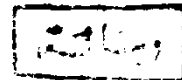


1119
1022V/P
11/12

Ain Shams University
Faculty of Engineering

INELASTIC BUCKLING OF STRUCTURAL BEAMS

By



Saleh Mohamed Ibrahim El-Mekawy

30581

A THESIS

SUBMITTED IN PARTIAL FULFILLMENT

FOR THE REQUIREMENTS OF THE DEGREE OF

MASTER OF SCIENCE IN CIVIL ENGINEERING (STRUCTURAL)

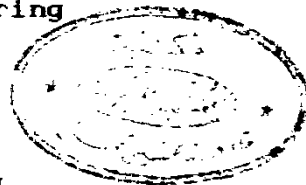
624.1 772
S.M.

SUPERVISED BY

Dr. SAAFAN A. SAAFAN

Prof. of Structural Engineering

Ain Shams University



Dr. SAID AHMED HASSANEIN

Lecturer of Structural Engineering

Al-Azhar University

Cairo-1990

EXAMINERS COMMITTEE

Name, Title and Affiliation

Signature

1- Professor MOHAMED EZZAT SOBaih

M. Ezzat

Prof. of Structural Engineering,
Faculty of Engineering,
Cairo University.

2- Professor MAHMOUD GALAL HASHISH

M. G. Hashish

Prof. of Structural Engineering,
Faculty of Engineering,
Ain Shams University.

3- Professor SAAFAN ABDEL-GAWAD SAAFAN

S. A. Saafan

Prof. of Structural Engineering,
Faculty of Engineering,
Ain Shams University.

ح. ع. ع. ع.



STATEMENT

This dissertaion is submitted to Ain Shams University for the degree of MASTER OF SCIENCE in Structural Engineering.

The work included in this thesis was carried out by the author in the department of Civil Engineering (Structural Division), Ain Shams University, from November 1984 to February 1990.

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

Date : / /1990

Signature : Saleh EL-Mekawy

Name : Saleh Mohamed Ebrahim El-Mekawy

DEDICATION

TO MY PARENTS AND MY BROTHER

ACKNOWLEDGMENTS

It is great honour for me to complete my work with sincere thanks to Professor *Saafan A. saafan*, Prof. of Structural Engineering, Ain Shams University. My acknowledgment represents inadequate expression of appreciation for his guidance, encouragement, valuable suggestions, excellent supervision and for the facilities he generously offered through this work.

With my great pleasure, I wish to express my deep gratitude to Doctor *Said A. Hassanein*, Lecturer of Structural Engineering, Al-Azhar University, for his perfect supervision, continued encouragement, unlimited help and useful instructions which were of great help to me.

My sincere appreciation and grateful thanks to Doctor *Kamal S. Abdelaziz* and Doctor *Mohamed N. Fayed*, Lecturers of Structural Engineering, Ain Shams University, for their concern and active interest in my work which has been of great benefit. They had so kindly and so carefully assisted and collaborated with me in every step of this work.

Finally, I would like to convey my thanks to Engineer *Bahaa S. Tork* and Engineer *Atef T. Fyad*, Ain Shams University, for their assistance and cooperation in the preparation of this research.

CONTENTS

	Page
CHAPTER 1 INTRODUCTION	
1-1 GENERAL	1
1-2 OBJECTIVES OF THE THESIS	2
1-3 LAYOUT OF THE THESIS	3
 CHAPTER 2 HISTORICAL REVIEW AND LITERATURE SURVEY	
2-1 INTRODUCTION	6
2-2 NONLINEAR ELASTIC ANALYSIS OF STRUCTURES	8
2-3 ELASTIC-PLASTIC ANALYSIS OF BEAM-COLUMN	13
2-4 ELASTIC-PLASTIC ANALYSIS OF FRAMES	25
 CHAPTER 3 ANALYSIS PROCEDURE OF INELASTIC BUCKLING OF FRAMED STRUCTURES	
3-1 INTRODUCTION	42
3-2 LARGE DEFORMATION DISCRETE ELEMENT METHOD	43
3-2-1 Assumptions	45
3-2-2 Load Displacement Equation for the Discrete Element	46
3-2-3 General Stiffness Matrix	49
3-3 THE EFFECT OF CHANGE OF GEOMETRICAL CONFIGURATION	51
3-4 FLEXURAL AND AXIAL RIGIDITIES IN THE INELASTIC RANGE	52
3-5 ELASTIC AND INELASTIC CRITICAL BUCKLING LOAD	58

3-6 CONVERGENCE TEST	59
3-7 STEP-BY-STEP PROCEDURE FOR THE PROPOSED NONLINEAR INELASTIC ANALYSIS	60
3-8 TEST OF THE PROGRAM	62
 CHAPTER 4 NONLINEAR INELASTIC CRITICAL FAILURE LOAD OF BEAM-COLUMN	
4-1 INTRODUCTION	69
4-2 BEAM-COLUMN MODEL	70
4-3 INTERACTION DIAGRAMS FOR THE MAXIMUM STRENGTH OF BEAM-COLUMN	72
4-4 COMPARISON OF THE RESULTS WITH DIFFERENT INTERACTION FORMULAE	76
4-5 EFFECT OF THE CROSS SECTION DIMENSIONS ON THE MAXIMUM STRENGTH OF BEAM-COLUMN	80
4-6 THE EFFECT OF STRAIN-HARDENING ON THE MAXIMUM STRENGTH OF BEAM-COLUMN	81
 CHAPTER 5 NONLINEAR INELASTIC BEHAVIOUR OF FRAMES	
5-1 INTRODUCTION	119
5-2 GEOMETRY AND PROPERTIES OF THE STUDIED FRAMES	119
5-2-1 Rectangular Portal Frames	120
5-2-2 Pitched Roof Portal Frames	121
i- Chin's Experimental Test	121
ii- Majid's Experimental Test	122

