ”	61

LIST OF FIGURES (Continued)

Figure		Page
58	Shear stress Q_x concentration when opening $a = 0.4$ m and $b = 1.6$ m at “ <i>edge</i> ”	61
59	Shear stress Q_y concentration when opening $a = 0.4$ m and $b = 1.6$ m at “ <i>edge</i> ”	62
60	Flat plate for opening critical size at “ <i>all-edge</i> ”	64
61	Flat plate for opening critical size at “ <i>all-in</i> ”	64
62	Bending moment M_x concentration in flat plate	65
63	Bending moment M_x concentration in flat plate with openings at “ <i>all-edge</i> ”	66
64	Bending moment M_x concentration in flat plate with openings at “ <i>all-in</i> ”	66
65	Bending moment M_y concentration in flat plate	67
66	Bending moment M_y concentration in flat plate with openings at “ <i>all-edge</i> ”	68
67	Bending moment M_y concentration in flat plate with openings at “ <i>all-in</i> ”	68
68	Shear stress Q_x concentration in flat plate	69
69	Shear stress Q_x concentration in flat plate with openings at “ <i>all-edge</i> ”	70
70	Shear stress Q_x concentration in flat plate with openings at “ <i>all-in</i> ”	70
71	Shear stress Q_y concentration in flat plate	71
72	Shear stress Q_y concentration in flat plate with openings at “ <i>all-edge</i> ”	72
73	Shear stress Q_y concentration in flat plate with openings at “ <i>all-in</i> ”	72
 Appendix Figure		
1	Plan of flat plate (without opening)	78

LIST OF ABBREVIATIONS

$\{a\}$	=	generalized d.o.f. vector
$[B]$	=	relationship matrix between strain and nodal displacement
D	=	flexural rigidity
$\{d\}$	=	nodal displacement vector
E	=	Young's modulus
$\{F\}$	=	external structure load vector
G	=	shear modulus
k	=	factor of effect of transverse shear stress
$[k]$	=	element stiffness matrix
$[K]$	=	structure stiffness matrix
M_x	=	bending moment in x -direction
M_y	=	bending moment in y -direction
M_{xy}	=	twisting moment in xy -plane
$[N]$	=	shape function
$\{p\}$	=	external element load vector
q	=	distributed lateral force
Q_x	=	shear stress per unit length in x -direction
Q_y	=	shear stress per unit length in y -direction
t	=	thickness of flat plate
T_0	=	temperature change
u	=	displacement in x -direction
U	=	strain energy
v	=	displacement in y -direction
w	=	the deflection of the midsurface in z -direction
$w_{,x}$	=	slope of the plate surface in x -direction
$w_{,y}$	=	slope of the plate surface in y -direction
ψ_x	=	rotations of a midsurface normal in x -direction
ψ_y	=	rotations of a midsurface normal in y -direction
ε_x	=	normal strain in x -direction
ε_y	=	normal strain in y -direction
γ_{xy}	=	shear strain in xy -plane
γ_{yz}	=	shear strain in yz -plane
γ_{zx}	=	shear strain in zx -plane
σ_x	=	normal stress in x -direction
σ_y	=	normal stress in y -direction
τ_{xy}	=	shear stress in xy -plane

LIST OF ABBREVIATIONS (Continued)

ν	=	Poisson's ratio
Ω	=	the potential of applied loads
Π	=	the potential energy
$\{\kappa\}$	=	curvature vector
$\{\kappa_0\}$	=	initial curvature vector