FINITE ELEMET ANALYSIS OF CONCRETE DEEP BEAMS WITH VARIUOS LOCATIONS OF OPENING AND REINFORCEMENT ARRANGEMENTS

LOO KIAN LOON

B. ENG (HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG



SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of B. Eng (Hons.) Civil Engineering.

(Supervisor's Signature) Full Name : MOHD ARIF BIN SULAIMAN Position : SUPERVISOR Date : 15 JUNE 2017



STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

(Student's Signature) Full Name : LOO KIAN LOON ID Number : AA13158 Date : 15 JUNE 2017

FINITE ELEMENT ANALYSIS OF CONCRETE DEEP BEAMS WITH VARIOUS LOCATIONS OF OPENING AND REINFORCEMENT ARRANGEMENTS

LOO KIAN LOON

Thesis submitted in fulfillment of the requirements for the award of the B. Eng (Hons.) in Civil Engineering

Faculty of Civil Engineering and Earth Resources UNIVERSITI MALAYSIA PAHANG

JUNE 2017

ACKNOWLEDGEMENTS

First, I would like to thank my university, UNVERSITI MALAYSIA PAHANG for giving me such a great opportunity and facilities so that, I am able to complete my research.

Second, I feel so thankful and pleasure to my supervisor, Mr. Mohd. Arif bin Sulaiman, who enlighten me and providing me tons of helpful discussions and recommendations throughout this study. His passion and consistent encouragements keep motivate me to complete my final year project. Again, I express my sincere appreciation with full respect to my competent supervisor, Mr. Mohd Arif bin Sulaiman.

Next, I would like to express my appreciation to my panels, Dr. Chin Siew Choo and Mr. Noram bin Ramli who have giving their professional suggestions to improve my project's outcomes to achieve the objectives of this research.

In addition, here are special thanks to my senior lecturers, Dr. Cheng Hock Tian and Dr. Gul A. Jokhio, who giving me precious guidance in manipulate ANSYS software to generate finest results of the project.

Moreover, I am so grateful to my parents who always being so supportive to me along the way. Lastly, thank to be beloved friends, Kun Chee Yong, Tan Woon Han and Tan Keen Hong who always sharing their knowledges and resources to assist me in completing this final year project.

TABLE OF CONTENTS

DECLARATION

TIT	LE PAGE	
ACK	KNOWLEDGEMENTS	1
ABS	STRAK	2
ABS	STRACT	3
ТАВ	BLE OF CONTENTS	4
LIST	T OF TABLES	7
LIST	Γ OF FIGURES	8
CHA	APTER 1 INTRODUCTION	11
1.1	General	11
1.2	Problem Statement	12
1.3	Objective	12
1.4	Scope of Study	12
CHA	APTER 2 LITERATURE REVIEW	18
2.1	General	18
2.2	Application of Deep Beam	18
2.3	Strut and Tie Model (STM)	18
2.4	Opening in Deep Beam	20
2.5	Effect of Opening to Deep Beam	21
2.6	Effect of Location of the Opening	21
2.7	Effect of Reinforcement in the Deep Beam	23
2.8	Failure Mode of Beam	24

2.9	Crack	ing In Reinforced Deep Beam with Opening	25
	2.9.1	Diagonal Tension Crack	26
	2.9.2	Critical Diagonal Crack	26
2.10	ANSY	S Modeling and Analysis on Deep Beam	26
	2.10.1	Concrete in ANSYS	27
	2.10.2	Steel Plates in Deep Beam Models	27
	2.10.3	Reinforcement Bars in Deep Beam Models	28
CHA	PTER 3	3 METHODOLOGY	29
3.1	Gener	al	29
3.2	Flow	Chart of the Methodology	30
3.3	PREP	ROCESSOR	31
3.4	SOLU	JTION	44
3.5	GENI	ERAL POSTPROCESSOR	48
CHA	PTER 4	4 RESULTS AND DISCUSSION	50
4.1	Gener	al	50
4.2	Failur	e Load	50
	4.2.1	The Effect of Various Location of Opening in Deep Beam with Same Reinforcement Arrangement	50
	4.2.2	Effect of Different Reinforcement Arrangement with Same Location of Opening in Deep Beam	51
4.3	Crack	Pattern	56
	4.3.1	The Effect of Various Location of Opening in Deep Beam with Same Reinforcement Arrangement	56
	4.3.2	Effect of Different Reinforcement Arrangement with Same Location of Opening in Deep Beam	57
			• •

CHAP	PTER 5 CONCLUSION	
5.1	General	

5.2	Conclusions	66
5.3	Recommendations	67

REFERENCES

LIST OF TABLES

Table 1.1: Detail of Models	15
Table 1.2: Properties of Concrete, Steel Plates and Reinforcement Bars	17

