

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	x
	LIST OF FIGURES	xi
	LIST OF ABBREVIATIONS	xiv
	LIST OF SYMBOLS	xv
	LIST OF APPENDICES	
1	INTRODUCTION	
	1.1 Background	1
	1.2 Problem Statement	4
	1.3 Objective of Study	6
	1.4 Scope of Project	6
2	LITERATURE REVIEW	
	2.1 Introduction	7
	2.2 Previous Studies	7
3	RESEARCH METHODOLOGY	
	3.1 Research Methodology	12
	3.1.1 The Steps of Analyses	14

3.2	Finite Element Analysis	15
3.3	A Simple Example of Finite Element Analysis	15
3.3.1	Potential Energy Approach	20
3.4	Theory of Vibration	23
3.4.1	Natural Frequency of Free Transverse Vibration	23
3.4.2	Natural Frequency of Free Longitudinal Vibration	25
3.5	Modal Analysis	27
3.7	Residual Space in Bus	28

4

RESULTS

4.1	Introduction	31
4.2	Simulation of Box Model	32
4.2.1	Inputs Used in Simulation	33
4.2.2	Results of Simulation	40
4.3	Simulation of Box Model to Extract Natural Frequency and Mode Shape	43
4.3.1	Inputs Used in Simulation	43
4.3.2	Results of Simulation	45
4.4	Validation of Box Model Simulation	47
4.4.1	Results of Rollover Experiment	47
4.5	Numerical Analysis of Box Model	49
4.6	Simulation of Bus Prototype	52
4.7	Results of Bus Simulation	55
4.7.1	Simulation of Bus with More Passenger Load	55
4.7.2	Simulation with More Structural Strength	58
4.7.3	Simulation of Bus with less Total Mass	60

	4.7.4 Simulation of Bus with Less Passenger Load	63
5	DISCUSSION	
	5.1 Introduction	67
	5.2 Analysis of the Results	67
6	CONCLUSION	
	6.1 Conclusion on Bus Structure	71
	6.2 Recommendation for Future Study	71
	REFERENCES	72
	Appendix	76
	Bibliography	83

LIST OF TABLES

TABLE NO.	TITLE	PAGE
3.1	The values of shape functions	30
4.1	Dimensions of box model	32
4.2	Dimensions of box profile	34
4.3	Properties of mesh	36
4.4	The comparison between two element libraries of Abaqus	37
4.5	Dimensions of bus prototype	53
4.6	Different masses of bus prototype	53
4.7	Dimensions of bus prototype	58
4.8	Different masses of bus prototype	58
4.9	Dimensions of bus prototype	61
4.10	Different masses of bus prototype	61
4.11	Dimensions of bus prototype	64
4.12	Different masses of bus prototype	64
5.1	Variation of maximum stress with total mass of bus	69
1	The plastic properties of mild steel	76
2	Values of stain obtained from TML Portable Data Logger	76
3	Values of stain obtained from numerical analysis	79
4	Values of stain obtained from UPC 601- G Data Logger	80
5	New values of offsets of the strain gauges	81
6	The values of strains after changing offsets	81
7	The new values of scaling factor for UPC 601- G Data Logger	82
8	Values of strain after calibration from UPC 601- G Data Logger	82

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Trip over of a vehicle on road surface	2
1.2	Fall over of vehicle out of road	2
1.3	Flip over of vehicle on road surface	2
1.4	Bounce over of vehicle after facing impact sidewise	3
1.5	Turn over motion of vehicle	3
1.6	Climb over situation of vehicle	4
1.7	End-over-end motion of vehicle	4
1.8	A bus has faced rollover	5
1.9	The damage of a bus frame after rollover crash	5
3.1	Flowchart of the steps of analyses	14
3.2	A simply supported beam with two types of loads	15
3.3	Deformation of beam neutral axis	16
3.4	The stress distribution in the beam transverse plane	16
3.5	Finite element discretization in global coordinate	17
3.6	Finite element discretization in local coordinate	17
3.7	Interpretation of Hermit shape function	18
3.8	Natural frequency of free transverse vibration of a cantilever beam	24
3.9	Natural frequency of free longitudinal vibration of a spring-mass system	25
3.10	Lateral arrangements of residual space inside the bus	29
3.11	Longitudinal arrangements of residual space inside a bus	29
4.1	Three dimensional view of the box model used in simulation	32
4.2	Two dimensional view of the box model used in simulation	33
4.3	The stress-strain plot of mild steel	34

