

**AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING**

**STRUCTURAL SYNTHESIS OF PREFABRICATED
PRESTRESSED CONCRETE BEAMS**

BY

Eng. MOHAMED AHMED MOHAMED SALAMA

A Thesis

**Submitted in Partial Fulfillment for The
Requirements of The Degree of Master of
Science in Civil Engineering
(Structural Departement)**



624.1834
H.A.

41166
✓

Supervised by

Dr. IBRAHIM MAHFOUZ MOHAMED IBRAHIM
Prof. and Head,
Department of Civil Eng.,
Zagazig University,
Banha Branch, Shoubra, Egypt

Dr. MAHMOUD GALAL HASHISH
Prof. of Structural Eng.,
Department of Civil Eng.,
Ain Shams University,
Egypt

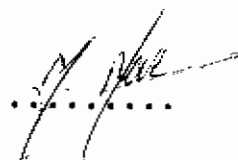
Cairo - 1991

Examiners Committee

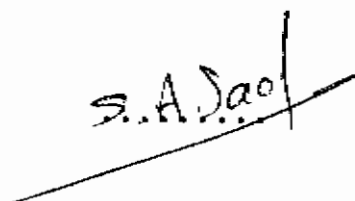
Name, Title & Affiliation

Signature

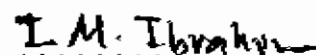
1- Prof. Dr. Mahmoud El-Sayed Nassr
Prof. of Reinforced Concrete Structures,
Faculty of Engineering,
Cairo University



2- Prof. Dr. Saafan Abd-Elgawad Saafan
Prof. of Structural Engineering,
Faculty of Engineering,
Ain Shams University



3- Prof. Dr. Ibrahim Mahfouz Mohamed Ibrahim
Prof. and Head,
Department of Civil Engineering,
Faculty of Engineering (shoubra),
Zagazig University, Banha Branch



4- Prof. Dr. Mahmoud Galal Hashish
Prof. of Structural Engineering,
Faculty of Engineering,
Ain Shams University



Date 5 / 5 / 1991



STATEMENT

This dissertation is submitted to Ain Shams University for the Degree of Master of Science in Civil Engineering, Structural Department.

The work included in this thesis was carried out by the author in the Department of Civil Eng., Ain Shams University, from November 1987 to April 1991.

No part of this thesis has been submitted for a degree or a qualification at any other university or institution.

Date : 5/ 5 /1991.

Signature: *Mohamed A.H. Salama*

Name : Mohamed Ahmed Mohamed Salama

ABSTRACT

The structural synthesis capability for the analysis of simply supported prefabricated prestressed concrete beams is presented. The problem is solved using nonlinear programming techniques. The method of Fletcher & Powell for the optimization of unconstrained functions is used with an interior penalty function of Fiacco-McCormick which accounts for the constrained problems. A comparison between different international codes for the design of prestressed concrete is presented, with the objective of choosing a well defined method of analysis and design for the synthesis procedure. The method of analysis used herein is mainly based on the American Concrete Institute Code (ACI318-89) provisions with some modifications to account for the requirements of the Egyptian Code of Practice for the design of reinforced concrete structures of 1989.

A computer program has been developed for the synthesis scheme under consideration. Several numerical results have been obtained which demonstrate the capability and efficiency of the optimization system in obtaining minimum weight design automatically.

ACKNOWLEDGEMENTS

I would not have been able to complete this study without the help of my supervisors, Professor Ibrahim Mahfouz Mohamed Ibrahim, Professor of Structural Engineering and Head of the Civil Engineering Departement at Zagazig University, Banha Branch and Professor Mahmoud Galal Hashish, Professor of Structural Engineering, Departement of Civil Engineerig, Ain Shams University.

Their constant guidance, their encouragement and their ability to impart a small proportion of their knowledge made the experience of writing this thesis a pleasent as well as an eductional experience. My gratitude to them is great indeed

My thanks are also to my colleagues at the faculty of Engineering of Shoubra , Zagazig University, Banha Branch for their cooperation in this work.

