



Cairo University

COMPUTRIZED DESIGN TOOL FOR POST-TENSIONING SLABS

By

Anas Abdulhkim Aburawwash Abdulhkim

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE
IN
STRUCTURAL ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2017

COMPUTRIZED DESIGN TOOL FOR POST-TENSIONING SLABS

By

Anas Abdulhkim Aburawwash Abdulhkim

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE
IN
STRUCTURAL ENGINEERING

Under the Supervision of

Prof. Dr. Youssef F. Rashed

Professor of Structural Engineering
Structural Engineering
Faculty of Engineering, Cairo University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2017

COMPUTRIZED DESIGN TOOL FOR POST-TENSIONING SLABS

By
Anas Abdulhkim Aburawwash Abdulhkim

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
In
STRUCTURAL ENGINEERING

Approved by the
Examining Committee

Prof. Dr. Youssef F. Rashed, Thesis Main Advisor

Prof. Dr. Ahmed H. Amer, Internal Examiner

Prof. Dr. Khaled M. Heiza, External Examiner

¹ Professor of Reinforced Concrete Structures and Bridges

² Vice Dean of Faculty of Engineering

Faculty of Engineering, Mnofia University, Mnofia, Egypt

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2017

Engineer’s Name: Anas Abdulhkim Aburawwash
Date of Birth: 17/02/1990
Nationality: Egyptian
E-mail: anas.aburawwash@yahoo.com
Phone: +201009001771
Address: Hadyek ELkoba, Cairo, Egypt
Registration Date: 1/3/2014
Awarding Date:/....../.....
Degree: Master of Science
Department: Structural Engineering



Supervisors:
Prof. Dr. Youssef F. Rashed

Examiners:
Prof. Dr. Khaled M. Heiza (External examiner)
Prof. Dr. Ahmed H. Amer (Internal examiner)
Prof. Dr. Youssef F. Rashed (Thesis main advisor)

Title of Thesis:

COMPUTRIZED DESIGN TOOL FOR POST-TENSIONING SLABS

Key Words:
Post-tensioning slabs; Boundary element method; Graphical user interface

Summary:
.....
.....
.....
.....
.....
.....
.....

Acknowledgments

Each one of us is here as result of influence from our parents, at the least they gave us birth. In my case, it was through the toil and tiresome work of my parents and my grandparents. They have taught me well, were patient, and always made the best of decisions for my education. I am dazzled at their ability to love me, even when I was disobedient. Therefore, I acknowledge my whole family for their love, bravery, motivation and most important of all unwavering confidence in me.

CUFE-BE is a young name, however, with an unbreakable experienced backbone. Probably the most energetic and solid backbone any Egyptian could wish for. This research group's most precious bone (just explained) is Prof. Dr. Youssef Rashed, whom without I would have never understood what smart and hard teamwork truly meant. I have learnt from him other countless skills, but I shall always remember his enthusiasm in motivating me to achieve.

Our group is full of bright Egyptians eager to learn and accomplish, and they were friends that always stood by me when I needed help in my research. To name the least, they are: Ahmed A. Torky, Ahmed Fady, Ahmed Khaled, Ahmed Usama, Ahmed Taiko, Ahmed Hegazy, Taha Abo ElNaga and Mahmoud ElGalad.

The Faculty of Engineering at Cairo University has supported the research done in this thesis by providing all the necessary hardware for experimentation.

Dedication

I dedicate this thesis to my infinitely wonderful Father, Mother, Brothers and Sisters:

Abdulahkim Aburawwash

Rokaya Mohammed Elsayed

Abdulrahman Aburawwash

Ahmad Aburawwash

Mohammed Aburawwash

Abdulla Aburawwash

Safa Aburawwash

Zeinb Aburawwash

Table of Contents

ACKNOWLEDGMENTS.....	I
DEDICATION	II
TABLE OF CONTENTS	III
LIST OF TABLES.....	V
LIST OF FIGURES.....	VI
ABSTRACT	XI
CHAPTER 1 : INTRODUCTION	1
1.1. FLAT SLAB TYPES	1
1.2. NUMERICAL METHODS FOR SOLVING FLAT PLATES	1
1.3. BOUNDARY ELEMENT AND PLPAK	2
1.4. POST-TENSIONING IN BOUNDARY ELEMENT ("PTPAK").....	9
1.4.1. RECENT IMPROVEMENTS.....	9
1.4.1.1. Proposed cable templates	9
1.4.1.2. Templates and cable concept	14
1.4.1.3. Prestressing losses	15
1.5. THESIS OBJECTIVE	16
1.6. THESIS ORGANIZATION	17
CHAPTER 2 : DEVELOPMENTS OF AN IMPROVED "PTPAK"	18
2.1. INTRODUCTION	18
2.2. DEVELOPMENT OF AN IMPROVED "PTCALCULATOR"	18
2.2.1. COMPUTING ALLOWABLE JACKING STRESS	19
2.2.2. SEATING LOSSES (DRAW-IN LOSSES)	19
2.2.3. STRESSING END.....	21
2.3. DEVELOPMENT OF AN IMPROVED "PTUPDATER"	23
2.3.1. Developed code discussion	23
2.3.2. Comparison between old and developed cod in reading data	23
2.3.3. Developed Code Computations	29
2.3.4. Updating BE model file "*.in"	32
2.3.5. Numerical implementation	34
2.3.6. Results of an improved "PTUpdater"	36
2.4. SUMMARY	38
CHAPTER 3 : DEVELOPED GRAPHICAL USER INTERFACE.....	39
3.1. INTRODUCTION	39
3.2. THE DEVELOPED GRAPHICAL USER INTERFACE (GUI).....	39
3.3. DEVELOPED PT MODEL DEFINITION TOOL STRIP	39
3.4. DEVELOPED DRAWING AND EDITING TOOL STRIP	45
3.5. DEVELOPED PRESTRESSING CABLE OBJECT	45
3.6. DEVELOPED TEMPLATE OBJECT	47

3.7.	DEVELOPED POST-TENSIONING DESIGN STRIP TOOL	52
3.7.1.	DEVELOPED DESIGN STRIP OBJECT	52
3.7.2.	DEVELOPED DESIGN SECTION OBJECT	56
3.7.3.	DEVELOPED STRESS PANEL	57
3.8.	DEVELOPED AUXILIARY TOOLS	58
3.9.	PRACTICAL EXAMPLES	59
3.9.1.	EXAMPLE ONE (CAR PARKING)	59
3.9.2.	EXAMPLE TWO (COMMERCIAL BUILDING)	66
3.10.	SUMMARY	66
CHAPTER 4 : NUMERICAL EXAMPLES		74
4.1.	INTRODUCTION	74
4.2.	EXAMPLE 1: RESIDENTIAL BUILDING	74
4.3.	EXAMPLE 2: COMMERCIAL BUILDING	106
4.4.	EXAMPLE 3: CAR PARKING	138
4.5.	EXAMPLE 4: STRESS CHECK VERIFICATION EXAMPLE (DEVELOPED DESIGN TOOL)	170
4.5.1.	GEOMETRY AND STRUCTURE DEFINITION	170
4.5.2.	DESIGN SECTION PROPERTIES	174
4.6.	EXAMPLE 5: DESIGN EXAMPLE 1	178
4.6.1.	GEOMETRY AND STRUCTURE DEFINITION	178
4.6.2.	PRESTRESSING CABLES LAYOUT	178
4.6.3.	PLAN DESIGN STRIPS	178
4.6.4.	CHECK STRESSES	183
4.7.	EXAMPLE 6: DESIGN EXAMPLE 2	189
4.7.1.	GEOMETRY AND STRUCTURE DEFINITION	189
4.7.2.	PRESTRESSING CABLES LAYOUT	189
4.7.3.	PLAN DESIGN STRIPS	189
4.7.4.	CHECK STRESSES	189
4.8.	SUMMARY	190
CHAPTER 5 : CONCLUSION AND FUTURE WORK		198
5.1.	SUMMARY	198
5.2.	CONCLUSION	198
5.3.	FUTURE WORK	198
REFERENCES		199

List of Tables

Table 2.1: A time comparison between the old and the developed "PTUpdater"	38
Table 4.1: Prestressing material properties used in example 1	74
Table 4.2: Prestressing material properties used in example 2	106
Table 4.3: Prestressing material properties used in example 3	138
Table 4.4: Prestressing material properties used in example 4	170
Table 4.4: Prestressing material properties used in example 5	178
Table 4.4: Prestressing material properties used in example 5	189

