

## **Abstract**

In this research, three configurations of tower cranes were taken to study the structural performance of them by using Structural Analysis Program SAP2000. Different load cases were considered as followed: dead, live and wind loads and their combinations. The analysis results were presented in graphical forms in order to study the structural performance of the three configurations (tower crane type 1, 2 and 3). It was taken the variation of axial forces and displacements with height of tower crane, and variation of axial forces and deflections on jib's arm. The design of tower cranes components is done using Allowable Stress Design (ASD) according to American Institute for Steel Construction (AISC). From the variation of axial forces, displacement in x- and y- directions, deflection on jib's arm. It was noticed that tower crane (1) is have best configuration in comparison with the other two tower cranes (2) and (3).

## المستخلص

في هذا البحث، ثلاثة نماذج الرفعات البرجيه أخذت لدراسة أدنها الإنشائي بإستعمال برنامج التحليل الإنشائي SAP2000 لحالات مختلفة من الأحمال (الأحمال الميتة، الحية، أحمال الرياح وتراكيب الأحمال المذكورة).

نتائج التحليل وُضحت في رسومات تخطيطية لكي يُدرس الأداء الإنشائي من النماذج الثلاثة (رافعه برجية نوع 1, 2, و3). أُخذ إختلاف القوى المحورية مع إرتفاع الرفعات البرجيه، وإختلاف القوى المحورية والازاحات على ارتفاع الرافعه البرجيه وإختلاف القوى المحوريه والانحراف على طول الزراع. إستخدم في تصميم مكونات الابراج طريقة تصميم الإجهاد المسموح به (ASD) طبقاً للمعهد الأمريكي للبناء الفولاذي (AISC).

من الإختلاف في القوى المحورية والإزاحة في اتجاه X والازاحه في اتجاه Y والانحراف على الذراع لوحظ أن تكوين رافعة البرج (1) افضل مقارنةً مع رافعة البرج (2) و(3).

## ACKNOWLEDGEMENTS

First I would like to thank the God, without the God, I could not have the Lowest level of knowledge much less completed this research. I am heartily thankful to my supervisor; **Dr. Abusamra Awad Attaelmanan**, whose encouragement, guidance and support from the initial to the final level enabled me to develop an understanding of the subject.

Also, my heartfelt thanks to my Mom and Dad, my family and all my friend who have contributed the lions share in the success of my life yet.

Lastly, I offer my regards and blessings to all of those who supported me in any respect during the completion of the research.

OSAMA SAYED OSMAN

2016

## TABLE OF CONTENTS

CONTENTS NO	PAGE
I. ABSTRACT	I
II. ABSTRACT ARABIC	II
III. ACKNOWLEDGEMENT	III
IV. TABLE OF CONTENTS	IV
V. LIST OF TABLES	IX
VI. LIST OF FIGURES	X
VII. LIST OF SYMBLES	XIII
<b>1. CHAPTER ONE: INTRODUCTION.</b>	
1.1 General Introduction	1
1.2 The Research Problem	2
1.3 Research objectives	2
1.4 Methodology	3
1.5 Organization of the Research	3
<b>2. CHAPTER TWO: LITTERATURE REVIEW.</b>	
2.1 Introduction	4
2.2 History of Tower Crane	5
2.2.1 Early Crane Evolution	5
2.2.2 The First Tower Cranes	6
2.2.3 Hans Liebherr tower Crane	6
2.2.4 Tower cranes Grow to New Heights	7
2.2.5 The Tallest Crane in the World	9
2.3 Theory of Tower Cranes	10
2.4 Tower Cranes Uses	10
2.5 Modern Tower Cranes	10

