Ain Shams University

Faculty of Engineering

INELASTIC BUCKLING OF STRUCTURAL BEAMS

By

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A THESIS

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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.

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DEDICATION

TO MY PARENTS AND MY BROTHER

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CONTENTS

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.