Finally words can not express my gzatitude to my parents and my brothers for their help and understanding during the long solitary hours I spent in preparing this study

LIST OF SYMBOLS

A	= area of concrete at cross section considered, cm^2
A_{ps}	= area of prestressed reinforcement in tension zone, cm^2
A_s	= area of nonprestressed tension reinforcement, cm^2
b	= width of compression face of member, cm.
d	= distance from extreme compression fiber to centroid of nonprestressed tension reinforcement, cm .
d_p	= distance from extreme compression fiber to centroid of prestressed reinforcement , cm.
D	= dead loads, or related internal moments and forces .
e	= base of nablerian logarithms or prestressing steel eccentricity
f_{cu}	=characteristic strength of standard concrete cube after 28 days , kg/cm^2
$\sqrt{f_{cu}}$	= square root of characteristic strength of standard concrete cube, kg/cm^2

f_{cul} = characteristic compressive strength of standard concrete cube at time of prestress transefer, kg/cm^2

$\sqrt{f_{cul}}$ = square root of characteristic compressive strength of standard concrete cube at time of prestress transefer, kg/cm^2

f_{pc} = average compressive, stress in concrete due to effective prestress force only (after allowance for all prestress losses), kg/cm^2

β_1 = $0.85 - (F_{cu} - 350)/1400 \geq 0.65$

f_{ps} = stress in prestressed reinforcement at ultimate strength of the cross section, kg/cm^2 .

f_{pu} = specified ultimate tensile strength of prestressing tendons, kg/cm^2

f_{py} = specified yield strength of prestressing tedons, kg/cm^2 .

f_r = modulus of rupture of concrete, kg/cm^2

f_{se} = effective stress in prestressed reinforcement, (after allowance for all prestress losses), kg/cm^2

f_y = specified yield strength of nonprestressed reinforcement, kg/cm^2

h	= overall thickness of member ,cm
k	= wobble friction coefficient per meter of prestressing tendon
l_x	= length of prestressing tendon element from jacking end to any point, x, m.
L	= live loads, or related internal moments and forces
P_s	= prestressing tendon force at jacking end
P_x	= prestressing tendon force at point X
α	= total angular change of prestressing tendon profile in radians from tendon jacking end to any point X
γ	= factor for type of prestressing tendon = 0.40, for f_{py} / f_{pu} not less than 0.85 = 0.28, for f_{py} / f_{pu} not less than 0.90
μ	= curvature friction coefficient .
μ	= ratio of nonprestressed tension reinforcement = A_s / bd
μ_{ps}	= ratio of prestressed reinforcement = A_{ps} / bd_p
ω	= $\mu_s f_y / 0.8 f_{cu}$

$$\omega_s = \mu_s f_y / 0.8 f_{cu}$$

$$\omega_p = \mu_{ps} f_{ps} / 0.8 f_{cu}$$

$$q = \text{Nominal shear strength provided by concrete, kg/cm}^2$$

$$q_u = \text{Factored shear stress at section, kg/cm}^2$$

$$q_{c1} = \text{nominal shear strength provided by concrete when diagonal cracking results from combined shear and moment, kg/cm}^2$$

$$q_{cw} = \text{nominal shear strength provided by concrete when diagonal cracking results from excessive principle tensile stress in web, kg/cm}^2$$

$$q_d = \text{shear stress at section due to unfactored dead load, kg/cm}^2$$

$$q_p = \text{shear stress provided by vertical component of effective prestress force at section considered, kg/cm}^2$$

$$f_d = \text{stress due to unfactored dead load at extreme fiber of section where tensile stress is caused by externally applied load, kg/cm}^2$$

TABLE OF CONTENTS

	Page
ABSTRACT.....	i
ACKNOWLEDGEMENT.....	ii
LIST OF SYMBOLS.....	iii
TABLE OF CONTENTS.....	vii
LIST OF FIGURES.....	xi
LIST OF TABLES.....	xii
CHAPTER 1 : INTRODUCTION.....	1
1.1 General.....	1
1.2 Review Of Previous Work.....	4
1.3 Objective and Scope.....	8
CHAPTER 2 : STRUCTURAL SYNTHESIS.....	10
2.1 General.....	10
2.2 Definitions And General Problem Statement.....	10
2.2.2 Design Variables.....	10
2.2.3 Preassigned Parameters.....	11
2.2.4 Behaviour Constraint.....	11
2.2.5 Side Constraint.....	13
2.2.6 Composite Constraint Surface.....	14
2.2.7 Free And Bound Points.....	15
2.2.8 Objective Function.....	15
2.3 Method Of Analysis.....	17