2.6	Types of Tower Crane-----	11
2.6. 1.	Self-Erect Tower Crane-----	12
2.6.2.	Assisted Erect Tower Crane-----	13
2.6.3.	Horizontal Jib-----	14
2.6.4.	Luffing Jib-----	14
2.6.5	Self-erecting Crane-----	15
2.6.6.	Rail mounted free Travelling-----	15
2.6.7.	Lorry mounted-----	16
2.6.8.	Crawler mounted-----	16
2.7	The Parts of Tower Cranes-----	17
2.8	Characteristics of Tower Cranes -----	21
2.9	Health and safety in Tower Cranes -----	22
2.9.1	Workplace Health and Safety-----	22
2.9.2	The Objective of the Workplace Health and Safety-----	23
2.9.3	Responsibilities in the Tower Crane site Place-----	23
2.9.4	The precautions and Regulations of Tower Cranes-----	24
2.10.	Tower Cranes Accident and Failures-----	24
2.10.1.	Categories of Crane Accidents-----	25
2.10.2.	Accidents of Cranes in Sudan-----	25
2.11.	Tower Cranes in the Sudan-----	25
2.12.	Marketing and Sales of Tower Crane-----	27
<b>3. CHAPTER THREE: ANALYSIS OF TOWER CRANES.</b>		
3.1.	Introduction-----	28
3.2.	General Loads -----	28
3.3.	Types of Loading in Tower Crane-----	29
3.3.1.	Structural Loads-----	29

3.3.2. Wind Loading-----	29
3.3.3. In service Loading-----	34
3.3.4. Out of Service Loading-----	34
3.3.5. Foundation Loads that are supplied with the Crane -----	35
3.3.6. Other Loading-----	35
3.4. Loads Applied to the Foundations-----	35
3.5. Determination of Load Vectors Data-----	35
3.6. The Theory of Loading-----	36
3.7. Load Combinations -----	37
3. 8. The Impact Factor -----	37
3.9. Design of Tower Crane Component-----	37
3.10. Analysis of the Case Study of the Research-----	43
3.10.1 Methods of Analysis of Tower Crane -----	43
3. 10.2. Short Brief about Computer aided Analysis and Design-----	45
3. 10.3. Background about SAP2000-v18.0.1 Program-----	46
3.10.4 The Loads Calculation for Case Study-----	58
3.10.5 Modeling of Tower Crane Geometry-----	50
3.10.6. Structural Analysis-----	52
3.10.7. Analysis Results of Tower Cranes-----	55
<b>4. CHAPTER FOUR: THE STRUCTURAL PERFORMANCE AND DESIGN OF TOWER CRANES.</b>	
4.1. Introduction -----	58
4.2. Design of Components of Tower Crane (1) -----	59
4.3. Design of Base Plate in Tower Crane-----	68
4.4. Design of Tower Crane Foundation-----	69
4.4.1. Stability of Tower Crane (3) -----	69

4.4.2. Geotechnical capacity of Tower Crane (3) -----	71
4.4.3. Structural Design of Foundation in Tower Crane (3) -----	74
4.5. Structural Performance of Tower Cranes -----	75
4.6. Discussion of Results-----	80
<b>5. CHAPTER FIVE: THE CONCLUSION AND RECOMMENDATION.</b>	
5.1. Conclusion-----	83
5.2. Recommendations-----	84
References-----	85
Appendices-----	87

## LIST OF TABLES

Table 3.1. External pressure coefficient-----	31
Table 3.2. Wind directionality factor $k_d$ -----	31
Table 3.3. Importance factor, I (wind load) -----	32
Table 3.4. Velocity pressure exposure coefficient $K_z$ -----	33
Table 3.5. The Impact and Duty Factors According to Crane type and Application-----	37
Table 3.6. Wind pressure on tower cranes-----	49
Table 3.7. General data of project in tower cranes-----	51
Table 3.8. Member types in tower cranes-----	52
Table 3.9. The results of maximum axial force, displacement in (X, Y) Direction and Deflection in Tower Cranes Components-----	56
Table 4.1. Design of Main Tower section-----	59
Table 4.2. Design of Tie rod section-----	60
Table 4.3. Design of Bracing section-----	61
Table 4.4. Design of Working Jib section-----	62
Table 4.5. Design of Counter Jib section-----	63
Table 4.6. Design of Bracing in Jib section-----	64
Table 4.7. Design of Cable section-----	65
Table 4.8.a. Design of Connection -----	66
Table 4.8.b. Design of Connection-----	66
Table 4.8.c. Design of Connection -----	67
Table 4.9. The soil Pressures at any Point -----	71
Table 4.10. The design result of Tower Cranes Components-----	75
Table 4.11. The Difference between the three Tower Cranes-----	79



