بسم الله الرحمن الرحيمP

SUDAN UNIVERSITY Of SCIENCES AND TECHNOLOGY

College of Graduate Studies

ComparativeAnalysis of bridge deck between Beam - Shell And 3D Solid Finite Element Models

مقارنة تحليلية لأرضية

جسربين عنصر العارضة ــالقشرة والعنصر الصلب ثلاثى الابعاد

A Thesis Submitted to

The College of Graduate Studies in Partial Fulfillment of the Requirement for the Degree of

Master in Civil Engineering (Structures)

By:

AsmaAbdEljalilFadulHamad

(B.Sc.)

Supervisor:

Dr. Ali Hussein Mohammed Ali Bass

January2014 الموافق ربيع أول 1435

بسم الله الرحمن الرحيم

✓قـــــال تعـــــالى :

وأَنزَلنَا الحَدِيدَ فِيهِ بَأسٌ شَدِيدٌ ومَنَافِعُ لِلنَّاسِ وَلِيَعْلَمَ اللهُ مَنْ يَنْصُرُهُ وَرُسُلَهُ بالْغَيْبِ إِنَّ اللهَ قَوِيٌّ عَزِيزٌ)

(سُورَةُالحَدِيْد، الآية 25)

صدق الله العظيم

Dedication

To my father

To my mother

To my husband

To my baby's (Mahmud & Mozun)

&

To all whom I love

ASMA

ACKNOWLEDGEMENTS

First and foremost I should thank Allah for bestowing me with health, patient and knowledge to complete this work.

I acknowledge, with deep gratitude and appreciation, the inspiration, encouragement, valuable time and guidance given to me by Dr. Ali Hussein, my supervisor of this research.

I also would like to thank all members of the thesis committee.

Great thanks and appreciation to staff of the great university, Sudan University in general and COLLEGE OF GRADUATE STUDIES & SCIENTIFIC RESEARCH in particular for their cooperation and providing a suitable environment for the study.

I also would like to thank engineer Khalid and engineer ThaniMohamed Amin.

Eventually, I would like to express my deepest gratitude to my family and especially to my mother for their emotional and moral support throughout my academic career and for their patience, encouragements and their prayers.

المستخلص

هذه الايام يتم استخدام برامج الكمبيوتر فى تحليل وتصميم الإنشاءات من قبل المهندسين ، كما توجد عدد من البرامج الهندسيه التى تستخدم فى مجال الهندسهالمدنيه ،وتمكن هذه البرامج المهندسين من تحليل وتصميم الإنشاءاتباخطاء اقل من الطرق التقليديه وكما تقلل الوقت الذى يستغرق فى التحليل والتصميم للإنشاءات المعقده مثل بلاطات الكبارى وغيرها. وبلاطات الكبارى يمكن تحليلها بعدة نظريات ولكن تعتبر نظرية طريقة العناصر المحدده من اشهر الطرق المستخدمه فى تحليل بلاطات الكبارى. فى طريقة العناصر المحدده توجد العديد من النماذج ثنائية وثلاثية الابعاد. فى هذه الدراسه يتم تحليل بلاطة الكبرى عن طريق نموذج العارضهوالقشره والنموذج المصمت ثلاثى الابعاد باستخدام برنامج)(SAFE.

اجريت هذه الدارسه لمقارنة سلوك المنشأ فى النموذجين لتحديد ايهما اكثر اقتصاديه . وأوضحت نتائج الدراسهأنّ النموذج المصمت ثلاثى الأبعاد يوفر العوامل المطلوبهوالضروريه للتصميم ويعطى نتائج مقبوله مقارنة مع نموذج البلاطة والقشرة.

ABSTRACT

Nowadays engineer use computer software foranalysis and design structures. There is a lot of engineering software that can be used in civil engineering practice. Using computer engineer can design and analyze structure with less error and time particularly for complex structures such as bridge decks. Bridge decks are analyzed using several methods. The most advanced method for analyzing the bridge deck is finite element method. In finite element analysis, bridge deck can be analyzed through a variety of models in 2D and 3D. In this study, bridge decks were analyzed by beam - shell and 3D solid model using SAF software. The study is focused to compare the behavior of the tow models to determine the more effective one. The result of the study show that 3D solid model is able to provide the necessary parameters for design purpose and more acceptable results compare with beam and shell model.