	Page
2.4 Methods Of Design.....	17
2.4.1 General.....	17
2.4.2 Search Methods.....	18
2.4.2.1 Steepest Descent Method.....	20
2.4.2.2 Method Of Fletcher And Powell.....	22
2.4.3 Local Vs. Global Minima.....	26
CHAPTER 3 : ANALYSIS OF PRESTRESSED CONCRETE BEAMS.....	29
3.1 Introduction.....	29
3.2 Proposed Method of analysis for the Design of Prestressed Concrete Comptable with the Requirements of the Egyptian Code of Practice for the Design of Reinforced Concrete Structures 1989.....	30
3.2.1 Basis of Design.....	30
3.2.1.1 General.....	30
3.2.1.2 Proposed Design Provision.....	30
3.2.2 Concrete and Non-prestressing Reinforcement.....	31
3.2.3 Prestressing Steel.....	32
3.2.3.1 ACI 318-89.....	32
3.2.3.2 BS 8110-85.....	32
3.2.3.3 CEB-79.....	32
3.2.3.4 Proposed Provision.....	33
3.2.4 Design Assumptions.....	33
3.2.4.1 General.....	33
3.2.4.2 Proposed Design Assumptions.....	33
3.2.5 Serviceability Limit State.....	34

	Page
3.2.5.1 Permissible Stresses In Concrete and Steel for Flexural Members.....	34
3.2.5.2 ACI 318-89.....	35
3.2.5.3 BS 8110-85.....	36
3.2.5.4 Proposed Permissible Stresses in Concrete and Prestressing Steel.....	38
3.2.5.5 Loss of Prestress.....	39
3.2.5.6 Friction loss in Post-tensioning Tendons.....	40
3.2.6 Ultimate Strength Limit State.....	41
3.2.6.1 Flexural Strength (ACI 318-89).....	42
3.2.6.2 Flexural Strength (BS 8110-85).....	43
3.2.6.3 Proposed Provision for Flexural Strength.....	45
3.2.6.4 Shear Strength (ACI 318-89).....	47
3.2.6.5 Shear Strength (BS 8110-85).....	49
3.2.6.6 Proposed Provisions for Shear Strength	50
3.2.6.7 Shear Strength Provided by Shear Reinforcement....	54
3.2.6.8 Tendon Anchorage Zones.....	57
3.2.6.9 Post-Tensioning Anchorages and Couplers.....	57
CHAPTER 4 : OPTIMIZATION OF PRESTRESSED BEAMS.....	59
4.1 GENERAL.....	59
4.2 Mathematical Formulation.....	59
4.3 Design Variables.....	60
4.4 Preassigned Parameters.....	60
4.5 Behaviour Constraints.....	61
4.5.1 Serviceability Limit State Behaviour Constraints.....	61
4.5.2 Strength Limit State Behaviour Constraints.....	67

	Page
4.6 Objective Function.....	69
4.7 Optimization Procedures.....	69
CHAPTER 5 : IMPLEMENTATIONS AND NUMERICAL EVALUATION.....	71
5.1 General.....	71
5.2 Behaviour Constraints.....	71
5.3 Side Constraints.....	73
5.4 Example 1.....	74
5.5 Example 2.....	75
5.6 Example 3.....	76
5.7 Example 4.....	76
5.8 Example 5.....	77
5.9 Example 6.....	77
CHAPTER 6 : SUMMARY AND CONCLUSION.....	85
REFERENCES.....	87
FIGURES.....	90
APPENDIX A : Computer Program.....	101
APPENDIX B : Design Curves.....	105

LIST OF FIGURES

Fig. No.	Title	Page
2.1	Design Space Nomenclature.....	90
2.2	Design Cycle Block Diagram.....	91
2.3	Constrained Steepest Descent Method.....	92
2.4	Contours Of Rosenbrock Function.....	93
2.5	Fletcher-Powell Method On Rosenbrock Function.....	94
2.6	Relative Minima.....	95
3.1	Stress-Strain Curve For Prestressing Steel (ACI 318-89).....	96
3.2	Stress-Strain Curve For Prestressing Steel (BS 8110-85).....	96
3.3	Stress-Strain Curve For Patented, Tempered, Drawn Prestressing Steel (CEB 79).....	97
3.4	Stress-Strain Curve For Hot-Rolled Prestressing Steel (CEB 79).....	97
3.5	Proposed Stress-Strain Curve For Prestressing Steel.....	98
3.6	ACI 318-89 & BS 8110-85 Permissible Stresses.....	98
3.7	Bonded Prestressing Steel Ultimate Strength.....	99
3.8	ACI 318-89 And BS 8110-85 Web Shear Strength.....	99
4.1	Design Variables And Preassigned Parameters.....	100
A.1	Logic diagram for Optimization Procedure..	104