iii- Horne's Experimental Tests	122
5-2-3 North-Light Portal Frames	123
5-3 COMPARISON BETWEEN THE EXPERIMENTAL AND THE THEORETICAL RESULTS	124
5-3-1 Analysis of Portal Frames	124
Comments	126
5-3-2 Analysis of Pitched Roof Frames	127
i- Pitched Roof Frame Tested by Chin	127
ii- Pitched Roof Frame Tested by Majid	129
iii- Pitched Roof Frames Tested by Horne	131
Comments	133
5-3-3 Analysis of North-Light Portals	134
Comments	136
 CHAPTER 6 CONCLUSIONS AND SUGGESTIONS	
6-1 SUMMARY AND CONCLUSIONS	161
6-2 SUGGESTIONS	164
 APPENDIX A	
STIFFNESS COEFFICIENTS USED IN THE GEOMETRICAL NONLINEAR ANALYSIS	166
 APPENDIX B	
THE NONLINEAR GEOMETRICAL ANALYSIS BY THE DISCRETE ELEMENT METHOD	168

APPENDIX C

COMPUTER PROGRAM

173

REFERENCES

185

CHAPTER 1

INTRODUCTION

1-1 GENERAL

The allowable stress design method, the elastic method, is widely used in the design of steel structures. This design criterion is essentially based on a fixed value of stress level which should not be exceeded in any structural element. The elastic theory assumes that the deformation and displacement remain sufficiently small and thus, the change in geometrical quantities, angles of inclinations and lengths, can be ignored. However, this method of design does not give a real indication of the true load-carrying capacity of the structure as it ignores a considerable part of strength reserve given by the nonlinear behaviour of steel material.

The recent development of the limit state approach to design has focussed particular attention on the use of maximum loads and the behaviour of the structure as a design criterion. The limit state criterion is essentially based on the limit of usefulness of a structure such as the state of structural failure, the deflection limit or the stability limit load. Thus, accurate informations regarding the behaviour of structures throughout the entire range of loading up to failure load is an essential part of this new

development.

Actually, the determination of the ultimate load carrying capacity of a structure is a nonlinear problem. The nonlinearity results from the deterioration in stiffness of the members caused by axial forces and from the changes in the geometrical configuration of the structure. Furthermore, as the loading is increased, parts of the structure are strained beyond the elastic region. The ultimate load is reached when the combination of the progressive yielding, instability caused by the axial forces and joint's displacements deteriorate the stiffness of the structure to such an extent that the frame loses its stability.

1-2 OBJECTIVES OF THE THESIS

The main objectives of the research presented in this thesis are to:

- 1- Present a numerical procedure for the determination of the nonlinear-inelastic behaviour of structural beams and frames subjected to static and planar loading, taking into consideration the instability effects caused by axial forces, changes of geometrical configuration of structural members, the material nonlinearity due to the stress-strain behaviour of steel, gradual penetration of yielding and the spread of inelastic zones along the member.

- 2- Obtain the maximum strength interaction diagrams for beams subjected to axial thrust and different end moments in single and double mode of failure, and to investigate the limits of practical applications of the interaction formulae proposed by other authors.
- 3- Carry out a comparison between the theoretical results obtained by using the numerical nonlinear-inelastic proposed procedure and the results of the experimental tests, for different types of framed structures, made by previous authors.

1-3 LAYOUT OF THE THESIS

The thesis consists of six chapters and three appendices.

Chapter 1 gives an introduction to the thesis and the aim of this study.

In chapter 2, a historical review and a literature survey on the stability of structural beams and frames is presented. Many previous researches concerning these topics in the elastic and inelastic ranges have been studied and summarized.

Chapter 3 contains a description of the proposed analytical procedure for the nonlinear-inelastic analysis of structures. The instability effects caused by axial forces, change of geometrical configuration of members, effect of

strain-hardening and the effect of yielding of the cross section on its flexural rigidity is taken into consideration. A computer program on personal computer is prepared for the determination of the nonlinear-inelastic behaviour of structures. The accuracy of the program is tested through number of examples previously solved by other authors.

By using the prepared computer program, the maximum strength interaction diagrams for beams subjected to axial thrust together with different values of end moments, in single or double mode of failure, are obtained in chapter 4. A comparison between the interaction diagrams obtained by the proposed numerical analysis with those obtained by the interaction formulae, proposed by other authors, is presented in order to determine the practical limits of usefulness of these formulae. A study of the effect of cross sectional dimensions on the maximum strength of beams is also carried out.

A comparison between the results of the proposed nonlinear-inelastic numerical procedure and the results of the experimental tests carried out by other researchers is presented in chapter 5. The experimental results are also compared with the theoretical ones obtained by the second-order elastic plastic approach.

Finally, in chapter 6, a summary of the work carried

out in the thesis is given together with the general conclusions and suggestions for the future extension of this work.