TABLE OF CONTENTS

Topic	Page(No.)
Acknowledgement	I
المستخلص	II
Abstract	III
Table of contents	IV
List of Figures	V
List of Tables	VI
CHAPTER (1)	
1 Introduction	1
1.1 Problem statement	4
1.2 Objective of the study	5
1.3 Scope of the study	5
1.4 Thesis organization	5
CHAPTER (2)	
2 Literature review	7
2.1 Introduction	7
2.2 Types of bridge deck	8
2.2.1 Solid slab deck	8
2.2.2 Beam deck	8
2.2.3 Voided slab deck	9

2.2.4 Cellular deck	9
2.2.5 Discrete box deck	10
2.2.6 Beam and slab composite deck	10
2.3 Previous studies	11
2.3.1. Comparison of bridge decks modeling between beam and shell and 3D solid finite element models	11
2.3.2 Finite-Element Analysis Of Bridge Decks	12
2.3.3 A Finite Element Model For The Analysis Of Bridge Decks	12
CHAPTER (3)	
3 Analysis of BridgeDecks	14
3.1 General	14
3.2 Structural analysis method	15
3.2.1 Finite elements method in structural analysis	16
3.2.2 General finite element method	17
3.3 Bridgedeckanalysismodelusing finite element method (FEM)	20
3.3.1 Grillage model	20
3.3.2 Orthotropic plate model	21
3.3.3 Beam and shell model	22
3.3.4 3D solid model	25
3.4 Bridge standard	28
3.5 Bridge Loading	28
3.5.1 Dead load	29
3.5.2 Live load	30
3.5.3 Other Loading	31

3.5.4. Application of HA and HB Loads	32
3.5.5. Types HA and HB loading combined	32
3.5.6 Highway carriageway and lanes	35
CHAPTER (4)	
4 Modeling and analysis of case studied	36
4.1 Research Methodology	36
4.2 Location of the Bridge	37
4.3 Design notes	37
4.3.1Four span Bridge input Data	37
4.3.2 Design Considerations	39
4.3.3 Deck loading	40
4.3.4 Load cases and load combination	44
CHAPTER (5)	
5 Analysis and Discussion of Results	47
5.1 Load Pattern Values	52
5.2 Analysis result for beam and shell and 3D solid element	57
5.2.1 Position (1)	58
5.2.2 Position (2)	61
5.3 Comparison between beam and shell and 3D solid element	64
5.4 Discussion	70
CHAPTER (6)	
6 Conclusion and Recommendations	71
6.1 Conclusion	71
6.2 Recommendations	72
References	**73**
Appendix (A)	**75**

LIST OF FIGURES

Fig	Title	Page No
Figures of chapter one		
1.1	Flowchart of research design	2
Figures of chapter two		
2.1	Solid Slab Deck	7
2.2	Beam Deck	7
2.3	Voided Slab Deck	8
2.4	Cellular Deck	9
2.5	Discrete box Deck	9
2.6	Beam and Slab Deck	10
Figures of chapter three		
3.1	Skew angle vs. Aspect ratio	14
3.2	Steps of finite element analysis	17
3.3	Simply supported beam	22
3.4	Euler–Bernoulli assumption for thin beams	23
3.5	Isolated beam cell of length dx	25
3.6	Normal stresses those results in moment.	25
3.7	Beam element and its local coordinate systems	28
3.8	thick shell element	36
3.9	The middle plane of a rectangular shell element	37
3.10	3D solid element	44
3.11	Solid block divided into four-node tetrahedron elements	44
3.12	A tetrahedron element	45
3.13	Volume coordinates for tetrahedron elements	47

3.14	Natural coordinate, where ξ = constant	53
3.15	Natural coordinate, where η = constant	54
3.16	Natural coordinate, where ζ = constant	54
3.17	Cartesian coordinates xyz of point O in term of ξ η ζ	55
3.18	Types HA and HB loading combined	65
Figures of chapter four		
4.1	Superstructure cross-section	68
4.2	Four span bridge elevation	69
4.3	Section of edge beam	77
Figures of chapter five		
5.1	Bridge Plan	83
5.2	Bridge superstructure 3D	84
5.3	Surfacing Load	85
5.4	Walkway Load	85
5.5	Railing Load	86
5.6	HA Load	86
5.7	HA Load (KEL) applied parallel to the bearing	87
5.8	HA Load (KEL) applied perpendicular to notional lane.	87
5.9	HA+ HB Load (UDL)	88
5.10	HA+ HB Load plus (KEL)	88
5.11	HB Loading	89
5.12	HB vehicle Position (1)	91
5.13	HB vehicle Position (2)	94

LIST OF TABLES

Table	Title	Page No
Tables of chapter three		
3.1	Number of notional lanes	66
Tables of chapter four		
4.1	Number of notional lanes	71
4.2	HA lane factors	73
4.3	Load cases	75
4.4	Load combinations	76
4.5	Factored moment and Shear force	80
Tables of chapter five		
5.1	Analysis results position (1) beam and shell element	92
5.2	Analysis results position (1) 3D Solid element	93
5.3	Analysis results position (2) beam and shell element	95
5.4	Analysis results position (2) 3D Solid element	96
5.5	Slab moment	98
5.6	Beam major moment	99
5.7	Beam major Shear Force	100
5.8	Beam Torsion	101
5.9	Reaction Force	102
5.10	Comparison between manual calculation and safe output data	103

Chapter One
Introduction

Chapter Two
Literature review

Chapter Three
Analysis of BridgeDecks

Chapter Four
Modeling and analysis of case studied

Chapter Five
Analysis and Discussion of Results

Chapter Six
Conclusion and Recommendations

Appendix

Save program output data