LIST OF FIGURES

Figure 1.1	Longitudinal Section of Deep Beam (Typical model detail; mm)	14
Figure 1.2	Cross Section of the Deep Beam (Typical model detail; mm)	14
Figure 2.1	Member in Deep Beam with STM	19
Figure 2.2	Illustration of Compression Stress Fields, (a) Fan-shaped, (b) Bottle-shaped, and (c) Parallel-shaped	20
Figure 2.3	Load Paths of Deep Beams with Web Openings	21
Figure 2.4	Equilibrium of Strut in Deep Beam with Circular Opening	22
Figure 2.5	Modes of Shear Failure at Small Openings.	25
Figure 2.6	Geometry of SOLID 65	27
Figure 2.7	Geometry of SOLID 185	28
Figure 2.8	Geometry of LINK 180	28
Figure 3.1	Flow Chart of Methodology	30
Figure 3.2	PREFERENCES	31
Figure 3.3	Define Elements	31
Figure 3.4	Material Properties of Concrete	32
Figure 3.5	Cross Section of Reinforcement Bar with Diameter 8mm	32
Figure 3.6	Cross Section of Reinforcement Bar with Diameter 18mm	32
Figure 3.7	Material Model for All Elements	33
Figure 3.8	Linear Isotropic Properties for Steel Plates	33
Figure 3.9	Linear Isotropic Properties for Concrete	33
Figure 3.10	Multilinear Isotropic Properties for Concrete	34
Figure 3.11	Material Properties for Concrete	34
Figure 3.12	Linear Isotropic Properties for Reinforcement Bars	34
Figure 3.13	Bilinear Isotropic Properties for Reinforcement Bars	35
Figure 3.14	Dimension of Deep Beam Models	35
Figure 3.15	Dimension of Steel Plate at Bottom Right Support	36
Figure 3.16	Dimension of Steel Plate at Bottom Left Support	36
Figure 3.17	Dimension of Steel Plate at Upper Right Support	36
Figure 3.18	Dimension of Steel Plate at Upper Left Support	37
Figure 3.19	Copy of Area in X-Direction for Placement of Main and Secondary Bars	37
Figure 3.20	Copy of Area in Y-Direction for Placement of Horizontal Stirrups	38

Figure 3.21	Copy of Area in Z-Direction for Placement of Vertical Stirrups	38
Figure 3.22	The Model was Divided Volume by Area	38
Figure 3.23	All The Separated Entities were Merged	39
Figure 3.24	Opening at Mid-span was Created	39
Figure 3.25	Link Component was Created	40
Figure 3.26	Side Bars Component was Created	40
Figure 3.27	Main Bars Component was Created	40
Figure 3.28	Secondary Bars Component was Created	41
Figure 3.29	Beam Component was Created	41
Figure 3.30	The Element Sizes on Picked Lines was Divided by 50	42
Figure 3.31	Meshing of Link	42
Figure 3.32	Meshing of Side Bars	42
Figure 3.34	Meshing of Main Bars	43
Figure 3.35	Meshing of Secondary Bars	43
Figure 3.36	Meshing of Beam	43
Figure 3.37	Meshing of Steel Plates	44
Figure 3.38	Meshed Model	44
Figure 3.39	The Boundary Condition were Set at the Selected Nodes	44
Figure 3.40	Fixed Boundary Condition was Selected	45
Figure 3.41	Front view (Z-Direction) of Fixed Support	45
Figure 3.42	Nodes on Steel Plates were Selected and Subjected to Applied Loads	45
Figure 3.43	Y-Direction of Applied Loads was Assigned	46
Figure 3.44	Loads were applied on Steel Plates above the Deep Beam Models	46
Figure 3.45	The Condition of Load Steps with Time Increment was Set	47
Figure 3.46	The Deep Beam Model was Ready to Analysed	47
Figure 3.47	The Deep Beam Model was Analysed	47
Figure 3.48	The Analysis of Deep Beam Model was Terminated	48
Figure 3.49	The Analysis was Done	48
Figure 3.50	Failure Loads was Read	49
Figure 3.51	Selection of Crack/Crush was Chosen to Plot the Crack Pattern	49
Figure 3.52	Example of Crack Pattern of Deep Beam Model was Plotted	49

Figure 4.1	Ultimate Load of Solid Deep Beams with Various Openings	53
Figure 4.2	Ultimate Load of Deep Beams at Various Location of Opening with Vertical and Horizontal Reinforcement	53
Figure 4.3	Ultimate Load of Deep Beams at Various Location of Opening with Horizontal Reinforcement	54
Figure 4.4	Ultimate Load of Deep Beams at Various Location of Opening with Vertical Reinforcement	54
Figure 4.5:	Ultimate Load of Deep Beam with Different Reinforcement Arrangement at Mid-span Opening	55
Figure 4.6	Ultimate Load of Deep Beam with Different Reinforcement Arrangement at Shear-Span Opening	55
Figure 4.7	Ultimate Load of Deep Beam with Different Reinforcement Arrangement with Opening outside Mid- span and Shear Zone	56
Figure 4.8	Crack Pattern of DB1 when Failure	57
Figure 4.9	Crack Pattern of DB2 when Failure	58
Figure 4.10	Crack Pattern of DB3 when Failure	58
Figure 4.11	Crack Pattern of DB4 when Failure	59
Figure 4.12	Crack Pattern of DB5 when Failure	59
Figure 4.13	Crack Pattern of DB6 when Failure	60
Figure 4.14	Crack Pattern of DB7 when Failure	60
Figure 4.15	Crack Pattern of DB8 when Failure	61
Figure 4.16	Crack Pattern of DB9 when Failure	61
Figure 4.17	Crack Pattern of DB10 when Failure	62
Figure 4.18	Crack Pattern of DB11 when Failure	62
Figure 4.19	Crack Pattern of DB12 when Failure	63
Figure 4.20	Crack Pattern of DB13 when Failure	63
Figure 4.21	Crack Pattern of DB14 when Failure	64
Figure 4.22	Crack Pattern of DB15 when Failure	64
Figure 4.23	Crack Pattern of DB16 when Failure	65