## LIST OF FIGURES

Figure 2.1. Typical Tower Crane-----	8
Figure 2.2. Luffing Jibs-----	8
Figure 2.3. The slewing in the Top -----	11
Figure 2.4.the Slewing in the Bottom-----	12
Figure 2.5.Self Erect Tower Crane-----	13
Figure 2.6.Assisted Erect Tower Crane -----	14
Figure 2.7.Trolley Jib Crane-----	14
Figure2.8.Luffing Jib Crane -----	15
Figure 2.9.Self-erecting Crane -----	15
Figure2.10. Rail mounted Tower Crane -----	16
Figure 2.11. Lorry mounted Tower Crane-----	17
Figure 2.12. Crewel Tower Crane -----	17
Figure 2.13.Jib arm-----	19
Figure 2.14.Counter Weight Balance-----	29
Figure 2.15. The Operators Cab-----	20
Figure 2.16.a .Section of Tower Crane Base-----	20
Figure 2.16.b. Layout of Tower Crane Base-----	21
Figure 2.16.c. Foundation Details-----	21
Figure 3.1.Shows the Load vectors of Tower Crane-----	36
Figure 3.2. Flow Chart for Design of Tension member. -----	38
Figure 3.3. Flow Chart for Design of Compression member. -----	39
Figure 3.4. Flow Chart for Design of Cable. -----	40
Figure 3.5. Flow Chart for Design of Connection-----	41
Figure 3.6. Flow Chart for Design of Base Plate-----	42
Figure 3.7.a. The Forces in Space Truss-----	44

Figure 3.7.b. Complex Space Truss-----	44
Figure 3.8. The Wind Pressure on Tower Crane-----	49
Figure 3.9. General Data of Project in Tower Crane-----	51
Figure 3.10. The Configuration of tower crane (1) -----	53
Figure 3.11. The Configuration of tower crane (2) -----	54
Figure 3.12. The Configuration of tower crane (3) -----	55
Figure 4.1. Loading on Foundation-----	69
Figure 4. 2. The Strip of $F_1$ -----	70
Figure 4. 3. The punching shear of $F_1$ -----	72
Figure 4. 4. Shear and moment force diagram foe strip AECF-----	73
Figure (4. 5).Variation of Axial Forces with the Height for Tower Cranes-	76
Figure (4. 6). Variation of Displacement in X-direction with the Height for Tower Cranes -----	77
Figure (4. 7). Variation of Displacement in Y-direction with the Height for Tower Cranes -----	77
Figure (4. 8). Variation of Axial forces with the Length for Working Jip. -	78
Figure (4. 9). Variation of Deflection with the Length for Working Jip ---	78

## LIST OF SYMBLES

A	Area
$P_U$	Ultimate load
$C_P$	External pressure coefficieant
D	Depth
e	Eccentricity
$F_b$	Allowable shear stress
$F_V$	Allowable bearing stress
G	Rigidity factor
$H_V$	Heavy Load Range
$H_{VR}$	Stated Load moment Capacity of the Crane
$K_d$	Directionality factor
$K_Z$	Varies with height z above the ground level
$K_{ZT}$	Topographic factor
L	Length
$L_e$	Effective length
$M_A$	Moment applied to base by tower crane
$M_O$	Overturning moment
$M_S$	Restoring moment
$M_U$	Ultimate moment
$N_b$	Number of bolt
$R_b$	Bearing bolt
$q_z$	Pressure resulting from winds
I.S	In-service
I.O.S	Out of service