List of Figures

Figure 1.1 Structural Model as shown in "PLGen"	3
Figure 1.2 3D View for the structural floor as shown in "PLGen"	4
Figure 1.3 Analysis Manager "PLCoreMan"	5
Figure 1.4 Results (vertical deflection) visualization "PLPost"	6
Figure 1.5 Boundary element model "PLview"	7
Figure 1.6 Design package environment "PLDesign"	8
Figure 1.7 Cross sectional view and properties of proposed templates.	۳۳-۳۶
Figure 1.8 Concept of cable and template.	15
Figure 1.9 "PTCalculator" input and output chart.....	16
Figure 2.1 "JackingForce" flow chart.....	20
Figure 2.2 Distribution of stress prior seating of cable	22
Figure 2.3 Distribution of stress after seating of cable.....	22
Figure 2.4 "PTUpdater" flow chart	24
Figure 2.5 Input file for old version of "PTUdpatet" (VB.NET)	25
Figure 2.6 Flow chart for reading input file process, old version	26
Figure 2.6 Cont. Flow chart for reading input file process, old version.....	27
Figure 2.7 Input file for new version of "PTUdpatet" (FTN95)	28
Figure 2.8 BE model of pre-stressing cable with arrays indication	30
Figure 2.9 Arrays of extreme points coordinates	31
Figure 2.10 Arrays contains cell loads	32
Figure 2.11 Changes in BE model file "*.in"	۵۵-۵۶
Figure 2.12 Boundary element model of pre-stressing slab with 172 load cells, distributed-distributed cables layout.....	35
Figure 2.13 Boundary element model of pre-stressing slab with 380 load cells, banded- banded cables layout.....	36
Figure 2.14 Boundary element model of pre-stressing slab with 11,425 load cells.....	37
Figure 3.1 Flow chart the developed environment	40
Figure 3.2 "PTDesign" GUI environment	41
Figure 3.3 Prestressing system window	42
Figure 3.4 Short-term losses window	43
Fig. 3.5 Cable division window.....	44
Fig. 3.6 Template and cable concept	45
Figure 3.7 Prestressing cable properties windows form.....	46
Figure 3.8 Prestressing cable drawing tools	47
Figure 3.9 Example for drawing tools	48
Figure 3.10 Prestressing cable drawn with "PTDesign" drawing tool	49
Figure 3.11a ACAD polyline representing a pre-stressed cable	50
Figure 3.11b ACAD polyline imported to "PTDesign" and converted to a prestressing cable.....	51
Figure 3.12 Windows form of developed template object	52
Figure 3.13 Windows form of developed template object	53
Figure 3.14 Post-tensioning design strip tool "PTDesStrip"	54
Figure 3.15 Parameters of post-tensioning design strip tool "PTDesStrip"	55
Figure 3.16 Post-tensioning design strip tool windows form.....	56
Figure 3.17 Section properties.....	56

Figure 3.18 Bending moment (M_{xx}) along sections in a design strip.....	57
Figure 3.19 Top fibers stress distribution along design strip	57
Figure 3.20 Top fibers stress distribution along design strip	58
Figure 3.21 Developed two-dimensional array of prestressed cables windows form....	58
Figure 3.22 Developed multi-selected editing windows form	59
Figure 3.23 Structural plan of a car parking.....	60
Figure 3.24 a) Finite element model (ADAPT- Floor Pro).....	۸۳-۸۴
Figure 3.25 a) Boundary element model (Developed "PTDesign").....	۸۵-۸۶
Figure 3.26 Numerical model of the boundary element model (PLView).....	65
Figure 3.27 Structural plan of a commercial building.....	67
Figure 3.28 a) Finite element model (RAM Concept) Banded-Distributed layout..	۹۰-۹۱
Figure 3.29 a) Boundary element model (Developed "PTDesign") Banded-Distributed layout	70
Figure 3.29 b) Boundary element model (Developed "PTDesign") Distributed-Distributed layout	71
Figure 3.30 a) Numerical model of boundary element model ("PLView") Banded-Distributed layout	72
Figure 3.30 b) Numerical model of the boundary element model ("PLView") Distributed-Distributed layout.....	73
Figure 4.1 The floor geometry and section locations (dimensions are in m)	75
Figure 4.3 Boundary element model (PLView)	77
Figure 4.4 Contour map for vertical deflection U_z due to self-weighting.....	78
Figure 4.5 Cables distributed distributed layout x-direction distribution.....	101-102
Figure 4.6 Boundary element model with cable cells (PLView)	81
Figure 4.7 Contour map for vertical deflection U_z due to transfer load case (including prestressing).....	82
Figure 4.8 Contour map for bending moment M_{xx} due to self-weighting.....	83
Figure 4.8 Cont. Contour map for bending moment M_{xx} due to transfer load case (including prestressing)	84
Figure 4.9 Contour map for bending moment M_{yy} due to self-weighting.....	85
Figure 4.9 Cont. Contour map for bending moment M_{yy} due to transfer load case (including prestressing)	86
Figure 4.10 Contour map for vertical deflection U_z due to service loads	87
Figure 4.10 Cont. Contour map for vertical deflection U_z due to service load case (including prestressing)	88
Figure 4.11 Contour map for bending moment M_{xx} due to service loads	89
Figure 4.11 Cont. Contour map for bending moment M_{xx} due to service load case (including prestressing)	90
Figure 4.12 Contour map for bending moment M_{yy} due to service loads	91
Figure 4.12 Cont. Contour map for bending moment M_{yy} due to service load case (including prestressing)	92
Figure 4.13 Finite element model (RAM Concept).....	93
Figure 4.14 Contour map for vertical deflection U_z due to self-weighting.....	94
Figure 4.14 Cont. Contour map for vertical deflection U_z due to transfer load case (including prestressing)	95
Figure 4.15 Contour map for bending moment M_{xx} due to self-weighting.....	96
Figure 4.15 Cont. Contour map for bending moment M_{xx} due to transfer load case (including prestressing)	97
Figure 4.16 Contour map for bending moment M_{yy} due to self-weighting.....	98