FIGURE NO.	TITLE	PAGE
4.4	The box profile used in all members of box model and in some members bus model	35
4.5	The deformation of cross section of Timoshenko beam	38
4.6	Linear brick, quadratic brick, and modified tetrahedral elements	40
4.7	Maximum deformation of box model during rollover motion	40
4.8	Maximum stress and its location in the box model	41
4.9	Plot of total energy (TE) of the box model simulation	41
4.10	Plot of kinetic energy (KE) of the bus model simulation	42
4.11	Plot of internal energy (IE) of the bus model simulation	42
4.12	Plot of linear velocity of the bus model in rollover simulation	44
4.13	Plot of angular velocity of the bus model in rollover Simulation	44
4.14	The first mode of the model during first impact	46
4.15	The second mode of the model during first impact	46
4.16	The third mode of the model during first impact	46
4.17	The box model used in the experiment of validation	47
4.18	The plot of strain obtained from dynamic strain measuring system	48
4.19	The position of critical deformation in the box model during rollover test	48
4.20	(a) position of box model before first impact, (b) position of box model during first impact (c) position of box model just after first impact and (d) the model is in rest after rollover process	49
4.21	The centre of gravity of the box model	50
4.22	The position of box model before rolling over	51
4.23	The position of box model during rolling over	52
4.24	The left side view of bus frame used in simulation	53
4.25	The isometric view of bus prototype used in simulation	54
4.26	The isometric view of bus prototype placed on the ditch by an angle of 53 degree with vertical plane before simulation	54

FIGURE NO.	TITLE	PAGE
4.27	The deformation of superstructure of bus during first impact of rollover	56
4.28	Plot of kinetic energy (KE) of the bus simulation	56
4.29	Plot of Internal energy (IE) of the bus simulation	57
4.30	Plot of total energy (TE) of the bus simulation	57
4.31	The deformation of superstructure of bus during first impact of rollover	59
4.32	Plot of kinetic energy (KE) of the bus simulation	60
4.33	Plot of internal energy (IE) of the bus simulation	60
4.34	Plot of total energy (TE) of the bus simulation	60
4.35	The deformation of superstructure of bus during first impact of rollover	62
4.36	Plot of kinetic energy (KE) of the bus simulation	62
4.37	Plot of internal energy (IE) of the bus simulation	63
4.38	Plot of total energy (TE) of the bus simulation	63
4.39	The deformation of superstructure of bus during first impact of rollover	65
4.40	Plot of kinetic energy (KE) of the bus simulation	65
4.41	Plot of internal energy (IE) of the bus simulation	65
4.42	Plot of total energy (TE) of the bus simulation	66
5.1	The plot of total mass vs. maximum stress	69

LIST OF ABBREVIATIONS

NHTSA	-	National Highway Traffic Safety Administration
CG	-	Center of Gravity
ADR	-	Australian Design Rule
UN-ECE	-	United Nations Economic Commission for Europe
ELR	-	Emergency Locking Retractors
MDOF	-	Multi-Degrees of Freedom
TE	-	Total Energy
KE	-	Kinetic Energy
IE	-	Internal Energy
SG	-	Strain Gauge

LIST OF SYMBOLS

L, l	-	Length
E	-	Modulus of Elasticity
A	-	Area
F	-	Force
D, d	-	Diameter
K	-	Stiffness
δ	-	Static Deflection
m	-	Mass
g	-	Constant due to Gravity
t	-	Time
f_n	-	Natural Frequency (Hz)
t_p	-	Time Period
W	-	Weight
ω	-	Natural Frequency (rad/s)
S_R	-	Residual Space
H	-	Height

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	The plastic properties of mild steel	76
B	Calibration of UPC 601- G (Dynamic Strain Measuring Instrument)	77