Figure 4.16 Cont. Contour map for bending moment M_{yy} due to transfer load case (including prestressing)	99
Figure 4.17 Contour map for vertical deflection U_z due to service loads	100
Figure 4.17 Cont. Contour map for vertical deflection U_z due to service load case (including prestressing)	101
Figure 4.18 Contour map for bending moment M_{xx} due to service loads	102
Figure 4.18 Cont. Contour map for bending moment M_{xx} due to service load case (including prestressing)	103
Figure 4.19 Contour map for bending moment M_{yy} due to service loads	104
Figure 4.19 Cont. Contour map for bending moment M_{yy} due to service load case (including prestressing)	105
Figure 4.20 The floor geometry.....	107
Figure 4.22 Boundary element model (PLView)	109
Figure 4.23 Contour map for vertical deflection U_z due to self-weighting.....	110
Figure 4.24 Cables distributed distributed layout a-direction distribution.....	111
Figure 4.24 Cont. Cables distributed distributed layout b-direction distribution.....	112
Figure 4.25 Boundary element model with cable cells (PLView)	113
Figure 4.26 Contour map for vertical deflection U_z due to transfer load case (including prestressing).....	114
Figure 4.27 Contour map for bending moment M_{xx} due to self-weighting.....	115
Figure 4.27 Cont. Contour map for bending moment M_{xx} due to transfer load case (including prestressing)	116
Figure 4.28 Contour map for bending moment M_{xx} due to self-weighting.....	117
Figure 4.28 Cont. Contour map for bending moment M_{yy} due to transfer load case (including prestressing)	118
Figure 4.29 Contour map for vertical deflection U_z due to service loads	119
Figure 4.29 Cont. Contour map for vertical deflection U_z due to service load case (including prestressing)	120
Figure 4.30 Contour map for bending moment M_{xx} due to service loads	121
Figure 4.30 Cont. Contour map for bending moment M_{xx} due to service load case (including prestressing)	122
Figure 4.31 Contour map for bending moment M_{yy} due to service loads	123
Figure 4.31 Cont. Contour map for bending moment M_{yy} due to service load case (including prestressing)	124
Figure 4.32 Finite element model (RAM Concept).....	125
Figure 4.33 Contour map for vertical deflection U_z due to self-weighting.....	126
Figure 4.33 Cont. Contour map for vertical deflection U_z due to transfer load case (including prestressing)	127
Figure 4.34 Contour map for bending moment M_{xx} due to self-weighting.....	128
Figure 4.34 Cont. Contour map for bending moment M_{xx} due to transfer load case (including prestressing)	129
Figure 4.35 Contour map for bending moment M_{yy} due to self-weighting.....	130
Figure 4.35 Cont. Contour map for bending moment M_{yy} due to transfer load case (including prestressing)	131
Figure 4.36 Contour map for vertical deflection U_z due to service loads	132
Figure 4.36 Cont. Contour map for vertical deflection U_z due to service load case (including prestressing)	133
Figure 4.37 Contour map for bending moment M_{xx} due to service loads	134
Figure 4.37 Cont. Contour map for bending moment M_{xx} due to service load case (including prestressing)	135

Figure 4.38 Contour map for bending moment M_{yy} due to service loads	136
Figure 4.38 Cont. Contour map for bending moment M_{yy} due to service load case (including prestressing)	137
Figure 4.39 The floor geometry (dimensions are in m).....	139
Figure 4.41 Boundary element model (PLView)	141
Figure 4.42 Contour map for vertical deflection U_z due to self-weighting.....	142
Figure 4.43 Cables distributed distributed layout x-direction distribution.....	143
Figure 4.43 Cont. Cables distributed distributed layout y-direction distribution.....	144
Figure 4.44 Boundary element model with cable cells (PLView)	145
Figure 4.45 Contour map for vertical deflection U_z due to transfer load case (including prestressing).....	146
Figure 4.46 Contour map for bending moment M_{xx} due to self-weighting.....	147
Figure 4.46 Cont. Contour map for bending moment M_{xx} due to transfer load case (including prestressing)	148
Figure 4.47 Contour map for bending moment M_{yy} due to self-weighting.....	149
Figure 4.47 Cont. Contour map for bending moment M_{yy} due to transfer load case (including prestressing)	150
Figure 4.48 Contour map for vertical deflection U_z due to ultimate loads	151
Figure 4.48 Cont. Contour map for vertical deflection U_z due to service load case (including prestressing)	152
Figure 4.49 Contour map for bending moment M_{xx} due to service loads	153
Figure 4.49 Cont. Contour map for bending moment M_{xx} due to service load case (including prestressing)	154
Figure 4.50 Contour map for bending moment M_{yy} due to service loads	155
Figure 4.50 Cont. Contour map for bending moment M_{yy} due to service load case (including prestressing)	156
Figure 4.51 Finite element model (RAM Concept).....	157
Figure 4.52 Contour map for vertical deflection U_z due to self-weighting.....	158
Figure 4.52 Cont. Contour map for vertical deflection U_z due to transfer load case (including prestressing)	159
Figure 4.53 Contour map for bending moment M_{xx} due to self-weighting.....	160
Figure 4.53 Cont. Contour map for bending moment M_{xx} due to transfer load case (including prestressing)	161
Figure 4.54 Contour map for bending moment M_{yy} due to self-weighting.....	162
Figure 4.54 Cont. Contour map for bending moment M_{yy} due to transfer load case (including prestressing)	163
Figure 4.55 Contour map for vertical deflection U_z due to service loads	164
Figure 4.55 Cont. Contour map for vertical deflection U_z due to service load case (including prestressing)	165
Figure 4.56 Contour map for bending moment M_{xx} due to service loads	166
Figure 4.56 Cont. Contour map for bending moment M_{xx} due to service load case (including prestressing)	167
Figure 4.57 Contour map for bending moment M_{yy} due to service loads	168
Figure 4.57 Cont. Contour map for bending moment M_{yy} due to service load case (including prestressing)	169
Figure 4.58 Structural plan (dimension in m)	171
Figure 4.59 Three-dimensional view of the structure	171
Figure 4.60 prestressing cables layout (PTDesign).....	172
Figure 4.61 Design strips in X-direction (developed design tool)	173
Figure 4.62 Properties of sections of design strip No. 1	174

Figure 4.63 Top fiber stresses of design strip No. 1.....	175
Figure 4.64 Bottom fiber stresses of design strip No. 1	176
Figure 4.65 The floor geometry and section locations (dimensions are in m)	179
Figure 4.66 Prestressing cables layout	180
Figure 4.67 Horizontal design strips	181
Figure 4.68 Vertical design strips.....	182
Figure 4.69 Top stresses at the initial stage (strip 3).....	184
Figure 4.69 Cont. Bottom stresses at the initial stage (strip 3).....	185
Figure 4.70 Top stresses at the service stage (strip 3).....	186
Figure 4.70 Cont. Bottom stresses at the service stage (strip 3).....	187
Figure 4.71 Bottom stresses at the final stage after increasing number of strands (strip 3).....	188
Figure 4.72 The floor geometry.....	191
Figure 4.73 Prestressing cables layout	192
Figure 4.74 Design strips layout.....	193
Figure 4.75 Top stresses at the initial stage (strip 12).....	194
Figure 4.75 Cont. Bottom stresses at the initial stage (strip 12).....	195
Figure 4.76 Top stresses at the service stage (strip 12).....	196
Figure 4.76 Cont. Bottom stresses at the service stage (strip 12).....	197

Abstract

In this thesis, a new software "PTDesign" is developed for systematic analysis and design of post-tensioned slabs based on the boundary element method. A full integrated and user-friendly environment is developed using a versatile GUI language (Visual Basic), which allows the user to: First: place pre-stressing cables on slabs (editing it through built-in template with actual cable profiles), second: visualize contours before and/or after the pre-stressing effects, third: check stresses and design of user-defined strips in any direction, and finally industrial and practical post-tensioned slab are analyzed and designed through the PTDesign and compared with results achieved similarly from commercial software.